Riverside at Tea Gardens

Probable Maximum Flood

CRIGHTON PROPERTIES

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Probable Maximum Flood

Final Report
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Status	Preliminary	☐	**Author**	Dr Brett C Phillips, Stephen Yu
	Draft	☐	**Signature**	Brett C. Phillips
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	Final	■	**Reviewer**	Dr Brett C Phillips
	Superseded	☐	**Signature**	Brett C. Phillips
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This report was prepared by a member of the Cardno group:

Cardno Willing (NSW) Pty Ltd
Level 2, 910 Pacific Highway
GORDON NSW 2072

Telephone (02) 9496 7799
Facsimile (02) 9499 3902
Email: sydney@cardno.com.au

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

Riverside at Tea Gardens is subject to flooding from both the Myall River and from runoff from the local catchment.

The sensitivity of river and local flood levels to climate change was assessed recently for the scenarios given in the 2007 DECC Guideline titled "Practical Consideration of Climate Change" (Cardno Willing, 2008a). These scenarios include +0.18m, +0.55 m and +0.91 rises in sea level as well as 10%, 20% and 30% increase in rainfall intensities.

An assessment of the PMF levels under river and local flooding (without climate change) at the request of the NSW Department of Planning and is reported herein.

The estimated PMF levels in the Myall River in the vicinity of Riverside are summarised as follows:

Event	Description	Estimated Flood Level (m AHD)
PMF	The PMF level under existing conditions with a 100 yr ARI downstream boundary level in the lower reach of the Myall River of RL 1.89 m.	2.82 – 2.89 m
PMF	The PMF level under existing conditions with an extreme downstream boundary level in the lower reach of the Myall River of RL 2.0 m	2.86 – 2.93 m

It is noted that the Riverside proposal has an additional freeboard of 0.3 m over and above Council's adopted minimum floor level of 2.6 m AHD in areas subject to inundation from the Myall River to avoid over floor flooding in a 100 yr ARI event under all climate change scenarios. The adopted minimum floor level of 2.9 m is comparable to the estimated PMF level in the Myall River.

The hydraulic model used for the assessments of local flooding and drainage up to 100 yr ARI events was used to also estimate PMF levels due to local runoff.

The estimated local PMF levels are summarised in **Table 2**.

It was noted that in almost all locations the 1 hour PMP storm gave the highest flood level except for the upper reach of the West Branch where the 30 minute PMP storm gave the highest estimated flood levels. In most locations it was estimated that the PMF level is between 0.9 m to 1.45 m higher than the local 100 yr ARI level.

It should be noted that the local PMF levels are based on floodwaters confined to the drainage corridors and as such these are conservative estimates. During a PMF event local runoff would spill from the drainage corridors into the residential areas which would result in lower PMF levels than summarised in Table 2.

1. BACKGROUND

Riverside at Tea Gardens is subject to flooding from both the Myall River and from runoff from the local catchment.

The sensitivity of river and local flood levels to climate change was assessed recently for the scenarios given in the 2007 DECC Guideline titled "Practical Consideration of Climate Change" (Cardno Willing, 2008a). These scenarios include +0.18m, +0.55 m and +0.91 rises in sea level as well as 10%, 20% and 30% increase in rainfall intensities.

An assessment of the PMF levels under river and local flooding (without climate change) at the request of the NSW Department of Planning and is reported herein.

2. PREVIOUS STUDIES

A number of flooding investigations of the Myall River and Port Stephens have been previously undertaken and reported as follows:

Department of Public Works, NSW (1980) "Lower Myall River Flood Analysis, 32 pp.

Public Works Department, NSW, Manly Hydraulics Laboratory (1993), Lower Myall River Compilation of Data, Report MHL622.

NSW Public Works, Manly Hydraulics Laboratory (1993a), Port Stephens Flood Study Stage 1, Analysis and Review of Existing Information, Report MHL623, Great Lakes Council and Port Stephens Council.

NSW Public Works, Manly Hydraulics Laboratory (1993b), Port Stephens Flood Study Stage 2, Design Water level and Wave Climate, Report MHL759, prepared for Great Lakes Council and Port Stephens Council.

Willing & Partners (1995) "Hawks Nest North Local Environment Study, Flood Impact Assessment", prepared for ERM Mitchell McCotter, September, 27 pp.

Webb, McKeown & Associates (2002) "Port Stephens Foreshore (Floodplain) Management Study, Final report, prepared for Port Stephens and Great Lakes Councils, April.

Cardno Willing (2008) "Riverside at Tea Gardens, Practical Consideration of Climate Change", prepared for Crighton Properties, May.

Several of these sties are outlined as follows.

Department of Public Works, NSW (1980) "Lower Myall River Flood Analysis, 32 pp.

Flood behaviour in the Myall River was studied in the Lower Myall River Flood Analysis (Department of Public Works, 1980). The study used mathematically modelled, synthesised floods of various frequencies to illustrate the range of expected flood flows in Myall Lakes and the River. Unfortunately there was little hydrological and water level data for the catchment, Lake and River available at the time, so the model could not be fully calibrated.

Peak lake heights were derived by running the model for a number of predetermined hydrological conditions and applying them for various durations.

A sensitivity analysis was also performed with the model. This involved changing various factors within the model such as rainfall intensities, losses, storage functions, initial levels in the Myall Lakes, Manning's "n" values and the lake outflow rating. The report found that flowrates and lake levels were maximised with higher rainfall intensities (3.6 mm/hr to 4 mm/hr), a reduced Manning's "n" on the overbanks (0.1 to 0.06) and a lake outflow rating raised by 25%.

The study used the HEC-2 backwater analysis program to compute water levels in the Myall River. Long-section profiles for the river showing water levels for low, mean and high tides and under a surge situation were plotted. The plot states (Figure 7, 1980), "these profiles are based on steady-state analyses at each tide and hence only represent real water levels upstream from about cross section 10 where the profiles nearly coincide". A peak surge level at Paddy Marrs Bar of 2 m AHD was used for the surge situation based on estimates supplied by the Coastal Branch of PWD. The derivation of the peak surge level was probably based on mean sea level including storm surge plus some allowance for wind and wave set-up.

The report recognised that its major shortcoming was the non-modelling of the tidal cycle in the lower river up to 10 km from the river mouth. Downstream of this point flood levels gradually change from river to ocean conditions however there was no information available at the time to determine accurate levels. The report does note however that the difference between the 100 Year ARI flood and a high tide at Tea Gardens is less than 100 mm although the actual levels were not given.

The 1980 PWD flood study also reported an indicative estimate of the PMF outflow from the Myall Lakes of around 1,000 m^3/s (ie. 3.46 times the 100 yr ARI peak outflow from the Myall Lakes).

Public Works Department, NSW, Manly Hydraulics Laboratory (1993a), Lower Myall River Compilation of Data, Report MHL622.

The report is a summary of existing data, both published and unpublished, on estuarine processes in the Lower Myall River. The report notes that most of the information is more than 10 to 15 years old, however little work of specific relevance has been collected since. Physical characteristics of the river are outlined including information on climate, ecology, geology, geomorphology, sediments and shoaling. Previous investigations into flooding, hydraulic conditions, hydrographic changes, numerical modelling, sediment transport and water quality are also presented.

Section 7 of the report deals with flooding. It mentions that historical records of flood levels in the Myall Lake System and the Lower Myall River are very limited, with most data only available from local observations. These data do not provide precise accounts of the events and given levels are difficult to relate to any specific datum. A brief description of the 1980 PWD flood study is also included.

Section 10 of the report provides an overview of model investigations into the lower Myall River. Of particular interest is a one dimensional numerical estuarine model set up by PWD in 1980. The report provides a reasonably detailed description of the model and provides results and discussion of the effects of flooding, tidal action and shoaling on sediment transport and water levels.

Willing & Partners (1995) "Hawks Nest North Local Environment Study, Flood Impact Assessment", prepared for ERM Mitchell McCotter, September, 27 pp.

Willing and Partners were commissioned to review the 100 Year ARI flood behaviour and the impact of floodplain filling for the Lower Myall River as part of a Local Environmental Study. The area of land under consideration is north of the existing Hawks Nest township at Port Stephens, between the coast and the Myall River.

A review of available data was undertaken including an overview of three reports by NSW Public Works. These reports provided much of the initial input for the hydraulic model, such as tailwater levels in Port Stephens and peak flow rates for the Myall River. Cross-section data was obtained from PWD hydrosurveys and 1:4000 orthophotomaps.

EXTRAN-XP was used for hydraulic modelling of the Lower Myall. Peak flows derived in the 1980 PWD flood study and tailwater levels discussed in the 1993 Port Stephens Flood Study were used as input to the model. A sensitivity analysis was performed by varying these tailwater and flow conditions. This provided upper and lower bounds for flood levels at the site under a range of scenarios.

Final adopted flood levels ranged from 2.01 m at Hawks Nest Bridge to 2.25 m at the northern end of the study area. This was based on a conservative tailwater level of 1.89 m and a peak flow of 341 m^3/s.

A line of ecological significance identified at the site by ERM Mitchell McCotter was set as the maximum westward limit of filling into the floodplain. The effect of filling was modelled by narrowing the appropriate cross-sections. The resulting levels showed little or no change from existing conditions.

NSW Public Works, Manly Hydraulics Laboratory (1993b), Port Stephens Flood Study Stage 1, Analysis and Review of Existing Information, Report MHL623, Great Lakes Council and Port Stephens Council.

The Port Stephens Flood Study represents the first stage of the management process identified under the State Government's Flood Policy. It was prepared for Port Stephens Council and Great Lakes Council to provide a preliminary assessment of flood behaviour under present day conditions. The report provides a description of the catchment, an overview of data available and an analysis of past studies. It also examines the joint probability of freshwater floods and peak ocean water levels and gives a discussion of previous study findings and preliminary design flood levels.

NSW Public Works, Manly Hydraulics Laboratory (1993b), Port Stephens Flood Study Stage 2, Design Water level and Wave Climate, Report MHL759, prepared for Great Lakes Council and Port Stephens Council.

This part of the study considered the tide behaviour, ocean storm conditions, catchment rainfall-runoff and local wind setup to estimate design water levels around the foreshore of Port Stephens and Tilligerry Creek. In addition, the local wind wave climate and the ocean wave climate (i.e. wave height and wave period) were estimated at selected locations around the Port Stephens foreshore.

Water level, tidal, rainfall, wind and wave data in the NSW coastal regions has in the past been collected and collated by the Department of Public Works and Services (DPWS). This data collection program then became the responsibility of the former Department of Land and Water Conservation (DLWC). This report refers to data collected in the past by DPWS and current data collection stations as being operated by the former DLWC.

The water levels for Port Stephens vary around the foreshore of Port Stephens and in Tilligerry Creek depending on the combination of flood conditions. bathymetry, wind direction and the impact of rainfall-runoff. As a result of potential development pressure, 42 locations were selected around the foreshore of Port Stephens (in consultation with Great Lakes and Port Stephens Councils) for flood assessment (refer **Figure 1**). Results were estimated at these 42 sites plus locations in Tilligerry Creek.

There was insufficient data available to decide which combination of rainfall, tides wind and ocean conditions would result in the worst flooding. Sensitivity analysis was carried out using the numerical models to check the results by assuming a particular combination of ocean level, wind, rainfall-runoff and wave climate. The sensitivity study identified the following important points that contribute to flooding in Port Stephens:

- elevated ocean levels control the water levels in Port Stephens;
- wind setup on top of Port Stephens water level has a significant impact on the final water level which can vary by as much as 0.3 m depending on the direction of the wind;
- the combination of rainfall-runoff and Port Stephens water levels controls flood levels in Tilligerry Creek;
- the occurrence of wind waves and ocean waves in Port Stephens has the potential to significantly impact on inundation levels around the foreshore;
- the analysis showed that water levels in Port Stephens could vary by as much as 0.3 m and the levels in Tilligerry Creek by as much as 0.1 m depending on the combination of factors selected.

Webb, McKeown & Associates (2002) "Port Stephens Foreshore (Floodplain) Management Study, Final report, prepared for Port Stephens and Great Lakes Councils, April.

Elevated water levels occur in Port Stephens mainly as a result of:

- ocean influences -tides and storm surges,
- wind and wave activity within the estuary,
- rainfall from the local catchment (this factor provides the least influence on levels).

This study was initiated by Port Stephens and Great Lakes Councils to help manage the flood problem. The primary objectives of the Study were to define the nature and extent of the hazard; to identify, assess and optimise measures aimed at reducing the impact of flooding on both existing and future development; and to make allowance for flood compatible future development.

The study builds on the Port Stephens Flood Study (Stages 1 to 3) which defines design flood levels for the foreshore area.

Cardno Willing (2008) "Riverside at Tea Gardens, Practical Consideration of Climate Change", prepared for Crighton Properties, May.

Riverside at Tea Gardens is subject to flooding from both the Myall River and from runoff from the local catchment. Sensitivity assessments of climate change were undertaken for the scenarios given in the 2007 DECC Guideline titled "Practical Consideration of Climate Change". These scenarios include +0.18m, +0.55 m and +0.91 rises in sea level as well as 10%, 20% and 30% increase in rainfall intensities.

It was concluded from the results of the sensitivity runs for the Myall River that:

- The current adopted 100 yr ARI level of 2.1 m AHD could accommodate up to a 30% increase in rainfall under conditions where there is no increase in sea level;
- The increase in 100 yr ARI levels in the Myall River in the vicinity of Riverside due to increases in rainfall reduce as the sea level rise increases ie. a 30% increase in rainfall increases 100 yr ARI levels in the Myall River by
  - 0.06 m to 0.07 m under a sea level rise of 0.18 m
  - 0.04 m to 0.06 m under a sea level rise of 0.55 m
  - 0.03 m to 0.04 m under a sea level rise of 0.91 m
- Under the +0.18 m sea level rise scenario the freeboard in Council's adopted minimum Flood Planning Level of 2.6 m AHD is around 0.43 to 0.25 m depending on the adopted increase in rainfall intensity
- Under the +0.55 m sea level rise scenario the freeboard in Council's adopted minimum Flood Planning Level of 2.6 m AHD is only around 0.02 to 0.07 m depending on the adopted increase in rainfall intensity
- Under the +0.91 m sea level rise scenario Council's Flood Planning Level of 2.6 m AHD is exceeded by 0.26 m to 0.3 m depending on the adopted increase in rainfall intensity

- It is noted that the Riverside proposal has an additional freeboard of 0.3 m over and above Council's adopted minimum floor level of 2.6 m AHD in areas subject to inundation from the Myall River to avoid over floor flooding in a 100 yr ARI event under all climate change scenarios.

It was concluded from the river flooding inundation plots that:

- River flooding under either a low or a medium climate change scenario would not inundate any unimproved lots;
- River flooding under a high climate change scenario would partially inundate around 180-220 unimproved lots (but not over floors) to a maximum depth of 0.3 m;
- Under a low climate change scenario there would be minimal inundation of planned roads;
- Under a medium climate change scenario there would be inundation of a number of planned roads by up to 0.5 m (which would be Low Hazard due to the expected very low velocity of the fringes of the river flooding through the development);
- Under a high climate change scenario there would be increased inundation of a number of planned roads by up to 0.8 m (which would be still Low Hazard due to the expected very low velocity of flow on the fringes of the river flooding through the development) but would comply with the requirements for safe wading.

It was concluded from the results of the sensitivity runs for the local catchment that:

- In areas where the estimated 100 yr ARI flood level is greater than 2.1 m AHD the 1.5 hour storm burst gives higher local 100 yr ARI flood levels than the 9 hour storm burst
- The East Branch and North Branch Flood Planning Levels are controlled by the Myall River under a +0.18 m or greater sea level rise;
- The Flood Planning Levels adjacent to the West Branch are controlled progressively by the Myall River as the sea level rise increases;
- The Flood Planning Levels adjacent to the lower reaches of the East West Branch are controlled progressively by the Myall River as the sea level rise increases;
- The greatest increase in the 100 yr ARI flood level in the East West Branch in the reach unaffected by sea level rise is 0.28 m;

It is noted that the Riverside proposal has an additional freeboard of 0.3 m for mimimum floor levels over and above Council's adopted minimum floor level of 2.6 m AHD in areas subject to inundation from the Myall River to avoid over floor flooding in a 100 yr ARI event under all climate change scenarios. The adoption of a minimum floor level of 2.9 m AHD for all homes in Riverside will provide all homes in the development with a far greater level of protection against climate change than a large number of existing properties in Tea Gardens.

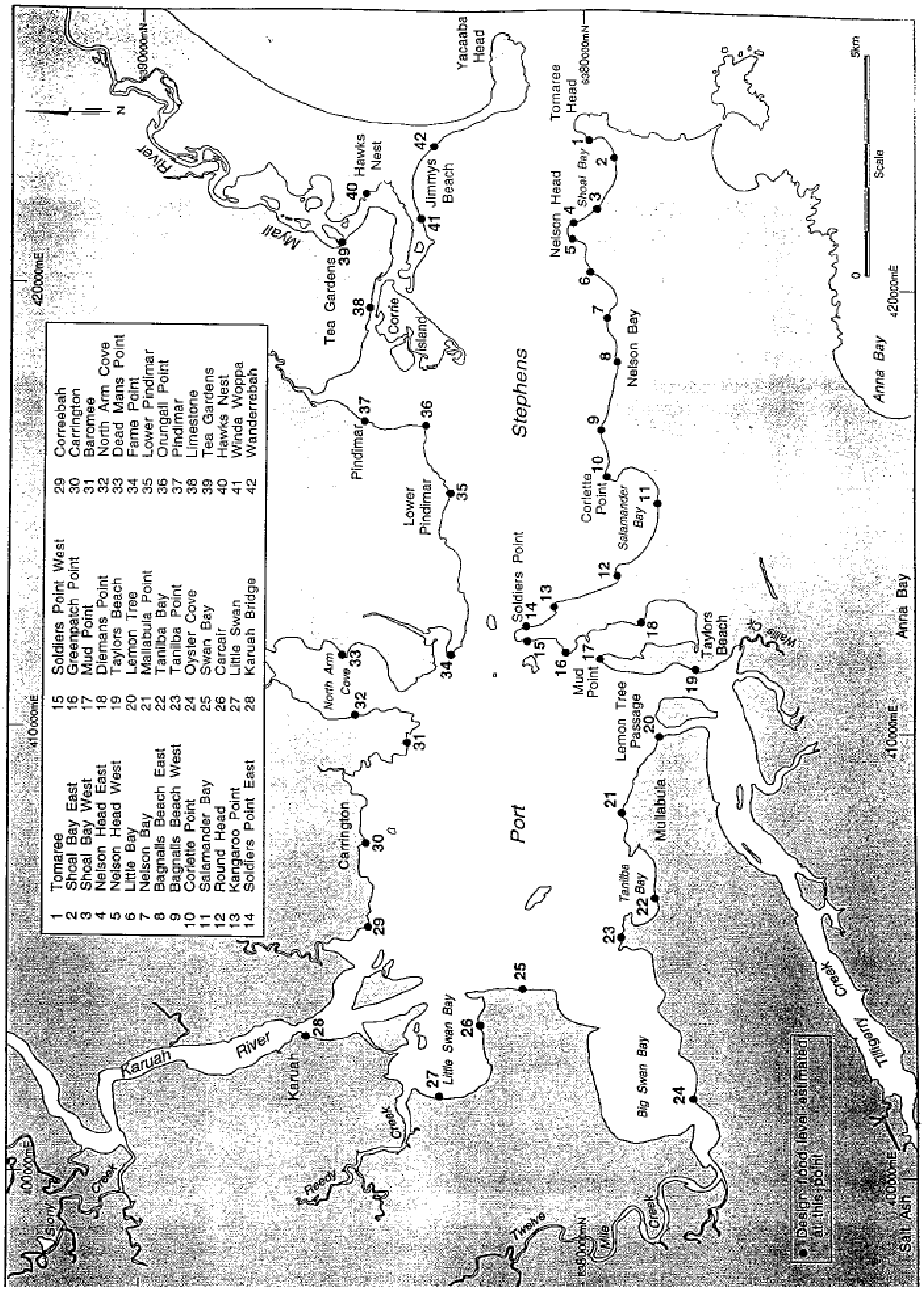

Figure 1 Location of Estimated Design water levels (after MHL, 1996)

3. ASSESSMENT APPROACH

Riverside at Tea Gardens is subject to flooding from both the Myall River and from runoff from the local catchment.

3.1 Myall River Flooding

The approach to assess the PMF levels in the Myall River was as follows:

- Adopt of modified version of the 1995 **xpswmm** model of the Myall River that was amended by Cardno Willing, 2008 by:
  - Updating the levels of Kingfisher Avenue in the vicinity of the site based on supplied survey spot levels (Cross Section CS3A);
  - Adding a new cross section was added to the model that was in part based on representative ground levels through the centre of the site immediately downstream of Kingfisher Avenue (New Cross Section CS3B);
  - Add a further cross section to the model to represent the Myall River and overbank levels downstream of the site (new Cross Section CS3C);
- Run the modified model and estimate:
  - Indicative PMF levels for Riverside with a 100 yr ARI downstream boundary level and an Extreme downstream boundary level without any allowance for climate change.

3.2 Local Flood Levels

The 100 yr ARI flood level in areas of Riverside where the land is higher than 2.1 m AHD is controlled by runoff from the local catchment. Assessments of local flooding and drainage have been previously undertaken and are described in the 2007 Riverside at Tea Gardens Integrated Water Management Report and the 2008 report titled Riverside at Tea Gardens, Practical Consideration of Climate Change.

Estimates of runoff from the Riverside at Tea Gardens catchment during design storms were obtained using the **xprafts** rainfall/runoff model.

Estimates of flood levels in the Riverside at Tea Gardens site were obtained using the **xpswmm** model.

The approach to assess climate change scenarios on PMF flood levels in the Riverside site was as follows:

- Estimate the 15 minute, 30 minute, 1hour, 1.5 hour, 2 hour, 3 hour, and 6 hour PMP rainfall intensities using Bulletin 53 released by the Bureau of Meteorology;
- Run the existing **xprafts** model for the 15 minute, 30 minute, 1hour, 1.5 hour, 2 hour, 3 hour, and 6 hour PMP rainfall intensities;
- Import the PMF hydrographs and run the existing **xpswmm** model for the following increases in the 15 minute, 30 minute, 1hour, 1.5 hour, 2 hour, 3 hour, and 6 hour PMP storms;

- It was assumed that the existing/extended lake will be swamped by the Myall River flooding during a PMF event. The assumed downstream flood level was equal to the 100 yr ARI flood level of 2.1 m AHD.

4. MYALL RIVER FLOODING

4.1 Hydraulic Model

The 1995 hydraulic model was initially based on the 1980 Flood Study hydraulic model. This was modified to include branches and the flow paths which short circuit meanders in the river. Levels were taken from the 1:4000 orthophotomaps and the 1978 hydrosurvey.

In many cases the cross section locations from the 1980 PWD flood study were chosen again, although the levels were altered. Most of the original cross sections were considered representative of the reach on which they were located. Where they were not considered representative extra cross sections were provided so that the entire Lower Myall River was satisfactorily defined. Looped flow was also introduced to more accurately define flow paths and flood levels in cases where overbank flow was possible (usually flow diverted from the main channel) or where there were large obstructions (such as islands) in the main channel.

- Adopt of modified version of the 1995 **xpswmm** model of the Myall River that was amended by Cardno Willing, 2008c by:
  - Updating the levels of Kingfisher Avenue in the vicinity of the site based on supplied survey spot levels (Cross Section CS3A);
  - Adding a new cross section was added to the model that was in part based on representative ground levels through the centre of the site immediately downstream of Kingfisher Avenue (New Cross Section CS3B);
  - Add a further cross section to the model to represent the Myall River and overbank levels downstream of the site (new Cross Section CS3C);

The amended model layout in **Figure 3**.

A schematic representation of the model as overlaid on the 1:25000 topographical map of the area is given in **Figure 4**. This shows the approximate location of the nodes and cross sections.

4.2 Peak Flow

The 1980 PWD flood study reported an indicative estimate of the PMF outflow from the Myall Lakes of around 1,000 m^3/s (ie. 3.46 times the 100 yr ARI peak outflow from the Myall Lakes).

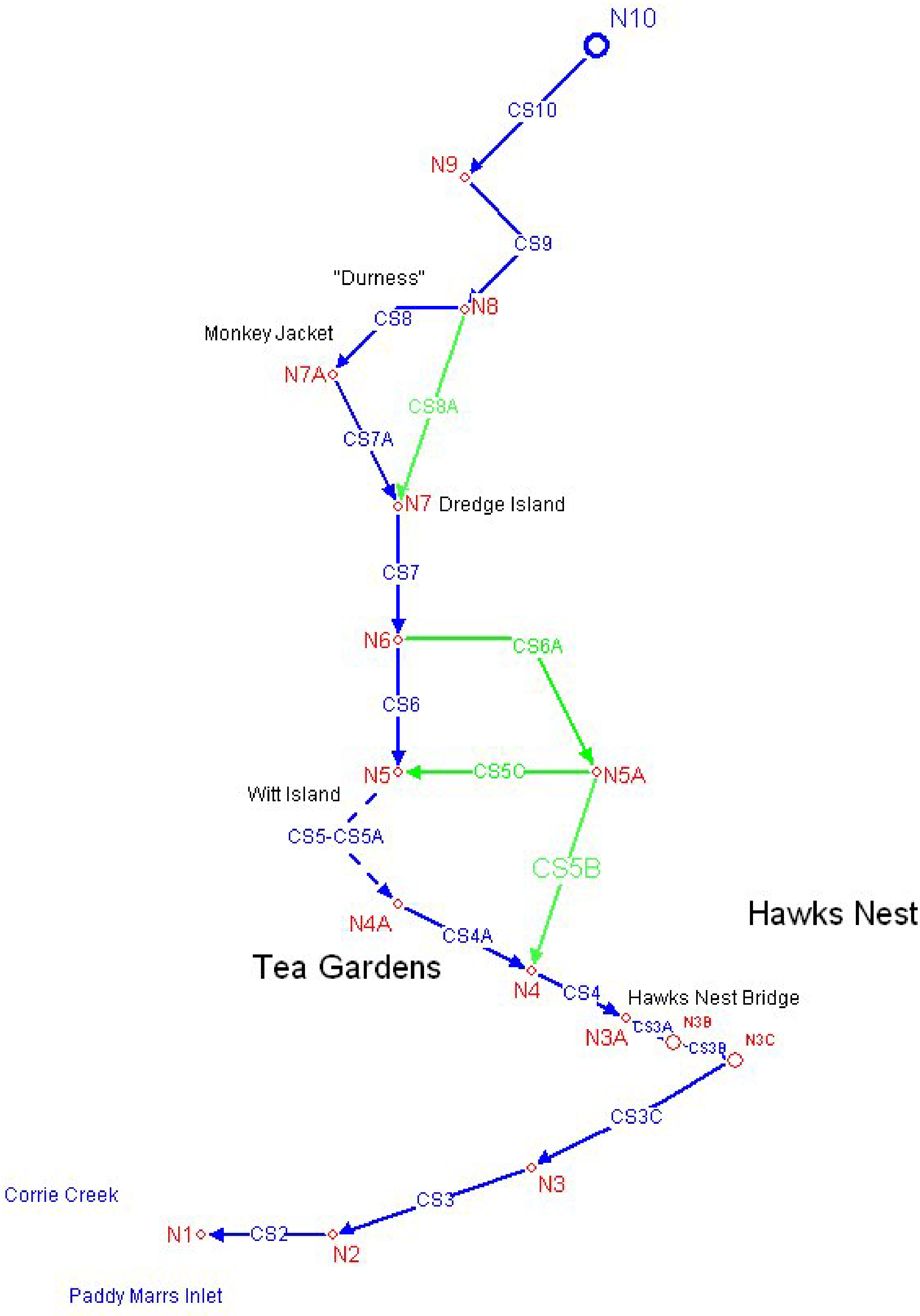

Figure 2 Amended xpswmm Model Layout for Lower Myall River (after Cardno Willing, 2008c)

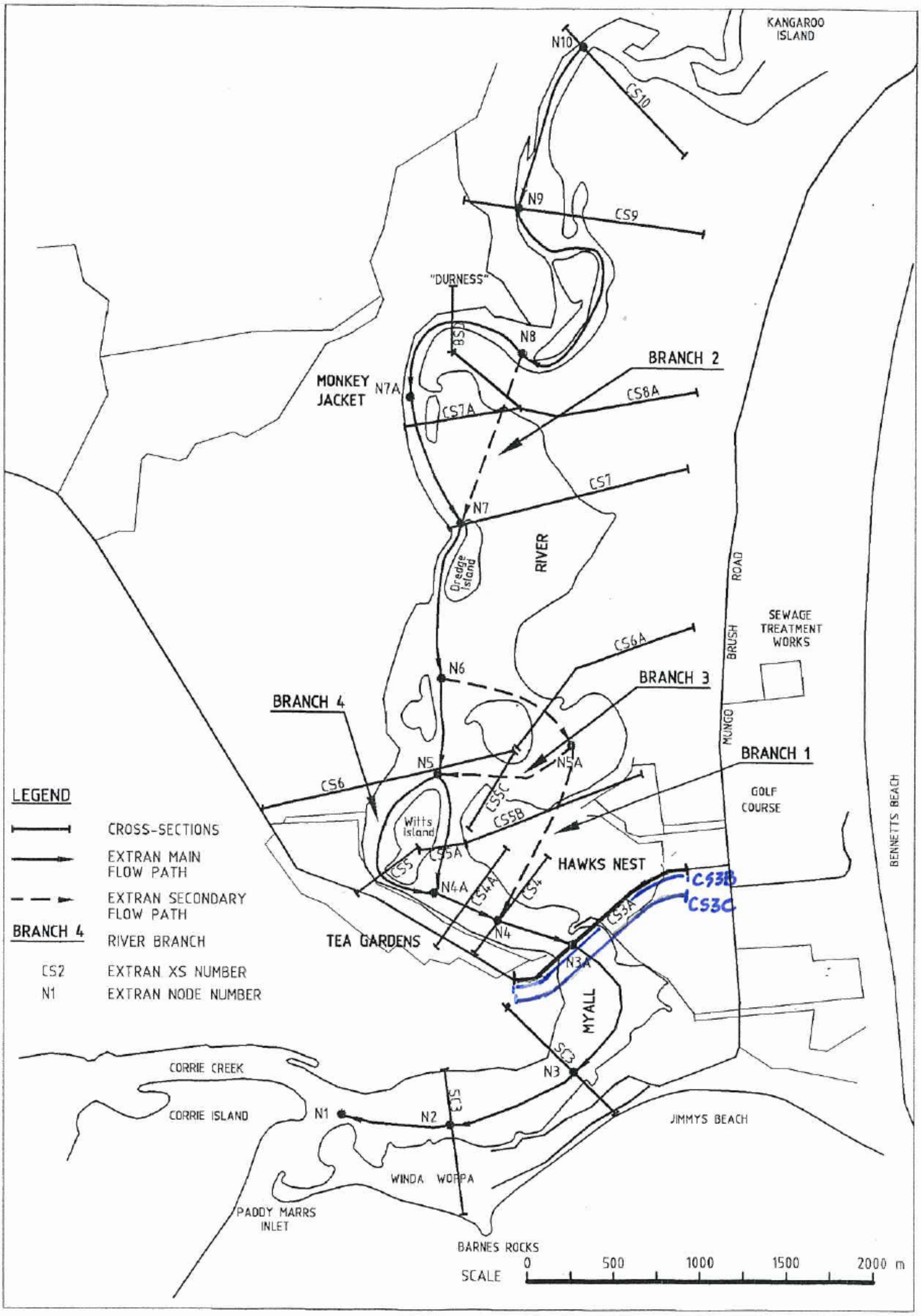

Figure 3 Amended Schematic xpswmm Model Layout (after Cardno Willing, 2008c)

4.3 Downstream Boundary Condition

For the purpose of the 1995 study, the tailwater level was determined in the lower reaches of the river somewhere between Tea Gardens and Corrie Island. The river ends at Corrie Island where it bifurcates into Corrie Creek and Paddy Marrs Inlet. This is a relatively sheltered location. Hydrosurvey information is available and it is the location of the last cross section in the 1980 PWD hydraulic model. On this basis the tailwater was positioned at Node 1 on the **xpswmm** layout (refer **Figure 3**).

Based on the approach adopted in the 1995 study and reported in Cardno Willing, 2008a the downstream 100 yr ARI boundary level of 1.89 m AHD was adopted.

The 2002 Port Stephen Foreshore (Floodplain) Management Study (Webb, McKeown & Associates, 2002) reported an Extreme Stillwater level of 2.0 m AHD (refer Table 2, page 7 of the report).

4.4 Results

The hydraulic model was run for two scenarios and estimated the following PMF levels on the site (refer **Table 1**):

Table 1
Estimated Peak Flood Levels (m AHD) at Riverside

Event	Description	Estimated Flood Level (m AHD)
PMF	The PMF level under existing conditions with a 100 yr ARI downstream boundary level in the lower reach of the Myall River of RL 1.89 m.	2.82 – 2.89 m
PMF	The PMF level under existing conditions with an extreme downstream boundary level in the lower reach of the Myall River of RL 2.0 m	2.86 – 2.93 m

5. LOCAL FLOODING AND DRAINAGE

5.1 Hydraulic Model

The hydraulic model used for the assessments of local flooding and drainage is described in the 2008 Riverside at Tea Gardens Integrated Water Management Report (see **Figure 4**).

5.2 Inflow Hydrographs

The 15 minute, 30 minute, 1hour, 1.5 hour, 2 hour, 3 hour, and 6 hour PMP rainfall intensities were estimated using Bulletin 53 released by the Bureau of Meteorology. These rainfall intensities were input into the existing **xprafts** model that was then run to estimate 15 minute, 30 minute, 1hour, 1.5 hour, 2 hour, 3 hour, and 6 hour PMP hydrographs.

5.3 Downstream Boundary Condition

It was assumed that the existing/extended lake will be swamped by the Myall River flooding during a PMF event. The assumed downstream flood level was equal to the 100 yr ARI flood level of 2.1 m AHD.

5.4 Results

The 100 yr ARI flood levels and PMF levels within the drainage corridors are summarised in **Table 4**.

The PMF levels within the drainage corridors under the 30 minute and 1 hour PMP storms are presented in **Figures 5** and **6**.

It should be noted that the PMF levels are based on floodwaters confined to the drainage corridors and as such these are conservative estimates. During a PMF event local runoff would spill from the drainage corridors into the residential areas which would result in lower PMF levels than summarised in **Table 2.**

It was noted that in almost all locations the 1 hour PMP storm gave the highest flood level except for the upper reach of the West Branch where the 30 minute PMP storm gave the highest estimated flood levels.

In most locations it was estimated that the PMF level is between 0.9 m to 1.45 m higher than the local 100 yr ARI level.

Table 2 Estimated 100 yr ARI and PMF Peak Flood Levels

Node	1% 1.5hr	1% 9hr	PMF 15min	PMF 30min	PMF 1hr		PMF - 1% AEP
	(mAHD)	(mAHD)	(mAHD)	(mAHD)	(mAHD)		(cm)
West Branch							
WB1	2.93	2.81	4.02	4.11	4.02		118
WB2	2.75	2.56	4.00	4.09	3.99		133
N69	2.16	1.97	3.51	3.62	3.55		146
WB3	2.16	1.97	3.51	3.62	3.55		146
WB4	2.16	1.97	3.51	3.62	3.55		146
N70	1.77	1.85	3.08	3.24	3.20		139
WB5	1.77	1.85	3.09	3.24	3.21		139
WB6	1.77	1.85	3.08	3.24	3.20		139
N71	1.68	1.78	2.80	2.96	2.97		119
WB7	1.68	1.78	2.80	2.96	2.97		119
WB8	1.61	1.67	2.47	2.61	2.68		101
East Branch							
EB1	2.58	2.50	2.82	2.77	2.79		23
EB2	1.74	1.71	2.51	2.60	2.66		92
N68	1.74	1.71	2.51	2.60	2.66		92
EB3	1.56	1.60	2.52	2.60	2.66		106
EB4	1.50	1.60	2.39	2.55	2.64		104
EB5	1.48	1.60	2.39	2.55	2.64		104
EB6	1.48	1.59	2.39	2.55	2.64		105
EB7_1	1.48	1.59	2.39	2.54	2.63		104
EB7_2	1.48	1.59	2.39	2.54	2.63		104
N73	1.48	1.59	2.39	2.54	2.63		104
North Branch							
NB1	2.19	2.14	3.08	3.20	3.21		103
NB2	1.98	1.90	3.07	3.19	3.21		124
NB3	1.97	1.87	3.07	3.19	3.21		125
NB4	1.68	1.78	2.80	2.96	2.97		119
NB5	1.68	1.78	2.80	2.96	2.97		119
NB6	1.68	1.78	2.80	2.96	2.97		119
East-West Branch							
EW1	8.69	8.61	9.09	9.21	9.23		54
EW1_1	4.71	4.63	5.14	5.29	5.40		69
EW2	3.85	3.84	4.51	4.88	5.14		129
EW3	3.79	3.79	4.49	4.84	5.09		130
EW4	2.93	2.93	3.50	3.79	3.99		106
EW5	2.81	2.81	3.42	3.67	3.84		103
EW6	2.48	2.48	2.83	3.10	3.29		81
N43	2.16	2.08	2.31	2.50	2.68		52
EW7	1.97	1.98	2.31	2.51	2.68		70
EW8	1.87	1.87	2.11	2.14	2.18		31
Lakes							
LakeA	1.61	1.67	2.47	2.61	2.68		101
LakeB	1.48	1.59	2.39	2.54	2.62		103
LakeC	1.46	1.56	2.31	2.40	2.44		88
Salt_Ext	0.91	1.09	2.41	2.54	2.60		151
ExtLake	0.89	1.03	2.10	2.10	2.10		107

Figure 4 Model Layout

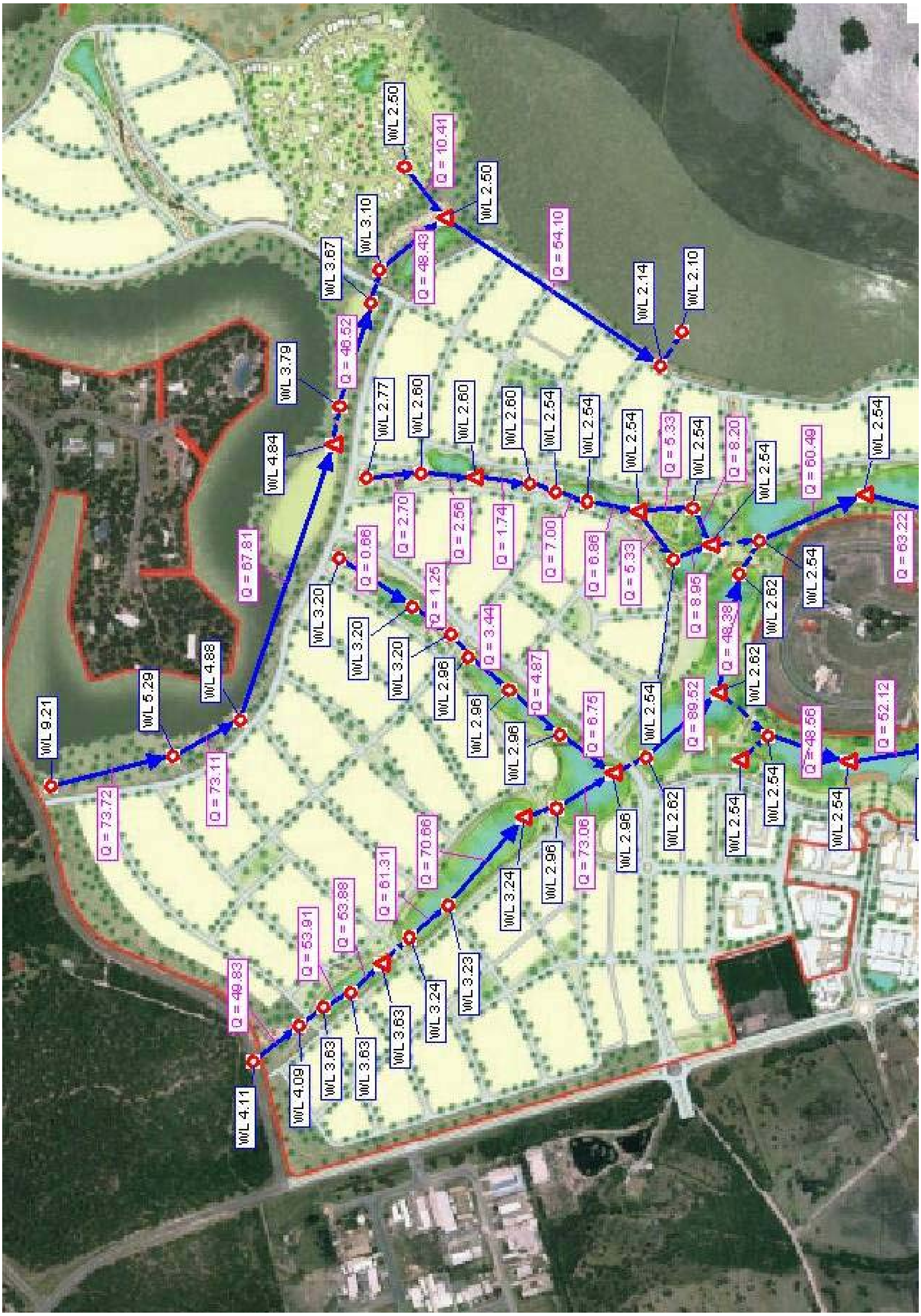

Figure 5 PMF Levels under a 30 Minute PMP Storm

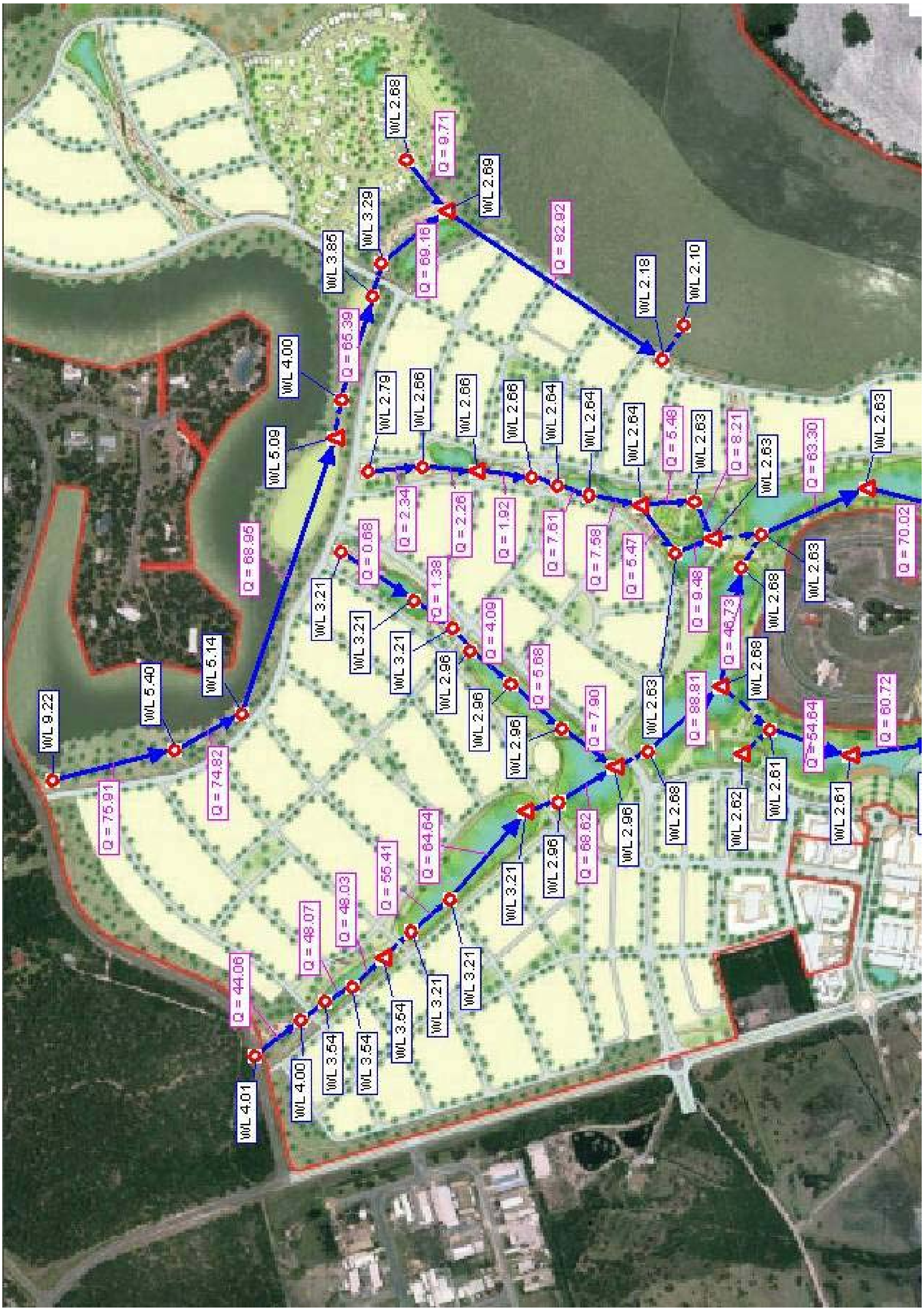

Figure 6 PMF Levels under a 1 Hour PMP Storm

6. REFERENCES

Cardno Willing (2008a) “Riverside at Tea Gardens, Practical Consideration of Climate Change”, prepared for Crighton Properties, May.

Cardno Willing (2008b) “Riverside at Tea Gardens, Integrated Water Management”, prepared for Crighton Properties, August.

Cardno Willing (2008c) “Assessment of Flooding, Pt Lot 1 DP546852, Hawks Nest”, prepared for Northwest Residential Pty Ltd, July.

Department of Environment and Climate Change (2007) “Practical Consideration of Climate Change, Floodplain Risk Management Guidelines, Version No. 1,14 pp.

Department of Public Works, NSW (1980) “Lower Myall River Flood Analysis, 32 pp.

NSW Public Works, Manly Hydraulics Laboratory (1993b), Port Stephens Flood Study Stage 1, Analysis and Review of Existing Information, Report MHL623, Great Lakes Council and Port Stephens Council.

NSW Public Works, Manly Hydraulics Laboratory (1993b), Port Stephens Flood Study Stage 2, Design Water level and Wave Climate, Report MHL759, prepared for Great Lakes Council and Port Stephens Council.

Public Works Department, NSW, Manly Hydraulics Laboratory (1993a), Lower Myall River Compilation of Data, Report MHL622.

Webb, McKeown & Associates (2002) “Port Stephens Foreshore (Floodplain) Management Study, Final report, prepared for Port Stephens and Great Lakes Councils, April.

Willing & Partners (1995) “Hawks Nest North Local Environment Study, Flood Impact Assessment”, prepared for ERM Mitchell McCotter, September, 27 pp.