Cardno LawsonTreloar

Shaping the Future

EMPIRE BAY CATCHMENT FLOOD STUDY
VOLUME 1 - REPORT

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Gosford City Council

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FOREWORD

The NSW Government's Flood Prone Lands Policy is directed towards providing solutions to existing flood problems in developed areas utilising ecologically positive methods wherever possible and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the policy, the management of flood prone land is the responsibility of Local Government. To achieve its primary objective, the policy provides for State Government financial assistance to Councils for flood mitigation works to alleviate existing flooding problems. The policy also provides for State Government technical assistance to Councils to ensure that the management of flood prone land is consistent with the flood hazard and that future development does not create or increase flooding problems in flood prone areas.

The Policy provides for technical and financial support by the State Government through the following sequential stages:

1. Flood Study	Determines the nature and extent of the flood problem.
2. Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed development.
3. Floodplain Risk Management Plan	Involves formal adoption by Council of a plan of management for the floodplain.
4. Implementation of the Plan	Construction of flood mitigation works to protect existing development. Use of Environmental Planning Instruments to ensure new development is compatible with the flood hazard.

The Empire Bay Catchment Flood Study is the first stage of the management process for the Empire Bay Catchment. The study, which has been prepared for Gosford City Council by Cardno Lawson Treloar Pty Ltd, defines flood behaviour for existing catchment conditions in the Empire Bay catchment floodplain.

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EXECUTIVE SUMMARY

This Flood Study has been undertaken to define the nature and extent of flooding due to local rainfall only within the Empire Bay catchment. It lies wholly within the Gosford City Council (GCC) Local Government Area on the south-eastern side of Brisbane Water. It is located to the east of Woy Woy on the southern side of Cockle Channel and Cockle Bay.

The study area occupies an area about 554 ha covering the suburb of Empire Bay to the south-western section of Bensville. It is bounded by a ridgeline along the southern and western sides extending north to Cockle Channel and Cockle Bay. The Empire Bay residential area is relatively flat with an elevation down to about RL 1.0m AHD at the foreshore and the area around Cockle Bay Nature Reserve is also relatively flat.

Land-use in the catchment is primarily residential with significant areas of bushland / vegetated areas. The density of residential areas varies from low-density detached houses in the main part of Empire Bay and within Bensville, to larger bushland residential lots between these two areas. Several shops are located within the two main residential areas. Large areas of bushland are located on the higher elevations in the southern part of catchment and also along areas adjoining the estuary including Cockle Bay Nature Reserve.

Pit and piped drainage infrastructure convey stormwater runoff through the main residential areas of Empire Bay and Bensville to the foreshore area. Several drainage depressions and natural channels convey runoff from the bushland areas to piped systems crossings Empire Bay Drive.

A questionnaire was delivered to each residence in the study area to gauge resident's awareness of flooding in the catchment and to identify specific accounts of flood inundation. Fifty percent of respondents were aware of flooding in the catchment with some experiencing inundation in their house. A high percentage of respondents recalled details of inundation during the June 2007 event and less information was noted for flood events prior to this date. The draft report was placed on public exhibition from 18th September to 16th October 2009 inviting submissions for the Study.

Hydrologic and hydraulic modelling was completed to assess flood behaviour within the catchment. The SOBEK 1D/2D model from WL|Delft Hydraulics Laboratory was used to model the catchment and to hydraulically route overland flood flows and street flow. An area of about 887 ha was modelled which includes parts of the estuary. To facilitate the modelling, the catchment has been divided into three sectors comprising the Empire Bay residential area, Bensville residential area, and the bushland residential section which covers the largest area. The SOBEK modelling of the Empire Bay catchment utilises the rainfall-on-grid methodology for developing the hydrology. In the model, rainfall is applied directly to the 2D terrain, and the hydraulic model automatically routes the flow.

Data for the model set-up was collated from various sources including Gosford City Council, Johnson Partners surveyors, Bureau of Meteorology and Manly Hydraulics Laboratory. This data included aerial photos, aerial laser scanning (ALS), field survey of piped drainage systems, historical rainfall from previous storm events and historical water levels in the Brisbane Water estuary.

A terrain grid representing the topography of catchment was generated from the ALS and input to the SOBEK model. Also input to the model was rainfall data, soil loss-rates, drainage pipes and culverts, and parameters for hydraulic roughness to account for the varying land-uses. A 1% probability of exceedance estuary level was adopted from the Brisbane Water Foreshore Flood Study as the boundary condition at the foreshore areas. This analysis thus determines flood behaviour due to runoff from the local catchment and the Brisbane Water Foreshore Flood Study (2009) assesses flood impacts due to raised storm event levels in the estuary. The model was calibrated to flood levels and responses from the resident questionnaire for the June 2007 and April 1988 events.

Flood behaviour was modelled in SOBEK for a series of Annual Exceedance Probabilities (AEP). The events modelled were 0.5% AEP, 1%, 2%, 5%, 10%, 20%, 50%, and 100% AEP and Probable Maximum Flood (PMF). The sensitivity of the model was tested to demonstrate the range of uncertainty in the model results for changes in key parameters. Variations to the rainfall parameters, hydraulic roughness, downstream boundary, pipe blockage, and land-use were assessed.

In a 1% AEP event, the modelling shows that some properties and roads may be inundated up to 0.5m. This occurs notably around Gordon Road, Boongala Avenue, Rickard Road, and Greenfield Road in the main residential area of Empire Bay and around the main drainage channels at Pomona Road and Empire Bay Drive to Palmers Lane in the rural-residential area. In the 1% AEP event, the modelling showed that 22 houses are flooded above the floor level when the storm runoff is combined with a 1% probability of exceedance level in the estuary.

Provisional flood hazard (low and high hazard) and hydraulic categorisation (floodway, flood storage, and flood fringe) were also assessed for the flows within the catchment. In the 1% AEP event, no roadways are indicated as provisional high hazard though some properties have high hazard channels / creeklines in the vicinity.

Economic impacts of flooding were evaluated by completing a preliminary flood damage assessment. Costs were estimated for damages resulting to buildings due to local catchment runoff for the various storm events modelled. An average annual damage estimated for the modelled floodplain is about $548,125.

Climate change is expected to result in increased sea levels and increased rainfall intensities. Potential impacts to flood behaviour in the Empire Bay catchment due to climate change have been analysed for:

- 10%, 20%, and 30% increase to rainfall intensity, and
- Estuary level rises of 0.2m and 0.91m.

Flood inundation in the low elevation areas of the catchment are particularly affected by increases in the sea level which influences the levels in the Brisbane Water estuary. Flooding in the higher elevation areas to the south is more influenced by the increases in rainfall intensities.

1. INTRODUCTION

The Empire Bay catchment lies within the Gosford City Council (GCC) Local Government Area on the south-eastern side of Brisbane Water. It is located to the east of Woy Woy on the southern side of Cockle Channel and Cockle Bay. The catchment is subject to flood inundation and GCC aims to undertake floodplain management in accordance with the Floodplain Management Process as set out in the New South Wales Government *Floodplain Development Manual* (2005).

Cardno Lawson Treloar (CLT) was commissioned by GCC to undertake a flood study as part of the floodplain management process. This flood study has been undertaken to determine the flood behaviour in the catchment due to local storm runoff for the 0.5% Annual Exceedance Probability (AEP), 1% AEP, 2% AEP, 5% AEP, 10% AEP, 20% AEP, 50% AEP and 100% AEP flood events and the Probable Maximum Flood (PMF). In accordance with its objectives, the study has determined the nature and extent of flooding through the estimation of design flood flows, levels and velocities. Flood impacts due to storm events in the Brisbane Water estuary are detailed in the Brisbane Water Foreshore Flood Study (2009).

In undertaking the flood study, a hydrologic-hydraulic computer model of the major channels and floodplain within the catchment was established and verified against historical flood event observations. The hydraulic model was then used with design rainfall conditions to simulate design flood behaviour in the catchment. The study has defined Provisional Flood Hazard and Hydraulic Categories for the flood affected areas.

2. STUDY OBJECTIVES

2.1 Regulatory Context

The NSW Government Floodplain Development Manual (2005) sets out a process for floodplain risk management. A flowchart representation of this process is shown in Figure 2.1, which is adapted from the Floodplain Development Manual (2005).

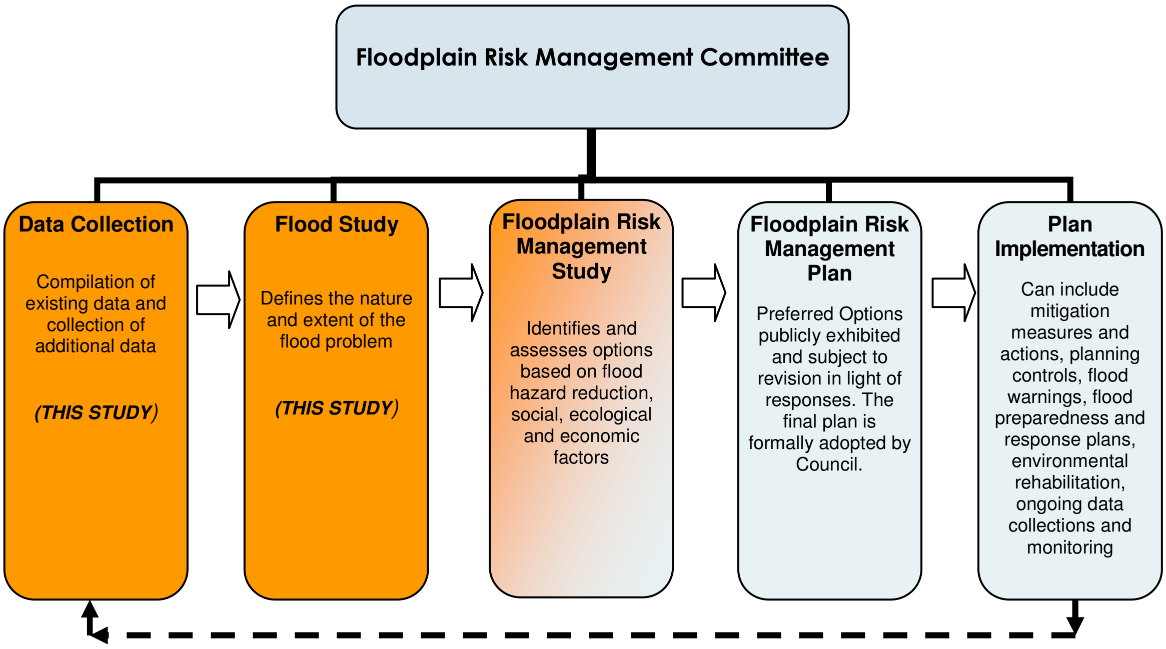

Figure 2.1 Floodplain Management Process

The tasks being undertaken in this Flood Study Report include the compilation of data and definition of the flood behaviour and extent. Assessment of flood management and mitigation options would be undertaken in the next stage of the risk management process as part of the Floodplain Risk Management Study.

2.2 Objectives

The objective of this Study is to define the nature of the existing flood behaviour due to local runoff in the Empire Bay catchment.

To achieve the objectives, the following tasks were undertaken:

- Collate available flood-related data,
- Define existing catchment condition flood behaviour for mainstream flooding in the catchment,
- Define design flood levels, velocities and flow distributions for the catchment,
- Define the extent of flooding the nominated AEP events and PMF for the catchment,
- Define the hydraulic categories for the flood-affected areas,
- Define provisional flood hazard for the flood-affected areas,
- Assess flood damages for the flood-affected areas.

2.3 Methodology

This Study was carried out using computer-based hydrologic-hydraulic modelling. The SOBEK 1D/2D program is a purpose-built flood model developed by WL|Delft Hydraulics. In this model, rainfall is applied directly to the elevation grid and flow is routed according to the topography and hydraulic controls of the catchment. Stormwater drainage pits, pipes and channels are represented in the model as one-dimensional elements which are dynamically linked to the water conveyed across the elevation grid.

The study details are grouped together under the following sections of the report:

- Section 3 provides a general description of the catchment,
- Section 4 discusses data which was utilised for the study,
- Section 5 describes the modelling procedure,
- Section 6 details results for the design flood events,
- Section 7 reviews the sensitivity of the model to data used,
- Section 8 identifies the provisional flood hazard,
- Section 9 identifies the hydraulic categorisation,
- Section 10 describes the potential flood damages,
- Section 11 reviews the impacts of climate change.

3. CATCHMENT DESCRIPTION

The Empire Bay catchment is located within the Gosford City Council (GCC) Local Government Area. It is a sub-catchment of Brisbane Water, which connects to Broken Bay covering an area of about 554 ha. The suburb of Empire Bay and the south-western section of Bensville are included in the study area. Cockle Channel and Cockle Bay are the waterbodies situated on the northern side of the catchment.

Land-use in the catchment is primarily residential with significant areas of bushland / vegetated areas. The density of residential areas varies from low-density detached houses in the main part of Empire Bay and within Bensville, to larger bushland residential lots between these two areas. Several shops are located within the two main residential areas. Large areas of bushland are located on the higher elevations in the southern part of catchment and also along some areas adjoining the estuary including Cockle Bay Nature Reserve.

The Empire Bay catchment is bounded by a ridgeline which runs along the southern and western sides. The southern ridgeline has elevations varying from about RL 60m AHD in the west to a peak of about RL 150m AHD in the south east. Bensville is separated by a ridgeline to Cockle Bay with a highest elevation of about RL 36m AHD. The Empire Bay residential area is relatively flat with an elevation down to about RL 1.0m AHD at the foreshore and the area around Cockle Bay Nature Reserve is also relatively flat.

Pit and piped drainage infrastructure convey stormwater runoff through the main residential areas of Empire Bay and Bensville to the foreshore area. Several drainage depressions and natural channels convey runoff from the bushland areas to piped systems crossings Empire Bay Drive.

4. DATA

4.1 Community Consultation

A questionnaire was delivered to residences in the Empire Bay study area in October 2007, totalling about 1300. The aim of the questionnaire was to gauge resident's awareness of flooding in the catchment and to identify specific accounts of flood inundation to be used for the calibration of the computer model. One hundred and thirty-two responses were received from across the study area as shown in Figure 4.1. Appendix A includes a copy of the questionnaire and a summary of each response. Photos forwarded by residents are included in Appendix A.

Of the responses, 50% indicated that they have lived in the area for more than 10 years. Fifty percent of respondents were aware of flooding in the catchment, 25% had some awareness of flooding, and 23% were not aware of flooding in the catchment.

The extent of flooding noted by respondents included 7% indicating flooding inside the house, 44% indicating flooding in the yard, and 39% were inconvenienced by flooding events. Similarly, the following areas were nominated as flooded by respondents – backyard 29%, garage 17%, above-floor 5%, below-floor 9%, and frontyard 23%.

Different occasions of storm events recalled by respondents are listed in Table 4.1.

Table 4.1 Historic Storm Events

Event Date	Responses	Event Date	Responses
June 2007	41(31%)	October 1985	3
January 1996	17(13%)	November 1984	2
February 1992	7(7%)	February 1981	2
February 1990	4	January 1978	0
January 1989	7	March 1977	1
April 1988	8	May 1974	2

Twenty percent of respondents advised they had noticed bridges / culverts as blocked during storm events. Comments were also made noting that the drainage systems were undersized and debris blocked some pipelines. Debris such as dirt, branches, overgrown grass or weeds were identified as materials blocking pipes.

From 18th September to 16th October 2009, the draft report was placed on public exhibition at Council's administration centre, local libraries and on its website. Comments and submissions were invited for review for the final report. No submissions were received for this Study.

4.2 Rainfall

Owing to the small area of the catchment, uniform areal distribution of design storms has been assumed for the hydrologic component of the analysis. Design rainfall depths and temporal patterns for the modelling of 0.5% AEP, 1%, 2%, 5%, 10%, 20%, 50%, and 100% AEP were developed using standard techniques provided in Australian Rainfall and Runoff (1998). The design Intensity-Frequency-Duration (IFD) parameters are presented in Table 4.2

Table 4.2 Design IFD Parameters

Parameter	Value
2-Years ARI 1-hour Intensity	38.50 mm/hr
2-Years ARI 12-hours Intensity	8.50 mm/hr
2-Years ARI 72-hours Intensity	2.60 mm/hr
50-Years ARI 1-hours Intensity	77.00 mm/hr
50-Years ARI 12-hours Intensity	17.00 mm/hr
50-Years ARI 72-hours Intensity	5.90 mm/hr
Skew	0.0
F2	4.3
F50	15.9
Temporal Pattern Zone	1

The Probable Maximum Precipitation (PMP) was estimated using the publication "*The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method*" (Commonwealth Bureau of Meteorology, 2003). The spatial distribution ellipses of the method are not required due to the small size of the catchment. Table 4.3 shows the data for the PMP calculations.

Table 4.3 PMP Calculation Values

Parameter	Value
Moisture Adjustment Factor	0.71
Elevation Adjustment Factor	1.00
Percentage Rough	100%

Estimated average design storm rainfall intensities for the full range of storm events and durations are presented in Table 4.4.

Table 4.4 Design Rainfall Intensities (mm/h)

Duration	1 year ARI	2 year ARI	5 year ARI	10 year ARI	20 year ARI	50 year ARI	100 year ARI	200 year ARI	PMP
15 min	62	79	101	113	130	151	168	191	680
30 min	43.7	56	72	82	94	110	122	138	480
45 min	35.1	45.2	58	66	76	90	100	114	413
1 hour	29.8	38.5	50.0	57	65	77	86	98	350
1.5 hour	23.4	30.3	39.3	44.6	51	61	67	76	307
2 hour	19.7	25.5	33.0	37.5	43.3	51	57	65	265
3 hour	15.4	19.9	25.8	29.2	33.8	39.7	44.3	51	217
4 hour	N/A	N/A	N/A	N/A	N/A	N/A	N/A	43	185
4.5 hour	12.0	15.5	20.1	22.8	26.3	31.0	34.5	N/A	N/A
5 hour	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	164
6 hour	10.0	13.0	16.8	19.1	22.1	26.0	28.9	33	143
9 hour	7.84	10.1	13.1	14.9	17.2	20.3	22.6	N/A	N/A

4.3 Pit and Pipe Field Survey

Stormwater drainage pit and pipe details were supplied by Gosford City Council. Johnson Partners completed a detailed field survey of parts of the drainage system to supplement Council's information.

Site inspections and the field survey identified that some of the pipelines were below the standing water level at their outlet due to debris blocking the flow of water or due to the tide level at the time of inspection.

4.4 Soil Type and Loss Rates

The Department of Conservation and Land Management (NSW) soil map of the Gosford-Lake Macquarie area (1993) and Sydney (1989) identifies the soil types within the Empire Bay catchment. The residential area of Empire Bay is predominantly on Woy Woy soil type with Mangrove Creek soil type located on the western and eastern areas. The bushland / rural residential area between Empire Bay and Bensville has Mangrove Creek soil type adjacent to Cockle Bay, then a large area of Cockle Bay soil type, with Erina soils on the southern side to the higher elevations.

Woy Woy soils in the region are noted for their permanently high water table and seasonal waterlogging. High permeability is identified as a feature of the soil. Mangrove Creek soils are a mix of high and low permeability but generally low permeability where not regularly inundated. High run-on of water is also noted as a limitation of the soil. Characteristics of the Cockle Bay soils are seasonal waterlogging and localised permanent waterlogging. The underlying soils of the group are typically of low permeability. Erina soils have the limitation of high run-on and underlying groups are generally of low permeability.

Responses from the resident questionnaire noted that in some cases water can remain on the ground for a couple of hours, days or even up to a week. The influence of tide levels in the estuary on water ponding in the Empire Bay area was also noted.

4.5 Boundary Conditions

The 'Brisbane Water Foreshore Flood Study' (2009) completed by Cardno Lawson Treloar established the water levels and flood behaviour for various design events in Brisbane Water. Simulations for design ARI event conditions were undertaken for 5, 10, 20, 50, 100, 200-years ARI and a PMF event. Peak water level results at 119 foreshore locations in Brisbane Water are presented, with 11 of these sites located within the Empire Bay catchment study area.

Peak water levels are shown in Table 4.5 for the Empire Bay area with the highest level occurring in Cockle Channel in the west and reducing heading eastward to Cockle Bay. The joint probability of severe catchment flooding from the Empire Bay catchment occurring together with severe estuary flooding is low. Hence modelling for the case of a rare storm event, such as 1% AEP, in the catchment with a rare estuary level, such as from a 1% AEP event, as a downstream boundary may not be appropriate.

For the purpose of local creek studies, such as the Empire Bay Catchment Flood Study, the 1% probability of exceedance (PoE) level is to be used as the downstream boundary level in the estuary (Cardno Lawson Treloar, 2009). The 1% probability of exceedance is the level that one can be 99% confident will not be exceeded during any creek flood event. The 1% PoE level for Empire Bay is 0.64m AHD (Cardno Lawson Treloar, 2009).

The Empire Bay Catchment Flood Study assesses flood behaviour due to runoff from the local catchment for the various storm events. Flood behaviour due to elevated water levels in the estuary in storm events is described in the Brisbane Water Foreshore Flood Study (2009).

Table 4.5 Empire Bay Foreshore Peak Water Level

Average Recurrence Interval (ARI)	Peak Water Level Range (m AHD)
PMF	1.5 – 1.78
200y ARI	1.41 – 1.57
100y ARI	1.37 – 1.51
50y ARI	1.32 – 1.44
20y ARI	1.27 – 1.37
10y ARI	1.23 – 1.31
5y ARI	1.18 – 1.25

5. FLOOD MODELLING

The SOBEK 1D/2D model from WL|Delft Hydraulics Laboratory was used to model the catchment and to hydraulically route overland flood flows and street flow. This modelling system dynamically couples the one-dimensional and two-dimensional flow in the floodplain.

An area of about 887 ha is modelled as shown in Figure 5.1 which includes parts of the estuary. To facilitate the modelling, the catchment has been divided into three sectors comprising the Empire Bay residential area, Bensville residential area, and the bushland residential section which covers the largest area.

5.1 Hydrology

The SOBEK modelling of the Empire Bay catchment utilises the rainfall-on-grid methodology for developing the hydrology. In the model, rainfall is applied directly to the 2D terrain, and the hydraulic model automatically routes the flow. The rainfall patterns are described in Section 4.2 and two different loss rates shown in Table 5.1 are applied to the model. Higher loss values are applied to the bushland sector compared to the residential sectors based on the soil types described in Section 4.4 and the larger amount of pervious area in the bushland sector.

Table 5.1 Hydrology Loss Rates

Description	Empire Bay Residential and Bensville Residential Values	Bushland Residential Sector Values
Initial Loss	5 mm	20 mm
Continuing Loss	1 mm/h	2.5 mm/h

5.2 Piped Drainage Systems

Piped drainage systems are incorporated into the SOBEK model as distinct 1D elements connected to the terrain grid. Detailed field survey by Johnson Partners supplemented the pipe information supplied by Gosford City Council.

The different size of inlet pit openings was included in the model as orifice-links of the same size to represent the restriction of flow into the piped system. An orifice-link was included between pipeline reaches to model the energy losses at pits and between conduits. Generally the open channel sections and drainage depression are represented in the terrain grid but specific lines, such as at Sorrento Road / Kendall Road and Wards Hill Road / Empire Bay Drive, are included as distinct 1D elements.

Figure 5.2 shows the pipe and channel systems incorporated in the model. About 11.6 km of pipeline and 0.2 km of channel systems are modelled. The roughness values adopted for the piped drainage systems are listed in Table 5.2.

Table 5.2 1D Element Roughness Values

Component	Roughness Value
Pipe	0.018
Culvert	0.025
Open Channel	0.03

5.3 Topography

A terrain grid was developed to represent ground elevations based on aerial laser scanning data from Gosford City Council supplemented by detailed field survey completed by Johnson Partners. Figure 5.3 shows the elevations of the Empire Bay catchment in the model. The ridgeline along the southern part of Empire Bay is at about RL 100 to 150 m AHD and a ridgeline through Bensville has a peak elevation of about RL 37 m AHD. The main residential area of Empire Bay grades from a peak of RL 15m AHD at Empire Bay Drive to about RL 1.0m AHD at the estuary foreshore areas. House footprints were retained at ground elevation to account for some potential storage of floodwaters at these locations (eg under-floor voids, verandah areas, and above-floor inundation).

Details of the elevation grids for the three sectors are listed in Table 5.3.

Table 5.3 Elevation Grids

Sector	Area	Grid Resolution	Number of Grid Cells
Empire Bay Residential	175 ha	3m x 3m	389,000
Bensville Residential	46 ha	3m x 3m	102,000
Bushland Residential	667 ha	9m x 9m	230,000

5.4 Hydraulic Roughness

Each cell of the elevation grids also has a roughness value to model the influence to flow behaviour of the particular land-use. The adopted roughness layout, shown in Figure 5.4, was based on aerial photographs, site inspections, and Council's land-use zonings. The roughness value applied for each land-use is listed in Table 5.4.

Table 5.4 Roughness Values

Land-use	Roughness Value
Channel	0.03
Bushland	0.06
Open Space	0.03, 0.04 or 0.05
Residential	0.09
Vegetated Marsh	0.06 or 0.07
Road	0.02
Estuary	0.02

5.5 Model Calibration

The resident questionnaire detailed in Section 4.1 indicated most respondents recalled the June 2007 event. Recollection of storm events prior to June 2007 was less but some details were noted for the April 1988 event.

The data required to calibrate the SOBEK model to particular events includes water levels, event rainfall data, and event water level data. Residents recalled particular flood details for the June 2007 event and the April 1988 event, but insufficient water levels were available for potential calibration to other events. Rainfall and water level data was available for the June 2007 event and April 1988 event. Thus the model was run for both these events as calibration storms.

5.5.1 June 2007 Storm Event

A significant storm event occurred between 7 and 12 June 2007 in the Central Coast area. A pluviograph at Kincumber operated by Manly Hydraulics Laboratory is the nearest rainfall record to the Empire Bay catchment. It is about 3 km from the shops at Empire Bay (Sorrento Road and Kendall Road) at an elevation of about 20m AHD and records data in 2 minute timesteps. Manly Hydraulics Laboratory also operates a pluviograph at Koolewong, about 5.6 km from Empire Bay shops. The location of these sites is shown in Figure 5.5. Rainfall across Cockle Channel from Empire Bay in the suburb of Davistown is recorded by Mr. B. Evans on a daily basis.

Table 5.5 lists the daily rainfall depths over the period of Wednesday 6 June 2007 to Tuesday 12 June 2007. Kincumber rainfall data was obtained from Manly Hydraulics Laboratory and is equivalent to a storm event of about 20% AEP. Koolewong data was obtained from the report "New South Wales Central Coast June 2007 Flood Summary" by NSW Department of Commerce and Manly Hydraulics Laboratory (2007).

Table 5.5 Rainfall Depths (mm/d)

Date	Davistown (from Mr. B. Evans)	Koolewong	Kincumber (depth to 9am)	Ratio of Davistown to Kincumber
6/6/07	0	n/a	0 (in 9 hours from 6/6/07 00:00)	
7/6/07	54	60.5	129	0.4
8/6/07	38	71	45	0.8
9/6/07	63	92.5	82.5	0.8
10/6/07	49	4.5	63.5	0.8
11/6/07	2	0.0	1	2.0
12/6/07	0	n/a	0.5	0.0
TOTAL	*206*	*228.5*	*321.5*	*0.6*

The Kincumber daily rainfall is significantly higher than the Davistown and Koolewong depths. For the calibration model, the Kincumber pluviograph rainfall will be used as the rainfall per day reflects the pattern of the nearby Davistown data better and is located closer to the catchment. The Kincumber rainfall is multiplied by 0.8 to reflect the rainfall recorded in the catchment and a continuing loss of 1 mm/hr is applied to the data. Figure 5.6 shows the adjusted rainfall depths at two minute intervals from the Kincumber pluviograph data.

Manly Hydraulics Laboratory operates a water level recorder at Koolewong (shown in Figure 5.5) which is the closest to the Empire Bay catchment. Figure 5.7 shows the water level time series for the June 2007 storm event. The peak water level of 1.12m AHD occurs at around 06:00 on Saturday 9th June, compared to the peak rainfall burst on Thursday 7th June though rainfall continued for periods up to and beyond the peak tide time.

The SOBEK model incorporating the adjusted Kincumber rainfall pattern and the Koolewong water level pattern was run for the time period of 02:00 on Thursday 7/6/07 to 00:00 on Sunday 10/6/07.

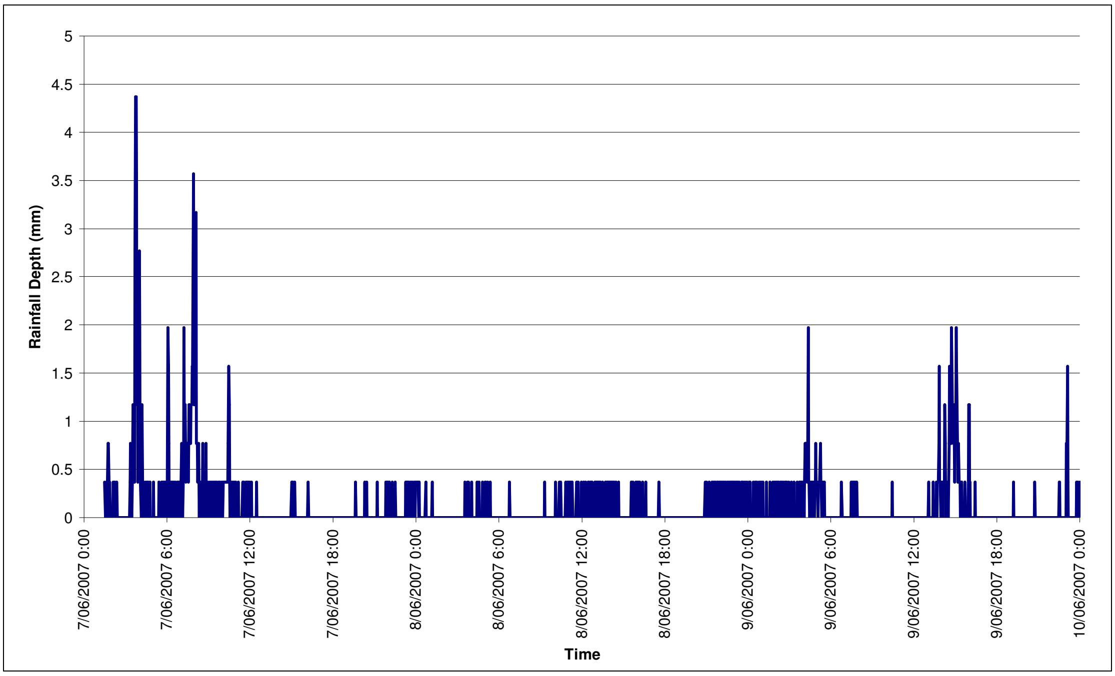

Figure 5.6 Kincumber Rainfall Depth per two-minutes (adjusted by 0.8) (June 2007)

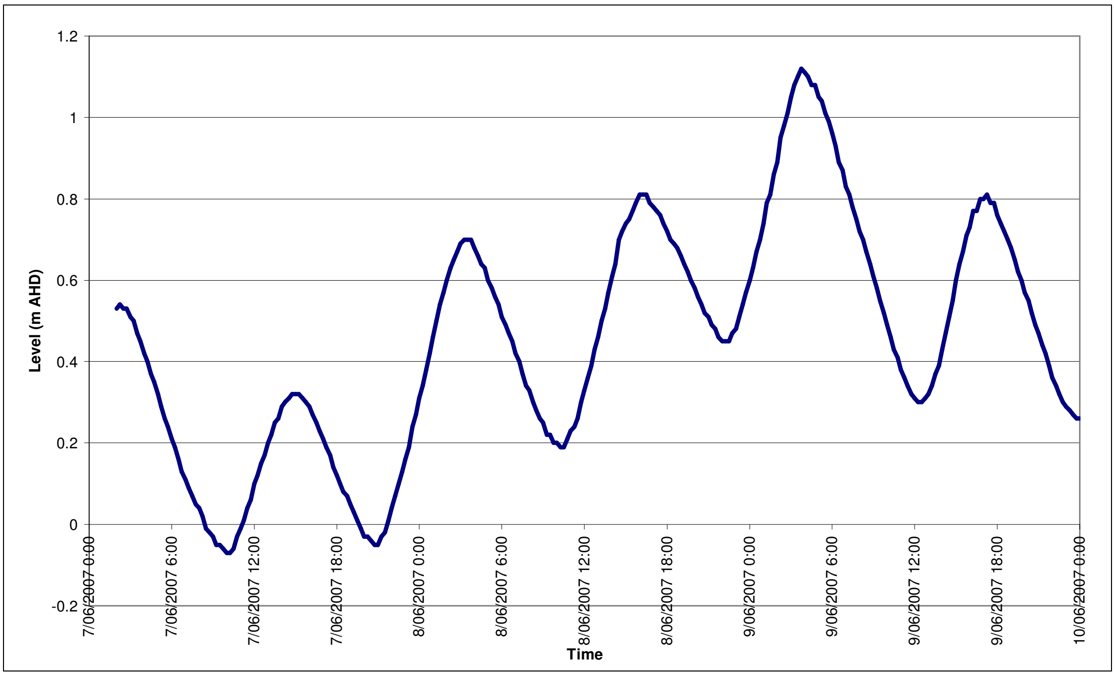

Figure 5.7 Koolewong Water Level Time Series (June 2007)

5.5.2 April 1988 Event

A storm with a rainfall depth equivalent to the 1% AEP event was experienced on the 29th and 30th April 1988. A depth of 318 mm was recorded at the Kincumber rainfall gauge on the 29th and 396 mm on the 30th. Similarly to the June 2007 data, the Kincumber data was adjusted by 0.8 to better represent the rainfall to the Empire Bay catchment. Figure 5.8 shows the rainfall depth in 15 minute timesteps adjusted by 0.8 for the flood modelling period of 29/4/88 00:00 to 1/5/88 00:00.

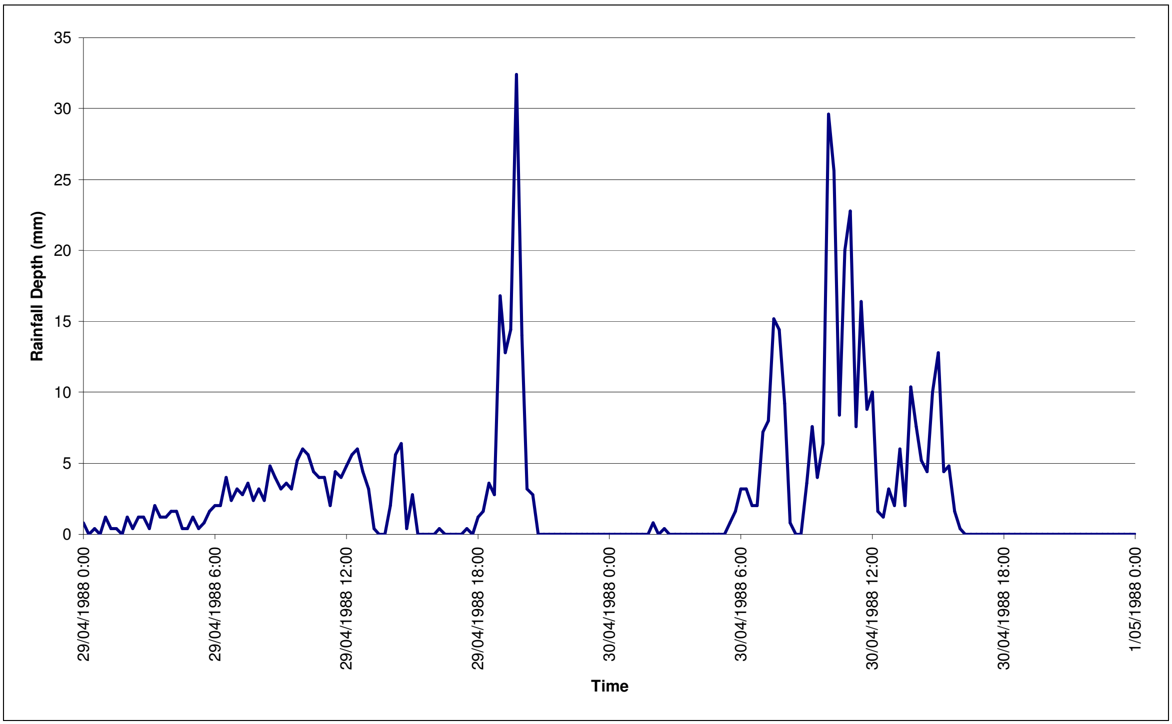

Figure 5.8 Kincumber Rainfall Depth per 15-minutes (adjusted by 0.8) (April 1988)

Figure 5.9 shows the water level recorded at the Koolewong site during the April 1988 storm event. A peak water level of 0.7m was recorded at 21:00 on 30th April 1988. In comparison to the June 2007 event, the April 1988 event received more rainfall but had a lower level in the estuary.

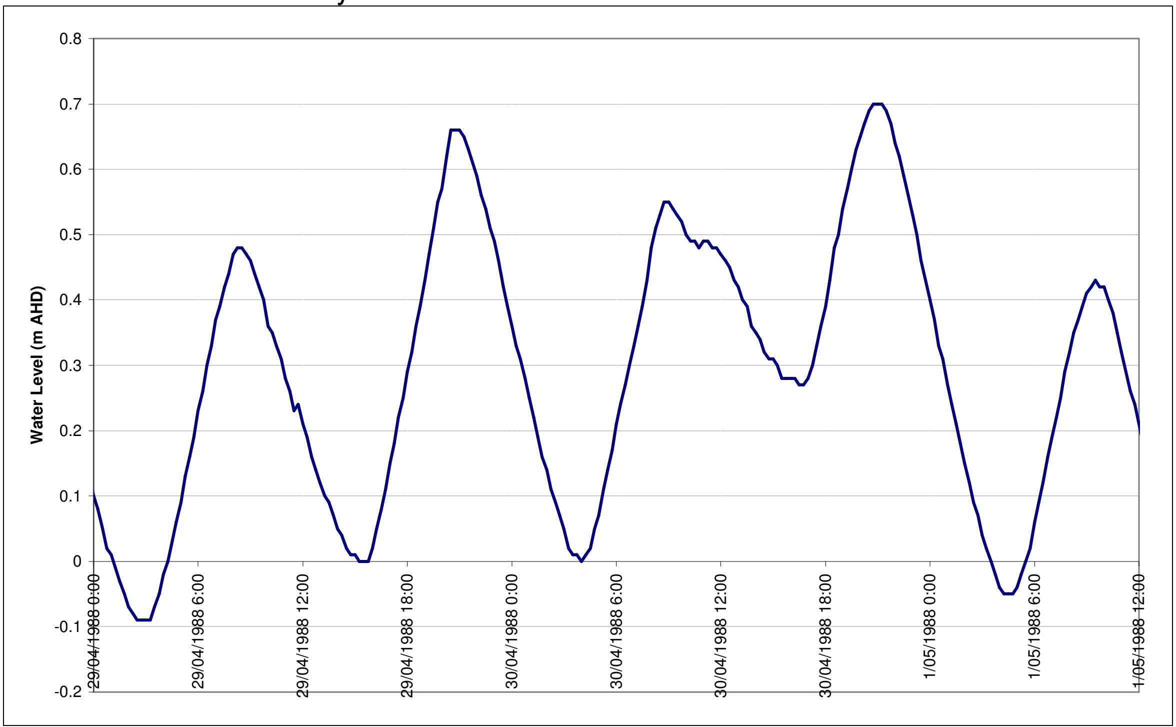

Figure 5.9 Koolewong Water Level Time Series (April 1988)

5.5.3 Results

Table 5.6 shows the results from SOBEK for flood levels satisfactorily model the flood descriptions noted in the questionnaire responses. The surveyed levels were obtained by Johnson Partners. Table 5.7 shows anecdotal flood inundation noted by respondents in the questionnaire and similar results modelled by SOBEK. The peak depths for the June 2007 event and April 1988 event are shown in Figure 5.10 and Figure 5.11 respectively.

Table 5.6 Model Results for June 2007 and April 1988 event – Surveyed (m AHD)

Location	Description	Surveyed Level (m AHD)	SOBEK Model June 2007	SOBEK Model April 1988	Comment
10 Pomona Road	~1988-89 within 25mm of floor	Dwelling floor level = 20.32	Peak WL 20.67 @ 0.05m depth	Peak WL 20.69 @ 0.08m depth	Model ground elevation is higher than floor thus ground level detail not sufficient for compare
8 Pomona Road	1988 & 1989 house flooded; about 300mm deep across yard	Dwelling floor level = 20.105	Peak WL 20.37 @ depth 0.06m; yard peak ~ 0.16m	Peak WL 20.40 @ depth 0.09m; yard peak ~ 0.22m	Model ground elevation is higher than floor thus ground level detail not sufficient for compare
8 Boongala Avenue	April 1988 water to bottom step and flooded garage	RL bottom step = 1.23; RL garage floor = 1.23	Peak WL 1.29 @ depth 0.08m	Peak WL 1.40 @ depth 0.19m	Model ground elevation close to levels thus potential ground level detail not sufficient for compare
1 Boongala Avenue	Not flooded above floor in 1988 or 2007 as house was raised post-1974	Dwelling floor level = 1.43	Peak WL 1.15 @ depth 0.12	Peak WL 1.37, @ depth 0.34	Satisfactory
11 Valencia Street	June 2007 water came up to house	RL flood level = 2.34	Peak WL 2.40 @ depth 0.05 (northside); Peak WL 2.22 @ depth 0.09 (southside)	Peak WL 2.42 @ depth 0.07 (northside); Peak WL 2.25 @ depth 0.12 (southside)	Satisfactory – location of level not specified
12 Valencia Street	2007 basement flooded	Dwelling floor level = 6.19	Peak WL 6.37 @ depth 0.02	Peak WL 6.38 @ depth 0.03	Model ground elevation is higher than floor thus ground level detail not sufficient for compare
12 Allawa Close	Inside house flooded - ~1988	Dwelling floor level = 5.80	Depth<0.01m	Depth<0.01m	Model depth <0.01m thus detail not sufficient to compare

Table 5.7 Model Results for June 2007 – Anecdotal Reports

Location	Description	SOBEK Model June 2007
6 Gordon Rd	~200mm deep across Gordon Road in Jun07, Jan96, Apr88. Apr88 water at steps below back door	~0.3m across Gordon Rd; ~0.2m in back yard
9 Gordon Road	Jun07 water across Gordon Rd but ok to drive through	~0.25m deep
2 Boongala Ave	Jun07 property has never flooded	<0.06m deep
52A Sorrento Road	Not flooded. In heavy rainfall Gordon Road connecting to Boongala Road covered by water	Peak ~0.11m deep on property. Gordon / Boongala intersection up to ~0.4m deep.
	Boongala Avenue has been like a river. Boongala always floods with heavy downpour	Depths across Boongala ~0.05 to 0.50m
14 Gordon Rd	Gordon Road about 1 foot deep	Depths on road near property ~0.05 to 0.40m
22 Myrtle Road	Jun07 backyard completely underwater, almost to backdoor	Yard mostly inundated to depths ~0.01 to 0.17m
8 Allawa Close	Jun07 rose to ~0.3m covering backyard and partial front yard	Part front yard to peak 0.07m, flood across backyard peak ~0.08m
11 Echuca Road	Jun07 ~3 inches in backyard	Peak ~0.10m
5 Echuca Road	No property flooding. Water covers intersection of Echuca Road and Rickard Road in downpours	Isolated locations on property peak~0.08m. Intersection ~0.15 to 0.45m deep
70 Shelley Beach Road	Jun07 property access blocked. Front yard ~8 inches deep	~0.30m deep across road. Front yard ~0.18m deep
55 Shelley Beach Road	Jun07 bottom end of rear yard ~0.2m	Peak ~ 0.2m
4 Shelley Beach Road	Jun07 road completely cut	Peak depth on road ~0.2m
41 Hillcrest Ave	Never affected by flooding	Peak depth in yard ~0.04m
9 Allawa Close	Jun07 paddock under 5-10cms water	Depth across paddock ~0.05 to 0.15m
Killdare Street	Jun07 no reported flooding	Isolated locations of water of peak depth up to 0.09m
10 Emma Street	Jun07 Backyard up to 0.20m deep	Backyard depth up to 0.17m
6 Emma Street	Jun07 up to 60mm from side neighbours properties	Peak about 0.06m runoff from neighbours not road
Empire Bay Drive (between Wards Hill Rd and Awinya Cl)	Several reports of no flooding	Road isolated inundation up to ~0.15m, respondent properties up to ~0.07m

6. DESIGN FLOOD ESTIMATION

Flood behaviour was modelled in SOBEK for a series of Annual Exceedance Probabilities (AEP). The 0.5% AEP, 1%, 2%, 5%, 10%, 20%, 50%, and 100% AEP and Probable Maximum Flood (PMF) events were modelled for local catchment runoff with a 1% Probability of Exceedance estuary level.

6.1 Critical Duration

The critical duration for the Empire Bay catchment was evaluated by reviewing the peak water level results for a range of durations for the 20% AEP, 1% AEP and PMF events. Durations of 15 minutes, 30, 60, 90, 120, and 180 minutes were modelled for the 1% AEP event. PMF durations of 15 minutes, 30, 45, 60 and 90 minutes were modelled. Reference locations across the catchment, shown in Figure 6.1, are listed in Table 6.1 for evaluating the results.

Table 6.1 Sensitivity Analysis Reference Locations

Number	Location
1	Intersection Gordon Rd & Boongala Ave
2	Intersection Sorrento Rd & Gordon Rd
3	Sorrento Rd near Kendall Rd
4	Intersection Greenfield Rd and Rickard R
5	Intersection Shelly Beach Rd & Sher Cl
6	Greenfield Rd
7	Empire Bay Dr (near Awinya Cl)
8	Palmers Lane
9	Empire Bay Dr
10	Empire Bay Dr
11	Wards Hill Rd
12	21 Pomona Rd
13	Pomona Rd
14	Valencia St
15	Emma St
16	Kildare St

The critical durations for the PMF, 1% AEP, and 20% AEP are shown in Figure 6.2, Figure 6.3 and Figure 6.4 respectively.

For the 1% AEP and 20% AEP, the higher elevations in the catchment show a shorter critical duration (about 15 minutes) compared to the lower elevations and less steep areas (between 90 and 180 minutes). Table 6.2 shows peak water levels at the reference locations for the 1% AEP durations modelled. Comparison of the separate durations for the 1% AEP and 20% AEP shows that the 2 hour duration storm is the critical event for the catchment as:

- there is no difference to peak water levels (in excess of +/- 0.01m) between the 2 hour and 15 minute storm,

- peak water levels for the 90 minute storm are lower than the 2 hour storm in some locations, but is generally only slightly higher (<0.02m) in other locations.

Table 6.2 1% AEP Critical Duration

Point	Peak Flood Level (m AHD) for Duration						
	15 min	30 min	60 min	90 min	120 min	180 min	Critical Duration
1	1.21	1.30	1.36	1.36	1.37	1.36	120 min
2	1.13	1.17	1.22	1.24	1.24	1.24	120 min
3	1.31	1.31	1.31	1.31	1.31	1.31	90 min
4	1.36	1.41	1.46	1.46	1.47	1.44	120 min
5	1.25	1.25	1.25	1.25	1.25	1.25	120 min
6	1.76	1.76	1.78	1.77	1.79	1.76	120 min
7	9.34	9.37	9.39	9.38	9.40	9.37	120 min
8	6.49	6.59	6.66	6.64	6.69	6.63	120 min
9	7.66	8.54	8.78	8.78	8.82	8.66	120 min
10	8.92	8.98	9.03	9.03	9.04	9.00	120 min
11	12.08	12.09	12.12	12.10	12.12	12.11	120 min
12	16.09	16.52	16.81	16.81	16.93	16.63	120 min
13	17.69	17.72	17.73	17.75	17.76	17.73	120 min
14	1.29	1.30	1.29	1.31	1.30	1.28	90 min
15	1.79	1.79	1.80	1.80	1.80	1.78	120 min
16	7.86	7.89	7.85	7.89	7.87	7.83	30 min

6.2 Model Scenarios

Catchment models were therefore run in SOBEK for the durations shown in Table 6.3.

Table 6.3 Model Scenarios

AEP	Rainfall Durations [min]	Estuary Level [m AHD)]
PMF	15, 30, 45, 60, 90	0.64 (1% PoE)
0.5%	120	0.64 (1% PoE)
1%	15, 30, 60, 90, 120, 180	0.64 (1% PoE)
2%	120	0.64 (1% PoE)
5%	120	0.64 (1% PoE)
10%	120	0.64 (1% PoE)
20%	15, 30, 60, 90, 120, 180	0.64 (1% PoE)
50%	120	0.64 (1% PoE)
100%	120	0.64 (1% PoE)

6.3 Results

Model results of the flood extent, peak depth, peak level, and peak flow speed due to local catchment runoff are shown in the figures as included in Volume 2 of this Study Report. Each of the figures is presented on two sheets – Sheet A focussing on the Empire Bay residential area and Sheet B focussing on the Empire Bay bushland residential and Bensville areas. As the rainfall-on-grid modelling methodology in SOBEK models rainfall on every cell within the extent, the results figures are filtered and show flood parameters at locations where the depth is greater than or equal to 0.10m. Model results from the foreshore within the estuary are not shown for clarity of presentation. This filtering process improves interpretation of results for evaluating areas with significant runoff. The extent figures presented therefore show locations where the flow depth is greater than or equal to 0.10m.

Table 6.4 Model Results Figures

AEP	Flood Extent	Peak Water Levels	Peak Flood Depth	Peak Flow Speed
PMF	Figure 6.5 A & B	Figure 6.14 A & B	Figure 6.23 A & B	Figure 6.32 A & B
0.5%	Figure 6.6 A & B	Figure 6.15 A & B	Figure 6.24 A & B	Figure 6.33 A & B
1%	Figure 6.7 A & B	Figure 6.16 A & B	Figure 6.25 A & B	Figure 6.34 A & B
2%	Figure 6.8 A & B	Figure 6.17 A & B	Figure 6.26 A & B	Figure 6.35 A & B
5%	Figure 6.9 A & B	Figure 6.18 A & B	Figure 6.27 A & B	Figure 6.36 A & B
10%	Figure 6.10 A & B	Figure 6.19 A & B	Figure 6.28 A & B	Figure 6.37 A & B
20%	Figure 6.11 A & B	Figure 6.20 A & B	Figure 6.29 A & B	Figure 6.38 A & B
50%	Figure 6.12 A & B	Figure 6.21 A & B	Figure 6.30 A & B	Figure 6.39 A & B
100%	Figure 6.13 A & B	Figure 6.22 A & B	Figure 6.31 A & B	Figure 6.40 A & B

7. SENSITIVITY ANALYSIS

The sensitivity of the model was tested to demonstrate the range of uncertainty in the model results for changes in key parameters. The following variables were tested for sensitivity:

- Catchment rainfall – increased and decreased by 20%
- Catchment roughness – increased and decreased by 20%
- Downstream boundary condition – increased and decreased by 20%
- Culvert and pipe blockage – for all systems and for particular systems
- Future conditions.

The impact of potential climate change scenarios, such as increased sea levels and increased rainfall intensity was also modelled as described in Section 11.

The sensitivity modelling was undertaken for the 2 hour duration event which is the critical duration for the Empire Bay catchment. The variables were assessed for the 1% AEP event except for the pipe blockage scenario which was modelled for the 20% AEP event. Results for the varied parameters for the selected reference locations are included in Appendix B. These reference locations are listed in Table 6.1 and included on Figure 6.1.

7.1 Catchment Rainfall

The average rainfall intensity for the 1% AEP 2 hour duration was increased by 20% and decreased by 20% for the sensitivity analysis. The resultant average intensities for the events were: 57 mm/h for the standard storm, 68.4 mm/h for the 20% increased scenario, and 45.6 mm/h for the 20% decreased scenario. Initial loss and continuing loss rates were applied to the resultant five minute timestep rainfall patterns.

The peak water levels shown in Table B.1 (in Appendix B) show that the 20% adjustment to the rainfall results in changes to the base case levels of several centimetres around the main residential areas at Bensville and Empire Bay. The largest fluctuations in water levels occur in the vicinity of Pomona Road and Palmers Lane where runoff from the high elevation areas is concentrated into drainage channels. The model shows consistent results as the reduced rainfall results in lower peak water levels and higher peak water levels for the increased rainfall scenario.

7.2 Catchment Roughness

Values of the hydraulic roughness parameter applied to the model, described in Section 5.4, were increased and decreased by 20% for the sensitivity analysis. Resultant peak water levels at the reference locations are listed in Table B.2 (Appendix B).

Water levels do not vary significantly in most reference locations as they are in locations where flow is not concentrated into a main flowpath conveying large flowrates. Locations 9, 10, and 12 show the largest variation for the roughness parameter as runoff from the upstream bushland areas are concentrated to these points. The model shows consistent results as the increased roughness results in an increase to the peak water level (noting that the difference at Location 8 is not significant at less than 0.01m different).

7.3 Downstream Boundary Condition

The downstream boundary condition applied to the model influences peak water levels in lower parts of the catchment where the estuary level controls peak water levels. Table B.3 (Appendix B) shows the variation in water levels for the 1% AEP 2h event with for three scenarios of water level in the Brisbane Waters estuary –

- Base scenario – 1% PoE level of 0.64m AHD,
- 20% decrease to base scenario at 0.51m AHD,
- 20% increase to base scenario at 0.77m AHD.

All of the reference locations are at elevations above the varied estuary level and thus peak water levels are unaffected. The change shown at Location 12 is not significant as it less than 0.01m.

7.4 Culvert and Pipe Blockage

Two scenarios for pipe blockage were analysed for the 20% AEP 2 hour storm event. The case of all pipes and culverts blocked was evaluated and a case for particular pipes and culverts blocked was also modelled. The drainage lines selected for the second case were based on determining flood behaviour that may result in a higher peak water level for certain areas. Specifically those selected were the downstream reaches of pipeline branches and pipelines located in properties that conveyed runoff from upstream roads or areas. Figure 7.1 shows the piped drainage infrastructure in the model, and the lines blocked for the second scenario.

Table B.4 in Appendix B shows that the peak water levels are generally increased by blockages to pipelines and culverts. Some of the reference locations are unaffected or increased only slightly (up to 0.01m) but other areas show a higher increase, such as Locations 1, 4, 7, 9, and 16.

Blockage of the pipelines results in a decrease in peak water levels (up to 0.09m) at intersection of Gordon Road and Boongala Avenue as the pipelines from Rickard Road do not convey runoff to Gordon Road. Instead, peak water levels increase around Rickard Road and flow overland towards the intersection of Sorrento Road and Boongala Avenue. Peak water levels increase along Rickard Road from about 0.05m at Myrtle Road to 0.16m near Kendall Road. The peak water level at the intersection of Sorrento Road and Boongala Avenue increases by about 0.10m for the pipe blockage scenario.

Peak water levels across Empire Bay Drive also increase at several locations where water is generally conveyed across the road through culverts. The increase due to pipe blockage is up to 0.11m near Awinya Close and rises by about 0.17m near Wards Hill Road.

7.5 Future Conditions

The Empire Bay catchment is effectively fully developed within Council's property zoning in the area. Land zoned for general residential development (zone 2(a)) is located within the north-western area of Empire Bay (north of Empire Bay Drive and West of Kendall Road), and in Bensville. Between these two areas, the zoning is generally 7(c2) for rural-residential properties or undeveloped areas (zoned 8 Nature Reserves or 6(a) Open Space Recreation).

Potential development identified by Council may comprise amending the zoning of rural-residential properties along Empire Bay Drive to low-density residential (2(a)). The SOBEK model was amended to represent these amended sites as low-density residential areas. Figure 7.2 shows the locations of the amended sites.

Figure 7.2 also shows the resultant difference in peak water levels for the increased development. Peak water levels are shown to increase at scattered locations within the re-developed areas by up to 0.11m.

8. PROVISIONAL FLOOD HAZARD

8.1 General

Flood hazard can be defined as the risk to life and limb and damage caused by a flood. The hazard caused by a flood varies both in time and place across the floodplain. The Floodplain Development Manual (NSW Government, 2005) describes various factors to be considered in determining the degree of hazard. These factors are:

- Size of the flood,
- Depth and velocity of floodwaters,
- Effective warning time,
- Flood awareness,
- Rate of rise of floodwaters,
- Duration of flooding,
- Evacuation problems,
- Access.

Hazard categorisation based on all the above factors is part of establishing a Floodplain Risk Management Plan. The scope of the present study calls for determination of provisional flood hazards only, which when considered in conjunction with the above listed factors provides comprehensive analysis of the flood hazard.

8.2 Provisional Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters as detailed in the Floodplain Development Manual (NSW Government, 2005). The provisional hazard is defined as either High or Low as shown in Figure 8.1. The transition zone between high and low is assumed as high hazard.

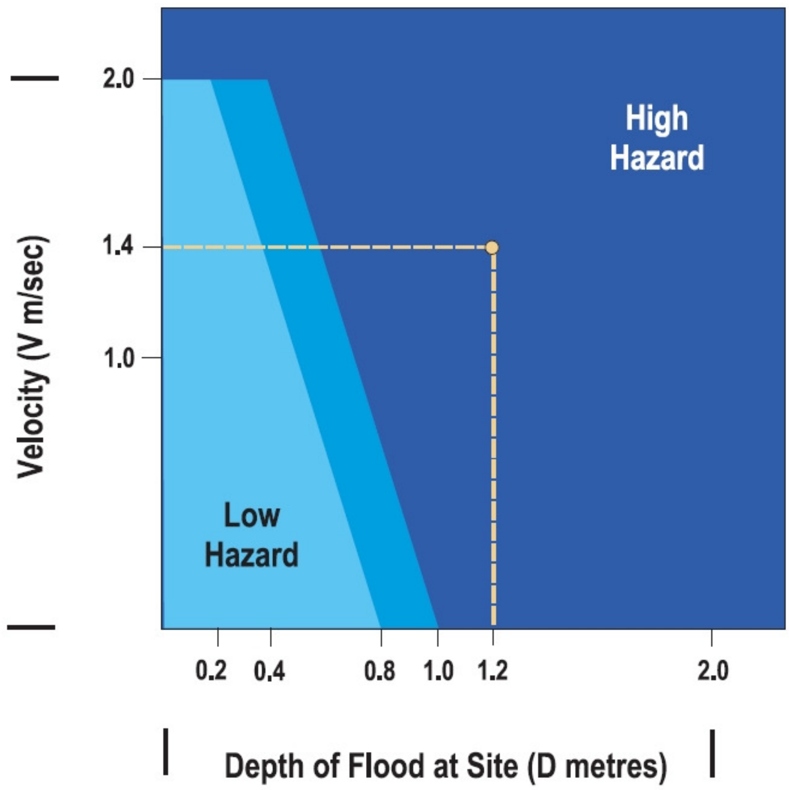

Figure 8.1 Provisional Hazard Classification (NSW Government)

The provisional flood hazard is determined using equations based on the graphs of Figure 8.1 relating the velocity and depth. Provisional hazard due to local catchment runoff determined in the flood model for the PMF, 1% AEP, 5% AEP, and 20% AEP events are shown in Figures 8.2 to 8.5 respectively.

In the 1% AEP event high hazard areas are shown in the channel near Myler Avenue and channels near Empire Bay Drive. Isolated areas adjacent to Empire Bay Drive are shown as high hazard locations. Some roadways are inundated in the 1% AEP event and are shown as low hazard conditions.

In the PMF event some roads are identified as provisional high hazard in the main residential areas of Empire Bay and Bensville. A large area of provisional high hazard is shown in the area between Pomona Road and across Empire Bay Drive to Palmers Lane.

9. HYDRAULIC CATEGORISATION

9.1 General

Hydraulic categorisation of the floodplain is used in the development of the Floodplain Risk Management Plan. The Floodplain Development Manual (2005) defines flood prone land to fall into one of the following three hydraulic categories:

- **Floodway** - Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.

- **Flood Storage** - Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10%.

- **Flood Fringe** - Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant affect on the flood pattern or flood levels.

9.2 Hydraulic Category Identification

Floodways were determined for the 1% AEP, 5% AEP, 20% AEP and PMF by considering those model branches that conveyed a significant portion of the total flow. These branches, if blocked or removed, would cause a significant redistribution of the flow. The criteria used to define the floodways are described below.

As a minimum, the floodway was assumed to follow the creekline from bank to bank. In addition, the following depth and velocity criteria were used to define a floodway:

- Velocity * Depth product must be greater than 0.25 m^2/s **and** velocity must be greater than 0.25 m/s; **OR**
- Velocity is greater than 1 m/s.

Flood storage was defined as those areas outside the floodway, which if completely filled would cause peak flood levels to increase by 0.1 m and/or would cause peak discharge anywhere to increase by more than 10%. The criteria were applied to the model results as described below.

Previous analysis of flood storage in 1D cross sections assumed that if the cross-sectional area is reduced such that 10% of the conveyance is lost, the criteria for flood storage would be satisfied To determine the limits of 10% conveyance in a cross-section, the depth was determined at which 10% of the flow was conveyed. This depth, averaged over several cross-sections, was found to be 0.2 m (Howells et al, 2003). Thus the criteria used to determine the flood storage is:

- Depth greater than 0.2m
- Not classified as floodway.

All areas that were not categorised as Flood Way or Flood Storage, but still fell within the flood extent, where the depth is greater than 0.05 m, are represented as Flood Fringe.

The hydraulic categories for the PMF, 1% AEP, 5% AEP, and 20% AEP based on the peak depth and velocity from local catchment runoff determined in the flood model, are shown in Figures 9.1 to 9.4 respectively.

Floodways are shown in the 1% AEP event along part of Greenfield Rd, Murrong Road, Empire Bay Drive and on parts of Empire Bay Drive. Sections of private property and the drainage channels around Pomona Road are also categorised as floodway. Flood storage areas occur across the catchment and concentrated in parts of Gordon Road, Boongala Avenue, Rickard Road and Palmers Lane.

In the PMF event the main residential area of Empire Bay is predominantly categorised as flood storage and several roads are classified as floodway. Large areas of floodway are shown in the rural residential area of Empire Bay, particularly along the main drainage channels around Pomona Road to Palmers Lane. Empire Bay Drive and several streets in Bensville are categorised as floodways.

10. ANNUAL AVERAGE DAMAGE

10.1 Background

The economic impact of flooding can be defined by what is commonly referred to as 'flood damages'. Table 10.1 lists classifications of various types of flood damages incurred in a catchment. Direct damage costs are just one component of the entire cost of a flood event. There are also indirect costs. Both direct and indirect costs are referred to as 'tangible' costs. In addition to this there are also 'intangible' costs. The values discussed in this report are the 'total' damages and include an assumed intangible cost of 25% of the tangible cost.

Table 10.1 Types of Flood Damages

Type	Description
Direct	Building contents (internal) Structural (building repair and clean) External items (vehicles, contents of sheds etc)
Indirect	Clean-up (immediate removal of debris) Financial (loss of revenue, extra expenditure) Opportunity (non-provision of public services)
Intangible	Social – increased levels of insecurity, depression, stress General inconvenience in post-flood stage

Flood damages can be assessed by a number of means including the use of programs such as FLDAMAGE or ANUFLOOD or via more generic methods using spreadsheets. For the purposes of this project, generic spreadsheets have been developed based on damage curves adapted from the Department of Environment and Climate Change (DECC) [formerly Department of Infrastructure Planning and Natural Resources (DIPNR)].

10.2 Stage – Damage Curves

The Stage-Damage curves are based on the category of property identified within the floodplain, being:

- Residential
- Commercial
- Industrial

The Empire Bay catchment consists of predominantly residential dwellings, with some on large rural-residential allotments. Several commercial properties are located at the intersection of Kendall Road and Sorrento Road, Empire Bay and at Kallaroo Avenue, Bensville. In the study area there are 1131 residential properties and eight commercial properties. No properties within the study area are categorised as industrial.

10.2.1 Residential

The draft DECC (DIPNR) Floodplain Management Guideline No.4 *Residential Flood Damage Calculation* (2004) was used for this study. This guideline includes a template spreadsheet program that determines damage curves for three types of residential buildings:

- Single Storey, slab on ground
- Two Storey, slab on ground

- Single Storey, 'high-set' eg piered structures (floor level assumed to be 1.5m above the ground).

All buildings were assumed to be single storey slab on ground with floor levels 0.30m above a ground level obtained by ALS at the dwelling.

The DECC (DIPNR) curves are derived for late 2001 (base curves). It is recommended to adjust values in the base residential damage curves by Average Weekly Earnings (AWE), rather than by the inflation rate as measured by the Consumer Price Index (CPI). While not specified, we have assumed that the base curves were derived in November 2001, which allows the use of November 2001 AWE statistics (issued quarterly). November 2001 AWE is shown in Table 10.2. The most recent data for AWE from the Australian Bureau of Statistics at the time of assessment was for August 2008. AWE values were sourced from the Australian Bureau of Statistics (ABS, 2008).

Table 10.2 AWE Statistics from 2001 and 2008

Month	Year	AWE
November	2001	$676.40
August	2008	$897.90
Change	32.7%	

All ordinates in the base residential flood damage curves were therefore converted into August 2008 dollars. The residential damage curve is shown in Figure 10.1.

Damages are generally incurred on a property prior to any over floor flooding. The curves allow for a damage of $8,891 (August 2008 dollars) to be incurred when the water level reaches the base of the house (determined as 0.1m below the floor level). Damage was assumed to occur for depths of water over the ground of 0.2m or more (that is, 0.1m below the floor level. Multi-unit properties, such as villas and townhouses, are calculated as a single dwelling.

10.2.2 Commercial

Commercial damage curves were determined based on those included in the FLDamage Manual (Water Studies Pty Ltd, 1992). FLDamage allows for three types of commercial properties:

- Low Value Commercial
- Medium Value Commercial
- High Value Commercial.

The FLDamage curves have a base date of 1990. The Consumer Price Index (CPI) was used to adjust the 1990 data to December 2008 dollars (this data was obtained from the Australian Bureau of Statistics website (ABS, 2009). It was assumed that the FLDamage data was in June 1990 dollars. The CPI data is shown in Table 10.3.

Table 10.3 CPI Statistics from 1990 and 2008

Month	Year	CPI
June	1990	102.50
December	2008	166.00
Change	61.95%	

Consequently, ordinates on the 1990 damage curves have been increased by 61.95% and GST has been included.

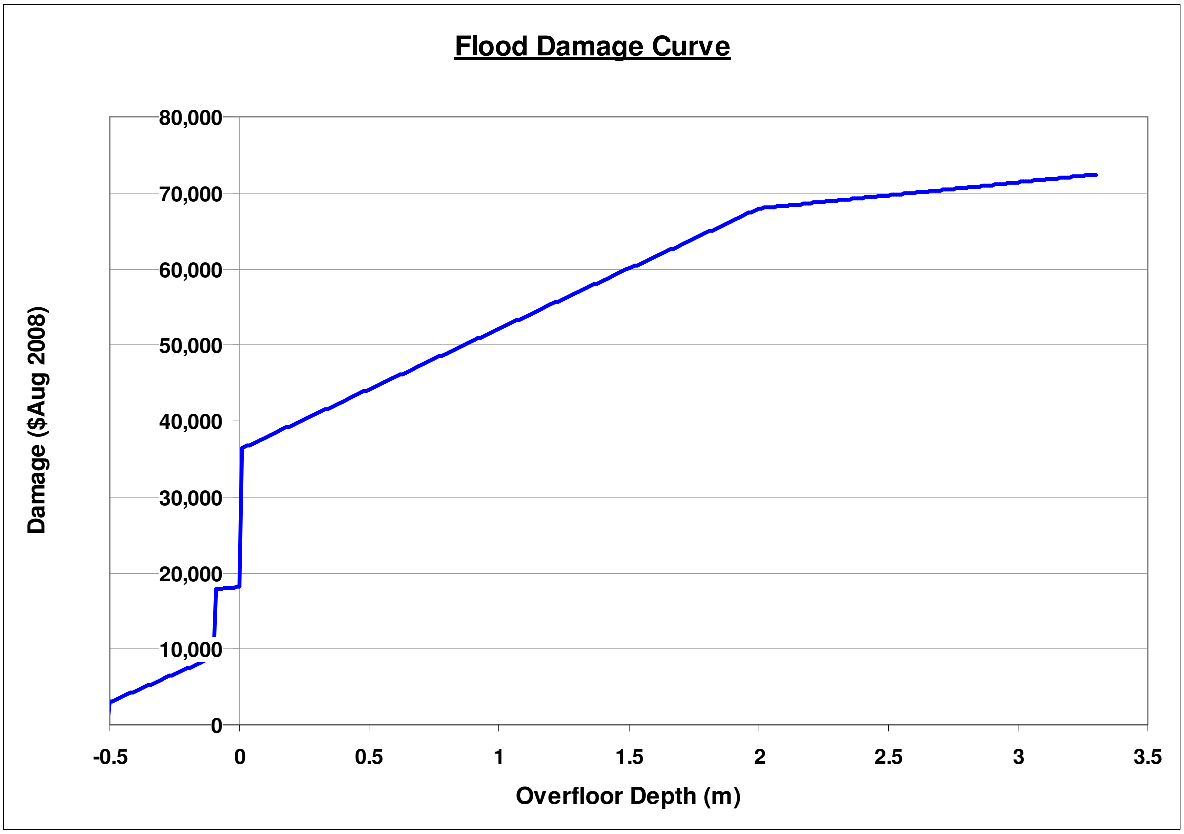

Figure 10.1 Residential Flood Damage Curve

In determining the ordinates on the damage curves, it has been assumed that the effective warning time is approximately zero, and the loss of trading days as a result of the flooding has been taken as 10.

The commercial properties in the study area are assumed as low-value commercial with a floor area of 100 m^2.

10.3 Results

Table 10.4 outlines the flood impacts due to local catchment runoff. Based on the analysis, the average annual damage for the catchment as modelled is estimated to be $548,125. A total of about 1140 dwellings are included in the assessment.

Table 10.4 Flood Damage Summary

Event/Property Type	Number of Properties with overfloor flooding	Maximum Overfloor Flooding Depth (m)	Number of Properties with overground flooding (within 0.10m of floor level)	Total Damage ($Dec 2008)
PMF				
Residential	142	0.76	252	$7,385,609
Commercial	1	0.03	2	$4,094
PMF Total	143		254	$7,389,703
0.5% AEP				
Residential	41	0.26	61	$1,655,750
Commercial	0	N/A	0	$0
0.5% AEP Total	41		61	$1,655,750
1% AEP				
Residential	22	0.24	51	$1,336,782
Commercial	0	N/A	0	$0
1% AEP Total	22		51	$1,336,782
2% AEP				
Residential	20	0.22	45	$1,165,192
Commercial	0	N/A	0	$0
2% AEP Total	20		45	$1,165,192
5% AEP				
Residential	14	0.19	40	$965,120
Commercial	0	N/A	0	$0
5% AEP Total	14		40	$965,120
10% AEP				
Residential	11	0.14	30	$705,320
Commercial	0	N/A	0	$0
10% AEP Total	11		30	$705,320
20% AEP				
Residential	8	0.12	25	$576,385
Commercial	0	N/A	0	$0
20% AEP Total	8		25	$576,385
50% AEP				
Residential	5	0.09	16	$363,591
Commercial	0	N/A	0	$0
50% AEP Total	5		16	$363,591
100% AEP				
Residential	1	0.05	9	$181,102
Commercial	0	N/A	0	$0
100% AEP Total	1		9	$181,102

11. CLIMATE CHANGE

Increased sea levels and increased rainfall intensities are expected to result from climate change effects. Potential impacts to flood behaviour in the Empire Bay catchment due to climate change have been analysed.

The Department of Environment and Climate Change in the guideline 'Practical Consideration of Climate Change' (2007) recommended that climate change assessments review three scenarios of increases to rainfall intensities: 10%, 20%, and 30%. A sea-level rise of up to 0.91m was identified as potentially occurring by the year 2100 due to climate change impacts. Council also nominated 0.2m sea level rise for assessment.

The 'Brisbane Water Foreshore Flood Study' (Cardno Lawson Treloar, 2009) assessed impacts to the Brisbane Water area resulting from sea level rise. Modelling showed that a rise in the mean sea level will result in an equivalent rise of the design levels within the estuary.

A combination of scenarios was modelled for the critical storm event of 1% AEP 2 hour duration with a base estuary level of the 1% probability of exceedance (PoE) level (0.64m AHD):

1. 10% increase to rainfall intensities,
2. 20% increase to rainfall intensities,
3. 30% increase to rainfall intensities,
4. 0.2m rise in estuary level,
5. 0.2m rise in estuary level and 30% increase to rainfall intensities,
6. 0.91m rise in estuary level,
7. 0.91m rise in estuary level and 30% increase to rainfall intensities.

Table C.1 (in Appendix C) lists results for the increased peak water levels at the reference locations of Figure 6.1 resulting from Scenarios 1, 2, and 3. The increased rainfall intensities show that peak water levels are generally unaffected or increased by up to 0.05m in some locations. However, in channels where runoff is concentrated and flows to the estuary, such as near Pomona Road and Empire Bay Drive, the peak water levels are increased significantly.

Table C.2 lists the peak water level results for Scenarios 4 and 5 with a 0.2m rise in estuary level and Table C.3 lists peak water levels for Scenarios 6 and 7. Figures 11.1 and 11.2 show the peak depths (>0.10m) for Scenario 5 and Scenario 7 respectively.

A 0.2m rise in estuary level above the 1% PoE level (namely 0.84m AHD) is below the general elevation of roads and properties in Empire Bay and Bensville, thus most areas are unaffected. The 30% increase to rainfall intensities results in similar peak water levels than those shown in Table C.1 without the raised estuary level showing that the dominant flooding in this scenario is the catchment runoff.

A 0.91m rise in estuary level above the 1% PoE level (namely 1.55m AHD) is higher than a large proportion of the properties in the main residential area of Empire Bay. Thus these properties are inundated by water flooding from the estuary rather than specifically from catchment runoff.

12. REPORT QUALIFICATIONS

This report has been prepared for Gosford City Council to define the nature and extent of flooding for the study area of the Empire Bay catchment. Hydrologic and hydraulic modelling was completed to assess flood behaviour within the catchment. Flood modelling is based on local catchment flooding only, the impact of flood levels from the Brisbane Water estuary has not been accounted for in the modelling. Estuary flooding is described in the Brisbane Water Foreshore Flood Study (2009). Flow characteristics including depth, velocity and provisional hazard were evaluated based on the computer modelling.

The investigation and modelling procedures adopted for this study follow current best practice and considerable care has been applied to the preparation of the results. However, model set-up and calibration depends on the quality of data available and there will always be some uncertainties. The flow regime and the flow control structures are very complicated and can only be represented by schematised model layouts.

Hence there will be an unknown level of uncertainty in the results and this should be borne in mind in their application.

Study results should not be used for purposes other than those for which they were prepared.

13. CONCLUSION

Flood modelling of local catchment runoff was completed the Empire Bay catchment for a range of annual exceedance probabilities of storms from 100% AEP to 0.5% AEP and up to a PMF event.

In a 1% AEP event, the modelling shows that some properties and roads may be inundated up to 0.5m. This occurs notably around Gordon Road, Boongala Avenue, Rickard Road, and Greenfield Road in the main residential area of Empire Bay and around the main drainage channels at Pomona Road and Empire Bay Drive to Palmers Lane in the rural-residential area. In the 1% AEP event, the modelling showed that 22 houses are flooded above the floor level when the storm runoff is combined with a 1% probability of exceedance level in the estuary.

Mapping of high provisional hazard in the catchment for the 1% AEP event shows that it is limited to the channel behind Myler Avenue and the channel north of Pomona Road which conveys runoff to Allawa Close. Scattered occurrences of high hazard also feature adjacent to parts of Empire Bay Drive. Hydraulic categorisation mapping for the 1% AEP shows floodway areas along the main watercourses from Pomona Road across Empire Bay Drive, and also some road near the main residential areas of Empire Bay and Bensville. Flood storage areas are identified in some properties, roads, and the open space / vegetated areas within the catchment. Increases to sea levels due to climate change have the potential to significantly affect flood impacts, particularly in the low elevation areas of the Empire Bay catchment.

The Floodplain Management Authority's Prioritisation Ranking table for the Empire Bay catchment is included as Appendix D.

14. REFERENCES

Cardno Lawson Treloar (2009). Brisbane Water Foreshore Flood Study.

Chapman, G.A. and Murphy, C.L. (1989). Soil Landscapes of the Sydney 1:100,000 Sheet. Soil Conservation Service of NSW.

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Howells, L., McLuckie, D., Collings, G., Lawson, N. (2003). Defining the Floodway – Can One Size Fit All?. Floodplain Management Authorities of NSW 43rd Annual Conference, Forbes, February 2003.

Murphy, C. (1993). Soil Landscapes of the Gosford – Lake Macquarie 1:100,000 Sheet, Department of Conservation and Land Management (NSW).

NSW Department of Commerce and Manly Hydraulics Laboratory (2007). New South Wales Central Coast June 2007 Flood Summary.

NSW Government (2005). Floodplain Development Manual.

FIGURES

Figure 1.1 Site Locality

Figure 5.5 Rainfall Stations Locations

APPENDIX A

Resident Questionnaire

Our Ref W4715

Contact Andrew Reid

10 October 2007

To The Resident

Cardno Lawson Treloar Pty Ltd
ABN 55 001 882 873

Level 2, 910 Pacific Highway
Gordon New South Wales
2072 Australia
Telephone: 02 9499 3000
Facsimile: 02 9499 3033
International: +61 2 9499 3000
Email: cltnsw@cardno.com.au
Web: www.cardno.com.au

Cardno Offices
Brisbane
Sydney
Canberra
Melbourne
Perth
Darwin

Cairns
Townsville
Mackay
Rockhampton
Hervey Bay
Sunshine Coast
Toowoomba
Gold Coast
Gosford
Baulkham Hills
Wollongong
Busselton

Papua New Guinea
Indonesia
Vietnam
China
Kenya
United Arab Emirates
United Kingdom
United States

Dear Sir/Madam,

EMPIRE BAY & BENSVILLE SOUTH CATCHMENT FLOOD STUDY

Cardno Lawson Treloar have been commissioned by Gosford City Council to undertake a Flood Study for the Empire Bay and Bensville South catchment. A catchment layout and the study area are shown on the attached figure.

This Flood Study will form part of the overall Flood Plain Risk Management process (Figure 1) for the catchment, and can be used to optimise development potential, and to obtain social and economic benefits from the reduction in flood damages.

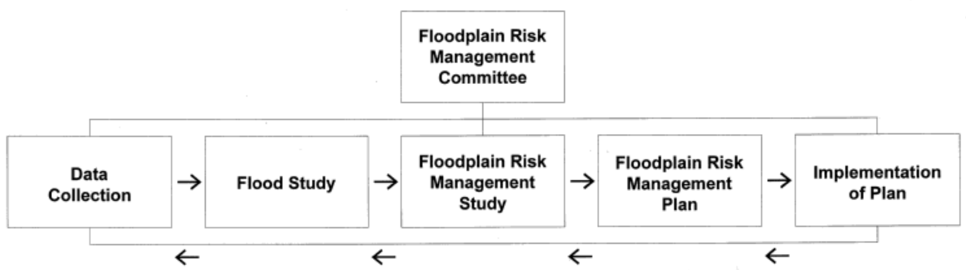


Figure 1: The Floodplain Risk Management Process

The Flood Study comprises a comprehensive technical investigation of flood behaviour in the catchment. The study defines the nature and extent of the flood risk by providing information on the level and velocity of floodwaters and on the distribution of flood flows at various locations in the floodplain.

The Flood Study provides a technical basis from which the Floodplain Risk Management Study (FRMS) and Floodplain Risk Management Plan (FRMP) are developed. They are usually completed in one project and would be completed immediately after the completion of the Flood Study, subject to grant funding.

The FRMS identifies, assesses and compares various risk management options and considers opportunities for environmental enhancement as part of floodplain management measures.

The FRMP provides input into the strategic and statutory planning roles of council. It also documents the adopted management strategy formally approved by Council after assessment of submissions following public exhibition.

The final stage of the process is the implementation of the Plan (which would need to compete for funding from various government sources where works are an option).

Community involvement is important at all stages of the Floodplain Management Process. Resident's local knowledge of the catchment and personal experiences of flooding provide an invaluable source of data to define the nature and extent of flooding at the Flood Study stage of the process. In this regard, Council seeks your assistance in undertaking this Flood Study.

You can participate in the study process through your local community associations who can represent your views at Council's Floodplain Risk Management Committee (FRMC) meetings. The FRMC is responsible for overseeing the study and to ensure it follows the Floodplain Risk Management Process. Your community representatives on the FRMC are:

Ms. Shirley Crocker (President) & Mr. Maurie Pacey
Empire Bay & District Progress Association
31 Rickard Road
Empire Bay NSW 2257
Phone (02) 4369 2034

Enclosed please find a questionnaire, which focuses on whether your property or any nearby property has been flooded in the past. This questionnaire is similar to one completed by some residents in August 2006. However, this questionnaire covers the entire Empire Bay and Bensville South Catchment and allows for responses based on the June 2007 storm event to be incorporated into the Flood Study assessment process.

Please take the time to read the questions and answer them as best as you can. Any information you provide may prove vital to the success and accuracy of the study results.

Would you **please return** the questionnaire in the enclosed reply paid envelope **within three weeks** of receipt of this letter.

Please contact Andrew Reid from Cardno Lawson Treloar or Jim Gowing from Gosford City Council if you want to discuss or clarify items regarding the catchment study.

- Andrew Reid
    - Cardno Lawson Treloar
    - Telephone: 02 9499 3000
    - Facsimile: 02 9499 3033
    - Email: andrew.reid@cardno.com.au

- Jim Gowing
    - Gosford City Council
    - Telephone: 02 4235 8818
    - Facsimile: 02 4323 2528
    - Email: jim.gowing@gosford.nsw.gov.au

Yours faithfully

Andrew Reid
Project Engineer
for **Cardno Lawson Treloar**

Encl. Empire Bay and Bensville South Questionnaire

Empire Bay & Bensville South Catchment Flood Assessment Study

QUESTIONNAIRE

Please answer the following questions as best as you can. When you have finished answering the questions, please return these pages in the enclosed "reply paid" envelope.

If you have any queries, please contact:

Andrew Reid – CARDNO LAWSON TRELOAR
Ph: 02 9499 3000
Fax: 02 9499 3033
andrew.reid@cardno.com.au

Jim Gowing – GOSFORD CITY COUNCIL
Ph: 02 4325 8818
Fax: 02 4323 2528

Question 1

Could you please provide us with the following details? We may need to contact you to check some of the information with you.

(The information will remain completely CONFIDENTIAL)

Name: ______________________________

Day time phone Number: ______________________________

Email Address: ______________________________

Address: ______________________________

____

____

Question 2

How long have you lived in this locality?

______ Years ______ Months

Have you previously lived at another address within the catchment (shown on the attached map)?

Details: ______________________________

____

____

GOSFORD CITY COUNCIL CENTRAL COAST

Cardno Lawson Treloar

Question 3

Are you aware of flooding in the catchment?

Please Tick One:

Aware _____

Some knowledge _____

Not Aware _____

Question 4

Have you ever been inconvenienced, or has your property been flooded because of uncontrolled floodwater in this locality?

(Your property may have been flooded inside the house or in your backyard, or you might have been stopped from getting to work)

Please Tick:

INSIDE HOUSE FLOODED -	YES	______	NO	______
PROPERTY/YARD FLOODED -	YES	______	NO	______
INCONVENIENCED -	YES	______	NO	______

Question 5

Can you remember when that was?

Please Tick:

YES ______

NO ______

If you answered YES, please give us as much detail as possible.
To assist, flooding may have occurred on the following dates:

1. June 2007 ☐
2. January 1996 ☐
3. February 1992 ☐
4. February 1990 ☐
5. January 1989 ☐
6. April 1988 ☐
7. October 1985 ☐
8. November 1984 ☐
9. February 1981 ☐

10. January 1978 ☐

11. March 1977 ☐

12. May 1974 ☐

13. ___________

14. ___________

Details of flooding and when it occurred:
(How long after the rain started? How high was the water level? How long did it stay at this level? When did the water level reach its peak?)

____

____

____

____

____

____

____

Question 6

If you have experienced flooding in the area, do you have any evidence of the extents of the floods (such as flood levels or depths at certain locations)?

Please Tick:

YES ______

NO ______

If you answered YES, please give as much detail as possible.

You may have an old photograph, or may have taken a video. Some people remember marks on walls and posts, and this information could prove quite important. Alternatively, you may know someone who has lived in the locality for a long time who might have that type of information.

Details of information:

____

____

____

____

____

____

____

____

Question 7

If you answered Yes to Question 6, what type of property did you see flooded?

You may tick more than one:

RESIDENTIAL	______	COMMERCIAL	______
PARKS	______	ROADS & PATHS	______
OTHER	______		

Please Specify: ____

Can you describe the area of the property that was flooded?

You may tick more than one.

BACKYARD	______
GARAGE	______
BUILDING (ABOVE FLOOR LEVEL)	______
BUILDING (BELOW FLOOR LEVEL)	______
FRONTYARD	______
OTHER	______

Please Specify: ____

Question 8

Did you notice any bridges and/or culverts to be blocked during the event?

_________ YES _________ NO

If YES, please provide details (please mark the location on the map if possible), and how blocked would you say it was? (eg. 50% blocked, 80% blocked)

____

____

If YES, what was causing the blockage? (eg. woody debris, shopping trolley, vehicle)

____

____

Question 9

If possible, can you show the location of the flooding on the enclosed map?

Please Tick:

YES ______

NO ______

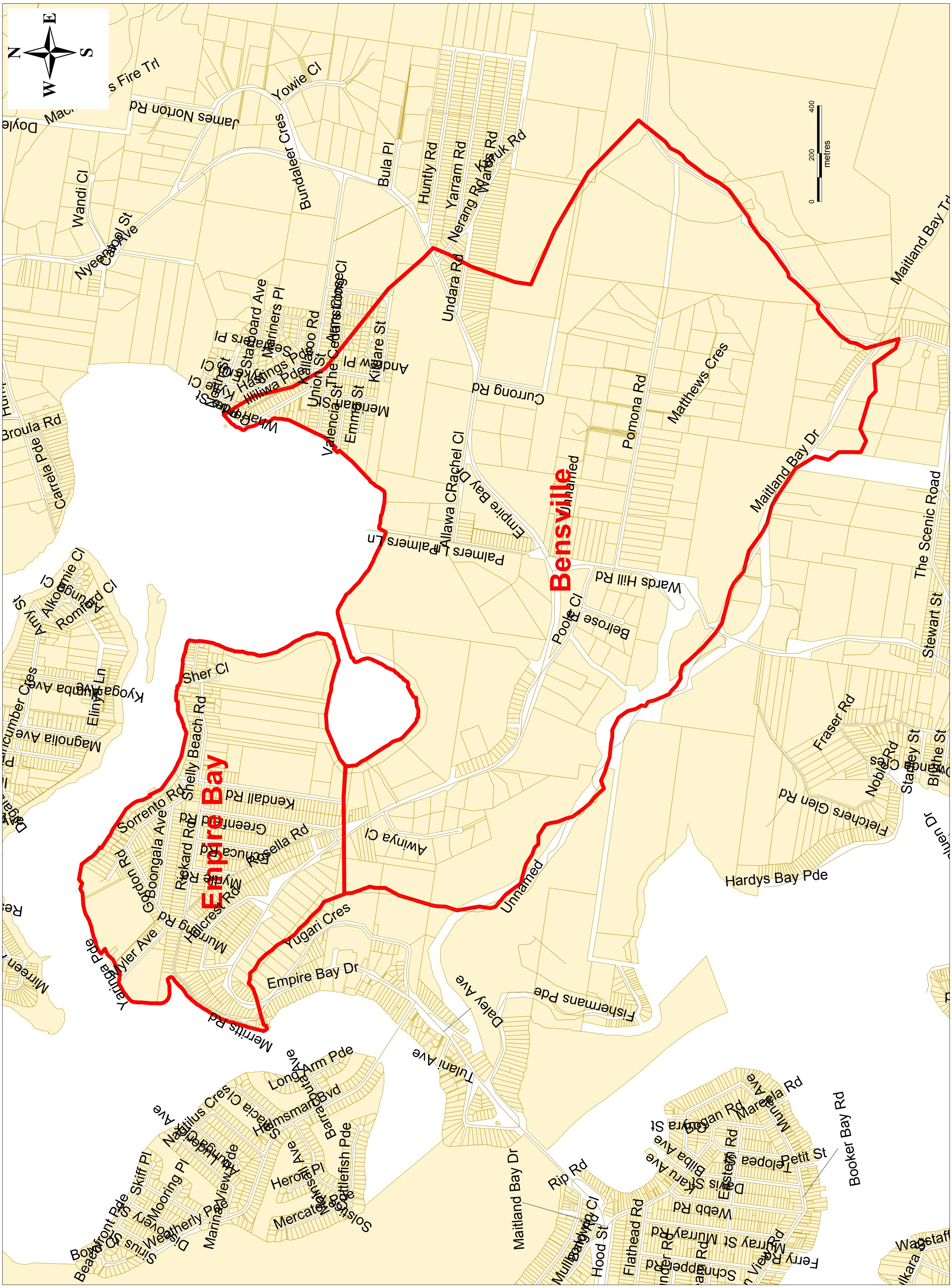
If you have indicated yes, please remember to enclose the map in the envelope, clearly marked.

Question 10

Is there anything else you can tell us about the flooding in this locality?

If so, please provide the information below.

Thank you for providing the above information. Please remember to put it back in the reply paid envelope. A representative from Cardno Lawson Treloar may contact you in the near future to discuss your response.



Cardno
Lawson
Treloar

FIGURE 1
CATCHMENT MAP

W4715
September 2007

Empire Bay and Bensville South Flood Study

W4715\MapInfo\EmpireBay ResidentMap.Wor

Empire Bay	Q1		Q2	Q3			Q4			Q5															Q6			Q7											Q8			Q9		Q10
Survey Ref. No	Street	Suburb	How long - years	Aware	Some knowledge	Not Aware	Inside	Yard	Inconv.	Yes	No	Jun-07	Jan-96	Feb-92	Feb-90	Jan-89	Apr-88	Oct-85	Nov-84	Feb-81	Jan-78	Mar-77	May-74	Comments	Yes	No	Comments	Res	Parks	Comm.	Rds & Paths	Other	Backyard	Garage	Bldg-Above	Bldg-Below	Front yard	Other	Yes	No	Comment	Yes	No	Comments
1	Andrew Close	Bensville	3			1	N	N	N		N															N																		
2	Pomona Rd	Empire Bay	1			1		Y		Y		1												Lots of water coming downhill from back to front.		N							1					Water to kitchen door		N			N	
3	Wharf Pde	Bensville	7			1	N	N	Y		N													Everytime it rains water runs off gravel on Wharf Pde and Illawa Pde causing gravel to end up in toilet block and road below. Severely washes away roadway in front of garages making it impossible to use them. Council fixes it only to happen again next rain.		N			1		1			1										People use stairway Wharf Pde to river - culvert alongside fills with gravel from roadway - when it rains you have "rapids" effect over stairway to river.
4	Kildare St	Bensville	5			1	N	N	N																															N				Heavy rain floods farmland to rear of property in Kildare St. but drains quickly to catchment.
5	Nerang Rd	Bensville	23	1			Y	Y	Y	Y		1	1	1										At least 3 occasions mostly over past 10 years. Flooding since turning circle for trucks put in - circle sloped towards rear of 16-18 Nerang Rd. Natural watercourse at rear - floods intermittently - 300 - 600mm deep a couple of hours from start of heavy rain.	Y		#14 Nerang Rd lost entire back fence to floodwaters (1996?). #12 Nerang Rd has been flooded. House in Undarra Rd rear of #18 extensively affected due to illegal cut in mountain	1			1		1	1	1			A regular occurrence	Y					Problems caused by poor design of turnaround in Undarra Rd - blocks of land being "built-up" to higher than neighbours - poor drainage and less maintenance. Can recall entire bottom end (from park) under a significant amount of water.
6	Emma St	Bensville	8			1	N	N	N																																			
7	Union St	Bensville	4			1	N	N	N																																			
8	Andrew Close	Bensville	3			1	N	N	N																																			
9	Kildare St	Bensville	5			1	N	N	N																															N				We are on highest point in Bensville so not affected by flooding.
10	Pomona Rd	Empire Bay	4	1			N	Y	Y	Y														In 2003 in Nerang Rd we lived on mountain backing onto National park. During major storms flood water poured down like a waterfall - water flooded basement & garage.		N		1			1		1	1		1			Y		70% blocked drains on street by woody debris, leaves, long grass.	Y		No flooding in Pomona Rd.
11	Allawa Cl	Bensville	13		1		N	Y	N	Y		1	1											Paddock under 5-10cm water - couple of days - peak? Not known. Creek on E boundary eroded by heavy water gushing thru creek. Large tree blown down in creek - still there.	Y				1		1						1	Front & back paddock		N	Creek hampered by tree - may hinder water flow.	Y		
12	Empire Bay Dr	Bensville			1		N	N	N																	N														N				
13	Kildare St	Bensville																																										
14	Andrew Close	Bensville	5			1	N	N	N																															N				
15	Emma St	Bensville	16			1	N	N	N																	N														N				
16	Emma St	Bensville	17		1		N	Y	Y	Y		1	1	1	1									Water from rear & side neighbours. Up to 60mm deep/flash flood lasting about 1 hour.		N		1						1		1	1			N				
17	Palmers Lane	Bensville	14	1				Y	Y															Numerous occcasions. Heavy rain - water level quite high quickly - stays at high level.		N		1			1		1	1		1	1			N		Y		3 drains surrounding property - front one fills & overflows in heavy rain. Entire yard is flooded with water as drains not large enough. On 2 occasions water level under house was within 2" of floor boards. As at the end of these drains we are most affected. We keep drains clear. Creek nearby could be used to drain water. **Old survey attached.**
18	Empire Bay Dr	Empire Bay	20	1			N	N	N		N													Never flooded.		N														N				After rain the land between Empire Bay Dr and Cockle Lagoon remains flooded for lengthy periods. This has produced a jungle type environment - good for wildlife.
19	Rickard Rd	Empire Bay	8	1			N	N	N		N															N																		
20	Gordon Rd	Empire Bay	4	1																				**COMMENTS ON ADDRESS OUTSIDE SURVEY AREA.**																				
21	Empire Bay Dr	Empire Bay	26			1	N	N	N																															N				Not affected by flooding. Rds in towhship remain very damp/wet after rain.
22	Empire Bay Dr	Empire Bay	19		1		N	N	N																	N																		
23	Pomona Rd	Empire Bay	10	1			N	Y	Y	Y		1	1												Y			1				Properties 13A, 15A, 17 & 19A	1		1	1	1			N		Y		Properties noted in Q7 lowest area of Pomona Rd. Water - runoff from properties 21+. Poor drainage infrustructure in Pomona Rd.
24	Pomona Rd	Empire Bay	19	1			N	N	N																	N														N				We are 10m above sea level - only get run-off - no flooding.
25	Pomona Rd	Empire Bay	1	1					N	Y		1												1/4hr. After rain commenced. Flooded end of driveway - flooded road. Stayed flooded 1-1/2 hrs.	Y		Stormwater drain could not handle volume of water. Spilled over into road - 8-10" deep.				1						1	1	Y		80% blocked. See map point A. Woody debris.	Y		Enormous amounts of water comes off hillside. Thru 6B Pomona Rd - then collects at bottom of 6A - the pipe under road is usually blocked with wood debris causing road flooding.
26	Greenfield Rd	Empire Bay	24	1			N	N	Y		N													Almost every year on more than one occasion.		N		1	1		1		1				1		Y			Y		
27	Boongala Ave	Empire Bay	20	1				Y	Y	Y		1	1	1	1	1	1							Worst flooding - April 88 - knee deep to Shelley Beach Rd. A lot of houses flooded.	Y		Worst flood (April 88) - rain few days then high tide - water to bottom step of front verandah - garage flooded - only time in 20yrs entire rd covered with water.	1			1		1	1			1			N				Since development in Gordon Rd situation improved dramatically. Problems now depend on tides + heavy rain - no drains - road higher than blocks of land.
28	Kendall Rd	Empire Bay	12	1				Y		Y		1												June 07 water rushed down from property behind (higher) - garage flooded & about 3/4 of back yard flooded. Easement behind encroached by neighbour's pool - now our property floods.		N																		Water lays in road also happens in Shelly Beach Rd and properties in Kendall Rd.
29	Empire Bay Dr	Empire Bay	22								N																																	
30	Pomona Rd	Empire Bay	9		1		N	N	N																																			
31	Pomona Rd	Empire Bay	5	1			N	Y	Y	Y		1													Y		Water flowing across causeway.				1	Pomona Rd/Private Drive 21/23		1				Washing drive out.		N		Y		
32	Palmers Lane	Empire Bay	1		1		N	Y	N	Y		1												Minor water flows thru backyard after constant rain.	Y		Water did not rise higher than 2".	1					1					Small flow thru yard 2m wide.		N				
33	Empire Bay Dr	Empire Bay	7	1					Y	Y			1											Combined heavy rain & King Tide - only 15 minutes to ready 30-40cm in middle of road up to 120cm near kerb. Car flooded to bonnet level. Water stayed several hrs till tide went out.	Y		End of Boongala Ave.flooded many times with rain + king tide.	1	1		1	Cars flooded.	1				1			N		Y		Properties cnr.Boongala-Gordon Rd most flooding. High tide + rain.
34	Empire Bay Dr	Empire Bay				1	N	N	N		N																																	
35	Sher Close	Empire Bay	23	1			N	N	N																																			
36	Kallaroo Rd	Bensville	30	1				Y														1		Water ran down Illiliwa Lne at rear of house and into yard. Stopped by building an embankment.	Y		Houses in Central St and farther down have water build up in toilets & sinks. Houses in Valencia and Emma Sts have water coming thru lower bricks.				1									N				Houses built on swamps and natural water courses always have trouble during heavy rain.
37	Valencia St	Bensville	28			1	N	N	N																																			
38	Empire Bay Dr	Empire Bay	4		1			N																																				
39	Empire Bay Dr	Empire Bay	12			1	N	N	N																	N																		We are on Empire Bay Dr. near Primary School & have had no problem with flooding.

Empire Bay	Q1		Q2	Q3			Q4			Q5															Q6			Q7											Q8			Q9		Q10
Survey Ref. No	Street	Suburb	How long - years	Aware	Some knowledge	Not Aware	Inside	Yard	Inconv.	Yes	No	Jun-07	Jan-96	Feb-92	Feb-90	Jan-89	Apr-88	Oct-85	Nov-84	Feb-81	Jan-78	Mar-77	May-74	Comments	Yes	No	Comments	Res	Parks	Comm.	Rds & Paths	Other	Backyard	Garage	Bldg-Above	Bldg-Below	Front yard	Other	Yes	No	Comment	Yes	No	Comments
40	Empire Bay Dr	Empire Bay	8			1	N	N	N																									1				Only with heavy rainfall. Drain overflows & garage get flooded.				Y		
41	Emma St	Bensville	8		1		N	Y	Y	Y		1				1								Backyard floods easily during heavy rain - up to 20cm in less than an hour. During June storms backyard remained covered in water for almost three days.															Y		See bridge in Kallaroo Rd covered in water.			Worry about street being so low. Are redraining property + installing raintank to help backyard cope better. No stormwater drains in street to take water away. Culdesac at end of st. often floods. This is where our water eventually goes then out to Brisbane water.
42	Awinya Cl	Empire Bay				1	N	N	N		N																																	
43	Kallaroo Rd	Bensville	30	1	1				Y		N														Y		Waterfront reserve adjacent floods regularly. Natural flood prone area. No problem.	1	1			Open space near North St, Calool St, Kallaroo Rd.							Y		Long time ago - all OK with new works Kallaroo Rd.			Nothing - except for very low lying lands with no natural drainage - all is OK with more recent planning & works.
44	Echuca Rd	Empire Bay	22		1		N	Y	N		N						1	1						Rained heavy Wed,Thurs & Fri. - Green Field Rd & Echuca Rd under water - Saturday morning kids rowing boats up Echuca Rd. Water to top of bottom step of our house.	Y		Water running over bottom rail of back paling fence.				1		1	1		1	1					Y		Echuca Rd flooded from #21 to Rickard Rd.
45	Shelly Beach Rd	Empire Bay	12	1				Y	Y	Y		1	1											Last June access blocked in & out of property - front yrd water 8" deep.		N					1			1			1		Y		No drainage works - badly designed road.			
46	Myrtle Rd	Empire Bay	23	1			N	Y	Y	Y									1					Peak reached 2am some day Oct or Nov? At that time 3 stormwater pipes connected to one in Myrtle Rd now fixed. Water reach 150mm approx from floor level.	Y		Myrtle Rd & Rickard Rd almost knee deep. Did not go past Junction of the two roads.	1			1		1							N				
47	Valencia St	Bensville	21		1	1	N	N	N																		Boongala Ave, Empire Bay was completely under water a couple of years ago.			1		Estate Agent at Bensville				1			Y		10% Bad drainage, heavy rain.	Y		There was a huge King Tide on night ship at Newcastle was lifted off sand. Water was highest ever seen but didn't come into property. (House is at end of street).
48	Hillcrest Rd	Empire Bay	5	1			N	Y	N	Y		1												Garage flooded - damage minimal. Don't think flooding was natural - water flow diverted due to works after burst main was repaired.		N					1	Open drains gather huge amounts of leaves.							Y		Some drains in Hillcrest & Murrong 80% blocked by leaves.	Y		Fortunate not badly affected by blocked drains.
49	Echuca Rd	Empire Bay	10		1		N	N	N																																			Water covers road corner of Rickard and Echuca Rd with downpours.
50	Valencia St	Bensville	14		1		Y	Y	Y	Y				1										1992 after approx 48 hrs when rain started flooded by run-off thru backyard, lasted 24 hrs. 2007 Heavy rain, basement flooded by run off in backyard.		N							1	1		1				N		Y		
51	Sorrento Rd	Empire Bay	5		1		N	N	N		N														Y		Visual sitings.	1									1			N				Sorrento Rd. Empire Bay
52	Wards Hill Rd	Empire Bay	19	1			Y	Y	Y	Y		1	1	1	1	1	1							June 1991 House flooded 4" in lounge floor 8-10" outside house. Yard flooding has occurred numerous times. Resulting in major damage to front yard. Unable to drive vehicle up driveway. Water in street enough to stop vehicles. Water running over Wards Hill Rd on other dates too approx 4 yrs. ago.	Y		Old photo's and Council complaint letters.	1	1		1		1		1		1			N		Y		**SEE EXTENSIVE NOTES**
53	Echuca Rd	Empire Bay	3		1		N	Y	N	Y		1												3" in backyard - soaked into ground when rain stopped.		N														N				
54	Andrew Close	Bensville	5			1	N	N	N		N																																	
55	Kallaroo Rd	Bensville	8		1		N	N	N																	N																		
56	Kildare St	Bensville	6			1	N	N	N		N															N														N				
57	Greenfield Rd	Empire Bay	11	1			N	Y	Y		N															N																		Poor drainage works - need footpaths, curb & guttering and covering of drainage channels. All this would help us cope with flooding.
58	Shelly Beach Rd	Empire Bay	7	1				Y		Y		1												Water built up while raining heavy. Bottom end of rear yard approx. 200mm. Drained off when rain stopped. Drainage pipe nearly blocked at outlet with mangroves & rubbish as pipe does not go through to shoreline. Some inlets to pipe have been blocked off by residents.		N														N		Y		The drainage pipe at entrance to Sher Close off Shelley Beach Rd will not cope with the amount of water that comes from further up Shelley Beach Rd. Consequently the water over flows down Shelley Beach Rd nearly covering the whole road in heavy rain.
59	Empire Bay Dr	Empire Bay	27			1	N	N	N																	N																	N	
60	Kendall Rd	Empire Bay	3	1			N	Y	Y	Y		1												Flooded backyard and back shed. Two inches of water.																				
61	Kendall Rd	Empire Bay	25	1			N	Y	Y	Y		1	1	1										Approx. 3 inches over my land - it stayed approx. 1 week to ten days.		N		1	1				1	1		1	1			N		Y		
62	Pomona Rd	Empire Bay	3			1	N	N	N	N																N																		
63	Empire Bay Dr	Empire Bay	18	1					Y		N													Live on side of hill - floodwaters passing through	Y		Daughter and family lived on corner of Gordon Rd and Boongalla Ave and floodwater depth was approx 24cm.	1			1	Unmade gutters					1		Y		Underground (uncovered) outward flowing to sea concreted in approx. Dimensions 6ft x 4ft. Nothing caused blockage - completely clear, unable to get away - tidal didn't help.	Y		The area in general is subject to tidal times although the flooding is still prevalent during low tides.
64	Hillcrest Rd	Empire Bay	4		1		N	N	Y	Y		1												Straight away too deep to drive through. Stayed like this for a few days.		N		1	1		1						1			N		Y		Richard Rd to Boongala Rd the worst.
65	Allawa Cl	Bensville	20		1		Y	Y	Y	Y							1							Don't remember. All I know is the creek 3 blocks up from my home was overflowing.		N													Y		Bridge between Allawa Cl and Rachel Cl Bensville. Before Empire Bay Dr was moved. Down pour of water			The problem has actually got worse instead of better. Mainly due to no drainage. As Council will not do anything (I have asked) for 20 years. Since they re-diverted Empire Bay Dr we now get more run off from Bruce Kerr's Land that sits behind Allawa, Rachel Cl and Palmers Lane. Still no drains to take this extra water. Council have a lot to answer for in this area.
66	Rickard Rd	Empire Bay	7		1		N	N	N		N															N														N			N	Immediate area at times suffers road flooding (not deeper than 50cm) due to blocked drains. Adjoining property (at lower building level/fill level) has had yard flooding several times in past 8 years from spill-over from roadway.
67	Empire Bay Dr	Empire Bay	5	1			N	N	N	Y		1													Y		After heavy rain and high tide streets near the Bay have flooded for a day/night ie Boongala Ave June 2007.													N			N	
68	Shelly Beach Rd	Empire Bay	29	1				Y		Y		1												The street does not drain away, lays for several days.		N		1			1		1					Council Reserve - inadequate drainage	Y		80% - No proper drainage	Y		

Empire Bay	Q1		Q2	Q3			Q4			Q5															Q6			Q7											Q8			Q9		Q10
Survey Ref. No	Street	Suburb	How long - years	Aware	Some knowledge	Not Aware	Inside	Yard	Inconv.	Yes	No	Jun-07	Jan-96	Feb-92	Feb-90	Jan-89	Apr-88	Oct-85	Nov-84	Feb-81	Jan-78	Mar-77	May-74	Comments	Yes	No	Comments	Res	Parks	Comm.	Rds & Paths	Other	Backyard	Garage	Bldg-Above	Bldg-Below	Front yard	Other	Yes	No	Comment	Yes	No	Comments
69	Gordon Rd	Empire Bay	40		1			Y	Y	Y		1	1				1			1			1	In each of the above floods the roadway - Gordon Rd was covered to a depth of 200mm. Water invaded my front yard to building foundations. The back yard was flooded in parts - eventually subsided on evaporation. In April 1988 and May 1974 water lapped bottom of two steps at back door. May 1974 involved like depth flooding of garage - damage to stuff on garage floor.	Y		Only as above				1		1	1		1	1	Roadway and drainage	Y		80% blocked pipes at Gordon Rd/Samento Dr and downstream of pipe across Samento Dr to local sea water.	Y		It is imperative for drainage system to work that rubbish is kept out of street drains. Suggest Council rangers be authorised to impose spot fines.. The subdivision - otherside of Gordon Rd has drainage system installed including an evaporation area - SW end of street which regrettably has become a rubbish dump inhabited by rats etc. Most offenders are people whose land adjoins the evaporation area. Fall to the evaporation area is so slight that pipe becomes blocked by solids from liquids travelling slowly SW.
70	Greenfield Rd	Empire Bay	2		1		N	Y	Y	Y		1												Shortly after the storm started.		N					1									N				The road storm drains on Greenfield Rd seem to be blocked - hence the gutters are flooded and as we live by a bus stop this can be dangerous and unhealthy.
71	Empire Bay Dr	Empire Bay	30	1			N	N	N															Aug 07. Rapid flow of water approx 300mm deep. Til rain stopped road is still affected, steep camber.		N					1							Roadway	Y		50% short term, side track off Empire Bay Dr. Road washed away (part sealed) steep grade. Blocked stormwater pipe at intersection of Empire Bay Dr and Empire Bay Dr (Hillcrest Rd) still blocked.	Y		
72	Rickard Rd	Empire Bay				1	N	N	N																	N																		
73	Rickard Rd	Empire Bay	4	1				Y	Y	Y		1					1							Water was evident during/end of rain two to 3 days. Peak was at end of "rain burst" eg. Next morning yards flooded, some entry to rear of garage and shed.	Y		Discussed and inspected with no solution as of yet. Photos of rear house drain supplied to Gosford Council. Heavy flooding in 1988 period. Septic tanks full - high level ground water and flooding street level in Empire Bay lower town areas in streets with drains full especially near shops @ War Memorial.	1	1		1		1	1			1	Water lying in yards, some water into garage after heavy rain - several days to run off or soak in.	Y		80% drain at rear does not flow at all illegal pipes and reclamation of Council drain by residents. Wood debris palm stumps home made drain pipes and filling in of Counci drain.	Y		It is common for low level nuisance flooding in the Empire Bay area. The drains are not maintained or cleared at all, especially the rear of properties. Eg filled in by residents. Illegal piping, poor design of recent development. Eg Gordon Rd Estate strip original drain system blocked. The system does not flow with the direction reversed. Dangerous open drains at shopping centre adjacent to the War Memorial.
74	Rosella Rd	Empire Bay	23		1		N	N	N																						1	Rosella Rd, flowing water in front of our house.												I think my local street could benefit from filling in the end of Rosella Road which has been blocked off to the traffic with metal pole signage. This now non existent part of the road is not only a waste of space but has the potential to help with flooding and also create a small natural garden area. If it can be filled and native plants are planted it will not only look better but it will have great benfits for the environment, wildlife and residents who already maintain the area adjacent to the road. I look forward to hearing your thoughts on this.
75	Myrtle Rd	Empire Bay	9			1	N	N	N																															N				
76	Wards Hill Rd	Empire Bay	22	1			N	Y	N	Y						1	1	1						Trench dug across these properties (either side) was raging river and down side of 421 to walkway. Only slight running water since drainage carried out in Pomona Rd - more required to carry water to Council drain opposite. Trench was dug by previous owner & neighbour.		N																		
77	Boongala Ave	Empire Bay	51	1			Y	Y		Y													1	1974 was worst flood - entered house to just above architrave level approx 600mm above ground level. Since elevated house. Combined high tides, heavy + strong wind, stormwater backs up stormwater easement till tide turns then water level drops. Water often over flows onto our property.																				
78	Rickard Rd	Empire Bay	20	1			N	N	N		N													During any of these storms water only reached letterbox once.																N				
79	Empire Bay Dr	Empire Bay	10	1			N	N	N		N															N																		Live on Empire Bay Dr and get a lot of runoff thru property down hill thru bottom property that in big downpours does experience floding in their huse in Hillview St.
80	Rickard Rd	Empire Bay	7	1			N	N	N																	N																		
81	Sorrento Rd	Empire Bay	15	1			N	N	N																Y		When living in 35 Sorrento Rd water came up to our side fence line which is in Gordon Rd. During high rain fall have seen Gordon Rd & connecting Boongala covered by water.		1		1							Roads & drains, coming up to fence lines		N		Y		
82	Echuca Rd	Empire Bay	2	1				Y	Y			1												After any heavy rain rainwater lays on ground but at this stage does not rise to cause house or garage to flood.		N													Y		Stormwater drains have been blocked at Southern end of Echuca Rd by debris.	Y		Curbing & Guttering should assist in dispersion of water.
83	Kendall Rd	Empire Bay	4		1		N	Y	Y	Y		1												Front (low lying) garden slightly under water due to ditch drain filling up and water nowhere to go. Took a week or two to dry out.		N											1			N		Y		Ditch drain on street (end of Kendall Rd) appears to be lower than where the water discharges and so fills up frequently and does not clear quickly
84	Valencia St	Bensville	2	1			Y	Y	Y	Y		1	1											When heavy rain falls, stormwater drain backs up - at its worst it came up to house. Probably 30-40cm + at back of property and stayed for 3-4 weeks also smelt of sewerage.	Y		Spoken to others in street - flood waters came half way up street so everyone from about our house were flooded	1			1		1	1		1	1			N		Y		Where our house is positioned 1/2 way down Valencia St. Just about everyone down to the water experiences some flooding. Drainage measures poor - can't cope.
85	Myler Ave	Empire Bay	3			1																																						No knowledge of flooding.
86	Boongala Ave	Empire Bay	2		1		N	N	N																	N		1			1		1							N				Have no experienced any substantial flooding since I have lived here - only water lying mainly on sides of road and in some front yards - however our property has never flooded.

Empire Bay	Q1		Q2	Q3			Q4			Q5															Q6			Q7											Q8			Q9		Q10
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87	Myrtle Rd	Empire Bay	4	1			N	Y	Y	Y						1	1							1988 or 1989 - water level reached its peak on bridge on Kallaroo Rd flooded for day - no access in or out. June 2007 backyard completely underwater almost to backdoor at its peak.	Y		Shed in garden - floor totally covered with mud residue about 4" there are holes in backyard where soil gave way. Also a river of water in garage at rear.	1				**See Photo - backyard**	1	1						N		Y		Empire Bay roads and gutters have numerous pools and puddles of water
88	Sorrento Rd	Empire Bay	1		1		N	N	N																Y		Flooded front garden/driveway	1									1			N		Y		
89	Gordon Rd	Empire Bay	7	1				Y		Y		1												Water about 1 foot deep and took several days to go down.		N																Y		Boongala St floods right across road. Gordon Rd at one end where there are no gutters floods badly around homes. Gordon Rd outside our house has an open drain - fills up - overflows. This does not drain away - water sits there weeks. There is catchment area in Gordon Rd (next #39) if cleaned out, made deeper problems may be solved.
90	Empire Bay Dr	Empire Bay	26	1			N	N	Y	Y		1	1											Carpark & surround Empire Bay Tennis courts.		N														N			N	Don't have water tank - could use a regular flood. How do you start a flood? Would help with water restrictions.
91	Pomona Rd	Empire Bay	29	1			N	Y	Y	Y		1				1	1							Serious flooding after prolonged heavy rain (several days) About 300mm deep right across block next door #8. Neighbours house flooded. This happened twice (1988? & 89?). Second occasion water came within 25mm of going thru our house. Remained at that level for 1/2 hr. Water rose out of existing watercourse over #8.	Y		Contacted son of previous owners of #8. He said he has a photo of watermark on door. He is going to send it to me - will forward when received.	1			1		1	1					Y		Culvert under Pomona Rd (at BDY of #6 & 8) blocked and totally inadequate to cope with volume of water. Difficult to determine degree of blockage - water over road - woody debris evident when water subsides.	Y		1. During heavy rain water is often over road (flooding over culvert) near boundary between #6 & 8. Culvert appears to be inadequate to cope with volume of water from ridge. 2. Previous flooding of #8 & 10 **PLS SEE ATTACHED PHOTO'S ETC.**
92	Andrew Close	Bensville	4			1	N	N	N																															N				
93	Sorrento Rd	Empire Bay	8		1		N	Y	N	Y		1														N		1					1							N			N	
94	Kendall Rd	Empire Bay	9	1			N	N	N																	N														N				
95	Allawa Cl	Bensville	17	1			N	Y	Y	Y		1	1											Almost immediately water level rose to approx 30cm covering all or most of backyard, driveway, garage & partial front yard. Stayed waterlogged for approx 4-5 days.		N														N		Y		Always floods when heavy rain. Runs down our street into our property as no kerb or gutter & no drainage on road at all.
96	Kallaroo Rd	Bensville	3			1	N	N	N																	N																		
97	Greenfield Rd	Empire Bay	1	1			N	Y	Y	Y		1														N		1	1				1	1			1	Roads	Y			Y		
98	Kendall Rd	Empire Bay	14	1				Y			N													Flooding straight away in yard after heavy rain - 7cm high - stays that high few days after rain stops then drains away.	Y		There is a telegraph pole situated next to my driveway with a floodwater mark on it of 2.6m																	Aware of flooding in 1978 - Greenfield Rd, Rickard Rd and all near bay were under water. When it rains heavily both front & back yard is covered in water 5-7cm deep. Can't walk across yard. **PHOTO'S ENCLOSED.** Has been worse than photo's show - pole with mark of 2.6m is in the photo with ducks.
99	Pomona Rd	Empire Bay	16		1		N	N	Y		N													After heavy rain and drains not kept clear of debris at (1) After/during heavy continuous rain - runoff from higher ground at (2).		N					1	Drain at front of property on Pomona Rd marked (1) & (2)							Y		(1) 85% (2) 100%. Woody debris.	Y		
100	Shelly Beach Rd	Empire Bay	9	1			N	Y	Y	Y		1												Aug 1998 4 hrs after rain started. Southerly wind and low tide. Flooding over reserve at Shelly Beach Rd and road. Front of house 1m. Back 30cm. June 2007 Five hours after rain. Stayed for over 24 hrs under house and back garden. Property is lower than estuary so flooding flows towards us. Water in road for over 3 days.	Y		Info sent to Council **see letter enclosed**. Despite levee and reflex pipe at the end of Shelly Beach Rd, the June 2007 flood covered the road, reserve and flooded under #51, 60, 62 & 49	1	1		1		1	1		1	1			N		Y		Flooding occurs when there is heavy rain, southerly wind and an ebbing tide. Flooding in backyard comes thru from the wetlands. We've been told there is a drainage pipe at the rear of our cack fence flowing into Cockle Bay but it certainly doesn't have an effect during storms and heavy rain. Can show consultants where problems occur.
101	Hillcrest Rd	Empire Bay	32			1	N	N	N																																			Never affected by flooding.
102	Shelly Beach Rd	Empire Bay	7	1			N	Y	Y	Y		1												How long after? Within 12 hrs. How high? 6". How long stay? 48 hrs. Peak? Within 12 hrs.		N		1			1		1							N		Y		We get large areas of water lying around on footpath and nature strip of road. We have large amount of mosquitos due to stagnant water lying around for mosquitos to breed in.
103	Pomona Rd	Empire Bay	22	1			Y	Y	Y	Y		1												Heavy rain brings water down watercourse that runs from Wards Hill thru properties (acres) opposite then hits the road. Follows water course drain thru property into water course defined area. Water floods across road causing water to backup then enters our driveways causing flooding on property and flooding on properties below us.	Y		Photos late 1980's - knee deep across road. Photos 1996 water thru garage 4" high - also thru shed. Always floods thru property in torrential rain especially since road tarred and pipe under road made larger for rain water.					Rural, small 1 acre properties and houses below us.	1	1	1		1		Y		50% blocked with woody debris	Y		Water too great to flow down thru the under road pipe (Wards Hill Rd) so it banks up along road, washes over then floods property. Roads drain thru our property to properties below us. Problems increased since tarring Pomona Rd & Wards Hill Rd.
104	Pomona Rd	Empire Bay	18	1			Y	Y					1											Flood in house in 20mins of rain commencing - freak flash flood & hailstones lasted approx 1 hour. Normal run-off flooding occurs when ground is saturated or we have heavy downpour. Water can run to 1m high across this area of valley. Clears within 1/2 hr of rain ceasing. Poor inapropriate, wrongly placed and not enough drainage by Council in this area.	Y		Flash flood up to 1 metre across valley. About road level on Empire Bay Drive.	1					1		1		1			N				Council in Pomona Rd has allowed areas to be filled & built on causing increased water flow. Drainage in area does not logically follow proper drainage patterns.
105	Empire Bay Dr	Bensville	42	1				Y					1											Not sure of water. Water flooded after powerful rainstorm. Drains along Empire Bay Dr overflooded causing flooding of parked cars.		N	Rainwater drains alongside water drains & rises until can flow across the road surface. On this occasion rainwater flooded two cars up to a height of sensitive components.	1						1			1		Y					
106	Kildare St	Bensville	25	1			N	N	Y	Y								1						1967 or 1968 as well. Water was across road & became impassable at bottom of Wards Hill Rd on Empire Bay Drive.	Y		Possibly 1967 or 68. My uncle had house at Shelly Beach Rd Empire Bay, water came up steps to entry level of house but didn't enter house.	1	1				1			1	1					Y		On opposite side of Kildare St to me was extremely wet before filled in for new estate when it rained heavily. Marsh at end of old Kildara St filled as did farm ditches.
107	Pomona Rd	Empire Bay	11	1			N	Y	Y			1	1											Runs down the block (acreage) from rear Mountain into watercourse which overflows onto properties below ie mine and #8 & 10		N							1				1		Y		90% blocked drain out front of #6 Pomona going under road. Wood debris.	Y		

Empire Bay	Q1		Q2	Q3			Q4			Q5															Q6			Q7											Q8			Q9		Q10
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108	Gordon Rd	Empire Bay	6	1			N																		Y		27 Sorrento Road - far end of backyard has flooded numerous times since lived here, including June 2007. Curbing & guttering always floods in front of 2A, 2B, 2D & 2E Gordon Rd.	1				Curb & guttering	1					Curb & guttering						Numerous verges and gutters flood in heavy rain. Swales have been shown to overcome this problem.
109	Sorrento Rd	Empire Bay	33	1			N	Y	Y	Y		1												Any flooding has required - high winds from SE-SW quadrant, high rainfall over 2 or 3 days and/or cloadburst 2-3 hrs in BW catchment. High tide above 1.6m which cannot move to any degree due to wind and/or rain input. Speed of dispersment of flooding depends on condition of drains - poorly maintained **SEE PHOTO'S.**	Y		Flood 1974 reached top step of front verandah - 32cm above grd level. Laundry flood (grd level at rear) recorded 10cm above floor level in 1974 and 1.5cm in 2007. Flooding usually begins at rear of property or from side #8) as drain on border (9-10A) overflows. Within an hour or so water encroaches from waterfront if conditions are as stated previously.		1		1	Drain outlets	1					Laundry @ flr level.				Y		Gary Lovell of 24 Greenfield Rd contacted me reflooding of his home on June 8 - if he has not returned his questionaire contact him on 4369 4279 for an accurate report. Minor nuisance flooding will always exist in Empire Bay streets which are barely above king tide highwater marks. Maintenance of existing drains & new ones in Shelley Beach Rd, Rickard Rd, Gordon Rd, Sorrents Rd & Boongala Ave will help shift water faster when weather conditions change. **SEE ENCLOSED PHOTOS**
110	Gordon Rd	Empire Bay	15			1	N	N	N															There has been water across road but not dep enough to stop us driving in June 2007 and also in 2006 (can't remember when)		N																		Wondering if some of the residents on the other side of Gordon Rd would say they were inconvenienced when the water was across the road as their side is a bit lower.
111	Rosella Rd	Empire Bay	16		1		N	N	N		N															N														N			N	Parents purchased property in late 1950 and related stories about flooding in the lower areas of Empire Bay during 1960's before stormwater drains were installed. The only form of flooding I can recall is around Gordon Rd Boongala Ave, Rickard Rd, Sorento Rd when low lying properties have had water covering their yards after heavy rain.
112	Shelly Beach Rd	Empire Bay	12	1			N	Y	Y	Y														During heavy rain Shelly Beach Rd floods. Very inconvenient - no drain pipes to take water away - no kerb & guttering.	Y				1		1		1				1			N		Y		Boongala Ave, Gordon Rd - any land lower than road floods. Water rises to near centre of roads. **SEE PHOTO'S**
113	Pomona Rd	Empire Bay	17	1				Y	N	Y		1	1	1	1	1								Water rushes across yard, runoff from Boudi National Park. Can be 30cm deep at times but quickly vanishes when heavy rain stops.		N						Rural land								N		Y		
114	Gordon Rd	Empire Bay	4	1			N	N	N																Y		Boongala Road Empire Bay - table drains overflowed, water covered the road and kids were able to ride their surfboards! From the Gordon Road end it appeared that 1/2 to 3/4 of Boongala was flooded.				1	Boongala Rd Empire Bay						Drains, road, nature strip	Y		The Council laid grass in the table drain outside 14 16 Gordon Rd, since then the water (tidal & flood) no longer runs away but rather sites and stagnates. Not sure why the grass was laid . . . It seems like a waste of money and time not to mention that it has stopped the water from draining away. (It's a great place for mozzies to breed unfortunately).	Y		So much of Empire Bay has large expanses of water that lays on the roads and footpaths when there is a light shower of rain. This was magnified with the June 30 storms. Proper stormwater drainage, gutters and the elimination of the open drains would make Empire Bay easier to negotiate by foot and by car in wet weather; would reduce possible diseases such as Ross River Fever; would aesthetically improve the overall appearence of our "pretty" neighbourhood, and help control the water from any future storm events.
115	Empire Bay Dr	Empire Bay	31		1		N	Y	Y		N													Each time very heavy rain water runs from fron ot road & flood driveway & backyard - which runs off quickly but causes damage to yard & removes topsoil. No kerb & guttering.		N							1	1			1			N				
116	Wanawong Cl	Empire Bay	8																							N																	N	
117	Boongala Ave	Empire Bay	3		1		N	N	N																Y		Was about 2005 summer/spring. Whole of Boongala Ave flooded. Children swimming & surfing in street. Neighbours backyard under water.	1					1						Y		80% blocked - woody debris, soil, etc.	Y		Not enough storm water drainage - no gutters. Water nowhere to go.
118	Myrtle Rd	Empire Bay	23	1				Y	Y	Y									1					Water was approx. 4" from entering house	Y		Myrtle Rd & Rickard Rd Junction was approx knee deep stormwater pipe couldn't handle it.	1			1		1						Y		Stormwater pipes part blocked with sand and gravel.	Y		
119	Rosella Rd	Empire Bay	12	1			N	N	N																																			
120	Rickard Rd	Empire Bay	10	1				Y	Y	Y		1												**Pomona R**d - Our block receives the run off from the hair pin on Wards Hill Rd as there is no drainage point the water is diverted onto our block thru 2 drains and then the overflow affects houses & blocks below.	Y		**Photo's - will email.**	1	1									Paddock & houses on the N side of Pomona Rd	Y		All of the previous.	Y		
121	Rosella Rd	Empire Bay	5				N	N	N																															N				No actual water damage to area since bought property.
122	Shelly Beach Rd	Empire Bay	10	1				Y	Y	Y		1												Flooding to property started within hours, road was completely cut, it stayed for days - reached a peak almost immediately.	Y		Melville Real Estate has photo's. Levels came up to & just entered our double garage.	1					1	1						N		Y		Flooding of Shelly Beach Rd occurs every time we have over 25mm of rain. As there are no gutters water will lay for days at a time on edge of road making entry or thru foot traffic extremely difficult.
123	Rickard Rd	Empire Bay	27		1			Y	Y	Y														1. Property is tidal i.e. tides of 2m encroach under the house. 2. Heavy rain or high tide make access on the side entrance run to depth of 3-5cm on footpath.		N														N				House is within 1/2 - 2m from sea wall. Hill 400m immediately east of building which means we have quite an impressive rain water thru property to Cockle Bay Creek. Intend to increase drainage of water to creek. When there is 750mm rise in sea level, I think we will be OK.
124	Merrits Rd	Empire Bay	5			1		N	N	N																																		
125	Myler Ave	Empire Bay	14	1			N	N	N	N																																	N	
126	Boongala Ave	Empire Bay	25	1				Y	Y															Have seen Boongala Ave like a river. Depends on tide how long it takes to recede.	Y		**Photos** taken a few years ago.																	

Empire Bay	Q1		Q2	Q3			Q4			Q5														Q6			Q7											Q8			Q9		Q10
Survey Ref. No	Street	Suburb	How long - years	Aware	Some knowledge	Not Aware	Inside	Yard	Inconv.	Yes	No	Jun-07	Jan-96	Feb-92	Feb-90	Jan-89	Apr-88	Oct-85	Nov-84	Feb-81	Jan-78	Mar-77	May-74	Comments	Yes	No	Comments	Res	Parks	Comm.	Rds & Paths	Other	Backyard	Garage	Bldg-Above	Bldg-Below	Front yard	Other	Yes	No	Comment	Yes	No	Comments
127	Shelly Beach Rd	Empire Bay	7	1				Y	Y															Every king tide sea water comes onto property and street floods. When tide is 1.6m or higher water comes up the street past drive way - can't use car.	Y		Can show you levels.	1	1		1		1				1	Public reserve, access to public wharf.				Y		Sea wall at end of road has pipe with flap which opens with movement in water which allows water to come up road. Council has been notified of problem - but states can't be rectified.
128	Rickard Rd	Empire Bay	27		1		N	N	N																	N																		
129	Rickard Rd	Empire Bay	12	1			N	N	Y	Y														1993/1994 Boongala St. only. One day after rain started, water in Boongala St was approx 300mm in street/stayed .5 day.		N														N		Y		
130	Kildare St	Bensville	6			1	N	N	N		N															N																		
131	Gordon Rd	Empire Bay	9		1		N	N	Y		N													Winter 1998. Rained all night drains backed up water over road. Had trouble getting car out of driveway and got wet brakes.		N														N			N	
132	Rickard Rd	Empire Bay	6			1	Y	Y	Y		N													2005 Water thru bathroom drains - hand basin then floor waste. Arrived home in ankle deep water thru hallway, bathroom, kitchen, 2nd bedroom. Reached peak approx 5pm.	Y	N		1			1		1		1					N		Y		Run-off limited by scope of drainage. House on either side built higher than middle house. - no retaining walls. Boongala always floods across road within sharp heavy downpour. Boongala Ave - parts of Rickard Road above car tyres.
133	Wards Hill Rd	Empire Bay	2	1			N	Y	Y	Y		1												2006 - Minutes after rain started - water level over a metre high - completely flooded over driveway & flooded property - takes several hrs for water level to go down and is very dangerous because stormwater canal runs thru property - always wet - breeding ground for mosquitos & bacteria.	Y		**Photo's** of our property plus road where water makes its way down property. It should be redirected in the stormwater drain at Romano Rd.	1					1			1	1			N		Y		There is a lot of information that I'd be happy to talk to you about. Pls call Brendan Attart on 0414 761 278. Too much to list here.

Photos forwarded by residents

May 2001 – Bundaleer Cres, Bensville

December 2005 - Bundaleer Cres, Bensville

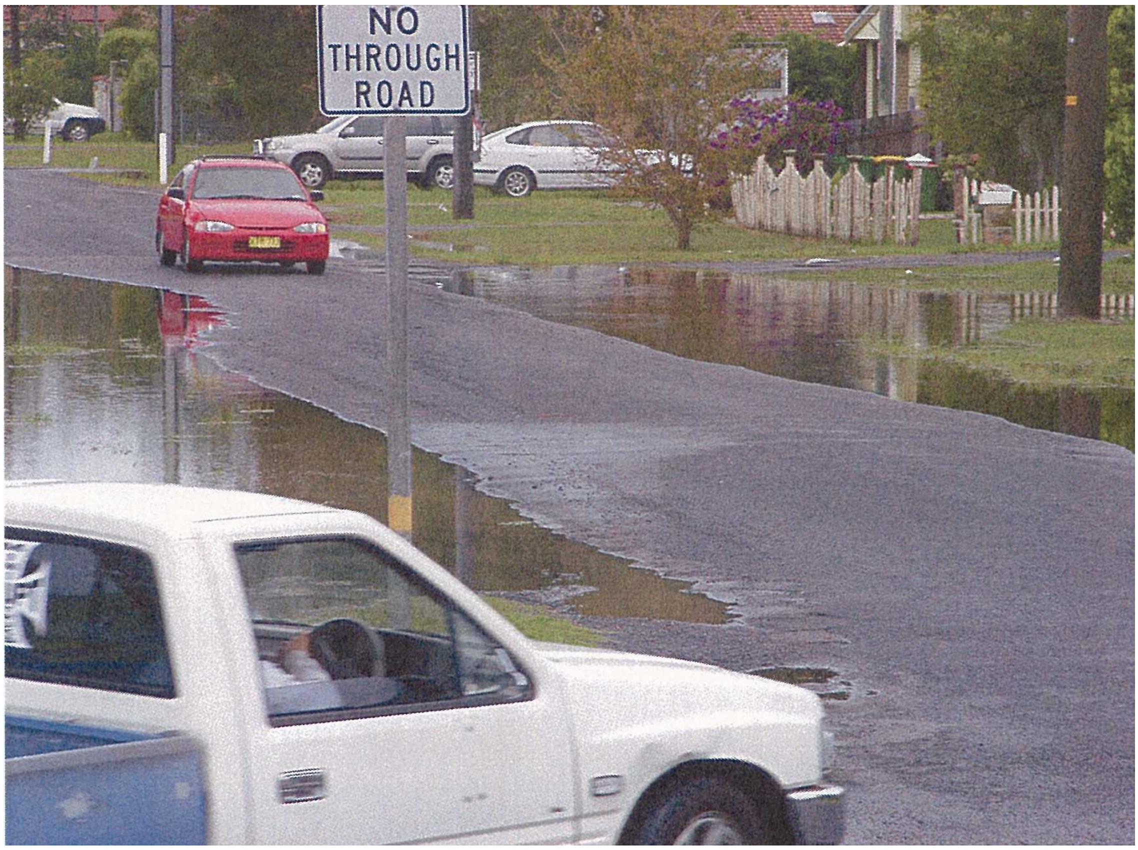
August 2006 – Rickard Road, Empire Bay

2006 – Vicinity of Wards Hill Road


2006 – Vicinity of Wards Hill Road


2006 – Vicinity of Wards Hill Road


2006 – Vicinity of Wards Hill Road



June 2007

June 2007

June 2007

June 2007 – Park at Sorrento Road

June 2007

07:00 June 9 2007 – at Sorrento Road

November 2007 - Boongala Road

Open Drain behind houses on Rickard Rd


Date and location not specified


Date and location not specified

APPENDIX B

Sensitivity Analysis

Table B.1 Catchment Rainfall Sensitivity

Point	Location	Base Case	20% Decrease		20% Increase	
		Peak Water Level (m AHD)	Peak Water Level (m AHD)	Difference to Base Case (m)	Peak Water Level (m AHD)	Difference to Base Case (m)
1	Intersection Gordon Rd & Boongala Ave	1.37	1.32	-0.05	1.41	0.04
2	Intersection Sorrento Rd & Gordon Rd	1.24	1.20	-0.04	1.28	0.03
3	Sorrento Rd near Kendall Rd	1.31	1.31	0.00	1.31	0.00
4	Intersection Greenfield Rd and Rickard R	1.47	1.42	-0.05	1.50	0.04
5	Intersection Shelly Beach Rd & Sher Cl	1.25	1.25	0.00	1.26	0.00
6	Greenfield Rd	1.79	1.76	-0.03	1.81	0.03
7	Empire Bay Dr (near Awinya Cl)	9.40	9.38	-0.02	9.42	0.02
8	Palmers Lane	6.69	6.62	-0.07	6.72	0.03
9	Empire Bay Dr	8.82	8.69	-0.14	8.87	0.05
10	Empire Bay Dr	9.04	9.01	-0.03	9.06	0.02
11	Wards Hill Rd	12.12	12.11	-0.01	12.13	0.01
12	21 Pomona Rd	16.93	16.72	-0.21	17.09	0.16
13	Pomona Rd	17.76	17.74	-0.02	17.77	0.02
14	Valencia St	1.30	1.29	-0.01	1.31	0.01
15	Emma St	1.80	1.79	-0.02	1.82	0.01
16	Kildare St	7.87	7.85	-0.02	7.90	0.03

* Location of reference points shown on Figure 6.1.

Table B.2 Catchment Roughness Sensitivity

Point	Location	Base Case	20% Decrease		20% Increase	
		Peak Water Level (m AHD)	Peak Water Level (m AHD)	Difference to Base Case (m)	Peak Water Level (m AHD)	Difference to Base Case (m)
1	Intersection Gordon Rd & Boongala Ave	1.37	1.36	-0.01	1.38	0.01
2	Intersection Sorrento Rd & Gordon Rd	1.24	1.24	-0.01	1.25	0.00
3	Sorrento Rd near Kendall Rd	1.31	1.31	0.00	1.31	0.00
4	Intersection Greenfield Rd and Rickard R	1.47	1.46	0.00	1.47	0.00
5	Intersection Shelly Beach Rd & Sher Cl	1.25	1.25	0.00	1.25	0.00
6	Greenfield Rd	1.79	1.78	0.00	1.80	0.01
7	Empire Bay Dr (near Awinya Cl)	9.40	9.39	-0.01	9.40	0.00
8	Palmers Lane	6.69	6.64	-0.05	6.68	-0.01
9	Empire Bay Dr	8.82	8.74	-0.09	8.88	0.06
10	Empire Bay Dr	9.04	9.01	-0.03	9.06	0.02
11	Wards Hill Rd	12.12	12.12	0.00	12.13	0.01
12	21 Pomona Rd	16.93	16.85	-0.08	17.00	0.07
13	Pomona Rd	17.76	17.73	-0.02	17.77	0.01
14	Valencia St	1.30	1.30	-0.01	1.31	0.01
15	Emma St	1.80	1.79	-0.01	1.82	0.01
16	Kildare St	7.87	7.86	0.00	7.87	0.00

* Location of reference points shown on Figure 6.1.

Table B.3 Downstream Boundary Sensitivity

Point	Location		Base Case	20% Decrease		20% Increase	
		Ground Elevation (m AHD)	Peak Water Level (m AHD)	Peak Water Level (m AHD)	Difference to Base Case (m)	Peak Water Level (m AHD)	Difference to Base Case (m)
1	Intersection Gordon Rd & Boongala Ave	1.17	1.37	1.37	0.00	1.37	0.00
2	Intersection Sorrento Rd & Gordon Rd	1.08	1.24	1.24	0.00	1.24	0.00
3	Sorrento Rd near Kendall Rd	1.30	1.31	1.31	0.00	1.31	0.00
4	Intersection Greenfield Rd and Rickard R	1.35	1.47	1.47	0.00	1.47	0.00
5	Intersection Shelly Beach Rd & Sher Cl	1.25	1.25	1.25	0.00	1.25	0.00
6	Greenfield Rd	1.62	1.79	1.79	0.00	1.79	0.00
7	Empire Bay Dr (near Awinya Cl)	9.30	9.40	9.40	0.00	9.40	0.00
8	Palmers Lane	6.23	6.69	6.69	0.00	6.69	0.00
9	Empire Bay Dr	7.60	8.82	8.82	0.00	8.82	0.00
10	Empire Bay Dr	8.85	9.04	9.04	0.00	9.04	0.00
11	Wards Hill Rd	12.05	12.12	12.12	0.00	12.12	0.00
12	21 Pomona Rd	15.33	16.93	16.92	-0.01	16.93	0.00
13	Pomona Rd	17.60	17.76	17.75	0.00	17.75	0.00
14	Valencia St	1.22	1.30	1.30	0.00	1.30	0.00
15	Emma St	1.75	1.80	1.80	0.00	1.81	0.00
16	Kildare St	7.73	7.87	7.87	0.00	7.87	0.00

* Location of reference points shown on Figure 6.1.

Table B.4 Pipe Blockage Sensitivity (20% AEP)

Point	Location	Base Case	All Pipes Blocked		Selected Pipes Blocked	
		Peak Water Level (m AHD)	Peak Water Level (m AHD)	Difference to Base Case (m)	Peak Water Level (m AHD)	Difference to Base Case (m)
1	Intersection Gordon Rd & Boongala Ave	1.26	1.23	-0.04	1.25	-0.01
2	Intersection Sorrento Rd & Gordon Rd	1.16	1.15	-0.01	1.16	0.01
3	Sorrento Rd near Kendall Rd	1.31	1.31	0.00	1.31	0.00
4	Intersection Greenfield Rd and Rickard R	1.37	1.44	0.07	1.45	0.08
5	Intersection Shelly Beach Rd & Sher Cl	1.25	1.25	0.00	1.25	0.00
6	Greenfield Rd	1.73	1.74	0.01	1.73	0.01
7	Empire Bay Dr (near Awinya Cl)	9.35	9.43	0.08	9.41	0.06
8	Palmers Lane	6.58	6.58	0.00	6.58	0.00
9	Empire Bay Dr	8.52	8.66	0.15	8.66	0.15
10	Empire Bay Dr	8.96	8.96	0.00	8.96	0.00
11	Wards Hill Rd	12.10	12.10	0.01	12.10	0.00
12	21 Pomona Rd	16.43	16.42	-0.01	16.43	0.00
13	Pomona Rd	17.72	17.73	0.01	17.72	0.00
14	Valencia St	1.28	1.28	0.00	1.28	0.00
15	Emma St	1.77	1.78	0.00	1.77	0.00
16	Kildare St	7.82	7.92	0.10	7.92	0.10

* Location of reference points shown on Figure 6.1.

APPENDIX C

Climate Change

Table C.1 Climate Change Assessment – Increased Rainfall (1% AEP 2h)

Point	Location	Base Case	10% Increased Rainfall		20% Increased Rainfall		30% Increased Rainfall	
		Peak Water Level (mAHD)	Peak Water Level (mAHD)	Diff. to Base Case (m)	Peak Water Level (mAHD)	Diff. to Base Case (m)	Peak Water Level (mAHD)	Diff. to Base Case (m)
1	Intersection Gordon Rd & Boongala Ave	1.37	1.39	0.02	1.41	0.04	1.43	0.05
2	Intersection Sorrento Rd & Gordon Rd	1.24	1.26	0.02	1.28	0.03	1.29	0.05
3	Sorrento Rd near Kendall Rd	1.31	1.31	0.00	1.31	0.00	1.31	0.00
4	Intersection Greenfield Rd and Rickard R	1.47	1.49	0.02	1.50	0.04	1.52	0.05
5	Intersection Shelly Beach Rd & Sher Cl	1.25	1.25	0.00	1.26	0.00	1.26	0.01
6	Greenfield Rd	1.79	1.80	0.01	1.81	0.03	1.82	0.04
7	Empire Bay Dr (near Awinya Cl)	9.40	9.41	0.01	9.42	0.02	9.42	0.02
8	Palmers Lane	6.69	6.70	0.02	6.72	0.03	6.73	0.04
9	Empire Bay Dr	8.82	8.85	0.03	8.87	0.05	8.97	0.15
10	Empire Bay Dr	9.04	9.05	0.01	9.06	0.02	9.08	0.03
11	Wards Hill Rd	12.12	12.13	0.01	12.13	0.01	12.14	0.02
12	21 Pomona Rd	16.93	17.00	0.07	17.09	0.16	17.22	0.30
13	Pomona Rd	17.76	17.77	0.01	17.77	0.02	17.78	0.03
14	Valencia St	1.30	1.31	0.01	1.31	0.01	1.32	0.02
15	Emma St	1.80	1.81	0.01	1.82	0.01	1.82	0.02
16	Kildare St	7.87	7.88	0.01	7.90	0.03	7.91	0.04

* Location of reference points shown on Figure 6.1.

Table C.2 Climate Change Assessment – 0.2m Raised Estuary Level

Point	Location	1% AEP 2h (Base Case)	1% AEP 2h Storm and 0.2m Raised Estuary Level		1% AEP 2h Storm with additional 30% rainfall & 0.2m Raised Estuary Level	
		Peak Water Level (mAHD)	Peak Water Level (mAHD)	Difference to Base (m)	Peak Water Level (mAHD)	Difference to Base (m)
1	Intersection Gordon Rd & Boongala Ave	1.37	1.37	0.00	1.43	0.06
2	Intersection Sorrento Rd & Gordon Rd	1.24	1.25	0.00	1.29	0.05
3	Sorrento Rd near Kendall Rd	1.31	1.31	0.00	1.31	0.00
4	Intersection Greenfield Rd and Rickard R	1.47	1.47	0.00	1.52	0.05
5	Intersection Shelly Beach Rd & Sher Cl	1.25	1.25	0.00	1.26	0.01
6	Greenfield Rd	1.79	1.79	0.00	1.82	0.04
7	Empire Bay Dr (near Awinya Cl)	9.40	9.40	0.00	9.42	0.02
8	Palmers Lane	6.69	6.69	0.00	6.73	0.04
9	Empire Bay Dr	8.82	8.82	0.00	8.97	0.15
10	Empire Bay Dr	9.04	9.04	0.00	9.08	0.03
11	Wards Hill Rd	12.12	12.12	0.00	12.14	0.02
12	21 Pomona Rd	16.93	16.92	-0.01	17.22	0.29
13	Pomona Rd	17.76	17.75	0.00	17.78	0.03
14	Valencia St	1.30	1.30	0.00	1.32	0.02
15	Emma St	1.80	1.80	0.00	1.82	0.02
16	Kildare St	7.87	7.87	0.00	7.91	0.04

* Location of reference points shown on Figure 6.1.

Table C.3 Climate Change Assessment – 0.91m Raised Estuary Level

Point	Location	1% AEP 2h (Base Case)	1% AEP 2h Storm and 0.91m Raised Estuary Level		1% AEP 2h Storm with additional 30% rainfall & 0.91m Raised Estuary Level	
		Peak Water Level (mAHD)	Peak Water Level (mAHD)	Difference to Base (m)	Peak Water Level (mAHD)	Difference to Base (m)
1	Intersection Gordon Rd & Boongala Ave	1.37	1.58	0.21	1.60	0.22
2	Intersection Sorrento Rd & Gordon Rd	1.24	1.56	0.31	1.56	0.32
3	Sorrento Rd near Kendall Rd	1.31	1.56	0.25	1.56	0.25
4	Intersection Greenfield Rd and Rickard R	1.47	1.59	0.12	1.61	0.14
5	Intersection Shelly Beach Rd & Sher Cl	1.25	1.55	0.30	1.55	0.30
6	Greenfield Rd	1.79	1.77	-0.01	1.81	0.03
7	Empire Bay Dr (near Awinya Cl)	9.40	9.39	-0.01	9.42	0.02
8	Palmers Lane	6.69	6.68	-0.01	6.73	0.04
9	Empire Bay Dr	8.82	8.80	-0.02	8.94	0.12
10	Empire Bay Dr	9.04	9.04	0.00	9.07	0.03
11	Wards Hill Rd	12.12	12.11	-0.01	12.14	0.01
12	21 Pomona Rd	16.93	16.87	-0.06	17.17	0.24
13	Pomona Rd	17.76	17.75	0.00	17.78	0.02
14	Valencia St	1.30	1.55	0.25	1.55	0.25
15	Emma St	1.80	1.80	0.00	1.82	0.02
16	Kildare St	7.87	7.86	-0.01	7.90	0.03

* Location of reference points shown on Figure 6.1.

APPENDIX D

FMA Prioritisation Ranking

Prioritisation of catchment areas regarding the undertaking of Flooding and Drainage Works
Flood Mitigation Works

Empire Bay Catchment

Categories		Attributes		
1. Hazard level in area	a	Area is a high hazard floodway, (defined by the Floodplain Management Manual)	1	-
Place tick in appropriate boxes	b	Little warning time, (less than 2 days)	1	**1**
(applies to worst recorded event)	c	Rapid water level rise, (more than 0.1m per hour)	1	**1**
	d	Typical depth above floor greater than 0.1m	1	**1**
	e	Typical depth above floor greater than 0.5m	1	-
2. Social Impact	a	Business area closes down affecting long term viability	1	-
Place tick in appropriate boxes	b	Community infrastructure affected (Hospitals, Schools etc.)	1	-
(Existing or anticipated problems)	c	Community isolated in major floods	1	**1**
	d	Essential infrastructure at risk of failure (electricity, water, sewerage etc.)	1	-
	e	Long term isolation / long duration flooding in the town area (greater than 1 day)	1	-
3. Scale of problem - No. of dwellings affected	a	1 - 4 dwellings affected	1	-
Place tick in one box for highest no. dwellings affected	b	5 - 9 dwellings affected	2	-
by above floor flooding	c	10 - 14 dwellings affected	3	-
(applies to worst recorded event)	d	15 - 19 dwellings affected	4	-
	e	Greater than 20 dwellings affected	5	**5**
4. Scale of problem - % of dwellings flooded	a	Reports/records show 9% or more dwellings affected	5	-
Place tick in one box for highest % dwellings	b	Reports/records show 6 - 9% or more dwellings affected	4	**4**
affected by overfloor flooding.	c	Reports/records show 4 -6% or more dwellings affected	3	-
(applies to worst recorded event)	d	Reports/records show 2 - 4% or more dwellings affected	2	-
	e	Reports/records show 0 -2% or more dwellings affected	1	-
5. Scale of Problem - Frequency of over floor flooding	a	Reports/records show at least 1 incidence of flooding	1	-
Place tick in one box for highest no. incidences of	b	Reports/records show at least 2 incidences of flooding	2	-
over floor flooding	c	Reports/records show at least 3 incidences of flooding	3	-
(all recorded events)	d	Reports/records show at least 4 incidences of flooding	4	-
	e	Reports/records show 5 or more incidences of flooding	5	**5**
6. Evacuation	a	Evacuation to centres outside the community required (adajcent suburbs etc.)	1	-
Placed tick in appropriate boxes	b	Urgent evacuation due to quickly rising water levels and associated danger to personal safety	1	**1**
(applies to worst recorded event)	c	Evacuation leaving no time for damage reduction	1	**1**
	d	Evacuation from entire area required (localised group of suburbs)	1	-
	e	External evacuation assistance required due to lack of overland evacuation route (SES etc.)	1	-
		DECC / DIPNR Sub-Total		**20**
7. Damage	a	Structural damage mainly to houses (house undermining, extensive structural damage etc.)	1	-
Place tick in appropriate boxes	b	Non-structural damage mainly to houses (hose out house, replace carpets etc.)	1	**1**
(applies to worst recorded event)	c	Flooding of yards, sheds, garages, pools, and or downstairs areas	1	**1**
	d	Minor property damages	1	**1**
8. Environmental Damage	a	Potential damage to designated environmentally sensitive areas (SEPP Wetlands etc.)	1	-
Place tick in appropriate boxes	b	Major erosion and siltation problems causing an increase in flood levels and /or loss of waterway area	1	**1**
(Existing or anticipated problems)	c	Loss of Riparian Vegetation and Fauna Habitat associated with erosion of banks or bed of creek	1	-

9. Maintenance Issues	a	Tendency to require regular maintenance (blocked pits/pipes, vegetation in open drains)	1	**1**
Place tick in appropriate boxes	b	Old pipelines in area (Possibility of cracking, mis-alignment, or requiring replacement)	1	**1**
(Existing or anticipated problems)				

10. Development	a	Detailed investigation complete	1	**n/a**
Place tick in appropriate boxes	b	Design Complete	1	**n/a**
	c	Approval Complete (owner, DLWC, Fisheries, DA, etc.)	1	**n/a**
	d	Environmental assessment complete	1	**n/a**
	e	Management plan complete	1	**n/a**
	f	Community involvement in project	1	**n/a**

GCC Sub-Total	**n/a**
TOTAL	**n/a**