Kirrawee Brickpit

Grey Headed Flying Fox Water Quality Requirements

Final

Prepared by Equatica September 2011

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Table of Contents

1 Introduction

Henroth Investments has submitted a Concept Plan application (MP10_0076) and is undertaking design development for the Kirrawee Brick Pit re-development. The site is located at 566 – 594 Princes Highway, Kirrawee, shown in Figure 1.

Grey Headed Flying Foxes (GHFF - Pteropus poliocephalus) have been observed drinking from the water body within the site in the past (Cumberland Ecology, 2010). A key requirement of the development is therefore to ensure that any modifications to the existing water body will maintain adequate water quality for this species of mega-bat is an important component of the development.

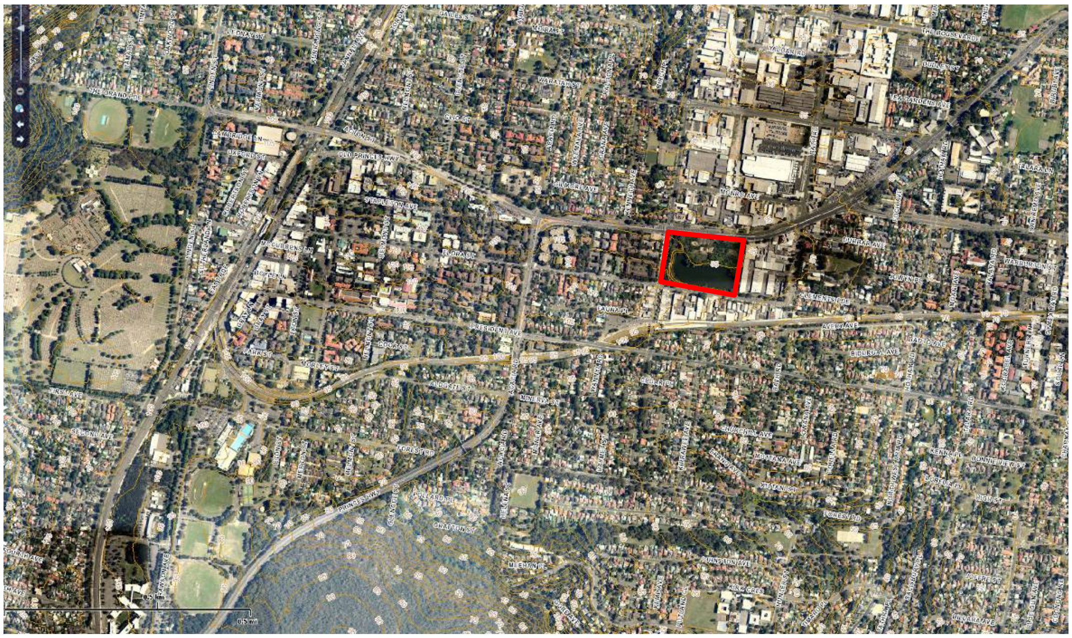

Figure 1: Site location (Sutherland Shire Council 2011b)

The Kirrawee Brickpit occupies a 4.25 ha site located immediately south of the Princes Highway at its intersection with Oak Road North. The site is shown in Figure 2. The site presently includes a disturbed vacant lot with a former brick pit which has become filled with water.

The proposed mixed use development on the site includes residential, retail and commercial uses with building envelopes principally between 5 and 11 storeys with one 14 storey building. The proposal also involves basement car parking, landscaping, services and the provision of a major new 0.9ha public park (City Plan, 2010).

Figure 2: Site plan showing Council drainage (Sutherland Shire Council 2011b)

In response to Sutherland Shire Council Council's indication that it would support development of site specific water quality guidelines as opposed to using generic ANZECC guidelines, as was previously the case, Henroth has commissioned Equatica to undertake this study. This document presents research and recommendations on the water quality to be achieved in the proposed water feature on the site. This report does not address GHFF habitat or drinking requirements in relation to the area or dimensions of water body required, or vegetation for foraging. The Eastern Bent-wing Bat is not dealt with specifically in this report though its water requirements are likely to be similar to those of the GHFF.

The report covers:

- The Kirrawee Brick Pit site;
- Research into the water quality of other water bodies known to be utilised by GHFF;
- Synthesis of water quality data and recommendations of water quality objectives for these water bodies; and

The report has been developed to determine the requirements of water bodies which are used by the GHFF. This document provides transparent and quantifiable objectives for water bodies used by GHFF. These water quality objectives will be used to assess the impact of the Kirrawee Brick Pit redevelopment and ensure that the water management strategy for the site can meet the water quality objectives that have been set for the water body at the site.

This document presents the following information:

- Section 2 outlines the methodology of this report.

- Section 3 includes information about the existing water body at the Kirrawee Brick Pit, including catchment information and water quality data.
- Section 4 presents information about other sites known to be used by GHFF, with water quality data;
- Section 5 presents a summary of the water quality data from Section 3 and Section 4 and the proposed water quality requirements for the proposed water feature;
- Section 6 outlines the methodology and results of the modelling of the proposed water body
- Section 7 completes the document with conclusions and recommendations

2 Water Quality Investigation Methodology

The methodology, which has been endorsed by Sutherland Shire Council, for setting water quality objectives included the following process:

1. Literature search to investigate GHFF habitat requirements;
2. Literature search to learn the locations of GHFF camp sites and areas where GHFF are known to forage or drink;
3. Investigation of WQ data:
    a. Publicly available documents online (incl. Streamwatch);
    b. Council provided water quality data and documentation;
    c. Sydney Water provided water quality data and documentation.
4. Review available WQ data and determine the sites that would provide most reliable and comprehensive WQ information;
5. Select sites for further WQ analysis and generate WQ statistics;
6. Apply the WQ statistics to recommend WQ guidelines for the proposed water body.

Table 1 presents a summary of the GHFF sites initially investigated for water quality data. From the complete list of sites six were selected due to them being known as GHFF habitat and reliability of water quality data (laboratory verified).

Table 1: GHFF Sites and WQ Data

GHFF Site	WQ Data Availability	Site chosen for WQ reference site?
Audley (Hacking River above weir)	Sutherland Council	
Bates Drive (Kareela)	-	
Bingara Reserve (Macquarie Fields)	-	
Cabramatta Creek Flying Fox Reserve	Fairfield Council Streamwatch	✓
Cannes/Gunyah Reserve (Avalon)	-	
Coffs Creek (Coffs Harbour)	-	
Engadine Wetlands	Sutherland Council (Evans & Peck 2009))	✓
Boat Harbour (Kurnell)	-	
Holt land at Kurnell (within the dredge pond)	Sutherland Council	
Hurstville	-	
Kirrawee Brick Pit	Consultants site investigation reports	✓

GHFF Site	WQ Data Availability	Site chosen for WQ reference site?
Ku-ring-gai Flying Fox Reserve (Gordon)	Ku-ring-gai Council	✓
Lachlan Swamp, Centennial Parklands	Streamwatch	
Miles Dunphy Reserve (Oatley)	-	
Parramatta Park	Parramatta Council UPRC (Laxton Report)	✓
Royal Botanic Gardens (Sydney)	Streamwatch	
Sydney Olympic Park	SOPA	
Towra Point Nature Reserve (Kurnell)	-	
Warriewood Wetlands	-	
Wolli Creek (Turella)	Sydney Water (multiple) Streamwatch	✓
Yarra Bend Park (Melbourne)	-	
Yarramundi (Nepean River)	Streamwatch	

3 Kirrawee Brickpit

The Brick Pit site is located at the top of the catchment. As can be seen in Figure 3, all Council drainage lines (pits & pipes) drain away from the site. As such, there is very little stormwater runoff draining to the site and the water in the pit is fed by rain and groundwater.

Figure 3: Site showing Council drainage and contours with flow paths in yellow (Sutherland Shire Council 2011b)

The CMJA hydrogeological data report (2010) states:

> *The surface of most of the site – excluding the area of the brick pit itself – falls gently to the east in accord with the structural inclination of the region. The elevation in the south-western corner of the site – which is also the highest point of the site – is about 105 metres above Australian Height Datum (AHD), and this part of the site is on the crest of a locally significant ridgeline, which generally follows the direction of the Princes Highway and forms a major surface watershed in the area. From here, the site gently slopes to the east and south-east, with the elevation in the south-eastern corner measured at 94 metres above AHD.*

The photos in Figure 4 and Figure 5 show the brick pit and catchment surrounding the Brick Pit.

Figure 4: Photo showing western end of site

Figure 5: Photo showing northern side of Brick Pit

As per the CMJA report (2010), there have been 5 sampling events at the Brick Pit:

- 1999 (AWT)
- 2001 (AWT)
- 2006 (URS)

- 2008 (Douglas)
- 2008 (CMJA)

In some sampling events water samples were taken from multiple depths within the Brick Pit. In this assessment the data from the sample closest to the water surface was adopted as it was viewed as being most relevant to the GHFF skimming/drinking.

Table 2: Brick Pit Selected WQ Data

	1999 AWT	2001 AWT			2006 URS			2008 Douglas			2008 CMJA		
	N =1	N =2			N =3			N =3			N =7		
		Low	Avg	High	Low	Avg	High	Low	Avg	High	Low	Avg	High
Turbidity (NTU)	13										2.1	11.24	59.5
TSS (mg/L)					1	1.67	2	<5	<5	<5			
DO (mg/L)		1.14	1.905	2.67	6.71	7.09	7.41				5.52	6.147	7.58
Total N (mg/L)	nt	0.58	0.605	0.63	*0.8*	*0.9*	*1*	*0.5*	*0.567*	*0.6*			
Total P (mg/L)	nt	0.038	0.04	0.042	<0.01		0.011	<0.05	<0.05	<0.05			
pH	6.93	6.7	6.705	6.71	8.08	8.32	8.44	8	8.17	8.3	8.59	8.61	8.65
Temp	14.1	19.09	19.27	19.45	22	22.0	22.1				22.2	23.96	25
EC (uS/cm)	992	1200	1250	1300	875	906	940	920	937	950	1022	1042	1060
TDS					542	553	558	540	540	540			
Salinity (ppt)	500	630	635	640									

Parameter	Data	Min	Avg	Max
DO (mg/L)	2001 (AWT)	1.14	1.91	2.67
	2006 (URS)	6.71	7.09	7.41
	2008 (CMJA)	5.52	6.1	7.58
EC (uS/cm)	1999 (AWT)	992	992	992
	2001 (AWT)	1200	1250	1300
	2006 (URS)	875	906	940
	2008 (Douglas)	920	937	950
	2008 (CMJA)	1022	1042	1060
pH	1999 (AWT)	6.93	6.93	6.93
	2001 (AWT)	6.7	6.71	6.71
	2006 (URS)	8.08	8.3	8.44
	2008 (Douglas)	8	8.2	8.3
	2008 (CMJA)	8.59	8.6	8.65

Parameter	Data	Min	Avg	Max
TSS	2006 (URS)	1	1.7	2
	2008 (Douglas)	<5	<5	<5
Ammonia	2008 (Douglas)	0.1	0.13	0.2
	2008 (CMJA)	<0.01	<0.01	<0.01
Nitrate	2006 (URS)	0.01	0.01	0.01
	2008 (CMJA)	0.01	0.01	0.01
Total P	2001 (AWT)	0.038	0.04	0.042
	2006 (URS)	<0.01	0	0.011
	2008 (Douglas)	<0.05	<0.05	<0.05
Turbidity (NTU)	1999 (AWT)	13	13	13
	2008 (CMJA)	2.1	11.2	59.5
Total N	2001 (AWT)	0.58	0.605	0.63
	2006 (URS)	0.8	0.9	1
	2008 (Douglas)	0.5	0.6	0.6
Salinity (ppt)	1999 (AWT)	500	500	500
	2001 (AWT)	630	635	640
Temperature	1999 (AWT)	14.1	14.1	14.1
	2001 (AWT)	19.09	19.27	19.45
	2006 (URS)	22	22.0	22.1
	2008 (CMJA)	22.2	24.0	25
Thermotolerant coliforms (/100mL)	2006 (URS)	20	23.3	30
	2008 (Douglas)	10	33.7	60
TDS	2006 (URS)	542	553	558
	2008 (Douglas)	540	540	540

4 GHFF Sites Water Quality

Water Quality data from a range of sites was selected for further analysis (the selection of these sites was discussed in Section 2). Data from the following GHFF sites has been collated and analysed:

- Wolli Creek
- Cabramatta Creek
- Parramatta Park
- Ku-ring-gai Flying Fox Reserve
- Engadine Wetland

This section discusses in more detail the

- Location of the sampling sites in relation to GHFF colonies and their use of the site
- data that was available for these sites
- the sampling periods and
- the source of the data

4.1 Wolli Creek

There is a Flying Fox Camp at Turella in the Wolli Creek Regional Park (WCPS 2011). This site is a well known flying fox colony and footage is available online of flying foxes using Wolli Creek for drinking and cooling purposes.

The water quality data available for sites in the vicinity of the Flying Fox Camp is summarised in Table 3.

Table 3: Wolli Creek WQ Data

Source	Number of Samples and Period	Reference
Sydney Water	4; Sep 1993	SWC 1993, Table D.4
Sydney Water	3; Oct 1993	SWC 1994a, Table D.4
Sydney Water	31 events (360 samples); Jan – Dec 1993	SWC 1995
Sydney Water	16; Nov 93 – Mar 94	SWC 1994b, pp. 30 – 56
Sydney Water	16; April – Sep 1994	SWC 1994c
Sydney Water	6; 2006-07	SWC 2007, Table 13, pp.102
Streamwatch	10; 2004-05	Streamwatch 2011

The GHFF camp site is shown in Figure 6, along with the location of the Sydney Water sampling site (213212/CR06).

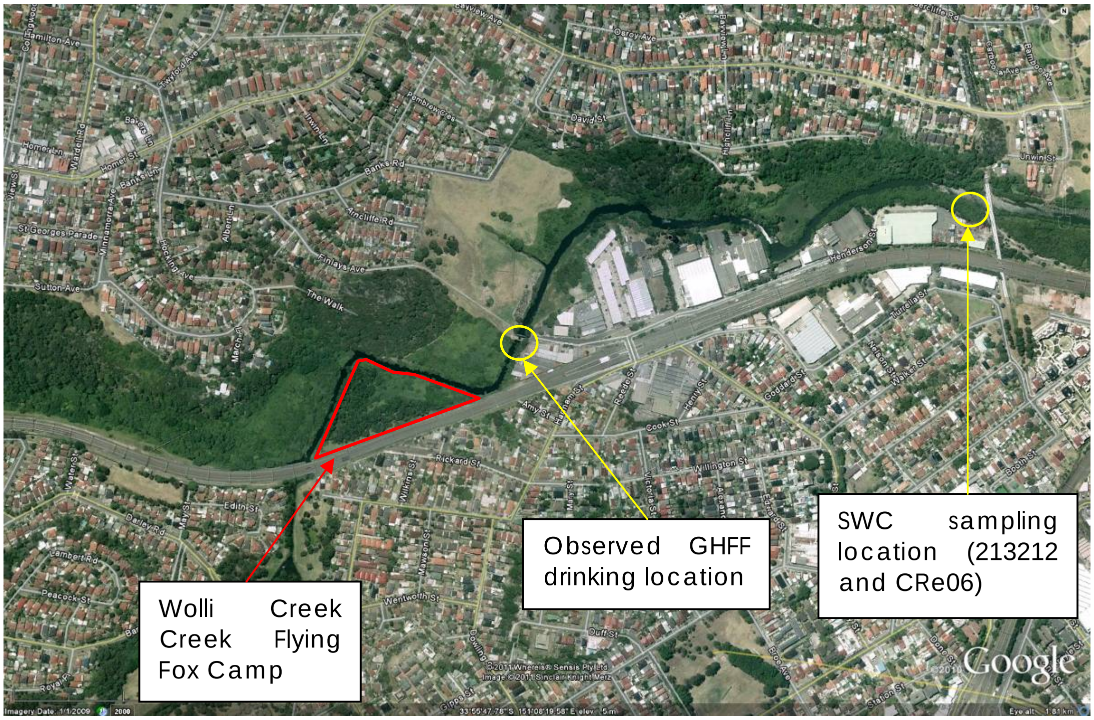

Figure 6: Wolli Creek GHFF Camp and WQ sampling location (image from Google)

GHFF have been observed drinking at Wolli Creek, and a YouTube video (refer Figure 7) shows GHFF skimming across the water at a site close to where water quality sampling is undertaken.

Figure 7: Wolli Creek GHFF drinking video snapshot (YouTube 2009)

Caption from YouTube video:

> *"Wolli Creek Valley, inner south-west Sydney. Sunday 22 November 2009. At dusk, after a day in which temperatures pushed past 40 degrees Centigrade, grey-headed flying foxes from the Turrella roost drink from the creek before heading out to forage." (YouTube 2009)*

A summary of the water quality data is shown in Table 4. Note that

- '1993' is from "1993 Annual Report Stats on log10 Raw data",
- '1994' is from "1994 Annual Report Stats on log10 EMC", and
- '2006-07' is from "2006-07 Data Report".

Table 4: Wolli Creek WQ Summary (highlighted cells indicate parameter not sampled)

Parameter	Report	Wea-ther	N	Min	10th Percentile	Mean	90th Percentile	Max
Suspended Solids	1993	Wet	386	1	4	26	51	630
		Dry	8	1	1	9	26	26
	1994	Mixed	18	6	7	30	63	108
	2006-07	Wet						
		Dry	-					
DO (mg/L)	1993	Wet	-					
		Dry	-					
	1994	Mixed	-					
	2006-07	Wet	6	2	2	4.9	8	8
		Dry	9	1.4	1.4	4.9	9.6	9.6
DO (%)	1993	Wet	-					
		Dry	-					
	1994	Mixed	-					
	2006-07	Wet	6	26.8	26.8	63.1	79.9	79.9
		Dry	9	18.3	18.3	64.1	125.5	125.5
TN	1993	Wet	336	0.68	0.91	2.21	3.7	9
		Dry	6	0.9	0.9	2.37	10.3	6
	1994	Mixed	18	1.1	1.24	1.92	2.34	3.28
	2006-07	Wet	6	0.73	0.73	1.94	3.06	3.06
		Dry	9	0.47	0.47	1.19	2.8	2.8
TP	1993	Wet	359	30	49	111	195	890
		Dry	20	5	37	68	126	170
	1994	Mixed	18	75	77	131	218	233
	2006-07	Wet	6	0.063	0.063	0.1	0.122	0.122
		Dry	9	0.031	0.031	0.08	0.152	0.152
Chlorophyll-a	1993	Wet	-					
		Dry	-					
	1994	Mixed	-					
	2006-07	Wet	3	0.9	0.9	2	2.7	2.7
		Dry	9	2	2	12.1	34	34
Faecal Coliforms	1993	Wet	392	80	360	32510	90000	400000
		Dry	20	40	40	971	984	14000
	1994	Mixed	18	920	1600	18165	62343	69787
	2006-07	Wet	6	4762	4762	17397	40472	40472
		Dry	9	34	34	248	40472	40472
Filterable Phosphorous	1993	Wet	359	1	6	18	36	91
		Dry	8	4	4	21	36	36
	1994	Mixed	18	9	12	30	43	51
	2006-07	Wet	6	0.036	0.036	0.056	0.072	0.072
		Dry	9	0.016	0.016	0.041	0.056	0.056
Total Uncombined Ammonia	1993	Wet	363	0.01	0.05	0.64	1.8	4.6
		Dry	20	0.06	0.11	0.66	1.51	2.8
	1994	Mixed	18	0.02	0.17	0.54	1.55	1.58
	2006-07	Wet	6	0.11	0.11	0.47	1.65	1.65
		Dry	9	0.04	0.04	0.6	1.73	1.73

Parameter	Report	Wea-ther	N	Min	10th Percentile	Mean	90th Percentile	Max
Oxidised Nitrogen	1993	Wet	364	0.08	0.17	0.56	0.93	5.7
		Dry	20	0.08	0.12	0.47	0.92	1.1
	1994	Mixed	18	0.09	0.1	0.44	0.72	1.68
	2006-07	Wet	6	0.37	0.37	1.09	2.1	2.1
		Dry	9	0.02	0.02	0.2	0.82	0.82
Inorganic Nitrogen	1993	Wet	-					
		Dry	-					
	1994	Mixed	18	0.217	0.515	0.932	1.427	1.443
	2006-07	Wet	-					
		Dry	-					
Conductivity	1993	Wet	-					
		Dry	-					
	1994	Mixed	-					
	2006-07	Wet	6	857	857	1645	3140	3140
		Dry	9	4023	4023	4466	4807	4807
pH	1993							
	1994							
	2006-07	Wet	6	7.1	7.1	7.7	8.2	8.2
		Dry	9	7.2	7.2	7.6	8.2	8.2

4.2 Cabramatta Creek Flying Fox Reserve

The Cabramatta Creek Flying Fox Reserve is usually occupied between September and May by between 5,000 and 30,000 GHFF (Fairfield Council 2001).

The water quality data available for sites in the vicinity of the Flying Fox Reserve is summarised in Table 5.

Table 5: Cabramatta Creek WQ Data

Source	Number of Samples and Period	Reference
Fairfield City Council	12; Sep 2010 – May 2011	Fairfield Council 2011a
GRCCC	2; 2009 - 2010	Fairfield Council 2011b, p.77
Streamwatch	4; May - Oct 2004	Streamwatch 2011

The GHFF site is shown in Figure 8, along with the location of the Fairfield Council sampling site.

Figure 8: Cabramatta Creek GHFF Camp (Google Maps)

A summary of the water quality data is provided in Table 6.

Table 6: Cabramatta Creek WQ Summary (highlighted cells indicate parameter not sampled)

Parameter	Units	Council (Broomfield St)				GRCCC (Lwr Cabramatta Ck)				Streamwatch (3 sites)			
		N	Min	Avg	Max	N	Min	Avg	Max	N	Min	Avg	Max
Temperature	deg C	10	16.5	20.1	23.2					15	11	18.5	27
pH		12	7.14	8.07	8.85	2	7.29	7.31	7.32	14	6	7.07	8
Conductivity	uS/cm	12	532	1,007	2,026	2	556	764	971	11	275	728	2718
DO	mg/L									14	1.9	5.5	8.2
DO	%	10	25%	63%	94%	2	23	42	62	14	17	59	99
Turbidity	NTU	12	2.28	6.95	23.40	2	4.9	18.7	32.5	14	10	34	150
Alkalinity	mg/L												
TP	ug/L	11	0.01	0.03	0.05	2	0.08	0.51	0.94				
TN	mg/L					2	0.9	3.9	6.9				
TKN	mg/L					2	0.9	3.9	6.9				
NOx-N	mg/L	11	0.01	0.12	0.60	2	0.005	0.013	0.02	3	0	0.17	0.3
Faecal Coliforms	count/ 100mL	11	90	4,372	35,000					9	0	7.78	40

4.3 Parramatta Park

The Parramatta Park Flying Fox Camp is usually occupied by between 5,000 and 6,000 GHFF (Eco Logical 2008).

The water quality data available for sites in the vicinity of the Flying Fox Camp is summarised in Table 7.

Table 7: Parramatta Park WQ Data

Source	Number of Samples and Period	Reference
Parramatta City Council	12; 2007	J.H. & E.S. Laxton 2008 (summary report)
Parramatta City Council	204; 1990 - 2006	Parramatta Council 2011 (raw data)
Streamwatch	10; Feb – March 2002	Streamwatch 2011

The sampling stations from the Laxton report that are nearest to the GHFF camp are (Laxton, 2008):

- Station 5 - Toongabbie Creek at Redbank Road bridge (1991). It was Finlayson's Creek (tributary to Toongabbie Creek) at Briens Road in 1990. Current position (150º 59' 05" E, 33 º 48' 03" S)
- Station 6 - Darling Mills Creek behind Parramatta Jail at Board Street. This station was at Northmead High School (Campbell Street) in 1990. Current position (150 º 59' 51" E, 33 º 47' 44" S).
- Station 8 - Parramatta River at Marsden Street weir. (151 º 00' 24" E, 33 º 48' 50" S).

These three sampling stations and the GHFF camp are shown in Figure 9.

A summary of the water quality data from between 1990 and 2006 is shown in Table 8.

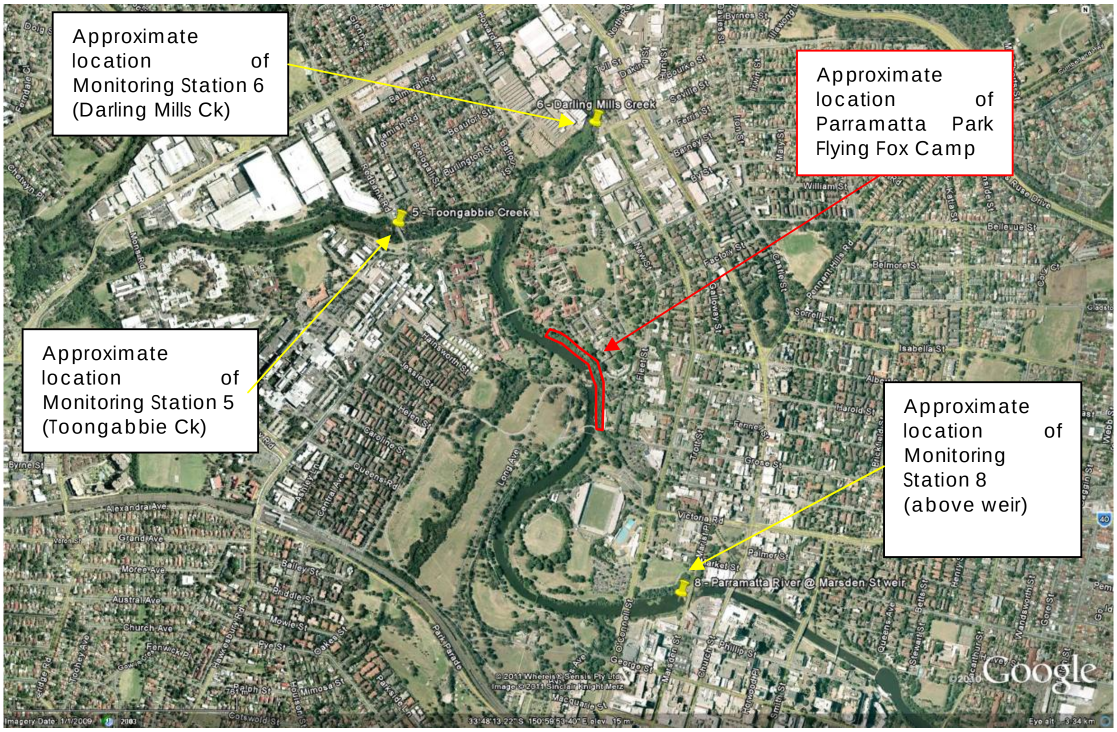

Figure 9: Parramatta Park WQ Sites (image from GoogleEarth)

Table 8: Parramatta WQ Summary

Parameter	Units	Sample Station	N	Min	10th %ile	Avg	90th %ile	Max
Temp	oC	Stn 5	204	7.80	10.15	17.38	23.49	26.99
		Stn 6	204	8.71	10.42	16.96	22.57	26.77
		Stn 8	197	8.83	11.32	18.02	23.81	27.83
Salinity	ppt	Stn 5	204	0.04	0.16	0.33	0.52	0.99
		Stn 6	204	0.02	0.12	0.19	0.28	0.38
		Stn 8	197	0.01	0.12	0.24	0.39	0.88
pH		Stn 5	204	4.12	7.16	7.46	7.80	8.82
		Stn 6	204	6.64	7.08	7.43	7.82	8.47
		Stn 8	197	6.94	7.35	7.74	8.21	9.07
DO % Sat	%Sat	Stn 5	204	12.0	28.1	56.3	7.8	8.8
		Stn 6	204	6.1	37.1	67.1	7.8	8.5
		Stn 8	197	30.3	51.9	77.5	8.2	9.1
DO mg/L	mg/ L	Stn 5	204	1.10	2.73	5.48	8.27	10.60
		Stn 6	204	0.50	3.40	6.57	9.20	11.00
		Stn 8	197	2.80	5.00	7.40	10.20	13.20
Ammonia	mg-N/L	Stn 5	204	0.03	0.07	0.19	0.31	3.10
		Stn 6	204	0.02	0.05	0.15	0.26	1.23
		Stn 8	197	0.03	0.07	0.17	0.30	1.28

Parameter	Units	Sample Station	N	Min	10th %ile	Avg	90th %ile	Max
Organic-N	mg-N/L	Stn 5	204	0.01	0.23	0.72	0.31	3.11
		Stn 6	204	0.04	0.22	0.59	0.26	2.54
		Stn 8	197	0.04	0.24	0.71	0.30	2.68
Oxidized-N	mg-N/L	Stn 5	204	0.00	0.03	0.33	0.76	1.93
		Stn 6	204	0.00	0.04	0.26	0.63	1.08
		Stn 8	197	0.01	0.06	0.33	0.72	2.16
Total-N	mg-N/L	Stn 5	204	0.24	0.56	1.24	1.90	4.20
		Stn 6	204	0.06	0.50	1.00	1.61	3.55
		Stn 8	197	0.22	0.58	1.21	1.95	3.65
Ortho-P	mg-P/L	Stn 5	204	0.002	0.007	0.033	0.062	0.287
		Stn 6	204	0.004	0.007	0.043	0.075	0.654
		Stn 8	197	0.002	0.006	0.023	0.050	0.214
Total-P	mg-P/L	Stn 5	204	0.024	0.060	0.160	0.062	0.797
		Stn 6	204	0.015	0.039	0.151	0.075	1.314
		Stn 8	197	0.026	0.043	0.128	0.050	0.606
% Trans.		Stn 5	204	0.60	21.80	61.70	86.37	95.30
		Stn 6	204	0.70	64.66	80.69	92.97	98.90
		Stn 8	197	0.40	28.98	64.69	86.32	96.20
Total S	mg/L	Stn 5	203	2.7	7.2	29.2	47.8	342.4
		Stn 6	204	0.3	3.2	12.6	19.7	300.0
		Stn 8	197	2.7	6.2	25.7	46.1	426.7
Volatile S	mg/L	Stn 5	203	0.7	1.8	5.2	8.5	34.0
		Stn 6	204	-	1.2	3.2	5.4	47.3
		Stn 8	197	1.0	2.1	5.1	7.5	55.3
Chloro-a	ug/L	Stn 5	204	1.36	4.03	13.85	29.29	77.31
		Stn 6	204	0.39	1.75	7.74	17.49	50.58
		Stn 8	197	0.95	5.05	20.38	40.70	107.89
Faecal Coliforms		Stn 5	204	-	95	1,454	2,000	20,000
		Stn 6	204	-	69	1,035	2,000	50,000
		Stn 8	197	-	50	1,397	1,700	100,000

4.4 Ku-ring-gai Flying Fox Reserve

Ku-ring-gai Flying Fox Reserve is a 15 hectare site in Gordon that has been occupied by GHFF since the 1960's (KBCS 2011).

Water quality data was sourced from Ku-ring-gai Council who have monitored 17 sites within the Ku-ring-gai LGA for a range of water quality characteristics through the Stream health assessment/Macroinvertebrate sampling program. Water quality data from 12 sites within the LGA was also collected by a postgraduate research student from Macquarie University. (Ku-ring-gai Council, 2006).

The data for two sampling sites in the vicinity of the Flying Fox Reserve is summarised in Table 9 and the sample sites are shown in Figure 10. The location of the Flying Fox Reserve was taken from the *Ku-ring-gai Flying-fox Reserve management plan* (Ku-ring-gai Council 1999).

Table 9: Ku-ring-gai GHFF Reserve WQ Data

Source	Number of Samples and Period	Reference
Ku-ring-gai Council (Stream macroinvertebrate study)	2; 1999 - 2000	Ku-ring-gai Council (2006), pp. 4 - 10
Ku-ring-gai Council (Postgraduate research data)	5; 2004 - 2005	Ku-ring-gai Council (2006), pp. 14 - 20

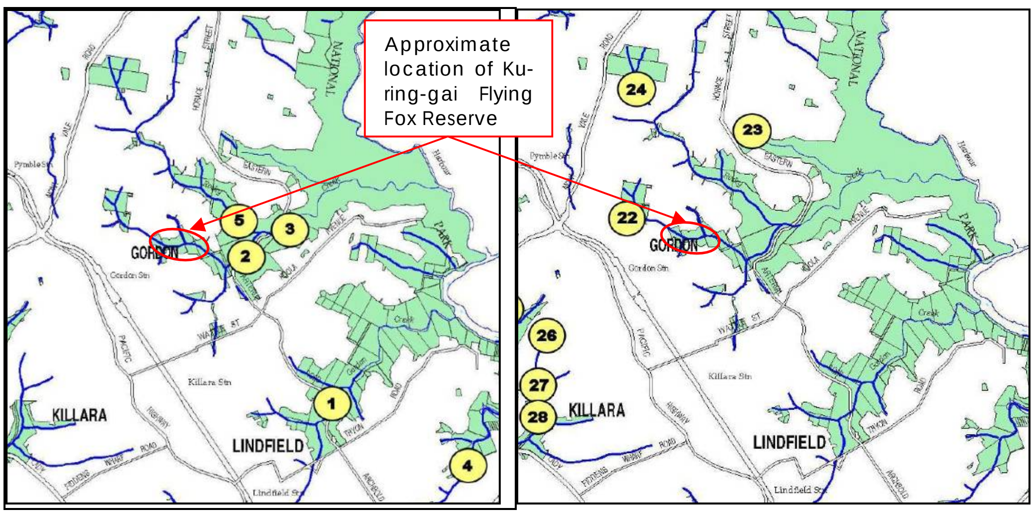

Figure 10: Ku-ring-gai WQ Monitoring Sites (Ku-ring-gai Council 2006)

The sampling stations from the Ku-ring-gai Council water quality monitoring report that are nearest to the GHFF camp are:

- Site 2 – stream macroinvertebrate study site - Rocky Creek Upper, 100m u/s High Ridge Ck junction. (*This site is approximately 500 m downstream of the GHFF Reserve*); and
- Site 22 - Postgraduate research site - Gordon Minns Rd, Ashley Grove. (*This site is approximately 300 m upstream of the GHFF Reserve*);

A summary of the water quality data is shown in Table 10.

Table 10: Ku-ring-gai WQ Summary

Parameter	Units	Site 2 (Stream Macro)				Site 22 (Postgrad)			
		N	Min	Avg	Max	N	Min	Avg	Max
Temperature	deg C	2	15.5	18.0	20.5	5	17.5	20.3	22.5
pH		2	6.23	6.6	6.99	6	6.86	7.22	7.54
Conductivity	uS/cm	2	332	382.0	432				

Parameter	Units	Site 2 (Stream Macro)				Site 22 (Postgrad)			
		N	Min	Avg	Max	N	Min	Avg	Max
DO	mg/L	2	7.72	8.1	8.45	6	2.05	6.58	8.05
Turbidity	NTU	2	1.82	2.2	2.66				
Alkalinity	mg/L	2	39.5	40.3	41				
TP	ug/L					5	44	83.8	140
TN	mg/L					6	0.4	0.74	1
Faecal Coliforms	count/ 100mL					7	68	1168	2519
Ammonia	mg/L					2	0.061	0.097	0.134

4.5 Engadine Wetland

GHFF have been observed to drink at a wetland at Engadine, by Sutherland Council, located to the east of the train station. This wetland has been subject to a significant amount of water quality testing as shown in Table 11.

Table 11: Engadine WQ Data

Source	Number of Samples and Period	Reference
Sutherland Shire Council (Outflow)	50; June 1997 – Feb 2001	Evans & Peck (2009) (Raw data provided to Evans & Peck by Council)
Sutherland Shire Council (Inflow)	20; Dec 1994 – Feb 2001	Evans & Peck (2009) (Raw data provided to Evans & Peck by Council)

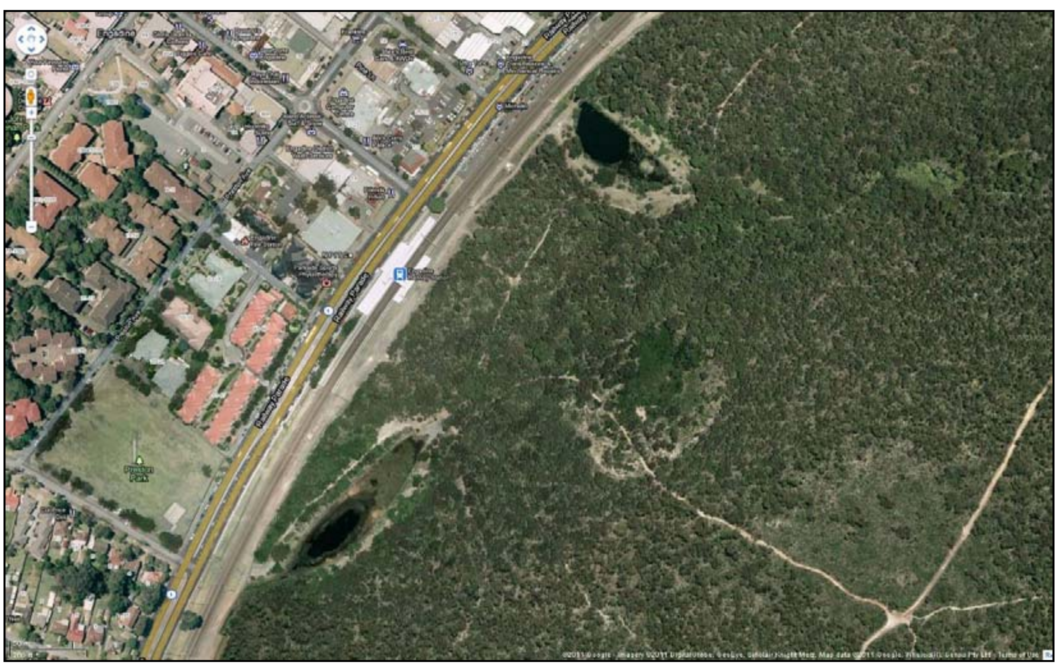

Figure 11: Engadine Wetland Site

The data provided by Sutherland Shire Council was analysed by Perrens, and the summary water quality data is shown in Table 12.

Table 12: Engadine WQ Summary

Parameter	Units	N		Min		10th Percentile		Average		90th Percentile		Max	
		In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
Temp	deg C	10	10	16.4	16.7	17.3	17.2	24.5	23.5	33.6	28.4	35.8	29.9
pH		16	9	6.5	6.8	6.6	6.8	7.3	7.2	8.3	7.5	8.9	7.7
EC Corrected	mS/cm	10	10	93	99	185	146	344	182	545	7	635	231
TSS	mg/L	32	19	2	2	2	2	58	7	168	12	480	26
Ammonia	mg/L	23	15	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	1.8	0.4
Nitrate	mg/L	10	10	0.0	0.0	0.0	0.0	0.8	0.1	2.2	0.2	3.7	1.2
Nitrite	mg/L	9	10	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0	0.2	0.0
TKN	mg/L	10	10	0.6	0.2	0.8	0.6	2.1	0.7	4.6	0.9	4.8	1.2
Total N	mg/L	32	20	0.1	0.1	0.3	0.2	1.4	0.6	3.4	0.9	5.0	1.8
Total P	mg/L	32	20	0.0	0.0	0.0	0.0	0.1	0.0	0.4	0.0	0.8	0.1
DO	mg/L	22	15	3.0	3.2	3.7	3.5	6.2	7.0	8.2	9.6	13.8	14.3
BOD	mg/L	22	15	0.5	0.1	2.0	1.0	5.5	3.9	14.5	3.6	26.0	30.0
Grease	mg/L	22	15	1.0	1.0	1.1	1.0	6.7	2.9	13.8	5.0	46.0	7.0
Enterococci	cfu/100ml	31	20	4	0	30	3	2995	438	10000	1640	15000	2500

Parameter	Units	Data Source	N	Min	10th %ile	Average	90th %ile	Max
Temp	deg C	Inflow	10	16.4	17.3	24.5	33.6	35.8
		Outflow	10	16.7	17.2	23.5	28.4	29.9
pH	mg/L	Inflow	16	6.5	6.6	7.3	8.3	8.9
		Outflow	9	6.8	6.8	7.2	7.5	7.7
EC	mS/cm	Inflow	10	93.3	184.7	344.1	545.0	635.0
		Outflow	10	98.7	146.0	182.2	7.5	230.7
TSS	mg/L	Inflow	32	2	2	58	168	480
		Outflow	19	2	2	7	12	26
Ammonia	mg/L	Inflow	23	0.005	0.006	0.111	0.128	1.790
		Outflow	15	0.005	0.007	0.047	0.086	0.350
Nitrate	mg/L	Inflow	10	0.005	0.005	0.794	2.151	3.690
		Outflow	10	0.005	0.005	0.143	0.233	1.160
Nitrite	mg/L	Inflow	9	0.005	0.005	0.059	0.178	0.210
		Outflow	10	0.005	0.005	0.007	0.011	0.020
TKN	mg/L	Inflow	10	0.60	0.78	2.10	4.62	4.80
		Outflow	10	0.20	0.56	0.70	0.93	1.20
Total N	mg/L	Inflow	32	0.060	0.281	1.405	3.380	5.000
		Outflow	20	0.120	0.160	0.565	0.930	1.800
Total P	mg/L	Inflow	32	0.002	0.012	0.122	0.372	0.830
		Outflow	20	0.010	0.015	0.032	0.043	0.128

DO	mg/L	Inflow	22	2.95	3.66	6.19	8.18	13.76
		Outflow	15	3.21	3.47	6.99	9.60	14.32
BOD	mg/L	Inflow	22	0.50	2.0	5.54	14.5	26.0
		Outflow	15	0.05	1.0	3.87	3.6	30.0
Grease	mg/L	Inflow	22	1.0	1.1	6.7	13.8	46.0
		Outflow	15	1.0	1.0	2.9	5.0	7.0
Enterococci	cfu/ 100mL	Inflow	31	4	30	2995	10000	15000
		Outflow	20	0	3	438	1640	2500

5 Water Quality Summary and Objectives

The water quality data outlined in Section 3 and Section 4 is summarised in the figures below for the following parameters:

- Suspended Solids
- Dissolved Oxygen
- Total Nitrogen
- Total Phosphorous
- Chlorophyll-a

These parameters have been selected as they are the key water quality parameters indicating the health of a receiving water.

The figures below show that the GHFF utilise water bodies from a varying range of receiving water quality habitat but these ranges are reasonably uniform on the broader scale. For example the average for TSS for all sites is typically in the region of 10 to 50 mg/L and the average for DO is typically in the range of 5 to 7 mg/L.

Note for all charts:

- Top and bottom values show maximum and minimum values respectively
- Gaps indicate that the parameter was not sampled at that site.
- 10%ile and 90%ile are currently shown for Engadine, Wolli Creek and Parramatta River as there is currently not sufficient data for the remaining sites.

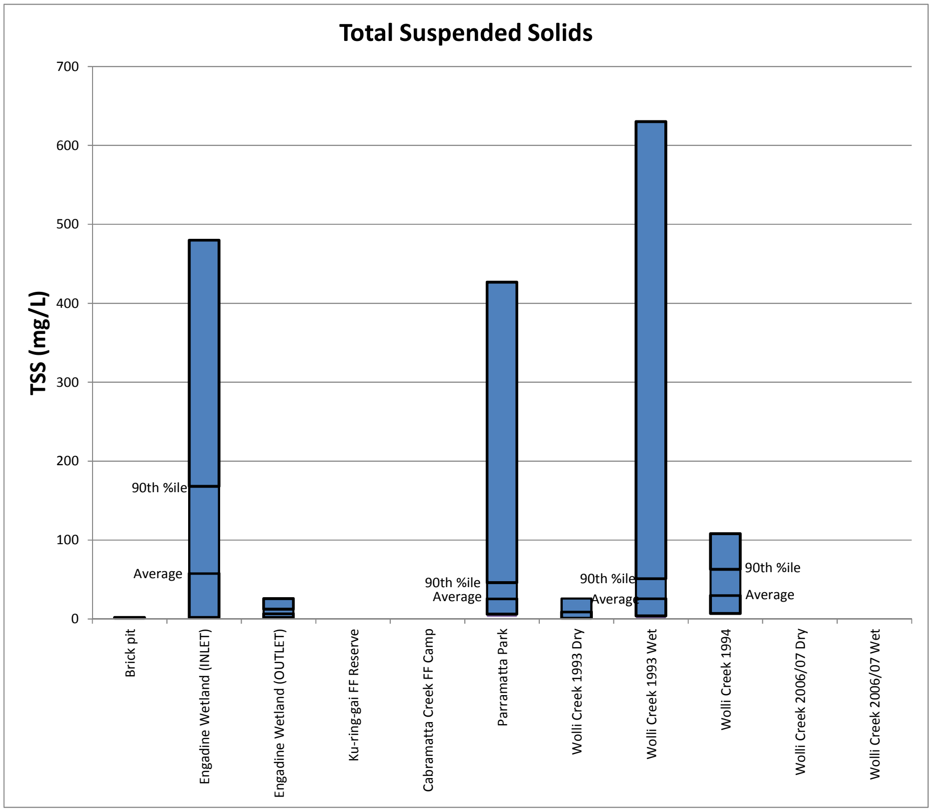

Figure 12: Water Quality of GHFF sites – Suspended Solids

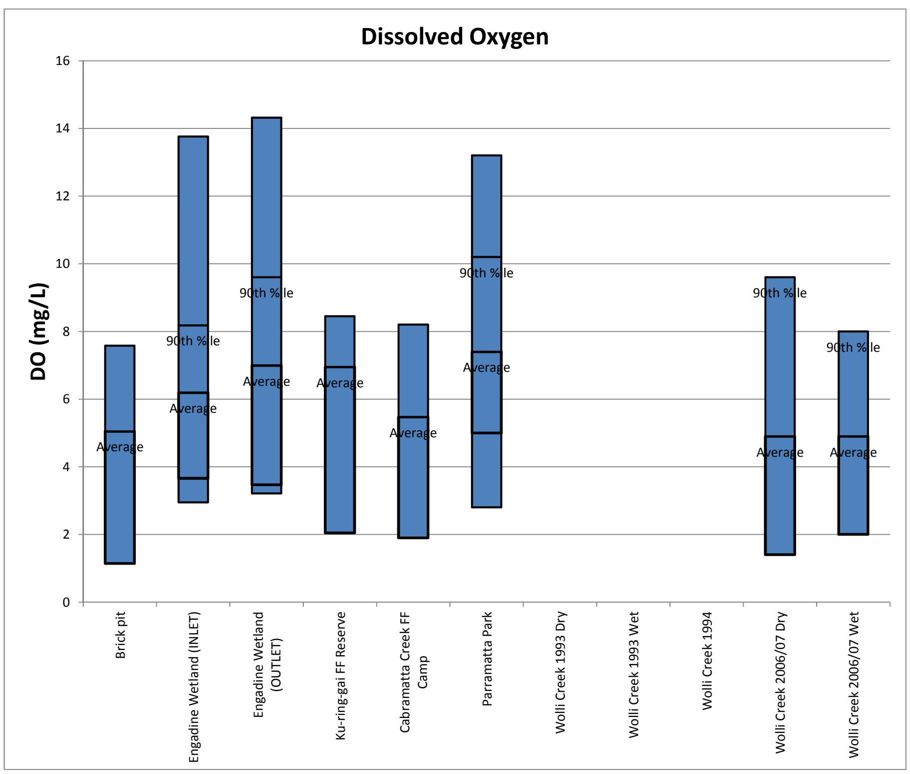

Figure 13: Water Quality of GHFF sites – DO (mg/L)

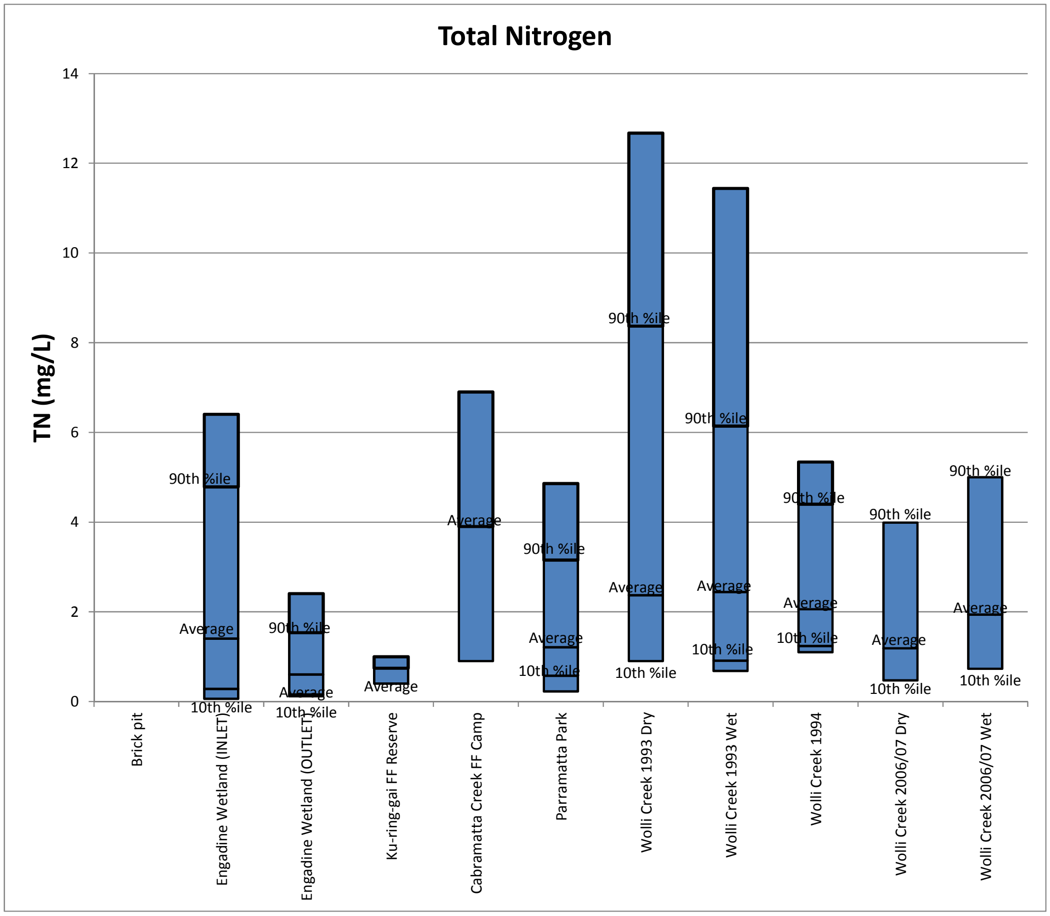

Figure 14: Water Quality of GHFF sites – Total Nitrogen

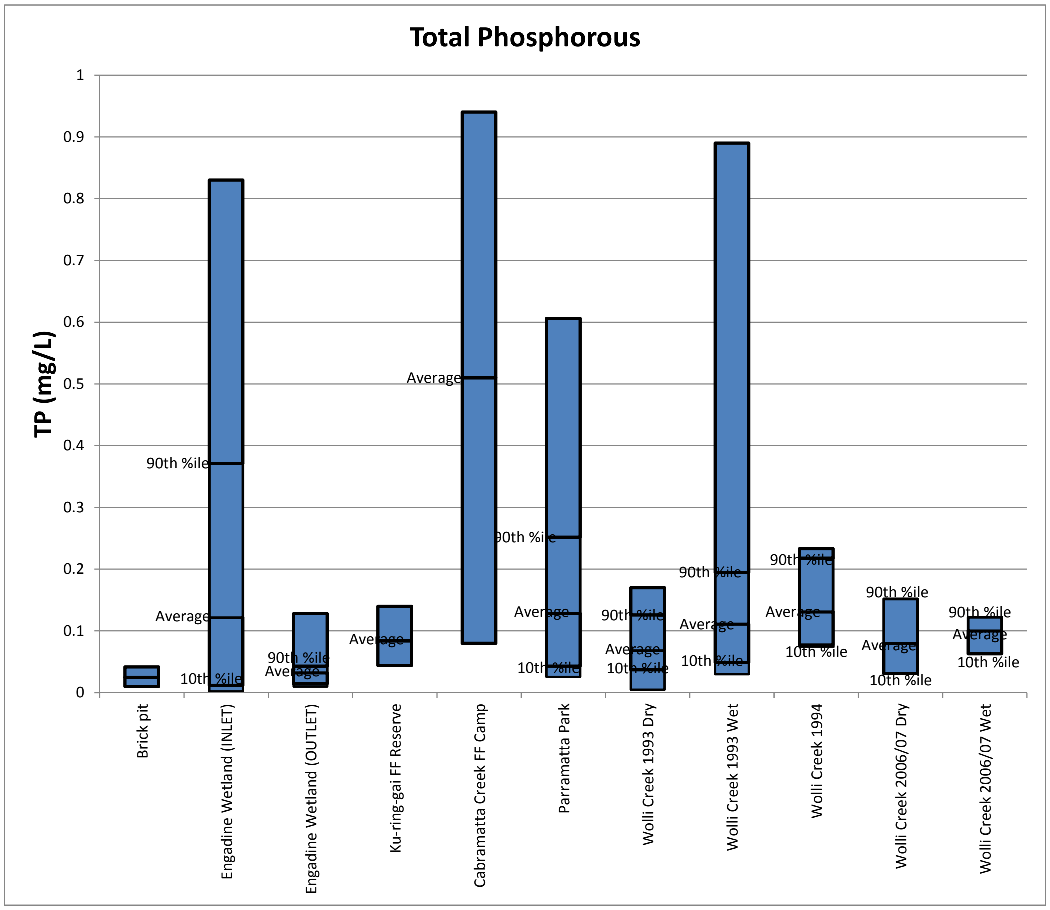

Figure 15: Water Quality of GHFF sites – Total Phosphorous (complete)

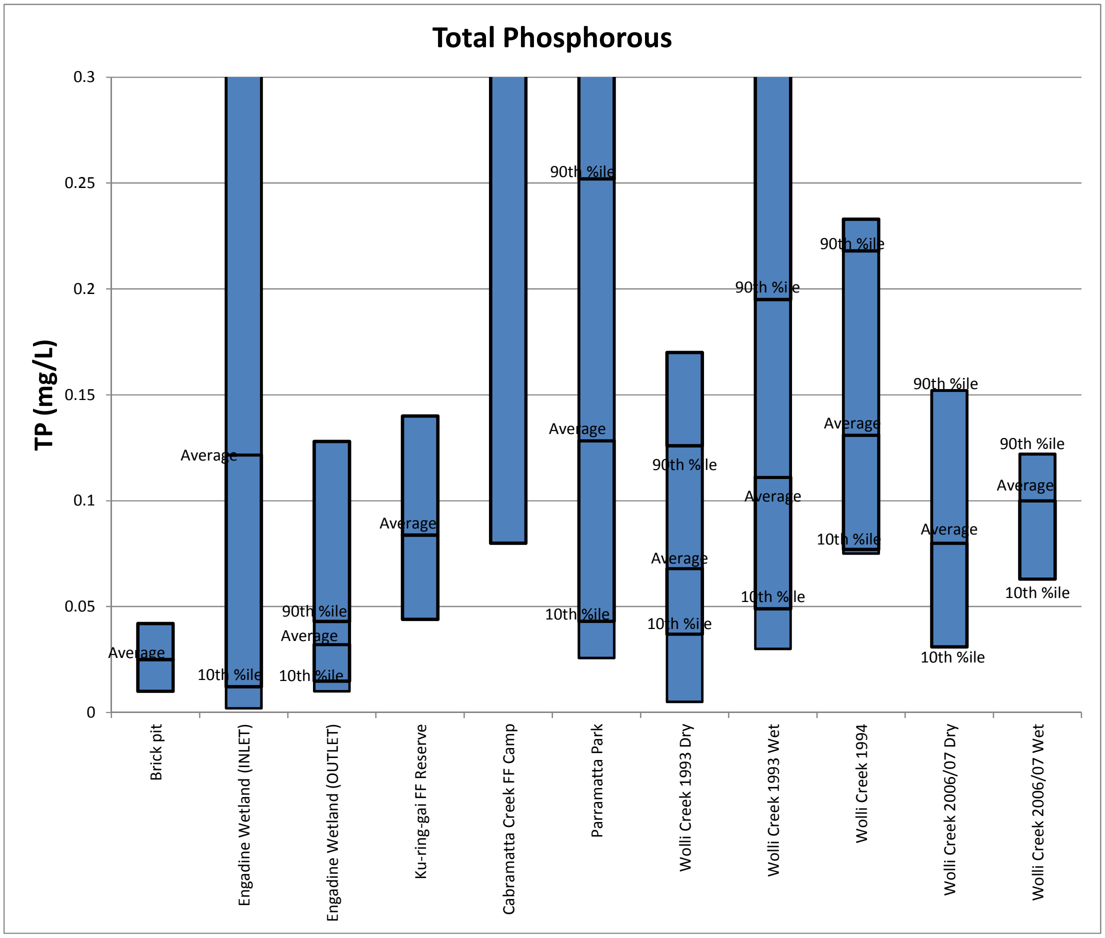

Figure 16: Water Quality of GHFF sites – Total Phosphorous (graph zoomed into values less than 0.3 mg/L)

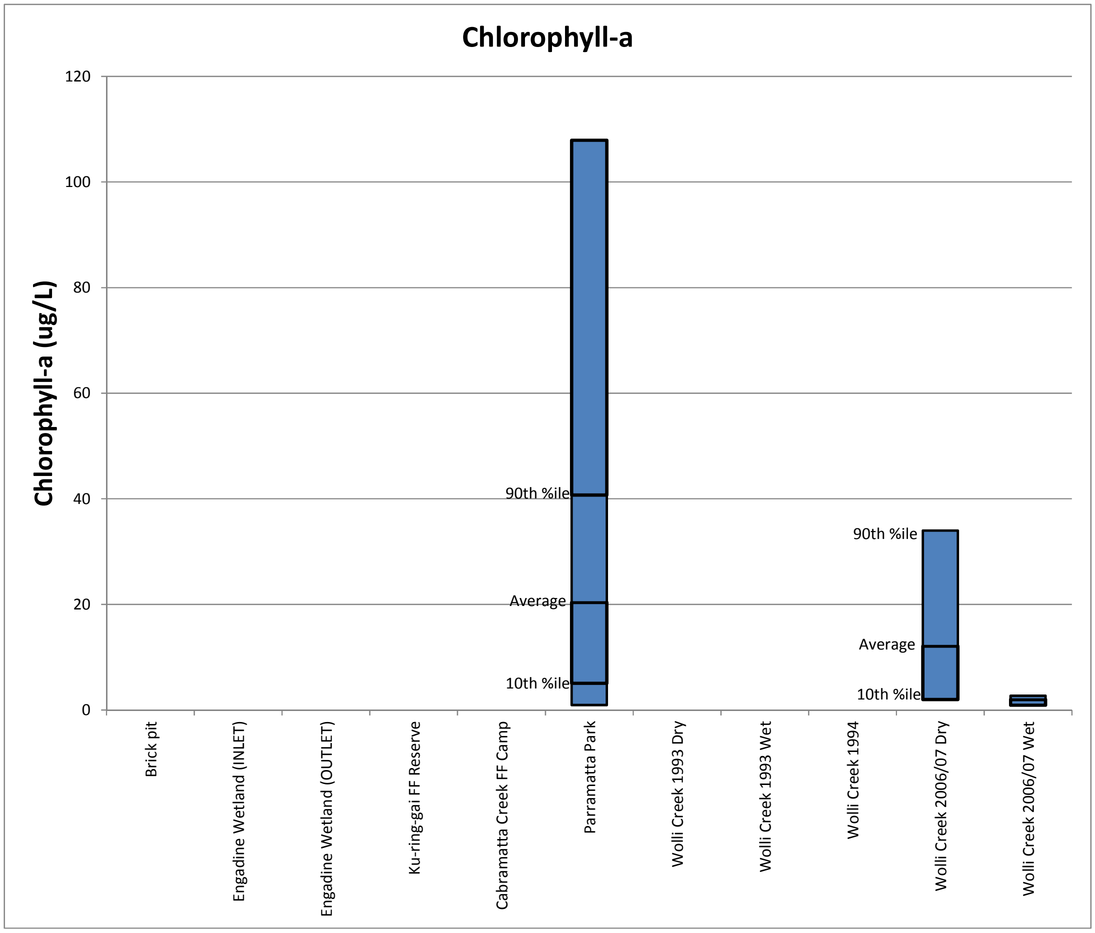

Figure 17: Water Quality of GHFF sites – Chlorophyll-a

5.1 Summary of WQ

Parameter	Data Source	10th %ile	Average	90th %ile
DO	Brick pit		5.05	
	Engadine Wetland (INLET)	3.66	6.192	8.18
	Engadine Wetland (OUTLET)	3.47	6.995	9.60
	Ku-ring-gai FF Reserve		6.9525	
	Cabramatta Creek FF Camp		5.47	
	Parramatta Park (Marsden St)	5.0	7.4	10.2
	Wolli Creek 1993 Dry			
	Wolli Creek 1993 Wet			
	Wolli Creek 1994			
	Wolli Creek 2006/07 Dry	1.4	4.9	9.6
	Wolli Creek 2006/07 Wet	2	4.9	8
	Recommended Value	**3**	**6**	**9**
TSS	Brick pit		2	
	Engadine Wetland (INLET)	2	58	168
	Engadine Wetland (OUTLET)	2	7	12.40
	Ku-ring-gai FF Reserve			
	Cabramatta Creek FF Camp			
	Parramatta Park (Marsden St)	6.2	25.7	46.1
	Wolli Creek 1993 Dry	1	9	26
	Wolli Creek 1993 Wet	4	26	51
	Wolli Creek 1994	7	30	63.0
	Wolli Creek 2006/07 Dry			
	Wolli Creek 2006/07 Wet			
	Recommended Value	**5**	**25**	**50**
TP	Brick pit		0.1216	
	Engadine Wetland (INLET)	0.0122	0.1216	0.37
	Engadine Wetland (OUTLET)	0.0148	0.0321	0.04
	Ku-ring-gai FF Reserve		0.0321	
	Cabramatta Creek FF Camp		0.51	
	Parramatta Park (Marsden St)	0.043	0.13	0.25
	Wolli Creek 1993 Dry	0.037	0.068	0.13
	Wolli Creek 1993 Wet	0.049	0.11	0.20
	Wolli Creek 1994	0.077	0.13	0.22
	Wolli Creek 2006/07 Dry	0.031	0.08	0.152
	Wolli Creek 2006/07 Wet	0.063	0.1	0.12
	Recommended Value	**0.05**	**0.15**	**0.25**

Parameter	Data Source	10th %ile	Average	90th %ile
TN	Brick pit			
	Engadine Wetland (INLET)	0.28	1.40	3.38
	Engadine Wetland (OUTLET)	0.16	0.57	0.93
	Ku-ring-gai FF Reserve		0.742	
	Cabramatta Creek FF Camp		3.90	
	Parramatta Park (Marsden St)	0.58	1.21	1.95
	Wolli Creek 1993 Dry	0.9	2.37	6.00
	Wolli Creek 1993 Wet	0.91	2.21	3.70
	Wolli Creek 1994	1.24	1.92	2.34
	Wolli Creek 2006/07 Dry	0.47	1.19	2.80
	Wolli Creek 2006/07 Wet	0.73	1.94	3.06
	Recommended Value	**0.9**	**2.0**	**3.5**
Chl-a	Brick pit			
	Engadine Wetland (INLET)			
	Engadine Wetland (OUTLET)			
	Ku-ring-gai FF Reserve			
	Cabramatta Creek FF Camp			
	Parramatta Park (Marsden St)	5.05	20.38	40.70
	Wolli Creek 1993 Dry			
	Wolli Creek 1993 Wet			
	Wolli Creek 1994			
	Wolli Creek 2006/07 Dry	2	12.1	34
	Wolli Creek 2006/07 Wet	0.9	2	2.70
	Recommended Value	***Insufficient***	***Data***	

5.2 ANZECC Guidelines

The framework for application of the ANZECC guidelines includes determining appropriate water quality guidelines after taking into account local environmental conditions. The trigger values provided in the ANZECC guidelines are conservative and not always appropriate, and there are benefits from developing site specific guidelines with the use of reference sites. Preference is given in the ANZECC guidelines to use of local reference data. These are designed to maintain environmental values.

"The Guidelines recommend numerical and descriptive water quality guidelines to help managers establish water quality objectives that will maintain the environmental values of water resources. They are not standards, and should not be regarded as such. The vast range of environments, ecosystem types and food production systems in Australia and New Zealand require a critically discerning approach to setting water quality objectives." (ANZECC 2000 p.2-16)

The approach taken for the Brick Pit is consistent with *Using the ANZECC Guidelines and Water Quality Objectives in NSW* (DEC 2006). "Trigger values are conservative assessment levels, not 'pass/fail' compliance criteria. Local conditions vary naturally between waterways and it may be necessary to tailor trigger values to local conditions or 'local guideline levels'." (DEC 2006 p.5)

The approach taken for the Brick Pit is also consistent with *ANZECC Water Quality Guidelines* (Sect 3.1.1.2 in Chapter 3):

"…the preferred approach to deriving trigger values follows the order: use of biological effects data, then local reference data (mainly physical and chemical stressors), and finally (least preferred) the tables of default values provided in the Guidelines (see figure 3.1.2). (While the default values are the least preferred method of deriving trigger values, it is conceded that these will be most commonly sought and applied until users have acquired local information.).."

As there had not been a study of the local data previously, it was understandable that the default ANZECC Water Quality reference guidelines had been proposed. Now that the local data has been obtained, the Guidelines state the preference of that data being used to define the trigger values as opposed to the default guidelines. This is approach followed in this report.

The process followed in this report was to set 'local guideline levels' based on local environmental conditions rather than to use or adopt more general ANZECC water quality guidelines, such as those for slightly disturbed ecosystems or similar. The ANZECC water quality guidelines, including guidelines for local disturbed ecosystems, are not considered as appropriate in this instance as the locally relevant water quality guidelines that have been recommended.

6 Water Quality Modelling of Proposed Water Feature

6.1 Introduction

The proposed Brick Pit open waterbodies needs to meet a number of design objectives including:

- Ecological services for bat species including the GHFF and the Eastern Bent-wing Bat
- Landscape and aesthetics
- Passive recreation
- Site runoff management (a portion of the site drains to the open water body)
- Sustainable ongoing operation and maintenance requirements

There are several interacting physical, ecological and social factors which play an important role in determining sustainable water quality of an open waterbody. A simplified diagram showing the key factors is shown in Figure 18.

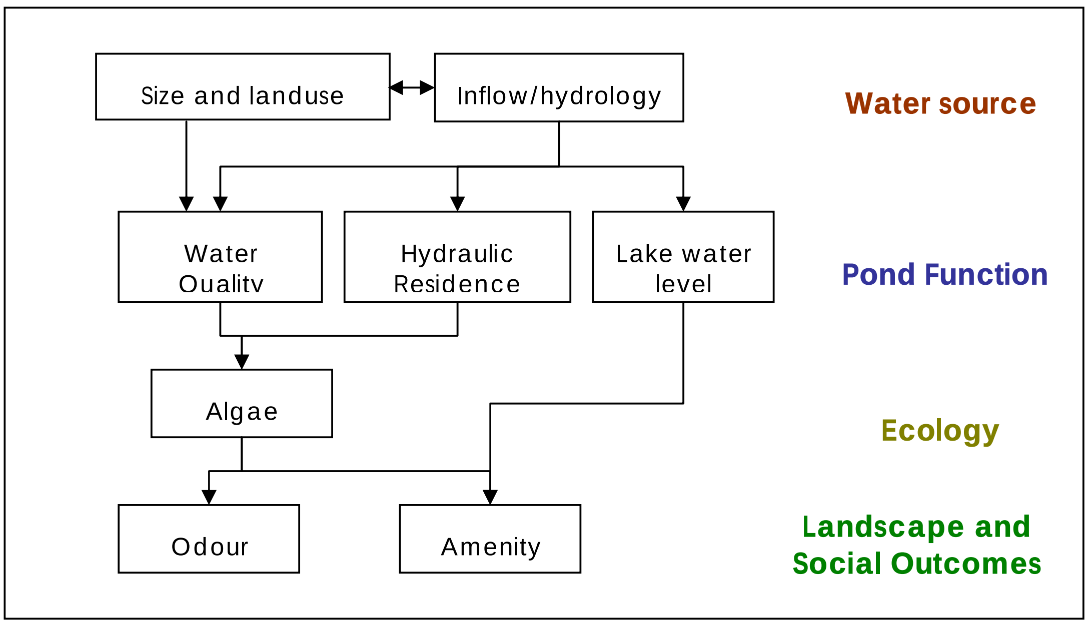

Figure 18: Factors determining waterbody design and sustainability

The design of pond waterbodies must ensure that the pond meets its roles in conserving a suitable water body for GHFF and generally promoting biodiversity as well as ensuring that the pond enhances the urban landscape. A common occurrence in past practices of incorporating large open waterbodies (relative to its natural catchment area) is water quality problems in ornamental ponds and lakes are caused by poor inflow water quality, especially high organic and nutrient load, infrequent waterbody "turnover" or "flushing" and inadequate mixing. The potential for algal blooms, in particular blue green algae, compromises the habitat function of the waterbody as well as providing a significantly reduced aesthetic and maintenance outcome.

The ecological health of the pond is directly linked with the water source and the characteristics of the waterbody and the internal processes in the waterbody.

The sustainability of the proposed pond has been assessed in two ways:

- **Hydrologic sustainability** – This is an assessment of the ability of the catchment to provide sufficient water to maintain adequate water levels in the pond. It is assessed through a water balance model and expressed as a water level – exceedance curve.

- **Ecological sustainability** – This is an assessment of the pond water quality and the water quality processes that are operating in the pond linked to sedimentation and oxidation and reduction processes. The ability of the pond system to provide for a healthy ecosystem is largely determined by the quality of inflowing water and the residence time of that water in the pond and the processes within the pond. Excessive algal growth is one of the key threats to the health of an open water body. The exponential rate of algal growth under unlimited conditions means that algal populations can rapidly reach levels where they become a risk to public health. In the past urban ponds have been poorly designed with limited hydrologic analysis undertaken in the design and little or no water quality analysis or treatment of stormwater inflows into urban water bodies. Many ponds have therefore subsequently suffered from significant operation and maintenance issues including frequent algal blooms

The rate of algal growth is a function of available nutrients, available oxygen, light, temperature and hydrologic conditions. When nutrients are available in sufficient quantities then managing residence times is critical to managing the risks of algal blooms. These are discussed in more detail below.

6.1.1 Availability of nutrients

Nutrients become available to algae in two ways;

- Dissolved or suspended in inflowing water, and

- Release from sediments under anaerobic conditions. There is substantial adsorption of nutrients by fine suspended solids discharged to ponds during storm events, which are then removed from the water column by physical sedimentation. The nutrients/sediment settle and accumulate on the base of the pond.

- Benthic microbes normally feed on decomposing organic material at the bottom of a pond or wetland. Their growth is determined by the amount of organic material available. High organic material increases oxygen demand and can deplete oxygen in the water column and sediments, with the potential to create anaerobic (reducing) conditions. If organic material remains after the oxygen has been used up, further microbial growth leads to chemically reducing conditions which may release nutrients (NH_4^+ and soluble reactive phosphorus) back into the water column in a highly bio-available form (Lawrence and Breen, 1998).

Minimising the accumulation of organic material reduces the risk of sediment-based nutrients being released, and this can be achieved by maintaining dissolved oxygen levels at a sufficient level to allow for its complete breakdown. Shorter residence times reduce the risk of low dissolved oxygen levels, and consequently reduce the risk of mobilisation of sediment-based nutrients.

6.1.2 Seasonality of Algal Growth

Algae thrive in conditions with adequate light, high temperature and long residence times. Considering the climatic conditions of the Coastal Sydney region, the critical time of year for algal growth is during spring and summer. The dry conditions (low rainfall) which prevail during these months leads to longer residence times within waterbody systems and the highest temperatures. The increased solar radiation during this period also provides for good light penetration into the pond. The average annual seasonality of these factors is shown in Figure 19.

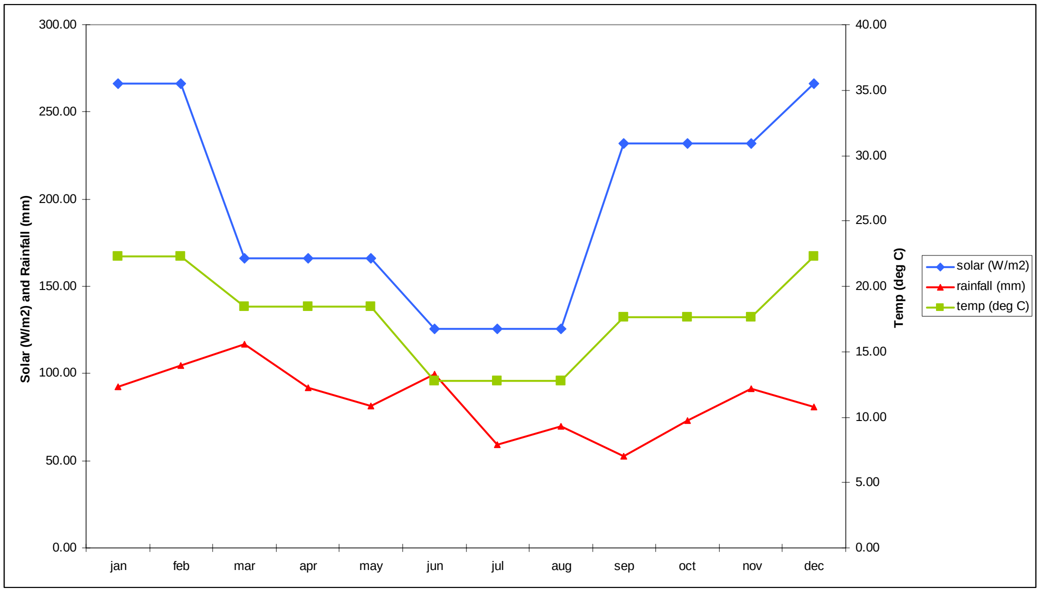

Figure 19: Annual pattern of temperature, solar input and rainfall (Lucas Heights rainfall station data from the Bureau of Meteorology)

6.1.3 Rates of Algal Growth

Rates of algal growth, represented in terms of biomass doubling time, range from 2 days up to 5 days (Lawrence & Breen, 1998).

The reportable threshold for a blue-green algal bloom is 15,000 cells/mL or approximately 30 to 40 ug/L chlorophyll-a which is commonly used as an indicator for algae. To reduce the risk of exceedance of this value a residence time of typically 20-30 days is recommended.

Extending the residence time greatly increases the risk of blue-green algal blooms due to the exponential rate of algal growth under unlimited conditions. Blue-green algae tend to dominate late in an algal bloom cycle. So while algal biomass may still be high with residence times under 20-30 days, the bloom is less likely to be dominated by blue-green algae. At shorter residence times green algae tend to dominate in high nutrient conditions.

The sensitivity of algal growth to residence time is shown in Figure 20.

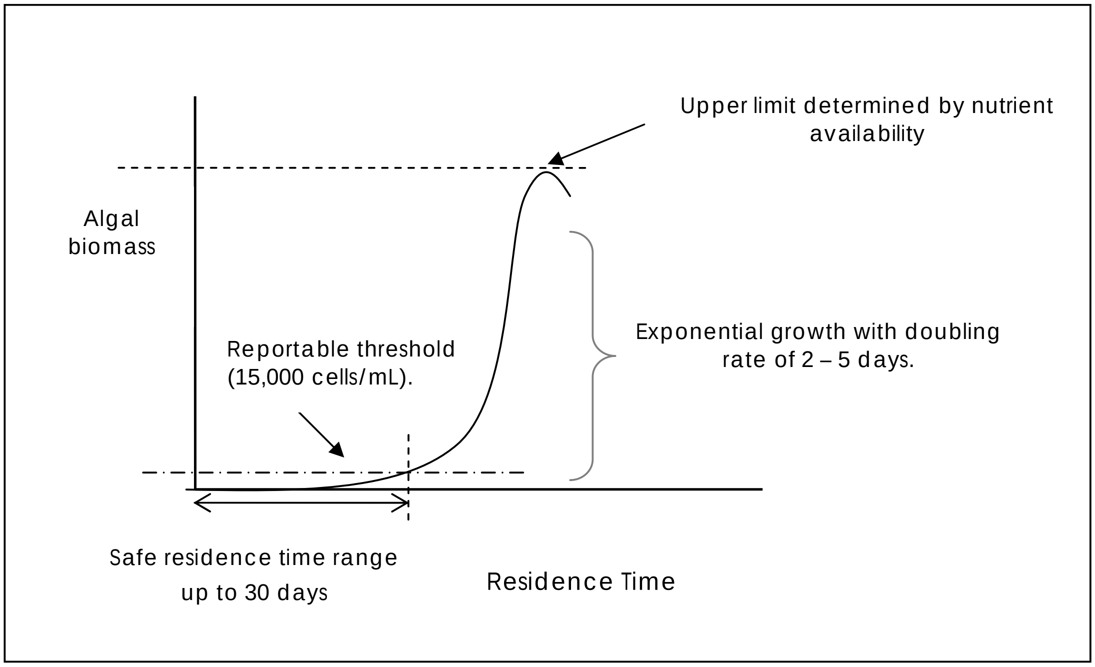

Figure 20: Algal growth and residence times

6.2 Modelling the Hydrology of the Open Waterbody

6.2.1 Background

The waterbody within the public park at the former Kirawee Brickpit will be fed from two separate sources. Two catchments which will drain by gravity into the pond and top up from a tank collecting treated stormwater runoff from the site and pumped into the waterbody to ensure that any water lost from evaporation during dry weather is replaced.

Two small sub-catchments in the Former Kirawee Brick Pit site drain to the waterbody:

1. approximately 0.4 hectares of Sydney Turpentine Ironbark Forest and effectively 100% pervious
2. and approximately 0.3 hectares including the village green area and associated landscaping and approximately 30% impervious

Figure 21: Waterbody Catchment Areas

To develop an understanding of the water level regime and residence times in the proposed waterbody a MUSIC model (*110711-preliminary-rev01.sqz* developed by Northrop), has been used to determine the runoff from these catchments

The model was developed and run on a 6 minute time-step using historical meteorological data from Sydney Observatory Hill from 1963 to 1993.

The average volume of runoff into the pond is estimated to be 3.7 ML/yr

The other source of water into the tank will be a top up from a storage tank collecting runoff from the proposed development. The tank has been designed to ensure there is a ready supply of top up water to the open water body as well as the water body in the plaza and that the loss of water from the water body due to evaporation and transpiration is replaced on a daily basis.

The tank will collect treated stormwater from a 1.2 hectare catchment with approximately 45% impervious areas. A preliminary tank size has been sized at 1000kL harvesting (refer to Northrop's stormwater strategy for further details)

The average annual volume of top up water into the water body is approximately 1.4 ML/yr.

The results were inserted into a pond water balance model. This water balance model accounted for lake size/depth, catchment and tank inflows, direct rainfall and evaporation on the pond surface.

6.2.2 Water Balance and Residence Times

Residence time is a key indicator. Residence time is defined as the number of days a parcel of water would remain in the water body. For example a water body that is emptied and filled every day has a residence time of one day, while a water body that is only emptied and filled once a year has a residence time of 365 days. The longer the residence time the more 'stagnant' the water and the increased risk of water quality deterioration.

The residence times of each daily outflow were calculated for the 30 year simulation period. The analysis assumes plug flow conditions in lake to simplify the lake water balance computation. In field conditions, plug flow rarely occurs and it is likely that some "parcels of stormwater inflow" will be subjected to shorter residence time and others subjected to longer residence time.

6.2.3 Water body characteristics

The total pond area is approximately 800 m^2. This surface area ensures that there is a minimum 40m length and 20m width to ensure that there are suitable access for GHFF.

The volume of the pond is approximately 1600 m^3 with an average depth of 2 m. Depth is an important consideration and needs to consider the following competing factors:

- sufficiently deep to reduce the presence of emergent vegetation that would reduce the area of open water– a depth of 1.5 to 2 m is recommended to adequately reduce emergent vegetation growth in the majority of the pond area;
- Achieving an optimal depth to area ratio, as increased depth for a given pond area would result in increased volume and residence times; and
- Reduce the likelihood of thermal/oxygen stratification. The risk of stratification increases with depth.

6.2.4 Hydrologic Sustainability

The hydrological sustainability of the pond waterbody is critical to ensuring the health of the water body. Residence time (or "flushing") is a key indicator as outlined in section 6.2.2.

As outlined above in section 6.1.3 the recommended residence time of a water body is 30 days and this residence time should not be exceeded more than 20% of the time on a long term average basis.

Figure 22 shows the results of the residence time analysis for the water body. The threshold residence time of 30 days will be exceeded more than 97% of the time (compared to the suggested criterion of exceedance in no more than 20% of the time). Also, for 50% of the time, the residence time will exceed 200 days suggesting that the pond waterbody remains poorly flushed throughout the year and for 50% of the time water will be sitting in the water body for more than 6 months.

The analysis shows that the water body has very poor natural flushing and is at a very high risk of algal blooms. Management measures will be required to ensure that the water body is well maintained and this is outlined in the following section.

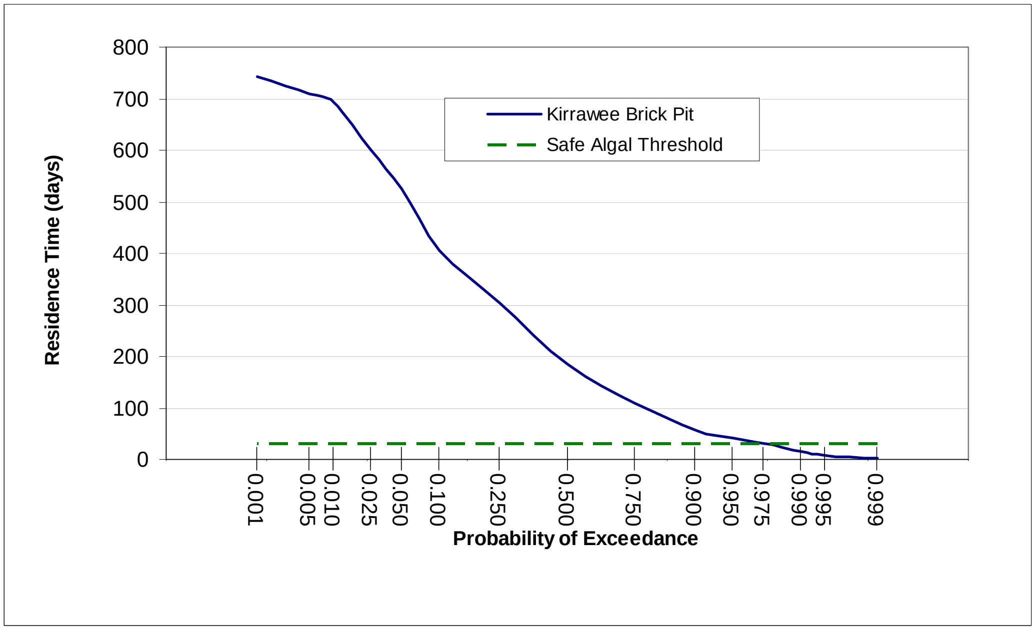

Figure 22: Hydrologic sustainability of Proposed Brick Pit Water body (1963 to 1993)

6.2.5 Managing risk of poor water quality

To ensure the water body maintains a good water quality, it will be necessary to improve circulation in the waterbody and reduce pollutant loads within the pond.

The recommended method of managing residence times below the safe algal threshold is to circulate water through a constructed wetland system during the high risk periods (Figure 21 and Figure 23). Constructed wetland systems have the capacity to remove nutrients and algal cells from water. The rate of circulation needs to be such that safe residence times in the lake are maintained. Recirculation through the wetland would be required when the 30 day residence time threshold is exceeded.

A water balance model can be used to develop a relationship between wetland area and wetland bathymetry, pond area and bathymetry and the required pump rate for the waterbody. This task should be undertaken during detailed design. An initial conservative estimate of the area for the wetland is provided at this stage of 800 m^2. This area will need to be refined during the detailed design phase and modelled in further detail to ensure a suitable water quality is able to be achieved. It is likely that during the detailed design phase the area of this wetland will be able to be reduced.

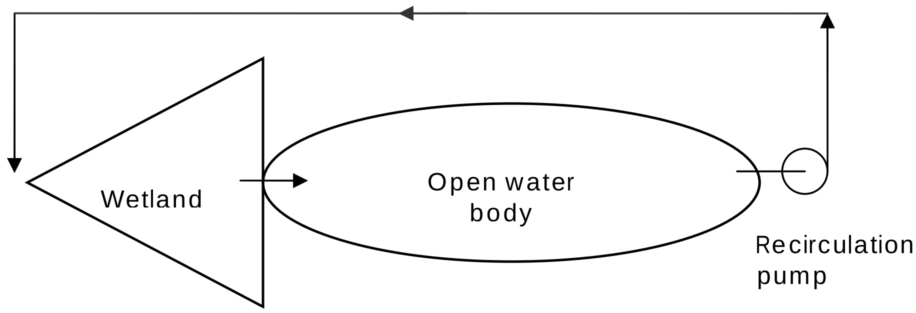

Figure 23: Schematic of wetland and recirculation system for the management of periods of extended detention

Utilising a recirculating wetland has a number of advantages in terms of improving water quality:

- It is a natural method of controlling and improving water quality
- Wetlands are often used in developments and infrastructure projects to control water quality and are well understood
- It is a very low energy solution (a 1 L/s pump is required to recirculate the water which would use less than 1000 kW/year or less than $500 in energy costs)
- The low pumping rates required means that the pump could be supplied with predominantly solar energy.
- It can be integrated into the landscape to be come a feature element and provide other outcomes including habitat and catchment water quality improvement
- It requires very low maintenance requirements and significantly less maintenance compared to other methods such as large recirculation devices, filtration systems or other similar devices

The recirculation wetland needs to be designed with a number of key design features to ensure that it functions correctly including

- the wetland needs to be fully vegetated and have a reasonably shallow depth (typically less than 0.5m)
- the wetland area should have no areas of open water
- the wetland must have a high hydrologic effectiveness with no opportunity for re-circulated water to short circuit the wetland cell

The wetland cells can be split up into separate components and the wetland cells can either be in series or parallel.

During detailed design the final components of the wetland cells should be designed using a continuous simulation tool such as MUSIC or XP SWMM to determine the final configuration of the system including the typical depth, the area, the volume and the extended detention and the inlet and outlet configuration.

The proposed location of this wetland is to be located in two separate cells. The first cell will be located around the edge of the existing wetland and will be integrated into the edge vegetation of the pond and the surrounding land vegetation. The second cell will be integrated into the swale which will convey any surface runoff of the surrounding forested and park areas. The wetland can be *combined* with a conveyance function of the runoff from this vegetated area. The velocities of the runoff through this section need to be designed to ensure the vegetation in the wetland is not scoured out.

6.3 Modelling the Receiving Water Quality

6.3.1 Background and Model Description

The receiving water quality of the pond was modelled using the Pond Model. This model was developed by the Cooperative Research Centre (CRC) for Freshwater Ecology in the 2000s. (*CRC for Freshwater Ecology 2001)*. The Pond Model is a synthesis of the research undertaken by the CRC for Freshwater Ecology, and is used to determine the dominant pollutant interception processes and water quality responses of ponds, for a range of inflow and pollutant conditions.

The pond model is commonly used in the assessment of existing urban ponds and the design of urban water bodies and lakes in new residential and commercial developments. It has been used to assess the development in urban residential developments in a range of developments in NSW including in Western Sydney including residential developments such as Rouse Hill Town Centre urban pond and ponds within the Turner Rd Precinct and at Riverside at Tea Gardens.

The model consists of a number of separate but inter-related model sub-compartments. The subcomponents consist of:

- Water body mixing and washout process
- Sediment settling processes (including particles attached to sediment)
- Algal growth model
- Oxidation and redox process

The model transfers water quality constituents (such as oxygen and phosphorous) between compartments as a result of physical, chemical, biological and microbial processes. The transfers of pollutants are described by physical, chemical, biological and microbial equilibrium and rates (thermodynamics).

A mixing and wash-out sub-model makes it possible to track the changes in mass associated with inflows to and discharges from the pond water column. The model also computes losses and gains over time (transfers between the water column and sediment compartments, between the water column and the algal compartments, and between the water column and the atmosphere.

The model computations use a daily time increment for inflows, discharges, and internal mixing, transformations and transfers. The pond model provides information about in-pond water quality and sediment changes over time and interception and re-mobilisation processes over time. The model sub-components are shown in Figure 24.

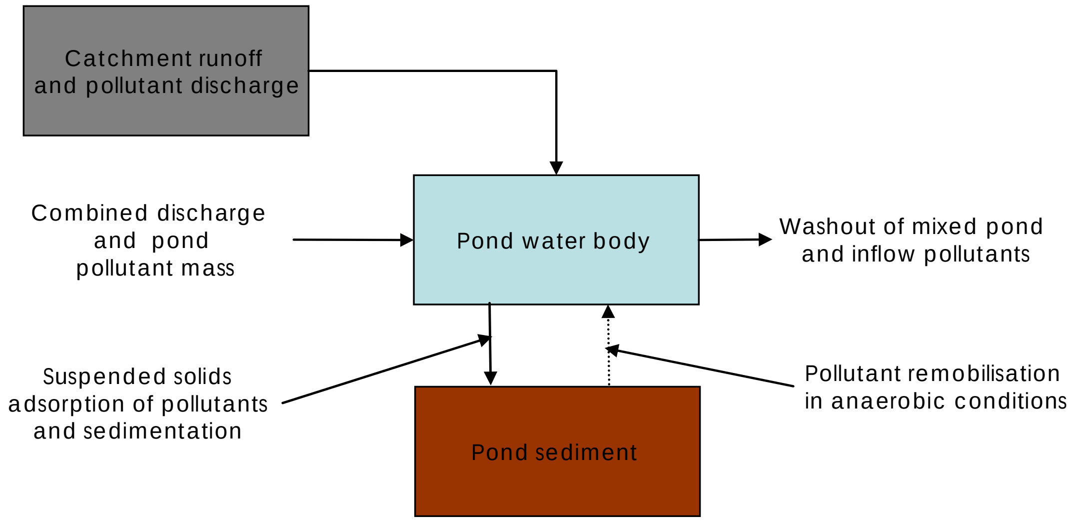

Figure 24 Pond Model Receiving Water Processes

6.3.2 Modelling Setup

The pond model was set up with

- 30 years of daily simulation from 1963 to 1993
- Surface runoff and pollutant inflow imported from MUSIC model output from the catchments draining to the pond
- Top up water and pollutant concentrations from the storage tank to replace daily evaporation losses imported from MUSIC model output
- Daily solar input from Lucas Heights
- Conservatively assumed that wind velocity is 0 m/s (due to the sheltered position and location of the waterbody). Wind velocity increases the aeration of the pond by mixing air/oxygen into the pond. Wind assists in *improving* water quality by assisting in aeration of the pond and assisting to prevent the pond from going anaerobic. By assuming it is 0 m/s, this is the most conservative case (the worst case scenario for water quality). This assumption while conservative is considered reasonable as the pond is heavily sheltered from the prevailing south easterly winds by the existing embankment which is to be retained.

6.3.3 Results

The model was run for the basic setup as outlined in section 6.2. The model was run and the results are shown for Chloropyhll a, TSS and TP in Figure 25, Figure 26 and Figure 27.

The results confirm hydrological modelling that has been undertaken. There are consistent algal bloom outbreaks in the waterbody. The algal blooms occur after periods of little or no rainfall and typically during periods of relatively high temperatures (spring and summer). The water body deteriorates during these periods as the partially stratified water at the bottom of the pond is partially anaerobic and releases readily available dissolved nutrients back into the water column (shown by frequent occurrences of high phosphorous levels greater than 0.5 mg/L).

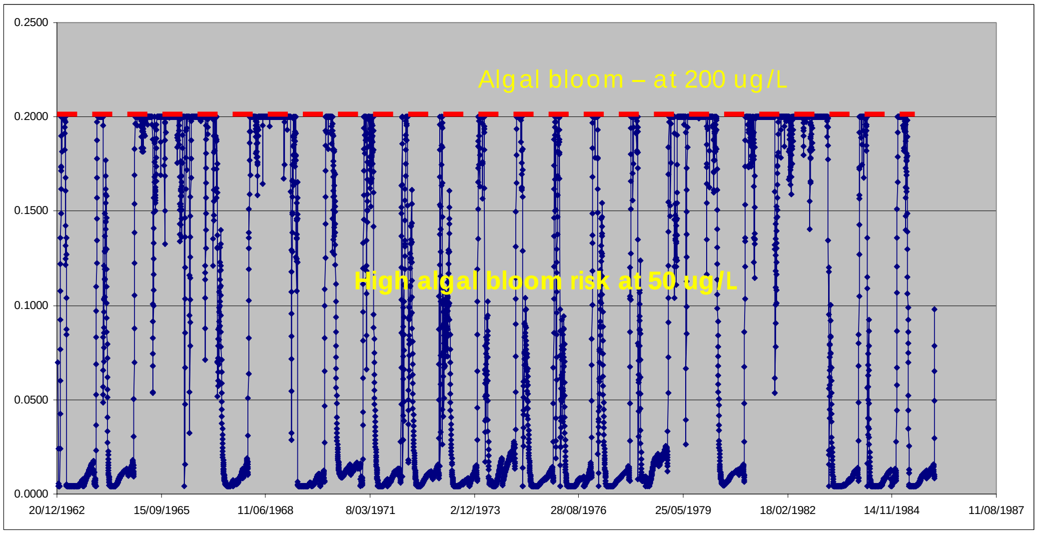

Figure 25 Pond Model Receiving Water Quality – Chlorophyll a

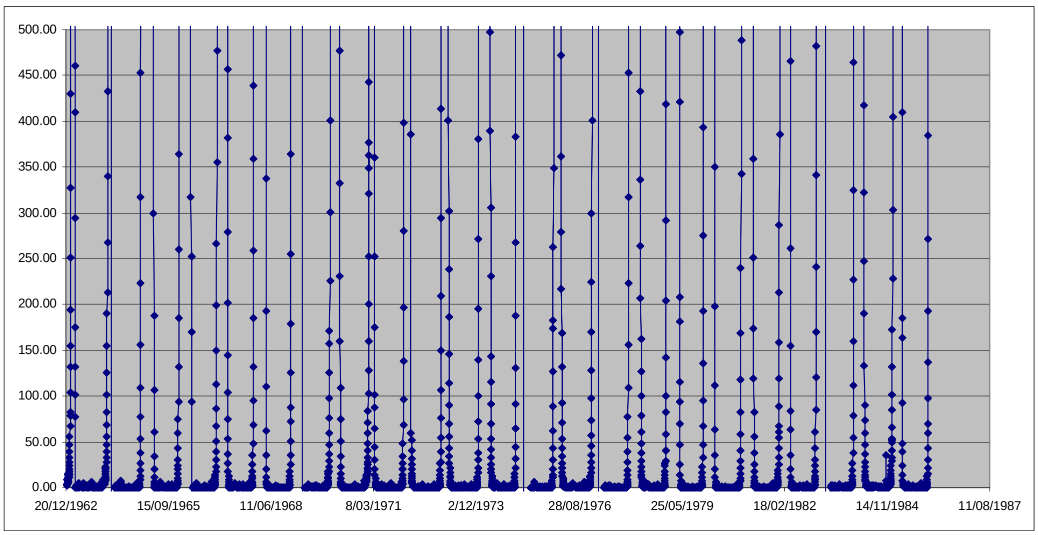

Figure 26 Pond Model Receiving Water Quality – TSS (mg/L)

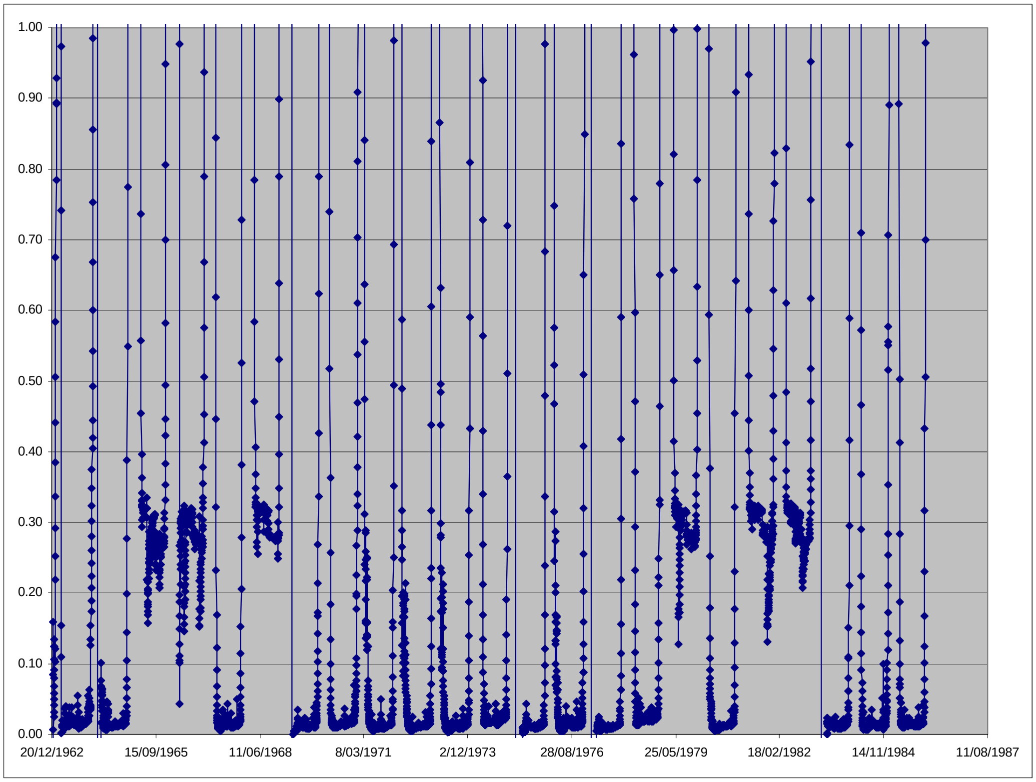

Figure 27 Pond Model Receiving Water Quality – TP (mg/L)

Thus based on this assessment water recirculation of the water in the pond is required to ensure that oxygen levels are maintained in the water body and that nutrient and other pollutant levels are kept at reasonable low levels to prevent water quality deterioration and subsequent algal outbreaks.

As outlined in section 6.2.5 a recirculating wetland is recommended for treatment. A recirculating wetland aimed at maintaining the wetland should be able to maintain the water quality at the following:

- TSS approximately 10 to 15 mg/L
- TP approximately 0.05 to 0.1 mg/L
- TN approximately 1 to 1.25 mg/L

Applying a recirculation flow rate of 20 days (a daily inflow of 80 kl/d or 1 L/s) and with the above water quality concentrations shows the water quality is significantly improved within the wetland. Initial modelling shows that if this water quality is maintained within the wetland the water quality and algal blooms is controlled and the risk of algal blooms and water quality deterioration in the water body is reduced significantly.

A pump to supply this flow rate at low static head (a few metres) will require 500 W of power to operate. A solar pump can be used to recirculate the water and is recommended to reduce energy use. Solar pumps are well suited to this operation as recirculation is most required during times of high solar input (spring and summer). It is recommended that a back up supply to the solar pump be provided to provide power during times of low sunlight (cloudy weather) or no sunlight (night time).

The modelling shows that the risk of algal blooms and deterioration of water quality is contained. During the higher temperatures and solar input there is a cyclical seasonal increase in chlorophyll a as expected. However the recirculating wetland is able to reduce the chlorophyll a concentration to a level below which algal blooms occur and thereby significantly control the risk of algal blooms in the waterbody.

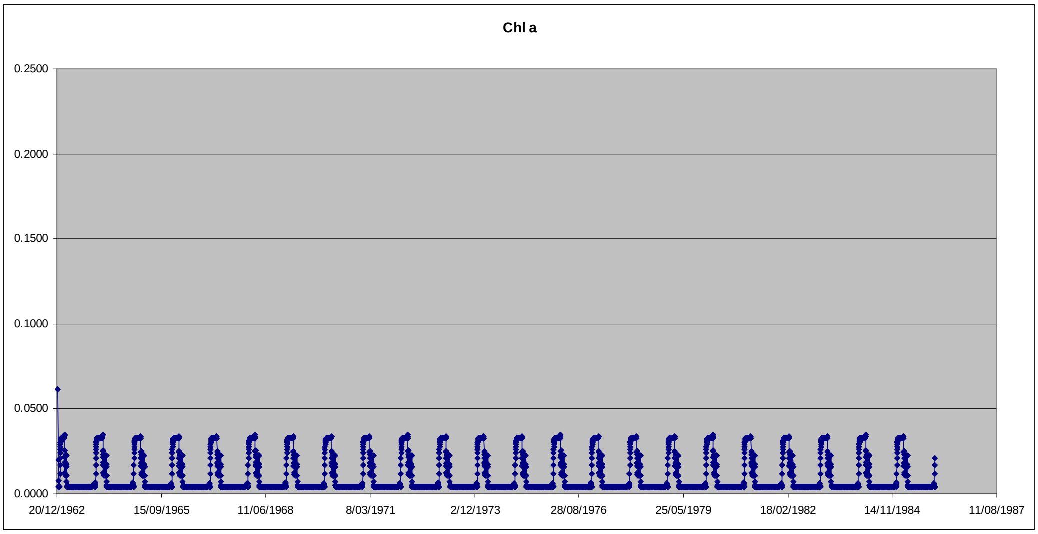

Figure 28 Pond Model Receiving Water Quality – Chlorophyll a

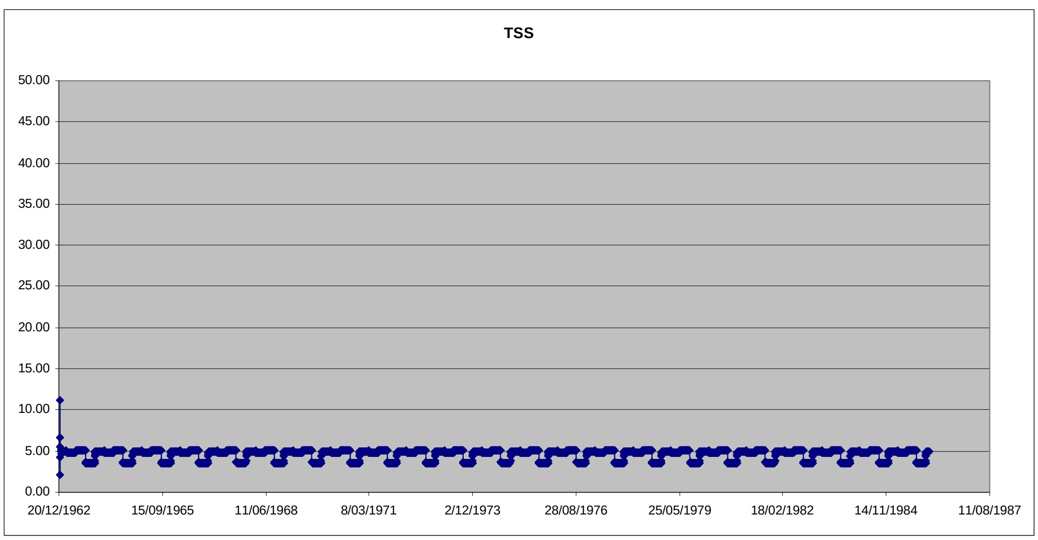

Figure 29 Pond Model Receiving Water Quality – TSS

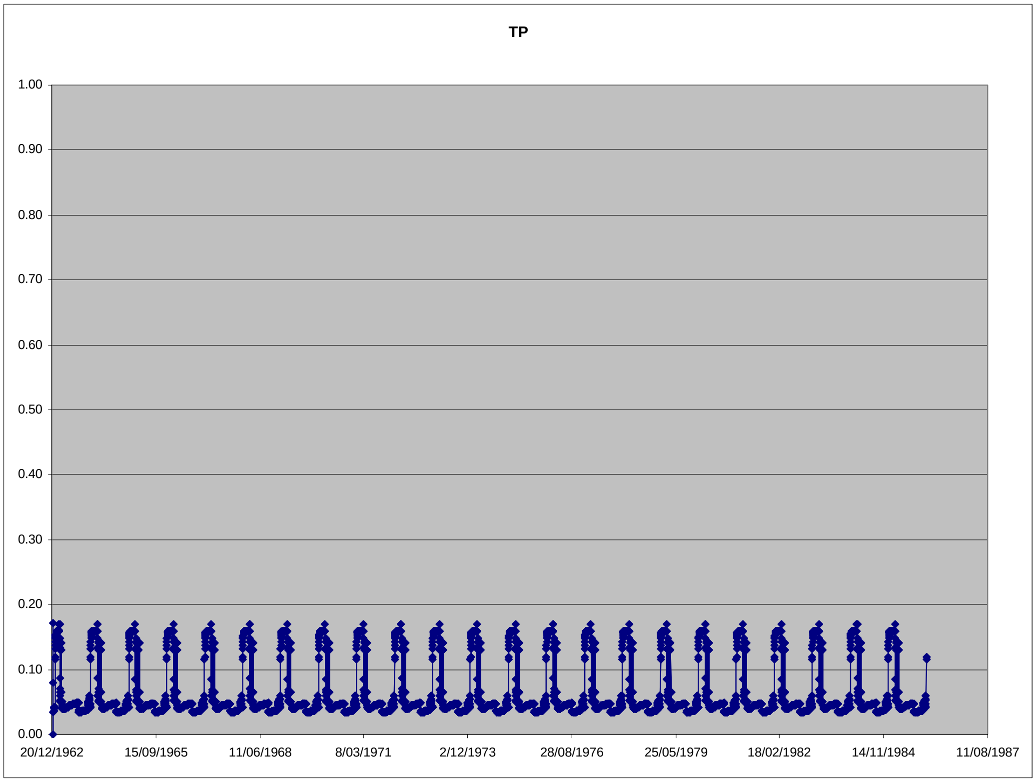

Figure 30 Pond Model Receiving Water Quality – TP

7 Conclusions

7.1 Water Quality Data

This report has documented the data collection and assessment of water bodies frequented and used by GHFF. Sufficient reliable data was gathered for six water bodies in Sydney which are known and documented to be used by GHFF. The water quality for these sites has been presented here. During this study 6 sites were selected from a total of 22 sites available because of their availability, reliability and completeness of data at these sites. The other 17 sites either had insufficient, incomplete or less reliable data that meant these sites could not be used.

This report provides the details of the water quality monitoring including the site locations, data source, data record and water quality data to ensure that the data used is transparent and readily verifiable.

7.2 Water Quality Objectives Methodology

In the absence of any other data on water quality requirements for GHFF, the water quality of water bodies frequented by GHFF provides

- the best available methodology to set water quality objectives for a water body to be used by grey headed flying foxes and

- source of information to set water quality objectives for a water body to be used by grey headed flying foxes.

The water bodies selected for analysis in this document are

- currently well known to be frequented by GHFF and

- have been known to be frequented by GHFF for a number of years

Therefore it is considered that the sites selected in this study are ideally suited for setting water quality objectives for water bodies frequented by GHFF.

Based on each of the sites selected, water quality data was analysed at these sites. For each site the average, 10%ile and 90%ile values were collated and reported. Across the sites there was variation for each value, as is expected for natural ecosystems. However it was found that while there was variation across the sites, the values were within a well defined range (e.g. range of TSS averages was 10 to 40 mg/L, DO was within 5 to 7 mg/L). Based on the assessment of each value for each site a recommended WQO was determined (e.g. TSS average value was selected as 25 mg/L and DO was selected as 6.0 mg/L).

7.3 Water Quality Objectives

Based on this methodology and data assessment the proposed water quality requirements for GHFF have been set as follows:

Parameter	Units	10th %ile	Average	90th %ile
DO	mg/L	**3**	**6**	**9**
TSS	mg/L	**5**	**25**	**50**
TP	mg/L	**0.05**	**0.15**	**0.25**
TN	mg/L	**0.9**	**2.0**	**3.5**

Parameter	Units	10th %ile	Average	90th %ile
Chl a [1]	ug/L	*Insufficient*	*data*	

[1] Note that no value has currently been set for Chlorophyll a at present as there is insufficient data, particularly to set percentiles. An interim guideline could be adopted if required based on the data collected in this report with 10%ile set at ug/L, mean set to 20u ug/L and a 90%ile set to 30 ug/L. This could be reviewed once more data is available.

7.4 Water Quality Objectives – Use for Operation and Management

Furthermore these water quality objectives can also be used as trigger values for remedial actions if water quality monitoring post development provides evidence that the water quality objectives are not being met. It is recommended that as part of the modified Kirawee Brick Pit management plan that

- these water quality objectives be included as trigger values for actions
- a series of remedial actions to improve water quality are outlined based on various water quality scenarios

7.5 Brick pit pond - Receiving Water Quality

It is predicted that the water quality in the water body, without additional management, will deteriorate from long residence times. Long residence times induce poor water quality as the water body stratifies from reduces flows into the pond (no 'flushing'). Particularly during periods of little inflow and high solar input, algal blooms are predicted to frequently occur in the water body without additional management.

Based on this assessment it is strongly recommended that management measures to control the risk of poor water quality and algal blooms are incorporated including:

- Treatment of all inflows into the water body as currently outlined in the stormwater strategy developed for the site to reduce the amount of nutrients entering the water body in the first instance
- A recirculating wetland, with a conservative estimated footprint of n 800m^2, to manage the in-pond water quality and improve the residence time by ensuring that oxygen levels are maintained and water quality is improved during extended periods of little or no rainfall

Preliminary modelling has shown that adopting a recirculation rate which minimises the residence time to 20 days within the water body will meet the water quality objectives set in this report. The predicted receiving water quality results, using the above management strategy are shown in the table below.

Parameter	10th %ile	Average	90th %ile
TSS	**3.5**	**4.6**	**5.1**
TP	**0.04**	**0.07**	**0.16**
TN	**0.12**	**0.21**	**0.43**
Chl a	*0.0*	*0.01*	0.03

8 References

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Appendix A: Water Quality Data – Kirrawee Brickpit

Water quality data:

- 1999 (AWT)
- 2001 (AWT)
- 2006 (URS)
- 2008 (Douglas)
- 2008 (CMJA)

Appendix B: Water Quality Data – Wolli Creek

Water Quality Data:

- Sydney Water –- Stormwater Monitoring Project - Station Information Sheet
- Sydney Water – Clean Waterways Programme - Stormwater Monitoring Project – 1993 Annual Report – Volume 4 –Event Mean Concentrations
- Sydney Water – Clean Waterways Programme - Stormwater Monitoring Project – 1993 Annual Report – Volume 4 – Statistics on Log10 Event Mean Concentrations
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- Sydney Water – Performance Assessment Monitoring Program, Data Report 2006-07, Receiving Water Quality of Sydney's Inland and Coastal Waterways

Appendix C: Water Quality Data – Cabramatta Creek

Water Quality Data:

- Fairfield Council – WQ monitoring;
- Fairfield Council – Cabramatta Creek Wetland Draft Plan of Managment (Georges River Combined Councils Committee);
- Streamwatch;

Water Quality Data from Fairfield City Council - Broomfield Street

Date	Time	Temperature (d.C)	Dissolved Oxygen (%)	pH	Turbidity (ftu)	Conductivity (uS)	Phosphorus (mg/L)	Nitrate (mg/L)	Fecal Coliform (cfu per 100mL)
5-May-11	10:20	19.6	88%	8.24	7.43	1042	0.04	0.6	630
14-Apr-11	11:10	21.7	24.5%	7.14	7.03	1077	0.05	0.1	2900
16-Mar-11	10:30	20.3	94%	8.85	8.75	878	0.04	0.02	160
25-Feb-11	9:30	23.2	55%	8.2	9.23	702	0.04	0.02	160
14-Jan-11	9:50	20.3	94%	8.19	2.28	532			
16-Dec-10	9:58	16.5	76%	8.14	4.4	902	0.02	0.01	600
1-Dec-10				7.69	6.05	1062	0.02	0.12	4000
26-Nov-10	9:45			8.05	23.4	820	0.03	0.41	96
12-Nov-10	10:00	18.4	35%	8.05	4.48	2026	0.02	0.04	960
29-Oct-10	9:45	18.3	39.8%	8.22	3.7	882	0.02	0.03	90
24-Sep-10	10:00	20.1	48.1%	7.58	2.66	1036	0.01	0.01	35000
9-Sep-10	10:10	22.1	72.1%	8.5	3.97	1129	0.02	0.01	3500
6-Aug-10	No Access								
23-Jul-10	No Access	Construction work							
2-Jun-10	No Access	construction work							

Fairfield City Council (GRCCC)

STREAMWATCH - http://www.streamwatch.org.au/streamwatch/flow/anon/k/_c84A987D9-03CC-AB27-A5C2-0719596305B9_kEABDCB0E-11E7-64B5-3366-121A63990424

Cabramatta Creek, Broomfield Street - Site Visit History (STREAMWATCH)														
Date Sampled	**Status**	**Group**	**Rain**	**Temp. (C)**	**DO%**	**DO (mg/L)**	**pH (pH)**	**Turb. (NTU)**	**EC (S/cm)**	**NO3 (mg/L)**	**FC (CFU/100ml)**	**AP (mg/L)**	**Gambusia**	**SPI**
11/11/2004	Verified	Fairfield City Council	unknown	22	Not tested	No data	No data	150	No data	No data	30	0.1	Not tested	Not tested
21/10/2004	Verified	Fairfield City Council	unknown	12.2	51	5.5	8	Over range	275	No data	No data	2.75	Not tested	Not tested
24/06/2004	Verified	Fairfield City Council	unknown	14.6	58	5.87	7.5	10	2718	0	40	No data	Not tested	Not tested
27/05/2004	Verified	Fairfield City Council	unknown	12.8	61	6.45	7.5	10	990	0.3	0	0	Not tested	Not tested
13/05/2004	Verified	Fairfield City Council	unknown	15.7	62	6.2	8	10	772	0.2	0	0	Not tested	Not tested

Appendix D: Water Quality Data – Parramatta Park

Water Quality Data:

- Laxton Report;
- Laxton Raw Data
- Streamwatch;

STREAMWATCH

Parramatta River, Parramatta Park - Site Visit History												
Date Sampled	Status	Group	Rain	DO (mg/L)	DOP	Turb. (NTU)	TP (mg/L)		TDS (mg/L)	Temp. (C)	pH (pH)	Gambusia
24/03/2002	Verified	Arthur Philip HS	unknown	3.8	44	10	No data		410	22.9	7	Not tested
19/03/2002	Verified	Arthur Philip HS	unknown	4.5	53	15	0.96		250	23.5	7	Not tested
05/03/2002	Verified	Arthur Philip HS	unknown	6.7	80	15	No data		350	24.5	7	Not tested
26/02/2002	Verified	Arthur Philip HS	unknown	7.7	91	50	No data		120	23.5	7	Not tested
19/02/2002	Verified	Arthur Philip HS	unknown	5.1	60	15	No data		400	23.5	8	Not tested
Parramatta River, FEATURE (upstream weir) - Site Visit History												
Date Sampled	Status	Group	Rain	DO (mg/L)	DOP	Turb. (NTU)	TP (mg/L)	BOD (mg/L)	FC (CFU/100ml)	Temp. (C)	pH (pH)	Gambusia
25/03/2002	Verified	MaCarthur Girls High School	unknown	2.7	34	20	0.36	4.1	Not tested	27	8	Not tested
18/03/2002	Verified	MaCarthur Girls High School	unknown	1.3	15	15	0.41	2.8	Not tested	23	8	Not tested
11/03/2002	Verified	MaCarthur Girls High School	unknown	1.3	15	15	3.6	3.6	Not tested	24	7	Not tested
27/02/2002	Verified	MaCarthur Girls High School	unknown	7	85	20	0.52	No data	Not tested	25	7	Not tested
18/02/2002	Verified	MaCarthur Girls High School	unknown	5.8	68	40	0.49	No data	Not tested	23	7	Not tested

Streamwatch is a schools and community water quality monitoring program run in partnership by Sydney Water and the Sydney Catchment Authority.

Water quality data is collected by trained groups using standardised equipment and methodologies. Data is verified before being stored as a permanent public record.

Water quality data is provided for non-commercial purposes. Sydney Water and the Sydney Catchment Authority do not accept responsibility for the use of this information.

Appendix E: Water Quality Data – Ku-ring-gai Flying Fox Reserve

Water Quality Data:

- Ku-ring-gai Council WQ Report;

Appendix F: Water Quality Data – Engadine Wetland

Water Quality Data:

- Sutherland Shire Council (analysis by Evans & Peck);