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Grange Resources

Report for Cape Riche Seawater Desalination Plant

Water Quality Monitoring

May 2011

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Executive Summary

Grange Resources intends to develop a seawater desalination plant near Cape Riche, Western Australia, to supply up to 12 GL/Y of water for the Southdown Magnetite Project. During 15-16 February 2011 water quality sampling was carried out within Cheyne Bay and Cheyne Inlet, respectively, north of Cape Riche, to supplement the previous quarterly water quality monitoring program of 2009 (360 Environmental 2010a). The previous seven (7) monitoring sites in the study area and an additional two (2) sites in Cheyne Inlet were sampled. The objectives of this monitoring study were to characterise baseline water quality in the study area and near the proposed seawater intake, and to evaluate the potential impact to seawater intake water quality in the event of a Cheyne Inlet sandbar breach.

The measurement programme included *in situ* physio-chemical measurements and grab samples at the surface and bottom of seven (7) Bay sites and only at the surface for the two (2) Inlet sites. Continuous *in situ* logger measurements of water depth, temperature and salinity at two (2) sites within the Bay were also recorded from 16 February to 9 April 2011.

The continuous *in situ* loggers at the two (2) Bay stations measured spring and neap tidal ranges of approximately 1 and 0.5 m, respectively. Surprisingly water temperatures increased over the nearly two (2) month deployment from the end of summer to the start of autumn. An anomalously warm March and April and cool February air temperatures likely contributed to the increased water temperatures. Further, the influence of a strong La Nina lead to further southern penetration of the Leeuwin Current that may have also influenced the increase in water temperatures with the study area. Salinity over the period was approximately 35.5 psu at the two (2) locations in the Bay, which is in agreement with autonomous glider measurements in Nov.-Dec. 2010 and Feb.-Mar. 2011 of 35.6-35.8 psu (GHD 2011a) and a 2009 seasonal range of 35.5-36.3 psu (360 Environmental 2010a).

Generally the physico-chemical parameters in the Bay of turbidity, DO saturation percentage and light attenuation coefficients for both the February 2011 and quarterly 2009 monitoring surveys complied with the ANZECC (2000) default guideline values for inshore coastal waters of southwestern Australia. Further, previous TN and TP measurements in the Bay were below the ANZECC (2000) default guidelines. Of the dissolved metal measurements during February 2011 (As, Cd, Cr, Cu, Ni, Pb, Zn, Hg) and previous 2009 (additionally Al, Mn, Mb, Se, V, Fe), only copper (Cu) was above the ANZECC (2000) default guideline. However copper was below the ANZECC (2000) guidelines when carried out by two (2) independent labs (360 Environmental 2010b), which has been adopted as the baseline. Chlorophyll a was below the ANZECC (2000) default guideline value. Hence, the inshore coastal waters of the study area meet the default ANZECC (2000) guidelines, and thereby the water quality is considered of a high standard from both ecological and desalination source water perspectives.

As per expectations the Cheyne Inlet water quality during 13 February 2011 had considerably higher turbidity, TSS and chlorophyll a than the inshore coastal waters of the study area. Chlorophyll a was at or just above the ANZECC (2000) default guidelines for southwestern Australia estuaries, whereas turbidity was considerably greater than the guideline value. The DO saturation percentage was within the ANZECC (2000) guideline range. Conductivity was considerably lower in the Inlet, which indicates that even during summer, freshwater (or brackish) inputs from surface waters and groundwater are sufficient to maintain salinity lower than the adjacent coastal waters. When the Inlet sandbar is breached due to rainfall-induced surface flows, the expectation is that the relatively fresh and turbid waters may impact the seawater intake water quality immediately to the east.

1. Introduction

Grange Resources Limited intends to develop a seawater desalination plant near Cape Riche, Western Australia, to supply up to 12 gigalitres per year (GL/y) of water to the Southdown mine, as part of the Southdown Magnetite Project.

In February 2011, GHD Pty Ltd (GHD) undertook water quality sampling within Cheyne Bay, immediately north of Cape Riche, to supplement previous water quality monitoring program in 2009 (360 Environmental 2010a).

The original water quality sampling locations were re-established within the study area with five (5) locations were inside the bay and two (2) sites further offshore (Figure 1). At these locations, a subset of the water quality parameters from previous monitoring (360 Environmental 2010a) was selected to establish a compatible monitoring program to facilitate comparative analysis between the two (2) datasets.

Additionally, two (2) new sampling sites were established within Cheyne Inlet to provide water quality data for design and operational purposes in the event of a sandbar breach. Lastly, two (2) *in situ* loggers were deployed in the Bay to collect continuous measurements of conductivity, temperature and depth.

The primary objectives of this monitoring study were to characterise the water quality:

- Of the locale of the seawater intake open channel (hereafter ‘seawater intake’) to serve as a baseline for any future monitoring;
- Near the proposed seawater intake for the desalination plant for design and operational information of the plant; and
- Of Cheyne Inlet to evaluate the potential impact on the seawater intake water quality during sandbar breaches for design and operational information of the plant.

2. Methodology

2.1 Monitoring Programme

From 15-16 February 2011, members of the GHD Marine Science Team undertook a water quality survey at the same (7) locations as 360 Environmental (2010a). Surface measurements from an additional two (2) sites within Cheyne Inlet were also collected. *In situ* measurements and water 'grab' samples were collected at the surface and bottom of the water column at each Bay location to characterise the water quality within the study area near the seawater intake. Water quality site coordinates for the 2011 and previous 2009 monitoring surveys are shown in Table 1, and illustrated in Figure 1.

Table 1 Site locations for 2009 and 2011 water quality surveys (DATUM GDA94).

Site Name and Locations of Sampling	Easting	Northing
R1 (SURFACE + BOTTOM)	660958	6170826
R2 (SURFACE + BOTTOM)	662526	6170097
R3 (SURFACE + BOTTOM)	662922	6169205
S1 (SURFACE + BOTTOM)	661301	6169810
S2 (SURFACE + BOTTOM)	661620	6169690
S3 (SURFACE + BOTTOM)	661925	6169576
S4 (SURFACE + BOTTOM)	662208	6169465
E1 (SURFACE, 2011 only)	660815	6169382
E2 (SURFACE, 2011 only)	660804	6169493

2.2 *In Situ* Physico-Chemical Parameters

In situ physico-chemical properties were measured with a TROLL 9500 Pro water quality meter and included:

- Temperature (°C);
- Conductivity (µS/cm);
- pH;
- Dissolved Oxygen (mg/L & %Sat);
- Turbidity (NTU); and
- Depth (m).

A LiCor Li250 light metre was used to measure photosynthetic active radiation (PAR, µE m^{-2} s^{-1}) at the surface and bottom at each site in the Bay. This data was used to estimate the light attenuation coefficient (LAC, 1/m) through the water column with Beers Law.

2.3 ‘Grab’ Samples

Grab samples were collected across the study area to obtain additional baseline information on nutrient, dissolved metals and other water quality parameters to complement the previous quarterly monitoring during 2009 (360 Environmental 2010a). Water grab samples were collected with an eight (8) litre ‘Niskin’ type water sampler near the surface (<1m) and seabed (approximately 1 m above seafloor) at the seven (7) Bay sites, and only at the surface at the two (2) Inlet sites. Samples were decanted into laboratory-provided vessels for storage and/or post-processing prior to transport for laboratory analysis. Cross-contamination precautions were carried out in accordance with GHD Water Quality Sampling Procedures.

2.3.1 Physico-Chemical Parameters

The water samples for total dissolved solids (TDS) were decanted into 1 L unpreserved plastic bottles. These were then stored and kept cold in an esky until transferral to a refrigerator. Samples were couriered to a NATA accredited laboratory (ALS) for analysis.

2.3.2 Nutrients

Nutrients were analysed for reduced inorganic nitrogen (NH_X), filterable reactive phosphorus (FRP), oxidised inorganic nitrogen (NO_X), nitrate (NO_3), nitrite (NO_2), total phosphorus (TP), total Kjeldhal nitrogen (TKN) and total nitrogen (TN). Water samples were decanted from the Niskin bottle into laboratory-provided 125 mL bottles with sulphuric acid preservative. All nutrient samples were kept chilled in an esky immediately after collection, stored in a refrigerator until couriered to a NATA accredited laboratory (ALS) in a chilled esky. All samples were collected during the last two (2) days of the field work programme, which enabled receipt and processing by the laboratory within the required holding times.

2.3.3 Dissolved Metals

Grab samples for dissolved metals (As, Cd, Cr, Cu, Ni, Pb, Zn, Hg) were field-filtered with a syringe through a 0.45 µm glass fibre disk filter into a 60 mL unpreserved plastic bottle. All dissolved metal samples were kept chilled in an esky immediately after collection, stored in a refrigerator until couriered to a NATA accredited laboratory (ALS) in a chilled esky for analysis within required holding times. Dissolved metals were analysed only for one (1) station, S2, at the surface and bottom as the 360 Environmental (2010a) quarterly monitoring program.

2.3.4 Other Parameters

Water samples for total suspended solids (TSS) analysis were collected from the surface waters across each of the nine (9) sampling locations. Due to observed differences in water clarity, five (5) litres of water were collected in the marine waters and only one (1) litre at those sites within the inlet. All samples were filtered with 0.50 µm glass fibre pre-weighed filter papers, rinsed with three (3) 50 ml aliquots of deionised water to remove any salt build up on the paper, wrapped in a second clean, separate piece of filter paper to prevent sticking to individual manila holding envelopes. These samples were sent to Marine and Fish Research Laboratory (MAFRL) at Murdoch University for TSS analysis.

Water samples for chlorophyll a (chla) were collected and transferred into one (1) L white unpreserved plastic bottles. Similar to the TSS method, chla samples were vacuum filtered through 0.50 µm glass fibre filter. The filter paper was then folded onto itself and then wrapped in a clean, separate, piece of filter paper to prevent sticking to the individual manila envelopes. Samples were then wrapped in tin foil, placed into a freezer and kept frozen until couriering to the NATA accredited (ALS) Laboratory for processing.

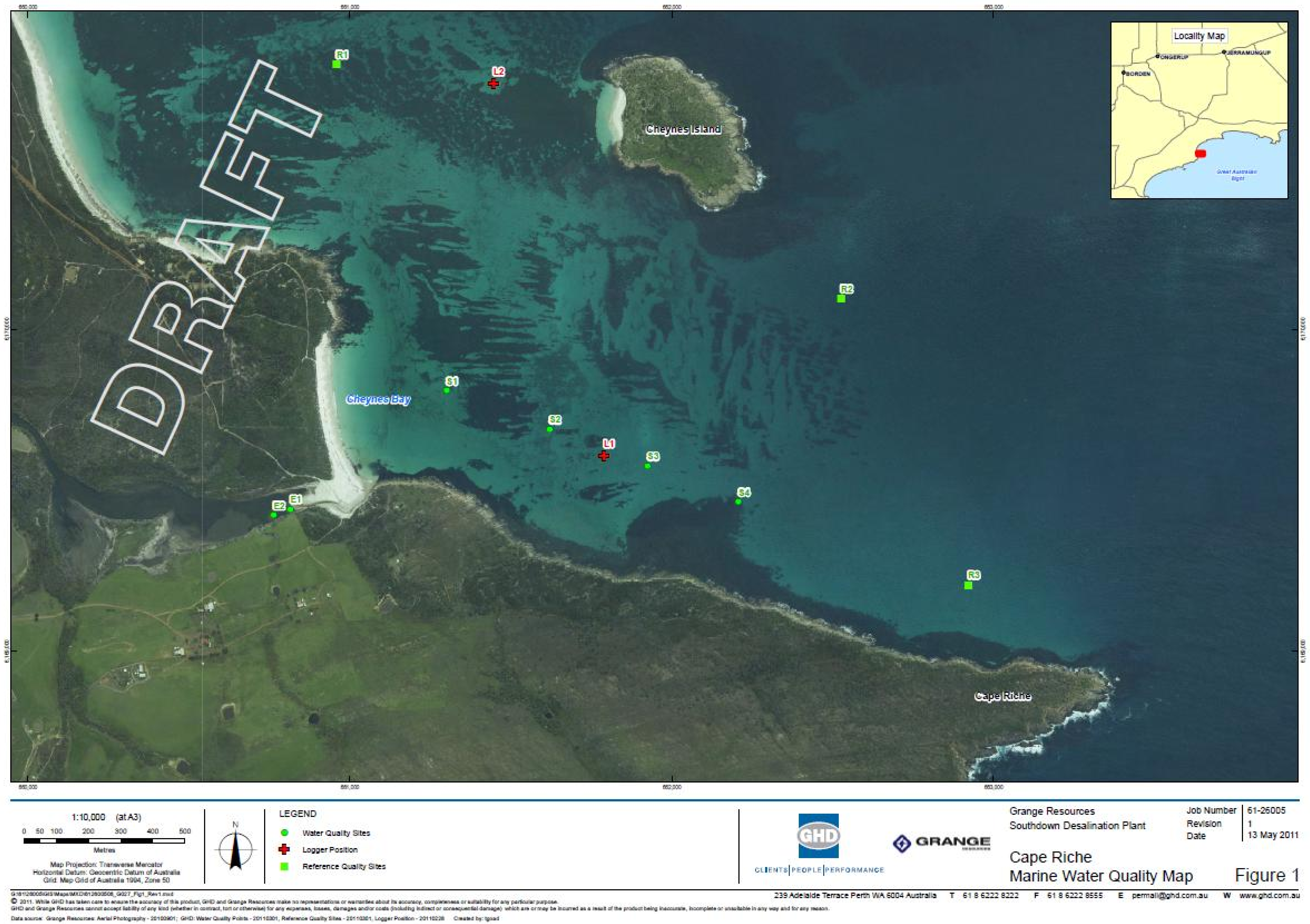
2.4 *In Situ* Continuous Logger Measurements

In order to provide baseline data of the seasonal temperature and salinity of Cheyne Bay, two (2) XR-420CTDm conductivity, temperature and depth loggers (RBR Ltd, Ottawa, Canada) were installed at two (2) Bay locations (Figure 1). These loggers were secured with cable ties to 1.5 m star pickets that were affixed into the sandy substrate to a depth of approximately 0.5 m. The logger sensors were positioned to point towards the surface with several centimetres clearance from the top of the star pickets.

One logger (site L1) was positioned north of Cheyne Bay and west of Cheyne Island within a sand patch. A second logger (site L2) was placed in relative proximity to the proposed location of the seawater intake within a sand patch. The logger locations were established to provide baseline monitoring for potential brine discharge into Cheyne Bay, however the brine discharge is now proposed at the exposed southern shoreline of Cape Riche a substantial distance (~1 km) from seagrass communities within the Bay.

The loggers were deployed from 16 February to 9 April 2011 with a measurement frequency of fifteen (15) minutes.

Figure 1 Sampling locations in marine (S1-S4 and R1-R3) and inlet (E1-E2).



3. Results

3.1 *In situ* Physico-Chemical Measurements

A summary of the *in situ* physico-chemical measurements is provided in Table 2 for the 15-16 February 2011 water quality survey. Temperatures were approximately 21°C at both the bay and inlet sites. Turbidity was considerably higher in the inlet (4-8 NTU) than the marine sites (<1.5) NTU, and were above the ANZECC (2000) default guideline. The dissolved oxygen was considerably greater in the inlet (135-140% DO saturation) than the marine waters (95-100%), but both water types were compliant with the ANZECC (2000) guidelines. TDS in the inlet (31.4-31.5 g/L) was considerably lower than the marine waters (40.7-45.4 g/L), presumably because of freshwater inputs from groundwater and surface water sources. LAC estimates from surface and bottom PAR measurements were low in both the Inlet and Bay (<0.13 1/m) and below the ANZECC (2000) default guideline of 0.13 1/m, except at site S1.

3.2 “Grab” Samples

A summary of the water grab samples is provided in Table 2 for the 15-16 February 2011 water quality survey. A brief overview of these data is provided next along with comparisons to relevant ANZECC (2000) default guidelines for southwestern Australia for inshore marine (Bay) and estuarine (Inlet) waters.

3.2.1 Nutrients

All measurements of FRP, NH_X, NO_3, NO_2 and NO_X were below the limit of reporting (LoR). NO_X was below the ANZECC (2000) default guideline. Unfortunately, matrix effects increased the LoR of NH_X 10-fold from 0.01 to 0.1 mg/L, hence a reasonable assessment of compliance of these waters to the ANZECC (2000) default guideline could not be made.

Similarly, matrix effects by salinity were not properly accounted for by the laboratory, which unfortunately also increased the LoR of TN from 0.1 to 1 mg/L and TP from 0.01 to 0.1 mg/L. Hence, the TN and TP data are not reported.

3.2.2 Dissolved Metals

LoRs of the dissolved metals were near, but generally greater than the ANZECC (2000) default guidelines at site S2. All of the dissolved metals except for copper were below their LoRs, which suggests compliance with the ANZECC (2000) guidelines. However, copper was nearly 10-fold greater than the ANZECC (2000) default guideline, which suggests ‘naturally’ high concentrations in the inshore coastal waters of the study area.

3.2.3 Other Parameters

TSS in the inlet (5.7-9.7 mg/L) was considerably greater than in the marine waters (<0.5-1.5 mg/L), consistent with the turbidity measurements (section 3.1).

Chla was below the limit of reporting (<1 µg/L) at all the marine stations, but ranged from 3-6 µg/L in the two (2) inlet stations. One of the measurements in the Inlet (6 µg/L) was greater than the ANZECC (2000) default guideline for estuaries.

3.3 Continuous *In Situ* Logger Measurements

The continuous *in situ* logger measurements of water depth, temperature and salinity are shown in Figure 2.

Water level variations indicate that spring tide ranges were typically ~1 m and neap tides were typically ~0.5 m with twelve (12) and 24 hour tidal cycles.

Water temperatures at site L1 to the west of Cheyne Island ranged between 20.6 °C near the start of the deployment to 22.3 °C near the end of the deployment. Similarly, water temperatures at site L2 near the shoreline adjacent to the proposed seawater intake ranged between 20.6 °C near the start of deployment to 22.4 °C near the end of the deployment. Surprisingly, temperatures at both sites increased over the deployment period. Diel (i.e. 24 hr) temperature variations were typically 0.2-0.4 °C. The mean water temperature at both sites was similar (site L1 mean = 21.4±0.4 °C, site L2 mean = 21.5±0.4 °C).

Salinity over the first half of the deployment period is reported as biofouling of the sensors affected the conductivity measurements thereafter. Over the first half of the deployment salinity was approximately 35.5 psu at both sites.

Table 2 GHD February 15-16 water quality monitoring results. Pink shading indicates exceedance of ANZECC (2000) guidelines.

Parameters	Units	LOR	ANZECC (2000) Marine	ANZECC (2000) Estuarine	E1	E2	R1-SRF	R1-BOT	R2-SRF	R2-BOT	R3-SRF	R3-BOT	S1-SRF	S1-BOT	S2-SRF	S2-BOT	S3-SRF	S3-BOT	S4-SRF	S4-BOT
Date	---	---			13-2-11	13-2-11	15-2-11	15-2-11	16-2-11	16-2-11	16-2-11	16-2-11	15-2-11	15-2-11	15-2-11	15-2-11	15-2-2011	15-2-2011	16-2-2011	16-2-2011
Time	---	---			12:40:22	12:53:42	13:45:48	13:44:01	9:41:49	9:36:39	9:10:25	9:06:38	14:10:43	14:09:15	14:30:19	14:29:06	14:53:19	14:50:49	9:25:28	9:18:56
Depth	m				0.2	8.6	0.3	16.5	0.2	4.1	0.2	7.4	0.9	8.5	0.4	10.1	0.4	10.0		9.9
Water Position	---	---			Surface	Surface	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
Physico-chemical																				
Temperature	°C	---			20.45	21.77	21.23	20.96	21.04	21.01	21.08	21.02	21.29	21.19		21.28	21.26	20.95	21.06	21.05
Turbidity	NTU	---	1-2	1-2	4.4	8.4	0.9	1.4	0.8	0.7	0.5	0.9	0.9	1.3	0.5	0.9	1.1	1.2	0.9	2
DO	mg/L	---			11.14	10.56	7.57	7.82	7.53	7.42	7.34	7.35	7.22	7.32	7.45	7.45	7.59	7.7	7.41	7.34
DO Sat	% Sat	---	>90	90-110	140.6	136.4	100.9	103.6	101.4	99.5	99.4	96.7	96.2	97.5	99.3	99.0	100.7	101.8	99.6	98.6
Conductivity	µS/cm	---			36162	35728	43269	43149	47176	46967	41898	41887	42765	43328	42280	42249	41977	42747	46730	46778
TDS	mg/L	-			31400	31500	45400	42000	40700	42400	41800	42200	42500	41200	42000	43300	42000	41700	42700	41900
PAR (Average)	µE/m^2/s						540	173	241	150	259	148	505	134	478	169	201	114	356	152
LAC (calculated)	1/m	---	0.09-0.13	0.3-1.0	---	---	0.07	---	0.12	---	0.08	---	0.17	---	0.11	---	0.06	---	0.09	---
Nutrients																				
NH_X-N	mg/L	0.1[1]	0.005	0.04	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
NO_3-N	mg/L	0.01			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NO_2-N	mg/L	0.01			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
NO_X-N	mg/L	0.01	0.005	0.045	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TKN-N	mg/L	1[1]			NR[2]	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
TN-N	mg/L	1[1]	0.23	0.75	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
TP-P	mg/L	0.1[1]	0.02	0.02	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
FRP-P	mg/L	0.01	0.005	0.005	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Metals																				
Arsenic	µg/L	10			---	---	---	---	---	---	---	---	---	---	<10	<10	---	---	---	---
Cadmium	µg/L	1	0.7	0.7	---	---	---	---	---	---	---	---	---	---	<1	<1	---	---	---	---
Chromium	µg/L	10	4.4	4.4	---	---	---	---	---	---	---	---	---	---	<10	<10	---	---	---	---
Copper	µg/L	10	1.3	1.3	---	---	---	---	---	---	---	---	---	---	22[3]	22	---	---	---	---
Nickel	µg/L	10	7	7	---	---	---	---	---	---	---	---	---	---	<10	<10	---	---	---	---
Lead	µg/L	10	4.4	4.4	---	---	---	---	---	---	---	---	---	---	<10	<10	---	---	---	---
Zinc	µg/L	50	15	15	---	---	---	---	---	---	---	---	---	---	<50	<50	---	---	---	---
Mercury	µg/L	0.1	0.1	0.1	---	---	---	---	---	---	---	---	---	---	<0.1	<0.1	---	---	---	---
Other																				
TSS	mg/L	<0.5			5.7	9.7	1.4	<0.5	0.6	0.5	<0.5	0.7	1	1.5	0.6	0.8	<0.5	1.5	<0.5	<0.5
Chlorophyll a	µg/L	<1	0.7	3	3	6	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	---

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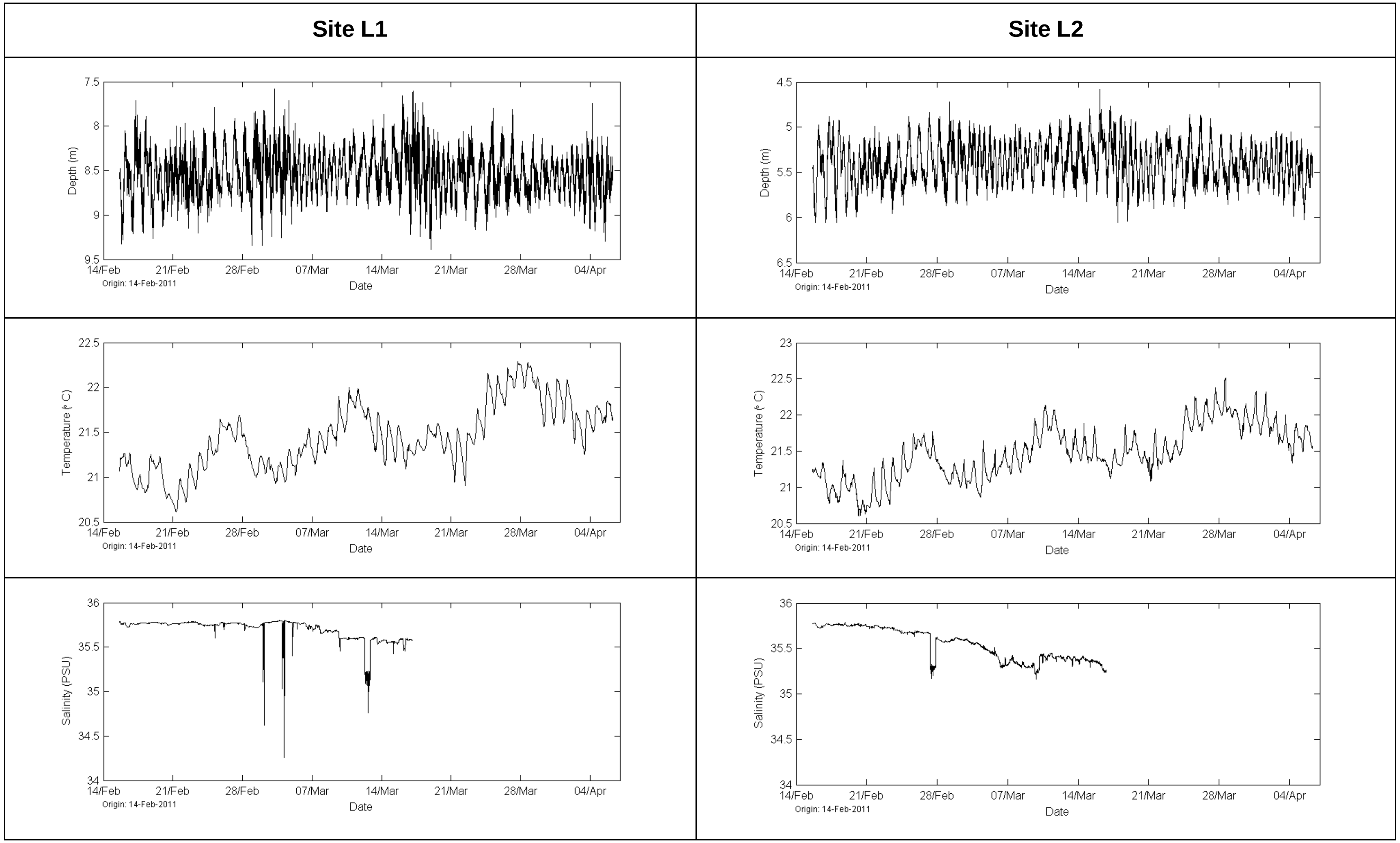
[1] LOR raised due to possible matrix effect from 0.01 to 0.1 mg/L for NH_X and TP and from 0.1 to 1 mg/L for TN and TKN.

[2] Not reported because of matrix effects from marine salinity levels not accounted for by the laboratory.

[3] See section 4.1 where March 2010 copper values at S2 from alternative labs (NMI, MAFRL) indicate copper results from ALS are suspect.

Figure 2 Continuous *in situ* measurements of water depth (top), temperature (middle) and salinity (bottom) as sites L1 (left) and L2 (right).



4. Discussion

4.1 Cheyne Bay Water Quality Comparison of with Previous Monitoring

A comparison of previous quarterly monitoring during 2009 over one (1) year (16 February, 13 May, 11 August and 1 December) (360 Environmental 2010a) and this study is provided in Table 3. Water temperatures, percentage DO saturation, TDS, LAC, Cu and chla values were similar between February 2009 and February 2011. The quarterly sampling during the 2009 surveys indicate water temperatures and TDS decreased to at least 15.5 °C and 31,200 mg/L, respectively.

Table 3 Comparison between 2009 and February 2011 water quality monitoring.

	Period	**All 2009**		**16 February 2009**		**15-16 February 2009**		**15-16 February 2009**	
	Stations	**Marine**		**Marine**		**Marine**		**Inlet**	
	Source	**360 Environmental**		**360 Environmental**		**GHD**		**GHD**	
Parameter	**Units**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
Physico-Chemical									
Temp	°C	15.52	21.64	21.09	21.64	20.95	21.29	20.45	21.77
Turb	NTU	0	10.3	0	10.3	0.5	2	4.4	8.4
DO Sat	% Sat	91.5	113.9	91.5	103.2	96.2	103.6	136.4	140.6
TDS	mg/L	31200	64000	41800	45000	41887	47176	35728	36162
LAC	1/m	0.04	0.16	0.07	0.16	0.06	0.17	NA	NA
Nutrients									
TN	mg/L	0.07	0.17	0.09	0.17	NR[4]	NR	NR	NR
TP	mg/L	<0.005	0.017	0.01	0.017	NR	NR	NR	NR
Dissolved Metals									
Cu	ug/L	7	21	17	21	22	22	NA	NA
Other Parameters									
TSS	mg/L	0.5	9.1	2.4	9.1	<0.5	1.5	5.7	9.7
Chla	µg/L	0.1	1.2	0.4	1.2	<1	<1	3	6

Comparisons between TN and TP could not be made because matrix effects from elevated marine salinities were not properly accounted for by the laboratory for the 2011 samples. However, based on the 360 Environmental (2010a) TN and TP measurements, it is clear that the marine waters are below the 0.23 mg/L and 0.02 mg/L ANZECC (2000) default guidelines in Cheyne Bay during 2009. Further LAC in the marine waters span a similar range and are generally below the ANZECC (2000) default guideline (0.13 1/m).

In both datasets copper was the only metal that exceeded the ANZECC (2000) guideline of 0.0013 mg/L, and by a considerable amount, which suggests high 'natural' background levels. However, because levels were well above the ANZECC (2000) guideline value, additional samples were collected on 16 March 2010 at station S2 and sent to two (2) independent labs (NMI and MARFL), which indicated copper was below these laboratories LoR of 1 µg/L (360 Environmental 2010b). Hence, this suggests that elevated copper levels are suspect, so copper is considered to be below 1 µg/L and below the ANZECC (2000) default guideline.

For the most part chla was below or near the ANZECC (2000) default guideline (0.7 µg/L).

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[4] Not reported because of matrix effects from marine salinity levels not accounted for by the laboratory.

4.2 Water Quality Comparison between Bay and Inlet

The primary differences between the Inlet and Bay waters were the TDS (and conductivity), turbidity (and TSS) and chla (Table 3).

4.2.1 TDS/Salinity/Conductivity

TDS (or conductivity or salinity) of the coastal inshore waters of the Bay in the study area are relatively stable around 35.5-35.7 psu (Figure 2). Autonomous Glider deployments from 16 November to 5 December 2010 and 9 February to 8 March 2011 had salinity ranges of 35.6-35.8 psu (GHD 2011a). The range of salinity measured over the 2009 quarterly monitoring was 35.5-36.3 psu with a seasonal range of 0.8 psu (360 Environmental 2010a).

Salinity variations in Cheyne Inlet are expected in response to the following mechanisms:

- Salinity approaches seawater values after the sandbar is breached and surface water inputs are low;
- Salinity decreases from rainfall and surface water inputs from the Eyre River; and
- Salinity increases from evaporation during summer periods and marine exchange below the sandbar.

During the February 2011 survey the TDS in the Inlet was less saline (~35 g/L) than the marine waters (~45 g/L). As these measurements were collected at the end of summer, this suggests that freshwater (or brackish) inputs into the inlet are sufficient to maintain salinities lower than seawater throughout the year. A substantial episodic decrease in TDS (or salinity) following a rainfall-induced breach of the Cheyne Inlet sandbar poses an operational concern because of the relative proximity of the proposed seawater intake.

4.2.2 TSS/Turbidity

Similarly, though TSS (and turbidity) during the February 2011 survey was low in the Bay, it was substantially greater in the Inlet (Table 3). This may in part be caused by the elevated chlorophyll-a levels in the Inlet (3-6 µg/L) relative to the Bay waters (<1 µg/L). The seagrass distribution in Cheyne Bay (GHD 2011b) indicates that the turbidity climate is low that allows sufficient light penetration to the seabed.

Hence, from an operational perspective, the concern would be a substantial episodic increase in TSS (and turbidity) following a rainfall-induced breaching of the Cheyne Inlet sandbar because of its relative proximity to the proposed seawater intake channel. An episodic increase the TSS (and turbidity) following a rainfall-induced breach of the Cheyne Inlet sandbar poses an operational concern because of the relative proximity of the proposed seawater intake.

4.3 Seagrass Wrack

Seagrass wrack was observed along the Inlet beach during both survey periods. Seagrass wrack may pose an operational concern because of the relative proximity of the proposed seawater intake.

4.4 Rising Water Temperatures from Summer to Autumn

Surprisingly, the continuous *in situ* loggers in Cheyne Bay measured increasing water temperatures from the end of summer (mid-February) to the start of autumn (beginning of March) (Figure 2). The two (2) main factors that influence ocean temperature within the region are air-water heat transfers and the Leeuwin current.

A comparison of the historical (1965-2010) to the recent 2010 (Nov.-Dec.) and 2011 (Jan.-Apr.) Albany Airport monthly air temperatures indicates that March had a higher mean maximum temperature than February and that April was nearly the same as February (Table 4). This is in contrast to historical climate data with decreasing temperatures from February through April. Hence, the anomalously cool February and warm March and April air temperatures likely contributed to the increase in water temperatures.

Table 4 Monthly air temperature over historical climate record from Albany Airport (1965-2011) and recent 2010 (Nov.-Dec.) and 2011 (Jan.-Apr.) measurements (BoM 2011).

Parameter	Nov	Dec	Jan	Feb	Mar	Apr	Dataset
Mean Max T (°C)	20.8	23.1	24.7	24.9	24.1	21.8	1965 – 2011
Mean Min T (°C)	10.8	12.5	13.7	14.4	13.4	11.6	1965 – 2011
Mean Max T (°C)	22.9	21.3	25.3	23.8	25.1	23.6	2010-2011
Mean Min T (°C)	11.8	13.6	14.9	16.7	13.4	11.7	2010-2011

Further, the Leeuwin Current had higher than average water temperatures over the 2010-2011 summer and it penetrated further south because of the strong La Nina conditions. This has had a large impact on the sea temperatures in the region.

Hence, the combination of the cool February and high March and April air temperatures, and higher water temperatures from the Leeuwin Current are the likely contributing factors to the observed increase in water temperatures over the logger deployment period within Cheyne Bay.

5. Conclusion

For the most part the inshore coastal waters of the study area meet the default ANZECC (2000) guidelines. Hence, the water quality of the coastal waters is good from both an ecological and desalination source water perspectives.

When the Inlet sandbar is breached due to rainfall-induced surface flows, the expectation is that the relatively fresh and turbid waters may impact the desalination plant source water quality from the proposed seawater intake channel to the west. Further, seagrass wrack may also pose some operational constraints for the seawater intake.

6. References

360 Environmental (2010a) Cape Riche Marine Water Quality Monitoring: Supplementary Report. Prepared for Grange Resources, Doc. No. A121-4 AN. January 2010.

360 Environmental (2010b) Cape Riche Marine Water Quality Monitoring Survey Report. Prepared for Grange Resources, Doc. No. A121-4 AQ. April 2010.

ANZECC (2000) National Water Quality Management Strategy: Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

BoM (2011) Bureau of Meteorology, Station number 9741 at Albany Airport, climate online data at http://www.bom.gov.au/ (Accessed 13-5-2011 @ 08:00am)

GHD (2011a) Cape Riche Seawater Desalination Plant: Autonomous Glider Monitoring. Report for Grange Resources, Doc. No. 61/26005/110725, May 2011

GHD (2011b) Cape Riche Seawater Desalination Plant: Cheyne Bay Benthic Habitat Assessment. Report for Grange Resources, Doc. No. 61/26005/110725, May 2011.

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