Riverside at Tea Gardens

Integrated Water Management

Appendices

CRIGHTON PROPERTIES

NOVEMBER 2008 JOB NO. W4332-7

CRIGHTON PROPERTIES

Riverside at Tea Gardens
Integrated Water Management

Final Report
November 2008

Client	Crighton Properties			
Document	Riverside at Tea Gardens, Integrated Water Management, Appendices			
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	Draft	☐	**Signature**	
	Draft Final	☐	**Date**	October 2008
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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

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	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	3.53	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	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	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.1 Aims

The aims of the 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 event;
- 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.

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.

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 detention 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 – Scheme 3

B.4.1 Scheme 3 Developed Conditions

A model of future developed conditions was also assembled based on a detailed concept layout of planned future stages of the Scheme 3 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 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 Scheme 3 development is presented in **Figure B.2**.

The active storage available in the proposed extended detention lake and a widened lake outlet were also represented as a retarding basin in the developed condition model.

The estimated peak 5 yr ARI, 20 yr ARI and 100 yr ARI outflows under Scheme 3 developed conditions (without ancillary retarding basins) are summarised in **Table B.5**.

Table B.5
Estimated Peak Flows at Key Locations in Riverside at Tea Gardens under Scheme 3 Developed Conditions

Node	5 yr ARI	20 yr ARI	100 yr ARI	Comment
Lake	24.5 *(1.5)*	33.0 *(1.5)*	42.0 *(1.5)*	Inflow to the extended detention lake
Lake	5.9 *(9)*	9.5 *(9)*	14.4 *(9)*	Outflow from the extended detention lake
N_out1	9.1 *(1.5)*	13.2 *(1.5)*	18.1 *(1.5)*	Aggregated flow to the Conservation Zone
N42	1.5 *(1.5)*	2.1 *(1.5)*	2.6 *(1.5)*	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.4.2 Scheme 3 Developed Conditions with Basins

A model of future developed Scheme 3 conditions with retarding basins was also assembled based on a detailed 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 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.6**.

The peak basin outflows and resulting peak discharges to the Conservation Zone under developed conditions are summarised in **Tables B.7** and **B.8**.

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

Table B.7
Estimated Peak Flows at Key Locations in Riverside at Tea Gardens under Scheme 3 Developed Conditions with Basins EW and N42

Node	5 yr ARI	20 yr ARI	100 yr ARI	Comment
Lake	24.5 *(1.5)*	33.0 *(1.5)*	42.0 *(1.5)*	Inflow to the extended detention lake
Lake	5.9 *(9)*	9.5 *(9)*	14.4 *(9)*	Outflow from the extended detention lake
ESout	3.3 *(9)*	8.6 *(9)*	14.7 *(2)*	Existing outflow from the existing detention lake
EW	9.1 *(1.5)*	13.2 *(1.5)*	18.1 *(1.5)*	Inflow to Basin EW
EW	1.5 *(1.5)*	2.1 *(1.5)*	2.6 *(1.5)*	Outflow from Basin EW
N_out	5.5 *(9)*	7.1 *(9)*	9.0 *(2)*	Aggregated flow to the Conservation Zone with Basin EW
ENout1	6.9 *(9)*	8.7*(9)*	10.9 *(9)*	Aggregated flow to the Conservation Zone under existing conditions
N42	1.5 *(1.5)*	2.1 *(1.5)*	2.6 *(1.5)*	Inflow to Basin N42
N42	0.55 *(9)*	0.83 *(9)*	1.25 *(9)*	Outflow from Basin N42
EN42	0.58 *(9)*	0.88 *(9)*	1.25 *(9)*	Existing outflow to an existing drainage line that discharges directly into the Myall River

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

Table B.8
Estimated Peak Flows at Key Locations in Riverside at Tea Gardens under Scheme 3 Developed Conditions with Basin N43

Node	5 yr ARI	20 yr ARI	100 yr ARI	Comment
N43	1.4 *(1.5)*	1.9 *(1.5)*	2.4 *(1.5)*	Inflow to Basin EW
N43	0.53 *(9)*	0.77 *(9)*	1.2 *(9)*	Outflow from Basin EW
EN43	0.51 *(9)*	0.77 *(9)*	1.2 *(9)*	Peak runoff under existing conditions
N_out	5.4 *(9)*	6.8 *(9)*	8.8 *(2)*	Aggregated flow to the Conservation Zone with Basin EW
ENout1	6.9 *(9)*	10.9 *(9)*	10.9 *(9)*	Aggregated flow to the Conservation Zone under existing conditions

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

B.5 Developed Conditions - Scheme 5

Subsequent to discussions held with the NSW Department of Planning regarding NSW Government stakeholder concerns regarding the concept Scheme 3 development a concept development based on Scheme 5 was investigated in detail.

The model of future developed Scheme 3 conditions with retarding basins was modified based on an amended detailed concept layout of planned future stages of the development under Scheme 5. Under the Scheme 5 concept it is also 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. 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 a series of ponds and freshwater lakes that will discharge into the proposed extended detention lake.

The 5 yr ARI, 20 yr ARI and 100 yr ARI hydrographs under Scheme 5 developed conditions were estimated and input into the hydraulic model of the Scheme 5 development to estimate peak outflows from the detention lake as well as the 5 yr ARI, 20 yr ARI and 100 yr ARI flood levels.

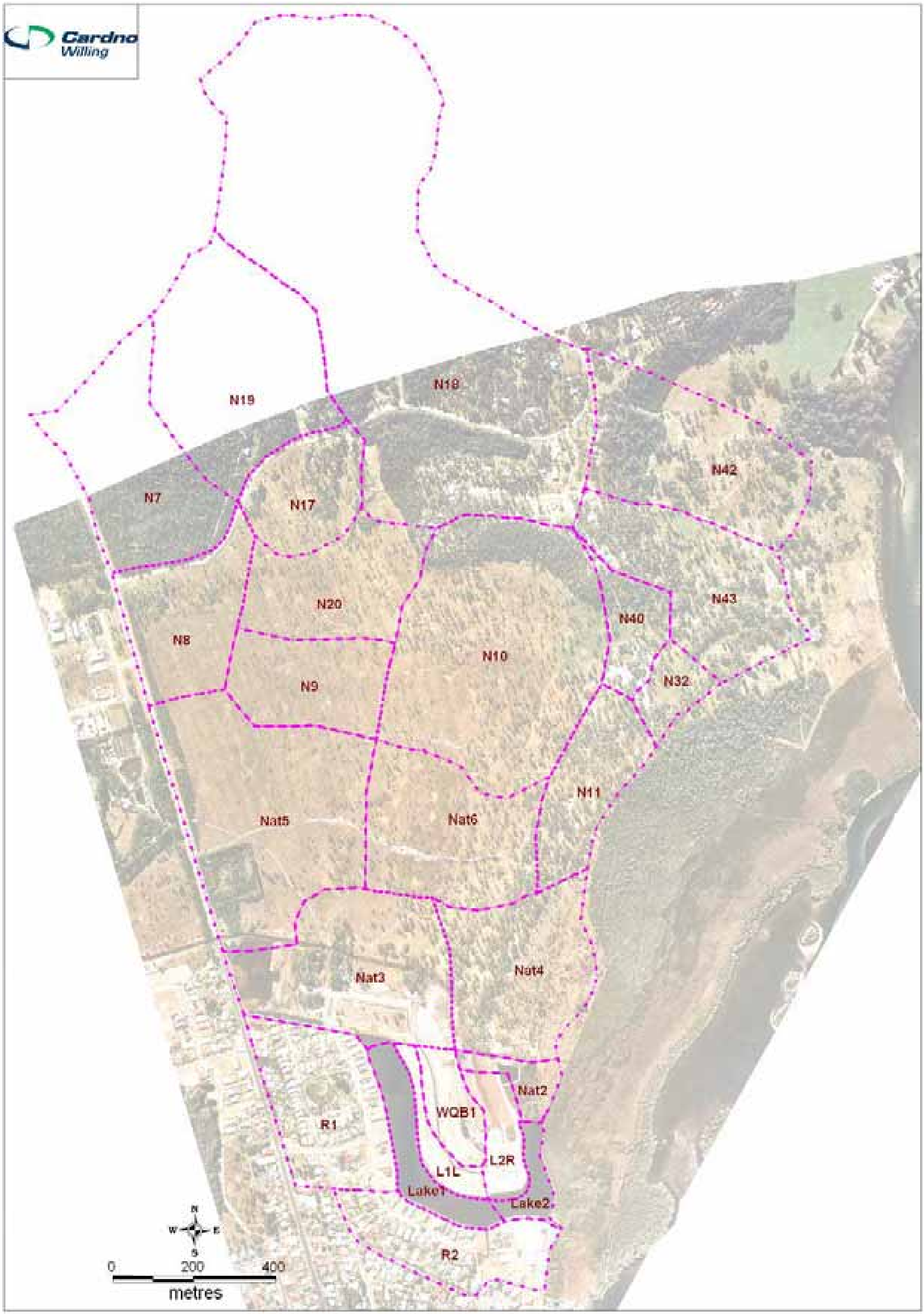

Figure B.1
Catchment Layout - Existing Conditions

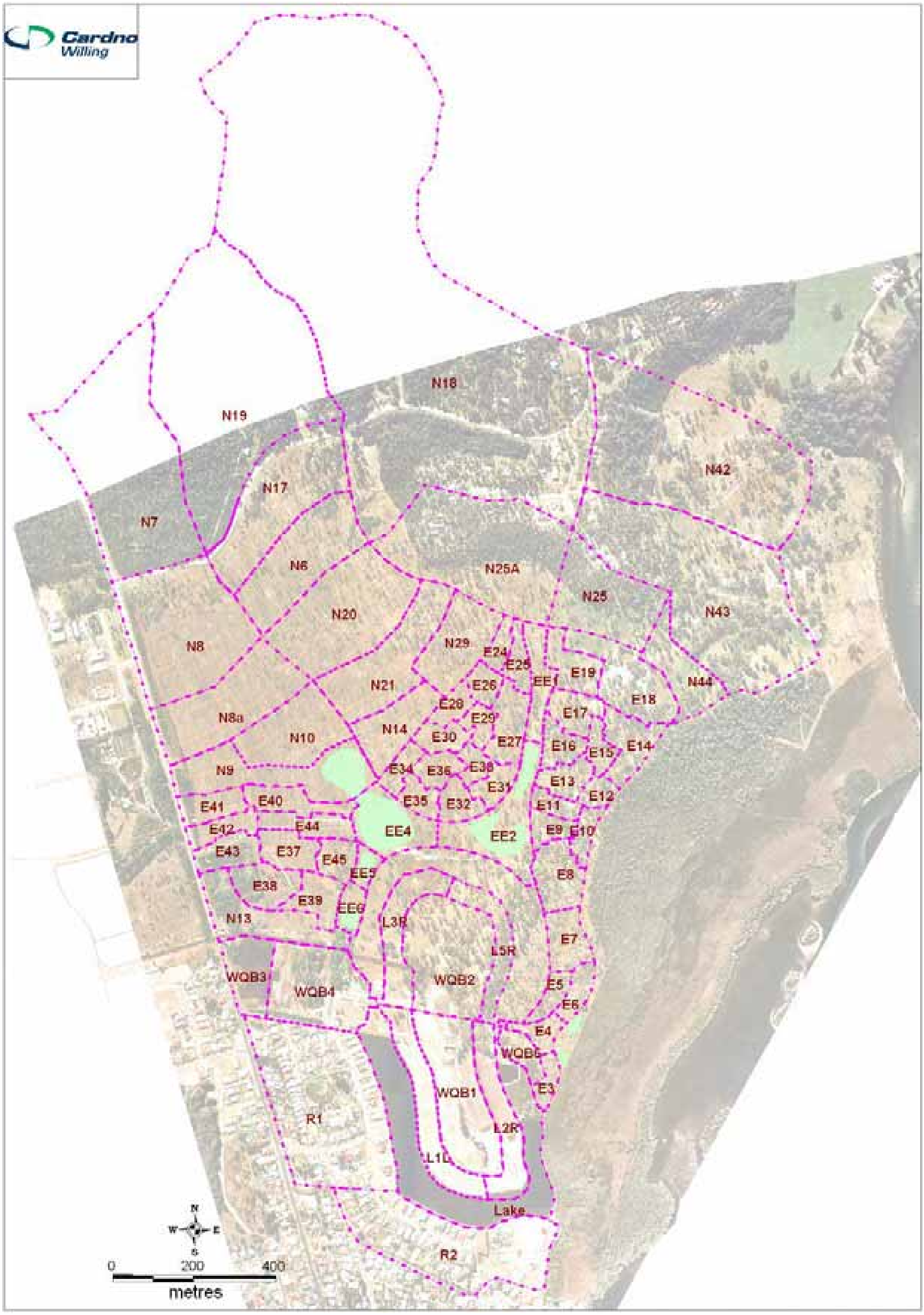

Figure B.2
Catchment Layout – Developed Conditions

APPENDIX 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 waterways and basins in place; and
- Estimate peak flows and peak flood levels under developed conditions for the 5 yr ARI, 20 yr ARI and 100 yr ARI events.

C.2 Concept Sizing of Waterways

Prior to assembling an **xpswmm** model of the main drainage lines, 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.

The concept waterway dimensions for the East Branch, West Branch, North Branch and EastWest Branch are given in **Tables D.1, D.2, D.3** and **D.4** respectively. The highlighted cells are the channel widths that were selected for inclusion in the **xpswmm** model. These tables disclose the "trade-off" between channel width v flow depth v flow velocity for other channel dimensions.

Table C.1
Concept Waterway Dimensions for East Branch

Reach between EB1 and EB2
Q100 = 0.75 m3/s
Channel Slope = 0.3%

Width (m)	Depth (m)	Velocity (m/s)
6	0.440	0.487
10	0.276	0.355
15	0.225	0.309
20	0.205	0.288
25	-	-
30	-	-

Reach between EB6 and EBd1
Q100 = 1.7 m3/s
Channel Slope = 0.3%

Width (m)	Depth (m)	Velocity (m/s)
6	-	-
10	0.471	0.509
15	0.354	0.419
20	0.308	0.380
25	0.284	0.359
30	0.271	0.347

Reach between EB2 and EB3
Q100 = 0.75 m3/s
Channel Slope = 0.3%

Width (m)	Depth (m)	Velocity (m/s)
6	0.350	0.418
10	0.240	0.324
15	0.200	0.285
20	-	-
25	-	-
30	-	-

(without influence from crossing at EB3)

Reach between EBd1 and EB7
Q100 = 1.7 m3/s
Channel Slope = 0.3%

Width (m)	Depth (m)	Velocity (m/s)
6	-	-
10	0.471	0.509
15	0.354	0.419
20	0.308	0.380
25	0.284	0.359
30	0.271	0.347

Table C.2
Concept Waterway Dimensions for West Branch

Reach between WB1 and WB2
Q100 = 9.01 m3/s
Channel Slope = 0.2%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	0.957	0.667
30	0.718	0.548
40	0.624	0.497
50	0.575	0.469
60	0.548	0.453

Reach between WB2 and WB3
Q100 = 9.48 m3/s
Channel Slope = 0.2%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	0.990	0.682
30	0.739	0.559
40	0.640	0.506
50	0.589	0.477
60	0.560	0.459

Reach between WB3 and WB4
Q100 = 9.35 m3/s
Channel Slope = 0.2%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	0.983	0.679
30	0.735	0.557
40	0.637	0.504
50	0.586	0.475
60	0.558	0.458

Reach between WB4 and WB5
Q100 = 10.73 m3/s
Channel Slope = 0.2%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	1.090	0.727
30	0.798	0.589
40	0.686	0.530
50	0.628	0.498
60	0.595	0.479
70	0.575	0.466

Reach between WB5 and WB6
Q100 = 11.58 m3/s
Channel Slope = 0.2%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	1.160	0.758
30	0.837	0.608
40	0.716	0.546
50	0.654	0.512
60	0.617	0.491
70	0.596	0.478

Table C.3
Concept Waterway Dimensions for North Branch

Reach between NB1 and NB2

Q100 = 0.18 m3/s

Channel Slope = 0.2%

Width (m)	Depth (m)	Velocity (m/s)
5	0.205	0.239
10	0.140	0.183
15	0.125	0.169
20	0.120	0.163
25	-	-
30	-	-

Reach between NB4 and NB5

Q100 = 0.57 m3/s

Channel Slope = 0.2%

Width (m)	Depth (m)	Velocity (m/s)
5	-	-
10	0.265	0.282
15	0.217	0.246
20	0.198	0.230
25	-	-
30	-	-

Reach between NB2 and NB3

Q100 = 0.21 m3/s

Channel Slope = 0.2%

Width (m)	Depth (m)	Velocity (m/s)
5	0.230	0.258
10	0.150	0.192
15	0.134	0.177
20	0.128	0.170
25	-	-
30	-	-

(without influence from crossing at NB3)

Reach between NB5 and NB6

Q100 = 0.78 m3/s

Channel Slope = 0.2%

Width (m)	Depth (m)	Velocity (m/s)
5	-	-
10	0.320	0.321
15	0.256	0.275
20	0.229	0.254
25	-	-
30	-	-

Table C.4
Concept Waterway Dimensions for EastWest Branch

Reach between EW1 and EW1_1
Q100 = 13.78 m3/s
Channel Slope = 2%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	0.592	1.527
30	0.478	1.317
40	0.431	1.223
50	-	-
60	-	-

Reach between EW4 and EW5
Q100 = 5.44 m3/s
Channel Slope = 0.3%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	0.600	0.597
30	0.483	0.514
40	0.436	0.477
50	0.413	0.458
60	0.403	0.448
70	-	-

Reach between EW1_1 and EW2
Q100 = 12.83 m3/s
Channel Slope = 1%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	0.705	1.214
30	0.555	1.031
40	0.494	0.949
50	0.464	0.906
60	-	-

Reach between EW6 and EW7
Q100 = 5.73 m3/s
Channel Slope = 0.3%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	0.619	0.609
30	0.497	0.524
40	0.447	0.486
50	0.423	0.466
60	0.412	0.455
70	-	-

Reach between EW2 and EW3
Q100 = 11.68 m3/s
Channel Slope = 0.15%

Width (m)	Depth (m)	Velocity (m/s)
10	-	-
20	-	-
30	0.915	0.559
40	0.777	0.500
50	0.705	0.467
60	0.662	0.446
70	0.637	0.433

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 Scheme 3 Hydraulic Model

An **xpswmm** hydraulic model was assembled for Riverside at Tea Gardens under the proposed Scheme 3 Developed Conditions. The model includes the four main drains and a concept retarding basin located on the EastWest Branch. The active storage available above the extended detention lake and major ponds and wetlands was represented as flood storage at selected nodes.

The adopted concept grading of Basin EW was as follows:

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

The adopted stage-storage-discharge relationship for the extended detention lake was as follows:

Stage (m AHD)	Storage (ML)	Outflow (m^3/s)
0.530	0.0	0
0.590	8.1	0.2
0.643	15.3	0.5
0.702	23.2	1
0.761	31.2	2
0.858	44.3	4
0.934	54.5	6
0.979	60.6	8
1.030	67.5	12
1.064	72.1	15
1.114	78.8	20
1.156	84.5	25
1.194	89.6	30
1.230	94.5	35

The layout of the **xpswmm** model of the proposed Scheme 3 developed condition is shown in **Figure C.1**.

C.3.2 Scheme 5 Hydraulic Model

Subsequent to discussions held with the NSW Department of Planning regarding NSW Government stakeholder concerns regarding the concept Scheme 3 development a concept development based on Scheme 5 was investigated in detail.

The **xpswmm** hydraulic model that was assembled for Riverside at Tea Gardens under the proposed Scheme 3 Developed Conditions was modified based on an amended detailed concept layout of planned future stages of the development under Scheme 5.

The concept Scheme 5 layout of waterways, ponds and lakes is given in **Figure C.5.**

The Scheme 5 hydraulic model includes a number of small ponds, three large ponds, three freshwater lakes and an extension of detention lake. It also includes the 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 is controlled by four 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 0.3 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.5**):

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 the proposed Scheme 5 developed condition is shown in **Figure C.6**.

C.4 Results

C.4.1 Scheme 3 Results

The **xpswmm** model of Scheme 3 was run to estimate the 5 yr ARI, 20 yr ARI and 100 yr ARI peak flows and basin water levels under the proposed Scheme 3 development. 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 and the flood level in the 5 yr ARI, 20 yr ARI and 100 yr ARI events are summarised in **Table C.5.** The estimated peak discharges to the Conservation Zone without and with the major basin on the EastWest Branch (Basin EW) in the 5 yr ARI, 20 yr ARI and 100 yr ARI events are summarised in **Table C.6**. This table also summarise the estimated peak basin water levels.

Table C.5
Estimated Peak Outflows from the Extended Detention Lake under Scheme 3 Developed Conditions

5 yr ARI	20 yr ARI	100 yr ARI	Comment
4.23 *(0.867)*	7.12 *(0.960)*	11.8 *(1.028)*	Outflow from the extended detention lake

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

Table C.6
Estimated Peak Outflows from Basin EW under Developed Conditions

5 yr ARI	20 yr ARI	100 yr ARI	Comment
3.73 *(0.86)*	4.65 *(1.07)*	5.48 *(1.30)*	Outflow from Basin EW
6.07	8.16	11.77	Aggregated flow to the Conservation Zoned (without Basin EW)
4.59	5.93	7.45	Aggregated flow to the Conservation Zone (with Basin EW)

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

The estimated 100 yr ARI peak flows, flood levels and flood depths within the hydraulic study area for storm bursts of 1.5 hours and 9 hours are presented in **Figures C.3** and **C.4** respectively.

C.4.2 Scheme 5 Results

The Scheme 5 **xpswmm** model was run to estimate the 5 yr ARI, 20 yr ARI and 100 yr ARI peak flows and basin water levels under the proposed Scheme 5 development. 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.7.**

Table C.7
Estimated Peak Outflows from the Extended Detention Lake under Scheme 5 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

The estimated 5 yr ARI, 20 yr ARI and 100 yr ARI flood levels under 1.5 hour and 9 hour storm bursts are presented spatially in **Figures C.7** to **C.12**.

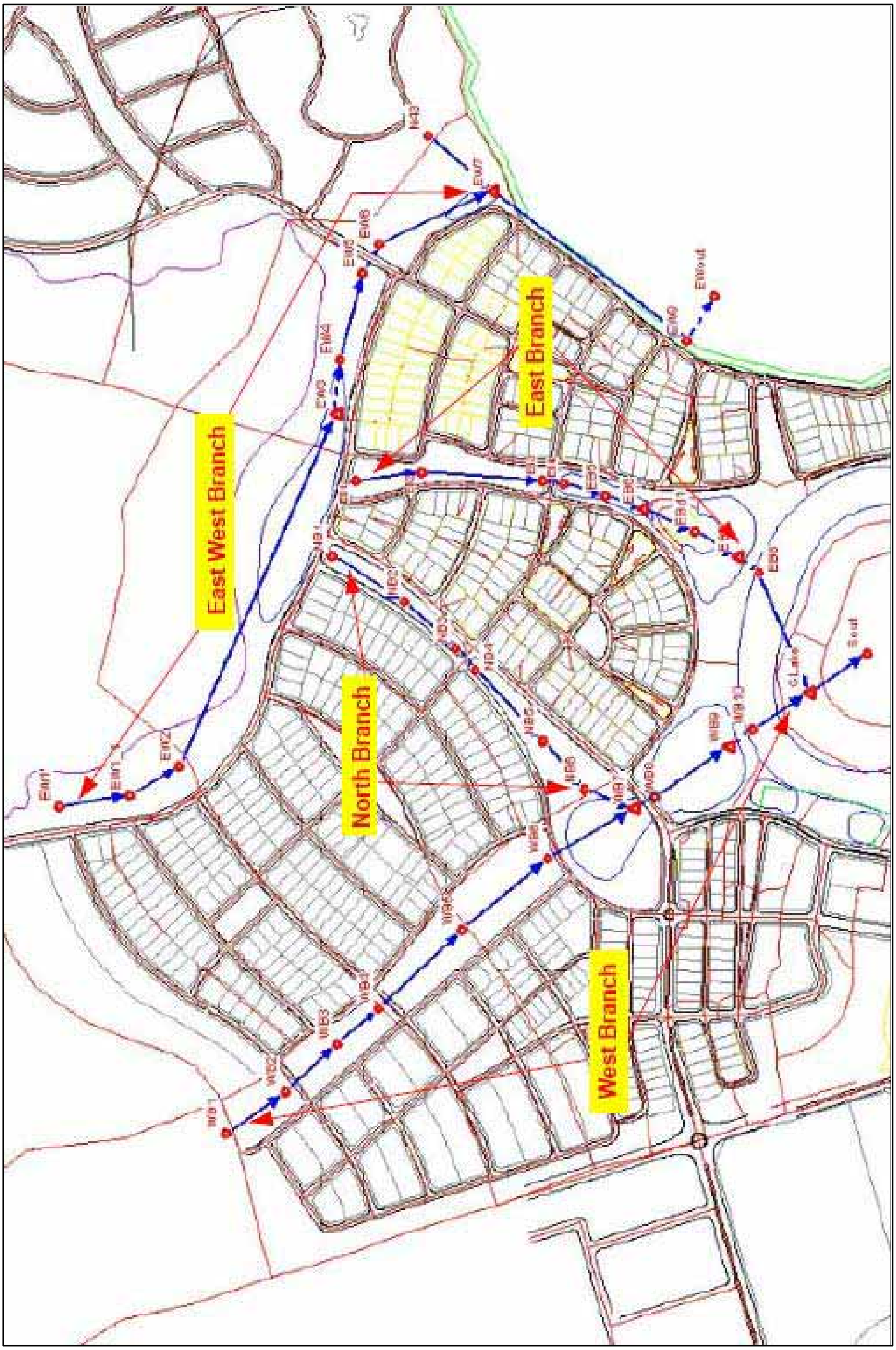

Figure C.1
Location of Main Drainage Lines

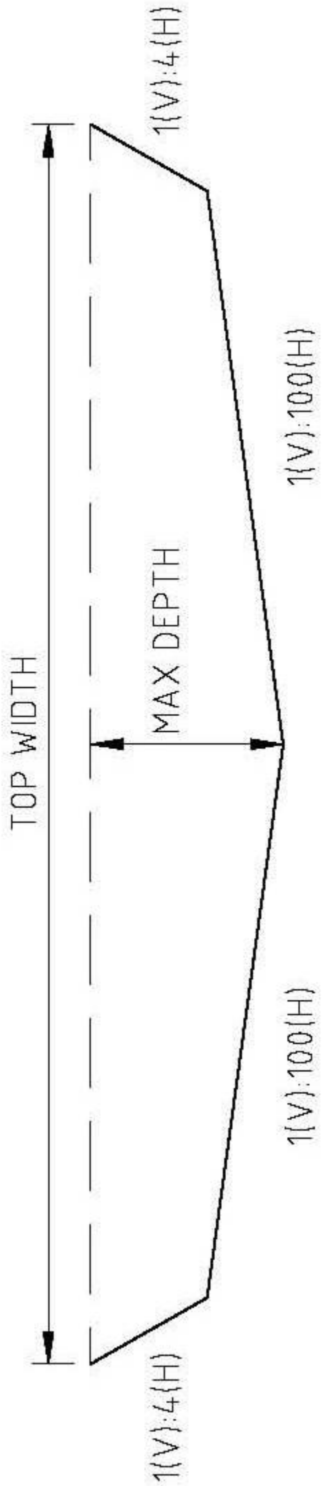

Figure C.2
Concept Waterway Geometry

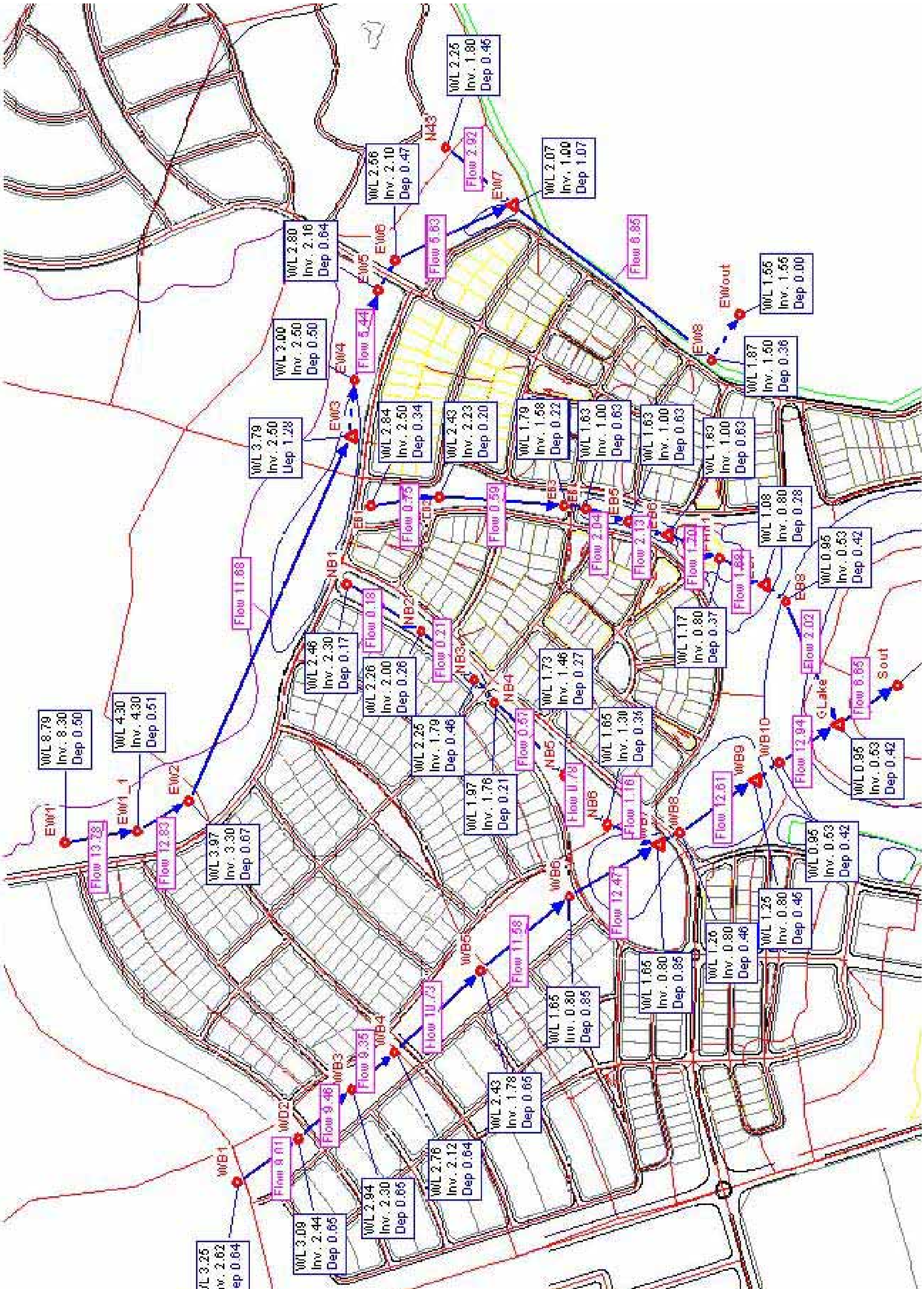

Figure C.3

100 yr ARI Peak Flows, Flood Levels and Flood Depths for 1.5 hour Storm Burst - Scheme 3

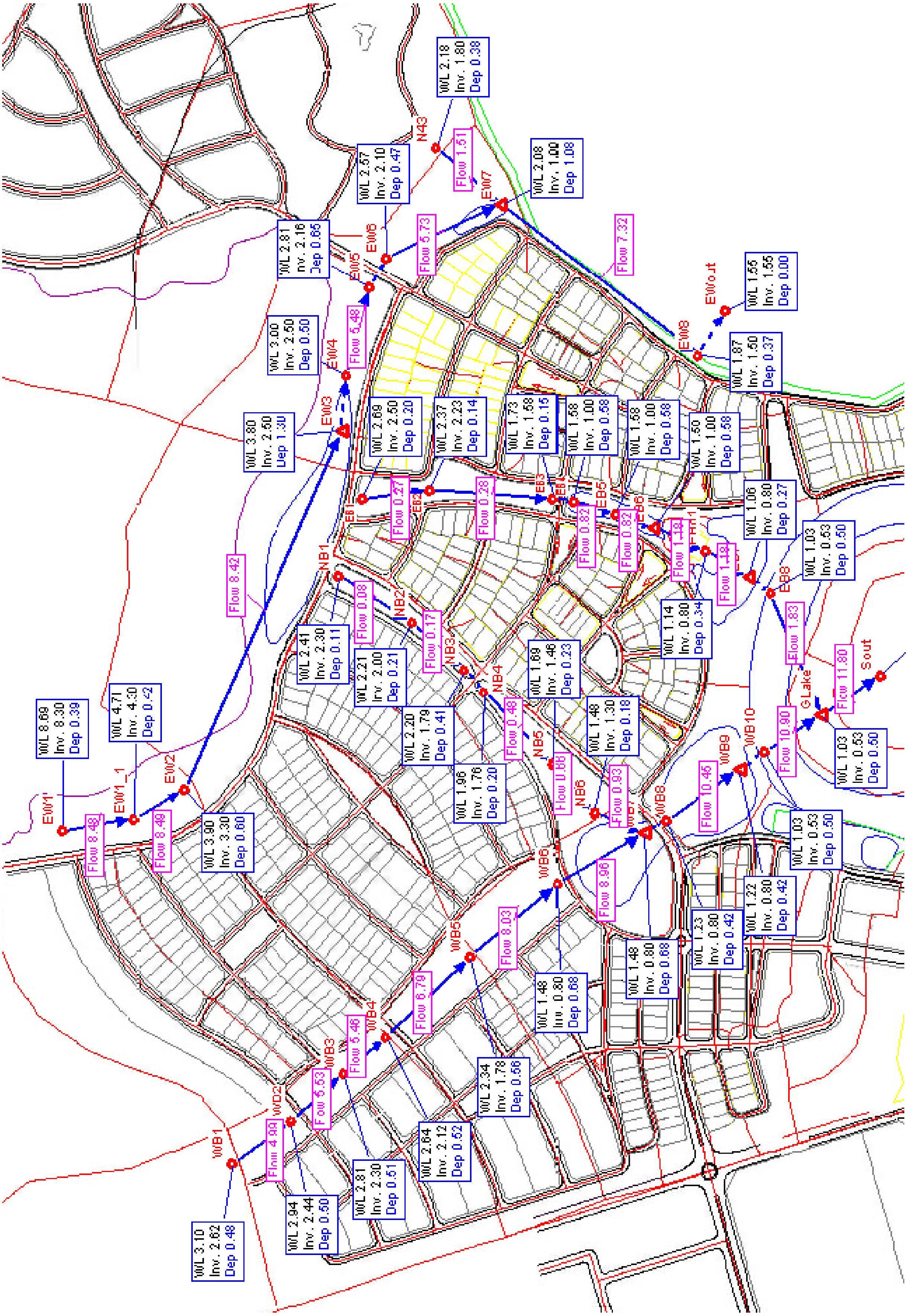

Figure C.4

100 yr ARI Peak Flows, Flood Levels and Flood Depths for 9 hour Storm Burst – Scheme 3

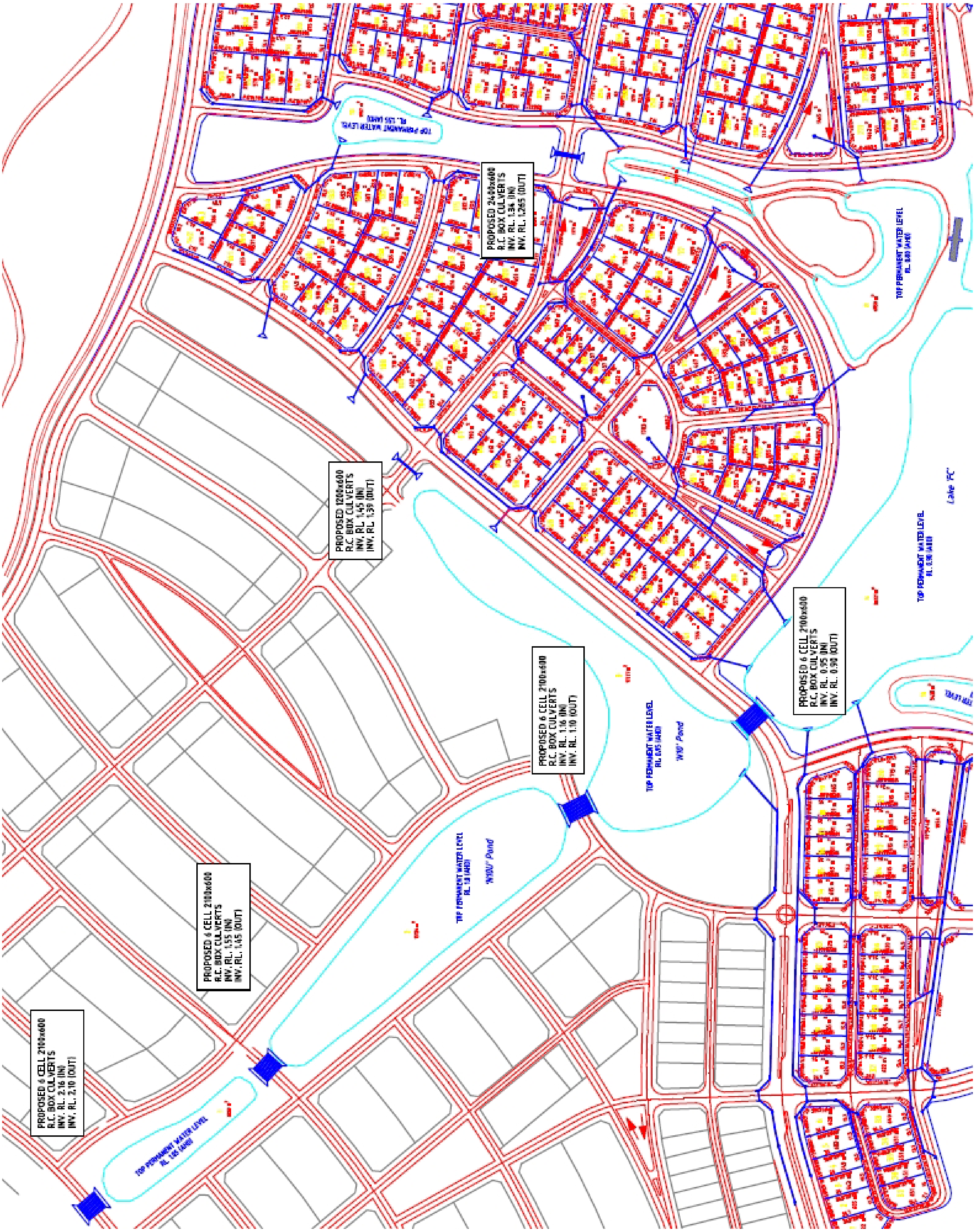

Figure C.5 (a)
Concept Layout and Crossing Details for Concept Scheme 5 Development

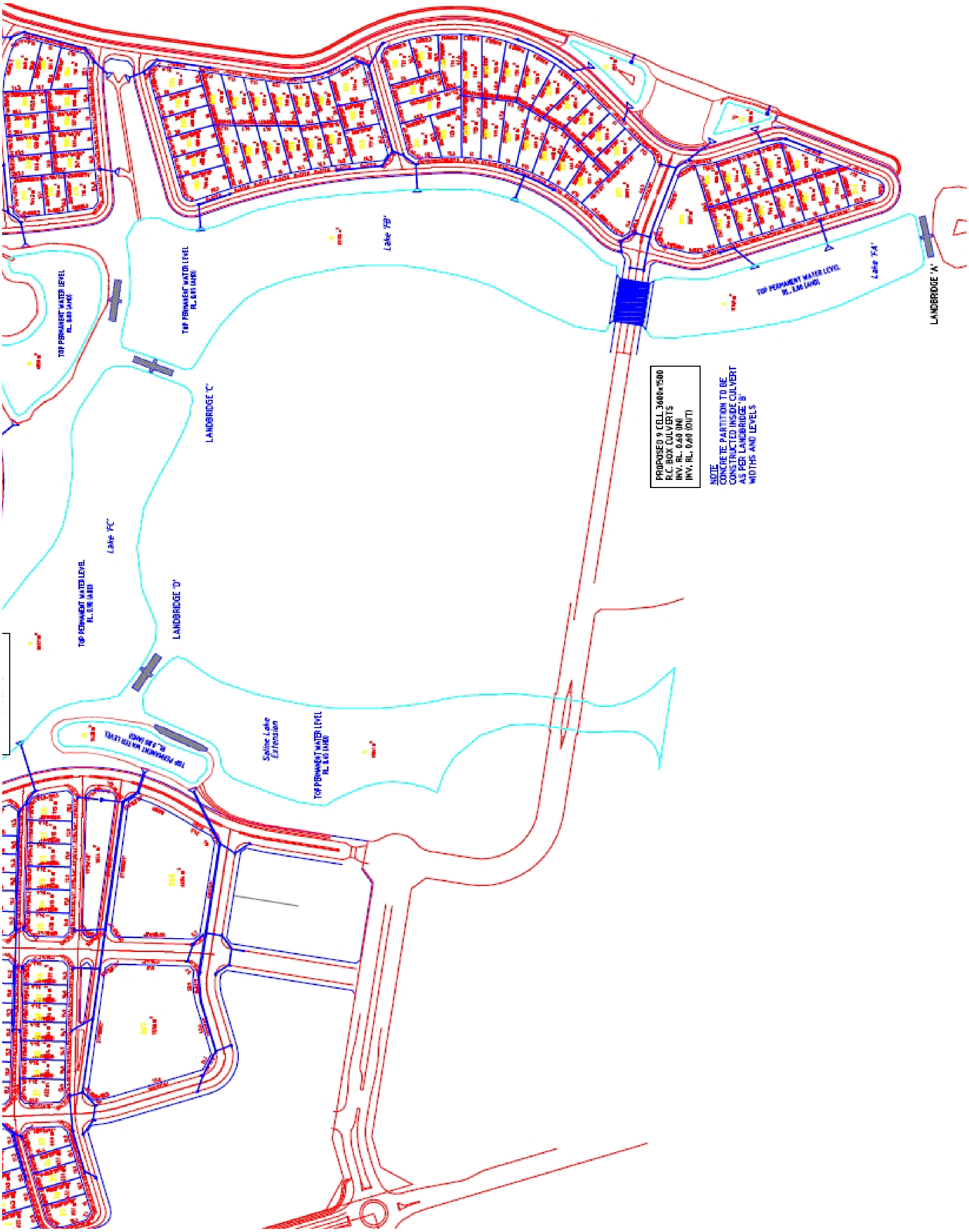

Figure C.5 (b)
Concept Layout and Crossing Details for Concept Scheme 5 Development

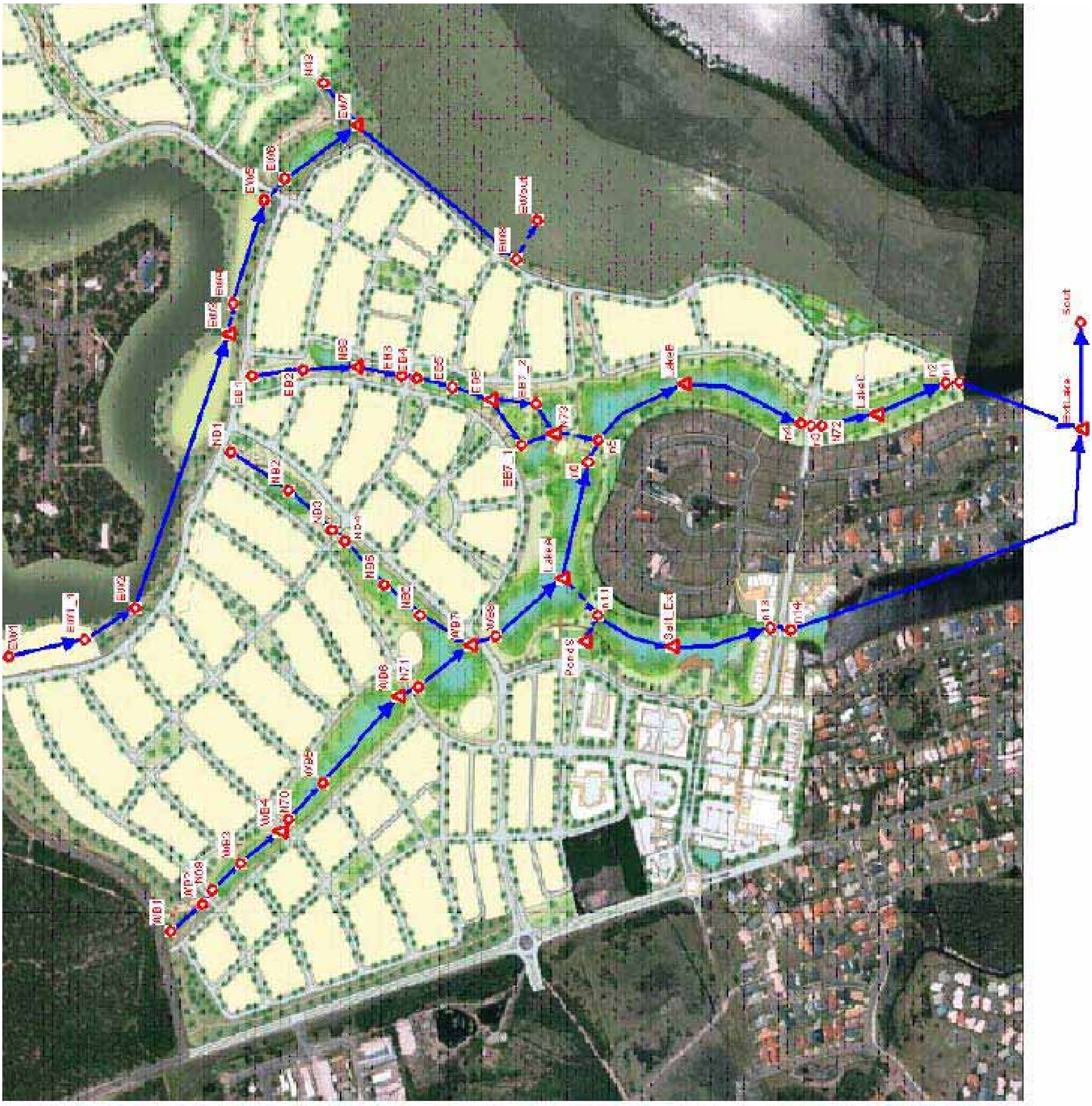

Figure C.6
Scheme 5 Hydraulic Model Layout

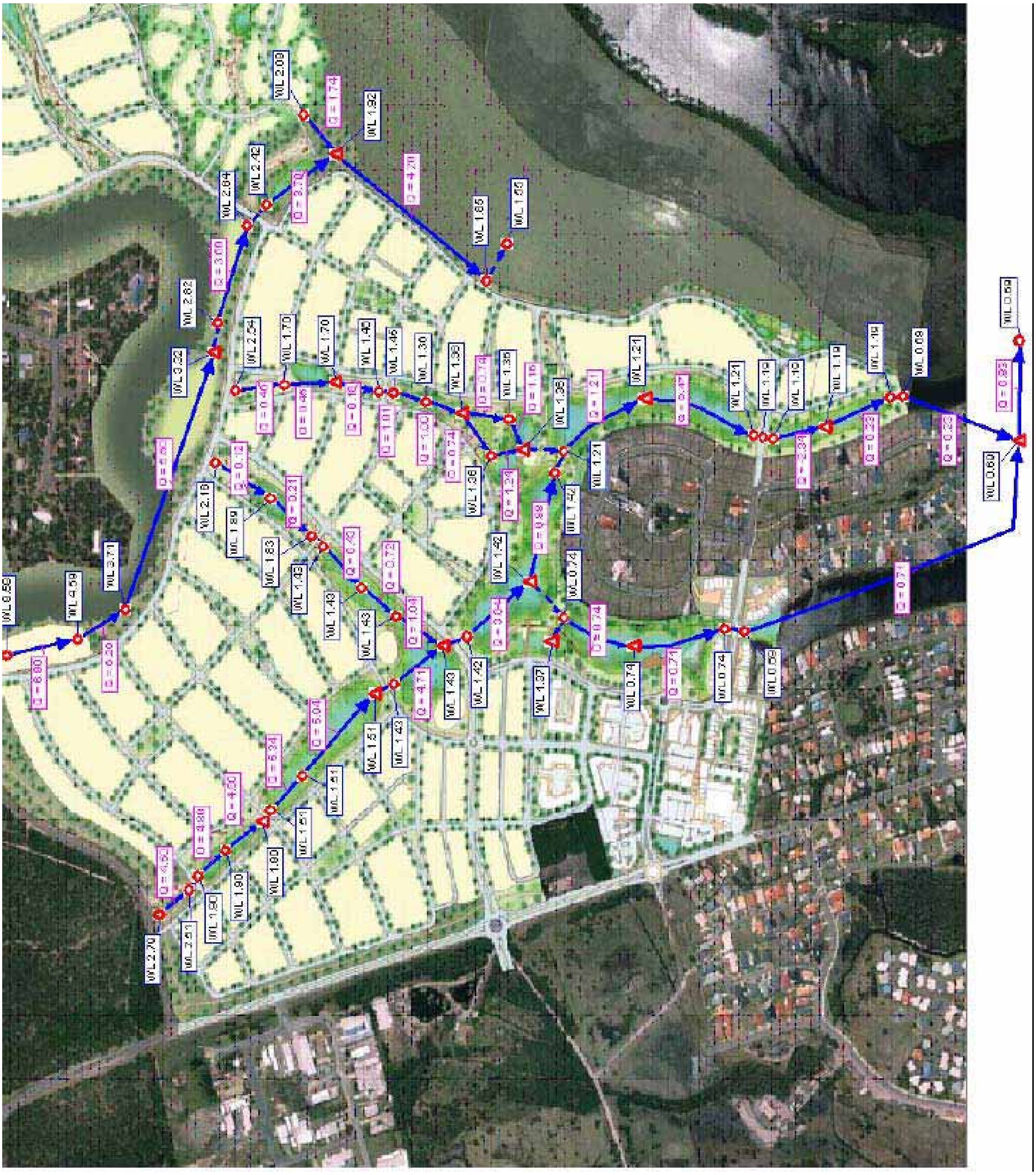

Figure C.7
5 yr ARI Peak Flows and Flood Levels for 1.5 hour Storm Burst

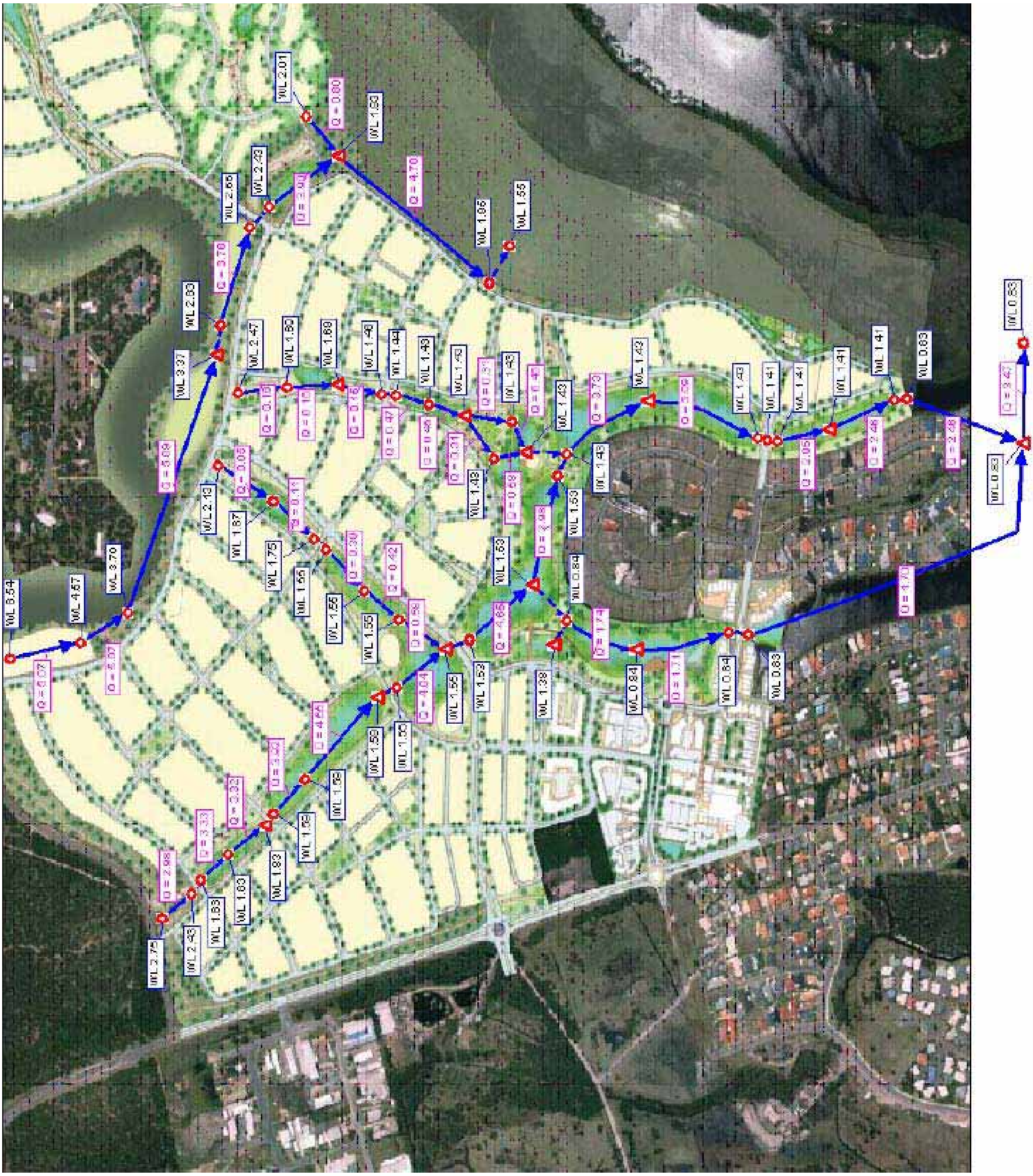

Figure C.8
5 yr ARI Peak Flows and Flood Levels for 9 hour Storm Burst

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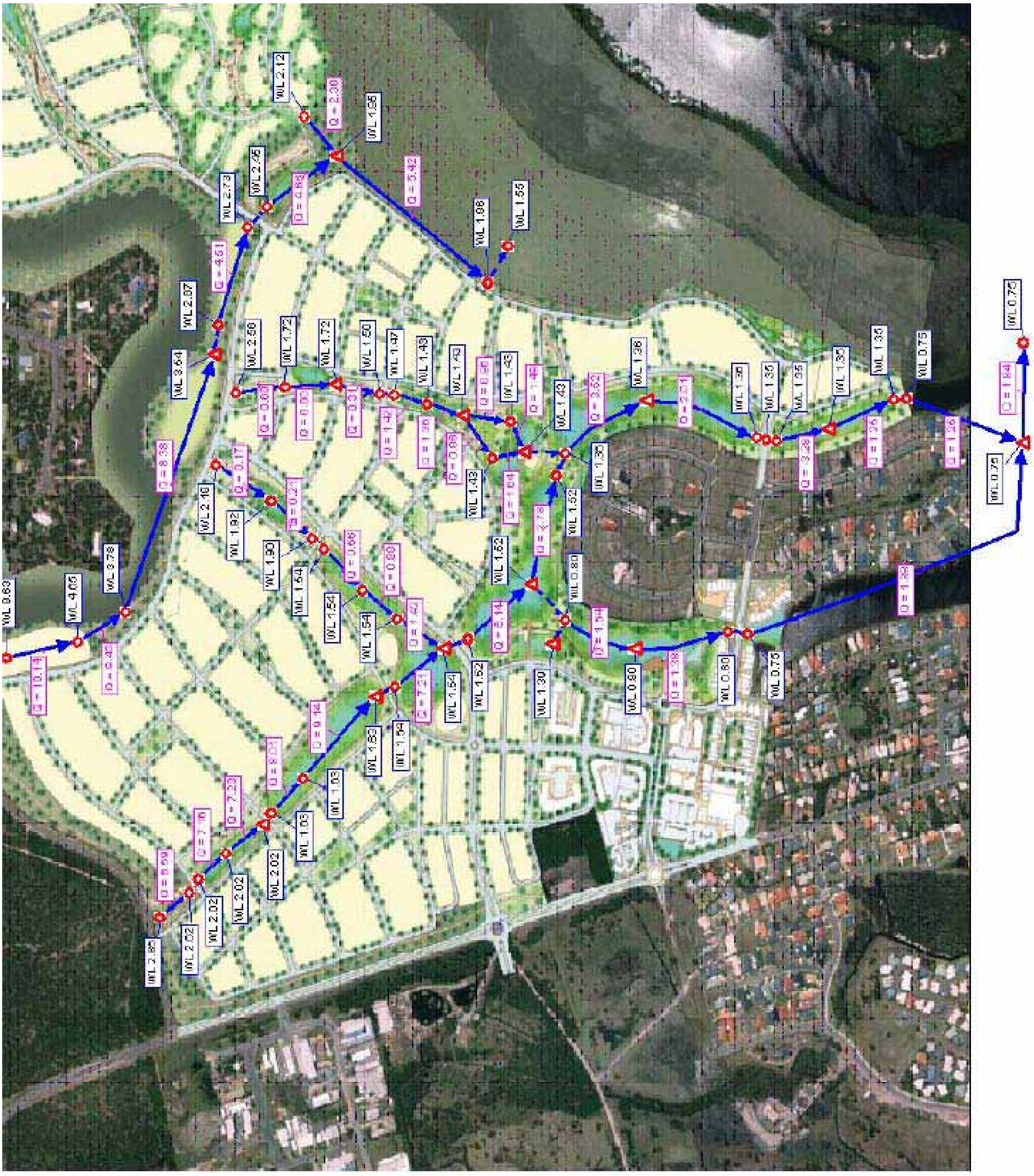


Figure C.9
20 yr ARI Peak Flows and Flood Levels for 1.5 hour Storm Burst

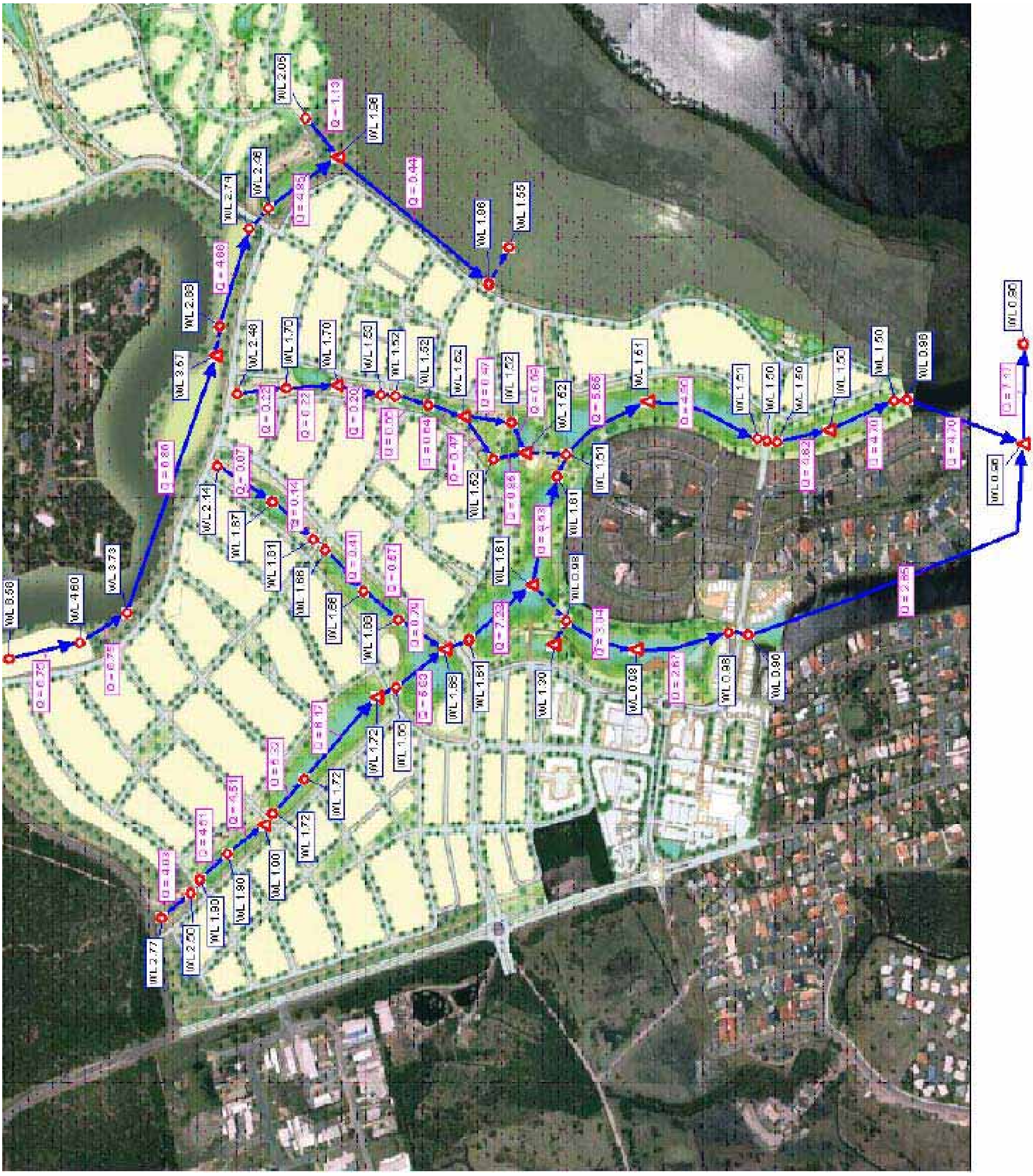


Figure C.10
20 yr ARI Peak Flows and Flood Levels for 9 hour Storm Burst

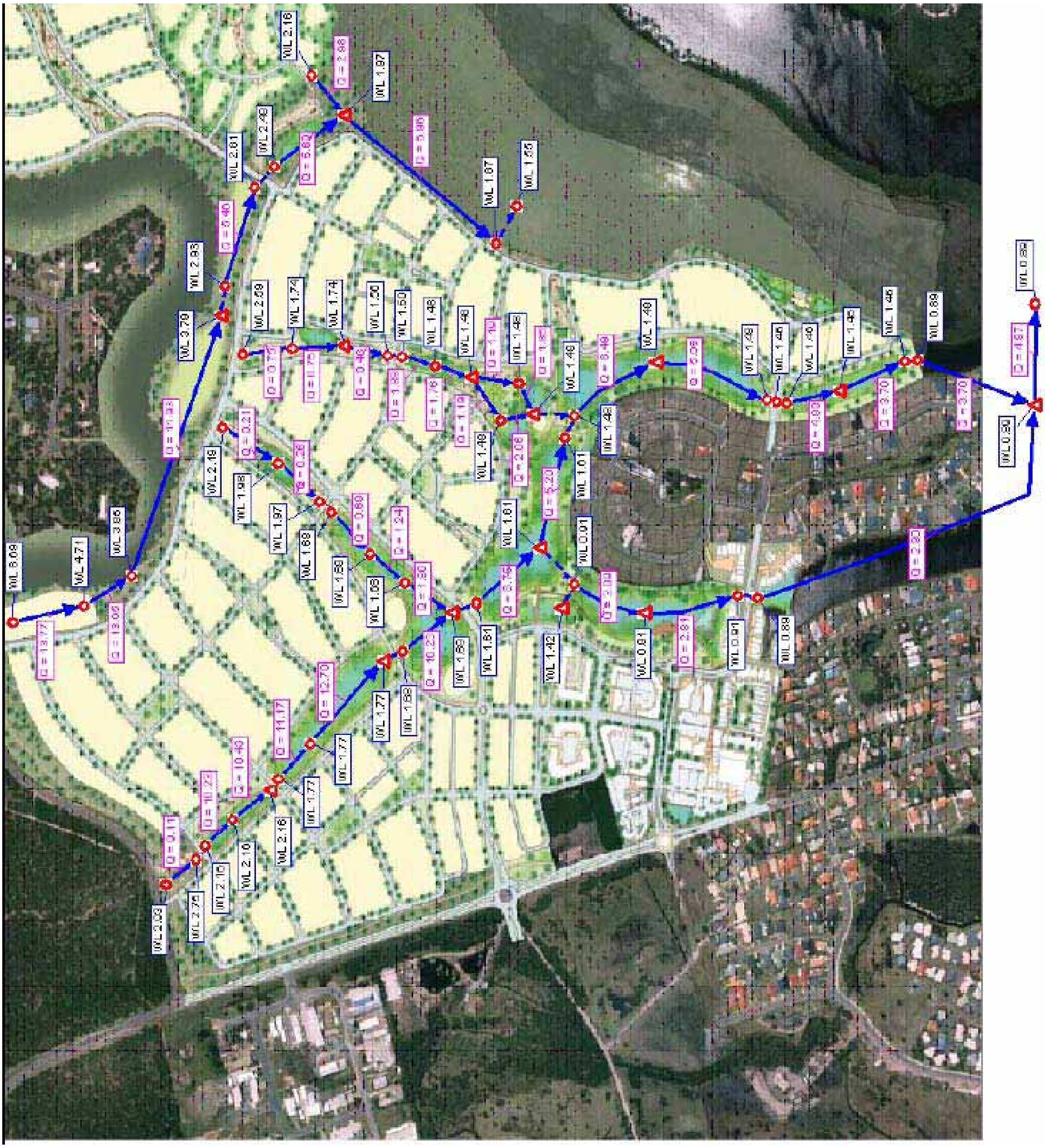


Figure C.11
100 yr ARI Peak Flows and Flood Levels for 1.5 hour Storm Burst

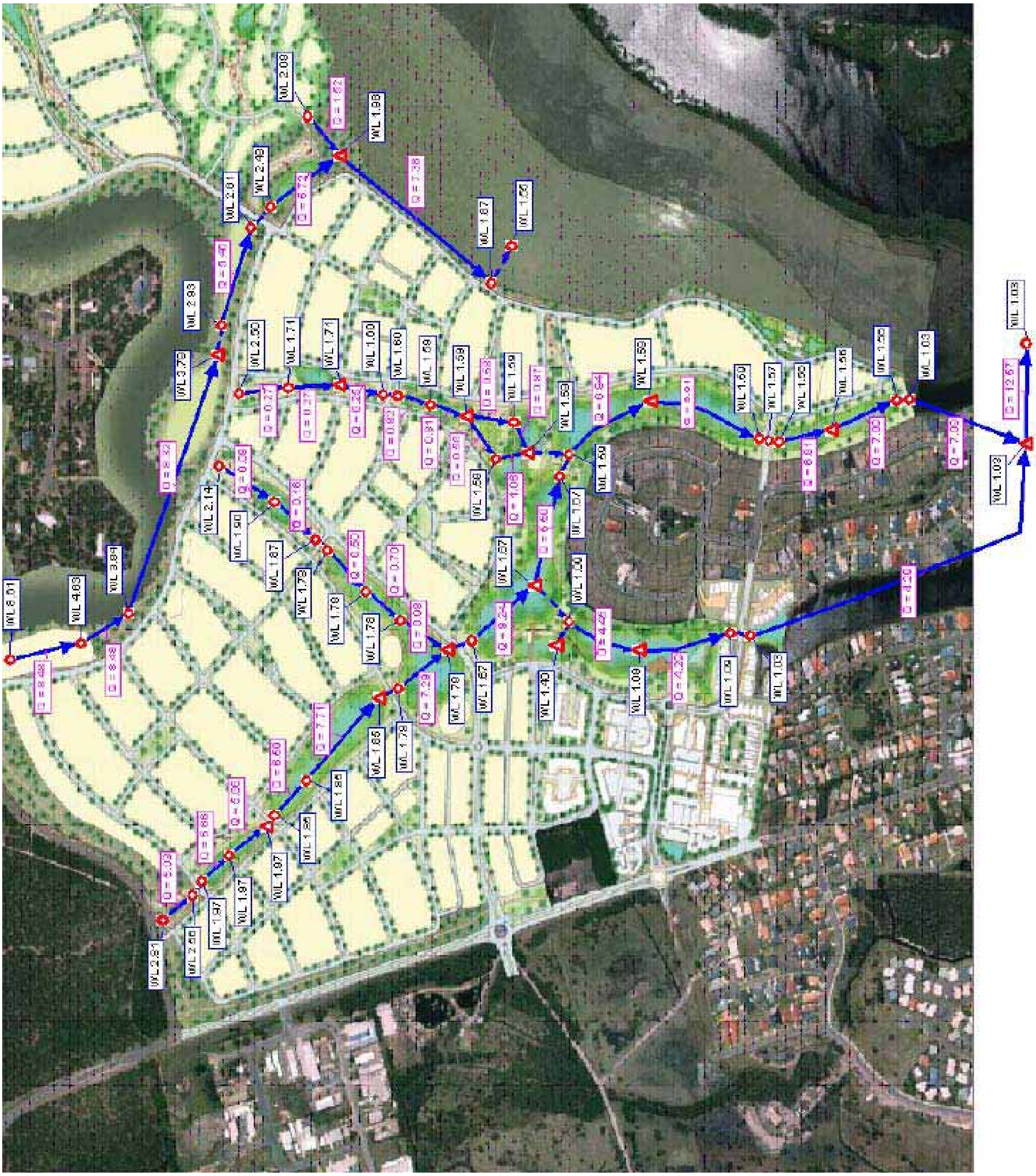


Figure C.12
100 yr ARI Peak Flows and Flood Levels for 9 hour Storm Burst

APPENDIX D

CATCHMENT WATER QUALITY MODELLING

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 concept development with and without rainwater tanks and run the generate for inputs into the Scheme 3 lake model;
- Create MUSIC models of the proposed concept development with and without rainwater tanks and run the generate for inputs into the Scheme 5 lake model; and
- If needed, size ancillary pond(s) and/or wetland(s) to achieve the receiving water quality objectives for the receiving waters.

D.2 MUSIC Overview

The CRC for Catchment Hydrology (CRCCH) has developed a Model for Urban Stormwater Improvement Conceptualisation (MUSIC), which packages the results of many research activities undertaken at the CRCCH and other organisations into a user-friendly stormwater management tool.

MUSIC enables urban catchment managers to (a) determine the likely water quality emanating from specific catchments, (b) predict the performance of specific stormwater treatment measures in protecting receiving water quality, (c) design an integrated stormwater management plan for a catchment, (d) evaluate the success of a treatment node or treatment train against a range of water quality standards, and (e) analyse the lifecycle costs of a treatment node or treatment train.

D.2.1 Background

MUSIC has modules for runoff and pollutant generation in source nodes and modules to assess stormwater treatment processes in treatment nodes. Four categories of source node are available in Version 3.01: agricultural, forest and urban source nodes and a user defined source node. These source nodes differ only in their default baseflow and stormflow pollutant concentrations.

In MUSIC Version 3.01, four default pollutants are modelled: total suspended solids (TSS), total nitrogen (TN), total phosphorous (TP) and gross pollutants.

The treatment devices that can be modelled in MUSIC include rainwater tank, buffer zone, gross pollutant trap (GPT), bio-retention, swale, sediment basin, infiltration system, pond and wetland.

The model outputs include runoff, pollutant concentrations and pollutant loads at each node as time series, from which monthly and annual loads and other statistics can be calculated.

Other features of MUSIC include:

- Multiple interconnected catchments (source nodes) and treatment devices (treatment nodes) in a network;
- Graphical import, export and editing of data;
- Graphical/tabular/statistical interpretation, presentation and export of modelling results;
- Multiple treatment devices to form a treatment train;
- Import of rainfall and evaporation data in BOM format or from ASCII files;
- Flexible time steps from 6 minute to daily;
- Import of data from upstream catchments (time series);
- Stochastic generation of pollutant concentrations;
- Direct export of results into other receiving waters model; and
- Life cycle cost estimates.

D.2.2 Rainfall/Runoff Model

MUSIC model simulates runoff using a modified version of the rainfall-runoff model developed by Chiew *et al* (1997). This model predicts runoff from rainfall based on an accounting of evaporation, and surface and soil moisture storages.

The concept structure of the rainfall /runoff model in Version 3.01 of MUSIC is presented diagrammatically in **Figure D.1**.

Moisture Stores

As shown in **Figure D.1**, three moisture stores are incorporated in the rainfall/runoff model as follows:

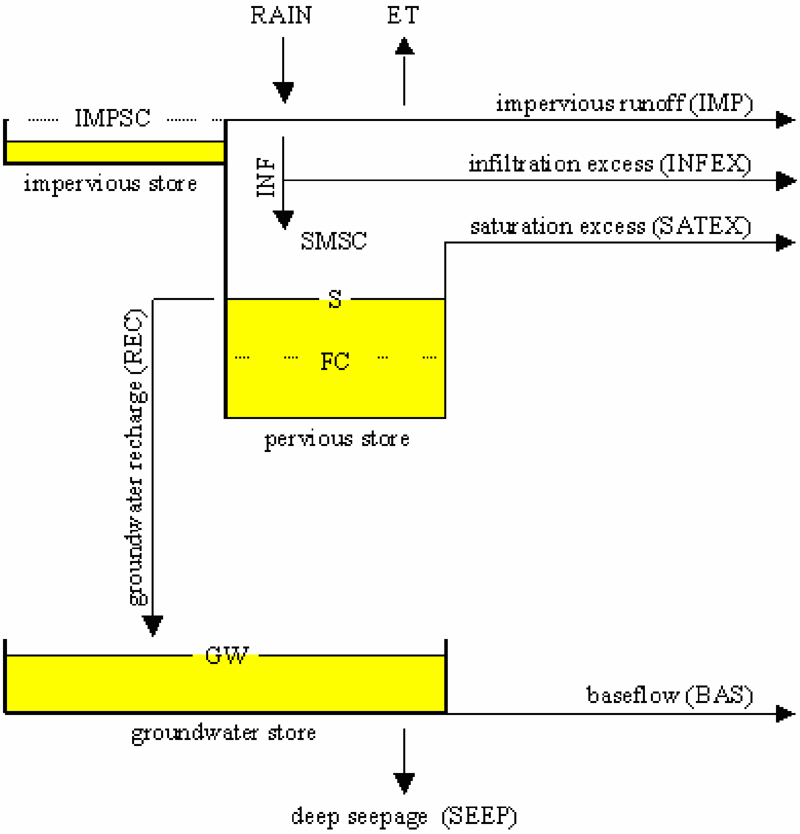
- Impervious Store;
- Pervious Store; and
- Groundwater Store.

A loss of moisture to a deep ground store is also accounted for in the model.

A number of coefficients for each of these moisture stores can be adjusted based on measured data. These coefficients relate to soil type and soil permeability.

Stormwater Reuse

MUSIC can account for the reuse of stormwater harvested from treatment devices such as pond, wetland or a sediment basin. Potential reuse of stormwater was not considered in this assessment.



Model inputs

RAIN = daily rainfall (mm)
PET = areal potential evapotranspiration (mm)

Model parameters

IMPSC = impervious store capacity (mm)
SMSC = soil moisture store capacity (mm)
COEFF = maximum infiltration loss (mm)
SQ = infiltration loss exponent
FC = field capacity of soil moisture store (mm)
RFAC = soil moisture to groundwater recharge factor
BFAC = groundwater to baseflow factor
SFAC = groundwater to deep seepage factor

Model relationships

IMP = greater of {(RAIN - ***IMPSC***), 0}
INF = lesser of { ***COEFF*** × exp (-***SQ*** × S / ***SMSC***), RAIN}
INFEX = RAIN - INF
SATEX = greater of {(S - SMSC), 0}
REC = greater of {(***RFAC*** × (S - ***FC***)), 0}
ET = lesser of {(10 × S / ***SMSC***), PET}
BAS = ***BFAC*** × GW
SEEP = ***SFAC*** × GW

Figure D.1
MUSIC Rainfall/Runoff Models
(Adapted from MUSIC Manual)

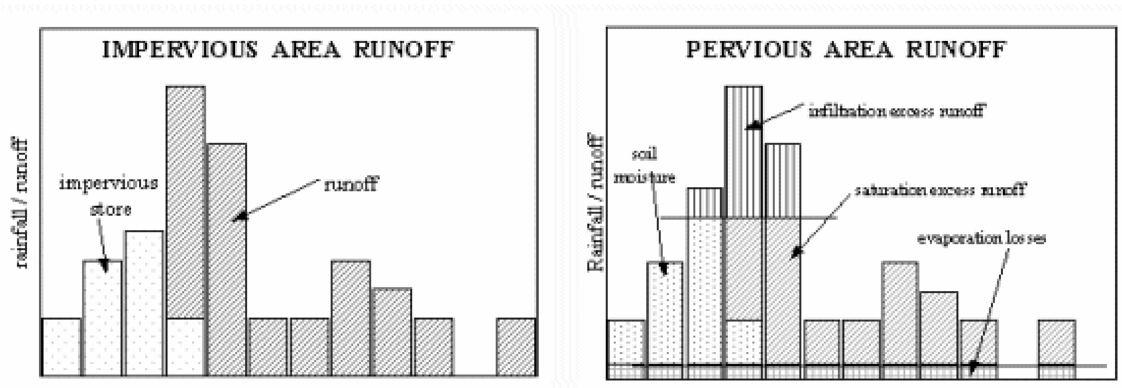


Figure D.2
MUSIC Runoff Components
(Adapted from MUSIC Manual)

Runoff

Runoff generated from source nodes includes impervious area runoff and pervious area runoff. The latter comprises infiltration excess runoff, saturation excess runoff and baseflow. These components of runoff are illustrated in **Figure D.2**.

Runoff Routing

Runoff from source and treatment nodes is routed in MUSIC using links. Runoff can be either routed without lag, with lag (pure translation) or with routing (Muskingum-Cunge procedure).

D.2.3 The Universal Stormwater Treatment Model

The second component of the MUSIC model is the Universal Stormwater Treatment Model (USTM). Two basic modelling procedures are adopted in the USTM – hydrological routing to simulate the movement of water through a treatment system, and a first order kinetic model to simulate the removal of pollutants within the treatment system.

The first order kinetic model which controls the pollutant removal processes is governed by an exponential decay equation which describes the physical movement of particulate pollutants. The process is expressed algebraically as:

$$(C_{out} - C^*) / (C_{in} - C^*) = e^{-k/q}$$

where C^* is the background concentration, C_{in} is the input concentration, C_{out} is the output concentration, k is the rate constant, and q is the hydraulic loading (flow rate per surface area) of the treatment measure. Thus, a higher k means a faster approach to equilibrium, and hence a higher treatment capacity (provided C^* is less than C_{in}).

The same algorithm is used for sedimentation basins, ponds, wetlands, swales, and temporary ponding above a bioretention system by changing the four main inputs – the storage-discharge relationship, the background concentration, the exponential decay coefficient and the number of CSTRs (Continuously Stirred Tank Reactors). No chemical or biological processes are considered in MUSIC. As such, dissolved pollutants are not modelled.

D.3 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.

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

The data covers daily rainfall record (March 1981 – present). 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 the latest Concept Plan 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.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	192	1487

D.4 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.4.1 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.3
Adopted MUSIC Rainfall/Runoff Parameters

Landuse	Adopted Parameter Values								
	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.3.** 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.4.2 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.4**.

Table D.4
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:

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

Developed Conditions:

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

D.4.3 Comparison of Runoff and Pollutant Exports

The MUSIC and **xpaqualm** average annual runoff and pollutant export rates are compared in **Table D.5**.

Table D.5
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

As is indicated in table D.5 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.

D.4.4 Parameters for Treatment Measures

Rainwater Tanks

Under the scenario with rainwater tanks in place 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.5 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.3**.

D.5.1 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.6** and **D.7** respectively.

Table D.6
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.7
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.5.2 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.8**. 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.8**.

Table D.8
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.6 Developed Conditions

A number of MUSIC models of Developed Conditions were created based on Scheme 3 and Scheme 5 from the 2004 assessment and concept development plans. These models were of the following scenarios:

(i) Developed with the Scheme 3 extended detention lake only;
(ii) Developed with the Scheme 3 extended detention lake plus rainwater tanks;
(iii) Scenario (ii) plus a series of proposed major ponds and wetlands to treat runoff from residential development discharging to the Myall River (subcatchment N42) or to the Conservation Zone (subcatchment N43) plus a 770m swale along the eastern edge of the development (to distribute flow to the Conservation Zone) – the wetlands were sized to achieve target reductions of 80%, 45% and 45% in the average annual export of TSS, TP and TN respectively);
(iv) Scenario (iii) but with rainwater tanks removed
(v) Scenario (iii) but reconfigured to include four small ponds, three large ponds, three freshwater lakes and an extension of detention lake in accordance with Scheme 5; and
(vi) Scenario (v) but with rainwater tanks removed.

The layouts of the developed conditions model with and without rainwater tanks are shown in **Figure D.4, D.5** and **D.6** (Scenarios (iii), (iv) and (v)) respectively.

D.6.1 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 in July 2006. 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 surfaces as shown on the latest Masterplan. The breakdown of landuse areas by subcatchment under Developed Conditions is given in **Tables D.9**.

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

Catch ID	Roof	Road	Driveway	Lawn/urban Clay	Lawn/urban Sand	Open Water
N18	5.42	2.92	1.32	51.29	3.00	
N19	0.77	0.41	0.19	18.42		
N42	2.32	0.83	0.89	4.41	7.31	
N43	2.18	0.78	0.84	2.30	8.71	
E4	0.26	0.09	0.10		0.28	
N44	1.69	0.60	0.65		4.21	
EE1	2.41	0.86	0.93	0.64	3.68	
N25				9.79	5.08	
E2	0.44	0.16	0.17		0.49	
L1L	0.78	0.42	0.19		1.65	
N7				13.05		
R1	2.81	1.51	0.68		5.86	
L2R	0.68	0.37	0.17		1.41	
L3R	0.64	0.34	0.16		1.34	
R2	2.02	1.08	0.49		4.24	
WQB2	1.44	0.78	0.33		2.99	
L5R	0.46	0.25	0.11		0.97	
WQB1	1.28	0.69	0.31		2.68	
Lake						14.21
E8	2.46	0.88	0.95	2.12	3.64	1.09
EE6	1.96	0.70	0.76		2.84	0.17
EE5	1.14	0.41	0.44		1.65	0.20
EE4	4.82	1.72	1.86	5.93	4.77	2.32
N10	6.00	2.14	2.32	7.51	2.31	
N8	4.68	1.67	1.81	5.70	6.27	
WQB4	1.65	0.89	0.40		3.48	
E1	0.30	0.11	0.12		0.33	
E6	0.71	0.25	0.27		0.79	
Total	**49.31**	**20.86**	**16.44**	**121.17**	**79.95**	**17.99**

D.6.2 Results

Scheme 3

The estimated average annual runoff and TSS, TN and TP exports to the Myall River, Conservation Zone and SEPP14 wetlands under the four scenarios (Scenarios (1) to (iv)) are summarised in **Table D.10**. The adopted properties of the lake, ponds, wetlands and swale and rainwater tanks are summarised in **Tables D.11** and **D.12** respectively.

Table D.10
Estimated Runoff and Pollutant Exports under Developed Conditions – Scheme 3

ID	Area (ha)	Rainfall (ML/yr)	Runoff and Pollutant Loads				Remark
			Runoff (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	
Developed + No RWT + 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*
Lake Inflow	187.2	2619	1320	129000	277	2170	Southern lake inflow
Lake Outflow			1154	20800	116	1370	
				84%	*58%*	*37%*	*Reduction to Developed Conditions*
			1640	93600	266	2490	Discharge to Wetland Zone
			N	Y	N	N	Less than Current Conditions?
Developed + RWTs + 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*
Lake Inflow	187.2	2619	1190	121000	249	1960	Southern lake inflow
Lake Outflow			1022	17800	102	1222	
				86%	*63%*	*44%*	*Reduction to Developed Conditions*
			1490	29400	171	2050	Discharge to Wetland Zone
			N	Y	Y	N	Less than Current Conditions?

Developed + RWTs + 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*
Lake Inflow	187.2	2619	1140	50600	144	1520	Southern lake inflow
Lake Outflow			975	14400	93	1103	
				89%	*66%*	*49%*	*Reduction to Developed Conditions*
			1440	24900	160	1920	Discharge to Wetland Zone
			N	Y	Y	Y	Less than Current Conditions?
Developed + No RWTs + 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*
Lake Inflow	187.2	2619	1260	54000	161	1700	Southern lake inflow
Lake Outflow			1096	16100	106	1245	
				88%	*62%*	*43%*	*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 = Lake Outflow + Myall-2 + N43

Table D.11
Adopted Properties of Stormwater Quality Improvement Devices – Scheme 3

	Pond / Lake							Swale	Wetland						BioFilter
Location	EE2	EE4	Lake	EE5	EE6	E2	E4	Swale	N42 nrwt	N42	N43 nrwt	N43	N44 nrwt	N44	N44 Bio
Lo-flow bypass rate (cum/sec)	0	0	0	0	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	100	100	100	100	100
Inlet pond volume	0	0	0	0	0	0	0		0	0	0	0	0	0	
Area (sqm)	10880	23220	135000	2019	1696	659	1050		5600	3152	5500	3030	2500	1430	200
Extended detention depth (m)	0.1	0.1	0.4	0.1	0.1	0.1	0.1	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Permanent pool volume (cum)	10880	23220	241700	2019	1696	659	1050		1680	945.6	1650	909	750	429	
Average Depth (m)	*1.0*	*1.0*	*1.79*	*1.0*	*1.0*	*1.0*	*1.0*		*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	
Proportion vegetated	0.1	0.1	0.1	0.1	0.1	0.1	0.1		0.5	0.5	0.5	0.5	0.5	0.5	
Equivalent pipe diameter (mm)	450	675	1350	300	300	300	300		350	350	600	600	600	450	
Overflow weir width (m)	100	100	10	3	3	3	3		3	3	10	10	10	10	10
Notional Detention Time (hrs)	2.03	1.92	5.59	0.846	0.71	0.276	0.44		1.72	0.97	0.576	0.317	0.262	0.266	
Orifice discharge coefficient	0.6	0.6	0.6	0.6	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	1.7	1.7	1.7	1.7	1.7
Number of CSTR cells	2	2	2	2	2	2	2	10	5	5	5	5	5	5	3
Total Suspended Solids k (m/yr)	400	400	400	400	400	400	400	8000	1500	1500	1500	1500	1500	1500	8000
Total Suspended Solids C* (mg/L)	12	12	12	12	12	12	12	20	6	6	6	6	6	6	20
Total Suspended Solids C** (mg/L)	12	12	12	12	12	12	12	14	6	6	6	6	6	6	
Total Phosphorus k (m/yr)	300	300	300	300	300	300	300	6000	1000	1000	1000	1000	1000	1000	6000
Total Phosphorus C* (mg/L)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.13	0.06	0.06	0.06	0.06	0.06	0.06	0.13
Total Phosphorus C** (mg/L)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.13	0.06	0.06	0.06	0.06	0.06	0.06	
Total Nitrogen k (m/yr)	40	40	40	40	40	40	40	500	150	150	150	150	150	150	500
Total Nitrogen C* (mg/L)	1	1	1	1	1	1	1	1.4	1	1	1	1	1	1	1.4
Total Nitrogen C** (mg/L)	1	1	1	1	1	1	1	1.4	1	1	1	1	1	1	
Threshold hydraulic loading for C** (m/yr)	3500	3500	3500	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	Off	Off	Off	Off
Constant Daily Re-use Demand (kL)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Filter area (sqm)															200
Filter depth (m)															0.6
Filter median particle diameter (mm)															0.24
Saturated hydraulic conductivity (mm/hr)															100
Voids ratio															0.3
Length (m)								437.5	0						
Bed slope								0.01	1.25						
Base Width (m)								6							
Top width (m)								10							
Vegetation height (m)								0.25							
Seepage Rate (mm/hr)	0	0	0	0	0	0	0	0		0	0	0	0	0	0
Evap Loss as proportion of PET	1	1	1	1	1	1	1			1.25	1.25	1.25	1.25	1.25	
Depth in metres below the drain pipe															0

Table D.12
Adopted Properties of Rainwater Tanks – Scheme 3

Location	Rainwater Tanks																			
	N8	N10	EE4	EE1	N44	N43	N42	E8	L5R	WQB2	L3R	L2R	WQB1	L1L	EE5	EE6	E1	E2	E4	E6
Lo-flow bypass rate (cum/sec)	0	0	0	0	0	0	0	0	0	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	100	100	100	100	100	100	100	100	100	100	100
Inlet pond volume	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area (sqm)	433	555	452	223	171	275	215	324	43	133	60	63	118	72	105	182	27	40	24	66
Extended detention depth (m)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Permanent pool volume (cum)	867	1111	893	447	313	403	429	455	85	267	119	126	237	144	211	363	55	81	47	131
Average Depth (m)																				
Proportion vegetated	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equivalent pipe diameter (mm)	300	300	300	300	300	300	300	300	50	50	50	50	50	50	50	218	50	50	50	300
Overflow weir width (m)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Notional Detention Time (hrs)	0.257	0.329	0.268	0.132	0.101	0.163	0.13	0.19	0.917	2.84	1.28	1.34	2.52	1.54	2.24	0.204	0.576	0.85	0.51	0.039
Orifice discharge coefficient	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	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	1.7	1.7	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	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Total Suspended Solids k (m/yr)	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
Total Suspended Solids C* (mg/L)	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Total Suspended Solids C** (mg/L)	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Total Phosphorus k (m/yr)	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
Total Phosphorus C* (mg/L)	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Total Phosphorus C** (mg/L)	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Total Nitrogen k (m/yr)	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Total Nitrogen C* (mg/L)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Total Nitrogen C** (mg/L)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Threshold hydraulic loading for C** (m/yr)	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500
Extraction for Re-use	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
Constant Daily Re-use Demand (kL)	69	89	71	36	25	32	34	36	7	21	9	10	19	12	17	29	4	6	4	11
Filter area (sqm)																				
Filter depth (m)																				
Filter median particle diameter (mm)																				
Saturated hydraulic conductivity (mm/hr)																				
Voids ratio																				
Length (m)																				
Bed slope																				
Base Width (m)																				
Top width (m)																				
Vegetation height (m)																				
Seepage Rate (mm/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Evap Loss as proportion of PET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Depth in metres below the drain pipe																				

In the case of ponds and the swale the size of ponds and swale remained unchanged for scenarios with or without rainwater tanks. In the case of wetlands these were re-sized if possible to account for differences in runoff from developed areas with or without rainwater tanks eg. Wetland N42 (with rainwater tanks in place) and Wetland N42 nrwt (no rainwater tanks) (refer Table D.11). Under Scenario (iv) it was necessary to include a bio-filter upstream of Wetland N44 to meet the 80/45/45 targets.

Scheme 5

The estimated average annual runoff and TSS, TN and TP exports to the Myall River, Conservation Zone and SEPP14 wetlands under the two Scheme 5 scenarios are summarised in **Table D.13**. The adopted properties of the lakes, ponds, wetlands and swale are summarised in **Tables D.14.** The rainwater tank properties are as given in **Table D.15** respectively.

In the case of ponds and the swale the size of ponds and swale remained unchanged for scenarios with or without rainwater tanks.

Table D.13
Estimated Runoff and Pollutant Exports under Developed Conditions – Scheme 5

ID	Area (ha)	Rainfall (ML/yr)	Flow and Pollutant Loads Runoff (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)	Remark
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.14
Adopted Properties of Stormwater Quality Improvement Devices – Scheme 5

Location	N10Pond	EE5Pond	EE6Pond	E4Pond	E2Pond	E8Pond	EE1Pond	N10uPond	EE0Pond	N8Pond	FLake	SLake	Swale	N42 nrwt	N42	N43 nrwt	N43	N44 nrwt	N44	N44 Bio
	Pond										Lake		Swale	Wetland						BioFilter
Lo-flow bypass rate (cum/sec)	0	0	0	0	0	0	0	0	0	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	100	100	100		100	100	100	100	100	100	100
Inlet pond volume	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	
Area (sqm)	17007	2019	1696	1050	659	6058	1269	10100	1957	3539	65542	80000		5600	3152	5500	3030	2500	1430	200
Extended detention depth (m)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.4	0.4	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Permanent pool volume (cum)	17007	2019	1696	1050	659	6058	1269	10100	1957	3539	98313	168000		1680	945.6	1650	909	750	429	
Average Depth (m)														*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	*0.3*	
Proportion vegetated	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		0.5	0.5	0.5	0.5	0.5	0.5	
Equivalent pipe diameter (mm)	600	300	300	300	300	450	375	600	375	600	1350	1350		350	350	600	600	600	450	
Overflow weir width (m)	100	3	3	3	3	100	100	100	100	100	10	10		3	3	10	10	10	10	10
Notional Detention Time (hrs)	1.78	0.846	0.71	0.44	0.28	1.13	0.34	1.06	0.53	0.37	2.71	3.31		1.72	0.97	0.576	0.317	0.262	0.266	
Orifice discharge coefficient	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	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	1.7	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	2	2	2	2	2	2	2	10	5	5	5	5	5	5	3
Total Suspended Solids k (m/yr)	400	400	400	400	400	400	400	400	400	400	400	400	8000	1500	1500	1500	1500	1500	1500	8000
Total Suspended Solids C* (mg/L)	12	12	12	12	12	12	12	12	12	12	12	12	20	6	6	6	6	6	6	20
Total Suspended Solids C** (mg/L)	12	12	12	12	12	12	12	12	12	12	12	12	14	6	6	6	6	6	6	
Total Phosphorus k (m/yr)	300	300	300	300	300	300	300	300	300	300	300	300	6000	1000	1000	1000	1000	1000	1000	6000
Total Phosphorus C* (mg/L)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.13	0.06	0.06	0.06	0.06	0.06	0.06	0.13
Total Phosphorus C** (mg/L)	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.13	0.06	0.06	0.06	0.06	0.06	0.06	
Total Nitrogen k (m/yr)	40	40	40	40	40	40	40	40	40	40	40	40	500	150	150	150	150	150	150	500
Total Nitrogen C* (mg/L)	1	1	1	1	1	1	1	1	1	1	1	1	1.4	1	1	1	1	1	1	1.4
Total Nitrogen C** (mg/L)	1	1	1	1	1	1	1	1	1	1	1	1	1.4	1	1	1	1	1	1	
Threshold hydraulic loading for C** (m/yr)	3500	3500	3500	3500	3500	3500	3500	3500	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	Off	Off	Off	Off	Off	Off	Off	Off	Off
Constant Daily Re-use Demand (kL)													n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Filter area (sqm)																				200
Filter depth (m)																				0.6
Filter median particle diameter (mm)																				0.24
Saturated hydraulic conductivity (mm/hr)																				100
Voids ratio																				0.3
Length (m)													437.5	0						
Bed slope													0.01	1.25						
Base Width (m)													6							
Top width (m)													10							
Vegetation height (m)													0.25							
Seepage Rate (mm/hr)													0		0	0	0	0	0	0
Evap Loss as proportion of PET	0	0	0	0	0	0	0	0	0	0	0	0			1.25	1.25	1.25	1.25	1.25	
Depth in metres below the drain pipe	1	1	1	1	1	1	1	1	1	1	1	1								0

Table D.15
Adopted Properties of Rainwater Tanks – Scheme 5

Location	Rainwater Tank																				
	N8RWT	N10RWT	EE4RWT	EE1RWT	N44RWT	N43RWT	N42RWT	E8RWT	L5RRWT	L3RRWT	L2RaRWT	L2RRWT	L1LRWT	EE5RWT	EE6RWT	E1RWT	E2RWT	E4RWT	E6RWT	N10aRWT	N10bRWT	EE0RWT
Lo-flow bypass rate (cum/sec)	0	0	0	0	0	0	0	0	0	0	0	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	100	100	100	100	100	100	100	100	100	100	100	100	100
Inlet pond volume	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Area (sqm)	346	380	168	179	156	201	215	175	132	104	54	58	142	349	182	27	40	24	66	173	14	101
Extended detention depth (m)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Permanent pool volume (cum)	692	759	235	349	313	403	429	350	264	207	108	115	284	698	363	55	81	47	131	347	28	203
Average Depth (m)																						
Proportion vegetated	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equivalent pipe diameter (mm)	300	300	300	300	300	300	300	300	50	50	50	50	50	50	218	50	50	50	300	300	300	300
Overflow weir width (m)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Notional Detention Time (hrs)	0.205	0.225	0.1	0.106	0.092	0.119	0.13	0.1	2.82	2.22	1.15	1.24	3.03	7.44	0.2	0.576	0.853	0.51	0.04	0.1	0.01	0.06
Orifice discharge coefficient	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	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	1.7	1.7	1.7	1.7	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	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Total Suspended Solids k (m/yr)	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
Total Suspended Solids C* (mg/L)	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Total Suspended Solids C** (mg/L)	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Total Phosphorus k (m/yr)	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300	300
Total Phosphorus C* (mg/L)	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Total Phosphorus C** (mg/L)	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Total Nitrogen k (m/yr)	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Total Nitrogen C* (mg/L)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Total Nitrogen C** (mg/L)	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Threshold hydraulic loading for C** (m/yr)	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500	3500
Extraction for Re-use	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On	On
Constant Daily Re-use Demand (kL)	55	60.7	18.8	27.9	25	32	34	28	21	17	9	9	23	56	29	4	6	4	11	27.8	2.2	16.2
Filter area (sqm)																						
Filter depth (m)																						
Filter median particle diameter (mm)																						
Saturated hydraulic conductivity (mm/hr)																						
Voids ratio																						
Length (m)																						
Bed slope																						
Base Width (m)																						
Top width (m)																						
Vegetation height (m)																						
Seepage Rate (mm/hr)																						
Evap Loss as proportion of PET	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Depth in metres below the drain pipe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

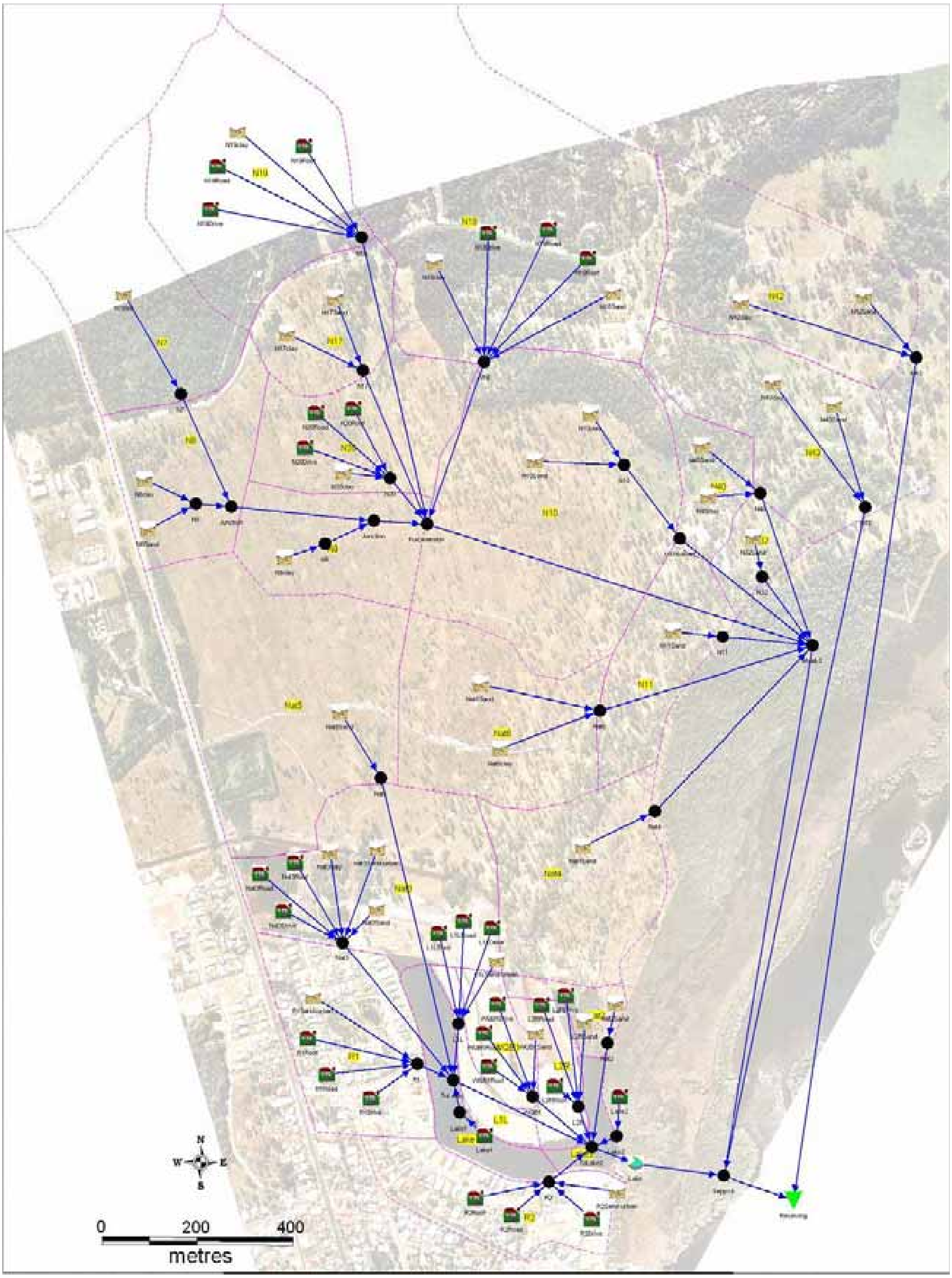


Figure D.3
MUSIC Model Layout for Pre-Existing and Existing Conditions

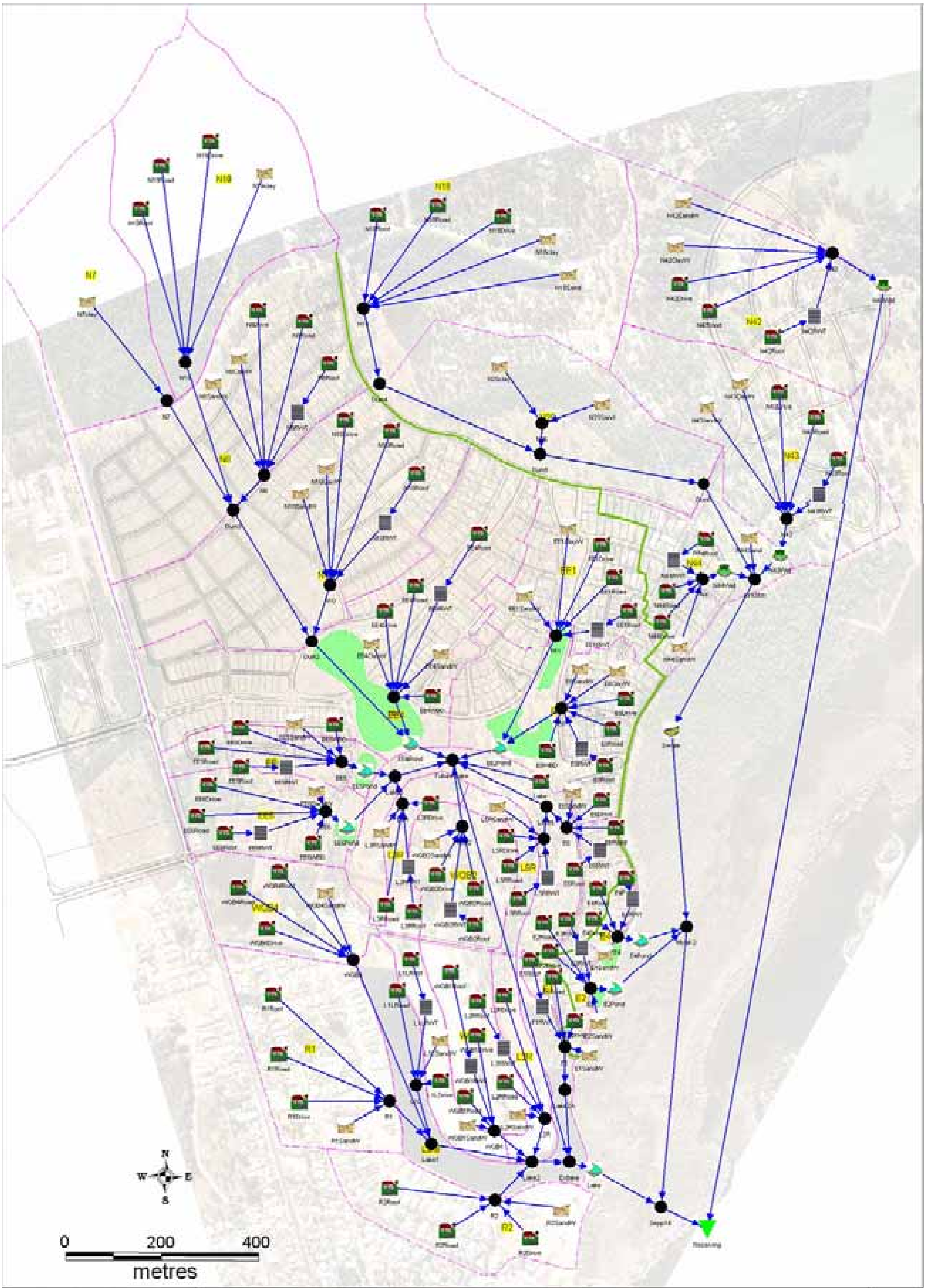


Figure D.4
MUSIC Model Layout for Developed Conditions with Rainwater Tanks – Scheme 3

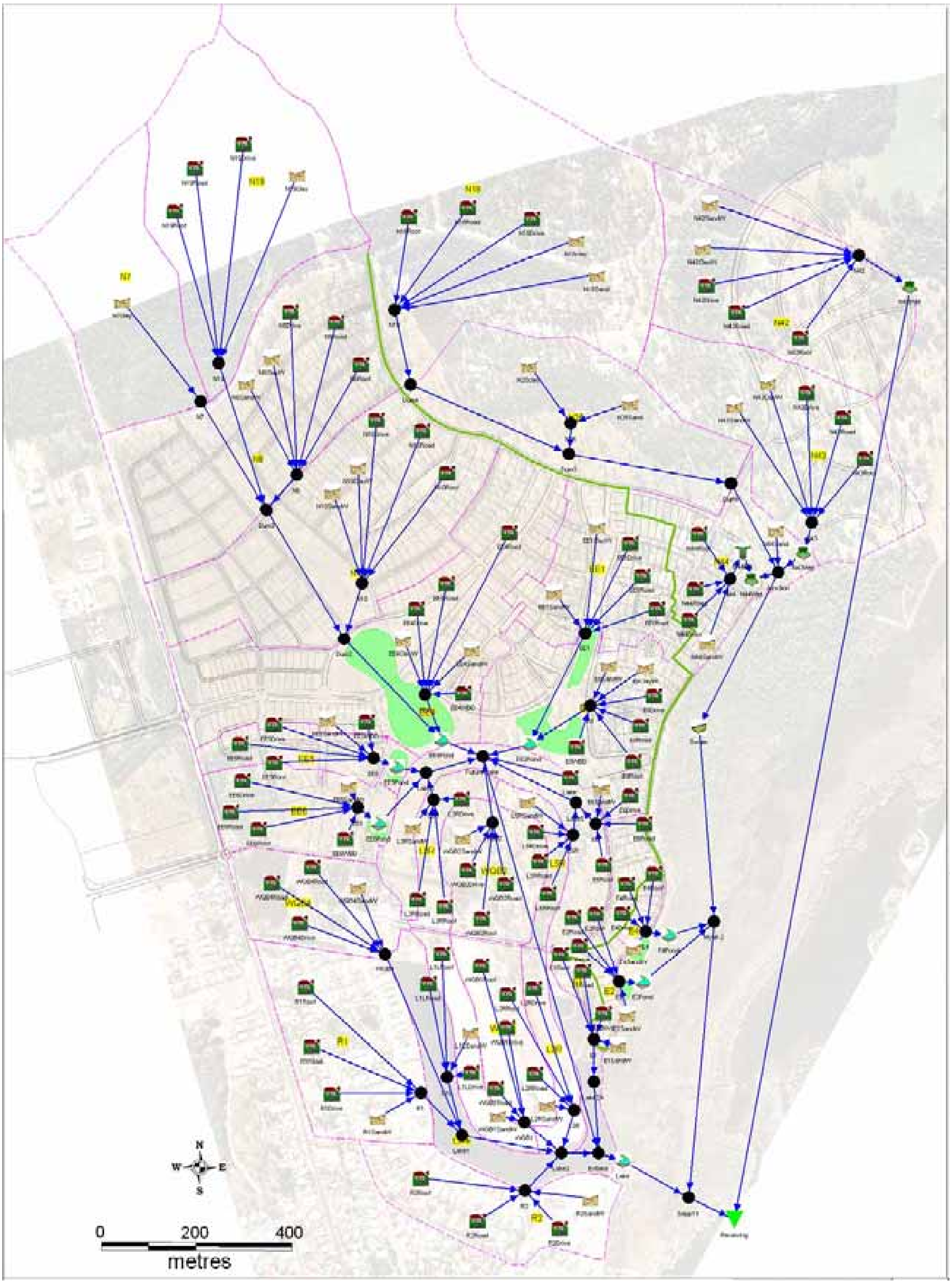


Figure D.5
MUSIC Model Layout for Developed Conditions without Rainwater Tanks – Scheme 3

Cardno Willing

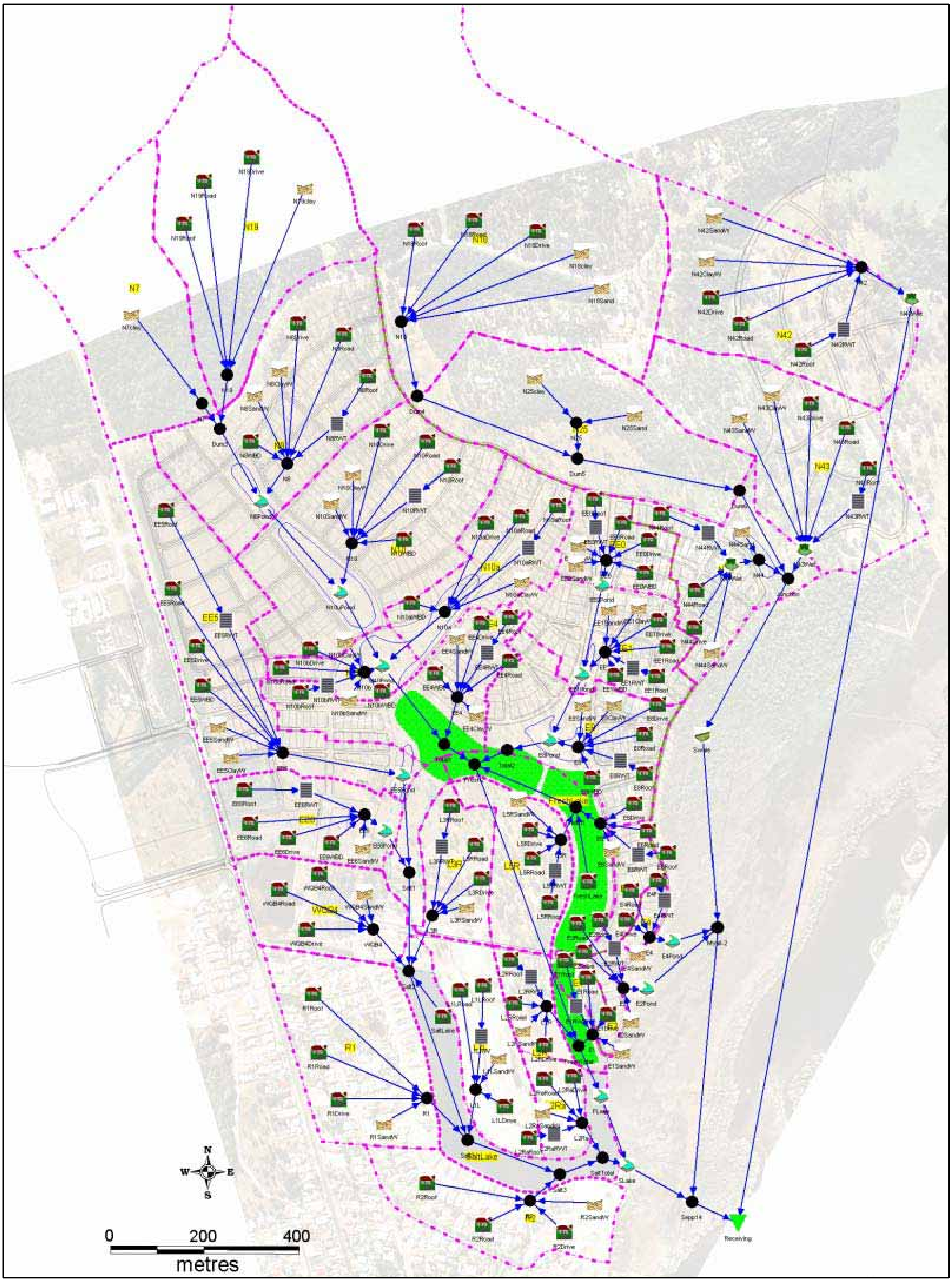


Figure D.6
MUSIC Model Layout for Developed Conditions with Rainwater Tanks - Scheme 5

APPENDIX E

LAKE MODELLING

E.1 Aims

The aims of the lake modelling were to

- Re-run the Pond models of the Pre-existing and Existing detention lakes using catchment inputs calculated using the MUSIC model and to confirm that similar results to previous runs were obtained;
- Re-run the Scheme 3 Pond model and Scheme 5 Pond models for catchment inputs under developed conditions and compare with the 2004 results; and
- If needed, size pond(s) and/or wetland(s) to achieve the receiving water quality objectives for receiving waters.

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).

A Do Nothing option and six schemes to mitigate the impact of planned future development on lake water quality were assessed. These schemes were:

0. **Existing conditions** ie. a 6 ha lake;
1. **Do nothing** – keep the current water body as it is without increasing the size (but with BASIX implemented).
2. **Existing** lake (6 ha) with **increased tidal flushing** (x4);
3. **Extended lake** (13.5 ha) with **increased tidal flushing** (x2);
4. Existing lake with **increased tidal flushing** (x1.6) and **a new freshwater lake** (12 ha);
5. **Partially extended lake** (8 ha) with **increased tidal flushing** (x1.8) and **new freshwater lake** (6.5 ha);
6. Existing lake (6 ha) with **increased tidal flushing** (x1.6) and **new wetlands** (16 ha); and
7. Existing lake (6 ha) and **dry swales**.

A multi-criteria assessment of water quality performance, environmental impacts and viability was undertaken. The assessment criteria included:

- Water Quality
  - Salinity
  - Dissolved Oxygen
  - Algae
  - Total Nitrogen
  - Total Phosphorous

- Environmental Impacts
  - Impact on existing water body
  - Impact on SEPP 14 wetlands
  - Impact on Myall River
  - Impact on Ground Water

- Viability
  - Loss of potential lots
  - Aesthetic/Health
  - Landtake for Basins
  - Landtake for Ponds / Wetlands
  - Filling

The highest ranked scheme to mitigate the impacts of planned development was Scheme 3. The second highest ranked scheme to mitigate the impacts of planned development was Scheme 5.

E.3 The CRCFE Pond Model

The CRC for Freshwater Ecology (now eWater) 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 CRCFE 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 2004 Lake Modelling

E.5.1 2004 Model Calibration

The challenge faced in using the Pond model to assess options to maintain observed levels of water quality in the existing lake at Riverside at Tea Gardens using the CRCFE pond model is that the lake 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. The catchment runoff and pollutant exports under pre-existing and existing conditions were estimated previously using an **xpaqualm** model of the catchment.

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.5.2 2004 Assessment of Water Quality Management Options

Six schemes were formulated to mitigate the impact of planned future development on lake water quality. These six schemes as well as a Do Nothing scheme were assessed.

Representative results of the predicted variations in salinity and TP concentrations in each of the proposed water bodies, using the calibrated models, are given in **Figure E.4.** Results of the assessments of the variations in salinity, DO, TN, TP and Chlorophyll 'a' concentrations in each of the proposed water bodies, using the calibrated models, are given in Cardno, 2004 (refer **Appendix F**).

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.6 Pre-Existing and Existing Conditions

The Pond models of the Pre-existing detention lake and the Existing detention lake were re-run using inputs calculated using the MUSIC model to compare with the previous results 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**.

E.7 Developed Conditions

E.7.1 Scheme 3

The highest ranked scheme to mitigate the impacts of planned development that was assessed in 2004 was Scheme 3. Scheme 3 comprises an extended detention lake with increased tidal flushing supported by additional ponds or wetlands as needed. The Pond model of Developed Conditions with the extended lake was run with inputs calculated using the MUSIC model. Three scenarios were assessed as follows:

(i) Developed Conditions with rainwater tanks and the extended detention lake;
(ii) Developed Conditions with rainwater tanks and the extended detention lake and ancillary ponds or wetlands; and
(iii) Developed Conditions without rainwater tanks and with the extended detention lake and ancillary ponds or wetlands.

The results of this assessment are compared with the previous results reported in 2004 in **Table E.2**.

E.7.2 Scheme 5

Scheme 5 comprises 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 pons draining to the lakes is 4.7 ha). The 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. Four scenarios were assessed as follows:

(i) Developed Conditions with rainwater tanks and freshwater lakes and a partially extended detention lake;
(ii) Developed Conditions with rainwater tanks and freshwater lakes and a partially extended detention lake and ancillary ponds or wetlands;
(iii) Developed Conditions without rainwater tanks and with freshwater lakes and a partially extended detention lake; and
(iv) Developed Conditions without rainwater tanks and with freshwater lakes and a partially extended detention lake and ancillary ponds or wetlands.

The results of the assessment of the original Scheme 5 are compared with the previous results reported in 2004 in **Table E.3**. The original Scheme 5 was based on widening the existing outlet channel by 80% and lowering the outlet channel uniformly by 0.09 m.

However concerns expressed by several stakeholders regarding any modification of the existing outlet channel within the SEPP 14 wetland zone meant that consideration was given to a different outlet arrangement. Under this outlet configuration the existing outlet channel remains unchanged while a second channel of equal width is constructed approximately 70 m north of the existing outlet channel with invert levels that are uniformly 0.10 m lower than the existing channel. The second outlet channel would be constructed without disturbing the SEPP 14 wetland. It would connect to a second existing drain located within the SEPP 14 wetland zone.

These two channels were represented as the existing channel width increased by 100% and the channel invert levels uniformly lowered by 0.05 m.

For comparison the impact on water quality in the saline lake of retaining the existing outlet channel unchanged without a second outlet channel was also assessed.

The results of the assessment of the retaining the existing outlet channel unchanged with and without a second outlet channel are compared with the original Scheme 5 results in **Table E.4**.

Table E.2
Estimated Lake Water Quality under Scheme 3 Developed Conditions

	Scheme 3				
Percentile	2004 Study	This Study RWT + Lake	This Study RWT + Lake + Ponds	This Study No RWT + Lake + Ponds	ANZECC, 2000 Trigger Value / Ranges
Salinity (g/L)					
5%	3.4	3.8	3.8	3.7	3-20 g/L
20%	8.2	7.9	8.0	7.7	
50%	13.7	14.0	14.4	13.7	
80%	21.6	22.6	23.3	22.0	
95%	26.7	28.1	28.8	27.7	
DO Bottom (mg/L)					
5%	2.8	2.0	3.0	2.6	
20%	5.8	5.7	6.1	5.9	
50%	7.1	6.9	7.2	7.1	
80%	8.2	7.9	8.2	8.1	
95%	9.1	8.8	9.0	9.0	
DO Saturation (%)					
5%	32%	22%	33%	30%	80%-100%
20%	69%	66%	73%	70%	
50%	86%	84%	87%	86%	
80%	94%	93%	95%	94%	
95%	99.3%	98.1%	99.6%	99.2%	
TP (mg/L)					
5%	0.0023	0.0028	0.0019	0.0020	0.03
20%	0.0051	0.0057	0.0038	0.0043	
50%	0.0103	0.0130	0.0077	0.0085	
80%	0.0240	0.0310	0.0175	0.0179	
95%	0.0527	0.0579	0.0362	0.0373	
TN (mg/L)					
5%	0.27	0.23	0.18	0.21	0.3
20%	0.34	0.30	0.24	0.27	
50%	0.45	0.41	0.33	0.36	
80%	0.59	0.63	0.50	0.52	
95%	0.91	0.91	0.76	0.78	
Algal Biomass (mg/L)					
50%	0.0011	0.0011	0.0011	0.0011	0.004
70%	0.0012	0.0012	0.0012	0.0012	
90%	0.0016	0.0018	0.0018	0.0019	
95%	0.0023	0.0035	0.0031	0.0034	
100%	0.0191	0.0305	0.0282	0.0253	

Table E.3
Estimated Lake Water Quality under Original Scheme 5 Developed Conditions

Percentile	Scheme 5										ANZECC, 2000 Trigger Value / Ranges
	2004 Study		This Study								
	Saline Lake	Fresh Lake(s)	Saline Lake	Fresh Lake	Saline Lake	Fresh Lake	Saline Lake	Fresh Lake	Saline Lake	Fresh Lake	
			RWTs only		RWTs + Ponds		No RWTs		No RWT + Ponds		
Salinity (g/L)											
5%	3.3		1.4		3.5		1.4		3.4		3-20 g/L
20%	8.2		5.9		7.9		5.6		7.6		
50%	14.1		12.5		15.2		11.5		14.3		
80%	22.8		22.1		25.1		20.2		23.7		
95%	28.9		30.4		32.2		27.9		30.4		
DO Bottom (mg/L)											
5%	2.7	5.9	1.5	3.1	3.6	4.8	1.4	2.7	3.6	4.4	
20%	4.6	7.9	4.4	6.9	4.7	7.6	4.3	6.6	4.8	7.4	
50%	6.0	8.6	5.9	8.1	6.2	8.6	5.9	7.9	6.2	8.5	
80%	7.4	9.4	7.2	8.8	7.5	9.2	7.1	8.8	7.6	9.1	
95%	8.4	10.1	8.2	9.4	8.5	9.8	8.1	9.4	8.5	9.8	
DO Saturation (%)											
5%	35%	62%	19%	33%	51%	52%	15%	29%	50%	46%	80%-100%
20%	65%	85%	61%	71%	72%	80%	57%	69%	71%	78%	
50%	80%	94%	79%	86%	82%	93%	77%	84%	82%	92%	
80%	88%	100%	87%	99%	89%	100%	86%	98%	89%	100%	
95%	93.0%	100.0%	92.8%	100.0%	93.8%	100.0%	92.5%	100.0%	93.5%	100.0%	
TP (mg/L)											
5%	0.0041	0.0007	0.0037	0.0007	0.0028	0.0007	0.0039	0.0007	0.0029	0.0007	0.03
20%	0.0065	0.0015	0.0066	0.0011	0.0049	0.0007	0.0073	0.0012	0.0052	0.0007	
50%	0.0098	0.0055	0.0126	0.0097	0.0081	0.0019	0.0140	0.0115	0.0086	0.0024	
80%	0.0174	0.0206	0.0247	0.0467	0.0142	0.0150	0.0261	0.0486	0.0147	0.0164	
95%	0.0332	0.0572	0.0490	0.0821	0.0251	0.0332	0.0506	0.0849	0.0258	0.0354	
TN (mg/L)											
5%	0.24	0.87	0.22	0.75	0.18	0.53	0.25	0.76	0.20	0.56	0.3
20%	0.30	0.92	0.29	0.81	0.23	0.56	0.32	0.81	0.24	0.58	
50%	0.39	0.98	0.42	0.92	0.30	0.62	0.45	0.92	0.32	0.63	
80%	0.52	1.08	0.64	1.19	0.43	0.75	0.66	1.19	0.45	0.77	
95%	0.77	1.30	0.94	1.39	0.63	0.97	0.96	1.40	0.65	0.99	
Algal Biomass (mg/L)											
50%	0.0012	0.0010	0.0012	0.0010	0.0011	0.0010	0.0013	0.0010	0.0012	0.0010	0.004
70%	0.0013	0.0010	0.0014	0.0010	0.0013	0.0010	0.0015	0.0011	0.0013	0.0010	
90%	0.0017	0.0013	0.0020	0.0016	0.0016	0.0014	0.0021	0.0016	0.0017	0.0015	
95%	0.0021	0.0017	0.0027	0.0026	0.0019	0.0018	0.0028	0.0027	0.0019	0.0022	
100%	0.0105	0.0304	0.0323	0.1397	0.0052	0.0592	0.0344	0.1860	0.0065	0.0912	

Table E.4
Estimated Lake Water Quality under Final Scheme 5 Developed Conditions

	Original Scheme 5		Existing Outlet Only		Final Scheme 5	
Channel Widening Factor	1.8		1.0		2.0	
Ave Lowering of Channel (m)	0.09		0.0		0.05	
Percentile						
Salinity	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	3.5	3.4	1.3	1.2	3.0	2.9
20%	7.9	7.6	3.1	2.8	6.9	6.6
50%	15.2	14.3	6.9	6.3	13.7	12.8
80%	25.1	23.7	12.2	10.8	23.1	21.6
95%	32.2	30.4	16.7	15.2	30.2	28.2
DO Bottom	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	3.6	3.6	4.4	4.4	3.7	3.8
20%	4.7	4.8	6.1	6.1	5.0	5.0
50%	6.2	6.2	7.1	7.1	6.3	6.4
80%	7.5	7.6	8.3	8.3	7.7	7.7
95%	8.5	8.5	9.0	9.0	8.6	8.6
DO % Saturation	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	51%	50%	54%	53%	52%	51%
20%	72%	71%	75%	74%	73%	71%
50%	82%	82%	85%	84%	83%	82%
80%	89%	89%	92%	92%	90%	89%
95%	94%	94%	97%	96%	95%	94%
TP	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	0.0028	0.0029	0.0009	0.0010	0.0022	0.0023
20%	0.0049	0.0052	0.0017	0.0019	0.0039	0.0043
50%	0.0081	0.0086	0.0047	0.0050	0.0074	0.0078
80%	0.0142	0.0147	0.0127	0.0134	0.0139	0.0148
95%	0.0251	0.0258	0.0252	0.0258	0.0256	0.0265
TN	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
5%	0.18	0.20	0.31	0.33	0.20	0.21
20%	0.23	0.24	0.35	0.37	0.25	0.26
50%	0.30	0.32	0.42	0.44	0.32	0.34
80%	0.43	0.45	0.55	0.56	0.45	0.47
95%	0.63	0.65	0.73	0.75	0.66	0.67
Algal Biomass	WSUD 1	WSUD 2	WSUD 1	WSUD 2	WSUD 1	WSUD 2
50%	0.0011	0.0012	0.0010	0.0010	0.0011	0.0011
70%	0.0013	0.0013	0.0011	0.0011	0.0012	0.0013
90%	0.0016	0.0017	0.0014	0.0014	0.0016	0.0016
95%	0.0019	0.0019	0.0017	0.0018	0.0018	0.0019
100%	0.0052	0.0065	0.0049	0.0060	0.0053	0.0066

WSUD 1 Scheme with RWTs + Ponds
WSUD 2 Scheme without RWTs + Ponds

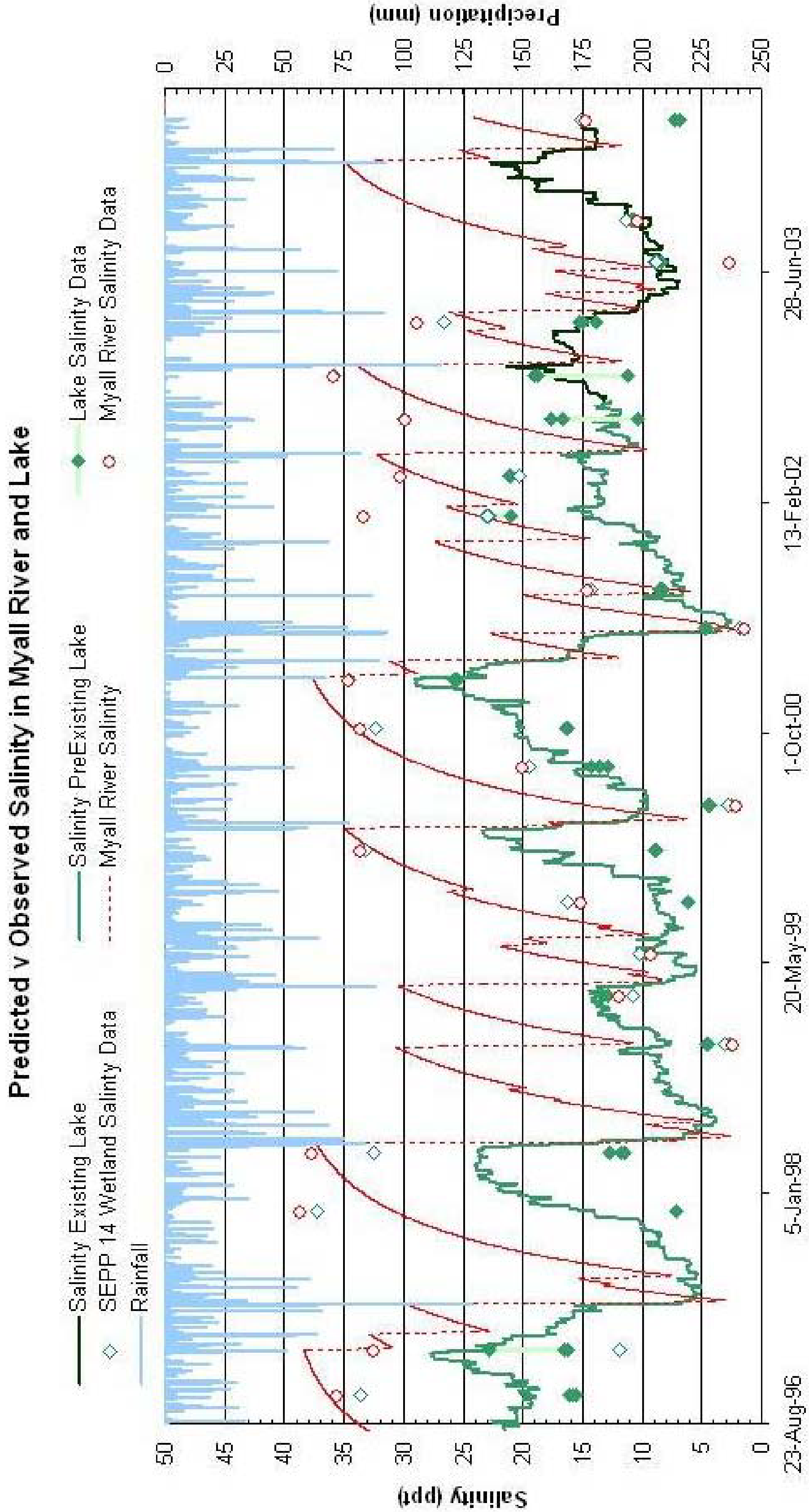


Figure E.1
Comparison of Predicted and Observed Salinity in the Myall River and Existing Lake

Cardno Willing

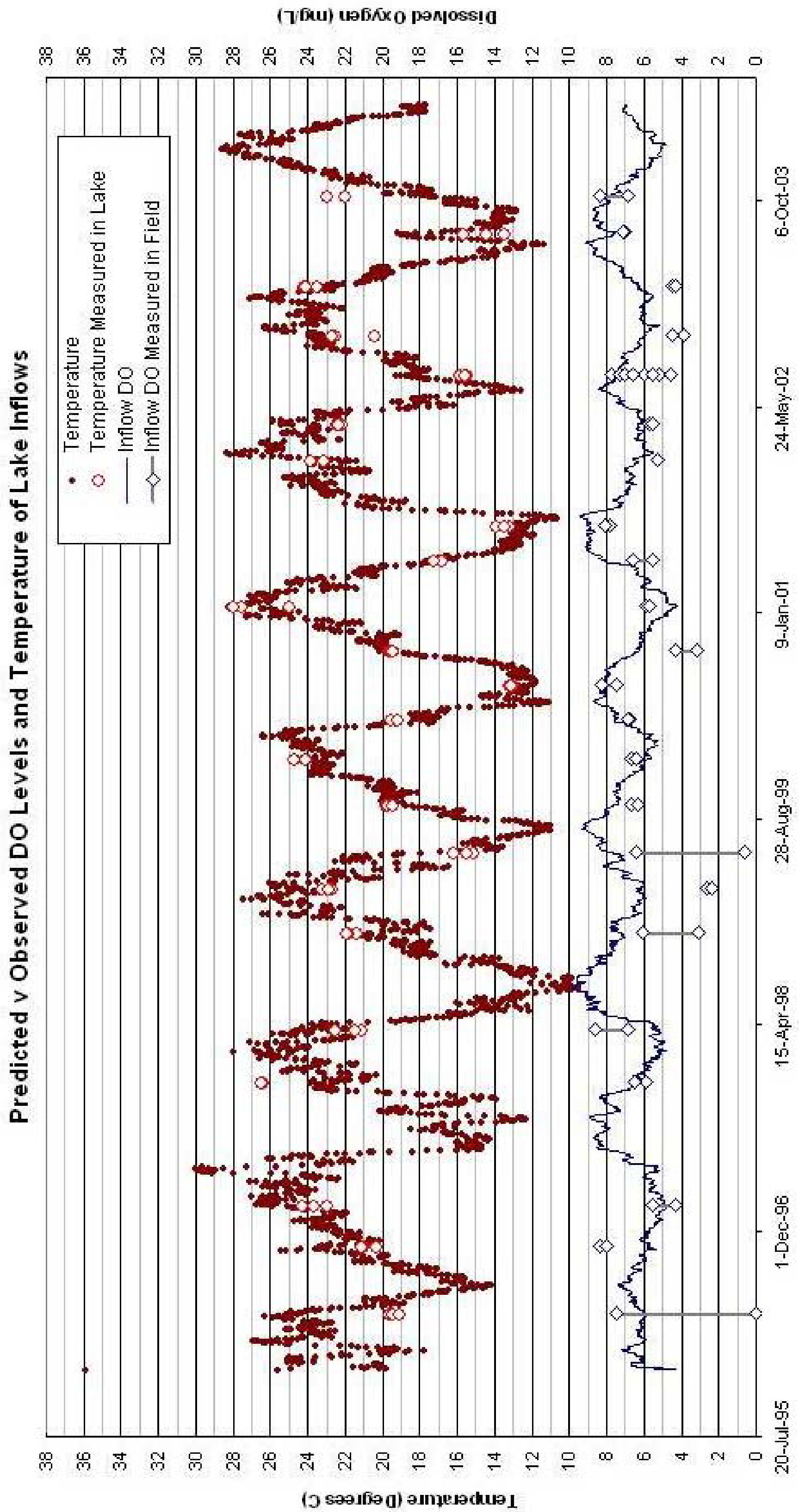


Figure E.2
Comparison of Predicted and Observed Dissolved Oxygen and Temperature of Lake Inflows

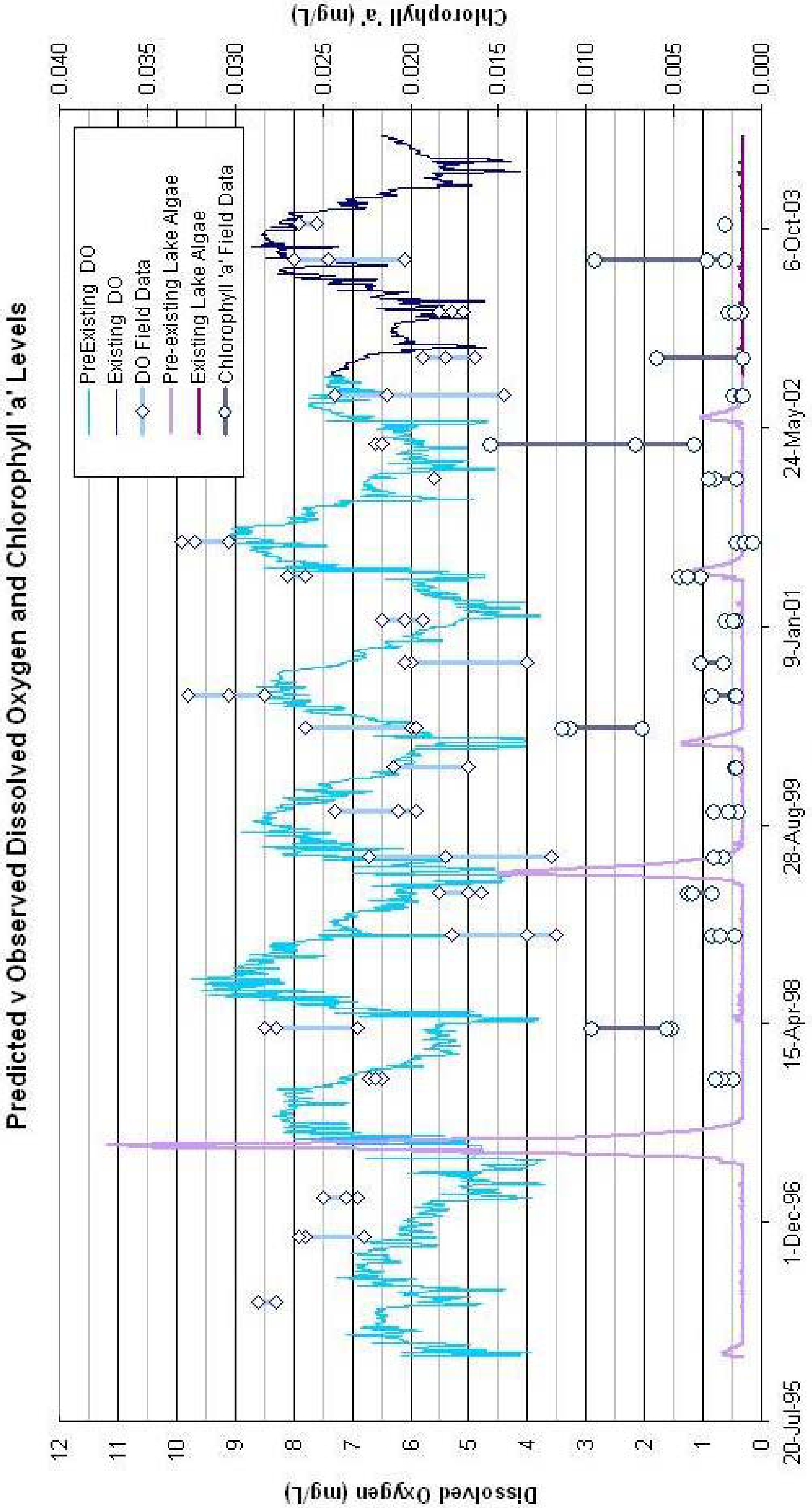
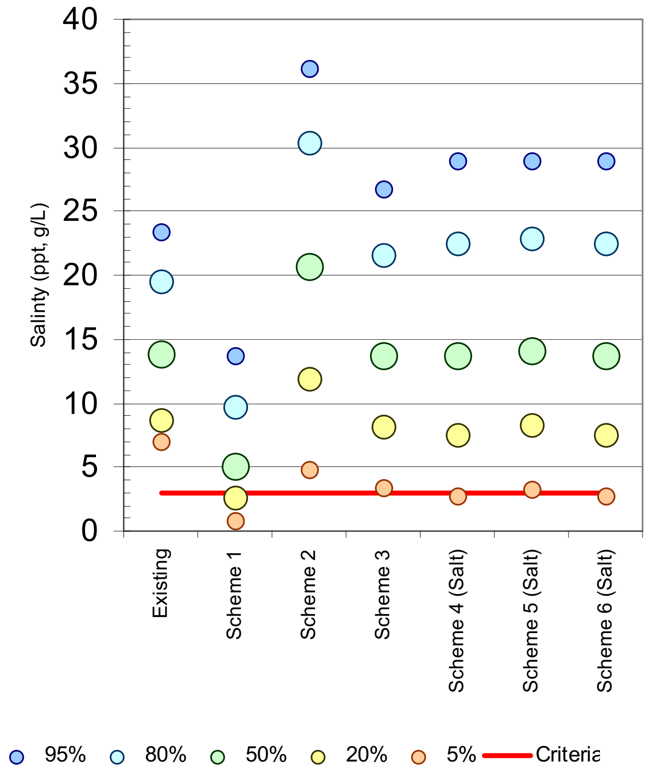


Figure E.3
Comparison of Predicted and Observed Dissolved Oxygen and Algae in the Existing Lake



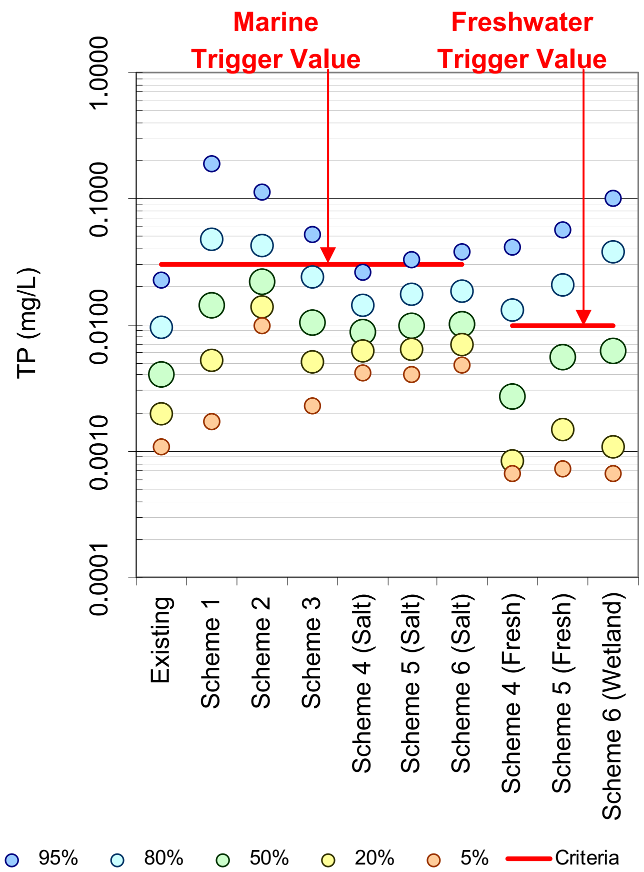


Figure E.4
2004 Comparison of Predicted Salinity and TP Concentrations for Various Management Options