APPENDIX I

PRACTICAL CONSIDERATION OF CLIMATE CHANGE
MAY 2008

Riverside at Tea Gardens

Practical Consideration of Climate Change

CRIGHTON PROPERTIES

MAY 2008

JOB NO. W4332-7

C R I G H T O N P R O P E R T I E S

Riverside at Tea Gardens
Practical Consideration of Climate Change

Final Report

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Client	Crighton Properties			
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[1] McLuckie, D., Lord, D. and Gibbs, J. (2006) "Climate Change – The Future is Uncertain, Practical Consideration of Climate Change in Flood Risk Management in NSW", proceedings, 46th NSW FMA Conference, Lismore, March.

SUMMARY

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.

Elsewhere in the development consideration a minimum floor level of 0.5 m above the local 100 yr ARI flood level (under no climate change) would provide a minimum 0.22 m freeboard above the local 100 yr ARI flood level under a high climate change scenario.

While 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. Even under a high climate change scenario, planned roads would provide flood free egress via a number of roads for residents evacuating from threatened properties to higher ground on the northern and north western boundaries of the development.

It was also noted from the 1980 flood study that the estimated 100 yr ARI outflow from the Myall Lakes peaked after 7 days. Consequently it is expected that the flood warning system in place to warn existing residents of Tea Gardens of major flooding in the Myall River would provide ample warning time for residents of properties that would be threatened under a high climate change scenario to safely evacuate their properties well before the Myall River would reach its peak.

1. BACKGROUND

In October 2007 the NSW Department of Environment and Climate Change (DECC) released a guideline titled "Practical Consideration of Climate Change".

As discussed in the guideline, climate change is expected to have adverse impacts upon sea levels and rainfall intensities, both of which may have significant influence on flood behaviour at specific locations.

Combining the relevant global and local information indicates that sea level rise on the NSW coast is expected to be in the range of 0.18 m to 0.91 m by between 2090 and 2100.

In addition, climate change impacts on flood producing rainfall events show a trend for larger scale storms (rainfall totals for the 40 year average recurrence interval (ARI) 1 day storm events) tend to increase by 2030 and 2070. **Figure 1** shows the potential impacts of changes in current design ARIs due to increases in rainfall. CSIRO is currently undertaking further work in the area of shorter duration rainfall events which is expected to lead to further advice in this area in the future.

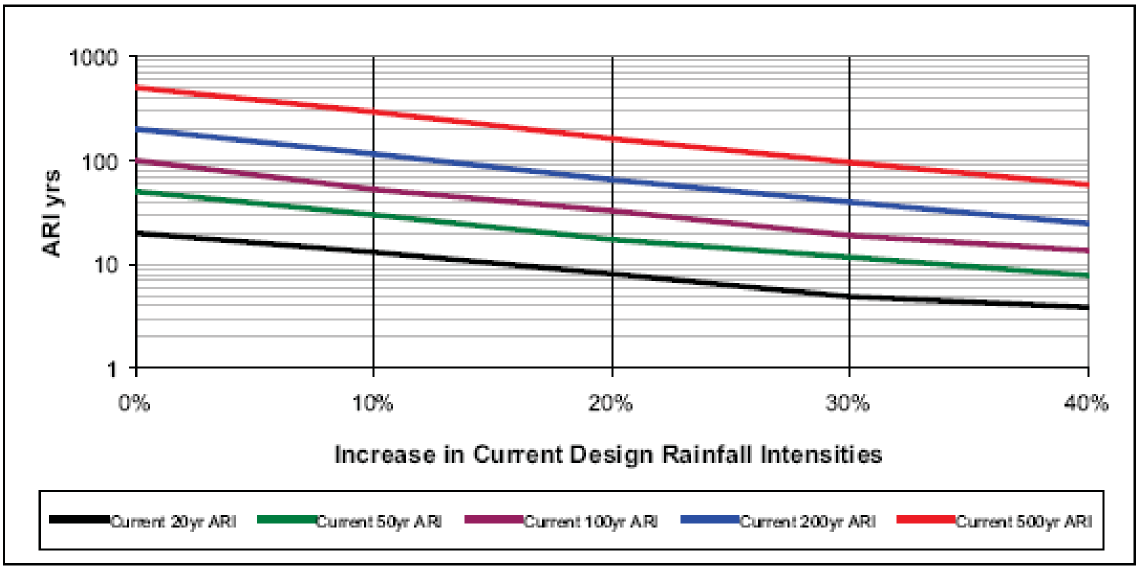

Figure 1
Indicative Change in Design ARI as Rainfall Intensities Increase
(after McLuckie et al, 2005)[2]

[2] McLuckie, D., Lord, D. and Gibbs, J. (2006) "Climate Change – The Future is Uncertain, Practical Consideration of Climate Change in Flood Risk Management in NSW", proceedings, 46th NSW FMA Conference, Lismore, March.

DECC, 2007 recommends that the following sensitivity analyses are undertaken:

- Sea level where relevant to a study area:
  - 0.18m (Low Level Ocean Impacts
  - 0.55m (Mid Range Ocean Impacts
  - 0.91m (High Level Ocean Impacts

- Rainfall intensities. Increases of:
  - 10% in peak rainfall and storm volume
  - 20% in peak rainfall and storm volume
  - 30% in peak rainfall and storm volume

  until more work is completed in relation to the climate change impacts on rainfall intensities

2. PREVIOUS STUDIES

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.

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 2**). 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.

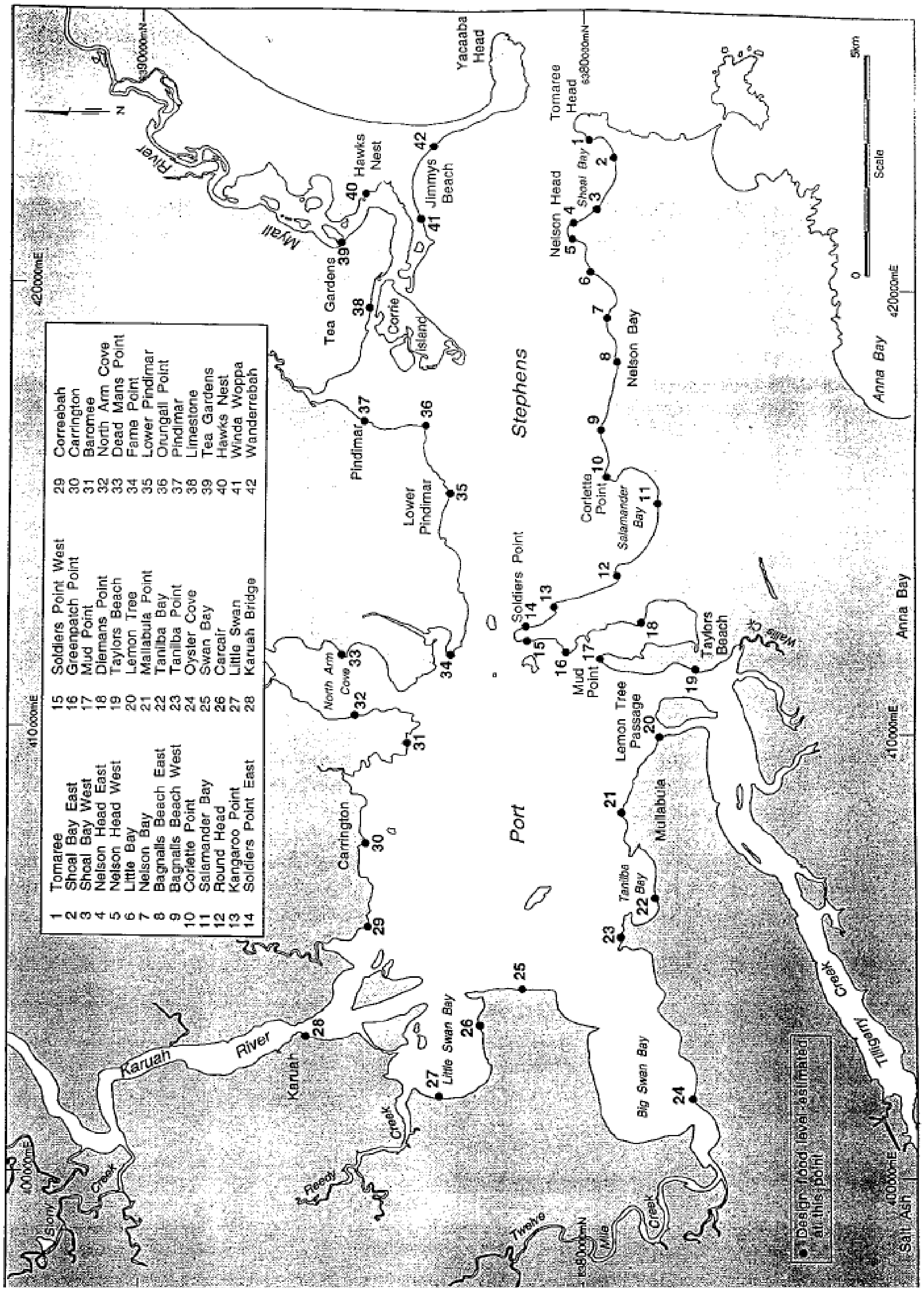

Figure 2 Location of Estimated Design water levels (after MHL, 1996)

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

Great Lakes first adopted a flood policy in December 1985 and adopted the 100 yr ARI event as the flood standard. A 100 yr ARI level of 2.1 m AHD for the foreshore area has been adopted for over 15 years. The exact source of the level is unknown (Webb, McKeown & Associates, 2002).

The foreshore area includes the Myall River. Consequently the 100 yr ARI level in the lower lying areas of the Riverside site is controlled by the 100 yr ARI level in the Myall River ie. 2.1 m AHD.

Prior to formulating an assessment approach the 1995 quasi-2D model of the lower Myall River was de-archived, uploaded into **xpswmm** and re-run to confirm it gives similar answer to the results reported in 1995.

The approach to assess climate change scenarios on 100 yr ARI flood levels in the Myall River was as follows:

- Adopt the 1995 **xpswmm** model of the Myall River for estimation of river flood levels;
- Calculate downstream boundary conditions that equate to sea level rises of: 0 m, 0.18 m, 0.55 m and 0.91 m
- Run the model for the following increases in the adopted peak outflow from the Myall Lakes: 0%, 10%, 20% and 30%
- Tabulate the estimated 100 yr ARI flood levels at two nodes that broadly correspond to the lower end and upper end of the Riverside site.

3.2 Local Flood Levels

The 100 yr ARI 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.

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 100 yr ARI flood levels in the Riverside site was as follows:

- Run the existing **xpswmm** model for the following increases in the 1.5 hr and 9 hr 100 yr ARI rainfall intensities: 0%, 10%, 20% and 30%
- It was assumed that the existing/extended lake will be swamped by the Myall River flooding so the 100 yr ARI flood levels within the drainage corridors are of primary interest
- Local runoff in combination with sea level rise in the Myall River was not modelled because the flood levels in the Myall River control in the lower lying areas of the site.

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. The final 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.

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.

4.2 Peak Flow

The 1980 PWD flood study undertook a sensitivity analysis. The results of this analysis for the 100 Year ARI event of seven days duration are given in **Table 1**.

Table 1 Results of 1980 Sensitivity Analysis

	Adopted	Maximum from Sensitivity Analysis
Peak Lake Level (m AHD)	3.00	3.22
Peak Lake Outflow (m^3/s)	289	341

Based on the adopted 100 yr ARI peak flow of 289 m^3/s (0% rainfall increase) it was assumed conservatively that increases in rainfall would equate to equal increases in the peak lake outflow. Consequently the adopted peak flows under climate change scenarios were 318 m^3/s (10% increase), 347 m^3/s (20% increase) and 376 m^3/s (30% increase).

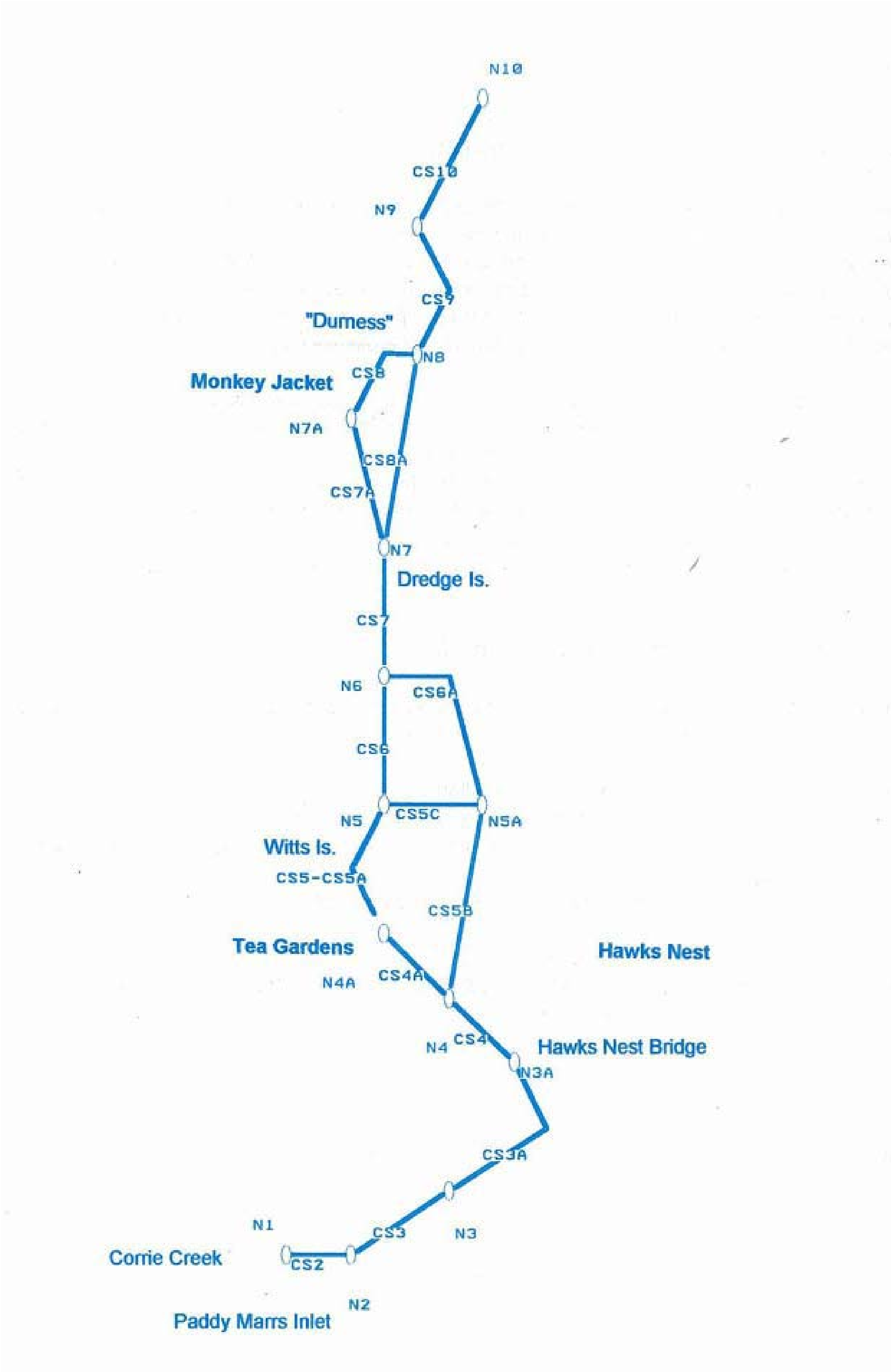

Figure 3 xpswmm Model Layout for Lower Myall River (after Willing & Partners, 1995)

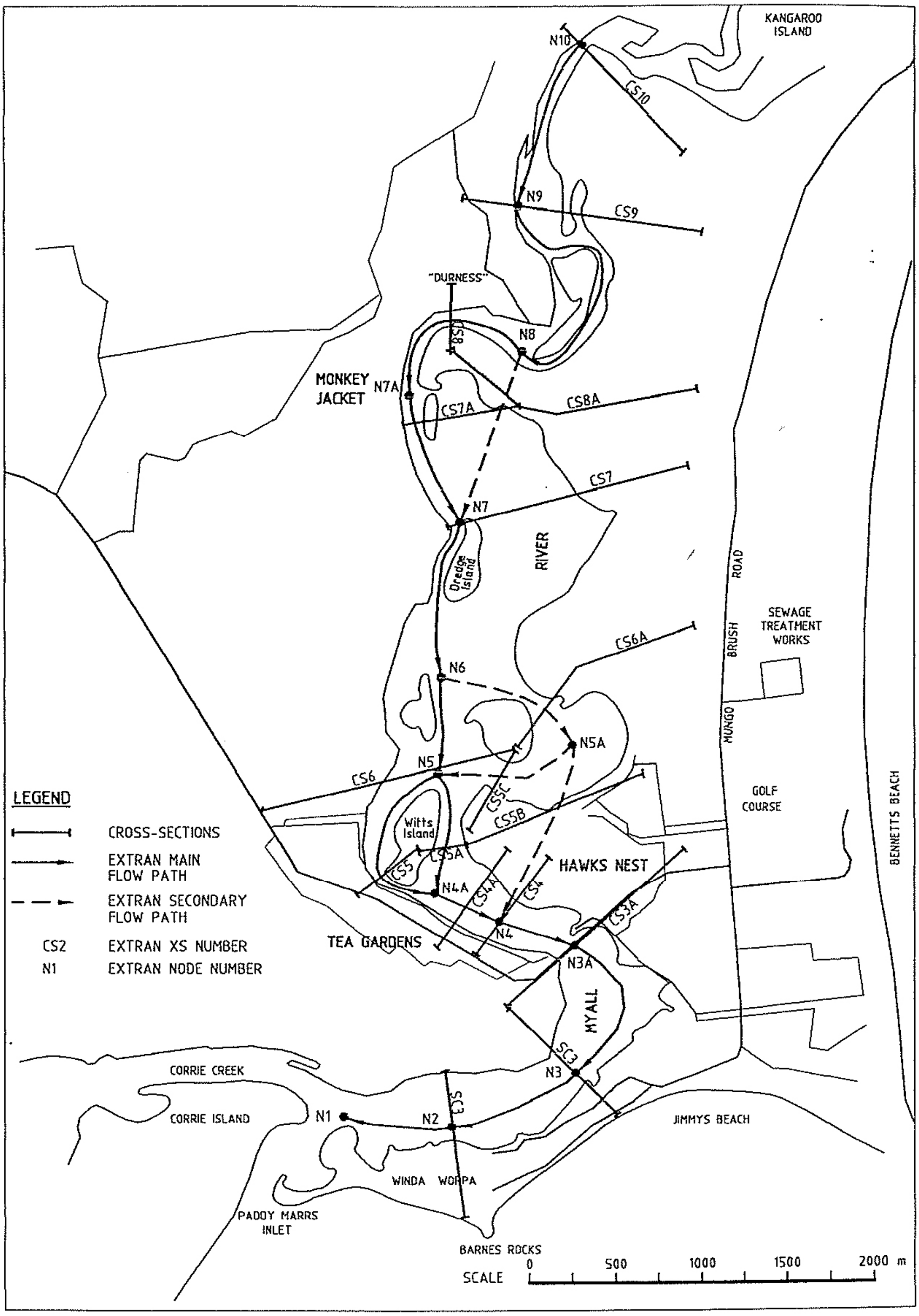

Figure 4 Schematic xpswmm Model Layout (after Willing & Partners, 1995)

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 4**).

Based on the approach adopted in the 1995 study the downstream boundary levels summarised in **Table 2** were adopted for the sensitivity testing under sea level rise scenarios.

Table 2 Adopted 100 yr ARI Downstream Boundary Levels with Sea Level Rise

Site Condition	Water Level Rise (m AHD)			
Mean Sea Level (MSL)	0	0	0	0
High Tide	1.0	1.0	1.0	1.0
Barometric Set-up	0.3	0.3	0.3	0.3
Wind Set-up	0.2	0.2	0.2	0.2
Local Wind & Wave Set-up	0.3	0.3	0.3	0.3
Flood Surcharge	0.2	0.2	0.2	0.2
Sea Level Rise	0	0.18	0.55	0.91
Tidal gradient	-0.11	-0.11	-0.11	-0.11
Total Level (m AHD)	1.89	2.07	2.44	2.80

4.4 Results

Sixteen sensitivity runs were undertaken.

The estimated 100 yr ARI flood levels at two nodes that broadly correspond to the lower end (Node N5) and upper end (Node N7)of the Riverside site are summarised in **Table 3**.

Table 3 Estimated 100 yr ARI Flood levels in the Myall River under Climate Change Scenarios

	Sea Level Rise (mAHD)							
Sea Level Rise	0 m		+ 0.18m		+ 0.55m		+ 0.91m	
100 yr ARI Boundary Level	1.89 mAHD		2.07 mAHD		2.44 mAHD		2.80 mAHD	
Node	**N5**	**N7**	**N5**	**N7**	**N5**	**N7**	**N5**	**N7**
Q_{peak} = 289 m^3/s	2.00	2.02	2.17	2.18	2.52	2.52	2.86	2.86
Q_{peak} = 318 m^3/s (+10%)	2.02	2.04	2.19	2.20	2.53	2.54	2.87	2.87
Q_{peak} = 347 m^3/s (+20%)	2.04	2.06	2.21	2.23	2.54	2.56	2.88	2.89
Q_{peak} = 376 m^3/s (+30%)	2.07	2.09	2.23	2.25	2.56	2.58	2.89	2.90

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.

The extent of incremental inundation of Riverside was also plotted for four cases as follows:

- No Climate Change Scenario (Existing Conditions) – 2.02 m AHD river flood level (see **Figure 5**);
- Low Climate Change Scenario – 2.2 m AHD river flood level which equates to a 0.18 m sea level rise + 10% increase in rainfall intensity (see **Figure 6**);
- Medium Climate Change Scenario – 2.55 m AHD river flood level which equates to a 0.55 m sea level rise + 20% increase in rainfall intensity (see **Figure 7**);
- High Climate Change Scenario – 2.90 m AHD river flood level which equates to a 0.91 m sea level rise + 30% increase in rainfall intensity (see **Figure 8**).

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.

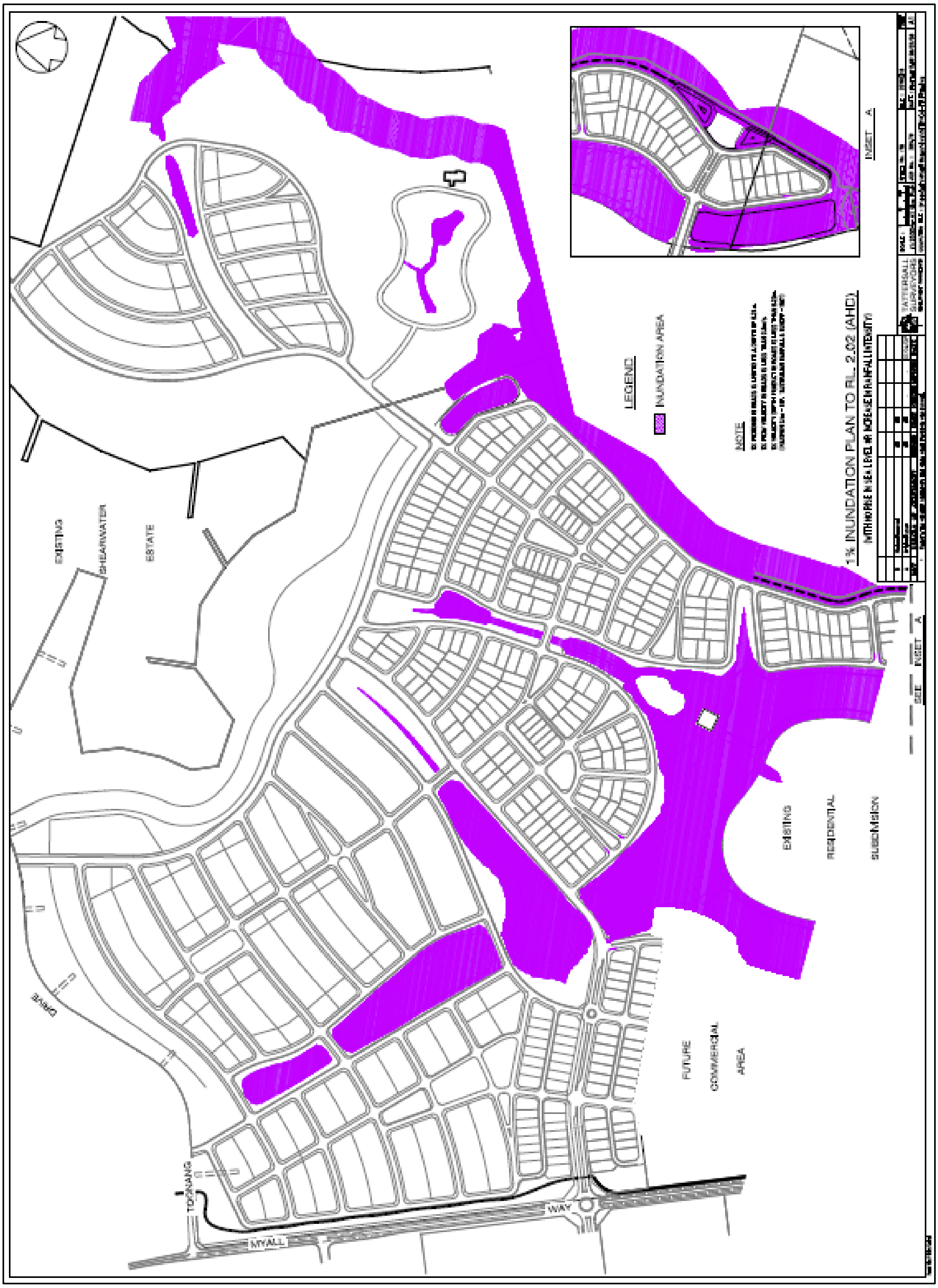

Figure 5 100 yr Inundation (0 m Sea Level Rise + 0% Rainfall Increase)

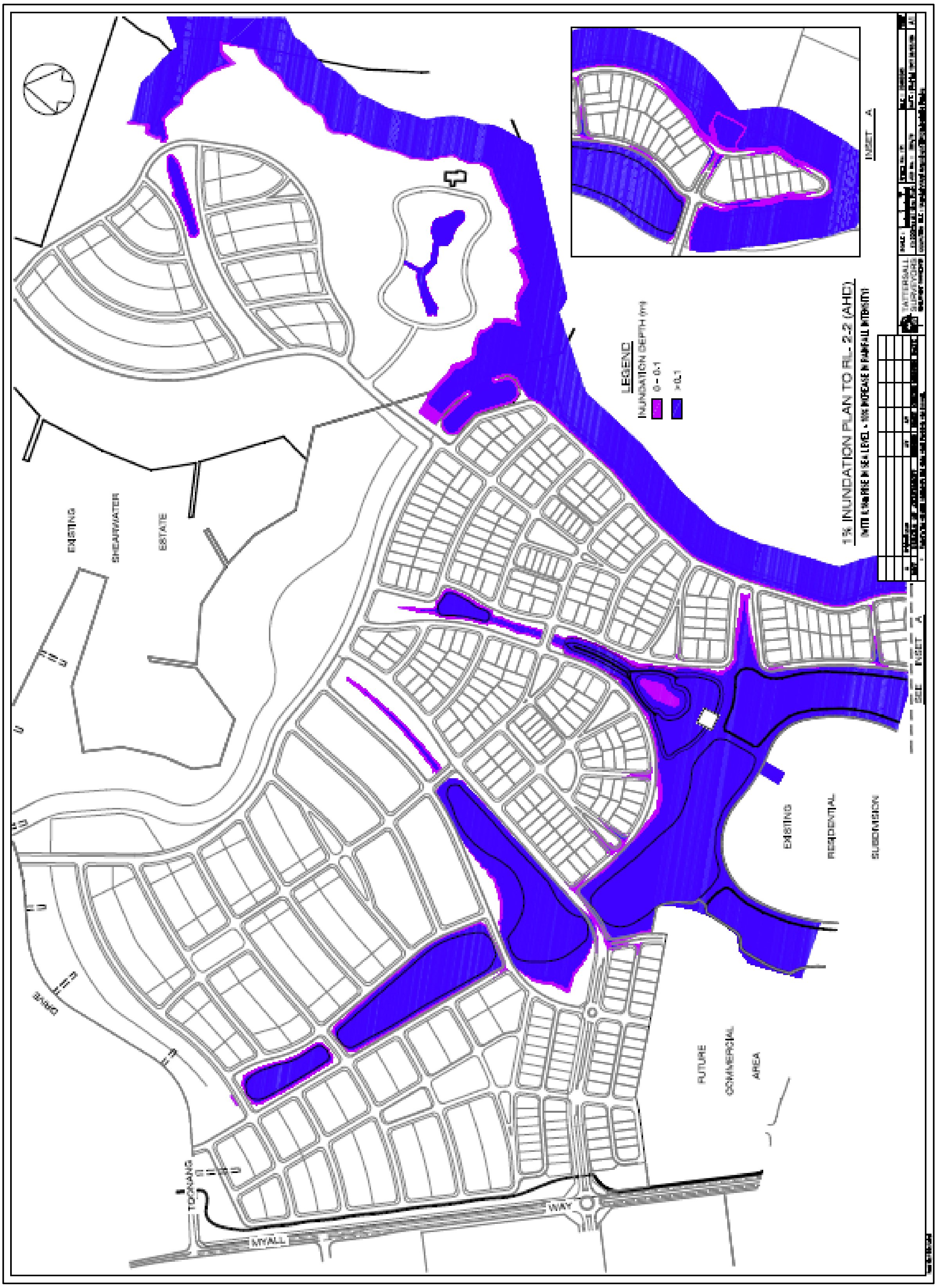

Figure 6 100 yr Inundation (0.18 m Sea Level Rise + 10% Rainfall Increase)

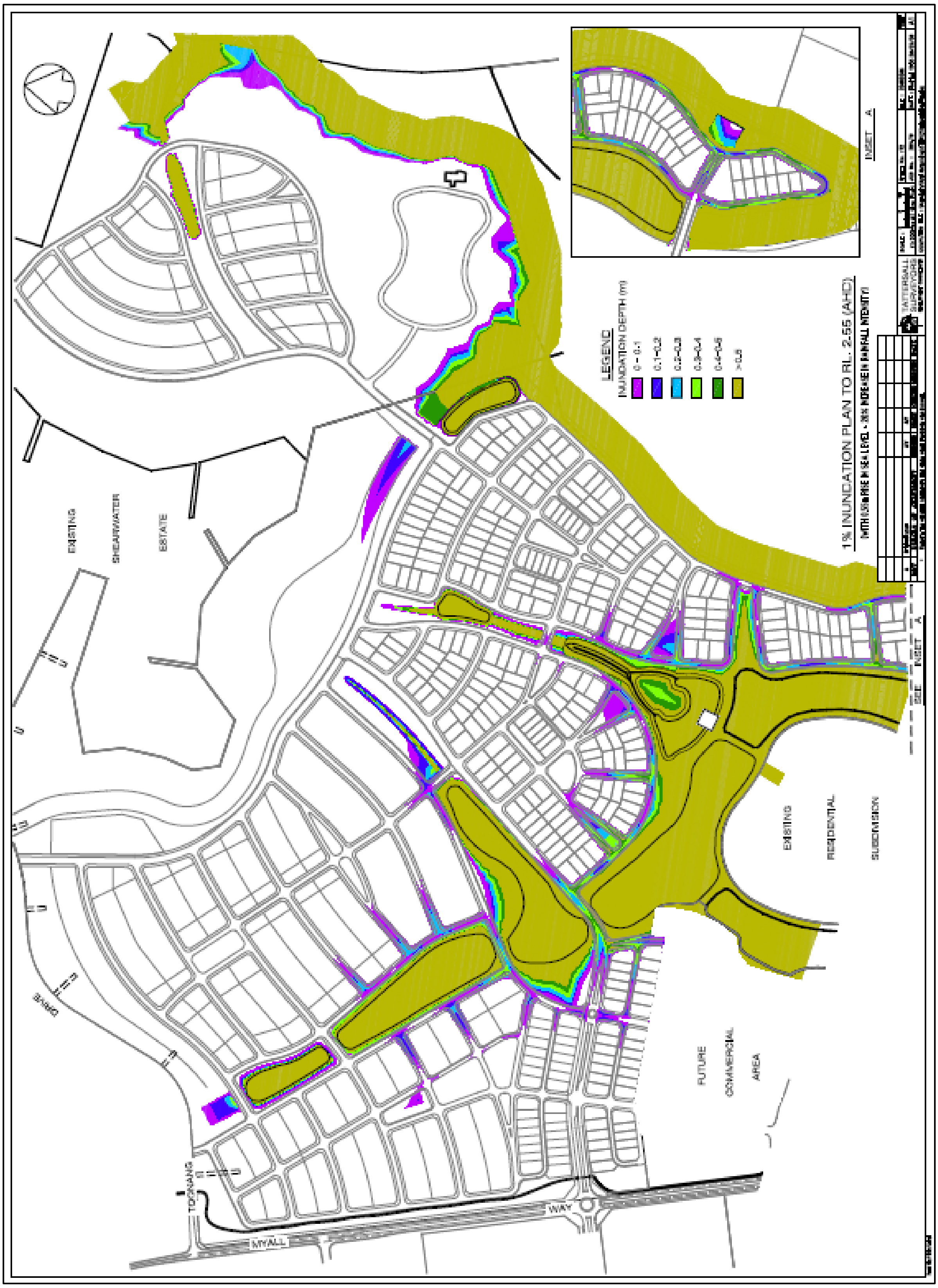

Figure 7 100 yr Inundation (0.55 m Sea Level Rise + 20% Rainfall Increase)

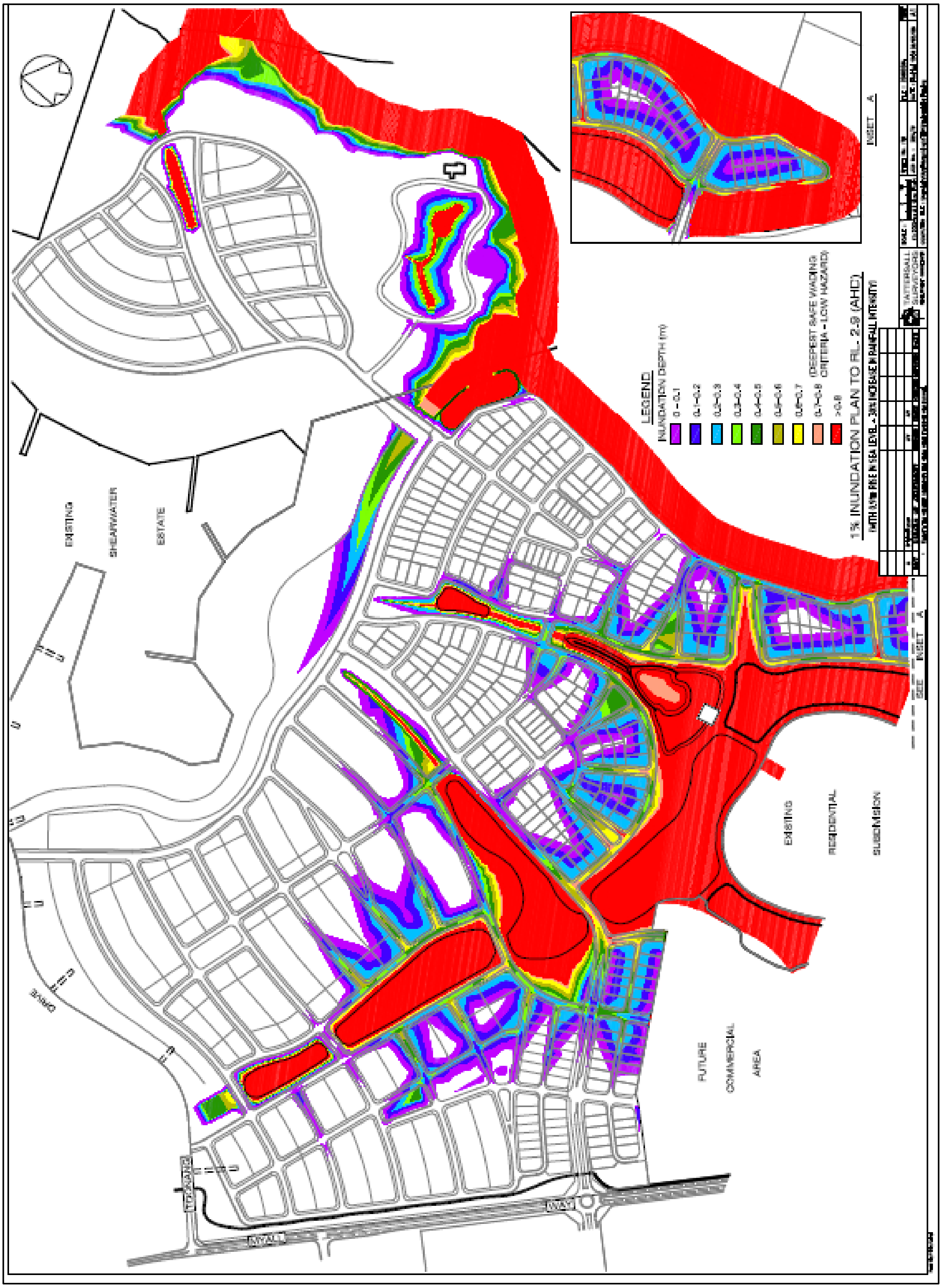

Figure 8 100 yr Inundation (0.91 m Sea Level Rise + 30% Rainfall Increase)

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 2007 Riverside at Tea Gardens Integrated Water Management Report (see **Figure 15**).

5.2 Inflow Hydrographs

It was assumed conservatively that increases in rainfall would equate to equal increases in the catchment runoff and inflow hydrographs. Consequently all inflow hydrographs were increased by 10%, 20% and 30% under the climate change scenarios.

5.3 Downstream Boundary Condition

The adopted downstream boundary condition from the 2007 assessments was adopted for these assessments. Sea level rise in the Myall River was not included in the downstream boundary condition because the flood levels in the Myall River control in the lower lying areas of the site.

5.4 Results

Six sensitivity runs were undertaken. The 100 yr ARI flood levels within the drainage corridors under the 1.5 hour and 9 hour duration storm burst are presented in **Figures 9** to **14** and are summarised in **Tables 4** and **5**.

Locations where the local 100 yr ARI is exceeded by the estimated Myall River 100 yr levels are colour coded as follows:

	Locations where the Myall River 100 yr Level with +0.0 m sea level rise exceeds the local 100 yr ARI flood level (2.02 m AHD)
	Additional locations where the Myall River 100 yr Level with +0.18 m sea level rise exceeds the local 100 yr ARI flood level (2.2 m AHD)
	Additional locations where the Myall River 100 yr Level with +0.55 m sea level rise exceeds the local 100 yr ARI flood level (2.55 m AHD)
	Additional locations where the Myall River 100 yr Level with +0.91 m sea level rise exceeds the local 100 yr ARI flood level (2.9 m AHD)

Table 4 Estimated 100 yr ARI Peak Flood Levels for 1.5 hour Storm Burst

Node	1% 1.5hr	1% 1.5hr +10%	*diff.*	1% 1.5hr +20%	*diff.*	1% 1.5hr +30%	*diff.*
	(a)	(b)	*(b)-(a)*	(c)	*(b)-(a)*	(d)	*(b)-(a)*
	(mAHD)	(mAHD)	*(cm)*	(mAHD)	*(cm)*	(mAHD)	*(cm)*
West Branch							
WB1	2.93	2.95	*3*	2.98	*6*	3.02	*9*
WB2	2.75	2.79	*4*	2.84	*9*	2.88	*13*
N89	2.16	2.20	*4*	2.25	*9*	2.32	*16*
WB3	2.16	2.20	*4*	2.25	*9*	2.31	*15*
WB4	2.16	2.20	*4*	2.25	*9*	2.31	*15*
N70	1.77	1.82	*5*	1.87	*11*	1.95	*18*
WB5	1.77	1.82	*5*	1.87	*11*	1.95	*18*
WB6	1.77	1.82	*5*	1.87	*11*	1.95	*18*
N71	1.68	1.73	*5*	1.78	*11*	1.83	*15*
WB7	1.68	1.73	*5*	1.78	*11*	1.83	*15*
WB8	1.61	1.63	*2*	1.66	*5*	1.68	*7*
East Branch							
EB1	2.58	2.59	*1*	2.61	*2*	2.62	*3*
EB2	1.74	1.75	*1*	1.76	*2*	1.77	*3*
N68	1.74	1.75	*1*	1.76	*2*	1.76	*3*
EB3	1.56	1.58	*2*	1.60	*4*	1.62	*6*
EB4	1.50	1.51	*1*	1.54	*4*	1.56	*6*
EB5	1.48	1.51	*3*	1.54	*6*	1.56	*8*
EB6	1.48	1.51	*3*	1.54	*6*	1.56	*8*
EB7_1	1.48	1.51	*3*	1.54	*6*	1.56	*8*
EB7_2	1.48	1.51	*3*	1.54	*6*	1.56	*8*
N73	1.48	1.51	*3*	1.54	*6*	1.56	*8*
North Branch							
NB1	2.19	2.20	*1*	2.20	*1*	2.21	*2*
NB2	1.98	2.00	*2*	2.02	*4*	2.04	*7*
NB3	1.97	1.99	*2*	2.01	*5*	2.04	*7*
NB4	1.68	1.73	*5*	1.78	*11*	1.83	*15*
NB5	1.68	1.73	*5*	1.78	*11*	1.83	*15*
NB6	1.68	1.73	*5*	1.78	*11*	1.83	*15*
East-West Branch							
EW1	8.69	8.70	*1*	8.72	*3*	8.74	*5*
EW1_1	4.71	4.72	*1*	4.74	*3*	4.76	*5*
EW2	3.85	3.90	*5*	3.98	*13*	4.05	*20*
EW3	3.79	3.88	*9*	3.96	*17*	4.04	*24*
EW4	2.93	2.94	*1*	2.96	*3*	3.00	*7*
EW5	2.81	2.83	*2*	2.85	*5*	2.90	*10*
EW6	2.48	2.49	*1*	2.50	*2*	2.51	*3*
N43	2.16	2.18	*2*	2.19	*3*	2.21	*5*
EW7	1.97	1.97	*1*	1.98	*2*	1.99	*3*
EW8	1.87	1.87	*0*	1.87	*1*	1.87	*1*

Table 5 Estimated 100 yr ARI Peak Flood Levels for 9 hour Storm Burst

Node	1% 9hr	1% 9hr +10%	*diff.*	1% 9hr +20%	*diff.*	1% 9hr +30%	*diff.*
	(a)	(b)	*(b)-(a)*	(c)	*(c)-(a)*	(d)	*(d)-(a)*
	(mAHD)	(mAHD)	*(cm)*	(mAHD)	*(cm)*	(mAHD)	*(cm)*
West Branch							
WB1	2.81	2.81	*0*	2.84	*3*	2.85	*4*
WB2	2.56	2.56	*0*	2.61	*5*	2.63	*7*
N89	1.97	1.99	*2*	2.07	*10*	2.13	*16*
WB3	1.97	1.99	*2*	2.07	*10*	2.13	*16*
WB4	1.97	1.99	*2*	2.07	*10*	2.13	*16*
N70	1.85	1.88	*3*	1.97	*12*	2.03	*18*
WB5	1.85	1.88	*3*	1.97	*12*	2.03	*18*
WB6	1.85	1.88	*3*	1.97	*12*	2.03	*18*
N71	1.78	1.80	*2*	1.85	*7*	1.90	*12*
WB7	1.78	1.80	*2*	1.85	*7*	1.89	*11*
WB8	1.67	1.68	*1*	1.70	*4*	1.72	*5*
East Branch							
EB1	2.50	2.50	*1*	2.51	*1*	2.52	*2*
EB2	1.71	1.71	*0*	1.72	*1*	1.73	*2*
N68	1.71	1.71	*0*	1.72	*1*	1.73	*2*
EB3	1.60	1.62	*2*	1.65	*5*	1.67	*7*
EB4	1.60	1.61	*1*	1.63	*3*	1.65	*5*
EB5	1.60	1.61	*1*	1.63	*3*	1.65	*5*
EB6	1.59	1.61	*2*	1.63	*4*	1.65	*6*
EB7_1	1.59	1.61	*2*	1.63	*4*	1.65	*6*
EB7_2	1.59	1.61	*2*	1.63	*4*	1.65	*6*
N73	1.59	1.61	*2*	1.63	*4*	1.65	*6*
North Branch							
NB1	2.14	2.15	*0*	2.15	*1*	2.15	*1*
NB2	1.90	1.91	*2*	1.94	*4*	1.97	*7*
NB3	1.87	1.90	*3*	1.93	*6*	1.97	*10*
NB4	1.78	1.80	*2*	1.85	*7*	1.89	*11*
NB5	1.78	1.80	*2*	1.85	*7*	1.89	*11*
NB6	1.78	1.80	*2*	1.85	*7*	1.89	*11*
East-West Branch							
EW1	8.61	8.61	*0*	8.63	*2*	8.65	*4*
EW1_1	4.63	4.63	*0*	4.66	*3*	4.67	*4*
EW2	3.84	3.84	*0*	4.01	*17*	4.08	*24*
EW3	3.79	3.80	*1*	4.00	*20*	4.07	*28*
EW4	2.93	2.93	*0*	2.97	*4*	3.08	*16*
EW5	2.81	2.81	*1*	2.86	*5*	3.02	*21*
EW6	2.48	2.48	*0*	2.50	*2*	2.53	*4*
N43	2.08	2.09	*1*	2.11	*3*	2.12	*4*
EW7	1.98	1.98	*0*	2.00	*2*	2.01	*3*
EW8	1.87	1.87	*0*	1.87	*1*	1.88	*1*

It was concluded from the results of the sensitivity runs 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.

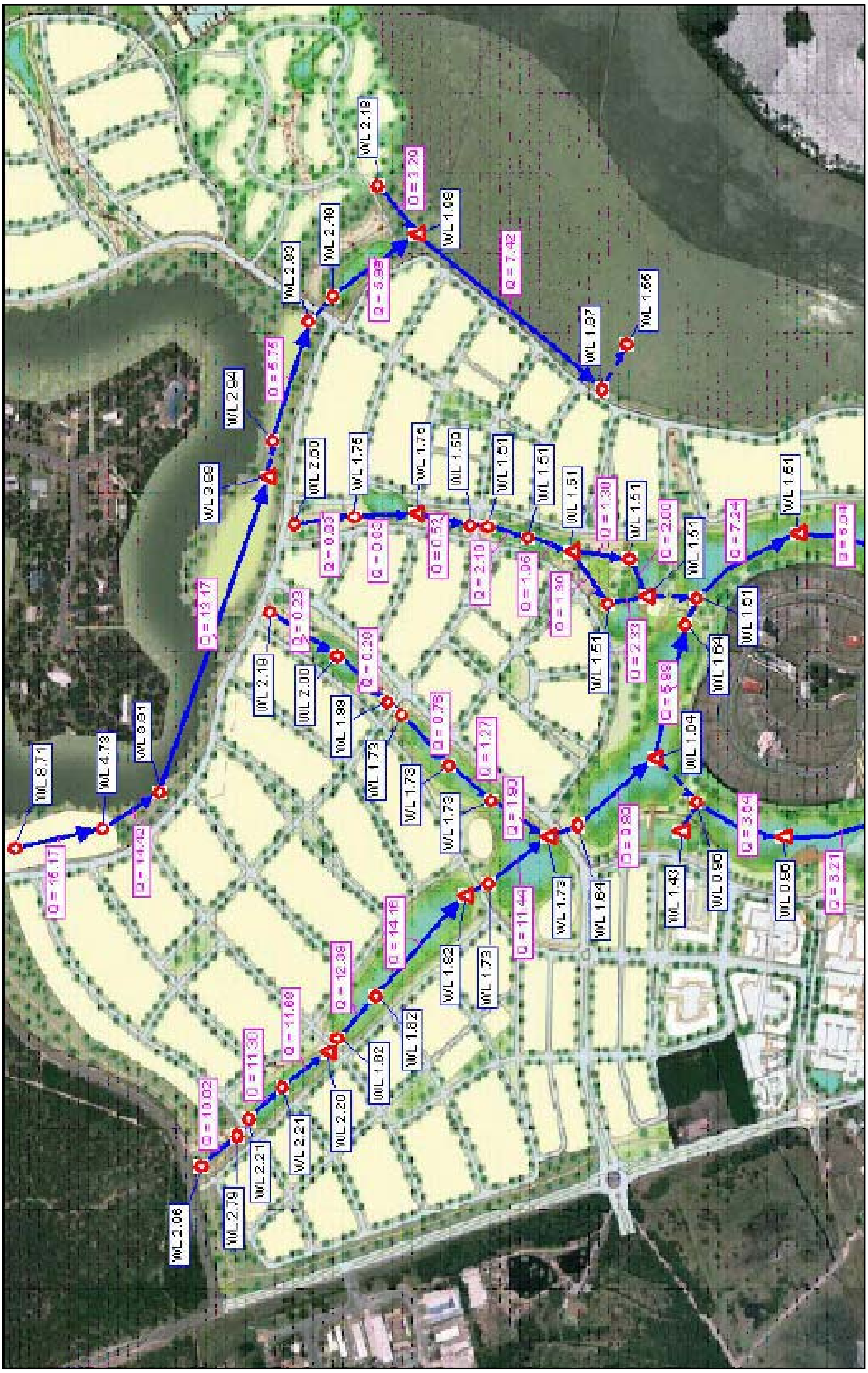

Figure 9 100 yr ARI Flood Levels under 1.5 Storm Burst + 10% Increase

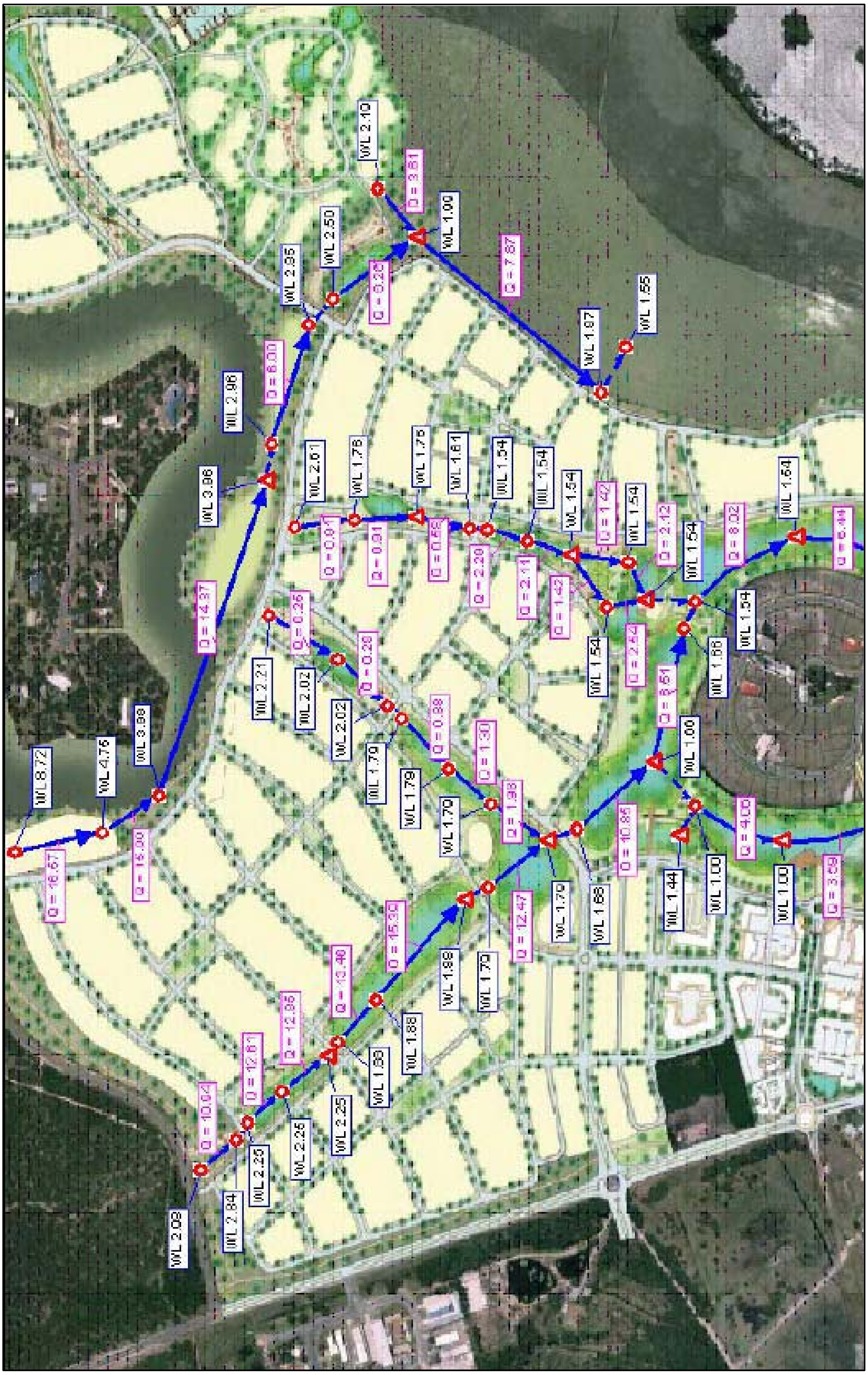

Figure 10 100 yr ARI Flood Levels under 1.5 Storm Burst + 20% Increase

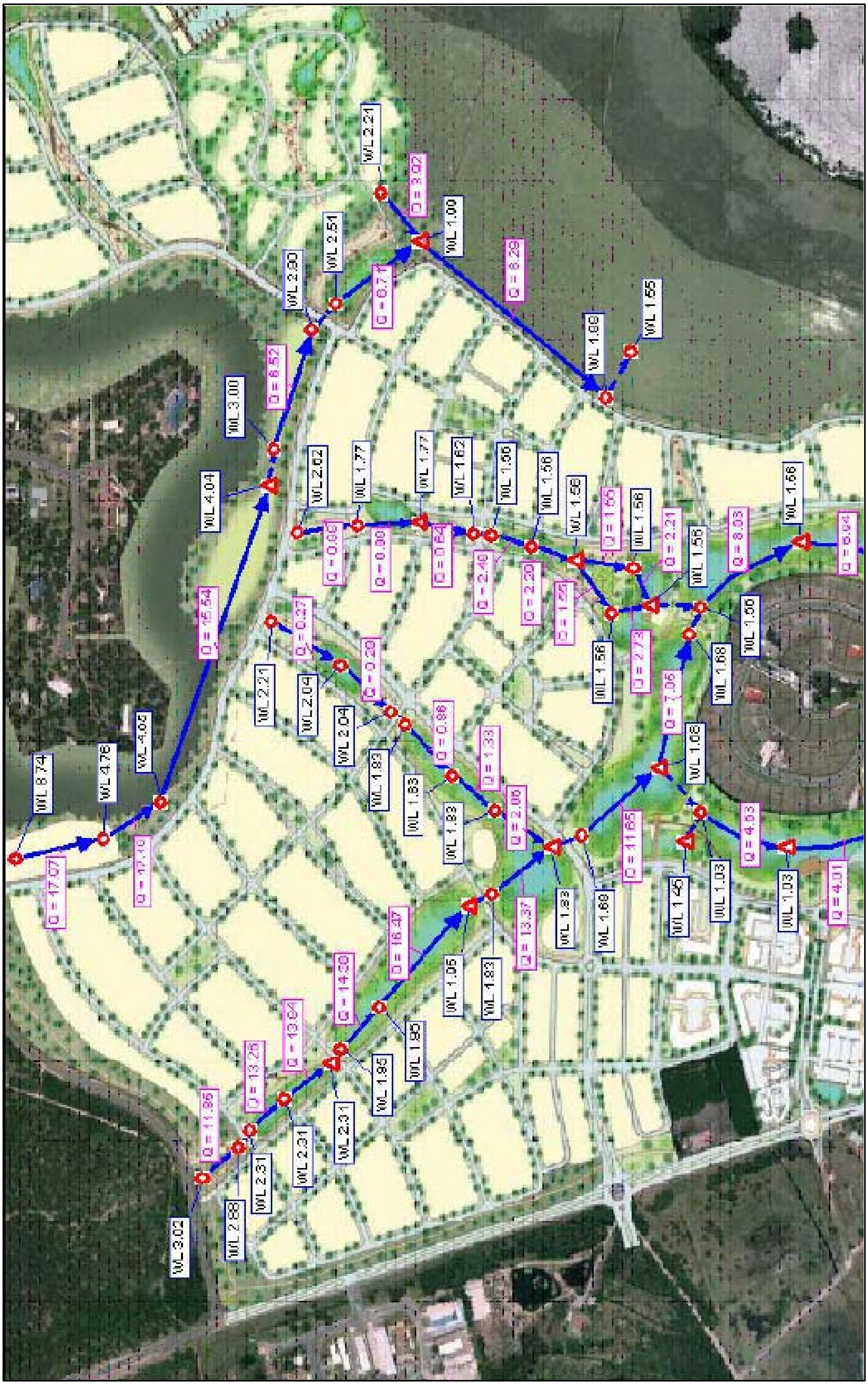

Figure 11 100 yr ARI Flood Levels under 1.5 Storm Burst + 30% Increase

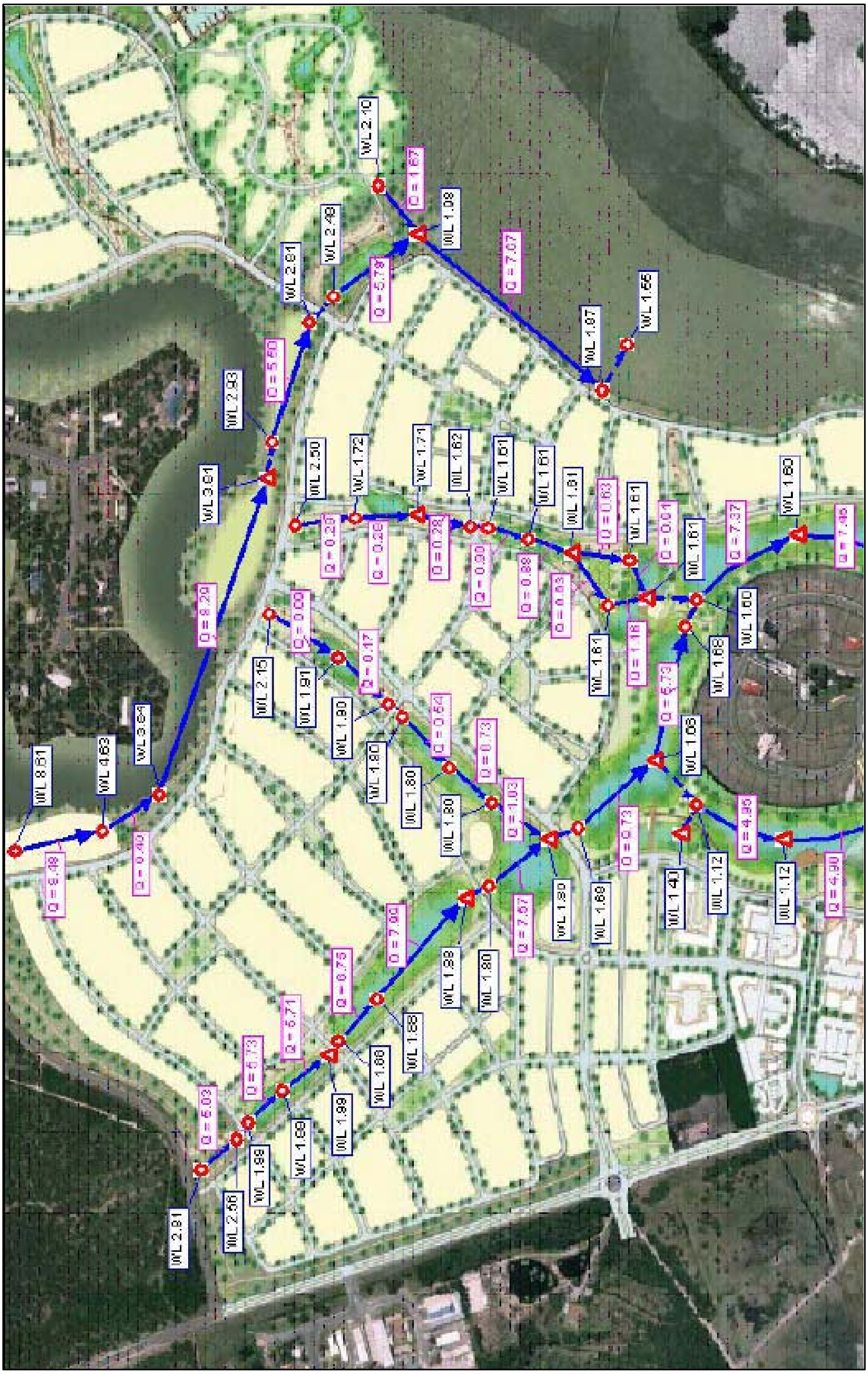

Figure 12 100 yr ARI Flood Levels under 9 Storm Burst + 10% Increase

Cardno Willing

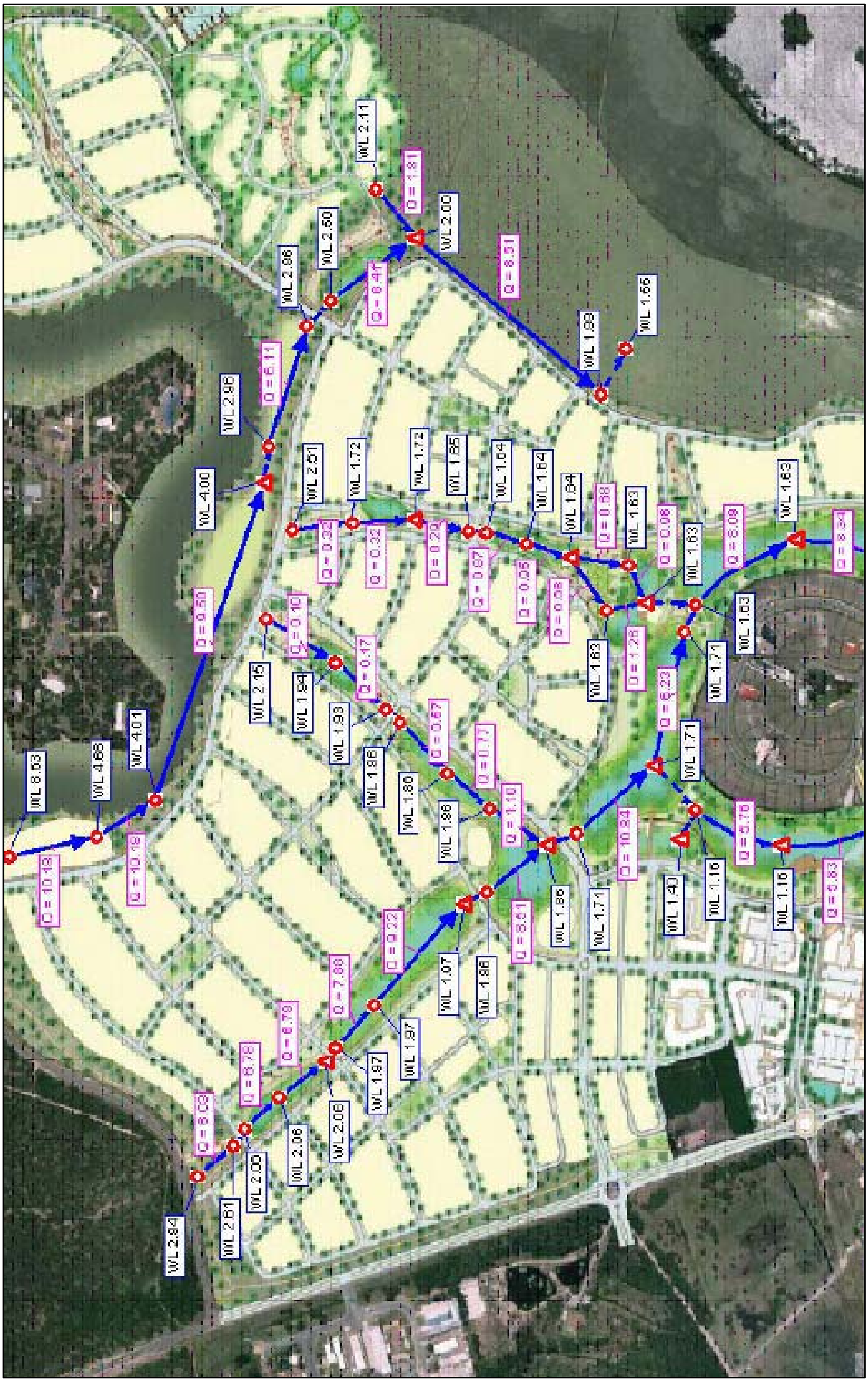

Figure 13 100 yr ARI Flood Levels under 9 Storm Burst + 20% Increase

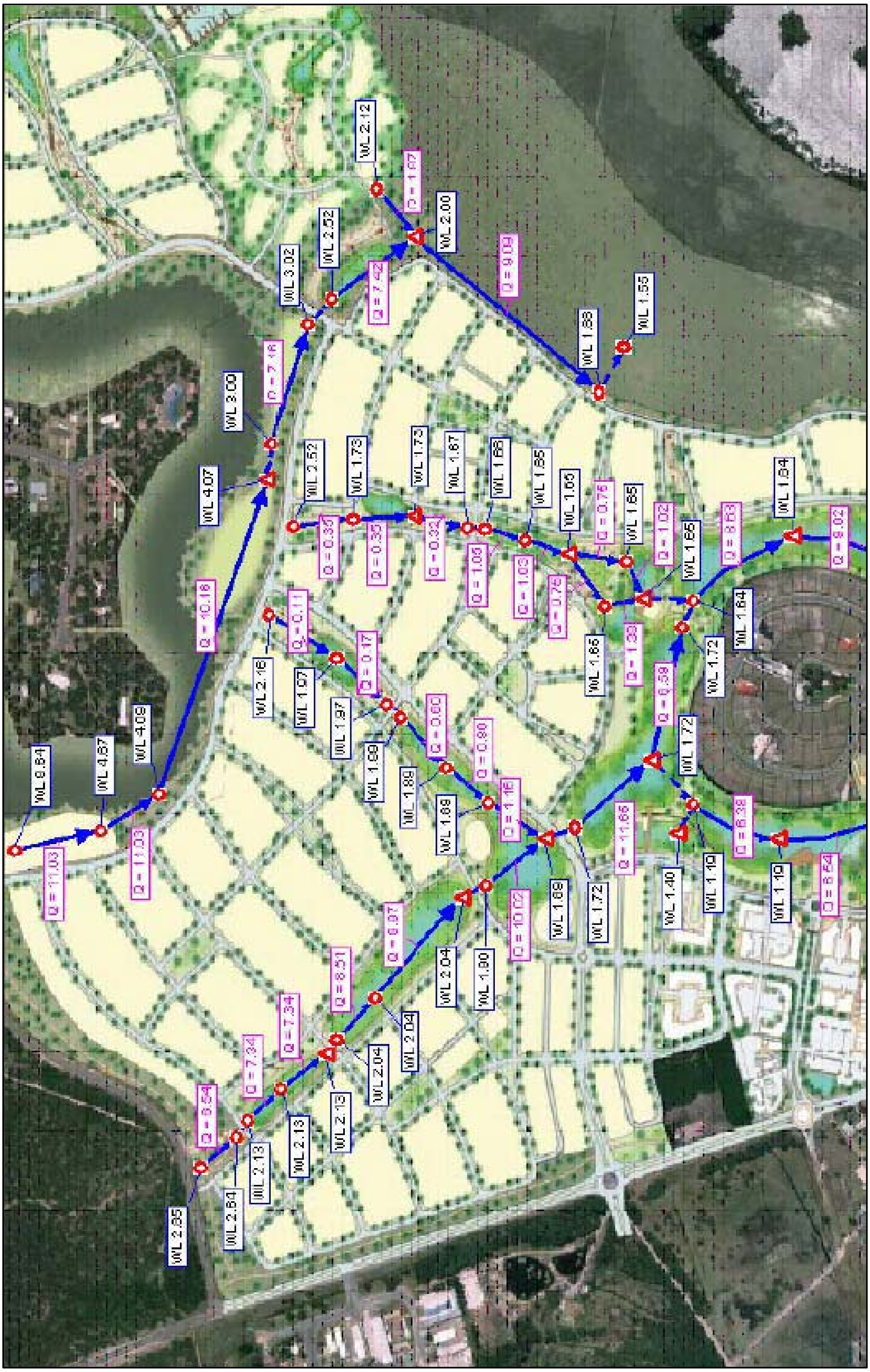

Figure 14 100 yr ARI Flood Levels under 9 Storm Burst + 30% Increase

Figure 15 Model Layout

6. OTHER CONSIDERATIONS

6.1 Floor Levels

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.

Elsewhere in the development consideration a minimum floor level of 0.5 m above the local 100 yr ARI flood level (under no climate change) would provide a minimum 0.22 m freeboard above the local 100 yr ARI flood level under a high climate change scenario.

6.2 Flood Evacuation

While 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. As indicated in **Figure 8**, even under a high climate change scenario, planned roads would provide flood free egress via a number of roads for residents evacuating from threatened properties to higher ground on the northern and north western boundaries of the development.

It was also noted from the 1980 flood study that the estimated 100 yr ARI outflow from the Myall Lakes peaked after 7 days. Consequently it is expected that the flood warning system in place to warn existing residents of Tea Gardens of major flooding in the Myall River would provide ample warning time for residents of properties that would be threatened under a high climate change scenario to safely evacuate their properties well before the Myall River would reach its peak.

7. REFERENCES

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