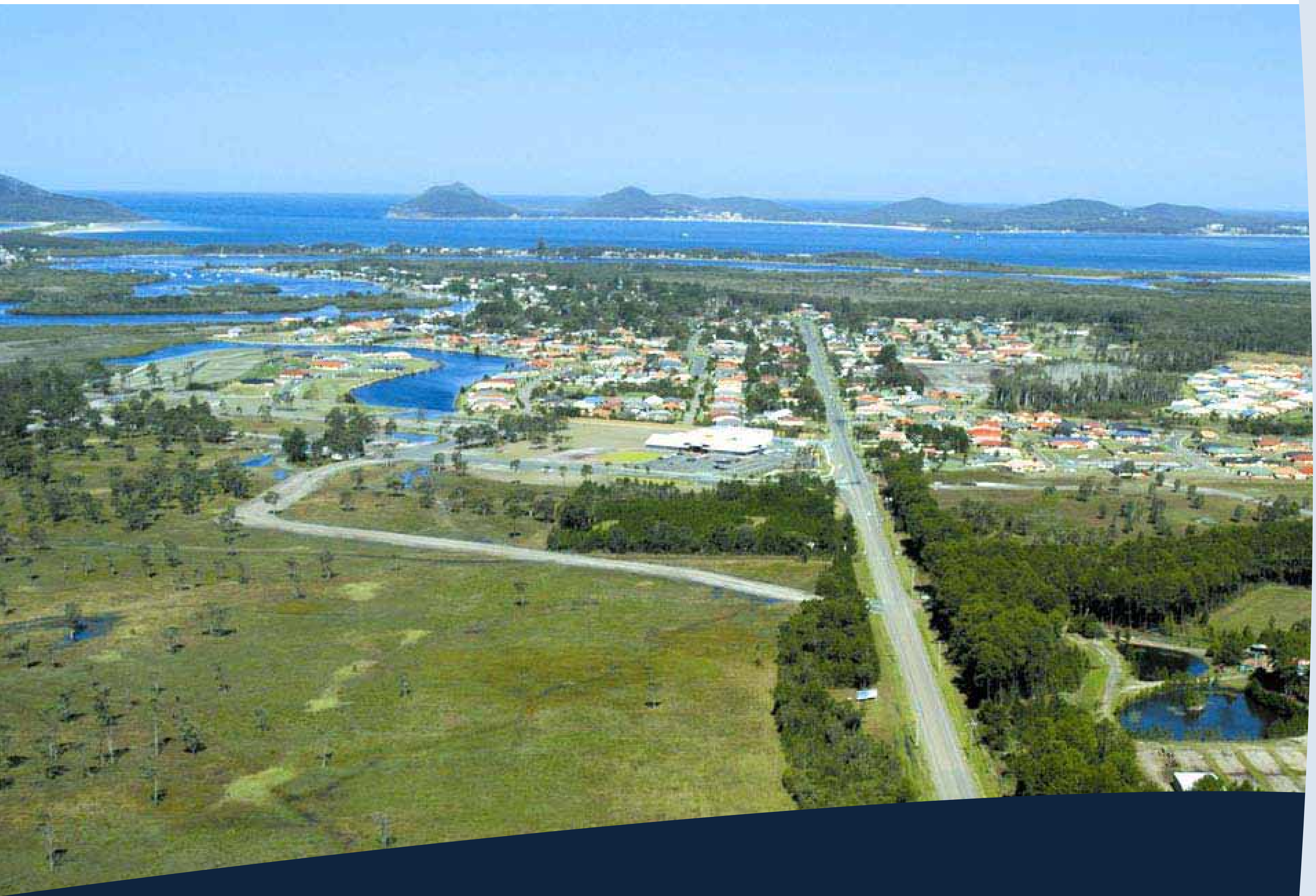
Shaping the Future



Riverside at Tea Gardens

Integrated Water Management

Appendices

Job Number W4332-7

Prepared for Crighton Properties

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As of 1 July 2009 Cardno Willing (NSW) Pty Ltd merged into Cardno (NSW/ACT) Pty Ltd. Any reference to Cardno Willing is to be read as a reference to Cardno.

Cover Image: Oblique aerial view of the Riverside at Tea Gardens site looking southeast.

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Appendix A

Available Information

A Available Information

A.1 Rainfall

Daily Rainfall

Daily rainfall data was obtained from the Bureau of Meteorology station at Hawks Nest (Langi St) [Station 60123]. Although some daily rainfall data is available for the study catchment it does not yet cover a sufficiently long period.

The data covers daily rainfall record (March 1981 – present). The average annual rainfall recorded at Hawks Nest over 25 years (1982-2006) is 1,380.5 mm. In comparison, the long term (104 years) average annual rainfall recorded at Nelson Bay (Nelson Head) (Station 06154) is 1,347 mm.

Table A.1
Annual Rainfall at Hawks Nest (Langi St) (Station 060123)

Year	Rainfall (mm)	Comment
1982	1660	
1983	1289	
1984	1210	
1985	1484	
1986	1092	
1987	1292	50th %tile (median) year
1988	1571	
1989	1372	
1990	2524	
1991	1116	
1992	1543	
1993	918	
1994	1184	
1995	1134	
1996	1068	
1997	1524	
1998	1760	
1999	1670	
2000	1076	10th %tile (dry) year
2001	1712	90h %tile (wet) year
2002	1187	
2003	1385	Average year
2004	1298	
2005	1215	
2006	1228	

A summary of the recorded annual rainfall for the period 1/01/1982 to 31/05/2004 is given in **Table A.1**. The average rainfall year is 2003 (1,385 mm), the 10% dry year is 2000 (1,076 mm), and the 90% wet year is 2001 (1,712 mm).

Design Storm Bursts
The IFD data was generated based on the method outlined in Australian Rainfall and Runoff (Engineers Australia, 1999). The IFD coefficients utilised are shown in **Table A.2** while the estimated design storm burst rainfall intensities are given in **Table A.3**.

Table A.2
Design IFD Parameters for Tea Gardens

Parameter	Value
2 Year ARI 1 hour Intensity	36.9 mm/hr
2 Year ARI 12 hour Intensity	7.3 mm/hr
2 Year ARI 72 hour Intensity	2.3 mm/hr
50 Year ARI 1 hour Intensity	72.4 mm/hr
50 Year ARI 12 hour Intensity	14.4 mm/hr
50 Year ARI 72 hour Intensity	4.5 mm/hr
Location Skew	0.0
F2	4.32
F50	16.05

Table A.3
Design Rainfall Intensities (mm/h) for Tea Gardens

Duration (hrs)	Average Recurrence Interval (years)						
	1	2	5	10	20	50	100
0.5	42.06	54.05	69.21	77.95	89.52	104.61	116.06
1	28.65	36.9	47.52	53.67	61.79	72.4	80.47
1.5	22.14	28.52	36.74	41.51	47.79	56.01	62.26
2	18.37	23.67	30.5	34.46	39.68	46.51	51.7
3	14.08	18.15	23.39	26.43	30.44	35.68	39.67
4.5	10.86	13.99	18.04	20.39	23.48	27.53	30.62
6	8.92	11.5	14.83	16.76	19.31	22.64	25.18
9	6.89	8.88	11.45	12.94	14.92	17.49	19.45
12	5.66	7.3	9.42	10.65	12.28	14.4	16.02
18	4.43	5.71	7.36	8.32	9.59	11.25	12.5
24	3.72	4.79	6.17	6.97	8.03	9.41	10.47
48	2.38	3.06	3.95	4.46	5.13	6.01	6.68
72	1.79	2.30	2.96	3.34	3.84	4.50	5.00

A.2 Pan Evaporation and Potential Evapotranspiration (PET)

The available pan evaporation data was average monthly pan evaporation data collected at Williamstown Air Base. An evaporation multiplier of 0.85 was applied to the pan evaporation data to calculate the potential evapotranspiration (PET).

The adopted average monthly potential evapotranspiration (PET) for Tea Gardens is summarised in **Table A.4**.

Table A.4
Average Monthly PET for Tea Gardens

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Year**
PET	182	150	132	97	69	66	66	93	127	148	166	192	1487

A.3 Streamflow

There is no recorded streamflow data for the study area.

A.4 Myall River Tides

Tide data for the Myall River was obtained from CPI (1996b).

A.5 Water Quality

Since 1996 a water quality monitoring program has been undertaken by the developer, and lately by the Myall Quays Community Association. Hunter Water Laboratories is contracted to collect and analyse samples at 5 locations approximately every 3 months.

Sampling locations are shown on **Figure A.1**.

Initial testing involved the following parameters:

pH
salinity
turbidity
suspended solids
Kjeldahl nitrogen
Oxidised nitrogen
Phosphate
Faecal coliform
Ammonia#
Nitrates#
Nitrites#
Chlorophyll#
Dissolved oxygen

(# denotes testing commenced in November 1997)

The results are reported in Hunter Water Laboratories, 2002 and summarised together with subsequent sampling results for Sites 1 to 5 in **Tables A.5** to **A.9.**

Table A.5
Observed Water Quality at Site 1

Site 1 North East Corner Lake near drain out

Date	ph	Salinity	Turbidity N.T.U	Suspended Solids	Kjeldahl Nitrogen mg/L as N	Oxidised Nitrogen mg/L as N	Phosphate mg/L as P	Faecal Coliform	Ammonia	Nitrates mg/L as N	Chlorophyll a	Dissolved Oxygen	Water Temperature °C	Nitrites mg/L as N
		g/kg	NTU	mg/L	mg/L	mg/L	mg/L	col/ 100ml	mg/L	mg/L	ug/L	mg/L	°C	mg/ L
7/02/1996	6.9	3.87	4	25	0.57	0.13	0.014	0	Not Tested	Not Tested	Not Tested	7.2	-	Not Tested
13/05/1996	7.3	4.37	3	33	0.36	<0.01	0.039	60	Not Tested	Not Tested	Not Tested	8.6	-	Not Tested
24/10/1996	7.3	15.60	2.4	38	1.2	0.05	0.200	4	Not Tested	Not Tested	Not Tested	6.8	-	Not Tested
31/01/1997	7.4	16.50	3.9	45	0.69	0.04	0.020	480	Not Tested	Not Tested	Not Tested	7.1	-	Not Tested
26/11/1997	7.7	7.22	4.3	13	-	0.01	0.005	2	0.06	<0.01	2.56	6.6	-	-
2/04/1998	7.5	12.76	1.4	28	-	0.05	0.005	58	0.05	0.05	9.61	6.9	-	-
23/11/1998	7.1	4.50	3.1	17	-	0.02	0.005	4	0.06	0.02	2.31	3.5	-	-
11/03/1999	7.4	12.90	1.1	20	-	0.14	0.007	2	0.08	0.14	2.78	4.8	-	-
9/06/1999	7	9.40	2.1	35	-	0.02	0.005	20	0.1	0.02	2.67	5.4	-	-
30/09/1999	7.5	6.20	1.1	34	-	0.01	0.029	12	0.05	0.01	2.72	7.3	-	-
19/01/2000	7.5	8.90	1.1	17	-	<0.01	0.011	0	<0.02	<0.01	1.37	6.3	-	-
27/04/2000	7.2	4.50	2.8	9	-	<0.01	0.031	91	<0.02	<0.01	11.3	6.0	-	-
19/07/2000	7.3	12.90	2.9	39	-	0.06	0.005	140	0.03	0.06	2.76	8.5	-	-
11/10/2000	7.4	16.30	2.8	47	-	<0.01	0.005	12	0.09	<0.01	2.14	4.0	-	-
25/01/2001	7.9	25.50	1.3	142	-	<0.01	0.013	1	0.03	<0.01	1.62	6.1	-	-
16/05/2001	6.8	4.70	2.3	12	-	0.04	<0.01	14	0.02	0.03	4.14	8.1	-	-
8/08/2001	7.1	8.20	0.6	15	-	<0.01	<0.01	0	0.03	<0.01	0.49	9.1	-	-
16/01/2002	7.6	22.80	1.9	98	-	0.01	<0.01	250	<0.02	<0.01	3.01	5.6	-	-
11/04/2002	7.5	21.10	2.8	29	-	0.03	<0.01	12	0.12	<0.01	3.78	6.6	-	-
12/08/2002	7.4	16.60	3	44	-	0.03	0.005	10.0	0.07	0.03	<1	7.3	15.6	<0.01
14/11/2002	7.6	19.10	0.5	19	-	<0.01	0.005	15.0	0.02	<0.01	1.01	5.4	22.7	<0.01
12/03/2003	7.4	15.00	0.8	13	-	0.007	0.001	33.0	0.088	<0.005	1.51	5.3	24.2	0.003
21/07/2003	7.1	8.40	1.4	32	-	0.11	0.004	3	0.005	0.01	2	7.4	13.5	<0.002
23/04/2004	7.3	6.90	1.3	5	-	0.012	0.002	15	0.023	0.007	<2.0	7	22	0.005
16/9/2004	7.7	12.80	0.8	1	-	<0.005	<0.001	2	0.012	<0.005	<2.0	9.4	15.9	<0.003
11/03/2005	7.5	14	1.8	12		0.007	<0.001	~155	0.005	0.007	<02	6.5	24.4	<0.003
14/11/2005	7.8	14.3	2	12		0.022	0.015	2	0.025	0.017	<2	8.3	24.8	0.004
30/06/2006	7.4	17.5	0.7	13		0.036	0.002	0	0.32	0.032	<2	6.64	12.7	0.004
19/10/2006	7.4	11.1	1.8	9		0.031	<0.001	1	0.23	0.028	<2.0	7.81	23.2	0.003
9/03/2007	7.5	9.1	2.3	10		<0.005	0.004	21	<0.005	<0.005	16	7.3	23.5	<0.003

\- No data available

Table A.6
Observed Water Quality at Site 2

Site 2 Southern Corner Lake

Date	ph	Salinity	Turbidity N.T.U	Suspended Solids	Kjeldahl Nitrogen mg/L as N	Oxidised Nitrogen mg/L as N	Phosphate mg/L as P	Faecal Coliform	Ammonia	Nitrates mg/L as N	Chlorophyll a	Dissolved Oxygen	Water Temperature C	Nitrites mg/L as N
		g/kg	NTU	mg/L	mg/L	mg/L	mg/L	col/ 100ml	mg/L	mg/L	ug/L	mg/L	°C	mg/ L
7/02/1996	6.9	3.38	4	25	0.57	0.13	0.007	0	Not Tested	Not Tested	Not Tested	7.1	-	Not Tested
13/05/1996	7.2	4.20	3	22	0.22	<0.01	0.028	60	Not Tested	Not Tested	Not Tested	8.6	-	Not Tested
24/10/1996	7.2	15.80	2.4	29	2.3	0.7	0.200	4	Not Tested	Not Tested	Not Tested	7.9	-	Not Tested
31/01/1997	7.8	22.80	5.8	63	0.78	0.03	0.020	144	Not Tested	Not Tested	Not Tested	6.9	-	Not Tested
26/11/1997	7.5	7.22	4.2	13	-	0.01	0.005	6	0.07	<0.01	2.26	6.7	-	-
2/04/1998	8	11.69	1.3	11	-	0.05	0.005	77	0.07	0.05	5.34	8.5	-	-
23/11/1998	7.1	4.60	3	14	-	0.02	0.005	12	0.07	0.02	2.77	4.0	-	-
11/03/1999	7.3	13.30	1.1	19	-	0.02	0.005	2	0.08	0.01	3.92	5.5	-	-
9/06/1999	6.7	9.70	4.7	42	-	0.01	0.005	27	0.08	0.01	2.67	3.6	-	-
30/09/1999	6.9	6.10	1	30	-	0.01	0.036	2	0.05	0.01	1.87	4.9	-	-
19/01/2000	7.1	8.80	1.5	14	-	<0.01	0.017	3	<0.02	<0.01	1.44	5.0	-	-
27/04/2000	7.4	4.40	3.2	9	-	<0.01	0.027	230	<0.02	<0.01	10.9	7.8	-	-
19/07/2000	7.2	13.60	1.7	47	-	0.02	0.005	180	0.04	0.02	1.41	9.1	-	-
11/10/2000	7.5	16.40	3.7	52	-	<0.01	0.005	7	0.04	<0.01	3.47	6.0	-	-
25/01/2001	7.9	25.60	1.4	182	-	<0.01	0.019	1	0.03	<0.01	1.37	6.5	-	-
16/05/2001	6.6	4.60	1.9	11	-	0.04	<0.01	18	0.02	0.003	3.42	7.8	-	-
8/08/2001	6.9	8.40	2.1	38	-	<0.01	<0.01	2	0.02	<0.01	0.97	9.9	-	-
16/01/2002	7.7	23.10	2.1	69	-	0.01	<0.01	330	<0.02	<0.01	2.56	5.6	-	-
11/04/2002	7.5	21.00	4.3	38	-	0.02	<0.01	32	0.09	<0.01	15.4	6.5	-	-
12/08/2002	7.2	17.60	1.4	46	-	0.02	0.005	43.0	0.07	0.01	1.09	6.4	15.5	0.01
14/11/2002	7.4	18.80	0.7	32	-	<0.01	0.005	5.0	<0.02	<0.01	<1	4.9	22.5	<0.01
12/03/2003	7.5	15.30	0.8	20	-	0.008	0.001	27.0	0.082	0.005	1.11	5.1	24.5	0.003
21/07/2003	6.9	8.70	2.2	12	-	0.11	<0.001	2	0.02	0.009	9.5	8.0	14.4	0.002
23/04/2004	7.3	7.30	1.3	10	-	0.012	0.001	14	0.026	0.007	3	7.9	22	0.005
16/9/2004	7.7	13.00	0.8	4	-	<0.005	<0.001	2	<0.005	<0.005	<2.0	9.6	16.1	<0.003
11/03/2005	7.4	14.2	1.8	17		0.007	<0.001	~155	<0.005	0.007	<2.0	5.5	24.3	<0.003
14/11/2005	7.8	14.8	1.4	17		0.021	<0.001	2	0.019	0.018	<2	9	24.8	0.003
30/06/2006	7.3	17.8	1.7	22		0.034	0.002	7	0.33	0.03	<2	7	13.2	0.004
19/10/2006	7.5	11.2	2.4	15		0.026	<0.001	3	0.075	0.026	2.1	8.91	23.7	<0.003
9/03/2007	7.3	9.1	1.7	5		<0.005	0.003	22	0.015	<0.005	13.9	7.6	23.9	<0.003

\- No data available

Table A.7
Observed Water Quality at Site 3

Site 3 North Western Corner Lake

Date	ph	Salinity	Turbidity N.T.U	Suspended Solids	Kjeldahl Nitrogen mg/L as N	Oxidised Nitrogen mg/L as N	Phosphate mg/L as P	Faecal Coliform	Ammonia	Nitrates mg/L as N	Chlorophyll a	Dissolved Oxygen	Water Temperature C	Nitrites mg/L as N
		g/kg	NTU	mg/L	mg/L	mg/L	mg/L	col/ 100ml	mg/L	mg/L	ug/L	mg/L	°C	mg/ L
7/02/1996	6.8	3.64	3.9	29	0.66	0.13	0.012	0	-	-	-	6.9	-	-
13/05/1996	7.1	4.08	2.7	32	0.29	<0.01	0.022	40	-	-	-	8.3	-	-
24/10/1996	7.4	16.1	3.7	38	1.2	<0.03	0.100	<2	-	-	-	7.8	-	-
31/01/1997	7.3	16.1	2.7	24	0.72	0.04	0.020	720	-	-	-	7.5	-	-
26/11/1997	7.2	7.22	3.8	22	-	0.02	0.005	2	0.07	0.01	1.55	6.5	-	-
2/04/1998	7.8	11.52	1.4	30	-	0.09	0.005	83	0.19	0.09	5.07	8.3	-	-
23/11/1998	6.7	2.7	5.2	12	-	0.02	0.005	0.08	0.02	1.44		5.3	-	-
11/03/1999	7.1	13.3	1.2	15	-	0.01	0.005	2	0.09	0.01	4.13	5.0	-	-
9/06/1999	7.1	10	1	40	-	0.01	0.000	10	0.08	0.01	2.14	6.7	-	-
30/09/1999	7	6.1	0.6	32	-	0.01	0.027	1	0.03	0.01	1.31	6.2	-	-
19/01/2000	7	8.8	1.1	10	-	<0.012	0.009	1	<0.02	<0.01	1.5	5.0	-	-
27/04/2000	6.7	2.5	6.1	9	-	<0.01	0.036	9	<0.02	<0.01	6.73	5.9	-	-
19/07/2000	7.3	14.3	2.5	46	-	0.02	0.005	110	0.03	0.02	1.51	9.8	-	-
11/10/2000	7.3	16.3	3.7	51	-	<0.01	0.005	27	0.04	<0.01	2.14	6.1	-	-
25/01/2001	7.8	25.8	1.6	103	-	<0.01	0.032	0	0.02	<0.01	2.01	5.8	-	-
16/05/2001	6.8	4.8	1.7	7	-	0.05	<0.01	31	<0.02	0.04	4.63	7.8	-	-
8/08/2001	7.3	8.5	1.1	14	-	<0.01	<0.01	29	0.03	<0.01	1.41	9.7	-	-
16/01/2002	7.5	21	4	66	-	0.01	<0.01	27	<0.02	<0.01	1.39	5.6	-	-
11/04/2002	7.5	21.1	3.4	39	-	0.03	<0.01	17	0.14	<0.01	7.12	6.5	-	-
12/08/2002	7.1	10.4	1.7	52	-	0.02	0.005	7.0	0.11	0.01	1.55	4.4	15.8	0.01
14/11/2002	6.9	11.2	70	48	-	0.01	0.050	~700	0.1	0.01	5.96	5.8	20.4	<0.01
12/03/2003	7.1	13.9	1.7	19	-	0.009	0.002	200.0	0.089	<0.005	1.83	5.5	23.5	0.005
21/07/2003	6.9	9	1.3	15	-	0.012	<0.001	10	0.02	0.01	3.1	6.1	15.7	0.002
23/04/2004	7.2	7.3	1.9	4	-	0.01	0.002	38	0.052	0.005	<2.0	6.8	22	0.005
16/9/2004	7.6	13	1.4	<1	-	<0.005	<0.001	3	<0.005	<0.005	<2.0	9.2	16	<0.003
11/03/2005	7.4	14.5	1.4	15		<0.005	<0.001	182	<0.005	<0.00	<2	5.7	25.4	<0.003
14/11/2005	14.7	7.6	2	15		0.026	<0.001	27	0.044	0.024	<2	6.2	24.8	<0.003
30/06/2006	7.2	18.3	2	18		0.026	0.002	33	0.32	0.23	<2	6.15	14.9	0.003
19/10/2006	7.3	10.4	4	14		0.018	<0.001	93	0.033	0.018	2.7	8.49	20.3	<0.003
9/03/2007	7.2	8.4	2.1	13		0.007	0.004	270	0.024	<0.005	13.5	7.1	22.9	0.004

\- No data available

Table A.8
Observed Water Quality at Site 4

Site 4 Drain to river from Lake

Date	ph	Salinity g/kg	Turbidity N.T.U NTU	Suspended Solids mg/L	Kjeldahl Nitrogen mg/L as N mg/L	Oxidised Nitrogen mg/L as N mg/L	Phosphate mg/L as P mg/L	Faecal Coliform col/ 100ml	Ammonia mg/L	Nitrates mg/L as N mg/L	Chlorophyll a ug/L	Dissolved Oxygen mg/L	Water Temperature C °C	Nitrites mg/L as N mg/ L
7/02/1996	6.9	3.53	4.8	42	0.66	0.13	0.012	0	-	-	-	7.1	-	-
13/05/1996	8.1	5.31	1.7	48	0.36	<0.01	0.032	120	-	-	-	7.8	-	-
24/10/1996	8.4	33.6	0.9	74	0.9	<0.03	0.200	12	-	-	-	8.0	-	-
31/01/1997	7.1	11.9	10.3	60	0.69	0.04	0.020	180	-	-	-	4.3	-	-
26/11/1997	8.2	37.3	1.3	6		<0.01	*0.005*	3	0.03	<0.01	1.81	5.9	-	-
2/04/1998	8.3	32.53	4.6	46		0.09	0.005	16	0.09	0.09	3.08	8.6	-	-
23/11/1998	7	3.1	8	20		0.04	0.005	32	0.08	0.04	11.2	6.1	-	-
11/03/1999	7.3	10.8	3.8	15		0.01	0.007	118	0.12	<0.01	6.88	2.4	-	-
9/06/1999	7.3	10.2	3.8	38		0.01	0.005	58	0.07	0.01	2.46	6.4	-	-
30/09/1999	7.9	16.3	4.1	78		0.01	0.017	6	0.03	0.01	6.22	6.3	-	-
19/01/2000	8.1	33.2	1.5	93		0.012	0.012	34	0.02	<0.01	1.21	6.4	-	-
27/04/2000	7.4	2.8	79	162		0.02	0.046	280	<0.02	0.01	30.3	6.9	-	-
19/07/2000	7.7	19.4	3.3	64		0.02	0.005	60	0.02	0.02	1.94	7.5	-	-
11/10/2000	7.8	32.3	5.3	97		<0.01	0.005	54	0.05	<0.01	3.42	4.3	-	-
25/01/2001	7.8	34.6	3.1	156		<0.01	0.020	3	<0.02	<0.01	2.22	5.7	-	-
16/05/2001	6.7	1.8	12	11		0.02	<0.01	60	<0.02	0.01	3.8	6.6	-	-
8/08/2001	7.8	14.3	3.5	37		0.04	<0.01	10	0.1	0.03	1.92	8.1	-	-
16/01/2002	7.3	23	3.2	89		0.17	<0.01	48	<0.02	0.16	0.99	5.3	-	-
11/04/2002	7.9	20.3	2.7	31		0.2	<0.01	73	0.3	<0.01	2.56	5.5	-	-
12/08/2002	8	30	1.7	70		<0.01	0.005	80	0.09	<0.01	1	7.0	17	<0.01
14/11/2002	7.7	35.8	3.2	24		<0.01	0.010	8	0.03	<0.01	2.46	3.9	22.1	<0.01
12/03/2003	7.3	26.6	6.8	53		0.007	0.001	530	0.1	<0.005	2.56	4.3	23.9	0.003
21/07/2003	7.2	8.8	1.4	19		0.007	<0.001	83	<0.005	0.007	1.4	7.0	14	<0.003
23/04/2004	7.8	15.1	1.8	9		<0.005	0.001	39	<0.005	<0.005	2.6	7.2	21.4	0.005
16/9/2004	8.1	22	2.7	6		<0.005	0.001	17	<0.005	<0.005	<2.0	8.4	16.1	<0.003
11/03/2005	7.9	32.8	1.8	3		<0.005	0.005	37	0.01	<0.005	<2.0	5.3	24.3	<0.003
14/11/2005	8	33.5	2	40		0.027	<0.001	6	0.023	0.026	<2	7.5	22.2	<0.003
30/06/2006	7.9	24.4	1	30		<0.005	0.004	13	0.44	<0.005	<2	7.28	14	<0.003
19/10/2006	7.7	14.5	3.1	14		0.007	<0.001	91	<0.005	<0.00	2	8.61	23.5	<0.003
9/03/2007	7.9	32.9	1.7	32		0.007	0.004	71	0.038	0.007	2	7.1	22.5	<0.003

\- No data available

Table A.9
Observed Water Quality at Site 5

Site 5 Copeland Avenue Wharf

Date	ph	Salinity g/kg	Turbidity N.T.U NTU	Suspended Solids mg/L	Kjeldahl Nitrogen mg/L as N mg/L	Oxidised Nitrogen mg/L as N mg/L	Phosphate mg/L as P mg/L	Faecal Coliform col/ 100ml	Ammonia mg/L	Nitrates mg/L as N mg/L	Chlorophyll a ug/L	Dissolved Oxygen mg/L	Water Temperature C °C	Nitrites mg/L as N mg/ L
7/02/1996	8.4	9.74	1.8	129	0.53	0.12	0.034	0	-	-	-	7.0	-	-
13/05/1996	8.2	5.48	1.6	41	0.69	<0.01	0.030	60	-	-	-	7.5	-	-
24/10/1996	8.3	35.6	1.6	43	1.2	0.06	0.100	2	-	-	-	8.4	-	-
31/01/1997	8.2	32.5	2.1	61	0.13	0.03	0.020	72	-	-	-	5.5	-	-
26/11/1997	8.3	38.7	2.1	52	-	0.01	0.006	3	<0.01	<0.01	6.5	6.5	-	-
2/04/1998	8.3	37.68	3.9	66	-	0.05	0.006	9	0.09	0.05	6.9	6.9	-	-
23/11/1998	6.9	2.4	5.6	14	-	0.06	0.006	126	0.09	0.06	3.59	3.1	-	-
11/03/1999	7.5	11.9	4	14	-	0.02	0.007	64	0.17	0.02	5.45	2.6	-	-
9/06/1999	7.5	9.2	3.1	30	-	0.06	0.000	58	0.1	0.06	3.04	0.6	-	-
30/09/1999	7.8	15.1	1.5	66	-	0.01	0.030	13	0.03	0.01	5.29	6.7	-	-
19/01/2000	8.1	33.6	1.8	35	-	<0.01	0.011	24	0.02	<0.01	1.47	6.7	-	-
27/04/2000	7.2	2.1	11.2	16	-	0.1	0.041	110	0.03	0.09	13.8	6.8	-	-
19/07/2000	7.7	20	3	63	-	0.02	0.005	30	0.03	0.02	1.06	8.3	-	-
11/10/2000	8.1	33.6	2.4	103	-	<0.01	0.005	7	0.04	<0.01	1.29	3.2	-	-
25/01/2001	8	34.6	2.6	169	-	0.01	0.006	4	0.04	<0.01	2.01	5.9	-	-
16/05/2001	6.7	1.4	9.2	10	-	0.03	<0.01	67	0.03	0.02	2.07	5.5	-	-
8/08/2001	7.8	14.5	2.2	53	-	0.04	<0.01	10	0.03	0.03	3.93	7.8	-	-
16/01/2002	8	33.3	1.4	88	-	0.01	<0.01	15	<0.02	<0.01	1.44	5.3	-	-
11/04/2002	8.1	30.3	1.6	59	-	0.02	<0.01	45	0.14	<0.01	1.53	5.7	-	-
12/08/2002	8.1	29.9	2.4	90	-	<0.01	0.005	10.0	0.07	<0.01	<1	7.3	16.6	0.01
14/11/2002	7.9	35.9	0.7	25	-	<0.01	0.010	7.0	0.04	<0.01	1.54	4.5	21.6	<0.01
12/03/2003	7.5	28.9	2.8	52	-	0.007	0.001	480.0	0.11	0.005	2.54	4.5	22.8	0.002
21/07/2003	7	2.7	2.1	11	-	0.038	0.002	11	0.061	0.029	2.3	7.1	14	0.009
23/04/2004	7.7	14.7	1.5	8	-	0.005	0.001	78	<0.005	<0.005	2.3	5.8	21.3	0.002
16/9/2004	8.1	23.9	2.2	<1	-	<0.005	0.001	13	<0.005	<0.005	<2.0	8.3	16	<0.003
11/03/2005	8.1	34.1	3.3	12		<0.005	0.003	19	0.021	<0.005	<2.0	5.9	23.3	<0.003
14/11/2005	8.1	34.8	2	45		0.031	<0.001	6	0.084	0.03	<2.0	6.9	21.7	<0.003
30/06/2006	7.9	24.4	1.1	21		<0.005	0.002	25	0.43	<0.005	<2.0	7.42	13.6	<0.003
19/10/2006	7.9	15.6	3.2	24		<0.005	<0.001	79	0.007	<0.005	2.3	8.8	22.8	<0.003
9/03/2007	7.9	33.4	2.1	54		0.007	0.002	~174	0.049	0.007	2	8	22.4	<0.003

- No data available

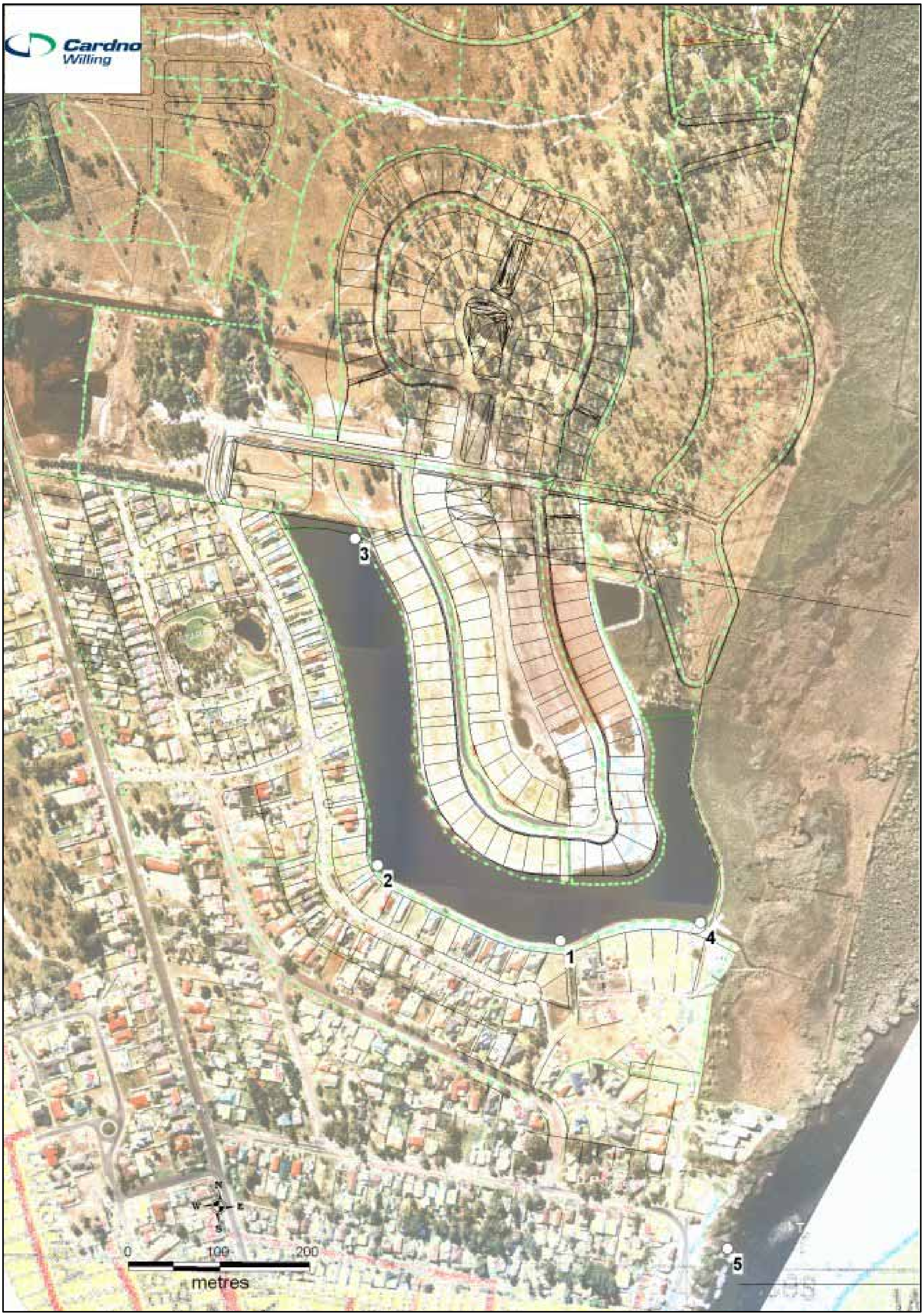

Figure A.1
Water Quality Sampling Site Locations

Appendix B

Hydrology

B Hydrology

B.1 Aims

The aims of hydrological analyses were to

- Assemble an **xprafts** rainfall/runoff model of the Riverside at Tea Gardens catchment;
- Estimate catchment runoff under existing catchment conditions as a benchmark for comparison with proposed development conditions for the 5 yr ARI, 20 yr ARI and 100 yr ARI events;
- Estimate catchment runoff under proposed development conditions; and
- If needed, size detention structure(s) to reduce the 100y ARI peak flow downstream of the proposed development areas to no greater than the 100 yr ARI peak flow under existing conditions.
- Generate 5 yr ARI, 20 yr ARI, 100 yr ARI and PMP hydrographs for input into the hydraulic model.

B.2 Catchment Model and Parameters

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

Design Storm Bursts

The IFD data was generated based on the method outlined in Australian Rainfall and Runoff (Engineers Australia, 1999). The IFD coefficients utilised are shown in **Table B.1** while the estimated design storm burst rainfall intensities are given in **Table B.2**.

Table B.1
Design IFD Parameters for Tea Gardens

Parameter	Value
2 Year ARI 1 hour Intensity	36.9 mm/hr
2 Year ARI 12 hour Intensity	7.3 mm/hr
2 Year ARI 72 hour Intensity	2.3 mm/hr
50 Year ARI 1 hour Intensity	72.4 mm/hr
50 Year ARI 12 hour Intensity	14.4 mm/hr
50 Year ARI 72 hour Intensity	4.5 mm/hr
Location Skew	0.0
F2	4.32
F50	16.05

Table B.2
Design Rainfall Intensities (mm/h) for Tea Gardens

Storm Burst Duration (hrs)	Average Recurrence Interval (years)						
	1	2	5	10	20	50	100
0.5	42.06	54.05	69.21	77.95	89.52	104.61	116.06
1	28.65	36.9	47.52	53.67	61.79	72.4	80.47
1.5	22.14	28.52	36.74	41.51	47.79	56.01	62.26
2	18.37	23.67	30.5	34.46	39.68	46.51	51.7
3	14.08	18.15	23.39	26.43	30.44	35.68	39.67
4.5	10.86	13.99	18.04	20.39	23.48	27.53	30.62
6	8.92	11.5	14.83	16.76	19.31	22.64	25.18
9	6.89	8.88	11.45	12.94	14.92	17.49	19.45
12	5.66	7.3	9.42	10.65	12.28	14.4	16.02
18	4.43	5.71	7.36	8.32	9.59	11.25	12.5
24	3.72	4.79	6.17	6.97	8.03	9.41	10.47
48	2.38	3.06	3.95	4.46	5.13	6.01	6.68
72	1.79	2.30	2.96	3.34	3.84	4.50	5.00

The synthetic design storms were assumed to be uniformly distributed across the catchments. Considering the size of the study catchments an areal reduction factor was not applied.

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

Rainfall Losses

The rainfall losses adopted in the **xprafts** model in the current study are shown in **Table B.3**.

Table B.3
Adopted Rainfall Losses for xprafts Model

Surface Type	Initial Loss (mm)	Continuing Loss (mm/h)
Impervious	1	0
Clay soils	10	2
Loam soils	10	5
Sand soils	50	25

Imperviousness

The area of impervious and pervious surfaces within each subcatchment was based on the areas of roads, roofs and paving and areas of the three soil types present in a subcatchment.

Vector Average Slope
The vector average slope for each subcatchment was determined from available topographic maps or supplied survey. Values ranged from a nominal 0.5% for the flatter areas of the study area up to 10% in the steeper upper subcatchments.

Surface Roughness
For each subcatchment, a surface roughness was entered for each surface type. The adopted surface roughness values ranged from 0.025 to 0.06 depending on the surface type.

Hydrograph Routing
Simple lagging of hydrographs was adopted for the drainage lines. The time of travel (or lag) for each reach (link) was calculated as the length of the reach divided by an average velocity of flow.

B.3 Existing Conditions

The catchment of Riverside at Tea Gardens is bounded to the north by the ridge line of the ridge outcrop, and to the south-west by Myall Road. Riverside at Tea Gardens represents a major portion of the catchment. With the exception of the portion at the south of the site that has already been developed, there is little natural development of surface drainage features and as the surface soils are generally sandy such that a high level of rainfall infiltration to the groundwater system takes place. As a result, significant surface runoff is unlikely except during periods of high rainfall.

The site contains several low natural sand ridges which tend to channel runoff in the western half of the site from north to south. However a number of shallow drains have been previously constructed to convey runoff from the western areas of the site to the east to join with runoff from the eastern area of the site that flows east towards the SEPP 14 wetlands and the Myall River.

During wet periods, water ponds in low lying areas in the western and northern areas of the site.

The Riverside at Tea Gardens catchment was subdivided into 25 subcatchments ranging in size from 1.66 ha to 56.6 ha.

The subcatchment layout is presented in **Figure B.1**.

The existing condition model includes a shallow basin to represent depression storage and shallow ponding of runoff in low lying areas in the western and northern areas of the site. The flows in the shallow drains that convey runoff from the western areas of the site to the east is represented as a diversion link. This diversion link conveys frequent runoff up to around the 1 yr ARI flow (around 4 m^3/s) east towards the SEPP 14 wetlands and the Myall River.

Flows greater than the adopted threshold flow are split with 90% of flows in excess of the threshold flow discharging south to the existing detention lake and the remaining 10% of flows in excess of the threshold flow discharging east.

The active storage available in the existing lake and the existing lake outlet were also represented as a retarding basin in the existing condition model.

The estimated peak 100 yr ARI outflows from the Riverside at Teagardens site are summarised in **Table B.4**.

Table B.4
Estimated Peak Flows at Key Locations in Riverside at Tea Gardens under Existing Conditions

Node	5 yr ARI	20 yr ARI	100 yr ARI	Comment
EExtLake	5.3 *(9)*	9.8 *(9)*	17.1 *(2)*	Inflow to the existing detention lake
ESout	3.3 *(9)*	8.6 *(9)*	14.7 *(2)*	Outflow from the existing detention lake
ENout1	6.9 *(9)*	8.7 *(9)*	10.9 *(9)*	Aggregated flow to the Conservation Zoned
EN42	0.58 *(9)*	0.88 *(9)*	1.25 *(9)*	Outflow to an existing drainage line that discharges directly into the Myall River

Note: The Critical Storm Burst Duration (hrs) is reported in brackets

B.4 Developed Conditions

B.4.1 Preliminary Developed Conditions

A model of developed conditions was also assembled based on a preliminary concept layout of planned future stages of the development. In concept it is proposed to direct runoff in events up to the 100 yr ARI event from the upper catchment areas east along the proposed open space corridor located on the northern boundary and then south east to swale located on the eastern boundary of the site. This swale is intended to distribute runoff along the western boundary of the buffer zone to reduce the concentration of runoff into the buffer zone and the SEPP14 wetland. With the exception of limited areas of planned development on the eastern boundary of the site that will drain to the buffer zone, the planned development located south of the open space corridor will drain southwards towards the proposed lakes and the extended detention lake.

The catchment was re-subdivided into 129 subcatchments to reflect the planned development. These subcatchments ranged in size from 0.5 ha to 63.9 ha.

The subcatchment layout for the preliminary development is presented in **Figure B.2**.

The active storage available in the detention lake was represented as a retarding basin in the developed condition model.

The 5 yr ARI, 20 yr ARI and 100 yr ARI hydrographs under preliminary developed conditions (without ancillary retarding basins) were generated and were exported to the hydraulic model of the preliminary Developed Conditions.

It was noted that the critical storm duration was a 1.5 hour storm in the upper and mid reaches of the catchment while the 9 hour storm was critical in the lower reaches of the catchment.

B.4.2 Preliminary Developed Conditions with Basins

A model of preliminary developed conditions with retarding basins was also assembled. In concept it is proposed to direct runoff in events up to the 100 yr ARI event from the upper catchment areas east along the proposed open space corridor located on the northern boundary to a major retarding basin with outflows from the basin discharging south east to a swale located on the eastern boundary of the site. This swale is intended to distribute runoff along the western boundary of the buffer zone to reduce the concentration of runoff into the buffer zone and the SEPP14 wetland. A separate basin was also sized to reduce peak flows from the area of planned development that discharges directly to the Myall River (subcatchment N42).

A concept retarding basin was also sized to manage runoff from an area of planned development that could discharge directly to the conservation zone (subcatchment N43).

Basin Properties

Concept basin sizes and outlet configuration were sized iteratively. In the case of Basin EW the aim was to either:

(i) limit the 100 yr ARI peak discharge to the Conservation Zone under developed conditions to no greater than the existing peak 100 yr ARI discharge to the Conservation Zone, or to

(ii) limit basin outflows to around 6 m^3/s based on the feasibility of constructing a waterway through rising ground to the east of the concept basin wall.

It was found that the latter aim controlled the basin size.

In the case of Basins N42 and N43 the aim of the basins was to limit 100 yr ARI peak flows to no greater than the 100 yr ARI peak flow under existing conditions.

The concept basin properties are summarised as follows:

Basin	Surface Area (ha)	Concept Outlet
EW	2.7	2 x 1.8 (W) x 0.6 (H)
N42	0.47	2 x 750 Diam RCP
N43	0.44	2 x 750 Diam RCP

The concept grading of Basin EW is as follows:

Level (m AHD)	Surface Area (ha)	Comment
2.5	0.45	Approx 0.5 m cut
3.0	1.11	Less than 0.5 m cut
3.5	1.95	Existing contour
4.0	2.64	Existing contour

Results

The estimated peak basin water levels for 20 yr ARI, 50 yr ARI and 100 yr ARI events are summarised in **Table B.5**.

Table B.6
Estimated Peak Basin Water Depths

Basin	5 yr ARI	20 yr ARI	100 yr ARI
EW	0.97	1.22	1.58
N42	0.55	0.79	0.92
N43	0.53	0.78	0.87

B.4.3 Final Developed Conditions

The final proposed developed conditions evolved through iterative consideration of a number of schemes that responded to issues raised by the PAC, DoP and other government agencies.

Under the final proposed developed conditions it is proposed to direct runoff in events up to the 100 yr ARI event from the upper catchment areas east along the proposed open space corridor located on the northern boundary to a major retarding basin with outflows from the basin discharging south east to a swale located on the eastern boundary of the site. This swale is intended to distribute runoff along the western boundary of the buffer zone to reduce the concentration of runoff into the buffer zone and the SEPP14 wetland. The planned development located south of the open space corridor will drain southwards towards a number of ponds, wetlands and freshwater lakes that will discharge via swales into the existing saline lake.

The 5 yr ARI, 20 yr ARI, 100 yr ARI and PMP hydrographs under developed conditions were estimated and input into the hydraulic model of the final proposed developed conditions to estimate peak outflows to the conservation zone and SEPP 14 wetlands as well as the 5 yr ARI, 20 yr ARI 100 yr ARI and local PMF flood levels.

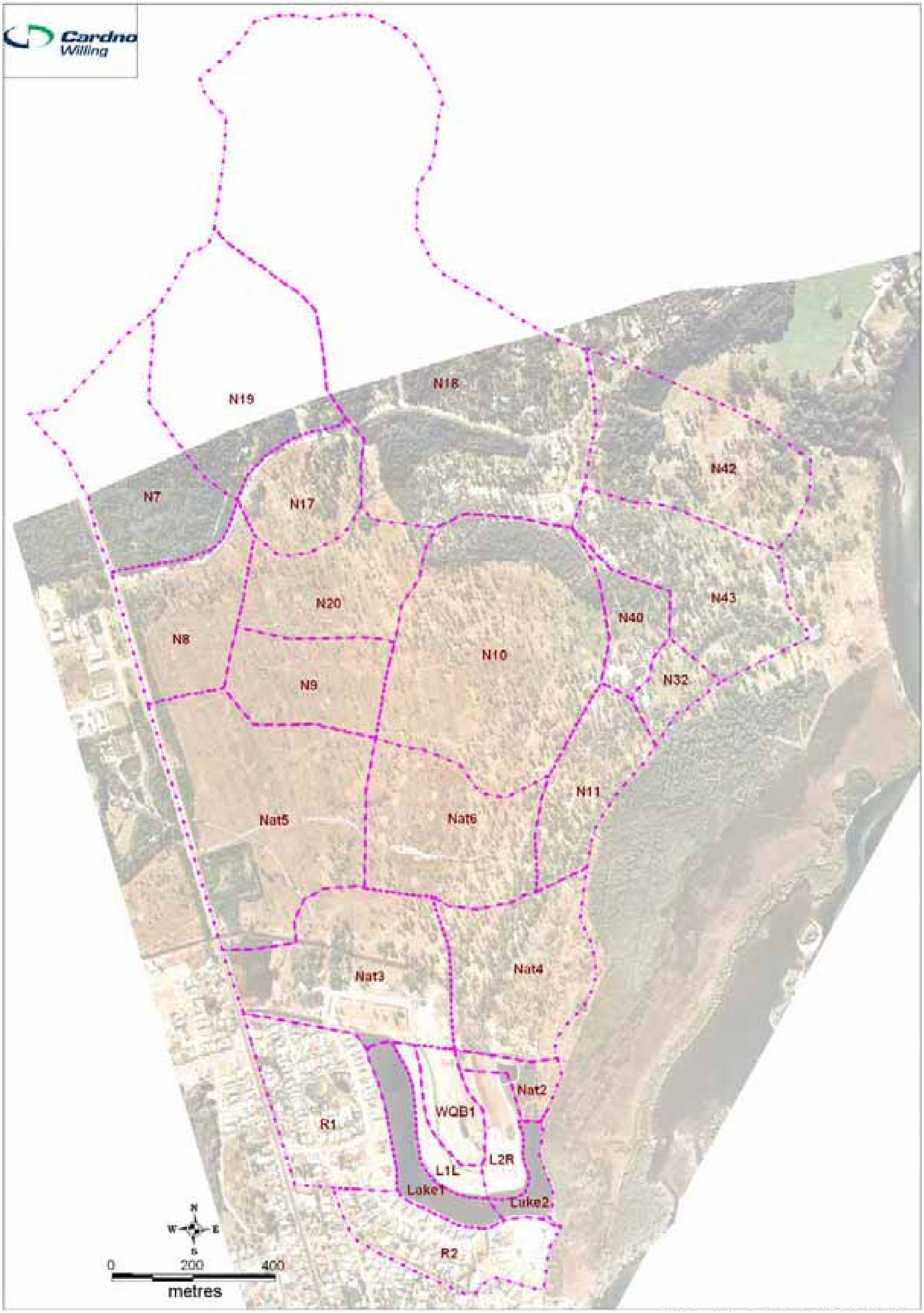

Figure B.1
Catchment Layout - Existing Conditions

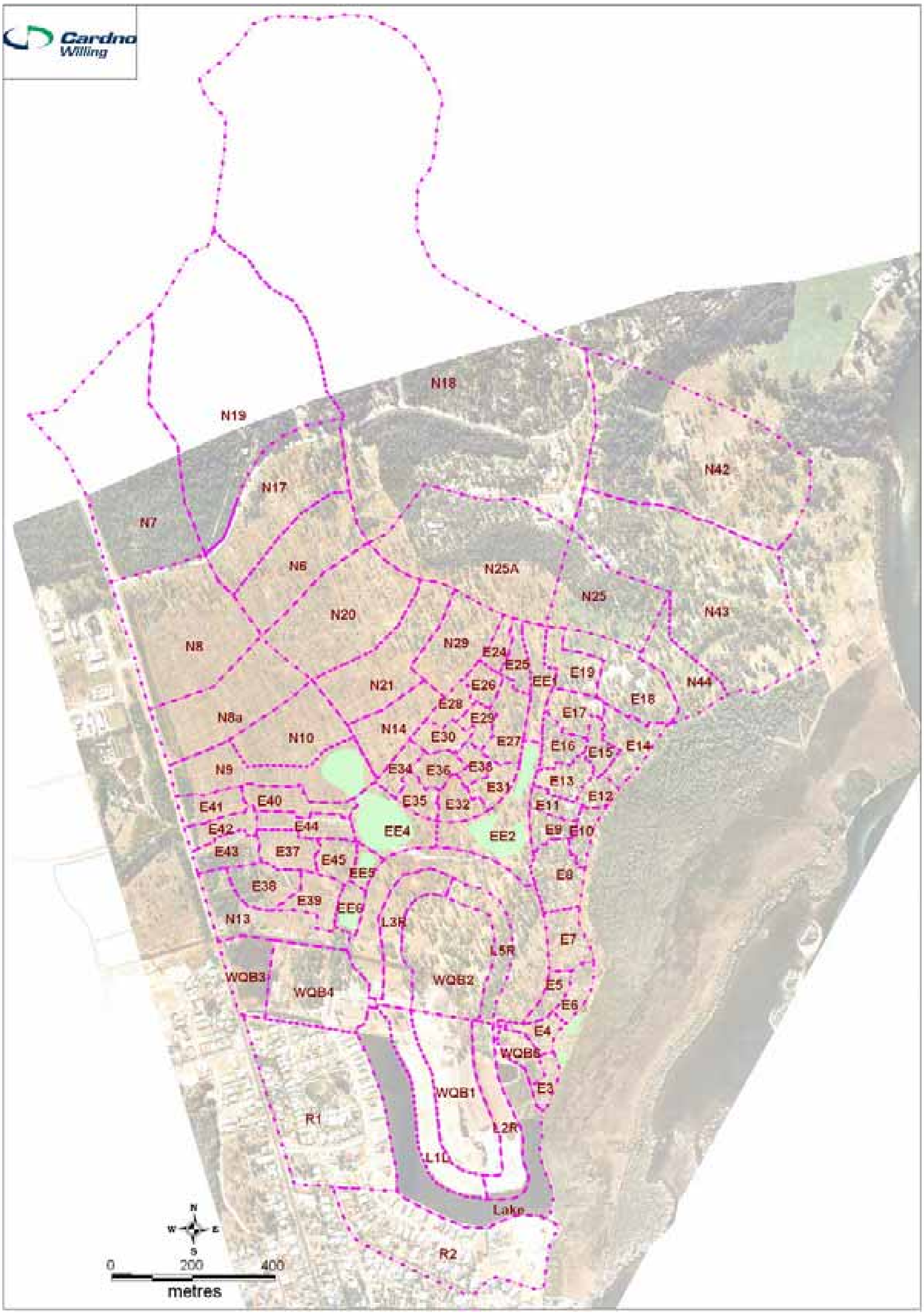

Figure B.2
Catchment Layout – Developed Conditions

Appendix C

Hydraulics

C Hydraulics

C.1 Aims

The aims of the hydraulic analyses were to

- Assemble an **xpswmm** hydraulic model of the main drainage lines under proposed developed conditions with concept water management measures in place; and
- Estimate peak flows and peak flood levels under developed conditions for the 5 yr ARI, 20 yr ARI, 100 yr ARI and PMF events.

C.2 Concept Sizing of Waterways

Prior to assembling an **xpswmm** model of the main drainage lines under the preliminary developed conditions, concept grading and concept sizing of each of the main drainage lines was undertaken. Four main drainage lines were identified. The East Branch, West Branch, North Branch and EastWest Branch drainage lines are identified in **Figure C.1**.

Hydraulic assessments of the sensitivity of maximum channel depth, channel top width and maximum flow velocity were undertaken using spreadsheet models of a single trapezoidal channel.

The adopted properties of the single trapezoidal channel are given in **Figure C.2**.

Each section was subdivided into 22 subsections. The top width, area, wetted perimeter, conveyance, discharge and velocity of flow were calculated for each subsection. The channel capacity was calculated as the sum of the flows in each subsection. The overall channel top width was calculated as the sum of the top widths of each subsection. The overall maximum velocity was the maximum of the velocities calculated for all subsections.

The assumed bed slopes for each reach were guided by the concept grading bed.

The assumed Manning roughness value was an average of 0.065 across all sections ie. some sections of a channel may be lightly vegetated while other sections of the channel may be more heavily vegetated.

Waterways were assessed for the 100 yr ARI event with basins in place.

C.3 Hydraulic Modelling

In this study **xpswmm** was selected to model the proposed Riverside at Tea Gardens development because it is a 1D/2D full unsteady flood routing package that is able to estimate flood levels under conditions of low gradients on floodwaters.

C.3.1 Preliminary Developed Conditions Hydraulic Model

An **xpswmm** hydraulic model was assembled for preliminary Developed Conditions.

The concept layout of waterways, ponds and lakes for preliminary Developed Conditions is given in **Figure C.2.**

The hydraulic model included a number of small ponds, three large ponds, three freshwater lakes and an extension of the detention lake. It also included four main drains and a concept retarding basin located on the EastWest Branch. The active storage available above the extended detention lake, freshwater lakes and ponds was represented as flood storage at selected nodes.

Discharges between freshwater lakes and the freshwater lakes and the extended detention lake was controlled by four land bridges (refer **Figure C.2**). The same concept geometry was adopted for each land bridge. The concept geometry comprises a 2 m wide and 0.3 m deep low flow channel in combination with a 30 m wide flat broad crested weir section. The assumed concept invert levels for the low flow channel and the broad crested weir section are summarised as follows:

	Low Flow Channel Invert Level (m AHD)	Broad Crested Weir Level (mAHD)
Land Bridge A	0.90	1.20
Land Bridge B	0.95	1.25
Land Bridge C	1.0	1.30
Land Bridge D	1.0	1.40

The assumed static water levels in the major ponds and freshwater lakes are summarised as follows (refer **Figure C.2**):

Pond or Lake	Static Water Level (m AHD)
Lake FA	0.80
Lake FA	0.85
Lake FA	0.90
N10	0.95
N10U	1.00

The layout of the **xpswmm** model of preliminary Developed Conditions is shown in **Figure C.3**.

C.3.3 Final Developed Conditions Hydraulic Model

The final Developed Conditions layout evolved from the preliminary layout in response to comments from the DoP, the PAC and other authorities. The preliminary model was adjusted to reflect changes in the planned extent of development and removal of a proposed reach of freshwater lake and its associated land bridge, the removal of the North Branch and the retention of an existing swale. It was found that four ponds proposed in the preliminary scheme could be removed in the upper arms of drainage lines while still meeting the stormwater quality objectives. Two remaining major ponds (N10Pond and E8Pond) were converted into shallow lined wetlands.

Previously, the approach to drainage design in Tea Gardens was to maintain drainage structure outlet levels at or above Mean High Water, at approximately RL 0.5 m AHD. This is reflected in the levels of drainage structures throughout the existing Tea Gardens township, including all existing stages of the Myall Quays estate.

In order to account for the possible impacts of climate change, modifications were made to the preliminary drainage concept for Riverside Estate. The most significant change was to lift the entire site, to ensure that the minimum invert of all new drainage structures in Riverside Estate are at or above the predicted 2100 climate change Mean High Water of 1.4 m AHD. This is to ensure that the drainage system would remain unaffected by tidal waters. In discussions with Great Lakes Council's engineering department, this has been supported as an appropriate response.

The other possible effect of climate change has been to increase flooding levels due to sea level rise and potential increases in rainfall intensities. Revised flood levels across the site have been accounted for in determining landform levels. A direct result of this raising of the drainage network is the raising of the surface levels across the site to provide cover to the pipes. Consequently the majority of the site is already raised above the revised flood levels. Additional lot filling is proposed in any remaining low-lying areas to ensure that all lots remain flood free above the modelled 100 yr flood levels with climate change. It should be noted that finished floor levels will be a minimum of a further 0.3m above this lot fill level.

The **xpswmm** hydraulic model was also modified to reflect the changes to the planned development east of the existing swale which will be retained ie. the possibility of runoff spilling from the swale into the Conservation Zone where previously this flow would have been confined by fill placed to achieve required levels for development.

The concept layout of waterways, ponds, wetlands, swales and lakes under final Developed Conditions is given in **Figure C.4.**

This hydraulic model includes a number of small ponds, two large wetlands, two freshwater lakes and the existing saline lake. It also includes the three main drains and a concept retarding basin located on the EastWest Branch. The active storage available above the extended detention lake, freshwater lakes and wetlands was represented as flood storage at selected nodes.

Discharges between freshwater lakes and the freshwater lakes swales that convey stormwater to the existing saline lake is controlled by three land bridges (refer **Figure C.5**). The same concept geometry was adopted for each land bridge. The concept geometry comprises a 2 m wide and 0.5 m deep low flow channel in combination with a 30 m wide flat broad crested weir section. The assumed concept invert levels for the low flow channel and the broad crested weir section which were adopted based on consideration of possible future climate change conditions where river levels could increase to 1.4 m AHD are summarised as follows:

	Low Flow Channel Invert Level (m AHD)	**Broad Crested Weir Level (mAHD)**
Land Bridge C	1.6	2.1
Land Bridge D	1.7	2.2
Land Bridge E	1.6	2.1

The assumed static water levels in the major wetlands and freshwater lakes under current conditions and under possible climate change conditions are summarised as follows (refer **Figure C.5**):

	Static Water Level (m AHD)	
Lake or Wetland	**Current Conditions**	**Under Climate Change**
FLake 1 (unlined)	1.1	1.4
FLake 2 (unlined)	0.9	1.4
N10Wet (lined)	1.68	1.68
E8Wet (lined)	1.70	1.70

C.4 Results

C.4.2 Preliminary Scheme Results

The **xpswmm** model of preliminary Developed Conditions was run to estimate the 5 yr ARI, 20 yr ARI and 100 yr ARI peak flows and basin water levels. Based on the outcomes of the hydrological analysis the **xpswmm** model was run for both the 1.5 hour and 9 hour storm durations.

The estimated peak outflows from the extended detention lake in the 5 yr ARI, 20 yr ARI and 100 yr ARI events are summarised in **Table C.1.**

Table C.1
Estimated Peak Outflows from the Extended Detention Lake under Preliminary Developed Conditions

5 yr ARI	20 yr ARI	100 yr ARI	Comment
3.47 *(0.83)*	7.17 *(0.96)*	12.57 *(1.09)*	Outflow from the extended detention lake

Note: The estimated peak basin water level (in m AHD) is reported in brackets

C.4.3 Final Scheme Results

The **xpswmm** model of final Developed Conditions was also run to estimate the 5 yr ARI, 20 yr ARI and 100 yr ARI peak flows and basin water levels. The **xpswmm** model was run for both the 1.5 hour and 9 hour storm durations.

The estimated peak outflows from the swale and the existing extended detention lake in the 5 yr ARI, 20 yr ARI and 100 yr ARI events are summarised in **Table C.2.**

Table C.2
Estimated Peak Outflows from the Swale and Existing Saline Lake under Final Scheme

5 yr ARI		**20 yr ARI**		**100 yr ARI**	
1.5 hr	9 hr	1.5 hr	9 hr	1.5 hr	9 hr
2.4	5.0	4.7	8.6	9.3	13.3

The estimated 5 yr ARI, 20 yr ARI and 100 yr ARI flood levels under 1.5 hour and 9 hour storm bursts under current conditions are presented spatially in **Figures C.6** to **C.11.**

The estimated 100 yr ARI flood levels under 1.5 hour and 9 hour storm bursts with possible climate change conditions (based on a 30% increase in rainfall intensities) are presented spatially in **Figures C.12** and **C.13**.

C.4.4 PMF Results

Riverside at Tea Gardens is subject to flooding from both the Myall River and from runoff from the local catchment. An assessment of the PMF levels under river and local flooding (without climate change) was undertaken at the request of the NSW Department of Planning and was reported in November 2008 (refer **Appendix H**).

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

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.

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.

The local PMF levels under final developed Conditions are presented spatially in **Figures C.14** and **C.15** for the 30 minute and 1 hour PMP storms respectively.

It was also 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 slightly lower PMF levels.

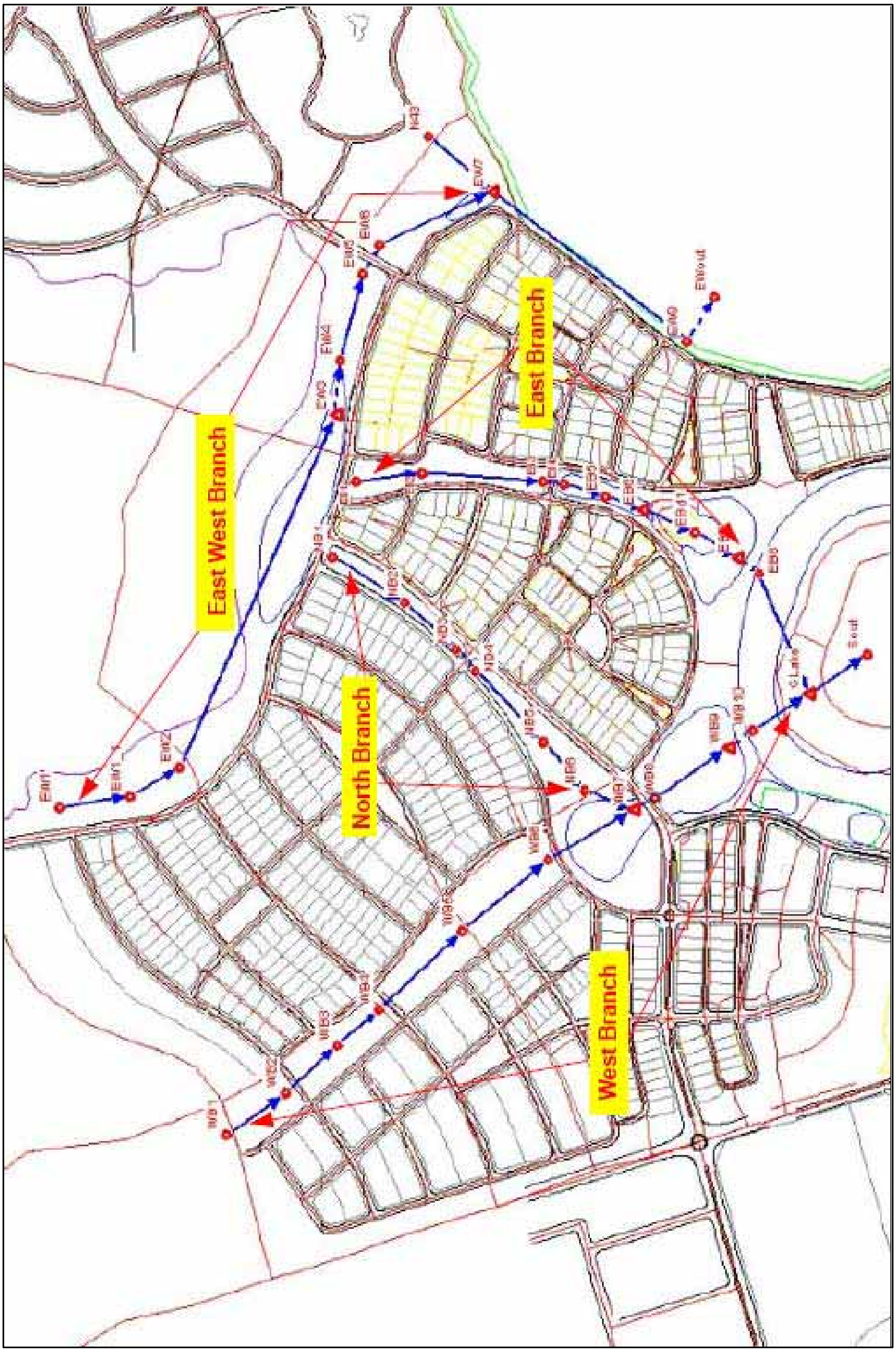

Figure C.1
Location of Preliminary Drainage Lines

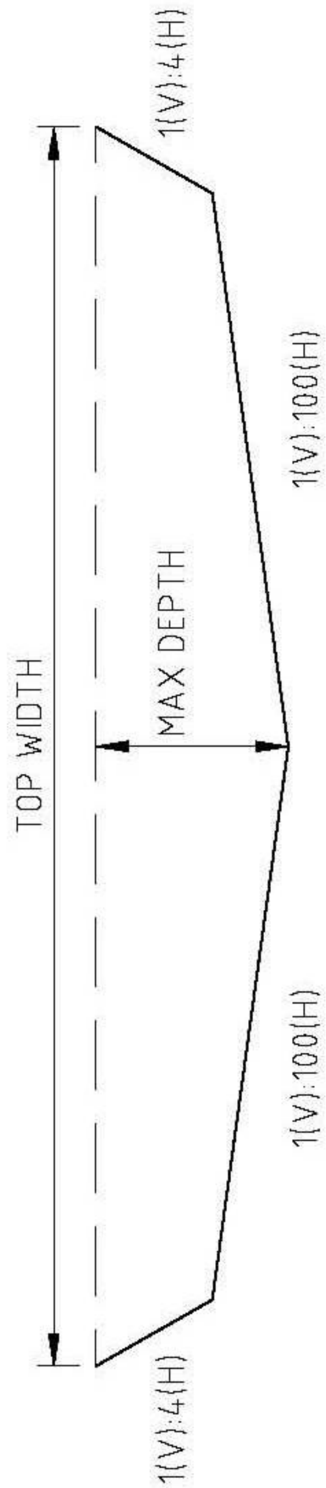

Figure C.2
Concept Waterway Geometry

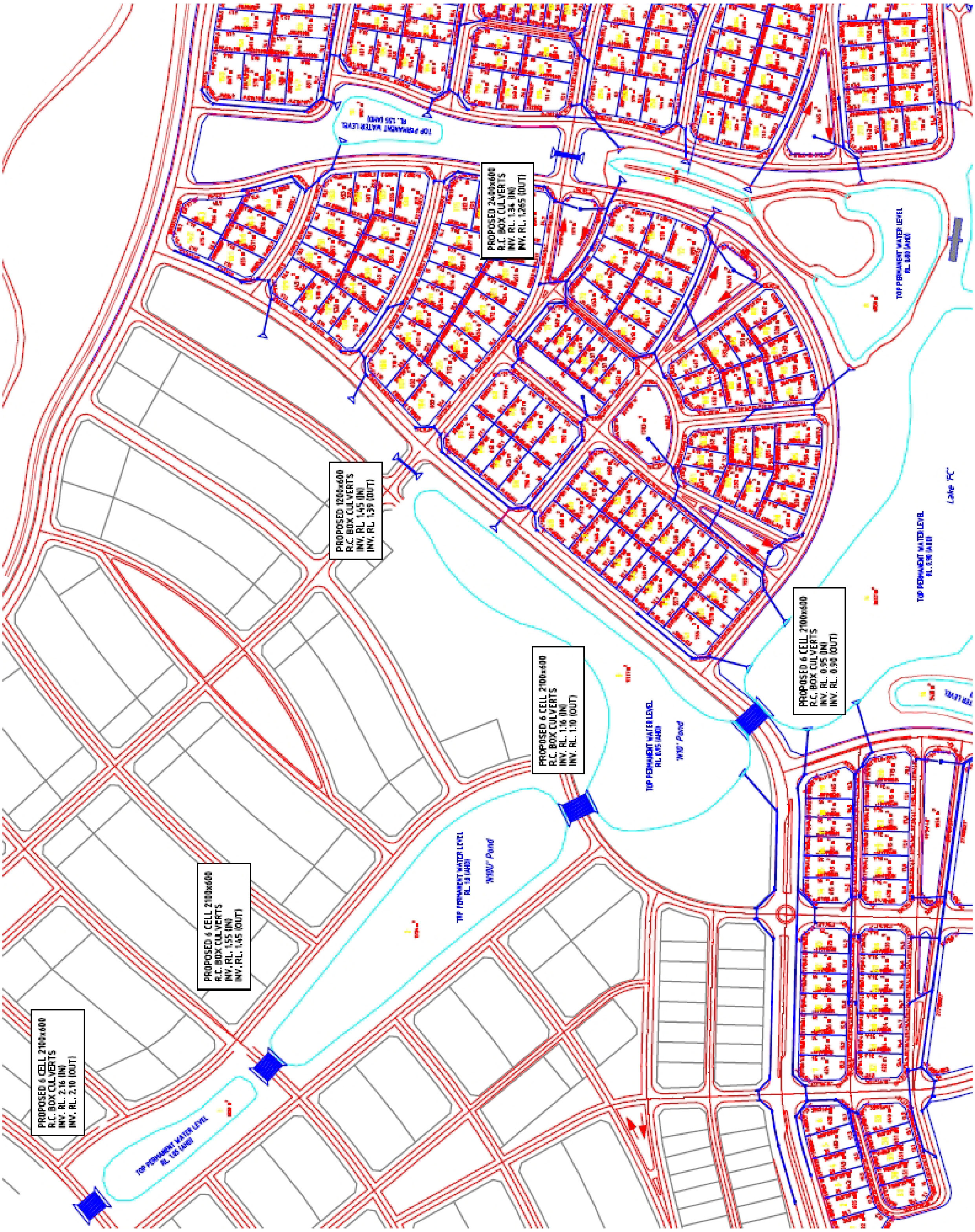

Figure C.3 (a)
Concept Layout and Crossing Details for Preliminary Concept Development

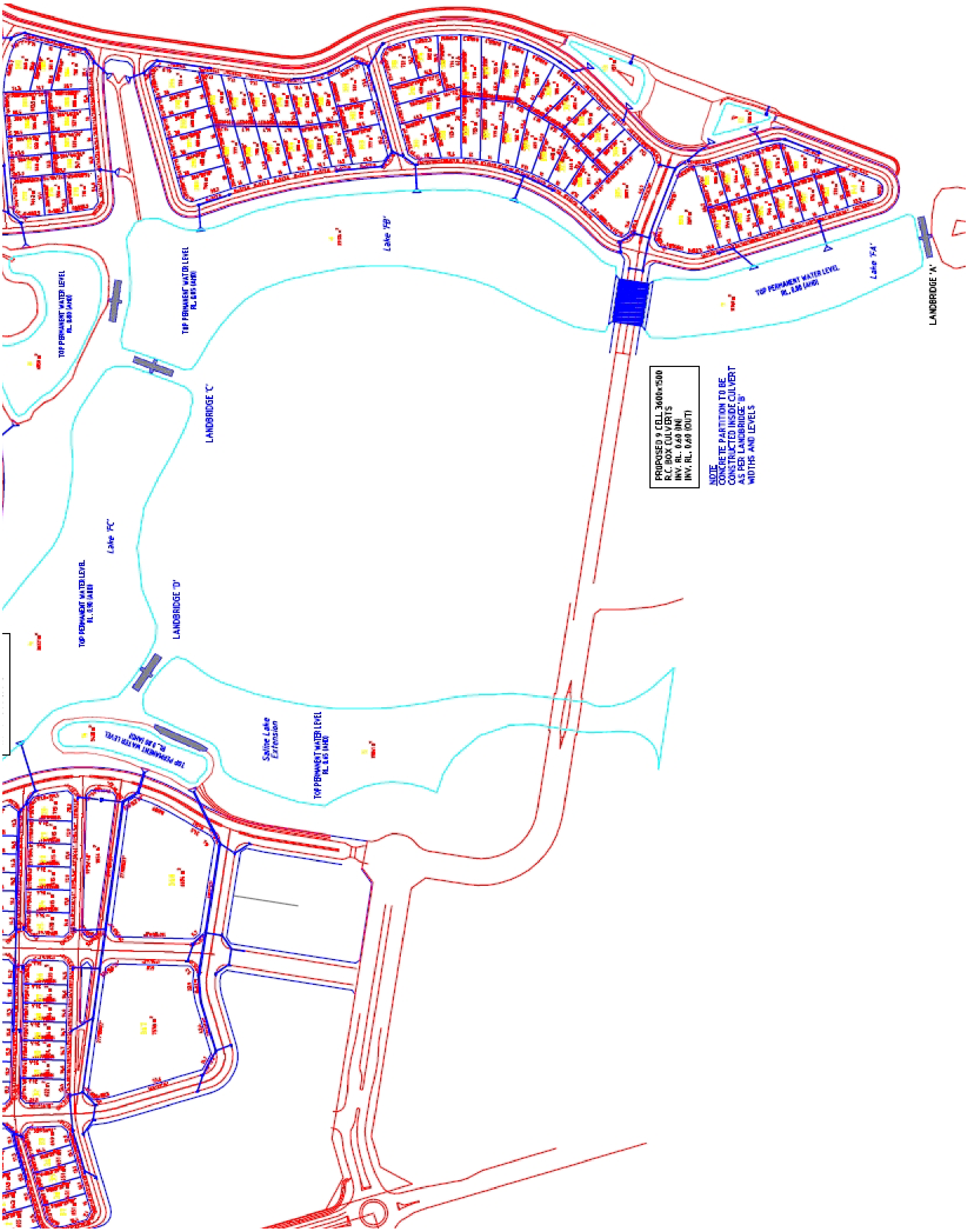

Figure C.3(b)
Concept Layout and Crossing Details for Preliminary Concept Development

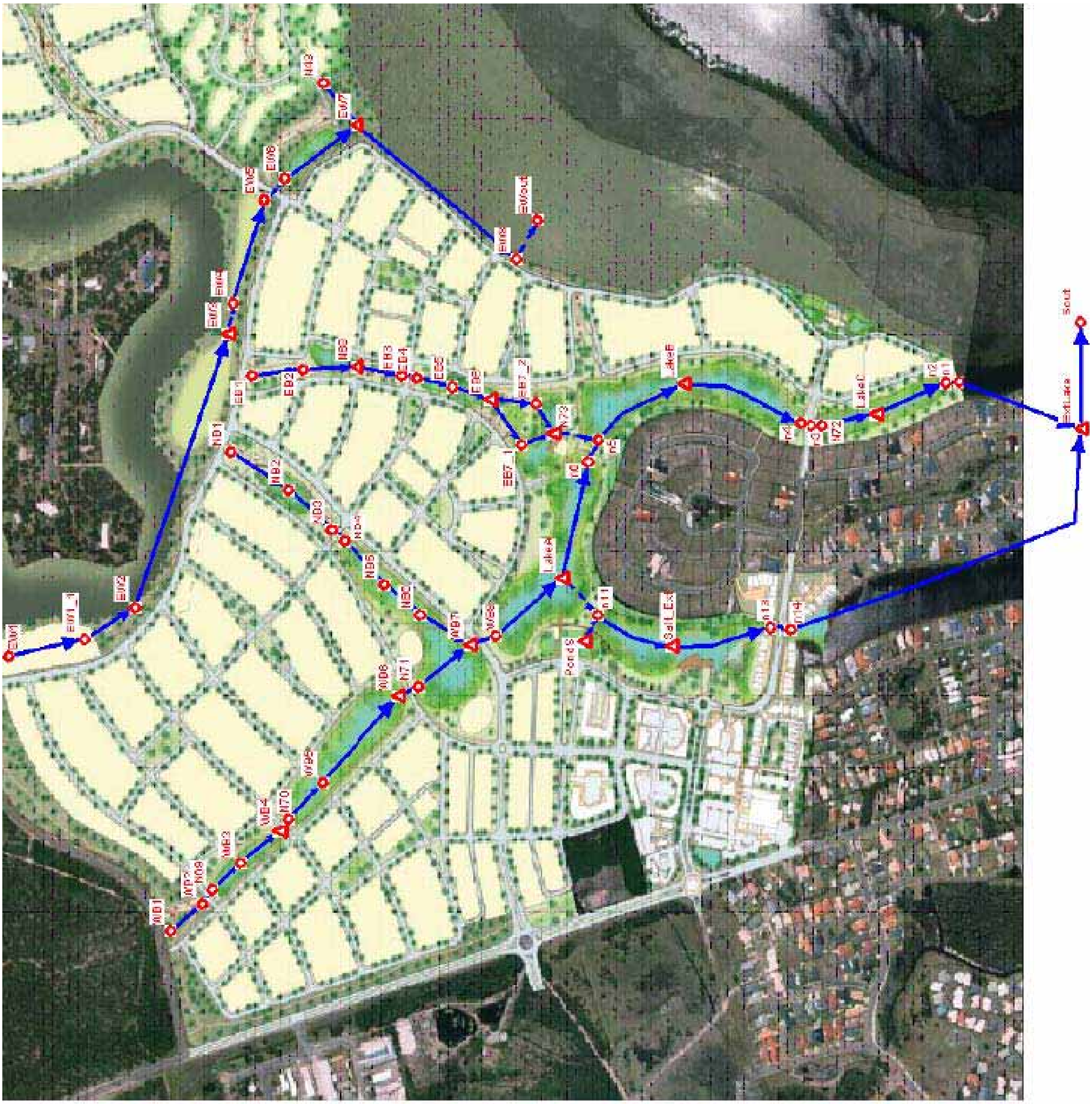

Figure C.4
Preliminary Hydraulic Model Layout

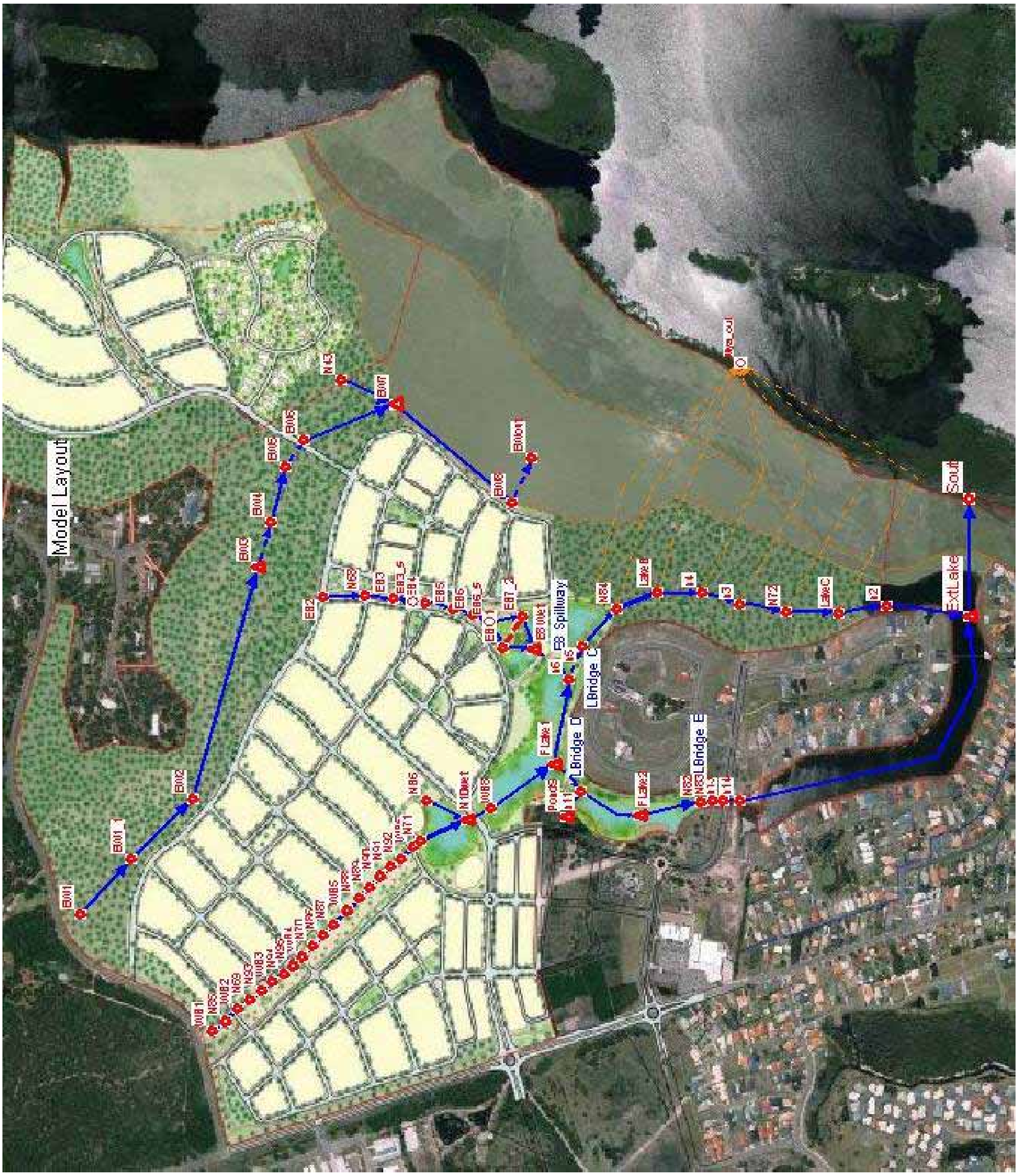

Figure C.5
Final Hydraulic Model Layout

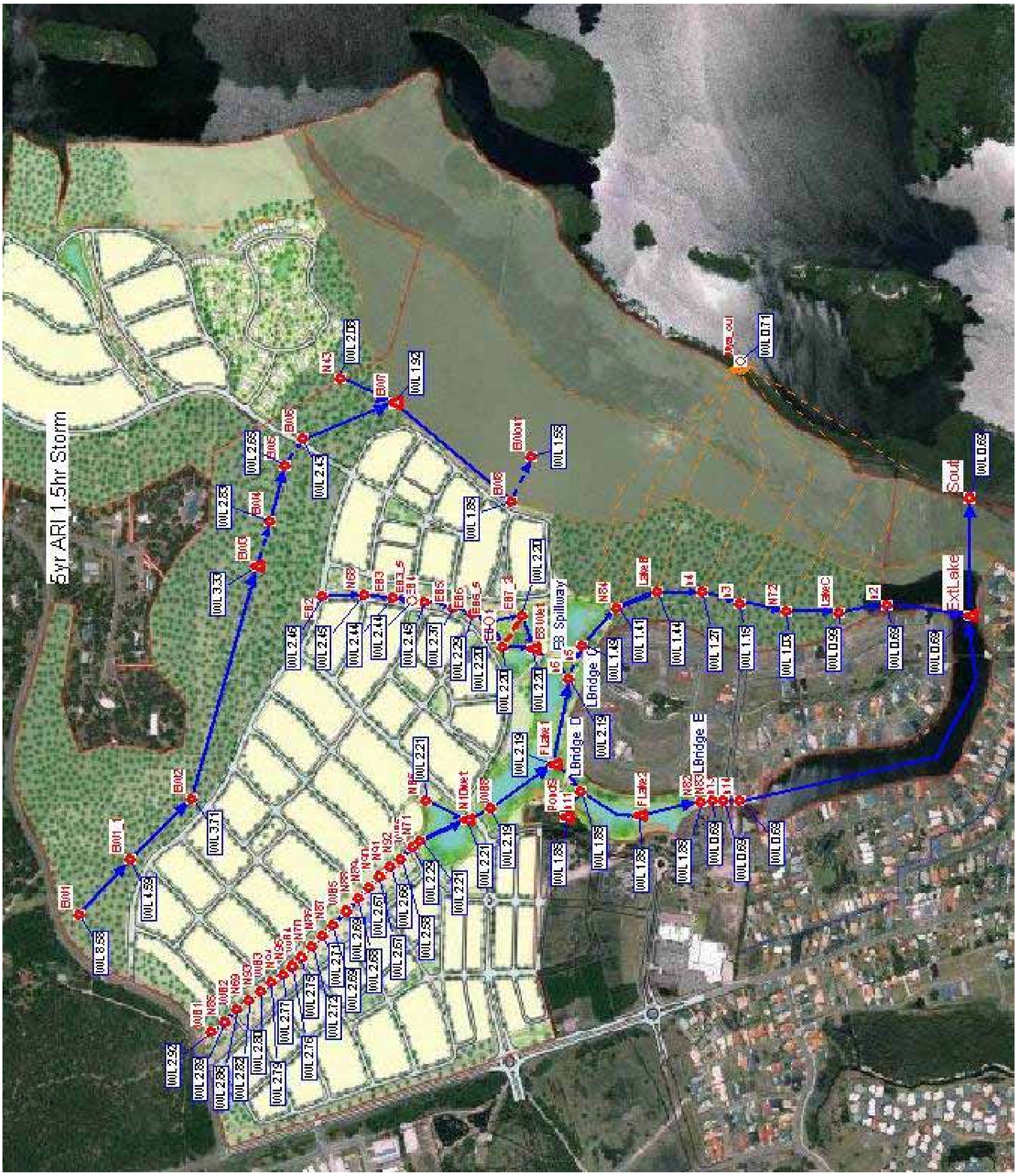

Figure C.6
5 yr ARI Peak Flows and Flood Levels for 1.5 hour Storm Burst – Final Scheme

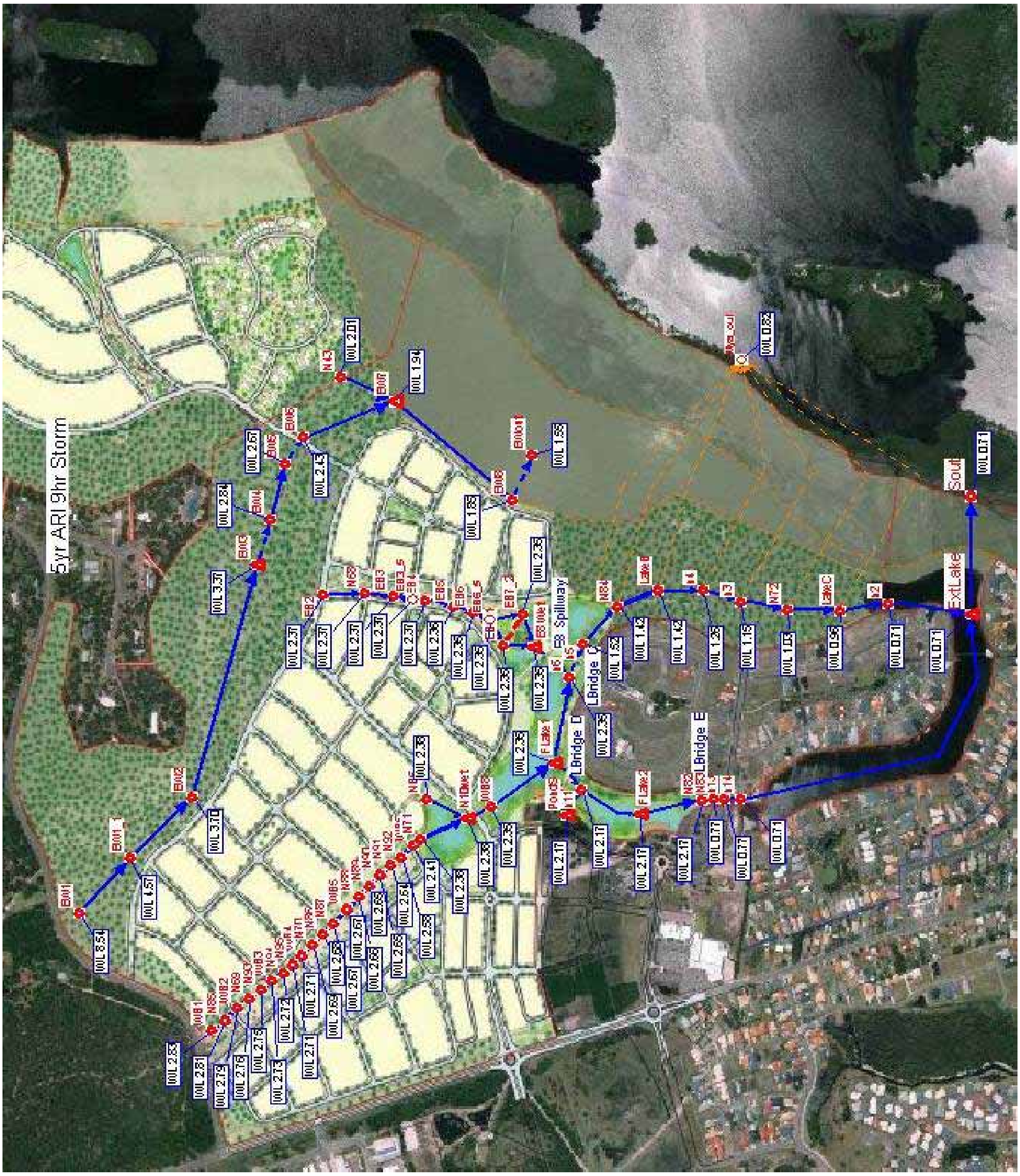

Figure C.7
5 yr ARI Peak Flows and Flood Levels for 9 hour Storm Burst – Final Scheme

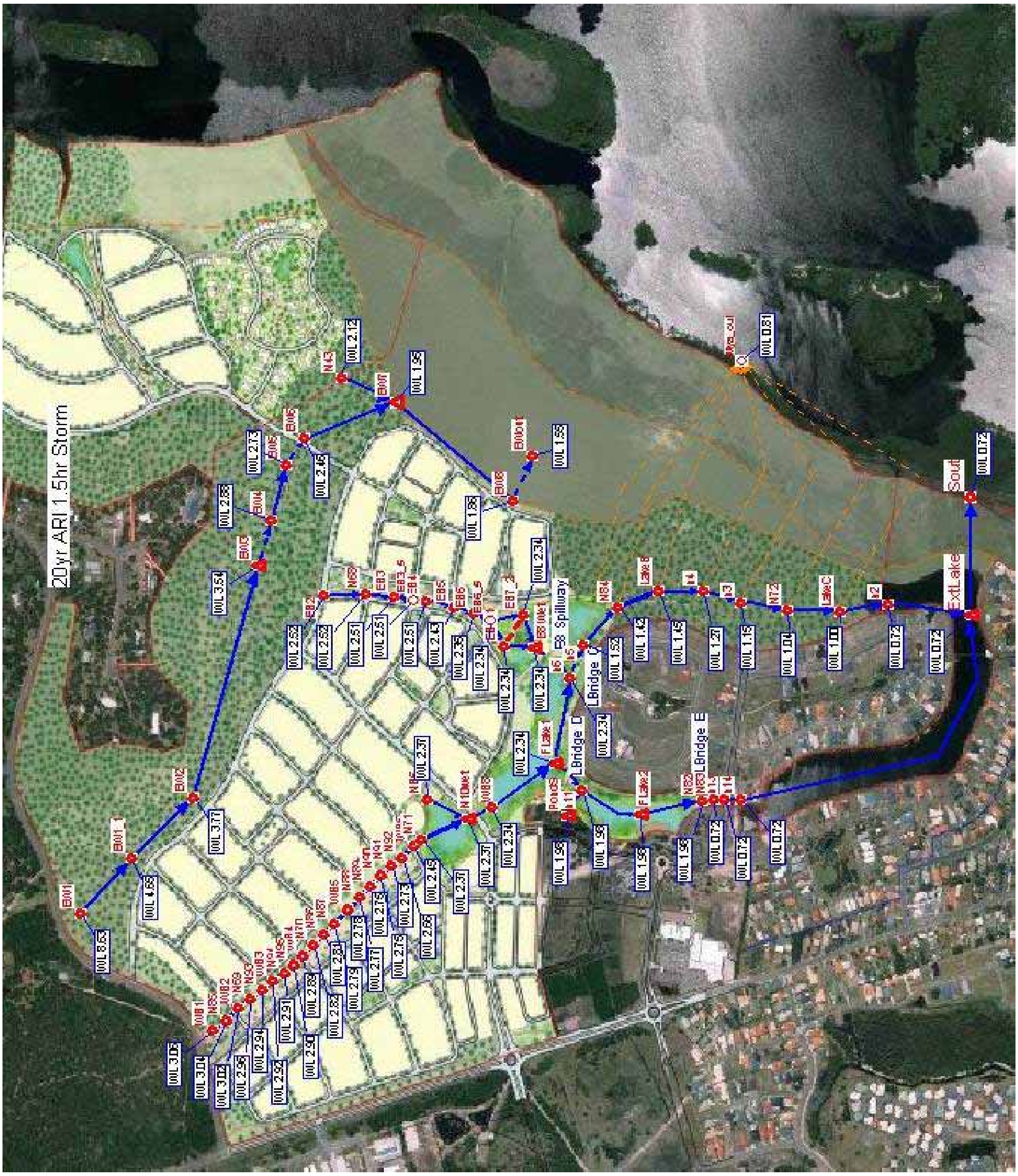

Figure C.8
20 yr ARI Peak Flows and Flood Levels for 1.5 hour Storm Burst – Final Scheme

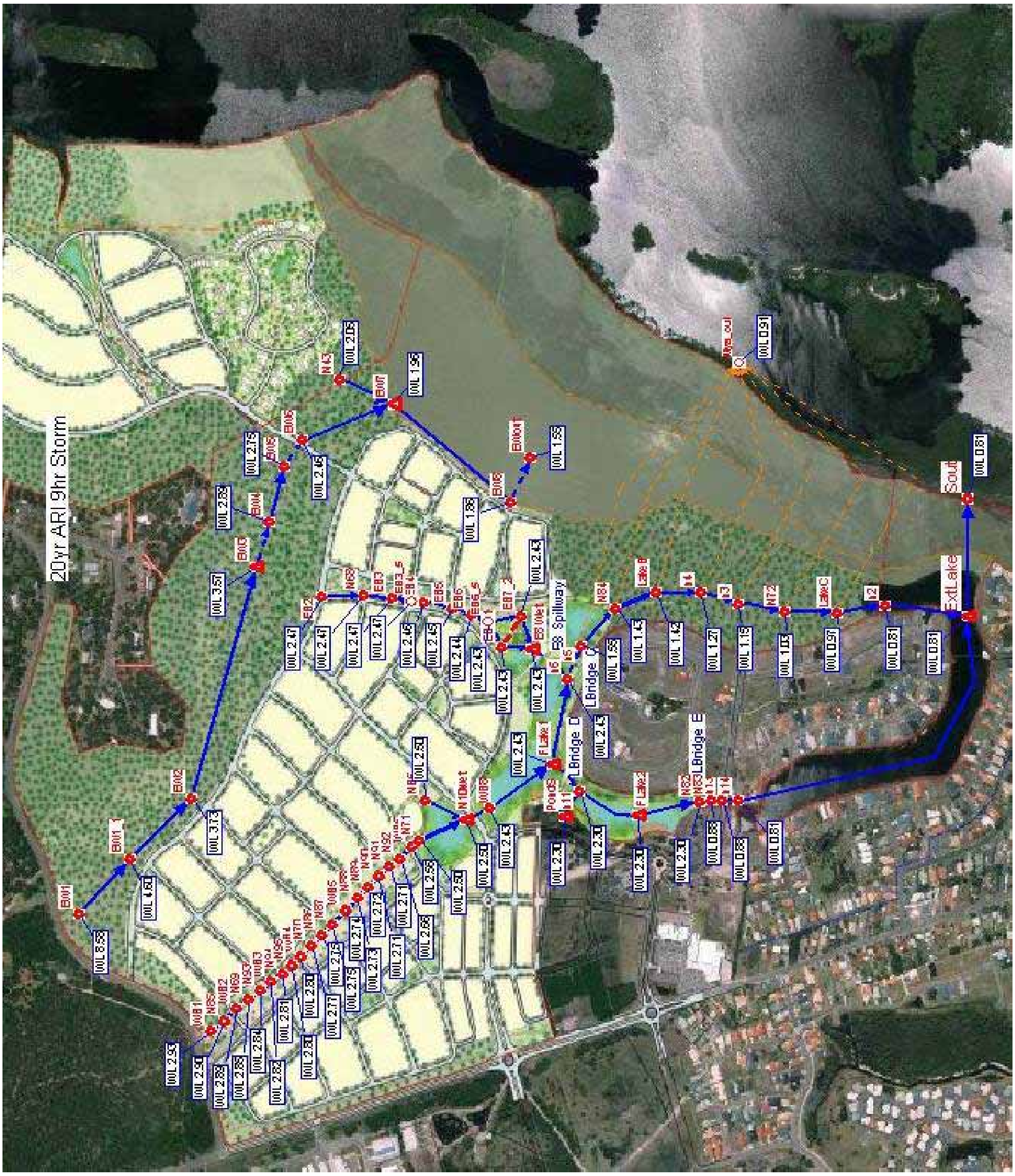

Figure C.9
20 yr ARI Peak Flows and Flood Levels for 9 hour Storm Burst – Final Scheme

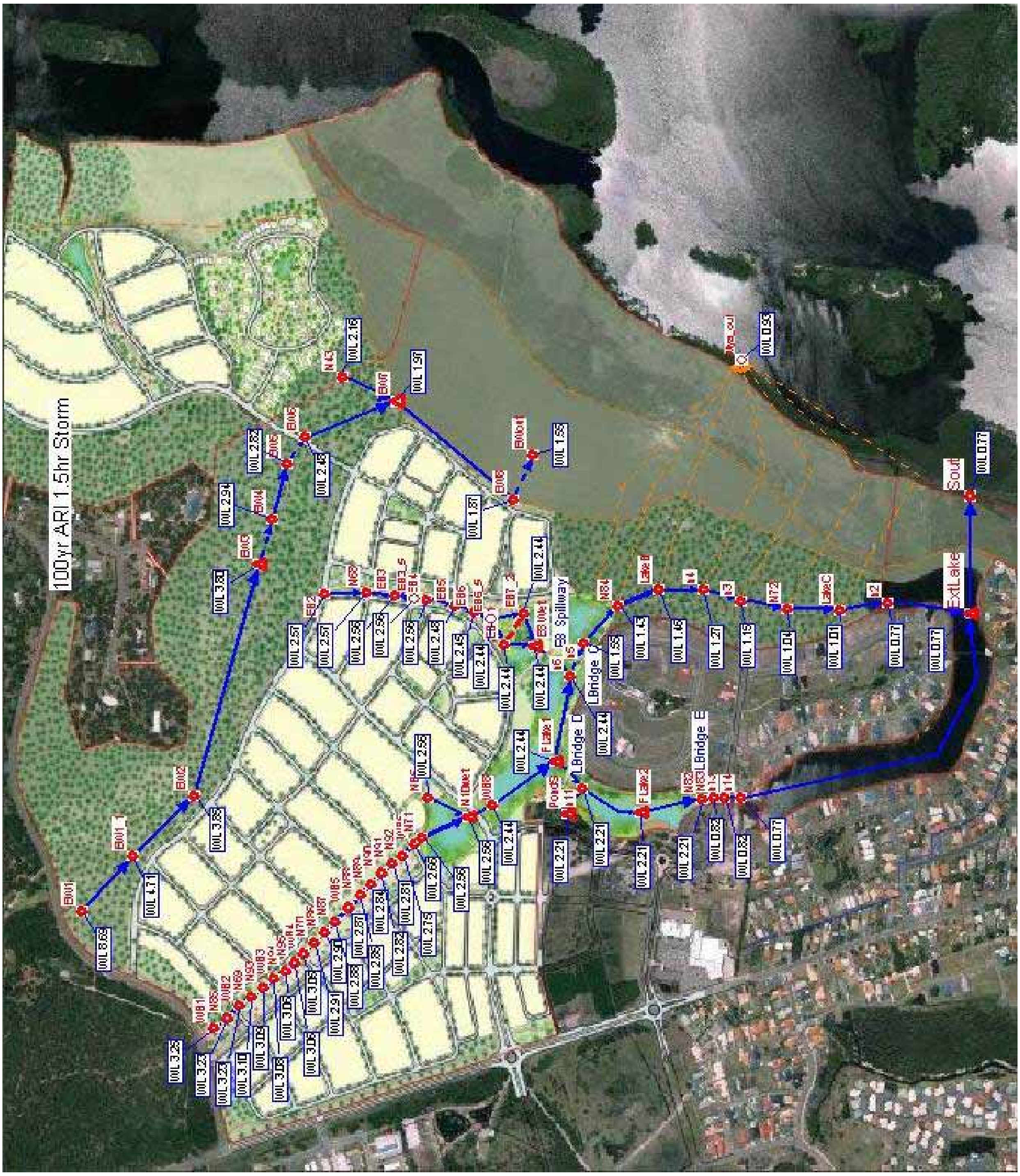

Figure C.10
100 yr ARI Peak Flows and Flood Levels for 1.5 hour Storm Burst – Final Scheme

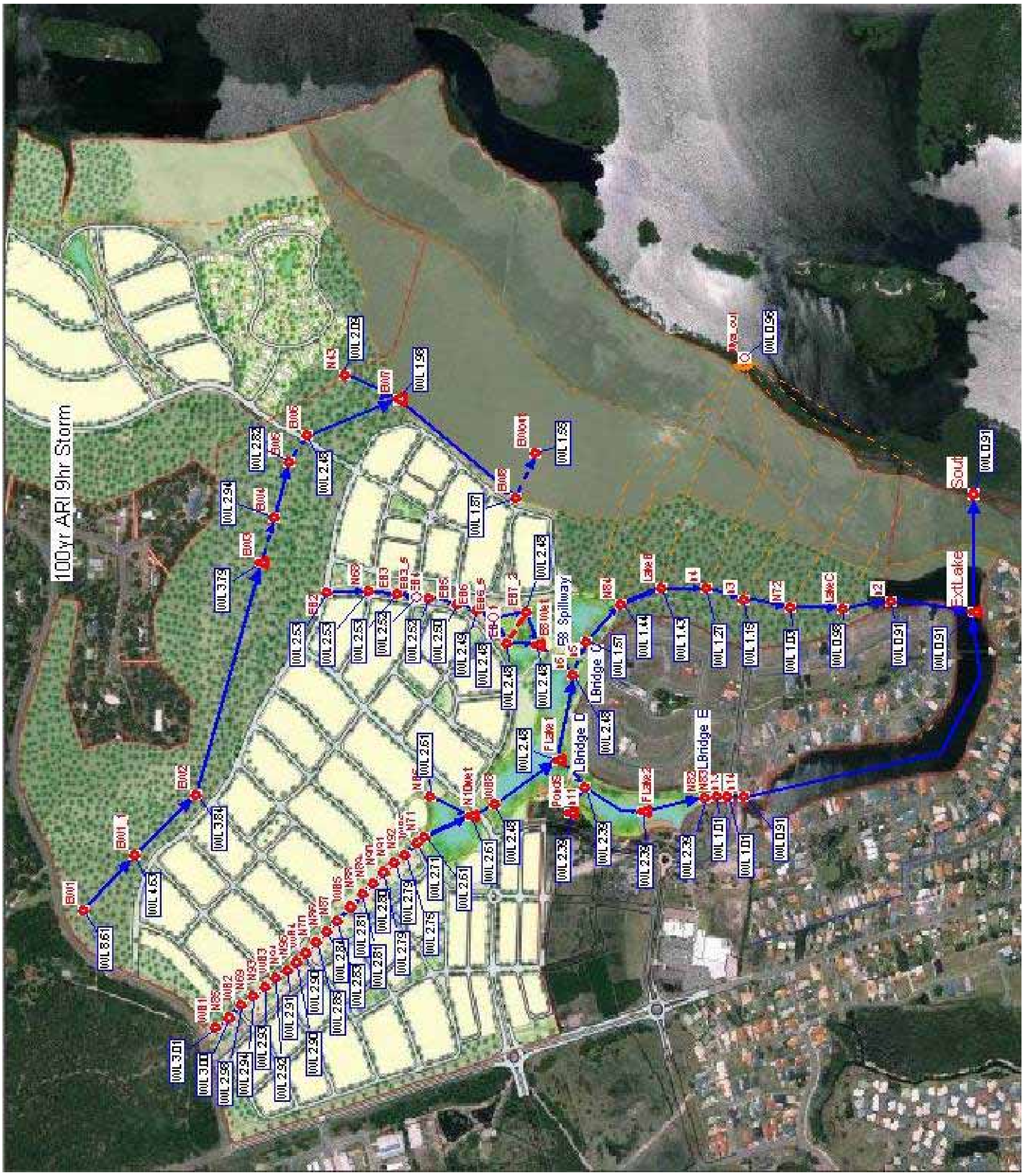

Figure C.11
100 yr ARI Peak Flows and Flood Levels for 9 hour Storm Burst – Final Scheme

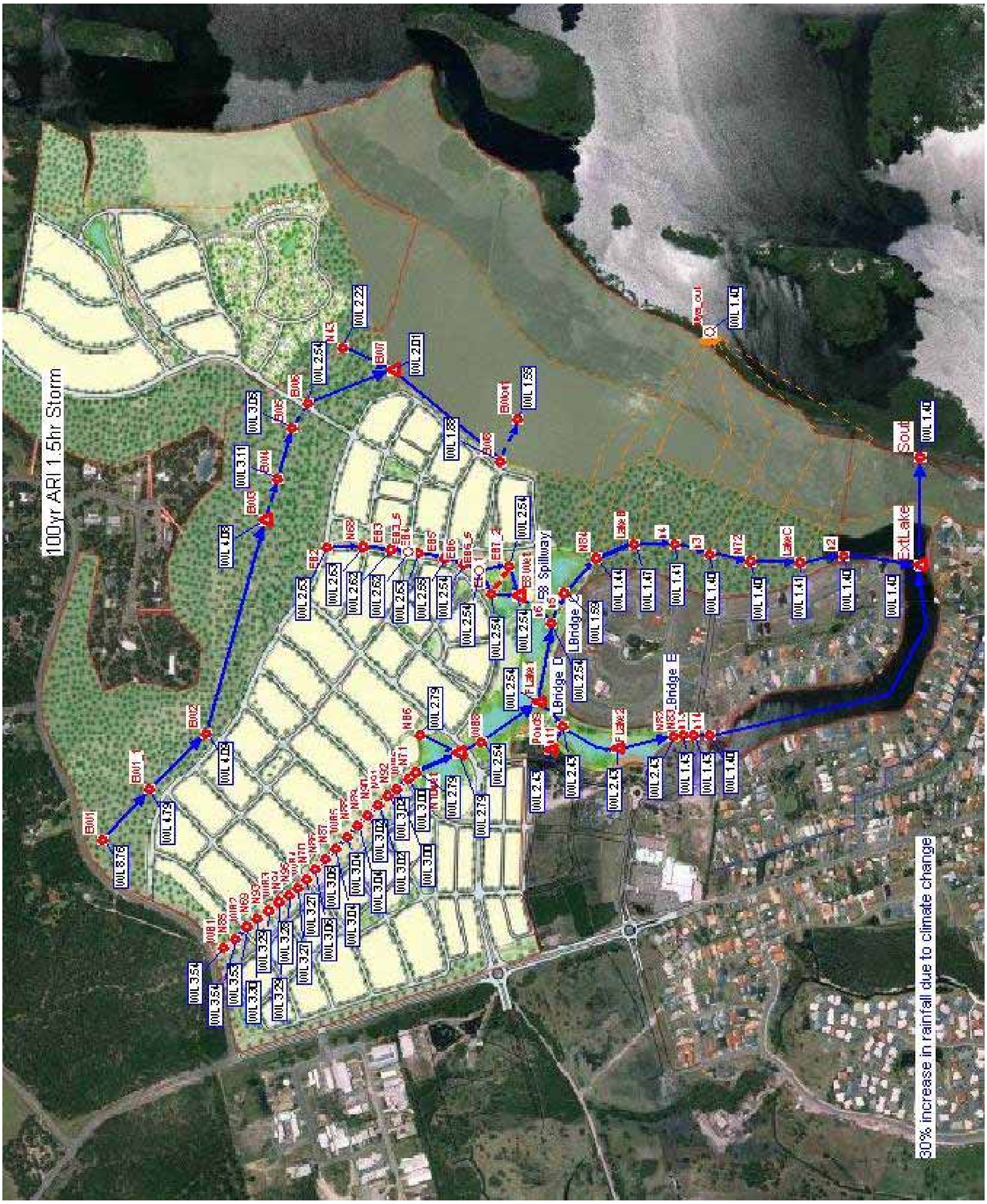

Figure C.12
100 yr ARI Peak Flows and Flood Levels for 1.5 hour Storm Burst under Climate Change - Final Scheme

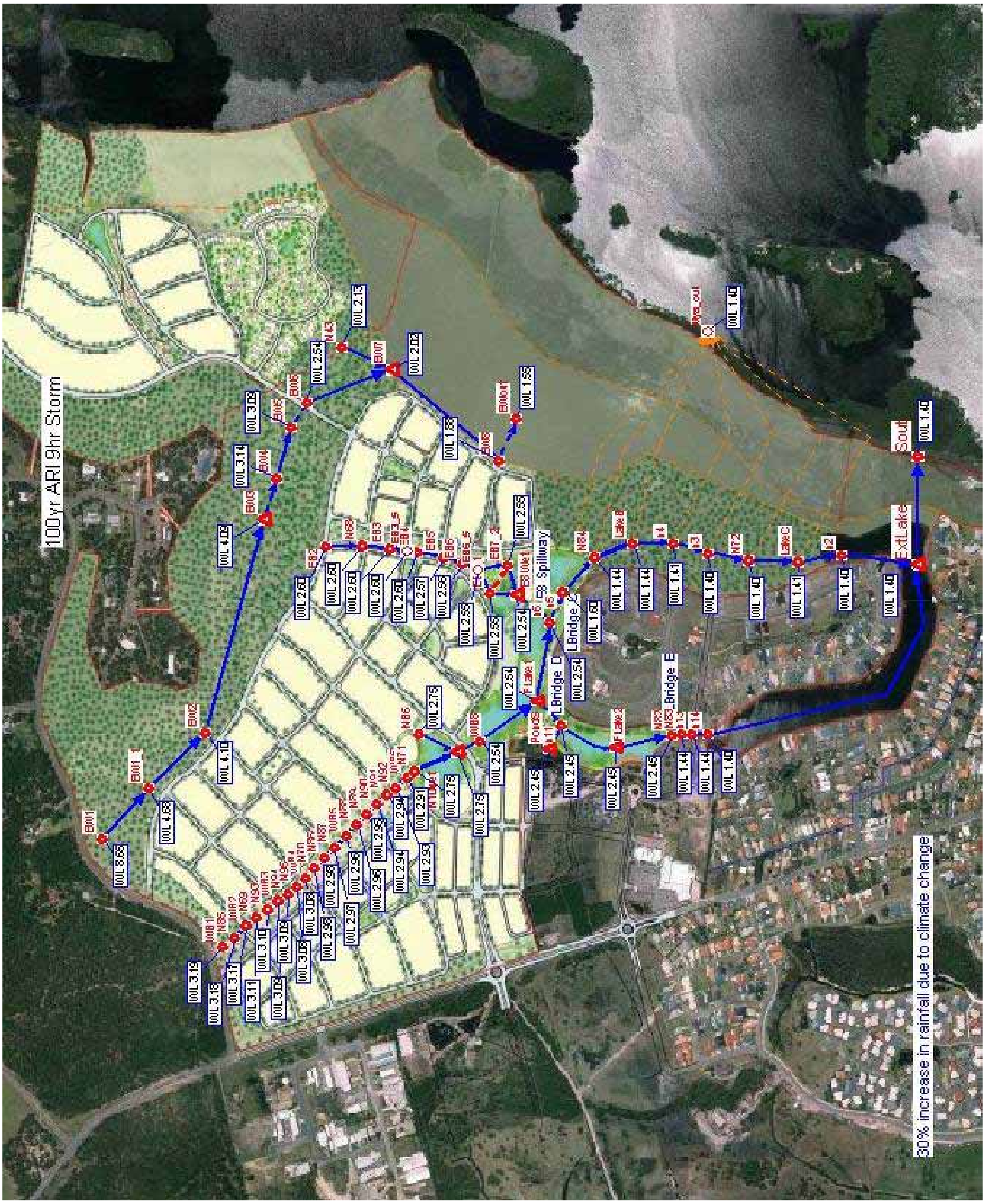

Figure C.13
100 yr ARI Peak Flows and Flood Levels for 9 hour Storm Burst under Climate Change - Final Scheme

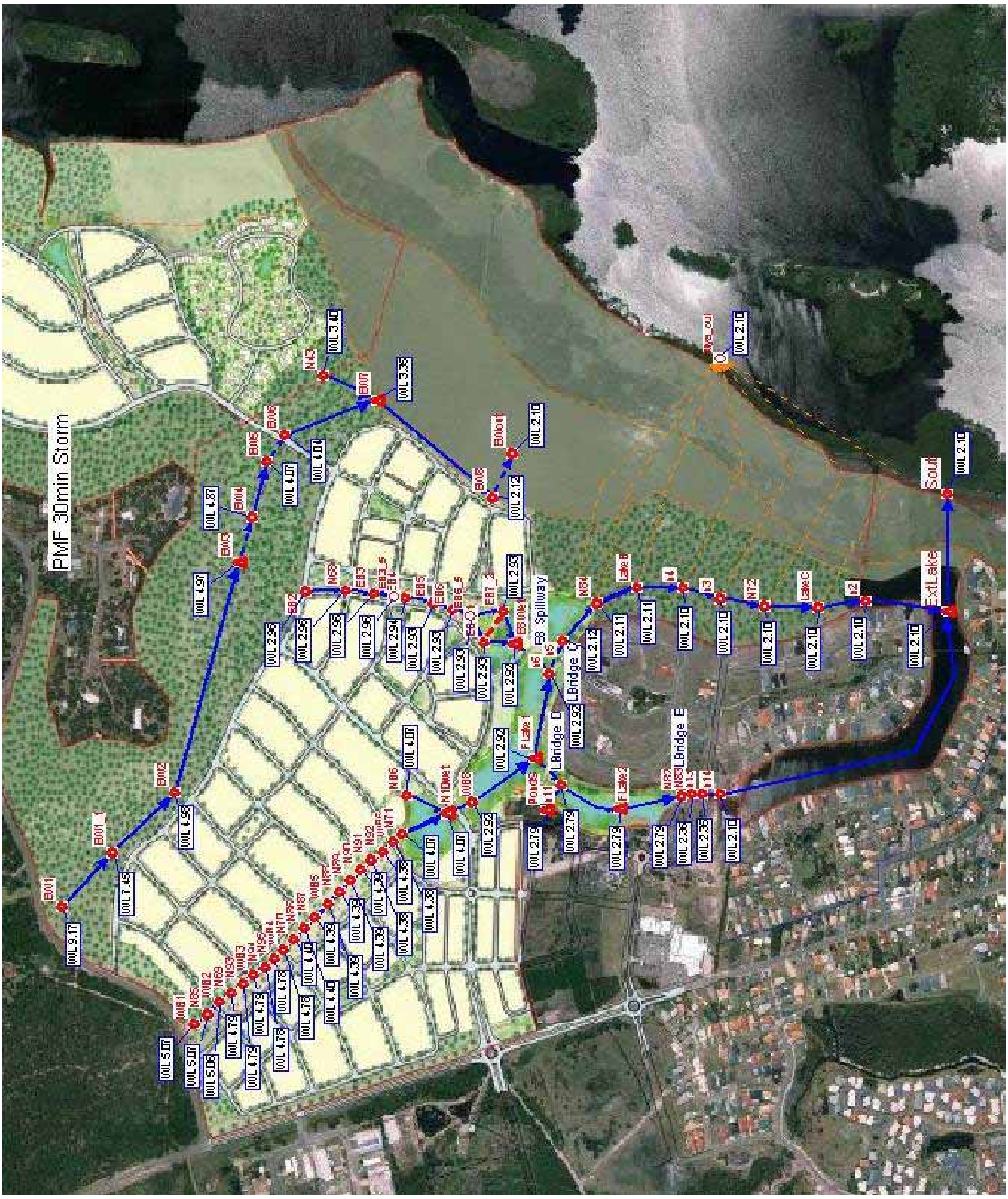

Figure C.14
Local PMF Levels for 30 minute PMP Storm – Final Scheme

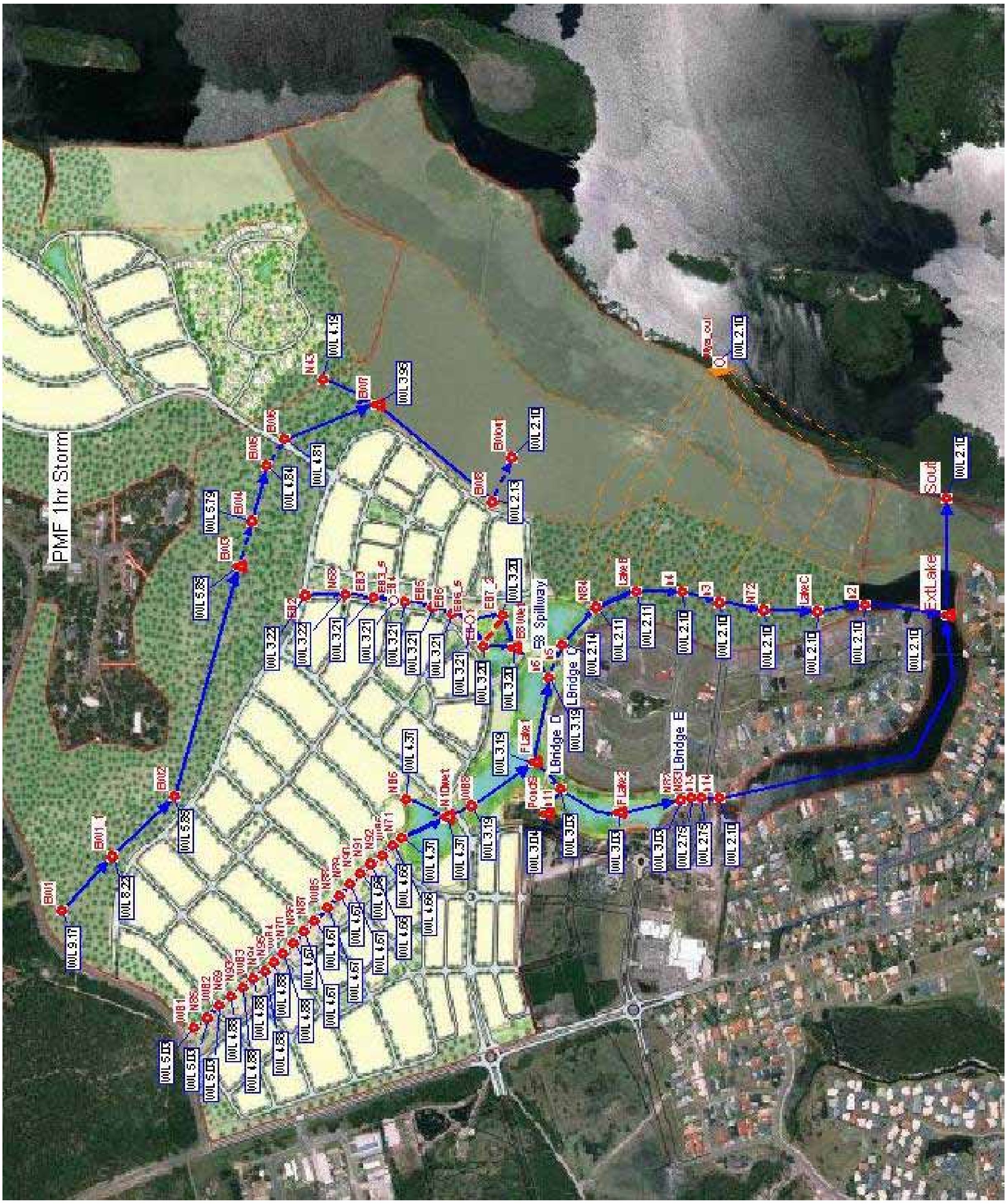

Figure C.15
Local PMF Levels for 1 Hour PMP Storm – Final Scheme

Appendix D

Catchment Water Quality Modelling

D Catchment Water Quality Management

D.1 Aims

The aims of the catchment based water quality modelling were to:

- Create MUSIC models of the Pre-existing and Existing conditions based on the approaches adopted in 2004 catchment based water quality (**xpaqualm**) assessments;
- "Calibrate" the MUSIC model parameters against the unit area results previously calculated using the **xpaqualm** model(s);
- Estimate catchment exports under the Pre-existing and Existing conditions for input into models of the Pre-existing detention lake and Existing detention lake;
- Create MUSIC models of the proposed preliminary and final concept development with and/or without rainwater tanks and run the generate for inputs into the lake model; and
- Create a MUSIC model of a possible change scenario and assess the performance of the final concept development.

D.2 Rainfall and Evaporation

D.2.1 Existing Rainfall and Evaporation

Daily rainfall data used for the analysis was obtained from the Bureau of Meteorology station at Hawks Nest (Langi St) [Station 60123]. Although some daily rainfall data is available for the study catchment it does not yet cover a sufficiently long period.

The data covers daily rainfall record (March 1981 – 2004). The average annual rainfall recorded at Hawks Nest over 22 years (1982-2003) is 1,399 mm. In comparison, the long term (104 years) average annual rainfall recorded at Nelson Bay (Nelson Head) (Stn 06154) is 1,347 mm.

For the purposes of catchment based water quality modelling, the MUSIC models representing the pre-existing, existing, and developed conditions were run from 1/01/1982 to 31/05/2004 inclusive. The rainfall data was applied uniformly over the Riverside at Tea Gardens catchments.

Table D.1 summarises the recorded annual rainfall for the period 1/01/1982 to 31/05/2004. The average rainfall year is 1989 (1,372 mm), the 10% dry year is 1996 (1,068 mm), and the 90% wet year is 2001 (1,712 mm).

Pan evaporation data was adopted from a previous catchment based water quality modeling for Myall River Downs west of Riverside at Tea Gardens. The evaporation data adopted for the Myall River Downs assessment were average monthly pan evaporation collected at Williamstown Air Base. An evaporation multiplier of 0.85 was applied to the pan evaporation data to calculate the potential evapotranspiration (PET) for the catchments.

The adopted average monthly potential evapotranspiration (PET) for Tea Gardens is summarised in **Table D.2**.

Table D.1
Annual Rainfall at Hawks Nest (Langi St) (Station 060123)

year	Rainfall (mm)	Comment
1982	1660	
1983	1289	
1984	1210	
1985	1484	
1986	1092	
1987	1292	
1988	1571	
1989	1372	Average year
1990	2524	
1991	1116	
1992	1543	
1993	918	
1994	1184	
1995	1134	
1996	1068	10^{th} %tile (dry) year
1997	1524	
1998	1760	
1999	1670	
2000	1076	
2001	1712	90^{th} %tile (wet) year
2002	1187	
2003	1385	
1/01 – 31/05/2004	503	5 months only

Table D.2
Average Monthly PET for Tea Gardens

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Year**
PET	182	150	132	97	69	66	66	93	127	148	166	193	1488

D.2.2 Possible Rainfall and Evaporation in Year 2100

The approach adopted to create a climate change adjusted rainfall sequence for the same period as previously modelled was to subtract 2.8 mm from each day of rainfall and to then increase all remaining rainfall by 11.5%.

As indicated in **Table D.3** this gave an average decrease of 10% in annual rainfall. The seasonal changes for Summer (December, January, February), Autumn (March, April, May), Winter (June, July, August) and Spring (September, October, November) are also summarised in **Table D.3.** This approach also gave a decrease in the average number of rain days per year (from 122.3 days to 81.2 days).

The potential evapo-transpiration (PET) was increased uniformly by 9.0%.

The ramifications for the frequency of rainfall are summarised in **Table D.4.**

Table D.3 Potential Impacts of Climate Change on Seasonal Rainfall, Number of Raindays and PET for Tea Gardens

	Summer	Autumn	Winter	Spring	Annual
Rainfall (mm)					
No CC	303.1	470.9	362.2	262.6	1398.7
With CC	266.8	432.5	321.3	236.3	1257.0
Difference	*-12.0%*	*-8.2%*	*-11.3%*	*-10.0%*	*-10.1%*
Raindays					
No CC	27.2	36.2	31.5	27.4	122.3
With CC	17.5	24.5	22.0	17.2	81.2
Difference (days)	*-9.7*	*-11.7*	*-9.5*	*-10.2*	*-41.1*
PET (mm)					
No CC	525.2	298.1	225.0	440.7	1488.9
With CC	572.4	324.9	245.3	480.3	1623.0
Difference	*9.0%*	*9.0%*	*9.0%*	*9.0%*	*9.0%*

Table D.4 Potential Impacts of Climate Change on Rainfall Frequency

% Time Exceeded	No CC	With CC	Change
90%	0	0	
80%	0	0	
70%	0	0	
60%	0	0	
50%	0	0	
40%	0	0	
30%	0.6	0.0	-100%
20%	3.8	1.1	-71%
18%	4.8	2.2	-54%
16%	6.0	3.6	-41%
14%	7.2	4.9	-32%
12%	9.0	6.9	-23%
10%	11.0	9.1	-17%
8%	14.6	13.2	-10%
6%	18.6	17.6	-5%
4%	25.4	25.2	-1%
2%	38.4	39.7	3%
1%	57.0	60.4	6%
0.5%	71.0	76.0	7%
0.0%	208.6	229.5	10%

D.3 MUSIC Model Parameters

Model parameters for MUSIC were "calibrated" to match as far as possible to match the runoff and pollutant export rates previously estimated using **xpaqualm** in 2004. The MUSIC parameters adopted by Patterson Britton and Partners in 2006 for the adjacent Myall River Downs development were also considered.

D.3.1 Runoff Parameters

Based on the previous approach to catchment based water quality modelling a unit area MUSIC model comprising eight (8) source nodes was assembled. The sources nodes represent the following adopted surface types and/or landuses - rooves, roads, driveways, rural (lawn) sand, rural (lawn) clay, urban sand (with watering), urban clay (with watering), and open water (lake surface). Source nodes reflect the presence of both clay soils and sandy soils within the Riverside at Teagardens development.

Table D.5
Adopted MUSIC Rainfall/Runoff Parameters

	Adopted Parameter Values								
Landuse	Roof	Road	Driveway	Lake	Lawn Clay	Lawn Sand	Urban Clay	Urban Sand	PBP, 2006 All landuses
Imperviousness (%)	100%	100%	100%	100%	2%	0%	2%	0%	varies
Impervious area rain threshold (mm/day)	1.2	1.2	1.2	1.2	2.5	2.5	2.5	2.5	2.5
Pervious area soil storage capacity (mm)	150	150	150	150	150	150	150	150	150
Pervious area soil initial storage (% cap)	25	25	25	25	25	25	25	25	25
Field capacity (mm)	100	100	100	100	100	81	100	85	100
Pervious area infiltration capacity coefficient - a	200	200	200	200	200	200	200	200	200
Pervious area infiltration capacity exponent - b	1	1	1	1	1	1	1	1	1
Groundwater initial depth (mm)	10	10	10	10	10	10	10	10	10
Groundwater recharge rate (%)	25	25	25	25	25	25	25	25	25
Groundwater baseflow rate (%)	4	4	4	4	2	1	3	1	4
Groundwater deep seepage rate (%)	1	1	1	1	1	25	1	25	1

The adopted rainfall/runoff parameters are summarised in **Table D.5.** The adopted values are compared with the values adopted by Patterson Britton and Partners in 2006 for the adjacent Myall River Downs development. The landuse categories adopted by Patterson Britton and Partners included parks, industrial, eco-resort, marina, urban, forest and rural landuses.

D.3.2 Water Quality Parameters

The same approach was also adopted to "calibrate" MUSIC water quality parameters ie. MUSIC parameter values were calibrated to the **xpaqualm** unit area pollutant export rates for total suspended solids (TSS), total nitrogen (TN), and total phosphorous (TP).

TSS, TN and TP

The unit area MUSIC model was run and water quality parameters were adjusted in an iterative manner until the **xpaqualm** unit area export rates for TSS, TP and TN were matched.

The MUSIC water quality parameters that were adopted are summarised in **Table D.6**.

Table D.6
Adopted EMC Values (mg/L)

Landuse	Adopted Parameter							
	Roof	Road	Drive	Lake	Lawn Clay	Lawn Sand	Urban Clay	Urban Sand
Stormflow TSS Mean (mg/L)	35	250	100	2	200	105	200	100
Stormflow TP Mean (mg/L)	0.18	0.3	0.25	0	0.4	0.21	0.40	0.20
Stormflow TN Mean (mg/L)	1.60	2.20	1.80	0.02	2.80	2.10	2.80	2.00
Baseflow TSS Mean (mg/L)	16	16	16	1	200	100	200	100
Baseflow TP Mean (mg/L)	0.14	0.14	0.14	0.00	0.40	0.20	0.40	0.20
Baseflow TN Mean (mg/L)	1.30	1.30	1.30	0.01	2.80	2.00	2.80	2.00

BOD

BOD is an important water quality parameter for the lake model. In 2004 BOD was included as one of the pollutants modelled using **xpaqualm**. In contrast to the flexibility in the number of pollutants that can be modelled in **xpaqualm**, MUSIC has only three "pres-set" pollutants, namely TSS, TN and TP.

In order to estimate BOD exports to the existing lake under Existing conditions and the future extended lake under Developed Conditions two empirical correlations between daily BOD and TN exports were established using the 2004 **xpaqualm** model. The first correlation was for BOD exports under Pre-existing and Existing Conditions while the second correlation was for BOD exports under Developed Conditions. These correlations then applied to the daily TN exports estimated using MUSIC to create a daily BOD time series for the lake model(s).

The empirical BOD~TN relationships were established as follows –

- The lake inflow BOD and TN time series (kg/day) were extracted from the 2004 **xpaqualm** model for Existing conditions;
- A power function form of correlation was assumed;
- A manual regression analysis was performed with 3 objectives: to match the total BOD loads (fitted and original over the period of modelling), achieve a unity gradient for the trend line between the fitted and original BOD time series data (to ensure the empirical relationship being unbiased), and to maximise the correlation coefficient (R^2).

This procedure was repeated using the Developed Condition data. The resulting BOD~TN relationships are –

Pre-existing and Existing Conditions:

$$BOD = 11.38TN^{0.80} \qquad (R^2 = 0.980)$$

Developed Conditions:

$$BOD = 9.0TN^{0.90} \qquad (R^2 = 0.985)$$

D.3.3 Comparison of Runoff and Pollutant Exports

The MUSIC and **xpaqualm** average annual runoff and pollutant export rates are compared in **Table D.7**. It was found that the average annual runoff and TSS, TN and TP exports for MUSIC very closely matched the **xpaqualm** average annual runoff and pollutant export rates adopted in 2004.

Table D.7
Comparison of Average Annual Unit Runoff and Pollutant Exports

Landuse	Runoff (ML/ha)		TSS (kg/ha)		TP (kg/ha)		TN (kg/ha)	
	xpaqualm	MUSIC	**xpaqualm**	MUSIC	**xpaqualm**	MUSIC	**xpaqualm**	MUSIC
Roof	12.6	12.6	441	442	2.27	2.27	20.2	20.3
Road	12.6	12.6	3156	3160	3.78	3.79	27.7	27.9
Driveway	12.6	12.6	1260	1260	3.15	3.16	22.7	22.8
Lake	12.6	12.6	0	25	0.00	0.01	0.0	0.3
Lawn Sand	1.08	1.08	114	112	0.23	0.23	2.3	2.3
Lawn Clay	3.42	3.41	686	681	1.37	1.37	9.6	9.6
Urban Sand	1.10	1.14	117	114	0.23	0.23	2.3	2.3
Urban Clay	3.68	3.64	738	727	1.47	1.46	10.3	10.2

D.3.4 Parameters for Treatment Measures

Rainwater Tanks

Under any scenario with rainwater tanks installed on all new residential developments it was assumed that a 5 kL rainwater tank would be installed on each residential property.

The sizing of the rainwater tanks for residential areas was based on the following assumptions:

- All new residential development is separate dwelling with 3 bedrooms;
- The average roof area is 270 m^2
- The average garden areas is 224 m^2; and
- The harvested roof runoff will be used for toilet flushing and garden watering only.

Based on the above assumptions, the BASIX calculator indicated that a 5 kL rainwater tank in combination with water efficient appliances would comply with BASIX Water requirements. However, the BASIX calculator does not report the estimated reuse demand. Consequently, the daily usage of rainwater stored in the rainwater tanks was estimated based on the Western Sydney WSUD Guidelines (UPRCT, 2003) as follows –

- Indoor use (toilet flushing for 3 effective persons) = 140 L/day/lot
- Outdoor use = 260 L/day/lot
- Total usage = 400 L/day/lot

Ponds and Wetlands

When analysing ponds/wetlands the following assumptions were made:

- the ponds/wetlands are freshwater only;
- the average depth of a permanent pool is 1.0 m for ponds and 0.3 m for wetlands;
- the extended detention depth is 0.10 m;
- the equivalent pipe diameter for extended detention was sized such that the best treatment efficiency could be achieved.

D.4 Pre-Existing and Existing Conditions

The site contains several low natural sand ridges which tend to channel runoff in the western half of the site from north to south. However a number of shallow drains have been previously constructed to convey runoff from the western areas of the site to the east to join with runoff from the eastern area of the site that flows east towards the SEPP 14 wetlands and the Myall River.

The hydrological model of existing conditions includes a shallow basin to represent depression storage and shallow ponding of runoff in low lying areas in the western and northern areas of the site. The flows in the shallow drains that convey runoff from the western areas of the site to the east is represented as a diversion link. This diversion link conveys frequent runoff up to around the 1 yr ARI flow (around 4 m^3/s) east towards the SEPP 14 wetlands and the Myall River. Consequently the MUSIC model layout reflected this diversion of frequent runoff from the western areas of the site to the east.

The layout of the model of Pre-existing and Existing Conditions is shown in **Figure D.1**.

D.4.1 Landuse

The Pre-existing Condition was defined as the conditions that existing in the early 1990s with a lake area of around 5 ha, subcatchments R1 & R2 were fully developed and there were a limited number of dwellings in subcatchments L1L, L2R, WQB1 and Nat3 (refer **Figure D.1** for location).

The Existing Condition was defined as the conditions at around 2004 with the lake area extended to 6 ha, and more dwellings constructed in subcatchments L1L, L2R, WQB1, and Nat3. The breakdowns of landuse areas by subcatchment under Pre-existing and Existing conditions are given in **Tables D.8** and **D.9** respectively.

Table D.8
Landuse Areas (ha) under Pre-Existing Conditions

Catch ID	Roof	Road	Driveway	Lawn/urban Clay	Lawn/urban Sand	Open Water
Lake1						4.08
Lake2						0.92
WQB1	0.23	0.45	0.21		2.25	
L1L	0.15	0.30	0.14		1.51	
L2R	0.11	0.22	0.10		3.39	
Nat5					23.61	
R1	2.81	1.51	0.68		5.87	
Nat3	0.38	0.75	0.35	0.83	13.37	
R2	2.02	1.08	0.49		4.21	
Nat2					2.06	
N9				7.44	0	
N8				6.58	3	
Nat6				5.83	8.74	
N7				14.46	0	
N19	0.77	0.41	0.19	17.75	0	
N18	5.42	2.92	1.32	54.73	3	
N20				10.2	0	
N17				3.59	3.58	
Nat4					13.67	
N32					1.79	
N40				0.825	3.725	
N11					8.44	
N10				14.87	13	
N43				2.286	11.192	
N42				4.501	11.258	
Total	**11.90**	**7.65**	**3.49**	**143.89**	**137.66**	**5.00**

Table D.9
Landuse Areas (ha) under Existing Conditions

Catch ID	Roof	Road	Driveway	Lawn/urban Clay	Lawn/urban Sand	Open Water
Lake1						4.08
Lake2						1.66
WQB1	0.46	0.65	0.30		1.73	
L1L	0.31	0.44	0.20		1.16	
L2R	0.23	0.32	0.15		2.39	
Nat5					23.61	
R1	2.81	1.51	0.68		5.87	
Nat3	0.77	1.09	0.49	0.83	12.50	
R2	2.02	1.08	0.49		4.21	
Nat2					2.06	
N9				7.44		
N8				6.58	3	
Nat6				5.83	8.74	
N7				14.46		
N19	0.77	0.41	0.19	17.75		
N18	5.42	2.92	1.32	54.73	3	
N20				10.2		
N17				3.59	3.58	
Nat4					13.67	
N32					1.79	
N40				0.825	3.725	
N11					8.44	
N10				14.87	13	
N43				2.286	11.192	
N42				4.501	11.258	
Total	**12.80**	**8.42**	**3.81**	**143.89**	**134.93**	**5.74**

D.4.2 Results

The adopted period of modelling was 1/01/1982 – 31/05/2004 in which 22 calendar years (1/01/1982 – 31/12/2003) were selected for generating statistics. The estimated average annual runoff and TSS, TN and TP exports to the Myall River, Conservation Zone and SEPP14 wetlands are summarised in **Table D.10**. The average annual runoff and TSS, TN and TP exports that would be estimated if the existing diversion drains were not in place were also estimated and are summarised in **Table D.10**.

Table D.10
Estimated Runoff and Pollutant Exports under Existing Conditions

ID	Area (ha)	Rainfall (ML/yr)	Runoff and Pollutant Loads				Remark
			Runoff (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	
Existing Catchment + Drains + Existing Lake (Current Conditions)							
N42	15.8	220	28	4330	9	68	Discharges direct to Myall River
N43	13.5	189	20	2810	6	47	Discharge to Conservation Zone
Myall-2	206.0	2882	684	116000	234	1710	Discharge to Conservation Zone
	219.5	3071	704	118810	240	1757	Total Discharge to Conservation Zone
Lake Inflow	74.4	1040	318	28700	55	459	
Lake Outflow			229	4190	22	263	
				85%	*59%*	*43%*	*Reduction*
			933	123000	262	2020	Discharge to Wetland Zone
Existing Catchment + No Drains + Existing Lake (Theoretical Condition)							
N42	15.8	220	28	4330	9	68	Discharges direct to Myall River
N43	13.5	189	20	2810	6	47	Discharges to Conservation Zone
Myall-2	70.7	988	128	20600	41	322	Discharges to Conservation Zone
	84.1	1177	148	23410	47	369	Total Discharge to Conservation Zone
Lake Inflow	209.7	2934	874	124000	247	1850	
Lake Outflow			785	21190	92	1131	
				83%	*63%*	*39%*	*Reduction*
			933	44600	139	1500	Discharge to Wetland Zone

Subcatchment N42 discharges direct to the Myall River
Total Discharge to Conservation Zone = Myall-2 + N43
Discharge to Wetland Zone = Lake Outflow + Myall-2 + N43

It was concluded from the results the effect of the existing diversion drains has been to redistribute runoff that would otherwise flow to the existing lake and to instead increase the runoff discharging directly to the Conservation zone (to the East) from around 148 ML/yr to 704 ML/yr with similar significant increases in the TSS, TP and TN exports direct to the Conservation Zone.

D.5 Developed Conditions

Two MUSIC models of preliminary Developed Conditions with and without rainwater tanks were created. The layout of the preliminary Developed Conditions model with rainwater tanks is shown in **Figure D.2.**

The final Developed Conditions layout evolved from the preliminary layout in response to comments from the DoP, the PAC and other authorities. The preliminary model was adjusted to reflect changes in the planned extent of development and removal of a proposed reach of freshwater lake, the removal of the North Branch and the retention of an existing swale.

Two MUSIC models of final Developed Conditions were also created based on:

- the final concept development (without rainwater tanks);
- a possible change scenario which was applied to the final concept development.

The layouts of the final Developed Conditions model (without rainwater tanks) under current conditions and under climate change are shown in **Figure D.3** and **D.4** respectively.

D.5.1 Landuse

The areas of roof, road, driveway and gardens in each subcatchment under Developed Conditions were estimated based on indicative unit areas advised by Crighton Properties.

The adopted unit areas were:

- Each lot has an internal lot area of approximately 577 m^2;
- Each lot has an external road reserve area of 192 m^2;
- the combined lot/road area per a lot is thus 769 m^2 which gives a around 13 lots per hectare; and
- Within each lot: 270 m^2 roof, 83 m^2 driveway + pavement, and 224 m^2 soft landscaping (garden).

Landuse areas were estimated for each developed subcatchment using the following fractions of road, roof and driveway and lawn/garden surface:

Road	Roof	Driveway	Lawn	Total
0.125	0.350	0.135	0.390	1.000

These fractions were not applied to designated open spaces or to water bodies.

D.5.2 Preliminary Developed Conditions Results

The estimated average annual runoff and TSS, TN and TP exports to the Myall River, Conservation Zone and SEPP14 wetlands under the two preliminary scenarios are summarised in **Table D.11**.

D.5.3 Final Developed Conditions Results

The final concept development is a modified version of the preliminary scheme without rainwater tanks which was amended in response to comments from the DoP, the PAC and other authorities. Key changes to the proposed development include the following:

(i) residential development of the site which will include the potential to create approximately 920 dwellings comprising 855 residential (variety of lots), 50 lodges and 15 houses in a Tourist Precinct;

(ii) residential lots have been moved from the north west portion and northern corridor. The overall number of dwellings proposed has been reduced from approximately 1040 to 920;

(iii) the proposed 4 hectare expansion of the existing commercial area has been removed from the Concept Plan;

(iv) Precinct 1 which included 71 lots previously located in the south east portion of the site has been deleted and will now become part of the conservation area;

(v) a biodiversity offsetting package is proposed which will consist of both on-site and yet to be identified off-site offsets; and

(vi) lined water management devices (not in contact with the groundwater table) are proposed and the number of detention ponds has been reduced. There will be no link between the saltwater and freshwater lakes and the single existing drain outlet to the Myall River will not be upgraded or duplicated.

Final Scheme

When formulating the final scheme and assessing its performance two criteria were considered as follows:

- Nil or Beneficial Effect ie, no increase in the overall TSS, TP and TN exports to the Myall River (based on the performance targets identified in the Great Lakes Council Draft Water Sensitive Design DCP (Version 1.1, May 2010);
- Mean TP and TN concentrations in discharges to window lakes/ponds to not exceed limits identified by Martens & Associates in November 2009, namely TN < 1.0 mg/L and TP < 0.2 mg/L.

The preliminary scheme was adjusted to reflect changes in the planned extent of development and removal of a reach of freshwater lake and retention of the existing swale. It was found that four ponds proposed in the preliminary scheme could be removed in the upper arms of drainage lines. The two remaining major ponds (N10Pond and E8Pond) were converted into shallow lined wetlands. There is no link between the saline and freshwater lakes and the single existing drain outlet to the Myall River will not be upgraded or duplicated.

The sensitivity of the performance of the final Scheme to 0 mm/h and 5 mm/h seepage losses along major swales was also assessed.

The estimated average annual TSS, TN and TP exports to the Myall River and the median concentrations of inflows to the window lakes are summarised in **Table D.12**. The adopted properties of the lakes, ponds, wetlands and swales are summarised in **Table D.13**.

Final Scheme under Climate Change
A MUSIC model of the final scheme under a possible change scenario was also created.

The rainfall sequence and PET were adjusted as described in **Section D.2.2**. To represent changes in the river levels and tidal extent the saline Lake and the existing swale around the "island" were removed. The volume of remaining ponds and lakes were increased by the equivalent of 0.6 m to reflect likely changes in groundwater levels.

The estimated average annual TSS, TN and TP exports to the Myall River and the median concentrations of inflows to the window lakes are summarised in **Table D.12**.

The adopted properties of the lakes, ponds, wetlands and swales are summarised in **Table D.14**.

Table D.11
Estimated Runoff and Pollutant Exports under Developed Conditions – Preliminary Scheme

ID	Area (ha)	Rainfall (ML/yr)	Flow and Pollutant Loads				Remark
			Runoff (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	
Existing Catchment + Drains + Existing Lake (Current Conditions)							
N42	15.8	220	28	4330	9	68	Discharges direct to Myall River
N43	13.5	189	20	2810	6	47	Discharge to Conservation Zone
Myall-2	206.0	2882	684	116000	234	1710	Discharge to Conservation Zone
	219.5	3071	704	118810	240	1757	Total Discharge to Conservation Zone
	74.4	1040	318	28700	55	459	Existing Lake Inflow
			229	4190	22	263	Existing Lake Outflow
				85%	*59%*	*43%*	*Reduction*
			933	123000	262	2020	Discharge to Wetland Zone
Existing Catchment + No Drains + Existing Lake (Theoretical Condition)							
N42	15.8	220	28	4330	9	68	Discharges direct to Myall River
N43	13.5	189	20	2810	6	47	Discharges to Conservation Zone
Myall-2	70.7	988	128	20600	41	322	Discharges to Conservation Zone
	84.1	1177	148	23410	47	369	Total Discharge to Conservation Zone
	209.7	2934	874	124000	247	1850	Existing Lake Inflow
			785	21190	92	1131	Existing Lake Outflow
				83%	*63%*	*39%*	*Reduction*
			933	44600	139	1500	Discharge to Wetland Zone
Developed + No RWT + Fresh Lakes + Extended Lake							
N42	15.8	220	78	9180	20	157	Discharges direct to Myall River
N43	14.8	207	68	7370	16	132	Discharges to Conservation Zone
Myall-2	87.9	1230	418	65430	134	988	Discharges to Conservation Zone
	102.7	1437	486	72800	150	1120	Total Discharge to Conservation Zone
				39%	*37%*	*36%*	*Reduction to Current Conditions*

			813	86400	185	1410	Fresh Lake Inflow
			724	13400	74	904	Fresh Lake Outflow
			502	41900	90	727	Local Inflows
			1226	55300	164	1631	Saline Lake Inflow
			1120	17200	107	1280	Saline Lake Outflow
				87%	*61%*	*40%*	*Reduction to Developed Conditions*
			1606	90000	257	2400	Discharge to Wetland Zone
			N	Y	Y	N	Less than Current Conditions?
Developed + RWTs + Fresh Lakes + Extended Lake							
N42	15.8	220	68	8610	18	142	Discharges direct to Myall River
N43	14.8	207	59	6840	14	117	Discharges to Conservation Zone
Myall-2	87.9	1230	409	4760	55	711	Discharges to Conservation Zone
	102.7	1437	468	11600	69	828	Total Discharge to Conservation Zone
				90%	*71%*	*53%*	*Reduction to Current Conditions*
			729	81700	167	1280	Fresh Lake Inflow
			641	12300	66	803	Fresh Lake Outflow
			462	39700	81	662	Local Inflows
			1103	52000	147	1465	Saline Lake Inflow
			995	15500	96	1140	Saline Lake Outflow
				88%	*65%*	*47%*	*Reduction to Developed Conditions*
			1463	27100	165	1968	Discharge to Wetland Zone
			N	Y	Y	Y	Less than Current Conditions?
Developed + RWTs + Fresh Lakes + Extended Lake + Ponds + Swale							
N42	15.8	220	63	1160	5	86	Downstream of constructed wetland
N43	14.8	207	59	6840	14	117	Discharges to Conservation Zone
Myall-2	87.9	1230	406	3660	53	700	Discharges to Conservation Zone
	102.7	1437	465	10500	67	817	Total Discharge to Conservation Zone
				91%	*72%*	*54%*	*Reduction to Current Conditions*
			675	22500	77	845	Fresh Lake Inflow
			587	8470	56	663	Fresh Lake Outflow
			457	29600	67	609	Local Inflows
			1044	38070	122	1272	Saline Lake Inflow
			936	13700	88	1030	Saline Lake Outflow

				89%	*68%*	*52%*	*Reduction to Developed Conditions*
			1401	24200	155	1847	Discharge to Wetland Zone
			N	Y	Y	Y	Less than Current Conditions?
Developed + No RWTs + Fresh Lakes + Extended Lake + Ponds + Swale							
N42	15.8	220	68	994	5.3	87	Downstream of constructed wetland
				89%	*74%*	*45%*	*Reduction to Developed Conditions*
N43	14.8	207	68	7370	16	132	Discharges to Conservation Zone
Myall-2	87.9	1230	416	3430	53	713	Discharges to Conservation Zone
	102.7	1437	484	10800	69	845	Total Discharge to Conservation Zone
				91%	*71%*	*52%*	*Reduction to Current Conditions*
			758	24500	87	955	Fresh Lake Inflow
			670	9520	63	755	Fresh Lake Outflow
			497	30900	73	668	Local Inflows
			1167	40420	136	1423	Saline Lake Inflow
			1060	15300	100	1160	Saline Lake Outflow
				88%	*64%*	*46%*	*Reduction to Developed Conditions*
			1580	26900	175	2090	Discharge to Wetland Zone
			N	Y	Y	N	Less than Current Conditions?

Subcatchment N42 discharges direct to the Myall River

Total Discharge to Conservation Zone = Myall-2 + N43

Discharge to Wetland Zone = Saline Lake Outflow + Myall-2 + N43

Table D.12
Estimated Pollutant Exports under Developed Conditions – Final Scheme

Average Annual Pollutant Exports to Myall River under Final Scheme

Average Annual Pollutant Exports to Myall River from Riverside Catchment	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	Comment
Current Conditions - Existing Catchment + Drains + Existing Lake	**127,330**	**271**	**2088**	
Development no Controls (Overall)	210,280	445	3414	
Development with Controls (without RWTs)	26,900	164	2000	Swale seepage = 0 mm/h
Nil or Beneficial Effect (NoBE)	Y	Y	Y	
	25,800	153	1890	Swale seepage = 5 mm/h
Nil or Beneficial Effect (NoBE)	Y	Y	Y	
Development with Controls (without RWTs) under Climate Change	52,500	187	2050	Swale seepage = 0 mm/h
Nil or Beneficial Effect (NoBE)	Y	Y	Y	
	51600	179	1950	Swale seepage = 5 mm/h
Nil or Beneficial Effect (NoBE)	Y	Y	Y	

Discharge to Window Lakes/Ponds under Final Scheme

		TP (ug/L)	TN (mg/L)	Comment
Water Quality Objectives		< 200	<1.0	
Development with Controls (without RWTs)				
From N10 Wet		46.2	0.73	Meets objective
From E8 Wetland		27.1	0.44	Meets objective
From EE5 Pond		54.3	0.69	Meets objective
From EE6 Pond		61.4	0.84	Meets objective
Development with Controls (without RWTs) under Climate Change				
From N10 Wet		41.6	0.65	Meets objective
From E8 Wetland		22.8	0.36	Meets objective
From EE5 Pond		49.3	0.61	Meets objective
From EE6 Pond		52.9	0.72	Meets objective

Table D.13

Adopted Properties of Stormwater Quality Improvement Devices – Final Scheme

USTM treatment nodes											
Location	EE5Pond	EE6Pond	FLake1	FLake2	SLake	SwaleCZ	Swale	E8Wet	N10Wet	N42Wet	N43Wet
ID	134	135	161	177	132	131	176	182	181	173	174
Node Type	Pond	Pond	Pond	Pond	Pond	Swale	Swale	Wetland	Wetland	Wetland	Wetland
Lo-flow bypass rate (cum/sec)	0	0	0	0	0	0	0	0	0	0	0
Hi-flow bypass rate (cum/sec)	100	100	100	100	100			100	100	100	100
Inlet pond volume	0	0	0	0	0			0	0	0	0
Area (sqm)	2019	1696	24000	11000	60000			6050	8000	5600	5500
Extended detention depth (m)	0.1	0.1	0.4	0.4	0.4	0.5	0.5	0.1	0.1	0.3	0.3
Permanent pool volume (cum)	2019	1696	30000	16500	126000			1815	2400	1680	1650
Proportion vegetated	0.1	0.1	0.1	0.1	0.1			0.5	0.5	0.5	0.5
Equivalent pipe diameter (mm)	300	300	1350	1350	1350			190	225	300	250
Overflow weir width (m)	3	3	40	40	100	100	30	3	20	10	10
Notional Detention Time (hrs)	0.846	0.71	0.993	0.455	2.48			6.32	5.96	4.06	5.75
Orifice discharge coefficient	0.6	0.6	0.6	0.6	0.6			0.6	0.6	0.6	0.6
Weir coefficient	1.7	1.7	1.7	1.7	1.7			1.7	1.7	1.7	1.7
Number of CSTR cells	2	2	2	2	2	10	10	5	5	5	5
Total Suspended Solids k (m/yr)	400	400	400	400	400	8000	8000	1500	1500	1500	1500
Total Suspended Solids C* (mg/L)	12	12	12	12	12	20	20	6	6	6	6
Total Suspended Solids C** (mg/L)	12	12	12	12	12	14	14	6	6	6	6
Total Phosphorus k (m/yr)	300	300	300	300	300	6000	6000	1000	1000	1000	1000
Total Phosphorus C* (mg/L)	0.09	0.09	0.09	0.09	0.09	0.13	0.13	0.06	0.06	0.06	0.06
Total Phosphorus C** (mg/L)	0.09	0.09	0.09	0.09	0.09	0.13	0.13	0.06	0.06	0.06	0.06
Total Nitrogen k (m/yr)	40	40	40	40	40	500	500	150	150	150	150
Total Nitrogen C* (mg/L)	1	1	1	1	1	1.4	1.4	1	1	1	1
Total Nitrogen C** (mg/L)	1	1	1	1	1	1.4	1.4	1	1	1	1
Threshold hydraulic loading for C** (m/yr)	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500
Extraction for Re-use	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
Annual Re-use Demand - scaled by daily PET (ML)											
Constant Daily Re-use Demand (kL)											
User-defined Annual Re-use Demand (ML)											
Filter area (sqm)											
Filter depth (m)											
Filter median particle diameter (mm)											
Saturated hydraulic conductivity (mm/hr)											
Voids ratio											
Length (m)						437.5	550				
Bed slope						0.01	0.001				
Base Width (m)						6	1.5				
Top width (m)						10	3				
Vegetation height (m)						0.25	0.25				
Proportion of upstream impervious area treated											
Seepage Rate (mm/hr)	0	0	0	0	0	5	5	0	0	0	0
Evap Loss as proportion of PET	1	1	1	1	1			1.25	1.25	1.25	1.25

Table D.14

Adopted Properties of Stormwater Quality Improvement Devices – Final Scheme under Climate Change

USTM treatment nodes									
Location	EE5Pond	EE6Pond	FLake1	FLake2	SwaleCZ	E8Wet	N10Wet	N42Wet	N43Wet
ID	134	135	161	177	131	182	181	173	174
Node Type	Pond	Pond	Pond	Pond	Swale	Wetland	Wetland	Wetland	Wetland
Lo-flow bypass rate (cum/sec)	0	0	0	0	0	0	0	0	0
Hi-flow bypass rate (cum/sec)	100	100	100	100		100	100	100	100
Inlet pond volume	0	0	0	0		0	0	0	0
Area (sqm)	2019	1696	24000	11000		6050	8000	5600	5500
Extended detention depth (m)	0.1	0.1	0.4	0.4	0.5	0.1	0.1	0.3	0.3
Permanent pool volume (cum)	3230	2714	44400	26400		1815	2400	1680	1650
Proportion vegetated	0.1	0.1	0.1	0.1		0.5	0.5	0.5	0.5
Equivalent pipe diameter (mm)	300	300	1350	1350		190	225	300	250
Overflow weir width (m)	3	3	40	40		3	20	10	10
Notional Detention Time (hrs)	0.846	0.71	0.993	0.455		6.32	5.96	4.06	5.75
Orifice discharge coefficient	0.6	0.6	0.6	0.6		0.6	0.6	0.6	0.6
Weir coefficient	1.7	1.7	1.7	1.7		1.7	1.7	1.7	1.7
Number of CSTR cells	2	2	2	2	10	5	5	5	5
Total Suspended Solids k (m/yr)	400	400	400	400	8000	1500	1500	1500	1500
Total Suspended Solids C* (mg/L)	12	12	12	12	20	6	6	6	6
Total Suspended Solids C** (mg/L)	12	12	12	12	14	6	6	6	6
Total Phosphorus k (m/yr)	300	300	300	300	6000	1000	1000	1000	1000
Total Phosphorus C* (mg/L)	0.09	0.09	0.09	0.09	0.13	0.06	0.06	0.06	0.06
Total Phosphorus C** (mg/L)	0.09	0.09	0.09	0.09	0.13	0.06	0.06	0.06	0.06
Total Nitrogen k (m/yr)	40	40	40	40	500	150	150	150	150
Total Nitrogen C* (mg/L)	1	1	1	1	1.4	1	1	1	1
Total Nitrogen C** (mg/L)	1	1	1	1	1.4	1	1	1	1
Threshold hydraulic loading for C** (m/yr)	3500	3500	3500	3500	3500	3500	3500	3500	3500
Extraction for Re-use	Off	Off	Off	Off	Off	Off	Off	Off	Off
Annual Re-use Demand - scaled by daily PET (ML)									
Constant Daily Re-use Demand (kL)									
User-defined Annual Re-use Demand (ML)									
Filter area (sqm)									
Filter depth (m)									
Filter median particle diameter (mm)									
Saturated hydraulic conductivity (mm/hr)									
Voids ratio									
Length (m)					437.5				
Bed slope					0.01				
Base Width (m)					6				
Top width (m)					10				
Vegetation height (m)					0.25				
Proportion of upstream impervious area treated									
Seepage Rate (mm/hr)	0	0	0	0	5	0	0	0	0
Evap Loss as proportion of PET	1	1	1	1		1.25	1.25	1.25	1.25

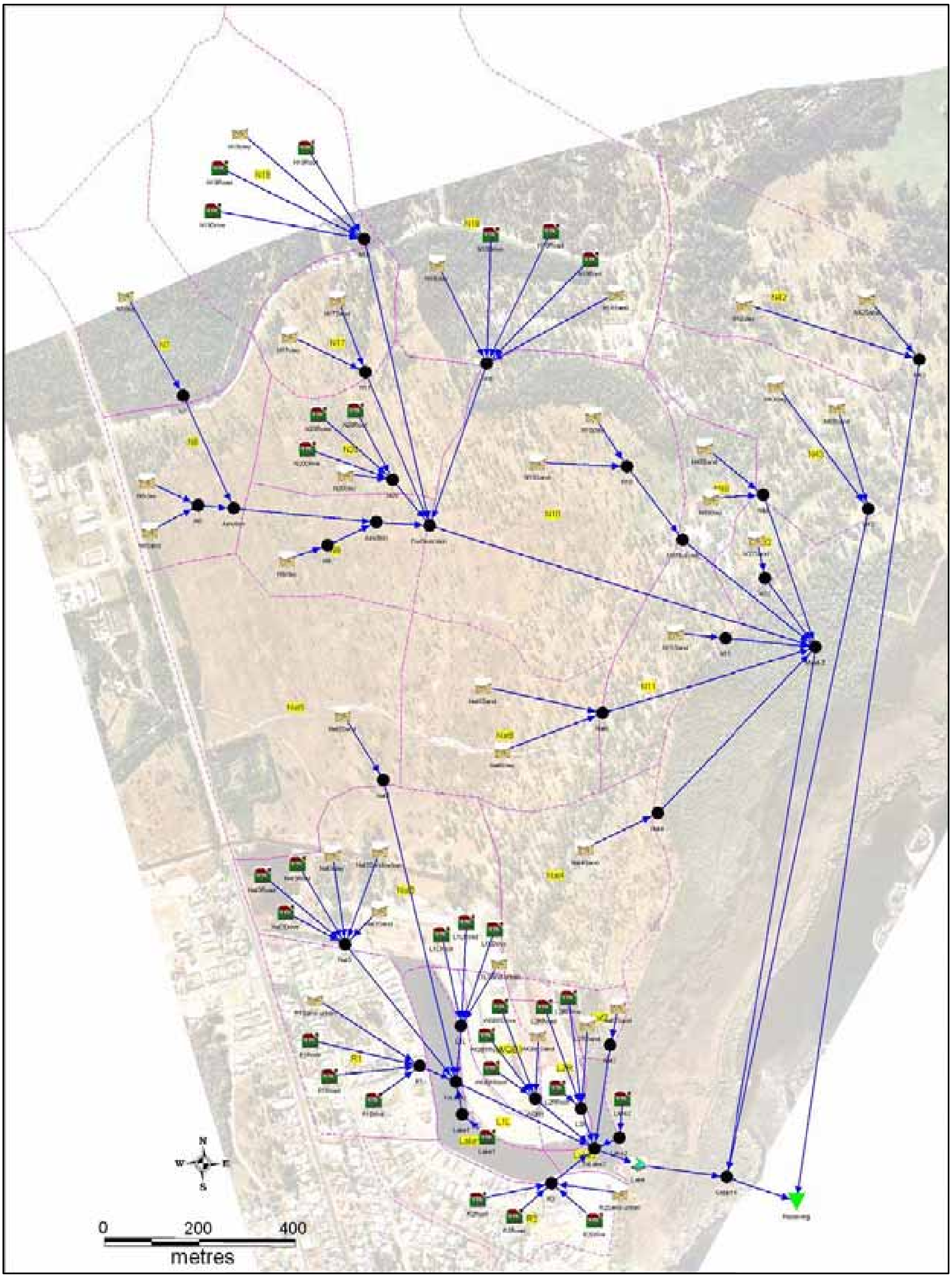

Figure D.1
MUSIC Model Layout for Pre-Existing and Existing Conditions

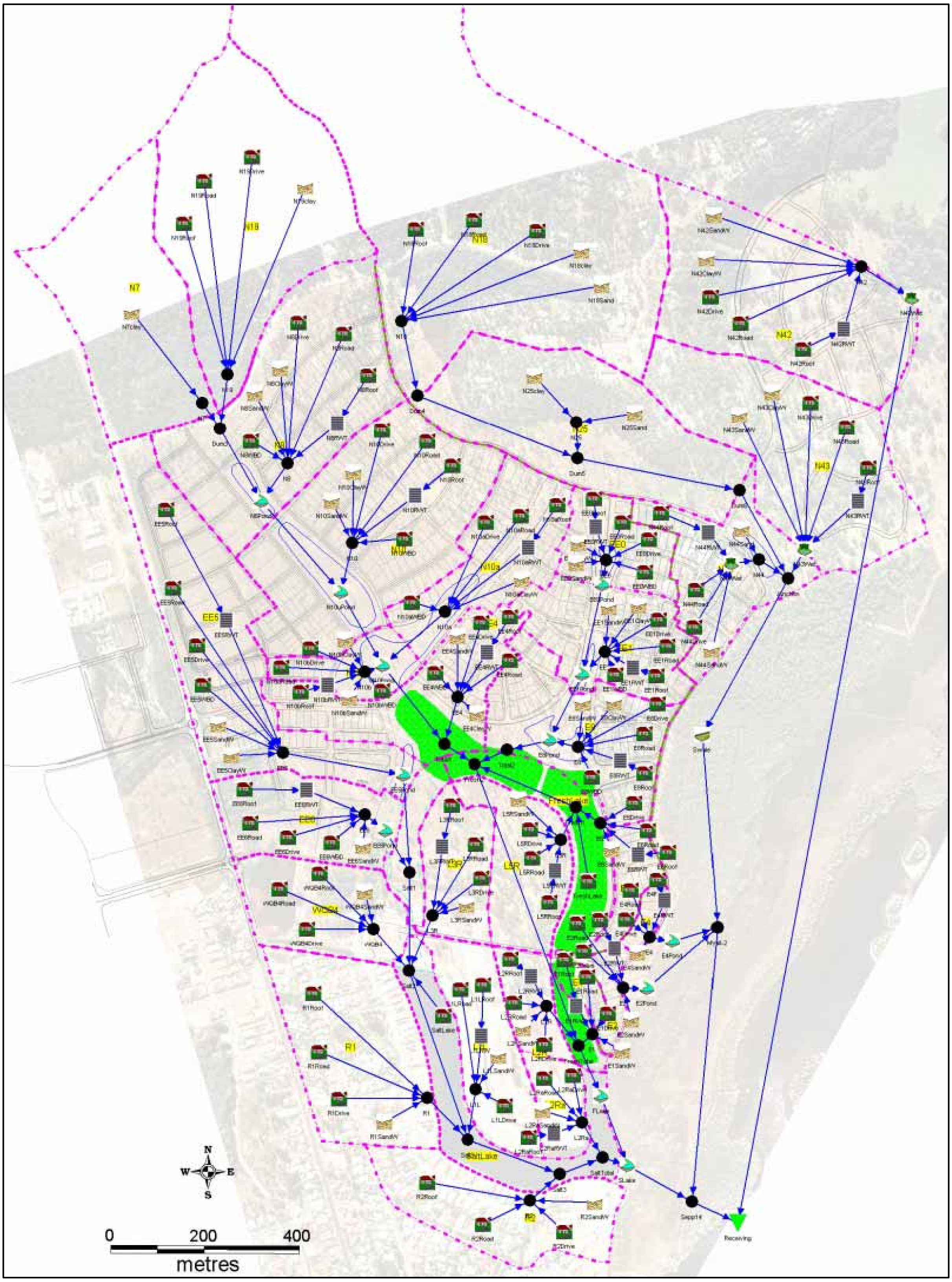

Figure D.2

MUSIC Model Layout for Developed Conditions with Rainwater Tanks – Preliminary Scheme

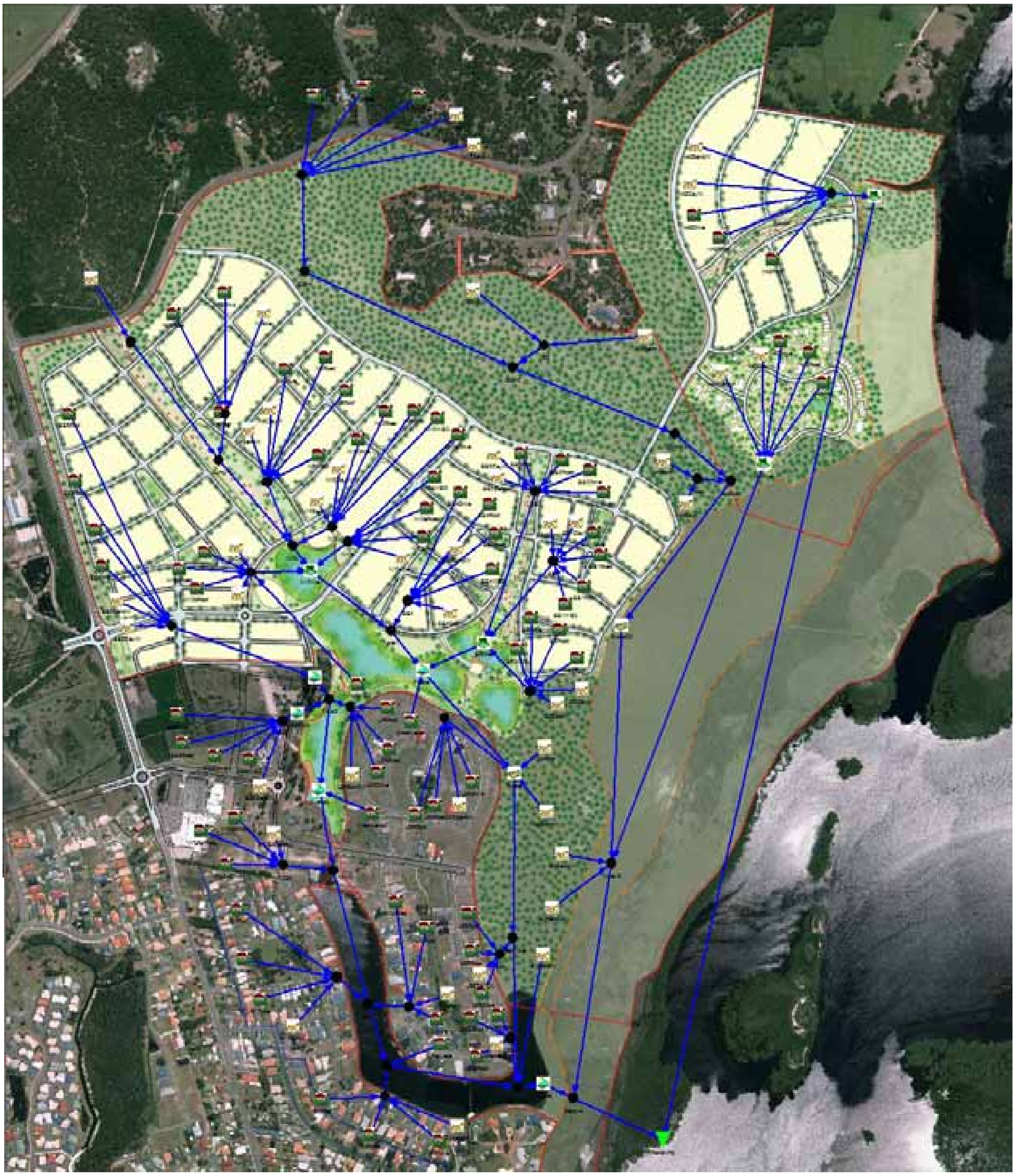

Figure D.3
MUSIC Model Layout for Developed Conditions without Rainwater Tanks – Final Scheme

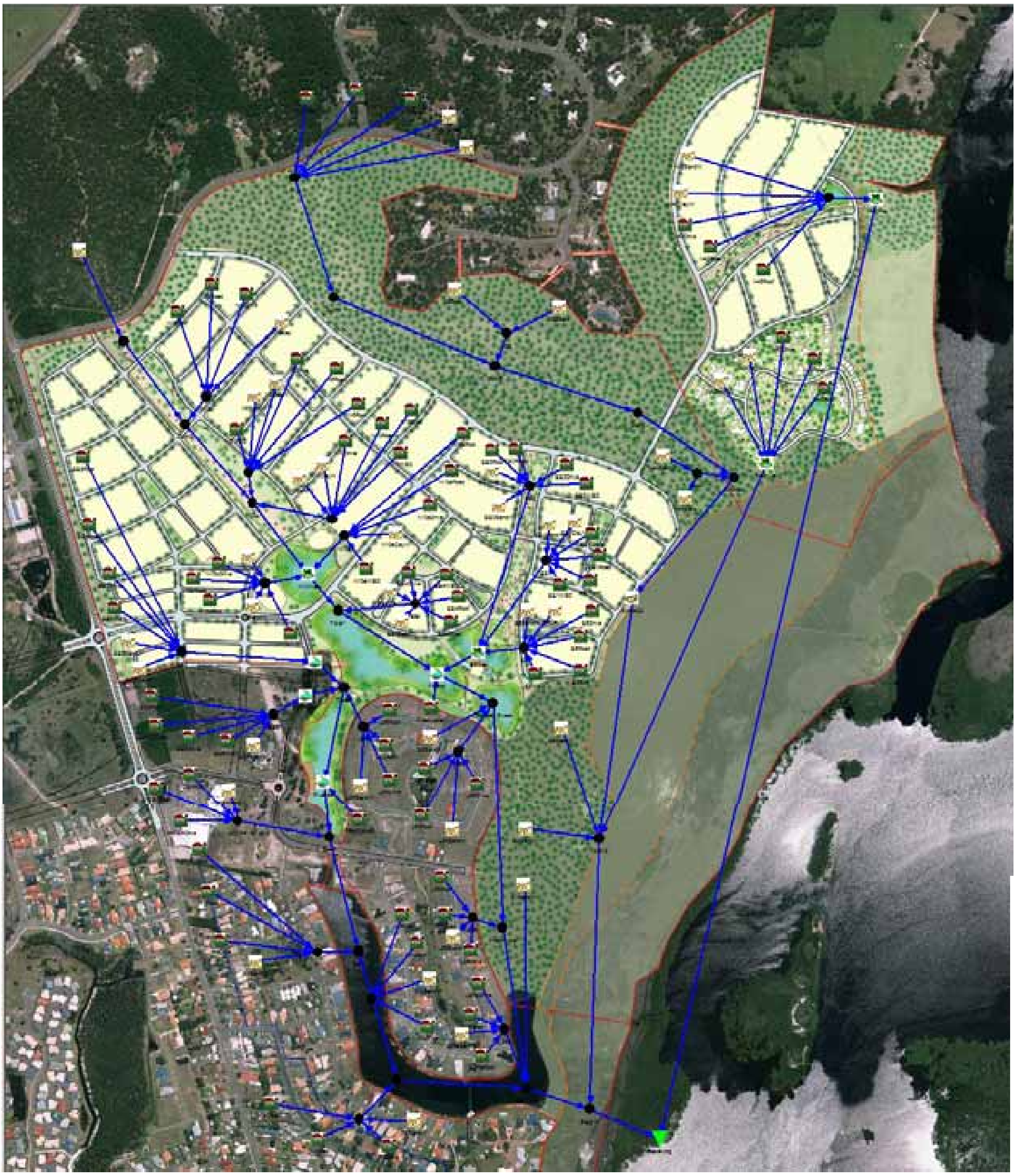

Figure D.4
MUSIC Model Layout for Developed Conditions without Rainwater Tanks - Final Scheme under Climate Change

Appendix E

Lake Modelling

E Lake Modelling

E.1 Aims

The aims of the lake modelling were to

- Assemble and run eWater Pond models of the Pre-Existing and Existing detention lakes using catchment inputs calculated using the MUSIC model;
- Assess water quality in lakes included in the preliminary and final Developed Conditions Pond models.

E.2 Background

Surface waters drain partly toward the existing detention lake and then through the wetland zone and partly toward the conservation zone that provides a buffer to the wetland zone on the eastern boundary of the site.

The primary aim for the existing management of water quality is to protect the wetland zone by directing the runoff from the developed areas of the catchment to a weakly tidally flushed lake. This is also supported by a number of smaller ponds and wetlands located within existing residential areas.

Water quality impacts on the existing detention lake at Riverside at Tea Gardens are due to event-driven loads from runoff, decay of in-lake algae and releases from sediments. Tidal inflows can also impact on water quality. The stormwater runoff impacts can be expected to increase with urban development in the northern part of the project site unless remedial measures are provided and / or the lake is increased in size.

A detailed assessment of existing and future catchment runoff and pollutant exports and water management options to maintain as far as possible to maintain the existing lake water quality and its current role as a fish habitat was reported in 2004 (Cardno, 2004).

E.3 The eWater Pond Model

The eWater CRC released a pond model (PDMOD) in 2001 for industry use. The model is daily time step spreadsheet model of inflow, mixing, sedimentation, sediment reduction and oxidation, and algal growth and washout processes.

The major model components comprise:

(i) advective mixing and washout associated with storm event driven inflows high in suspended solids, nutrients, organic matter and toxicants;

(ii) adsorption of nutrients, metals and organic material on surfaces of suspended solids and their removal by sedimentation in the period after the storm event;

(iii) decomposition of sedimented organic material after each event, by benthic heterotrophic bacteria, with the associated depletion of dissolved oxygen, denitrification and the potential for reduction of insoluble ferric iron to dissolved ferrous iron and the release of ortho-phosphate previously bound to ferric iron into the water column; and the

(iv) rapid uptake of released ortho-phosphate and other nutrients by algae under conditions of post storm low inflows and extended detention.

Significant modifiers of the sediment redox processes incorporated into the model include:

(v) transfer of atmospheric oxygen by wind mixing, through the water surface and water column to the sediments, offsetting sediment BOD;

(vi) heating of turbid surface waters under low wind and high summer solar radiation conditions, resulting in steep thermal gradient and the limitation of oxygen transfers;

(vii) the role of emergent macrophytes in directly transferring oxygen to their sediment rhizome root zone.

The application of the eWater Pond Model to the assessment of water quality in a number of freshwater ponds and lakes under Sydney, Cairns and Tea Gardens conditions have been previously outlined by Lawrence and Phillips, 2001 and Phillips et al, 2003 and Phillips and Wade, 2006 respectively.

E.4 Observed Water Quality

A water quality monitoring programme was established in 1996 firstly by the developer, and more recently taken over by the Myall Quays Community Association. Hunter Water Laboratories collects and analyse samples at 5 lake locations every 3 months.

Salinity

The sampling indicates that the lake water is brackish having a 50th percentile value of salinity of 12.8 g/L, which is approximately one third of the salinity of seawater. There is variability in the salinity concentration due to both catchment (freshwater) runoff as well as the influence of tides and varying salinity in the Myall River. The observed salinity varied from 4.2 g/L to 25.6 g/L (between the 10th percentile and 90th percentile values).

Dissolved Oxygen (DO)

The 50th percentile of all Dissolved Oxygen (DO) values (100 readings) in the lake for the sampling period is 6.6 mg/L, with a 10th percentile level of 4.8 mg/L. The 4.8 mg/L level is just below the recommended ANZECC trigger value of 5.0 mg/L for freshwater fish. A comparison of the DO levels measured within the existing lake and the Myall River disclosed that the ANZECC guidelines for DO are not currently met at all times, in either the lake or river (at Copeland Ave Wharf). As indicated in **Figure 9** the DO levels in the existing lake are often better that in the Myall River.

Nutrients

The adopted ANZECC, 2000 trigger value for Phosphorus (TP) is 0.03 mg/L for estuarine systems. Most of the samples have been below the recommended value with a 50th percentile (100 readings) of 0.005 mg/L. Higher P levels occurred soon after the lake was constructed, possibly due residual P released from exposed soil.

The ANZECC, 2000 trigger value for Nitrogen (TN) is 0.3 mg/L, (NO_x) is 0.015 mg/L and Ammonia is 0.015 mg/L for estuarine systems. TN values could not be calculated from the available data. The 50th percentile of all NO_x values (24 readings) in the lake for the sampling period was 0.0105 mg/L. The 50th percentile of all Ammonia values (84 readings) in the lake for the sampling period is 0.03 mg/L.

The nutrient levels measured have generally been low, contributing to the overall good water quality in the existing lake.

E.5 Lake Modelling

E.5.1 Pond Model Calibration

The challenge faced in using the Pond model to assess lake water quality is to match as far as possible observed levels of water quality in the existing lake at Riverside at Tea Gardens which is partially flushed by high tides in the adjacent Myall River.

The Pond model was therefore modified to reflect the dominant process in a lake that is partially flushed on the top of tides. The model was also extended to include a salinity submodel.

The inflows to the model include catchment runoff and tidal inflows from the Myall River.

Tidal inflows were estimated using a hydrodynamic model of the SEPP 14 wetlands at the south eastern end of the existing lake and the Myall River.

The salinity of tidal inflows was observed to vary in response to varying salinity levels in the Myall River. An algorithm was developed to estimate daily salinity in the Myall River based on daily rainfall.

A further challenge was that the original lake was enlarged in early 2003.

The models were calibrated against observed data collected during the following periods:

- Salinity — 24 October 1996 – 23 May 2004
- Temperature — 13 May 1996 – 20 October 2003
- Dissolved Oxygen — 13 May 1996 – 20 October 2003
- Chlorophyll ‘a’ — 13 May 1996 – 20 October 2003

The Pond models were run for the period 1 January 1996 – 31 May 2004.

A comparison of predicted and observed salinity in the Myall River and the existing lake is given in **Figure E.1** while a comparison of the predicted and observed dissolved oxygen (DO), water temperature and algal levels (chlorophyll 'a') are given in **Figures E.2** and **E.3**. It was concluded that very good agreement with observed water quality was achieved.

E.6 Pre-Existing and Existing Conditions

The Pond models of the Pre-Existing detention lake and the Existing detention lake were run using inputs calculated using the MUSIC model and were compared with the results previously reported in 2004. The results are compared in **Table E.1**.

It was concluded that the calculated lake water quality using inputs generated by MUSIC are very similar to the lake water quality previously calculated using inputs generated by **xpaqualm**.

Table E.1
Comparison of Lake Water Quality under Pre-existing and Existing Conditions

Percentile	Pre-existing Condition		Existing Condition	
	2004 Study	This Study	2004 Study	This Study
DO Bottom				
5%	1.0	0.7	1.5	1.6
20%	4.5	4.3	4.6	4.4
50%	5.9	5.8	5.9	5.8
80%	7.2	7.1	7.2	7.1
95%	8.2	8.1	8.1	8.1
DO % Saturation				
5%	12%	8%	21%	20%
20%	59%	57%	61%	59%
50%	78%	76%	78%	77%
80%	88%	88%	89%	88%
95%	95%	94%	95%	95%
TP				
5%	0.0014	0.0014	0.0011	0.0010
20%	0.0028	0.0026	0.0019	0.0019
50%	0.0055	0.0055	0.0040	0.0040
80%	0.0124	0.0135	0.0094	0.0106
95%	0.0283	0.0371	0.0221	0.0278
TN				
5%	0.29	0.27	0.31	0.29
20%	0.34	0.31	0.36	0.33
50%	0.41	0.39	0.42	0.40
80%	0.50	0.51	0.50	0.51
95%	0.68	0.77	0.64	0.72
Algal Biomass				
50%	0.0010	0.0010	0.0010	0.0010
70%	0.0011	0.0011	0.0010	0.0010
90%	0.0016	0.0021	0.0012	0.0014
95%	0.0034	0.0048	0.0022	0.0026
100%	0.0374	0.0323	0.0268	0.0265

E.7 Developed Conditions

E.7.1 Preliminary Scheme

The preliminary scheme comprised a partial extended saline lake (8 ha) with increased tidal flushing and new freshwater lakes (6.5 ha in total); supported by additional ponds or wetlands as needed (total area of ponds draining to the lakes is 4.7 ha). The preliminary Developed Conditions Pond models of the freshwater lakes and a separate linked model of the partially extended saline lake were run with inputs calculated using the MUSIC model.

The results of the assessment of the preliminary scheme and its sensitivity to increases in the overall width of the channel outlet are given in **Table E.2**.

E.7.2 Final Scheme

The final concept scheme is a modified version of the preliminary scheme without rainwater tanks which was amended in response to comments from the DoP, the PAC and other authorities. The final scheme was adjusted to reflect changes in the planned extent of development and removal of a reach of freshwater lake and retention of the existing swale. It was found that four ponds proposed in the preliminary scheme could be removed in the upper arms of drainage lines while still meeting the stormwater quality objectives. Two remaining major ponds (N10Pond and E8Pond) were converted into shallow lined wetlands.

The final Developed Conditions Pond models of the freshwater lakes and a separate linked model of the existing saline lake were run with inputs calculated using the MUSIC model.

The results of the assessment of the final scheme are compared with the results reported for Existing Conditions in **Table E.3**.

A comparison of the saline lake under the final scheme with the saline lake under existing conditions concluded that:

(i) In the near term the lake will become less brackish due to the requirement that the existing outlet remain unchanged. In the longer term sea level rise and increasing tidal inflows will increase the salinity of the lake. In the event that a sea level rise of 0.9 m or greater occurs then the lake will become part of the Myall River and salinity levels would be expected to match the salinity of the Myall River;
(ii) The DO levels in bottom waters and DO saturation would improve slightly;
(iii) TP and TN concentrations would increase slightly;
(iv) Algal concentrations are comparable to existing conditions;
(v) Salinity and DO saturation remain within the ANZECC, 2000 range; and
(vi) TP, TN and algal concentrations remain under ANZECC, 2000 trigger values.

It was also noted that the freshwater lakes may experience algal blooms occasionally. Consideration could be given to incorporating monitoring the water quality in the freshwater lakes to establish if there is any need to aerate any of the lakes from time to time.

Table E.2

Estimated Lake Water Quality under Preliminary Developed Conditions

Channel Widening Factor	1		1.8		2.0	
Ave Lowering of Channel (m)	0.00		0.09		0.05	
Percentile						
Salinity (g/L)	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	1.3	1.2	3.5	3.4	3.0	2.9
20%	3.1	2.8	7.9	7.6	6.9	6.6
50%	6.9	6.3	15.2	14.3	13.7	12.8
80%	12.2	10.8	25.1	23.7	23.1	21.6
95%	16.7	15.2	32.2	30.4	30.2	28.2
DO Bottom (mg/L)	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	4.4	4.4	3.6	3.6	3.7	3.8
20%	6.1	6.1	4.7	4.8	5.0	5.0
50%	7.1	7.1	6.2	6.2	6.3	6.4
80%	8.3	8.3	7.5	7.6	7.7	7.7
95%	9.0	9.0	8.5	8.5	8.6	8.6
DO % Saturation	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	54%	53%	51%	50%	52%	51%
20%	75%	74%	72%	71%	73%	71%
50%	85%	84%	82%	82%	83%	82%
80%	92%	92%	89%	89%	90%	89%
95%	97%	96%	94%	94%	95%	94%
TP (mg/L)	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	0.0009	0.0010	0.0028	0.0029	0.0022	0.0023
20%	0.0017	0.0019	0.0049	0.0052	0.0039	0.0043
50%	0.0047	0.0050	0.0081	0.0086	0.0074	0.0078
80%	0.0127	0.0134	0.0142	0.0147	0.0139	0.0148
95%	0.0252	0.0258	0.0251	0.0258	0.0256	0.0265
TN (mg/L)	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	0.31	0.33	0.18	0.20	0.20	0.21
20%	0.35	0.37	0.23	0.24	0.25	0.26
50%	0.42	0.44	0.30	0.32	0.32	0.34
80%	0.55	0.56	0.43	0.45	0.45	0.47
95%	0.73	0.75	0.63	0.65	0.66	0.67
Algal Biomass (mg/L)	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
50%	0.0010	0.0010	0.0011	0.0012	0.0011	0.0011
70%	0.0011	0.0011	0.0013	0.0013	0.0012	0.0013
90%	0.0014	0.0014	0.0016	0.0017	0.0016	0.0016
95%	0.0017	0.0018	0.0019	0.0019	0.0018	0.0019
100%	0.0049	0.0060	0.0052	0.0065	0.0053	0.0066

WSUD 1 Scheme with RWTs + Ponds

WSUD 2 Scheme without RWTs + Ponds

Table E.3
Estimated Lake Water Quality under Final Developed Conditions

	Existing	Final Scheme	ANZECC, 2000 Trigger Value / Ranges
Channel Widening Factor	1.0	1.0	
Ave Lowering of Channel (m)	0.00	0	
Percentile			
Salinity		WSUD 2	
5%	5.1	0.9	
20%	8.3	2.8	
50%	14.0	6.3	3-20 g/L
80%	20.2	11.2	
95%	24.3	16.0	
DO Bottom		WSUD 2	
5%	1.6	4.02	
20%	4.4	6.0	
50%	5.8	7.2	
80%	7.1	8.3	
95%	8.1	9.0	
DO % Saturation		WSUD 2	
5%	20%	45.3%	
20%	59%	74%	
50%	77%	84%	80%-100%
80%	88%	92%	
95%	95%	96%	
TP		WSUD 2	
5%	0.0010	0.0013	
20%	0.0019	0.0030	
50%	0.0040	0.0078	0.03
80%	0.0106	0.0211	
95%	0.0278	0.0495	
TN		WSUD 2	
5%	0.29	0.32	
20%	0.33	0.38	
50%	0.40	0.47	0.3
80%	0.51	0.65	
95%	0.72	0.99	
Algal Biomass		WSUD 2	
50%	0.0010	0.0010	0.004
70%	0.0010	0.0012	
90%	0.0014	0.0017	
95%	0.0026	0.0022	
100%	0.0265	0.0330	

WSUD 1
WSUD 2

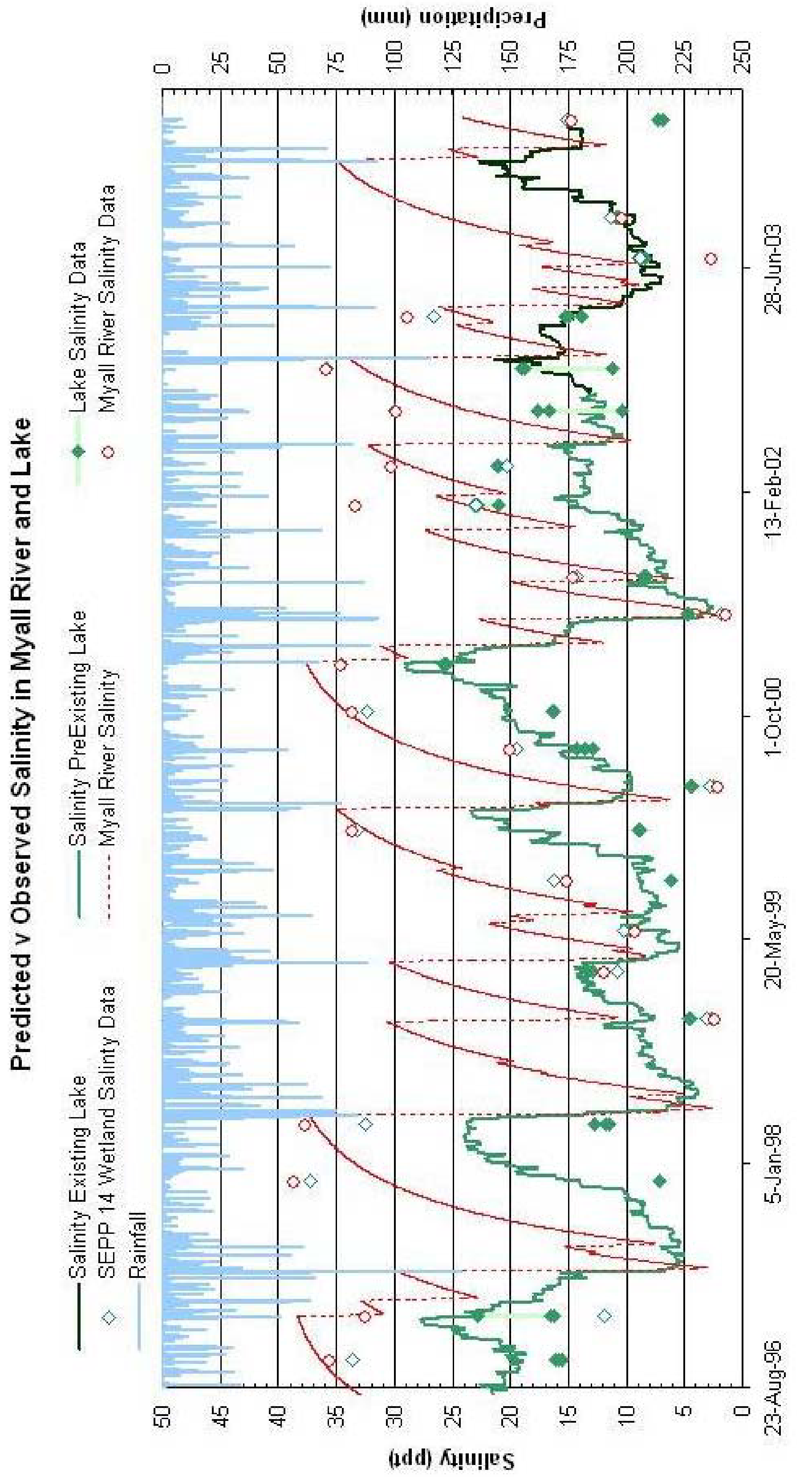

Figure E.1
Comparison of Predicted and Observed Salinity in the Myall River and Existing Lake

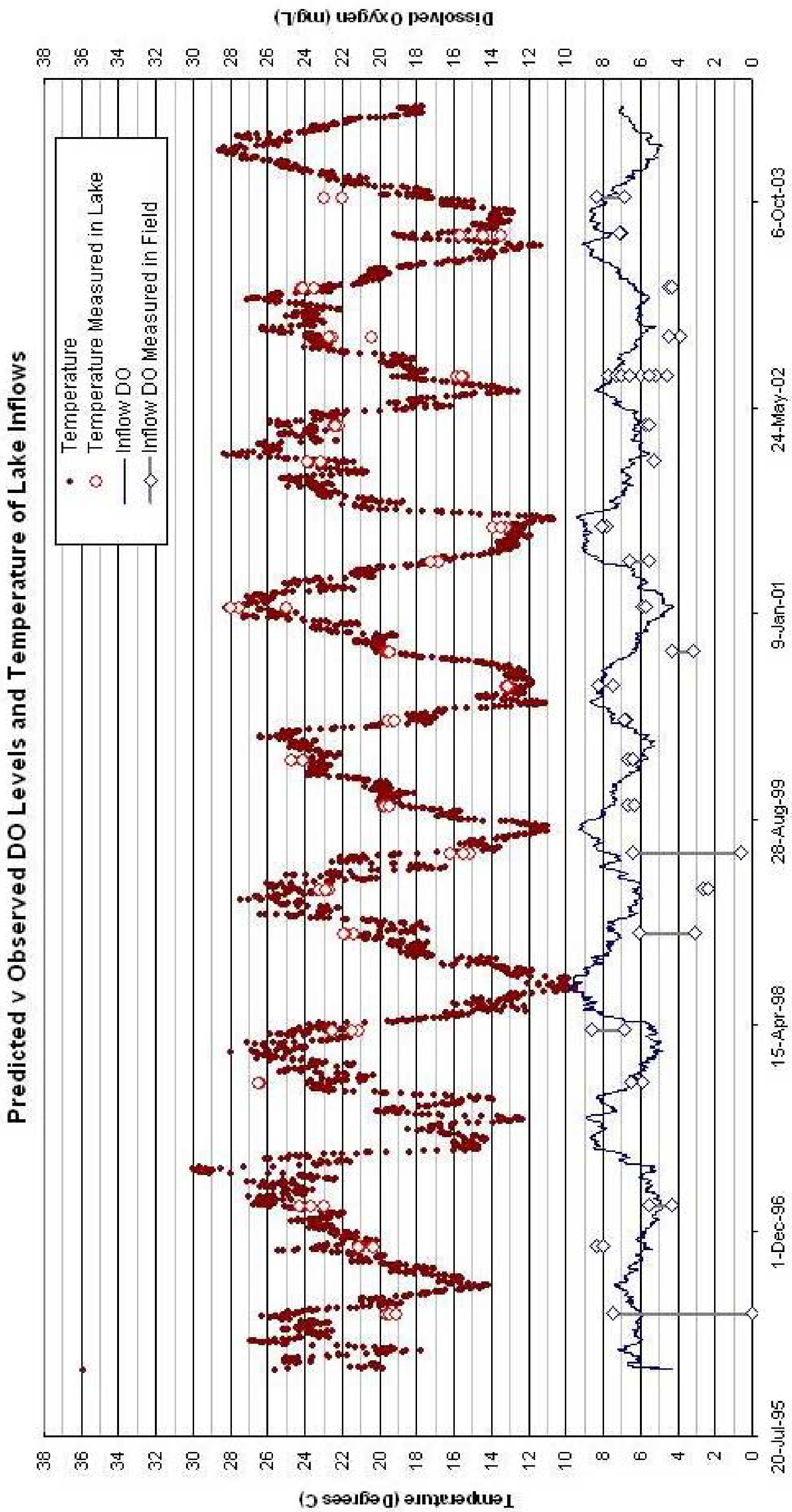

Figure E.2
Comparison of Predicted and Observed Dissolved Oxygen and Temperature of Lake Inflows

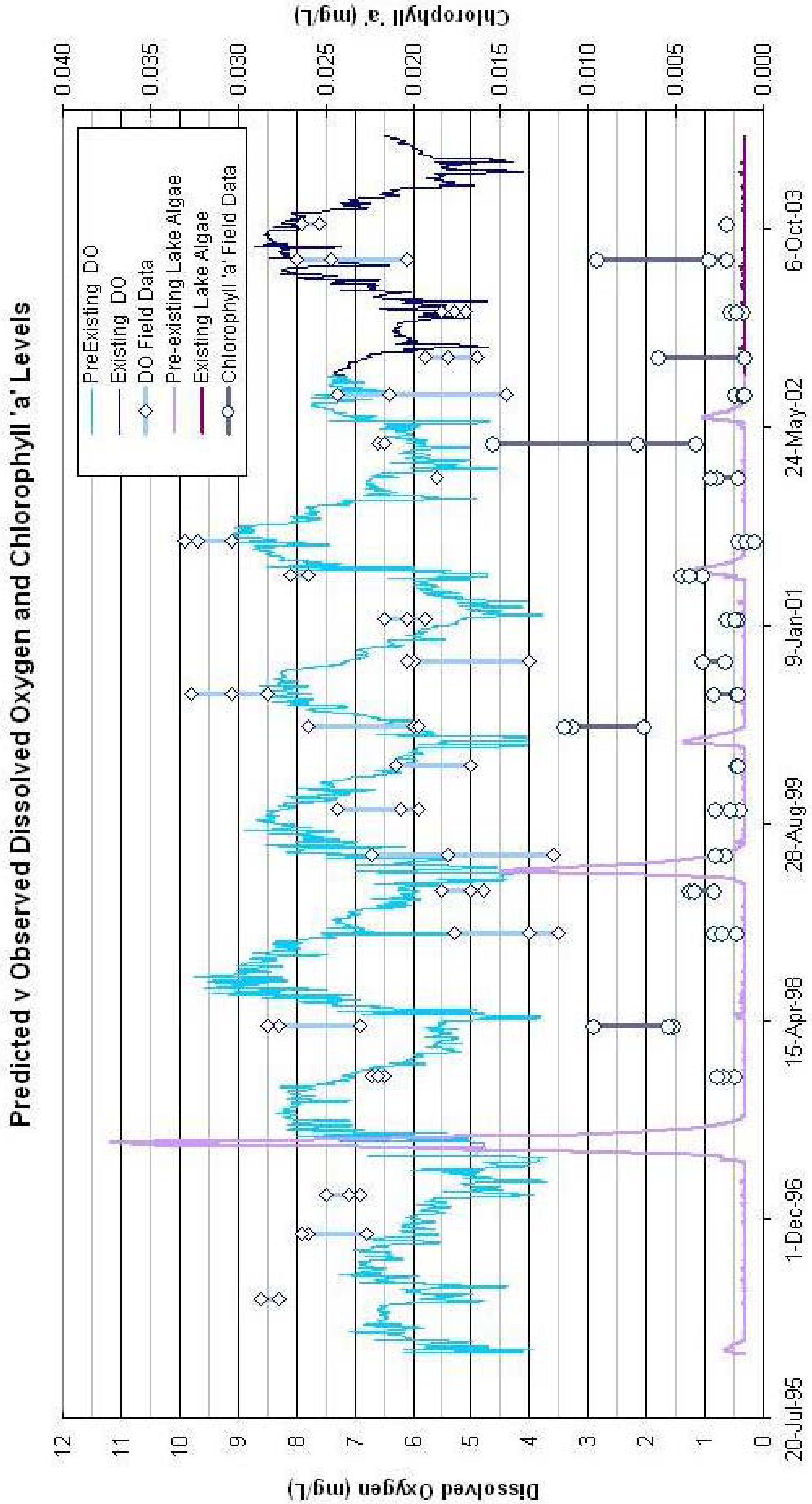

Figure E.3
Comparison of Predicted and Observed Dissolved Oxygen and Algae in the Existing Lake

Appendix F

Groundwater Assessments, November 2011

Appendix G

IWCM Strategy and Sewerage Servicing, November 2010

Appendix H
Riverside at Tea Gardens
Probable Maximum Flood, November 2008