Catchment Water Quality Monitoring for Newcastle Wetland Connections (NWC)

Report 3:

December 2013 – December 2014

Prepared by Dr Steven Lucas

The Tom Farrell Institute for the Environment

The University of Newcastle

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Australian Government

This report is part of the Newcastle Wetland Connections program coordinated by WetlandCare Australia with funding from the Australian Government

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1. Introduction

A component of the Newcastle Wetland Connections (NWC) funding is to determine water quality (pre and post "works") within the Boatman's Creek catchment. The Tom Farrell Institute for the Environment (TFI) at the University of Newcastle is undertaking water quality monitoring as part of the NWC project.

Water quality site locations are shown in Figure 1. Note that the locations of these sites are likely to alter over the 4 year funding period as works are completed.

Figure 1: General location of water quality monitoring sites

Table 1 provides the latitude and longitude of water sampling sites shown in Figure 1.

Table 1: Latitude and longitude of water sampling sites

Site	Location	Latitude	Longitude
1	Braye Park - Quarry	-32.899958	151.713674
2	Alnwick Road remnant	-32.901857	151.705408
3	Allowah Street Playground	-32.900170	151.715775
4	Sunset Blvd	-32.899412	151.698809
4-1	Heaton Public School	-32.898099	151.695249
5	Reservoir site outflow	-32.898528	151.706439
6	Allowah Reserve	-32.898103	151.709918
6-1	Allowah reserve (sub-inflow)	-32.899378	151.708780
7	Waratah West Public creek	-32.898302	151.717843
8	Callaghan Creek (UoN)	-32.889052	151.702829
8-1	University Wetland	-32.891766	151.700043
9	Warabrook wetland	-32.882710	151.711130
10	Jersey Street Wetland	-32.872931	151.708774
10-1	Outflow from Jersey St wetland	-32.874895	151.710193
10-2	Inflow to Jersey St wetland	-32.873077	151.707139
11	Market Swamp	-32.877498	151.708129
12	Newcastle Wetland Reserve	-32.876105	151.703559
13	Hunter Wetlands Centre Canoe Channel	-32.875926	151.697527
14	Astra Street operational land channel	-32.875045	151.697527
15	Ayshire Cres inflow to Market Swamp	-32.877561	151.695249

2. Water quality monitoring (December 2013 – December 2014)

The first stage of the project was to characterise the water quality of flows into areas that will be improved by future works and as of the end of November 2014 there have been twelve (12) sampling campaigns. Details of these visits are summarised below in Table 2. Since the Mobilisation Report (February 2014), access to site 12 has been obtained from ARTC and monitoring has commenced.

Table 2: Water quality monitoring summary (Dec 2013 – December 2014)

Date	Type	Sites sampled (from Figure 1)	WQ parameters	Participants
9/12/2013	dry weather	9, 10 and 13	pH, EC, ^{o}C, TSS, DO, Turbidity, TON, TKN, TN, TP and PO_4^{3-}	S. Lucas (TFI), V. Robson (WCA)
16/02/2014 (25.6 mm)	rainfall based	5, 6, 8, 8.1, 9, 10.2, 13, 14 and 15	pH, EC, ^{o}C, TSS, DO, Turbidity, TON, TKN, TN, TP and PO_4^{3-}	S. Lucas (TFI), V. Robson (WCA), D. Robson (WCA volunteer)
19/02/2014 (99.2 mm)	rainfall based	2, 4, 5, 6, 6.1, 7, 8, 8.1, 9, 10.1, 14 and 15	pH, EC, ^{o}C, TSS, DO, Turbidity, TON, TKN, TN, TP and PO_4^{3-}	S. Lucas (TFI)
1/04/2014	Monthly sampling	11 and 12	pH, EC, ^{o}C, TSS, DO, Turbidity, TON, TKN, TN, TP and PO_4^{3-}	Norm Rushbrook (ARTC + Norm Rushbrook Consulting)

27/04/2014	Monthly sampling	11 and 12	pH, EC, ^{o}C, TSS, DO, Turbidity, TON, TKN, TN, TP and PO_4^{3-}	Norm Rushbrook (ARTC + Norm Rushbrook Consulting)
30/05/2014	Monthly sampling	11 and 12	pH, EC, ^{o}C, TSS, DO, Turbidity, TON, TKN, TN, TP and PO_4^{3-}	Norm Rushbrook (ARTC + Norm Rushbrook Consulting)
19/07/2014	rainfall based	5, 6, 6.1, 8, 8.1, 9, 10, 13 and 14	pH, EC, ^{o}C, TSS, DO, Turbidity, TON, TKN, TN, TP and PO_4^{3-}	S. Lucas (TFI) Norm Rushbrook (ARTC + Norm Rushbrook Consulting)
26/07/2014	rainfall based	4.1, 5, 6, 6.1, 9, 13 and 14	pH, EC, ^{o}C, TSS, DO, Turbidity, TON, TKN, TN, TP and PO_4^{3-}	S. Lucas (TFI)
7/08/2014	Monthly sampling	11 and 12	pH, EC, ^{o}C, TSS, DO, Turbidity, TON, TKN, TN, TP and PO_4^{3-}	Norm Rushbrook (ARTC + Norm Rushbrook Consulting)
9/09/2014	rainfall based	5, 6, 8, 8.1, 9, 10, 13 and 14	pH, EC, ^{o}C, TSS, DO, Turbidity, TON, TKN, TN, TP and PO_4^{3-}	S. Lucas (TFI)
8/10/2014	Monthly sampling	11 and 12	pH, EC, ^{o}C, TSS, DO, Turbidity, TON, TKN, TN, TP and PO_4^{3-}	Norm Rushbrook (ARTC + Norm Rushbrook Consulting)
14/10/2014	rainfall based	5, 6, 6.1, 7, 9, 10, 13 and 14	pH, EC, ^{o}C, TSS, DO, Turbidity, TON, TKN, TN, TP and PO_4^{3-}	S. Lucas (TFI) Ben Everingham (TFI)

EC = electrical conductivity; ^{o}C = temperature; DO = dissolved oxygen; TSS = total suspended solids; TON = Total Oxidisable Nitrogen; TKN = Total Kjeldahl Nitrogen; TN = Total Nitrogen (TKN + TON); TP = total phosphorus; PO_4^{3-} = orthophosphate (plant available P)

Table 3 summarises the range of water quality parameters from “All Urban” areas in Australian Runoff Quality (ARQ) (Engineers Australia, Chapter 3, 2006) and trigger values from the Australian and New Zealand guidelines for fresh and marine water quality (ANZECC, 2000) with respect to “Aquatic Ecosystems – SE Australia – Lowland Rivers” (Tables 3.3.2 and 3.3.3 in ANZECC, 2000). These will be used during assessment of water quality at each site in the NWC project areas.

Table 3: Typical stormwater runoff characteristics from ARQ (2006) and trigger values from ANZECC (2000)

Parameter	**Units**	**ARQ, 2006**	**ANZECC, 2000**
pH	no units	6.2 - 7.6	6.5 - 8
EC	µS/cm	-	125 - 2200
DO	mg/L	-	> 6.5
TSS	mg/L	50 - 350	6 - 50
Total N	mg/L	1.5 - 6	0.5
TP	mg/L	0.15 - 0.7	-
PO_4^{3-}	mg/L	-	0.02
Turbidity	NTU	15 - 250	10 - 50

Site 1

Site 1 is near the top of the Boatman's Creek catchment and requires a large rain event to initiate surface flow. No water samples have been obtained at this time due to the (lack of) timing and safety issues associated with this type of event.

Site 2

Water sampling only occurred on the 19/2/2014 as there were no flows at other times. Sampling occurred upstream of the proposed works (refer to Site Action Plan) to characterise water quality before works commence and to provide comparative data for post works assessment. Table 4 provides water quality data and comparison to ANZECC guidelines and value ranges in ARQ.

Table 4: Site 2 water quality

Date	**Time**	**Rain (24 hr) mm**	**pH**	**EC**	**Temp**	**DO**	**TSS**	**TKN**	**TON**	**TN**	**TP**	**PO_4^{3-}**	**Turbidity**
			-	**µS/cm**	**°C**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**NTU**
19/02/2014	19:05	99.2	7.03	90	23.1	7.86	<1	<0.5	0.71	1.21	0.09	0.06	8
Exceed ANZECC guideline?			***N***	***N***	***-***	***N***	***N***	***-***	***-***	***Y***	***-***	***Y***	***-***
Within ARQ range?			***Y***	***-***	***-***	***-***	***Y***	***-***	***-***	***Y***	***Y***	***-***	***Y***

TN and PO_4^{3-} exceeded the ANZECC guidelines however other values are within ranges as reported in ARQ. Revegetation works have been initiated and monitoring will continue over the next 3 years to obtain a significant water quality dataset.

Site 3

Site 3 is near the top of the Boatman's Creek catchment and requires a large rain event to initiate surface flow. No water samples have been obtained at this time due to the (lack of) timing and safety issues associated with this type of event.

Site 4

Site 4 flows into the Dark Creek catchment. Water sampling occurred on the 19/2/2014 as there were no flows at other times. Sampling occurred upstream of the proposed works (refer to Site Action Plan) from a residual pool that formed after the rain event. Table 5 provides water quality data and comparison to ANZECC guidelines and value ranges in ARQ.

Table 5: Site 4 water quality

Date	Time	Rain (24 hr) mm	pH	EC	Temp	DO	TSS	TKN	TON	TN	TP	PO_4^{3-}	Turbidity
			-	µS/cm	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
19/02/2014	19:10	99.2	6.53	175	23.2	1.62	10	1.4	0.25	1.65	0.83	0.61	12
Exceed ANZECC guideline?			***N***	***N***	***-***	***Y***	***N***	***-***	***-***	***Y***	***-***	***Y***	***-***
Within ARQ range?			***Y***	***-***	***-***	***-***	***Y***	***-***	***-***	***Y***	***N***	***-***	***Y***

PO_4^{3-} exceeded the ANZECC guidelines and TP marginally exceeded the typical range as reported in ARQ (> 0.7 mg/L). TN exceeded the ANZECC guidelines (> 0.5 mg/L) however values are within typical ranges as reported in ARQ. DO levels were also low however would be expected to increase under flow conditions.

Longitudinal water sampling of Dark Creek occurred from August – October 2014 and results are detailed in a separate Report (Appendix 1).

Site 4-1

Site 4-1 is near the middle of the Dark Creek catchment and requires a large rain event to initiate surface flow. Longitudinal water sampling occurred from August – October 2014 and results are detailed in a separate Report (Appendix 1). Re-vegetation works have been completed and monitoring will continue over the next 3 years to obtain further water quality data.

Site 5

Site 5 is at the top of the Boatman's Creek catchment and Hunter Water Corporation have previously undertaken works (sediment pond) to reduce sediment loads being exported downstream. Water sampling occurred on 6 occasions as there were no flows at other times. Sampling occurred downstream of the proposed works (refer to Site Action Plan) to characterise existing water quality discharging from the site. Table 6 provides water quality data and comparison, using the average values from several rain events, to ANZECC guidelines and value ranges in ARQ.

Table 6: Site 5 water quality

Date	Time	Rain (24 hr) mm	pH	EC	Temp	DO	TSS	TKN	TON	TN	TP	PO_4^{3-}	Turbidity
			-	µS/cm	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
16/02/2014	14:06	25.6	7.54	150	22.4	7.57	5	1.7	0.3	2	0.18	0.06	5
19/02/2014	18:55	99.2	6.82	120	22.7	7.46	42	<0.5	0.22	0.72	0.06	<0.02	52
16/07/2014	05:15	7.4	6.94	140	17.4	7.6	15	<0.5	0.15	<0.5	0.80	0.05	20
26/07/2014	12:55	16.6	6.98	110	14.1	9.1	15	<0.5	0.12	<0.5	0.40	0.05	12
9/09/2014	10:55	9.6	7.24	220	19.8	8.45	5	0.7	0.09	0.79	<0.05	<0.02	5
14/10/2014	09:15	36	7.5	330	18.5	8.91	1	1.7	0.26	1.96	0.05	<0.02	4
Maximum			*7.54*	*330*	*22.7*	*9.1*	*42*	*1.7*	*0.3*	*2*	*0.80*	*0.06*	*52*
Minimum			*6.82*	*110*	*14.1*	*7.46*	*1*	*<0.5*	*0.09*	*<0.5*	*<0.05*	*<0.02*	*4*
*Average**			*7.17*	*178*	*19.2*	*8.18*	*14*	*1.37*	*0.19*	*1.37*	*0.30*	*0.05*	*16*
SD			*0.30*	*84*	*3.2*	*0.73*	*15*	*0.58*	*0.08*	*0.71*	*0.31*	*0.01*	*19*
Exceed ANZECC guideline?*			***N***	***N***	***-***	***N***	***N***	***-***	***-***	***Y***	***-***	***Y***	***-***
Within ARQ range?*			***Y***	***-***	***-***	***-***	***Y***	***-***	***-***	***Y***	***Y***	***-***	***Y***

**Average value used for comparison*

TN and PO_4^{3-} marginally exceeded the ANZECC guidelines on several occasions however other values were within typical ranges as reported in ARQ. Whilst TSS were below guideline limits there was a significant range in values (4 – 52 mg/L) and can be attributed to the difference in rainfall events. For example, the 99.2 mm of rainfall on the 19/2/2014 provided more energy than the 25.6 mm of rain on the 16/2/2014 to mobilise sediment. Further sampling before and after works will provide insight into the efficacy of restoration projects in improving water quality.

Site 6

Site 6 is in the middle of the Boatman's Creek catchment and is targeted for works such as sediment removal and tree planting/landform design. Water sampling occurred on 6 occasions as there were minimal flows at other times. Sampling occurred upstream of the proposed works (refer to Site Action Plan) and downstream of Site 5. Table 7 provides water quality data and comparison, using the average values from several rain events, to ANZECC guidelines and value ranges in ARQ.

Table 7: Site 6 water quality

Date	Time	Rain (24 hr) mm	pH	EC	Temp	DO	TSS	TKN	TON	TN	TP	PO_4^{3-}	Turbidity
			-	µS/cm	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
16/02/2014	14:00	25.6	7.46	145	22.4	7.52	5	1.6	0.3	1.9	0.15	0.05	5
19/02/2014	18:35	99.2	7.04	133	22.8	7.46	20	<0.5	0.31	<0.5	0.10	0.06	30
16/07/2014	05:30	7.4	6.58	245	15.8	7.6	10	<0.5	0.21	<0.5	0.10	0.07	25
26/07/2014	12:50	16.6	6.84	220	14.9	9.6	10	<0.5	0.26	<0.5	0.10	0.06	20
9/09/2014	10:55	9.6	8.44	845	20.2	9.89	5	0.8	0.11	0.91	<0.05	<0.02	6
14/10/2014	09:25	36	7.5	364	18.7	8.9	4	2.8	0.18	2.98	0.08	<0.02	6
Maximum			*8.44*	*845*	*22.8*	*9.89*	*20*	*2.8*	*0.31*	*2.98*	*0.15*	*0.07*	*30*
Minimum			*6.58*	*133*	*14.9*	*7.46*	*4*	*<0.5*	*0.11*	*<0.5*	*<0.05*	*<0.02*	*5*
*Average**			*7.31*	*325*	*19.13*	*8.5*	*9*	*1.73*	*0.23*	*1.93*	*0.11*	*0.06*	*15*

SD	*0.66*	*268*	*3.30*	*1.11*	*6*	*1.01*	*0.08*	*1.04*	*0.03*	*0.01*	*11*
Exceed ANZECC guideline?*	***N***	***N***	***-***	***N***	***N***	***-***	***-***	***Y***	***-***	***Y***	***-***
Within ARQ range?*	***Y***	***-***	***-***	***-***	***Y***	***-***	***-***	***Y***	***Y***	***-***	***Y***

**Average value used for comparison*

PO_4^{3-} exceeded the ANZECC guidelines however values are near typical ranges as reported in ARQ. TN exceeded the ANZECC guidelines on several occasions (> 0.5 mg/L) however values are within typical ranges as reported in ARQ. TSS was below guideline limits with a range in values (5 – 30 mg/L) and can be attributed to the difference in rainfall events as described for Site 5. Note that Site 6 is likely to have a similar water quality profile to Site 5 as Site 6 is a downstream sampling point. Further sampling before and after works will provide insight into the efficacy of restoration projects in improving water quality.

Site 6-1

Site 6-1 provides inflow to Site 6 that is not sourced from within the Site 5 sub-catchment. Water sampling occurred on 4 occasions as it was a site added after the first sampling campaign. Sampling occurred upstream of the proposed works (refer to Site Action Plan) and Site 6. Table 8 provides water quality data and comparison, using the average values from several rain events, to ANZECC guidelines and value ranges in ARQ.

Table 8: Site 6-1 water quality

Date	Time	Rain (24 hr) mm	pH	EC	Temp	DO	TSS	TKN	TON	TN	TP	PO_4^{3-}	Turbidity
			-	µS/cm	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
19/02/2014	18:25	99.2	7.1	159	22.9	7.85	26	<0.5	0.37	0.37	0.13	0.09	40
16/07/2014	05:20	7.4	7.08	145	17.8	7.8	18	0.6	0.38	0.98	0.10	0.09	25
26/07/2014	13:15	16.6	7.04	165	17.4	7.85	20	<0.5	0.19	0.19	0.11	0.05	22
14/10/2014	09:35	36	7.5	538	18.4	8.89	1	2.2	0.24	2.44	0.08	0.05	4
Maximum			*7.50*	*538*	*22.90*	*8.89*	*26*	*2.2*	*0.38*	*2.44*	*0.13*	*0.09*	*40*
Minimum			*7.04*	*145*	*17.40*	*7.80*	*1*	*<0.5*	*0.19*	*0.19*	*0.08*	*0.05*	*4*
*Average**			*7.18*	*252*	*19.13*	*8.10*	*16*	*1.4*	*0.30*	*1.00*	*0.11*	*0.07*	*23*
SD			*0.21*	*191*	*2.55*	*0.53*	*11*	*1.1*	*NA*	*1.02*	*0.02*	*0.02*	*15*
Exceed ANZECC guideline?*			***N***	***N***	***-***	***N***	***N***	***-***	***-***	***Y***	***-***	***Y***	***-***
Within ARQ range?*			***Y***	***-***	***-***	***-***	***Y***	***-***	***-***	***Y***	***Y***	***-***	***Y***

**Average value used for comparison*

PO_4^{3-} exceeded the ANZECC guidelines however other values are near typical ranges as reported in ARQ. TN exceeded the ANZECC guidelines on several occasions (> 0.5 mg/L) however values are within typical ranges as reported in ARQ. TSS was below guideline limits there was a range in values (4 – 40 mg/L). Further sampling before and after works will provide insight into the efficacy of restoration projects in improving water quality.

Site 7

Site 7 is near the top of the Boatman's Creek catchment. Water sampling occurred on the 19/2/2014 and 14/10/2014 as there were no flows at other times. Sampling occurred upstream of the proposed works (refer to Site Action Plan). Table 9 provides water quality data and comparison, using the average values from several rain events, to ANZECC guidelines and value ranges in ARQ.

Table 9: Site 7 water quality

Date	Time	Rain (24 hr) mm	pH	EC	Temp	DO	TSS	TKN	TON	TN	TP	PO_4^{3-}	Turbidity
			-	µS/cm	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
19/02/2014	18:45	99.2	7.06	20	23.5	7.82	9	<0.5	<0.05	<0.05	<0.05	<0.02	7
14/10/2014	9:00	36	7.41	140	19.2	8.12	18	0.8	0.06	0.86	0.08	<0.02	24
Maximum			*7.41*	*140*	*23.5*	*8.12*	*18*	*0.8*	*0.06*	*0.86*	*0.08*	*<0.02*	*24*
Minimum			*7.06*	*20*	*19.2*	*7.82*	*9*	*0.8*	*<0.05*	*<0.05*	*0.08*	*<0.02*	*7*
*Average**			*7.24*	*80*	*21.4*	*7.97*	*14*	*0.8*	*0.06*	*0.86*	*0.08*	*<0.02*	*16*
SD			*0.25*	*85*	*3.0*	*0.21*	*6*	*NA*	*NA*	*NA*	*NA*	*NA*	*12*
Exceed ANZECC guideline?*			***N***	***N***	*-*	***N***	***N***	*-*	*-*	***Y***	*-*	***N***	*-*
Within ARQ range?*			***Y***	*-*	*-*	*-*	***Y***	*-*	*-*	***Y***	***Y***	*-*	***Y***

**Average value used for comparison*

No parameter exceeded the ANZECC guidelines and all were within ranges as reported in ARQ. Further sampling, before and after re-vegetation works, will provide insight into the efficacy of restoration projects in improving water quality.

Site 8

Site 8 was sampled from the University Wetland. Water sampling occurred on 4 occasions downstream of site 8-1 and the proposed works (refer to Site Action Plan). Table 10 provides water quality data and comparison, using the average values from several rain events, to ANZECC guidelines and value ranges in ARQ.

Table 10: Site 8 water quality

Date	Time	Rain (24 hr) mm	pH	EC	Temp	DO	TSS	TKN	TON	TN	TP	PO_4^{3-}	Turbidity
			-	µS/cm	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
16/02/2014	14:30	25.6	6.96	665	23.4	1.6	10	1.4	<0.05	1.4	0.13	<0.02	10
19/02/2014	19:15	99.2	6.89	555	23.4	1.6	8	1.3	<0.05	1.3	0.11	<0.02	11
16/07/2014	6:00	7.4	6.94	580	18.5	4.8	5	1.2	<0.05	1.2	0.08	<0.02	10
9/09/2014	10:00	9.6	7.2	375	16.9	5.9	12	1.1	0.06	1.16	0.05	<0.02	19
Maximum			*7.20*	*665*	*23.4*	*5.90*	*12*	*1.4*	*0.06*	*1.40*	*0.13*	*<0.02*	*19*
Minimum			*6.89*	*375*	*16.9*	*1.60*	*5*	*1.1*	*<0.05*	*1.16*	*0.05*	*<0.02*	*10*
*Average**			*7.00*	*544*	*20.6*	*3.48*	*9*	*1.3*	*0.06*	*1.27*	*0.09*	*<0.02*	*13*
SD			*0.14*	*122*	*3.4*	*2.21*	*3*	*0.1*	*NA*	*0.11*	*0.04*	*NA*	*4*
Exceed ANZECC guideline?*			***N***	***N***	*-*	***Y***	***N***	*-*	*-*	***Y***	*-*	***N***	*-*
Within ARQ range?*			***Y***	*-*	*-*	*-*	***Y***	*-*	*-*	***N***	***Y***	*-*	***Y***

**Average value used for comparison*

The wetland was characterised as having a low DO and high TN that exceeded the ANZECC guidelines. The February rain events were the first significant falls since November 2013 and as a result there would likely be an accumulation of TN and loss of DO from decay within the wetland. Further sampling before and after works (and during wetter periods) will provide insight into the efficacy of upstream restoration projects in improving water quality.

Longitudinal water sampling of Bowinbah Creek occurred from August – October 2014 and results are detailed in a separate Report (Appendix 1) which also includes Site 8-1.

Site 8-1

Site 8-1 (Bowinbah Creek) provides inflow to Site 8 (University Wetland) which then connects with Boatman's Creek. Water sampling occurred on 4 occasions downstream of the proposed works (refer to Site Action Plan). Table 11 provides water quality data and comparison, using the average values from several rain events, to ANZECC guidelines and value ranges in ARQ.

Table 11: Site 8-1 water quality

Date	Time	Rain (24 hr) mm	pH	EC	Temp	DO	TSS	TKN	TON	TN	TP	PO_4^{3-}	Turbidity
			-	µS/cm	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
16/02/2014	13:40	25.6	7.18	200	22.6	5.40	15	<0.5	<0.05	<0.05	<0.05	<0.02	18
19/02/2014	19:20	99.2	6.91	282	22.9	7.26	12	0.6	0.36	0.96	0.06	<0.02	20
16/07/2014	5:50	7.4	6.94	310	17.9	7.40	10	0.5	<0.05	<0.05	<0.05	<0.02	14
9/09/2014	10:10	9.6	7.36	60	13.9	7.14	20	0.8	<0.05	0.8	0.07	<0.02	37
Maximum			*7.36*	*310*	*22.9*	*7.40*	*20*	*0.8*	*0.36*	*0.96*	*0.07*	*<0.02*	*37*
Minimum			*6.91*	*60*	*13.9*	*5.40*	*10*	*0.5*	*<0.05*	*<0.05*	*<0.05*	*<0.02*	*14*
*Average**			*7.10*	*213*	*19.3*	*6.80*	*14*	*0.6*	*0.36*	*0.88*	*0.07*	*<0.02*	*22*
SD			*0.21*	*112*	*4.3*	*0.94*	*4*	*0.2*	*NA*	*0.11*	*0.01*	*NA*	*10*
Exceed ANZECC guideline?*			***N***	***N***	*-*	***N***	***N***	*-*	*-*	***Y***	*-*	***N***	*-*
Within ARQ range?*			***Y***	*-*	*-*	*-*	***Y***	*-*	*-*	***Y***	***Y***	*-*	***Y***

**Average value used for comparison*

TN exceeded the ANZECC guidelines on the 19/2/2014 and the 9/9/2014 however values are within the typical range as reported in ARQ. Further sampling before and after works will provide insight into the efficacy of restoration projects in improving water quality.

Site 9

Site 9 is the located at Warabrook Wetland near the outflow of a stormwater quality improvement device (SQID). Water sampling occurred on 7 occasions in 2013/14. Table 12 provides water quality data and comparison, using the average values from several rain events, to ANZECC guidelines and value ranges in ARQ.

Table 12: Site 9 water quality

Date	Time	Rain (24 hr) mm	pH	EC	Temp	DO	TSS	TKN	TON	TN	TP	PO_4^{3-}	Turbidity
			-	µS/cm	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
9/12/2013	10:30	0	8.09	260	27.4	2.30	5	0.8	<0.05	0.8	0.09	<0.02	11
16/02/2014	14:45	25.6	7.52	90	24.5	7.67	5	1.4	0.18	1.58	0.19	0.08	15
19/02/2014	19:35	99.2	7.82	565	23.2	6.57	90	1.4	0.08	1.48	0.2	<0.02	76
16/07/2014	6:10	7.4	7.72	640	18.5	6.90	25	0.8	0.05	0.85	0.15	<0.02	35

26/07/2014	11:30	16.6	7.64	585	17.8	7.22	20	0.6	0.05	0.65	0.08	<0.02	35
9/09/2014	11:30	9.6	7.87	400	20.6	9.48	45	1.4	0.49	1.89	0.16	0.05	70
14/10/2014	10:20	36	7.6	402	18.9	8.03	26	1.1	0.23	1.33	0.16	<0.02	38
Maximum			*8.09*	*640*	*27.4*	*9.48*	*90*	*1.4*	*0.49*	*1.89*	*0.20*	*0.08*	*76*
Minimum			*7.52*	*90*	*17.8*	*2.30*	*5*	*0.6*	*<0.05*	*0.65*	*0.08*	*<0.02*	*11*
*Average**			*7.75*	*420*	*21.6*	*6.88*	*31*	*1.07*	*0.18*	*1.23*	*0.15*	*0.07*	*40*
SD			*0.19*	*197*	*3.6*	*2.23*	*29*	*0.34*	*0.17*	*0.46*	*0.05*	*0.02*	*25*
Exceed ANZECC guideline?*			***N***	***N***	***-***	***N***	***N***	***-***	***-***	***Y***	***-***	***Y***	***-***
Within ARQ range?*			***Y***	***-***	***-***	***-***	***Y***	***-***	***-***	***Y***	***Y***	***-***	***Y***

**Average value used for comparison*

TN exceeded the ANZECC guidelines on all occasions however values are within the typical range as reported in ARQ. TP exceeded the ANZECC guidelines on the 16/2/2014 however values are within the typical range as reported in ARQ. TSS exceeded the ANZECC guidelines on the 19/2/2014 however values are within the typical range as reported in ARQ. DO was relatively low on the 9/12/2013 however increased after rainfall in February 2014. Further sampling before and after works will provide insight into the efficacy of restoration projects in improving water quality. The data obtained indicates the dynamic nature of wetlands and water quality processes.

Site 10

Site 10 is located in the Jersey St Wetland. Water sampling occurred on 4 occasions and occurred downstream of the proposed works (refer to Site Action Plan). Table 13 provides water quality data and comparison, using the average values from several rain events, to ANZECC guidelines and value ranges in ARQ.

Table 13: Site 10 water quality

Date	Time	Rain (24 hr) mm	pH	EC	Temp	DO	TSS	TKN	TON	TN	TP	PO_4^{3-}	Turbidity
			-	µS/cm	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
9/12/2013	10:40	0	10.20	235	27	2.10	5	0.6	<0.05	0.6	0.06	<0.02	9
16/07/2014	6:20	7.4	7.54	380	18.9	5.80	10	0.7	0.05	0.75	0.06	<0.02	15
9/09/2014	10:50	9.6	7.37	320	19.6	4.21	5	<0.5	<0.05	<0.5	0.06	<0.02	2
14/10/2014	10:40	36	7.10	360	20.2	4.67	1	2.2	<0.05	2.2	0.11	<0.02	4
Maximum			*10.20*	*380*	*27.0*	*5.80*	*10*	*2.2*	*0.05*	*2.20*	*0.11*	*<0.02*	*15*
Minimum			*7.10*	*235*	*18.9*	*2.10*	*1*	*<0.5*	*0.05*	*0.60*	*0.06*	*<0.02*	*2*
*Average**			*8.05*	*324*	*21.4*	*4.20*	*5*	*1.2*	*0.05*	*1.18*	*0.07*	*<0.02*	*8*
SD			*1.44*	*64*	*3.8*	*1.55*	*4*	*0.9*	*NA*	*0.88*	*0.03*	*NA*	*6*
Exceed ANZECC guideline?*			***N***	***N***	***-***	***Y***	***N***	***-***	***-***	***Y***	***-***	***N***	***-***
Within ARQ range?*			***Y***	***-***	***-***	***-***	***Y***	***-***	***-***	***Y***	***Y***	***-***	***Y***

**Average value used for comparison*

Only TN exceeded the ANZECC guidelines however values are within the typical range as reported in ARQ. DO is relatively low however would be expected to increase during wetter periods. Further sampling before and after works will provide insight into the efficacy of restoration projects in improving water quality.

Site 10-1

Site 10-1 is the outflow from Jersey St Wetland to Market Swamp. Water sampling occurred on the 16/2/2014 during a rain event. Sampling occurred downstream of the proposed works (refer to Site Action Plan). Table 14 provides water quality data and comparison to ANZECC guidelines and value ranges in ARQ.

Table 14: Site 10-1 water quality

Date	Time	Rain (24 hr) mm	pH	EC	Temp	DO	TSS	TKN	TON	TN	TP	PO_4^{3-}	Turbidity
			-	µS/cm	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
19/02/2014	19:45	0	7.43	60	23.3	7.23	12	0.6	0.08	0.68	0.06	<0.02	20
Exceed ANZECC guideline?*			***N***	***N***	**-**	***N***	***N***	**-**	**-**	***Y***	**-**	***N***	**-**
Within ARQ range?*			***Y***	**-**	**-**	**-**	***Y***	**-**	**-**	***Y***	***Y***	**-**	***Y***

TN exceeded the ANZECC guidelines however values are within the typical range as reported in ARQ. Further sampling, before and after works, will provide insight into the efficacy of restoration projects in improving water quality.

Site 10-2

Site 10-2 is the inflow from the street drain to Jersey St Wetland and water sampling occurred on the 19/2/2014. Sampling occurred upstream of the proposed works (refer to Site Action Plan). Table 15 provides water quality data and comparison to ANZECC guidelines and value ranges in ARQ.

Table 15: Site 10-2 water quality

Date	Time	Rain (24 hr) mm	pH	EC	Temp	DO	TSS	TKN	TON	TN	TP	PO_4^{3-}	Turbidity
			-	µS/cm	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
16/02/2014	15:00	25.6	7.56	50	23.2	6.34	5	9	0.1	9.1	0.1	0.06	15
Exceed ANZECC guideline?*			***N***	***N***	**-**	***Y***	***N***	**-**	**-**	***Y***	**-**	***Y***	**-**
Within ARQ range?*			***Y***	**-**	**-**	**-**	***Y***	**-**	**-**	***N***	***Y***	**-**	***Y***

TN exceeded the ANZECC guidelines and also exceeded the typical range as reported in ARQ. DO was slightly below the guideline value of > 6.5 mg/L. Further sampling before and after works will provide insight into the efficacy of restoration projects in improving water quality.

Site 11

Site 11 is sampled from Market Swamp near the railway line and water sampling has occurred on 5 occasions. Due to restricted access, sampling has been undertaken by Norm Rushbrook (Norm Rushbrook Consulting on behalf of ARTC). Table 16 provides water quality data and comparison, using the average values from several rain events, to ANZECC guidelines and value ranges in ARQ.

Table 16: Site 11 water quality

Date	Time	Rain (24 hr) mm	pH	EC	Temp	DO	TSS	TKN	TON	TN	TP	PO_4^{3-}	Turbidity
			-	µS/cm	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
1/04/2014	9:30	27.8	6.64	386	22.8	0.63	156	2.8	<0.05	2.8	3.8	0.37	100
27/04/2014	17:00	26	6.43	345	20.9	1.39	11	0.8	<0.05	0.8	0.33	0.13	50
30/05/2014	17:00	23	6.38	453	19.2	3.10	7	2	<0.05	2	0.13	<0.02	10
7/08/2014	9:15	0.2	6.42	410	17	0.90	350	1.4	<0.05	1.4	0.65	0.21	550
8/10/2014	10:00	0.2	6.48	450	17.3	2.25	35	1.2	0.06	1.26	0.18	0.06	26
Maximum			*6.64*	*453*	*22.8*	*3.10*	*350*	*2.8*	*0.06*	*2.8*	*3.8*	*0.37*	*550*
Minimum			*6.38*	*345*	*17*	*0.63*	*7*	*0.8*	*<0.05*	*0.8*	*0.13*	*<0.02*	*10*
*Average**			*6.47*	*409*	*19.4*	*1.65*	*112*	*1.64*	*0.06*	*1.65*	*1.02*	*0.19*	*147*
SD			*0.10*	*45*	*2.45*	*1.02*	*146*	*0.78*	*NA*	*0.77*	*1.57*	*NA*	*228*
Exceed ANZECC guideline?*			***N***	***N***	*-*	***Y***	***Y***	*-*	*-*	***Y***	*-*	***Y***	*-*
Within ARQ range?*			***Y***	*-*	*-*	*-*	***Y***	*-*	*-*	***Y***	***N***	*-*	***Y***

**Average value used for comparison*

TN and PO_4^{3-} exceeded the ANZECC guidelines on occasions however values are within the typical range as reported in ARQ. Market Swamp was characterised by elevated nutrients, low DO and moderate-high turbidity on both sampling occasions. Further sampling before and after works will provide insight into the efficacy of restoration projects in improving water quality.

Site 12

Site 12 is sampled from the Newcastle Wetland Reserve near the railway line and water sampling has occurred on 5 occasions. Due to restricted access, sampling has been undertaken by Norm Rushbrook (Norm Rushbrook Consulting on behalf of ARTC). Table 17 provides water quality data and comparison, using the average values from several rain events, to ANZECC guidelines and value ranges in ARQ.

Table 17: Site 12 water quality

Date	Time	Rain (24 hr) mm	pH	EC	Temp	DO	TSS	TKN	TON	TN	TP	PO_4^{3-}	Turbidity
			-	µS/cm	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
1/04/2014	9:45	27.8	6.82	523	21.7	1.00	32	0.6	0.06	0.66	0.39	0.15	44
27/04/2014	16:30	26	6.82	392	20.8	4.67	33	0.6	0.13	0.73	0.16	0.08	50
30/05/2014	16:30	23	7	493	19.4	7.11	38	2	1.1	3.1	0.14	0.06	50
7/08/2014	9:30	0.2	6.41	3950	19.2	4.01	8	0.6	<0.05	0.64	0.15	0.09	10
8/10/2014	9:45	0.2	6.64	750	19.3	4.62	25	1.1	0.05	1.15	0.18	0.06	22
Maximum			*7*	*3950*	*21.7*	*7.11*	*38*	*2*	*1.1*	*3.1*	*0.39*	*0.15*	*50*
Minimum			*6.41*	*392*	*19.2*	*1.00*	*8*	*0.6*	*<0.05*	*0.64*	*0.14*	*0.06*	*10*
*Average**			*6.74*	*1222*	*20.08*	*4.28*	*27*	*0.98*	*0.34*	*1.26*	*0.2*	*0.09*	*35*
SD			*0.22*	*1531*	*1.12*	*2.19*	*12*	*0.61*	*0.51*	*1.05*	*0.11*	*NA*	*18*
Exceed ANZECC guideline?*			***N***	***N***	*-*	***Y***	***N***	*-*	*-*	***Y***	*-*	***Y***	*-*
Within ARQ range?*			***Y***	*-*	*-*	*-*	***Y***	*-*	*-*	***Y***	***Y***	*-*	***Y***

**Average value used for comparison*

TN and PO_4^{3-} exceeded the ANZECC guidelines however values are within the typical range as reported in ARQ. The Newcastle Wetland Reserve was characterised by elevated nutrients, low DO and moderate-high turbidity on both sampling occasions. Further sampling before and after works will provide insight into the efficacy of restoration projects in improving water quality. Further sampling before and after works will provide insight into the efficacy of restoration projects in improving water quality.

Site 13

Site 13 is located in the canoe channel at the Hunter Wetlands Centre and water sampling has occurred on the 9/12/2013 and 16/2/2014. Sampling occurred within the area of the proposed works (refer to Site Action Plan). Table 18 provides water quality data and comparison, using the average values from several rain events, to ANZECC guidelines and value ranges in ARQ.

Table 18: Site 13 water quality

Date	Time	Rain (24 hr) mm	pH	EC	Temp	DO	TSS	TKN	TON	TN	TP	PO_4^{3-}	Turbidity
			-	µS/cm	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
9/12/2013	10:55	0	7.36	14000	20.6	6.30	5	0.6	<0.05	0.6	0.11	0.08	5
16/02/2014	15:15	25.6	7.43	36600	22.4	5.92	10	0.8	0.09	0.89	0.9	<0.02	5
16/07/2014	06:30	7.4	7.45	35700	18.4	6.40	10	0.5	0.06	0.56	0.61	<0.02	10
26/07/2014	14:20	16.6	7.54	36750	17.8	6.50	10	<0.5	0.04	<0.5	0.42	<0.02	12
9/09/2014	11:10	9.6	7.23	5570	19.2	5.25	11	0.6	0.06	0.66	0.07	<0.02	16
14/10/2014	10:50	36	7.22	27600	19.4	6.14	19	1.1	0.09	1.19	0.12	<0.02	16
Maximum			*7.54*	*36750*	*22.4*	*6.50*	*19*	*1.1*	*0.09*	*1.19*	*0.9*	*0.08*	*16*
Minimum			*7.22*	*5570*	*17.8*	*5.25*	*5*	*<0.5*	*0.04*	*<0.5*	*0.07*	*<0.02*	*5*
*Average**			*7.37*	*26037*	*19.63*	*6.09*	*11*	*0.72*	*0.07*	*0.78*	*0.37*	*0.08*	*11*
SD			*0.13*	*13311*	*1.66*	*0.46*	*5*	*0.24*	*0.02*	*0.26*	*0.33*	*NA*	*5*
Exceed ANZECC guideline?*			***N***	*-*	*-*	***Y***	***N***	*-*	*-*	***Y***	*-*	***Y***	*-*
Within ARQ range?*			***Y***	*-*	*-*	*-*	***Y***	*-*	*-*	***Y***	***Y***	*-*	***Y***

**Average value used for comparison*

TN exceeded the ANZECC guidelines however values are within the typical range as reported in ARQ. PO_4^{3-} exceeded ANZECC guidelines on the 9/12/2013. Since the opening of the Hexham floodgates the canoe channel was characterised by estuarine conditions such as low turbidity, acceptable DO, relatively higher pH < 7 (compared to urban runoff) and high EC. Further sampling before and after works will provide insight into the efficacy of restoration projects in improving water quality.

Site 14

Site 14 is located in the operational channel managed by Newcastle City Council and drains to Iron Bark Creek. Water sampling has occurred on 5 occasions within the area of the proposed works (refer to Site Action Plan). Table 19 provides water quality data and comparison, using the average values from several rain events, to ANZECC guidelines and value ranges in ARQ.

Table 19: Site 14 water quality

Date	Time	Rain (24 hr) mm	pH	EC	Temp	DO	TSS	TKN	TON	TN	TP	PO_4^{3-}	Turbidity
			-	µS/cm	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
16/02/2014	15:05	25.6	7.29	36900	22.5	4.61	10	1.4	0.09	1.49	0.09	0.09	12
19/02/2014	20:05	99.2	7.38	27300	21.7	4.76	41	0.8	0.98	1.78	0.08	<0.02	22
16/07/2014	6:40	7.4	7.52	36500	18.6	5.20	20	0.9	0.45	1.35	0.06	0.05	18
26/07/2014	14:05	16.6	7.56	36800	17.8	6.10	15	1.2	0.34	1.54	0.07	<0.02	21
9/09/2014	12:00	9.6	7.34	610	16.3	6.02	8	0.6	0.05	0.65	0.09	<0.02	12
14/10/2014	11:00	36	7.24	10800	18.9	6.89	13	1.1	0.05	1.15	0.09	<0.02	12
Maximum			*7.56*	*36900*	*22.5*	*6.89*	*41*	*1.4*	*0.98*	*1.78*	*0.09*	*0.09*	*22*
Minimum			*7.24*	*610*	*16.3*	*4.61*	*8*	*0.6*	*0.05*	*0.65*	*0.06*	*<0.02*	*12*
*Average**			*7.38*	*24818*	*19.3*	*5.60*	*18*	*1*	*0.33*	*1.33*	*0.08*	*0.07*	*16*
SD			*0.13*	*15587*	*2.36*	*0.89*	*12*	*0.29*	*0.36*	*0.39*	*0.01*	*NA*	*5*
Exceed ANZECC guideline?*			***N***	*-*	*-*	***Y***	***N***	*-*	*-*	***Y***	*-*	***Y***	*-*
Within ARQ range?*			***Y***	*-*	*-*	*-*	***Y***	*-*	*-*	***Y***	***Y***	*-*	***Y***

**Average value used for comparison*

Since the opening of the Hexham floodgates the operational channel appears to be characterised by estuarine conditions with periodic low DO and low turbidity. Further sampling before and after works will provide insight into the efficacy of restoration projects in improving water quality.

Site 15

Site 15 is the inflow to Market Swamp from the street drain in Ayrshire Crescent. Water sampling occurred on the 16/2/2014 and 19/2/2014 during rain events. Sampling occurred upstream of the proposed works (refer to Site Action Plan). Table 20 provides water quality data and comparison, using the average values from several rain events, to ANZECC guidelines and value ranges in ARQ.

Table 20: Site 15 water quality

Date	Time	Rain (24 hr) mm	pH	EC	Temp	DO	TSS	TKN	TON	TN	TP	PO_4^{3-}	Turbidity
			-	µS/cm	°C	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
16/02/2014	14:55	25.6	7.65	454	21.9	7.98	15	0.6	0.12	0.72	0.06	<0.02	5
19/02/2014	19:55	99.2	7.03	545	23.8	1.52	50	0.6	<0.05	0.6	0.12	<0.02	18
Maximum			*7.65*	*545*	*23.8*	*7.98*	*50*	*0.6*	*0.12*	*0.72*	*0.12*	*<0.02*	*18*
Minimum			*7.03*	*454*	*21.9*	*1.52*	*15*	*0.6*	*0.12*	*0.60*	*0.06*	*<0.02*	*5*
*Average**			*7.34*	*500*	*22.9*	*4.75*	*33*	*0.6*	*0.12*	*0.66*	*0.09*	*<0.02*	*12*
SD			*0.44*	*64*	*1.3*	*4.57*	*25*	*0.0*	*NA*	*0.08*	*0.04*	*NA*	*9*
Exceed ANZECC guideline?*			***N***	***N***	*-*	***Y***	***N***	*-*	*-*	***Y***	*-*	***N***	*-*
Within ARQ range?*			***Y***	*-*	*-*	*-*	***Y***	*-*	*-*	***Y***	***Y***	*-*	***Y***

**Average value used for comparison*

TN exceeded the ANZECC guidelines however values are within the typical range as reported in ARQ. DO on the 19/2/2014 was low and TSS was near the upper limit of ANZECC guidelines however there were no obvious sources observed at the time. Further sampling before and after works will provide insight into the efficacy of restoration projects in improving water quality.

3. Report Card

Table 21 provides a brief snapshot of the ecological health of the waters sampled with respect to water quality (in 2013/2014). Based on water quality, the health of the aquatic ecosystems are rated between 1 and 5 (for example, 1 = healthy and 5 = very poor)

Table 21: Water Quality Report Card for NWC sites

Site	Location	Water Quality
1	Braye Park - Quarry	ND
2	Alnwick Road remnant	2
3	Allowah Street Playground	ND
4	Sunset Blvd	3
4-1	Heaton Public School	3
5	Reservoir site outflow	2
6	Allowah Reserve	2
6-1	Allowah reserve (sub-inflow)	2
7	Waratah West Public creek	2
8-1	Callaghan Creek (UoN)	2
8	University Wetland	4
9	Warabrook wetland	3
10	Jersey Street Wetland	4
10-1	Outflow from Jersey St wetland	3
10-2	Inflow to Jersey St wetland	2
11	Market Swamp	5
12	Newcastle Wetland Reserve	5
13	Hunter Wetlands Centre Canoe Channel	2
14	Astra Street operational land channel	2
15	Ayshire Cres inflow to Market Swamp	3

Water quality for sites 8, 10, 11 and 12 could be considered poor to very poor however these sites are wetlands and a large variation in water quality results would be expected. Restoring connectivity of these water bodies to the natural catchment drainage will dramatically improve water quality at these sites.

4. Future monitoring and reporting

Rainfall event-based sampling will continue in 2015 to characterise catchment inflows/outflows to proposed works areas. Water quality reporting will be summarised in July 2015 as the dataset increases and transects have been measured in the field (for flow/discharge measurement) over numerous events.

5. References

ANZECC (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality - Volume 1*, Australia and New Zealand Environment and Conservation Council (ANZECC) and the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), ISBN 09578245 0 5.

Engineers Australia (2006) *Australian Runoff Quality (ARQ)*, Ed. T. Wong, ISBN 0 85825 860 9.

Appendix 1:

Longitudinal Water Quality Study of Dark Creek and Bowinbah Creek

Catchment Water Quality Monitoring for NWC project:

Dark Creek and Bowinbah Creek: 21st August 2014 – 14th October 2014

Prepared by Benjamin Everingham

The Tom Farrell Institute for the Environment (TFI)

The University of Newcastle, NSW Australia

Contents

1. Introduction

Characterising stream water quality within urban catchments is important in determining stream health. Bowinbah Creek at the University of Newcastle (UoN) Callaghan Campus and the nearby Dark Creek are currently being monitored as part of Newcastle Wetland Connections (NWC) project managed by WetlandCare Australia (WCA).

Water quality monitoring sites undertaken in this study are shown in Figure 1. Note that the locations of these sampling sites may alter over the 4 year funding period as restoration works are completed within each catchment.

Figure 1: General location of water quality monitoring sites

Table 1 provides location, latitude, longitude and elevation of water sampling sites shown in Figure 1.

Table 1: Latitude, longitude and elevation of water sampling sites

Site	Location	Latitude	Longitude	Elevation (metres above sea level)
1	Sunset Boulevard - Sediment Trap	32°53'57.81"S	151°41'55.73"E	24m
2	Sunset Boulevard - Sediment trap drain exit	32°53'58.40"S	151°41'54.06"E	23m
3	Riparian Zone between houses and school oval	32°53'57.96"S	151°41'51.10"E	19m
4	Riparian zone adjacent to school	32°53'56.48"S	151°41'45.99"E	15m
5	Drain exit from southern car park	32°53'42.02"S	151°42'3.68"E	36m
6	Riparian zone underneath bridge	32°53'30.85"S	151°42'0.62"E	25m
7	Riparian zone adjacent to large concrete structure	32°53'29.31"S	151°41'55.51"E	28m
8	University Wetland	32°53'21.06"S	151°42'7.06"E	19m

2. Water Quality Monitoring (Aug 2014 – Oct 2014)

This project aimed to characterise the longitudinal water quality of both Bowinbah Creek and Dark Creek. As of 14th October 2014 a total of 11 sampling campaigns were conducted. Details of these visits are summarised in Table 2. Daily rainfall and minimum/maximum temperature during the sampling period are shown in Figure 2.

Table 2: Water quality monitoring summary (Aug 2014 - Oct 2014)

Date	Type	Sites Sampled	WQ parameters	Participants
21/08/2014	scheduled	All sites	pH, EC, °C, DO and Turbidity	S. Lucas (TFI), B. Everingham (UoN)
26/08/2014	scheduled	All sites	pH, EC, °C, DO and Turbidity	B. Everingham (UoN)
28/08/2014	scheduled	All sites	pH, EC, °C, DO and Turbidity	B. Everingham (UoN)
2/09/2014	scheduled	All sites except Site 1 (Lack of flow)	pH, EC, °C, DO and Turbidity	B. Everingham (UoN)
4/09/2014	scheduled	All sites except Site 1 (Lack of flow)	pH, EC, °C, DO and Turbidity	B. Everingham (UoN)
9/09/2014	scheduled	All sites except Site 1 (Lack of flow)	pH, EC, °C, DO and Turbidity	S. Lucas (TFI), B. Everingham (UoN)
11/09/2014	scheduled	All sites except Site 1 (Lack of flow)	pH, EC, °C, DO and Turbidity	B. Everingham (UoN)
16/09/2014	scheduled	All sites except Site 1 (Lack of flow)	pH, EC, °C, DO and Turbidity	B. Everingham (UoN)
18/09/2014	scheduled	All sites except Site 1 (Lack of flow)	pH, EC, °C, DO and Turbidity	B. Everingham (UoN)
26/09/2014	scheduled	All sites except Site 1 (Lack of flow)	pH, EC, °C, DO and Turbidity	B. Everingham (UoN)
14/10/2014	rainfall event	All sites except Site 1 (Lack of flow)	pH, EC, Turbidity	B. Everingham (UoN)

EC = electrical conductivity; °C = temperature; DO = dissolved oxygen

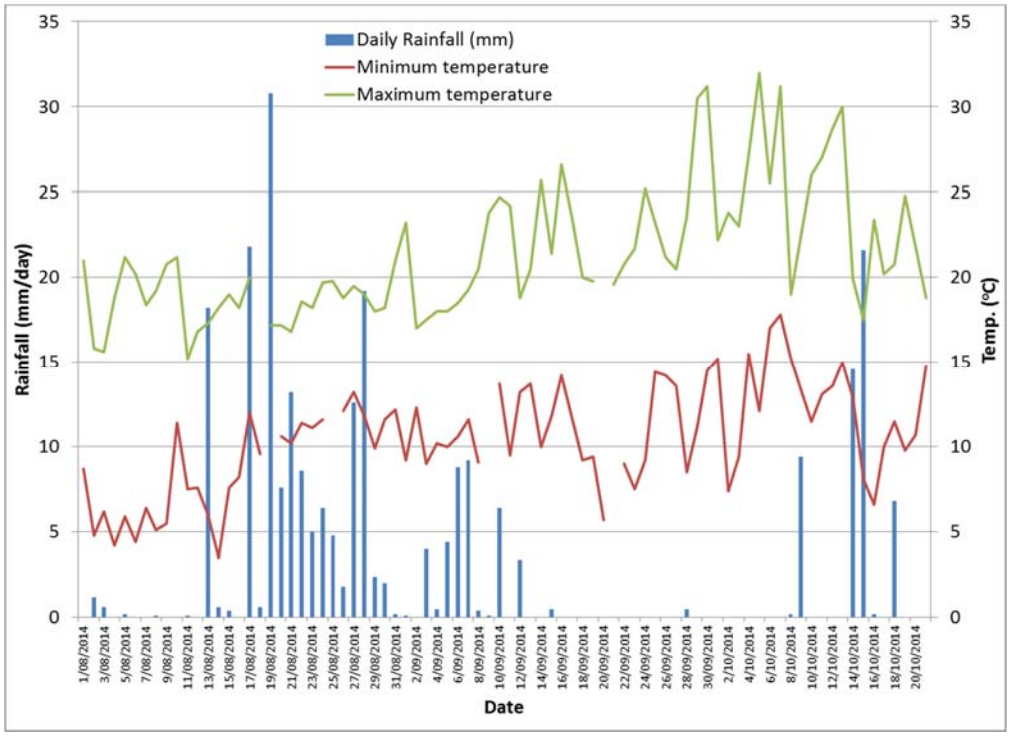

Figure 2: Daily rainfall and minimum/maximum temperature during the sampling period

2.1 Method

The general procedure involved collecting grab samples from each site on scheduled dates in order to get a total of 10 individual samples for each site. Each sample was then analysed in the lab using a YSI meter which measured the pH, electrical conductivity EC, µS/cm), temperature (°C) and dissolved oxygen (DO); and a Hach 2100p Turbidimeter to measure turbidity. Note that the final sampling event was conducted after a rainfall event in order to achieve more realistic results given a general lack of rainfall for the majority of sampling events. The final samples were analysed using a Hach HQ 40d meter due to issues with the YSI. This resulted in not receiving results for temperature and DO for these final samples.

Table 3 summarises the range of water quality parameters from "All Urban" areas in Australian Runoff Quality (ARQ) (Engineers Australia, Chapter 3, 2006) and trigger values from the Australian and New Zealand guidelines for fresh and marine water quality (ANZECC, 2000) with respect to "Aquatic Ecosystems – SE Australia – Lowland Rivers" (Tables 3.3.2 and 3.3.3 in ANZECC, 2000). These will be used during assessment of water quality at each site in the NWC project areas.

Table 3: Typical stormwater runoff characteristics from ARQ (2006) and trigger values from ANZECC (2000)

Parameter	**Units**	**ARQ, 2006**	**ANZECC, 2000**
pH	no units	6.2 - 7.6	6.5 - 8
EC	µs/cm	-	125 - 2200
DO	mg/L	-	> 6.5
Turbidity	NTU	15 - 250	10 - 50

3. Results

3.1 Dark Creek

3.1.1 Site 1

Description: Runoff from houses enters large grassed basin designed to allow infiltration of runoff. A course sediment trap is located at the lowest point allowing excess water to drain underneath Sunset Boulevard into Dark Creek.

Number of Samples: 3

Observations: Only three samples were collected at this site due to the infiltration properties of the grassed basin area. Significant extended rainfall events were needed to produce an amount of water large enough to sample. This site had no surface flow during the majority of the sampling events however subsurface flow was evident on all occasions indicated by the observed outflow into Dark Creek at site 2.

Sediment trap over drainage point

Grassy basin

Table 4: Site 1 water quality

Date	Rainfall in previous 24 hrs		pH	EC (µs/cm)	Temperature (°C)	DO (mg/L)	Turbidity (NTU)
21/08/2014	3.2mm		7.71	400	15.3	8.95	4
26/08/2014	1.8mm		7.35	427	16	11.30	22
28/08/2014	15.0mm		7.45	350	17.5	8.25	12
2/09/2014	0mm	No Flow					
4/09/2014	0mm	No Flow					
9/09/2014	0mm	No Flow					
11/09/2014	0mm	No Flow					
16/09/2014	0mm	No Flow					
18/09/2014	0mm	No Flow					
26/09/2014	0mm	No Flow					
14/10/2014	14.6mm	No Flow					
		Max	7.71	427	17.5	11.30	22
		Min	7.35	350	15.3	8.25	4
		Avge	7.50	392	16.3	9.50	12
		SD	0.19	39	1.1	1.60	9

None of the parameters tested exceeded ANZECC guidelines however given that there were no flows at most times further testing during rainfall events may be required to provide more accurate runoff water quality results.

3.1.2 Site 2

Description: Surface and subsurface flows pass under Sunset Boulevard from Site 1 to Dark Creek. Runoff from Sunset Boulevard is drained to this point.

Number of Samples: 11

Observations: Substantial flow was recorded at this site on all sampling events even during dry conditions (baseflow). Milky colouration often observed.

Inflow to Site 2

Site 2 sample point

Table 5: Site 2 water quality

Date	Rainfall in previous 24 hrs		pH	EC (µs/cm)	Temperature (°C)	DO (mg/L)	Turb. (NTU)
21/08/2014	3.2mm		7.58	220	15.3	7.90	34
26/08/2014	1.8mm		6.52	370	15.7	6.90	49
28/08/2014	15.0mm		7.40	270	16.8	7.45	68
2/09/2014	0mm		6.50	820	15.5	6.90	70
4/09/2014	0mm		6.85	905	14.7	6.50	46
9/09/2014	0mm		7.32	825	17.3	7.35	31
11/09/2014	0mm		6.85	756	17.1	7.25	32
16/09/2014	0mm		7.19	904	18.2	6.30	25
18/09/2014	0mm		7.08	986	16.9	5.75	22
26/09/2014	0mm		6.75	860	18.6	3.85	9
14/10/2014	14.6mm		7.20	160	ND	ND	34
		Max	7.58	986	18.6	7.90	70
		Min	6.50	160	14.7	3.85	9
		Avge	7.02	643	16.6	6.62	38
		SD	0.36	317	1.3	1.15	19

All parameters measured averaged within the ANZECC guidelines. Turbidity exceeded the recommended ANZECC guidelines on 2 occasions following significant rainfall reaching 70 NTU.

3.1.3 Site 3

Description: Riparian zone downstream from Site 2. Larger trees more prominent with less defined flow way.

Number of Samples: 11

Observations: Flow more dispersed than Site 2 which leads to lower flow rate and increased standing time of water. Extensive ground vegetation conceals any obvious inflow.

Sample site 3

Vegetation cover concealing inflow

Large trees more prominent with outflow more dispersed

Table 6: Site 3 water quality

Date	Rainfall in previous 24 hrs		pH	EC (µs/cm)	Temperature (ºC)	DO (mg/L)	Turbidity (NTU)
21/08/2014	3.2mm		7.18	150	15.1	7.40	22
26/08/2014	1.8mm		6.62	285	15.6	5.40	20
28/08/2014	15.0mm		7.18	270	16.7	6.70	61
2/09/2014	0mm		6.85	735	15.1	5.00	33
4/09/2014	0mm		6.92	810	14.3	5.25	25
9/09/2014	0mm		7.27	755	16.6	5.79	18
11/09/2014	0mm		6.98	677	16.4	5.80	22
16/09/2014	0mm		6.95	903	17.8	5.10	12
18/09/2014	0mm		6.99	948	16.2	6.20	9

26/09/2014	0mm		6.82	860	20.0	5.30	8
14/10/2014	14.6mm		7.21	294	ND	ND	19
		Max	7.27	948	20.0	7.40	61
		Min	6.62	150	14.3	5.00	8
		Avge	7.00	608	16.4	5.79	22
		SD	0.20	296	1.6	0.77	15

The DO at Site 3 averaged lower than the ANZECC recommended guidelines at 5.79 mg/L. Turbidity for Site 3 averaged within the ANZECC guidelines however following periods of significant rainfall it did exceed these guidelines reaching 61 NTU. All other parameters tested fell within the ANZECC guidelines.

3.1.4 Site 4

Description: Further downstream from Site 3 located at the last easily accessible point before a land bridge. Drain pipes underneath allow water to move further downstream during high flow conditions.

Number of Samples: 11

Observations: Little flow at all times (pooled). Substantial vegetation hinders flow and produces 'oily' film on surface of water (organics). Significant levels of debris has accumulated at outflow of sample site.

Sample Site 4

Inflow concealed by vegetation

Outflow with debris. Oily film clearly visible (organics)

Table 7: Site 4 water quality

Date	Rainfall in previous 24 hrs		pH	EC (µs/cm)	Temperature (°C)	DO (mg/L)	Turbidity (NTU)
21/08/2014	3.2mm		6.92	210	15.2	6.80	24
26/08/2014	1.8mm		6.52	330	15.7	6.60	19
28/08/2014	15.0mm		7.06	225	17.2	6.80	55
2/09/2014	0mm		6.7	840	15.3	5.80	9
4/09/2014	0mm		6.75	800	15.1	6.10	9
9/09/2014	0mm		7.19	680	17.8	7.30	12
11/09/2014	0mm		6.93	580	17.4	7.30	11
16/09/2014	0mm		6.85	753	18.2	5.25	10
18/09/2014	0mm		6.73	869	18.0	4.95	9
26/09/2014	0mm		6.73	1035	21.9	5.30	21
14/10/2014	14.6mm		7.26	322	ND	ND	22
		Max	7.26	1035	21.9	7.30	55
		Min	6.52	210	15.1	4.95	9
		Avge	6.88	604	17.2	6.22	18
		SD	0.22	288	2.1	0.87	13

As with Site 3, DO averaged slightly below ANZECC guidelines at 6.22 mg/L and turbidity averaged within the guidelines with a peak exceeding recommended levels during high rainfall periods reaching a 55 NTU maximum. pH and EC fell comfortably within the guidelines recommended by ANZECC.

3.2 University (Bowinbah Creek)

3.2.1 Site 5

Description: Inflow from the drainage system for the car park (P2) and road located at the southern end of the UoN Callaghan Campus. Inflow exits 2 large concrete pipes directly into the creek.

Number of Samples: 11

Observation: Combination of large trees and shrubby undergrowth. Creek contains larger stones in addition to a silty bed. Significant levels of leaf matter present in the water.

Sample site 5

Inflow with drain pipes clearly visible

Table 8: Site 5 water quality

Date	Rainfall in previous 24 hrs		pH	EC (µs/cm)	Temperature (°C)	DO (mg/L)	Turbidity (NTU)
21/08/2014	3.2mm		6.77	200	14.2	8.20	58
26/08/2014	1.8mm		6.58	280	15.2	7.80	53
28/08/2014	15.0mm		7.07	230	16.0	8.05	51
2/09/2014	0mm		6.95	605	15.2	7.50	14
4/09/2014	0mm		7.05	540	13.9	7.85	15
9/09/2014	0mm		7.4	515	14.6	8.75	19
11/09/2014	0mm		7.62	478	16.6	7.90	23
16/09/2014	0mm		7.06	766	18.3	6.80	11
18/09/2014	0mm		7.23	819	17.1	5.75	11
26/09/2014	0mm		7.09	825	18.6	6.85	19
14/10/2014	14.6mm		7.38	263	ND	ND	62
		Max	7.62	825	18.6	8.75	62
		Min	6.58	200	13.9	5.75	11
		Avge	7.11	502	16.0	7.55	31
		SD	0.29	236	1.6	0.86	21

Generally all parameters averaged within the ANZECC guidelines however DO fell below the guidelines on one occasion dropping to 5.75 mg/L. Turbidity exceeded the ANZECC guidelines on multiple occasions during periods of increased rainfall reaching a maximum of 62 NTU.

3.2.2 Site 6

Description: Downstream from Site 5 underneath a footbridge just before a junction which joins the south-north running stream from the car park and the west-east running stream that drains from the Newcastle Inner-City Bypass (NICB) which skirts the western edge of Callaghan Campus.

Number of Samples: 11

Observation: Similar vegetation to site 5 however with a more pronounced flow way. Evidence of grass clippings being dumped adjacent to site was observed with significant levels of sediment runoff possible.

Site 6

Grass clippings and leaf litter disposal leading to increased levels of sediment transfer and organic matter potentially entering creek

Table 5: Site 6 water quality

Date	Rainfall in previous 24 hrs		pH	EC (µs/cm)	Temperature (°C)	DO (mg/L)	Turbidity (NTU)
21/08/2014	3.2mm		7.02	330	14.2	7.50	34
26/08/2014	1.8mm		6.71	594	15.2	7.10	46
28/08/2014	15.0mm		7.05	285	15.7	7.90	55
2/09/2014	0mm		7.00	905	14.8	6.60	19
4/09/2014	0mm		7.05	545	13.9	6.85	16
9/09/2014	0mm		7.36	630	13.9	7.14	14
11/09/2014	0mm		7.11	425	16.8	6.60	32
16/09/2014	0mm		7.03	862	18.7	5.50	11
18/09/2014	0mm		6.92	1074	17.7	4.80	6
26/09/2014	0mm		6.99	1376	18.1	5.71	5
14/10/2014	14.6mm		7.36	301	ND	ND	38
		Max	7.36	1376	18.7	7.90	55
		Min	6.71	285	13.9	4.80	5
		Avge	7.05	666	15.9	6.57	25
		SD	0.18	352	1.8	0.96	17

All measured parameters averaged within the ANZECC guidelines however DO fell below the recommended guidelines on three occasions falling to a minimum of 4.80 mg/L. Turbidity both exceeded and fell below the recommended range reaching a maximum of 55 NTU and a minimum of 5 NTU.

3.2.3 Site 7

Description: Located adjacent to large concrete structure presumed to be some type of sewerage/waste water facility on west-east flowing creek from NICB.

Number of Samples: 11

Observation: During periods of normal flow, flow path clearly identifiable. During periods of increased rainfall concrete structure becomes a wall channelling water downstream. This can be clearly seen by large amounts of leaf debris present on the edge of the flow path post large flow events.

Inflow

Site 7

Table 6: Site 7 water quality

Date	Rainfall in previous 24 hrs		pH	EC (µs/cm)	Temperature (°C)	DO (mg/L)	Turbidity (NTU)
21/08/2014	3.2mm		6.80	145	14.5	6.65	20
26/08/2014	1.8mm		6.30	332	15.5	7.50	30
28/08/2014	15.0mm		7.01	250	16	7.50	51
2/09/2014	0mm		6.70	115	15.3	3.10	2
4/09/2014	0mm		6.91	400	14.7	3.05	3
9/09/2014	0mm		7.10	430	14.6	3.10	5
11/09/2014	0mm		6.90	351	17.3	3.80	7
16/09/2014	0mm		6.94	533	19.0	3.55	2
18/09/2014	0mm		6.87	712	17.7	3.90	2
26/09/2014	0mm		6.94	512	18.5	3.03	3

14/10/2014	14.6mm		7.28	266	ND	ND	7
		Max	7.28	712	19.0	7.50	51
		Min	6.30	115	14.5	3.03	2
		Avge	6.89	368	16.3	4.52	12
		SD	0.25	176	1.7	1.90	16

EC and pH both fell comfortably within the ANZECC guidelines. pH fell just below the ANZECC guidelines on one occasion dipping to 6.30 and EC fell below the recommended ANZECC guidelines on a single occasion falling to 115 µS/cm. DO averaged below the typical range averaging 4.53 mg/L and reaching a minimum of 3.03 mg/L. DO was significantly lower on drier sample events. Turbidity averaged within the typical range recommended by ANZECC; and only once exceeding these levels (51 NTU) however fell below the recommended values on all but 3 occasions reaching a minimum of 2 NTU.

3.2.4 Site 8

Description: Large deep swamp located towards the north-eastern corner of the UoN Callaghan campus. The creeks that contain sites 5, 6 and 7 flow into this wetland.

Number of Samples: 11

Observations: Reeds surround the perimeter of the swamp with vegetation present on the water surface. Bird life is abundant and the presence of fish in the swamp was noted.

Sampling at Site 8

Table 7: Site 8 water quality

Date	Rainfall in previous 24 hrs		pH	EC (µs/cm)	Temperature (°C)	DO (mg/L)	Turbidity (NTU)
21/08/2014	3.2mm		6.50	310	14.7	4.45	22
26/08/2014	1.8mm		6.15	323	15.8	6.25	25
28/08/2014	15.0mm		7.00	180	16.6	7.45	41
2/09/2014	0mm		6.70	405	15.3	4.10	14
4/09/2014	0mm		6.74	470	16.1	5.25	8
9/09/2014	0mm		7.20	376	17.8	7.30	12
11/09/2014	0mm		6.86	385	18.5	7.05	13
16/09/2014	0mm		6.96	450	18.9	6.50	5
18/09/2014	0mm		6.84	579	20.1	4.95	5
26/09/2014	0mm		6.90	731	20.2	6.03	3
14/10/2014	14.6mm		7.16	345	ND	ND	19
		Max	7.20	731	20.2	7.45	41
		Min	6.15	180	14.7	4.10	3
		Avge	6.82	414	17.4	5.93	15
		SD	0.30	146	2.0	1.19	11

EC and pH fell within ANZECC guidelines with pH only once dropping below the typical range, falling to 6.15. The average DO fell short of the specified guidelines reaching levels as low as 4.10 mg/L. Turbidity averaged an acceptable level of 15 NTU however did fall below the specified range on multiple occasions falling to a minimum of 3 NTU.

4. Summary

This study provides storm water quality data from scheduled and rainfall based events for the period between 21st August 2014 and 14th October 2014. In general, data averages for all parameters were within the recommended Australian Runoff Quality (Engineers Australia, 2006) but ANZECC guidelines were exceeded for some parameters.

Dark Creek fell outside ANZECC guidelines for:

- DO at sample sites 3 and 4 with 5.79 mg/L and 6.22 mg/L average respectively.
- Turbidity at sample sites 2, 3 and 4 occasionally spiked above ANZECC recommended guidelines but average results fell within the recommended range.

Bowinbah Creek fell outside ANZECC guidelines for:

- DO at sample sites 7 and 8 with 4.52 mg/L and 5.93 mg/L average respectively
- DO at sample sites 5 and 6 occasionally fell below ANZECC guidelines however average results were within the recommended range.
- Turbidity at sample sites 5, 6, 7 and 8 occasionally spiked above and fell below ANZECC recommended guidelines however average results fell within the recommended ranges.
- pH at sample sites 7 and 8 dipped below ANZECC recommended levels however averages were comfortably within the recommended range.

Much of the variation in measured water quality can be attributed to rainfall. For example, DO and turbidity typically decreased in the absence of rain and both increased when rain events occur and increased the flow.

The data provided in this report has assisted characterising the longitudinal water quality within Bowinbah Creek and Dark Creek. The data will provide useful information for the NWC project and for future catchment modelling and the efficacy of specific works in improving water quality.

5. References

ANZECC (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality – Volume 1,* Australia and New Zealand Environment and Conservation Council (ANZECC) and the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ), ISBN 09578245 0 5.

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