

Appendices

Appendix B – Surface water chemistry

Sample		EC	PH	Temp	DO	DO	TDS	TSS	TS	WAD	Aluminium	Cadmium	Cobalt	Copper	Chromium	Iron	Lead	Manganese	Mercury	Nickel	Zinc	Calcium	Sodium	Magnesium	Hardness	onate Alkali	tal Alkalini	Sulphate	Chloride				
Description		(µS/cm)			(mg/L)	% Sat	(grav)	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mgCaCO ₃ /l	CaCO ₃	as CaCO ₃	mg/L	mg/L				
SW13		38.2	6.05	30.5	3.89			30	5		99	0.1	<1		1	700	<1	110	<0.1		1	1	1.2	1	1.7	10	13	13	<1	2			
SW13	5/12/2011	34.1	7.06	34.7	7.25			6	30		35	<0.1	<1		2	500	<1	22	<0.1	<1		6	0.8	1.1	0.9	6	9	9	<1	4			
SW13	11/01/2012	20	5.75	32.2	6.75			5	10		18	<0.1	<1		1	110	<1	20	<0.1	<1		10	0.6	1.4	0.6	4	5	5	2	<1			
SW13	14/02/2012	20.2	6.68	33.8	7.26			5	9		5	<0.1	<1	<1	<1	98	<1	16	<0.1	<1		1	<0.5	1.1	0.5	3	4	4	<1	<1			
SW13	15/03/2012	11.3	6.41	29.4	6.33			18	40		33	<0.1	<1	<1	<1	73	<1	9	<0.05	<1		1	<0.5	1.1	0.5	3	5	5	<1	<1			
SW13	10/04/2012	23.9	5.86	31.5	7.37			5	5		27	<0.1	<1	<1	<1	130	<1	12	<0.05	<1		3	<0.5	1.4	0.5	3	9	9	<1	<1			
SW13	9/05/2012	14.9	6.66	28.6	5.11			5	14		22	<0.1	<1	<1	<1	100	<1	14	<0.1	<1		1	<0.5	1.7	0.6	3	10	10	<1	1			
SW13	14/06/2012	28.6	6.76	26.9	5.62			5	20		23	<0.1	<1	<1	<1	120	<1	12	<0.1	<1		1	<0.5	2.5	0.7	3	6	6	<1	1			
SW13	8/01/2013	28	7.49	32.9	4.79	64.7		5	160		<0.004	<0.1	<1	<1	<1	460	<1	8	<0.05	<1		2	1.2	1.2	1.1	8	13	13	<1	1			
SW13	10/03/2013	19.9	6.17	31.3	6.84	92.8		5	16	16	<0.004	20	<0.1	<1	<1	130	<1	20	<0.05	<1		1	<0.5	1.2	0.5	3	9	9	<1	1			
SW13	8/04/2013	15.4	5	30.2	7.06	93.2		7	32	39	<0.004	27	<0.1	<1	<1	69	<1	23	<0.05	<1		1	<0.5	1.2	0.5	3	13	13	<1	<1			
SW13	7/05/2013	18.4	5.83	27.9	7.01	89.8		6	35	41	<0.004	44	<0.1	<1	<1	160	<1	10	<0.05	<1		1	<0.5	1.8	0.9	3	11	11	<1	1			
SW13	4/06/2013	24.3	7.18	28.7	7.93	102.6		5	44	44	<0.004	37	<0.1	<1	2	170	<1	15	<0.05	<1		1	<0.5	2.6	0.9	3	10	10	<1	1			
SW13	3/12/2013	32.7	5.85	36.5	5.6	8.19		6	79	82	<0.004	240	<0.1	<1	<1	330	<1	41	<0.05	<1		1	0.9	1.3	1.2	7	13	13	<1	<1			
SW13	7/01/2014	29.2	6.07	36.6	7.15	106.1		5	29	29	<0.004	23	<0.1	<1	<1	360	<1	15	<0.05	<1		1	1.1	1.2	1.2	7	10	10	<1	2			
SW13	4/02/2014	13.6	5.32	28	7.29	93		27	22	49	<0.004	68	<0.1	<1	<1	98	<1	13	<0.05	<1		4	<0.5	1.3	0.5	3	6	6	<1	<1			
SW13	4/03/2014	12.2	5.45	30.4	6.77	90.3		5	16	16	<0.004	27	<0.1	<1	<1	110	<1	14	<0.05	<1		1	<0.5	1	0.5	3	7	7	<1	<1			
SW13	1/04/2014	16.6	5.93	33.1	6.52	91.1		19	38	57	<0.004	35	<0.1	<1	<1	150	<1	6	<0.05	<1		1	<0.5	0.5		3	8	8	<1	1			
	Count	18	18	18	18	10		18	18	9	BDL	17	BDL	BDL	4	BDL	18	BDL	18	BDL	BDL	BDL	18	BDL	6	18	17	18	18	18	BDL	1	10
	Minimum	11.3	5	26.9	3.89	8.19		5	5	16		5			1	69		6				1	0.6	0.5	0.5	3	4	4	2	1			
	Median	20.1	6.06	30.9	6.805	91.95		5	25.5	41		27		1.5	130		14.5				1	1	1.2	0.6	3	9	9	2	1				
	Maximum	38.2	7.49	36.6	7.93	106.1		30	160	82		240		2	700		110		10			10	1.2	2.6	1.7	10	13	13	2	4			
	20th%ile	14.64	5.69	28.48	5.502	69.72		5	9.8	16		21.2		1	98		9.8		1			1	0.68	1.08	0.5	3	5.8	5.8		1			
	80th%ile	29.9	6.82	33.98	7.266	100.72		18.2	40.8	57		53.6		2	380		22.2					3.2	1.2	1.72	1.14	7	13	13		2			

Sample	Date Sampled	EC	PH	Temp	DO (mg/L)	DO % Sat	TSS mg/L	TDS mg/L	TS mg/L	Cyanide mg/L	Aluminium µg/L	Arsenic µg/L	Cadmium µg/L	Cobalt µg/L	Chromium µg/L	Copper µg/L	Iron µg/L	Lead µg/L	Manganese µg/L	Mercury µg/L	Nickel µg/L	Uranium µg/L	Zinc µg/L	Magnesium mg/L	Sodium mg/L	Chloride, Cl mg/L	Calcium mg/L	Sulphate, SO4 mg/L	Total Alkalinity mg/L	Carbonate Alkalinity mg/L	Hardness mgCaCO3	
SW2	10/07/2012	15	6.9	2.4	7.22	81.2	<5	41			10	<1	<0.1	<1	<1	<1	130	<1	2.5	<0.1	<1	<0.5	1	0.5	<0.5	1.7	2	<0.5	<1	<5	<5	<3
SW2	13/08/2012	14	6.55	20.8	7.03	76.8	<5	32	<0.004		5	<1	<0.1	<1	<1	<1	110	<1	2.5	<0.1	<1	<0.5	1	0.5	<0.5	1.7	1	<0.5	<1	7	7	<3
SW2	10/09/2012	15.3	6.74	26.8	3.76	46.6	<5	14	<0.004		30	<1	<0.1	<1	<1	<1	150	<1	10	<0.05	<1	<0.5	1	0.5	<0.5	1.7	1	<0.5	<1	5	5	<3
SW2	15/10/2012	21.6	6.68	39.2	5.78	73.4	<5	15	<0.004		5	<1	<0.1	<1	<1	<1	180	<1	16	<0.05	<1	<0.5	110		1.8	2	0.7	<1	9	9	4	
SW2	12/11/2012	26	6.68	31.5	3.5	48.2																										
SW2	10/12/2012	26.4	6.24	31.2	6.25	84.2	<5	12	<0.004		5	<1	<0.1	<1	<1	<1	230	<1	15	<0.05	<1	<0.5	5	0.8	1.7	2	0.8	<1	8	8	5	
SW2	7/01/2013	27.1	5.72	33.1	6.34	89.1	<5	28	<0.004		5	<1	<0.1	<1	<1	<1	240	<1	11	<0.05	<1	<0.5	140	0.6	1.5	2	0.7	<1	28	28	4	
SW2	5/02/2013	24.8	6.32	32.5	6.12	82.7	<5	150	<0.004		33	<1	<0.1	<1	<1	<1	270	<1	13	<0.05	<1	<0.5	4	1	2.1	2	1.4	<1	18	18	8	
SW2	9/03/2013	20.8	6.37	29.6	6.51	85.6		5	46	<0.004	15	<1	<0.1	<1	<1	<1	220	<1	8	<0.05	<1		0.5	0.8	1.6	1	<0.5	<1	12	12	3	
SW2	6/04/2013	15.9	5.44	30.4	7.17	95.6		6	17	<0.004	58	<1	<0.1	<1	<1	<1	160	<1	5	<0.05	<1		0.5	<0.5	1.2	1	<0.5	<1	15	15	<3	
SW2	6/05/2013	19.8	5.85	27.8	7.2	91.8	<5	42	<0.004		23		<0.1	<1	<1	<1	190	<1	6	<0.05	<1		0.5	0.6	1.5	2	<0.5	<1	11	11	3	
SW2	6/05/2013								<0.004				[NT]							<0.05												
SW2	4/06/2013	16.4	6.5	23.1	7.17	83.6	<5	35	35	<0.004	15	<1	<0.1	<1	<1	2	170	<1	9	<0.05	<1		7	0.6	1.9	2	<0.5	<1	6	6	<3	
SW2	1/07/2013	13.9	6.04	21.1	8.05	90.6	<5	50	50	<0.004	5	<1	<0.1	<1	<1	<1	160	<1	5	<0.05	<1		2	<0.5	1.6	1	<0.5	<1	6	6	<3	
SW2	1/07/2013										5	<1	<0.1	<1	<1	<1	160	<1	2.5		<1											
SW2	6/08/2013	14	5.66	21.9	8.38	95.3	<5	15	15	<0.004	5	<1	<0.1	<1	<1	<1	140	<1	5	<0.05	<1		1		1.7	1	<0.5	<1	6	6	<3	
SW2	2/09/2013	16.2	5.55	26	6.31	7.77	<5	20	20	<0.004	5	<1	<0.1	<1	<1	<1	150	<1	13	<0.05	<1		0.5	<0.5	1.4	1	<0.5	<1	7	7	<3	
SW2	1/10/2013	18.5	5.52	28.8	5.59	72.2	<5	21	21	<0.004	5	<1	<0.1	<1	<1	2	170	<1	20	<0.05	<1		3	<0.5	1.6	2	0.6	1	7	7	<3	
SW2	3/11/2013	24.2	5.82	30.7	4.95	66.2		5	47	<0.004	5	<1	<0.1	<1	<1	<1	330	<1	27	<0.05	<1		1	0.9	2	2	1.4	<1	10	10	7	
SW2	3/11/2013										5	<1	<0.1	<1	<1	<1	390	<1	27		<1		1									
SW2	3/12/2013	27.3	5.62	29.6	6.18	81.2	<5	81	81	<0.004	40	<1	<0.1	<1	<1	<1	340	<1	27	<0.05	<1		0.5	0.9	1.7	2	0.8	2	9	9	5	
SW2	7/01/2014	22	5.61	29.9	5.68	75	<5	43	40	<0.004	14	<1	<0.1	<1	<1	<1	300	<1	16	<0.05	<1		2	0.8	1.7	2	0.7	<1	8	8	5	
SW2	3/02/2014	13.9	5.79	28.9	6.24	75.7		14	46	<0.004	65	<0.1	<1	<1	<1	1	130	<5	7	<0.05	<1	0.6	0.5	7	4	<5	7	0.5	<1			
SW2	3/03/2014	14.2	5.63	30.7	6.14	80.6	<5	28	28	<0.004	30	<1	<0.1	<1	<1	<1	190	<1	6	<0.05	<1		3	<0.5	1.1	0.5	<0.5	<1	8	8	<3	
SW2	2/04/2014	17.7	5.75	29.9	6.56	86.3	<5	62	62	<0.004	5	<1	<0.1	<1	<1	<1	310	<1	5	<0.05	<1		0.5	0.7	1.6	2	<0.5	<1	9	9	3	
SW2	2/04/2014										5	<1	<0.1	<1	<1	<1	310	<1	5		<1		0.5									
											BDL																					
	Count	22	22	22	22	22		4	21		14	BDL	BDL	BDL	BDL	BDL	24	BDL	23	BDL	BDL	BDL	24	11	20	21	BDL	BDL	19	19	10	
	Minimum	13.9	5.44	2.4	3.5	7.77		5	11		5						110		2.5				0.5	0.6	1.1	0.5	0.5	5	5	3		
	Medium	18.1	5.835	29.6	6.28	81.2		5.5	32		41						185		9				1	0.8	1.7	2	0.7	8	8	4.5		
	Maximum	27.3	6.9	39.2	8.38	95.6		14	150		81						390		27				140	4	2.1	7	1.4	28	28	8		
	20th%ile	14.12	5.616	22.62	5.644	69.8		5	20		20						148		5				0.5	0.6	1.5	1	0.6	6	6	3		
	80th%ile	25.28	6.602	31.32	7.182	89.7		14	48.8		30						310		16.8				5	0.96	1.78	2	1.4	12	12	6.6		

Appendix C – Surface Water Monitoring Program



Surface Water Monitoring Procedure

1. Purpose

This procedure details the collection of surface water samples for compliance to the WDL 178-2 and monthly sampling to provide information for the management of discharges from designated sites.

Current sampling locations are shown in Figure 1.

This procedure details sample collection and analysis, quality, documentation, and reporting. The primary reason for surface monitoring programs is to obtain chemical and physical system attributes that allows sample results to be analysed for:

- Identification of contaminant sources;
- Regulation of activities to ensure compliance with the Mining Management Plan, and Waste Discharge Licence (WDL 178-2) commitments;
- Assessment of water quality against the dilution factors for RP3, RP1 and RP7, interim site specific trigger values (ISSTVs) (GHD 2012), defined guidelines and standards such as the Australian and New Zealand Environment and Conservation Council (ANZECC & ARMCANZ 2000) water quality guidelines for ecosystem protection;
- Development and refinement of water management plans, site water balances, and rehabilitation strategies; and
- Demonstration of environmental due diligence and measure future improved environmental performance.
- Investigate options to manage any identified impacts that result from the discharge.

2. Scope

The scope of this procedure applies to:

- Discharge of waste water into the Edith River from Vista Gold Australia Pty Ltd Mount Todd Project Mine Lease Northern (MLN) number 1071 which also receives surface waters from within MLN 1070; and
- Other monitoring programs that aid progress in meeting the water management objectives.

3. Legal framework

The principal articles of legislation dealing with surface and ground water monitoring at the Mt Todd Project site are:

- The NT Water act 2004;
- The NT Mining Act; 1980 and
- The NT Mining Management Act, 2008.

4. Standards

The following documents were used in the development of this procedure.

- AS/NZS 5667.1:1998 Water quality – Sampling. Part 1: Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples.
- AS/NZS 5667.4:1998 Water quality – Sampling. Part 4: Guidance on sampling from lakes, natural and man-made.

- AS/NZS 5667.6:1998 Water quality – Sampling. Part 6: Guidance on sampling of rivers and streams.

5. Site Safety when Collecting Samples

Surface water (SW) monitoring sites should be kept free from anything which may provide a risk whilst collecting samples. If a site provides a risk of any nature, it should be noted on the field data sheet, with the Environmental Manager notified upon the field staff members' return. All sample sites listed in this SOP have been assessed under Vista Gold Safety and Risk Assessment Procedures, including site specific job safety environmental assessments. Any new sites will be assessed by the Environmental Manager and/or Site Safety Supervisor under existing OH&S protocols as required.

A range of factors may preclude sampling on a given day; potentially including safety (access / flooding) and/or environmental reasons.

Any incidents should be reported to the Environment Manager immediately.

6. Ordering Sample Bottles

Clean sample bottles are required and available through Envirolab Services. Envirolab Services (Aileen Hie) can be contacted on 02 9910 6200 or email ahie@envirolabservices.com.au.

Order clean sample bottles sufficient for the number of samples plus field duplicates (plus spares). The bottles required for each sampling event are shown in Table 1.

Table 1. Bottles Required

Monthly Surface Water per Sample (17 sites)	
1 x 500mL Plastic Unpreserved (Green Label)	TSS, TDS, Anions, Cations, Hardness, (DOC, TOC: SW2, SW4only)
1 x 60mL Plastic NaOH Preserved (Blue Label)	WAD CN
1 x 60mL Plastic HNO ₃ Preserved (Red Label)	Total Metals
1 x 60mL Plastic HNO ₃ Preserved (Red Label)	Dissolved Metals (field filter and tick label)
1 x 100 mL Plastic Unpreserved (Green Label)	NO ₃ and PO ₄ (field filter and freeze. SW2, SW4 only)
1 x 200mL Glass Unpreserved (Green Label)	TRH (C10-C36)
Daily Waste Discharge per Sample (3 sites)	
1 x 500mL Plastic Unpreserved (Green Label)	Anions, Cations, Hardness, TDS, TSS, (DOC, TOC: SW2, SW4 only)
1 x 100mL Plastic NaOH Preserved (Blue Label)	WAD CN and Cr VI
1 x 60mL Plastic HNO ₃ Preserved (Red Label)	Total Metals
1 x 60mL Plastic HNO ₃ Preserved (Red Label)	Dissolved Metals (field filter and tick label)
1 x 100 mL Plastic Unpreserved (Green Label)	NO ₃ and PO ₄ (field filter and freeze. SW2, SW4 only)
1 x 100mL Plastic Unpreserved (Green Label) – SW4 only	For Location SW4 (in case Chelex needed)

7. Equipment

Equipment to be used to collect samples must be appropriately cleaned and decontaminated, field meters should be calibrated according to the manufacturer's instructions and sufficient sample bottles prepared.

7.1 Calibration of Equipment

Daily calibration of the pH meter, EC meter and DO meter is required following YSI User Manual procedures. A calibration sheet is attached to this SOP.

Equipment Required:

- YSI ProODO: Dissolved Oxygen (% saturation and ppm)
- YSI pH100: pH (pH units)
- YSI EC300: Conductivity ($\mu\text{S}/\text{cm}$)

Note: It is important to carry the water meter manuals for troubleshooting purposes.

pH: The pH meter should be calibrated according to the manufacturers requirements, using a two point calibration with buffers of pH 4 and 7. Calibration standards should be stored appropriately (e.g. do not exceed "use by" dates, refrigeration) to ensure their accuracy.

Temperature: The temperature of the water to be sampled will change throughout the day and influence parameters such as pH and dissolved oxygen. Temperature will move toward ambient upon sampling so should be recorded as soon as a stable reading is obtained after collection.

Conductivity: The electrical conductivity (EC) of the water is a measure of the concentration of chemical ions in the water. The total dissolved solids in the sample water can be calculated from this reading using the following formula:

$$\text{TDS (mg/L)} = 0.5 * 1000 * \text{EC mS/cm}$$

As with pH measurement, calibration of conductivity meters should be performed using standards of a known concentration appropriate to the anticipated range of conductivity of the water to be sampled (i.e. 146.9 $\mu\text{S}/\text{cm}$ for fresh water off site and 1.413 mS/cm for Retention Pond [RP] water). Calibration standards should be stored appropriately (e.g. do not exceed "use by" dates, refrigeration) to ensure their accuracy.

Dissolved Oxygen: The amount of dissolved oxygen in a sample can vary with depth, temperature, and biological demand. Measurements of dissolved oxygen can be most accurately obtained by placing the probe directly into the water body to be sampled in an area with flow or moved, not too vigorously, to simulate flow.

7.2 Other Items Required for Field Sampling

- Clipboard and pencil;
- Labelled sample bottles;
- Chain of Custody form;
- A copy of this procedure;
- Field sample collection sheets;
- A reach pole or bailer and rope for hard to reach areas;

- Plastic syringe, filter cup and 45 µm filter papers for dissolved metals filtration in the field (*you may need 2–3 filters per sample depending on suspended solids*);
- Powder-less nitrile gloves (blue);
- Powder-less latex gloves (white);
- Permanent marker;
- Clear sticky tape;
- Esky with ice bricks;
- Decon 90; and
- Personal Protective Equipment, first aid and communication equipment.

8. Field Sample Collection Sheet Details

At each sample location, details relevant to the subsequent analysis and interpretation are recorded on the field sheets. Information recorded on the field sheets includes:

- Name and location of sampling point;
- Date and time of sample collection;
- Any relevant descriptive information, e.g. water level/flow;
- Sample appearance at the time of collection, eg colour, clarity and odour;
- Field parameters measured or results of any on site analysis (EC, pH, DO & Temp); and
- Sample treatment post collection, eg filtration, preservation, analysis required.

9. WDL 178-2 Surface Water Monitoring Locations

The surface water monitoring program is a requirement of WDL 178-2 (commencing xxxx and expiring xxxx) and is outlined in Sections X and Appendix X of the licence.

Presented in Table 2 are the authorised monitoring points for the Surface Water Monitoring Program. The points are also illustrated in the map presented in Figure 1.

Table 2 Authorised Monitoring Points

Authorised Monitoring Point	Description	Location
SW 2	Edith River at Bridge on Edith Falls Road	Easting: 0189088 Northing: 8431347
SW 4	Gauge station on Edith River downstream of RP1 siphons (Burrell Creek) and RP1 Spillway (West Creek), near boundary of mine property	Easting: 0186745 Northing: 8431490
SW 10	Edith River at old Stuart Highway Causeway	Easting: 0179781 Northing: 8430015

9.1 Parameters

Parameters to be monitored from WDL 178-2 are listed in Table 3.

Table 3 Parameters to Measure at Sample Locations SW2, SW4, SW10 (WDL 178-2) Plus Additional Parameters for Mine Water Discharge Management

Parameter	Methodology	Comments
River Height at SW4	Gauging Station	
Flow/volume through siphon and spillway	Flow meter if available	
Estimated volume/flow via spillway	Rating table if flow meter not available	
Dissolved Oxygen	In-situ (% saturation)	
Temperature	In-situ (°C)	
Electrical Conductivity	In-situ (µS/cm)	
pH	In-situ (pH units)	
Aluminium ^{1,2}	Lab (µg/L)	
Cadmium ^{1,2}	Lab (µg/L)	Monitoring Value for RP3 discharge TBA
Cobalt ^{1,2}	Lab (µg/L)	
Copper ^{1,2}	Lab (µg/L)	Monitoring Value RP1 = 4.3 & RP7 =4.2
Chromium III ²	Lab (µg/L)	Only if total Cr over PQL
Chromium VI ²	Lab (µg/L)	Only if total Cr over PQL
Chromium ¹	Lab (µg/L)	
Iron ^{1,2}	Lab (µg/L)	
Lead ^{1,2}	Lab (µg/L)	
Magnesium ^{1,2}	Lab (mg/L)	
Manganese ^{1,2}	Lab (µg/L)	
Mercury ^{1,2}	Lab (µg/L)	
Nickel ^{1,2}	Lab (µg/L)	
Zinc ^{1,2}	Lab (µg/L)	Monitoring Value for RP3 discharge TBA
Sulfate	Lab (mg/L)	
Bicarbonate (HCO ₃)	Lab (mg/L)	
Unfiltered Alkalinity (CaCO ₃)	Lab (mg/L)	
Hardness	Lab (mg/L)	
Total Dissolved Solids	Lab (mg/L)	
Total Suspended Solids	Lab (mg/L)	
Total Solids	Lab (mg/L)	
Sodium	Lab (mg/L)	

Parameter	Methodology	Comments
Chloride	Lab (mg/L)	
Calcium	Lab (mg/L)	
WAD Cyanide	Lab (µg/L) Monthly	
Total Organic Carbon	Lab (mg/L)	SW2 and SW4
Dissolved Organic Carbon	Lab (mg/L)	SW2 and SW4 (additional to WDL)
NO ₃	Lab (mg/L)	SW2 and SW4 (additional to WDL)
PO ₄	Lab (mg/L)	SW2 and SW4 (additional to WDL)

¹Total specific metal analysis ²Dissolved metal analysis filtered through a 0.45 micrometre (µm) filter
TBA = To be advised

9.2 Sample Frequency

The frequency and timing of sample events required by site and by parameter are presented in Table 4.

Table 4 Timing of Sampling Events for Sample Types (WDL 178-2)

Sampling Point	Field Parameters (pH, EC, Temp, Flow, DO)	Total, filtered metals and metalloids	Other major cations/anions	WAD CN
SW 2	A	A	A	B
SW 4	A	A	A	B
SW 10	A	A	A	B

A Daily (when discharging); and 1 week after the cessation of discharge; and monthly during flow (November, December, January, February, March and April); and once during the period of first flush
B Monthly during the wet season (November, December, January, February, March and April)

10. Surface Water Monitoring for Mt Todd Surrounds

The following sample sites have been identified to provide additional data for WDL 178-2, with the following provision:

- The sites are safely accessible in wet weather.

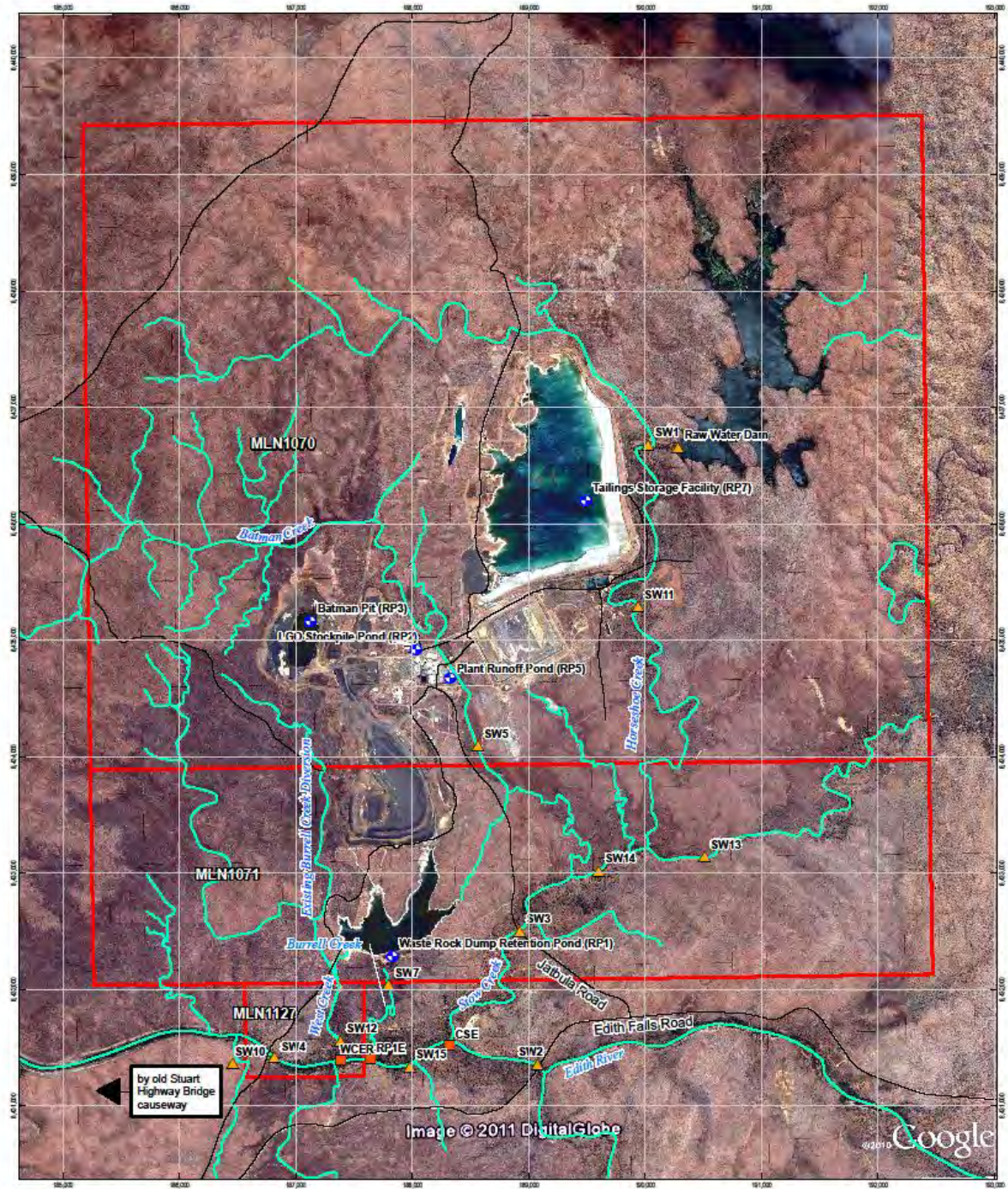
In addition to the SW2, SW4 and SW10, the sites listed in Table 5 are to be sampled. These sites are shown in Figure 1.

Table 5 Summary of Water Sampling Sites for Mt Todd Mine

Site	Water body
Raw Water Dam	
SW1	Raw water supply



Site	Water body
SW11	Horseshoe Creek
SW5	Batman Creek
SW3	Stow Creek
SW13	
SW14	
SW7	Burrell Creek
SW15	Edith River
SW12	West Creek
RP 7	Tailings storage area
RP3	Batman Pit
RP 1	Waste rock retention pond
Heap Leach Pad Moat	Heap leach pad



LEGEND

- Impoundment Sampling Location
- Mine to Edith River discharge point
- Surface Water Sampling Station
- Mt Todd Mining Leases
- Access Roads
- Waterways

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Grid: Map Grid of Australia 1994, Zone 53

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Vista Gold Australia Pty Ltd
Mt Todd Gold Project

Job Number: 43-21801
Revision: 0
Date: 16 Nov 2012

Location of Surface Water Sampling Figure 10-6

MT Todd reserves all rights in and to the map. GHD agrees to represent and warrant about its accuracy, reliability, completeness or suitability for any particular purpose and cannot accept liability and responsibility of any third parties in contact, verbal or otherwise) for any expenses, losses, damages and/or costs (including indirect or consequential damages) which are or may be incurred by any party as a result of the map being inaccurate, incomplete or unsuitable in any way and for any reason.
Data source: Google - Imagery (Date extracted: 28/03/2011), NRETA - Mining Leases (2011), GHD - Sampling Sites, Access Roads, Waterways (2012). Created by: CM

Figure 1 Sample Locations

10.1 Water Quality Parameters and Sampling Regime

Table 6 outlines the parameters to be monitored for each site shown above on a monthly basis.

Table 6 Parameters to be Monitored Monthly

Sample Sites	Parameter
Raw water dam, SW1, SW11, SW5, SW3, SW13, SW14, SW7, SW2, SW15, SW4, SW10, SW12, RP7, RP3, RP1, Heap Leach Pad Moat	
In situ	Flow
	Dissolved Oxygen (mg/L and % Saturation)
	Temperature (°C)
	Electrical Conductivity (µS/cm)
	pH
Laboratory	Total Suspended Solids (mg/L)
	Total Dissolved Solids at 180° C (mg/L)
	Total Organic Carbon, Dissolved Organic Carbon (SW2 and SW4 only)
	Unfiltered Alkalinity, bicarbonate, carbonate (mg/L)
	Major cations: Na, K, Ca, Mg (mg/L)
	Major anions: Cl, SO ₄ (mg/L)
	Nitrate and Phosphate (mg/L)
	Hardness (mg/L)
	Cyanide-WAD (µg/L)
	TRH C10 – C36 (µg/L)
	Dissolved Metals (0.45µm) (Al, As, Cd, Co, Cu, Cr, Fe, Pb, Mn, Hg, Ni, U, Zn) (µg/L)
Total Metals (Al, As, Cd, Co, Cu, Cr, Fe, Pb, Mn, Hg, Ni, U, Zn) (µg/L)	

11. Surface Water Sampling Monitoring Methodology

Sampling should only be undertaken by appropriately trained and experienced personnel. Preparation for a sampling event must include knowledge of and compliance with site Occupational Health and Safety protocols for the sampling activities, including familiarisation with relevant Material Safety Data sheets and precautions necessary for handling chemicals.

11.1 Procedure (*in situ* physico-chemical analysis)

Setup water quality meters and ensure they are functional and calibrated.

Place probes into the water body, ensuring there is at least 10 cm of water covering all probes and that the probes do not touch the bottom.

Wait at least 1 minute for the instrument to initialise, and then allow the parameters to stabilize.

Record time and other parameters on field sheets; including anything untoward including weather etc.

11.2 Procedure (laboratory samples for Envirolab Services)

Fill each sample bottle by transferring sample using a reach pole/bailer.

Note that one of the two red preserved metals bottle (dissolved) requires the sample to be field filtered through the 0.45 µm filter paper and syringe, as the sample is transferred into the bottle. This latter bottle will then be identified via the tick box on the label stating it is to be analysed for dissolved metals.

Label each sample bottle, ensuring that the following information is provided:

- Date
- SW site
- Sampler's initials
- Analysis required; (distinguishing total or dissolved metals on preserved red bottles)

Note that two blind field duplicate samples will be collected for analysis by Envirolab.

11.4 Collection for Analysis

The choice of sample collection device is influenced by the nature of the sample site and the type of sample required. For example, a sample pole and container may be necessary where steep banks make accessing the water a safety risk. A clean pair of gloves should be worn at each sample site to minimise potential contamination problems. To collect a grab sample from shallow water body or a channel of flowing water:

Select a point in the stream that is downstream of any channel braiding or inputs from tributaries to allow thorough mixing.

Remove sample container lid (for locations with known very low concentrations of analytes this may need to be performed beneath the surface of the water to reduce contamination risk)

Immerse sample container with the opening pointing directly down to maintain a volume of air in the container, thereby avoiding the collection of any surface films.

Once under the surface of the water point the mouth of the sample container up stream so that gloved hands, sample container and/or sample collection device is downstream of the sample being collected.

When sampling from a shallow water body, where possible select a point that is a reasonable distance from the edge. If the water is still (or flowing very slowly) move the sample container forward away from the sampler and any equipment to collect a continuous uncontaminated sample.

Fill container, rinse and empty rinse water downstream or at a sufficient distance from sample site to prevent mixing of rinse water with the water to be sampled. Repeat.

Fill container completely to exclude air and replace cap.

Perform necessary filtration and/or preservation procedures, ensuring that sufficient sample is collected to perform the required analyses and any repeat analyses necessary.

Complete sample labels and field data sheets.

11.4.1 Grab Sampling

Grab samples can be collected using a hand-held plastic scoop or bottle, depending on the depth of water, and if required, composited into a narrow-mouth plastic container. Volatile organic sample containers (inc TRH) should be filled directly from the source by dipping the sample container into the liquid. The remaining sample containers can be filled from the composite sample. Care must be taken to minimise aeration.

The procedure for grab sampling is normally as follows:

Place container by hand directly into water body, open end vertically down and fill with an arc motion with the bottle mouth facing upstream. Take care to avoid collecting surface films. For waters less than half a metre in depth, collect a grab sample at half the water depth. For waters greater than half a metre in depth, a grab sample should be taken at 20 to 30 cm below the surface water.

- If collecting a grab sample from a stream bank, weir or jetty:
 - select a sampling site which is representative of the stream;
 - avoid disturbance at the sampling site, particularly at the stream bank. If disturbance occurs
 - collect the sample upstream; and
 - collect grab sample as described previously.

11.4.2 To Collect a Grab Sample at Depth:

Specific depth sampling equipment is required, either pump and tubing, or sample collection device.

If the sample is to be pumped, ensure that sufficient volume has passed through the collection tubing to rinse the tube thoroughly.

Sample collection for field measurements and for laboratory analysis can then begin as previous.

11.4.3 Sample Storage and Transport

Place samples into an ice chilled esky and continue to next location; repeat. Once sampling run is completed; store samples prior to transport at 4°C in the fridge (be aware of holding times), When sufficient numbers of samples have been collected proceed by driving samples to Katherine for transfer and analysis.

A completed CoC form in a waterproof ziplock bag is to be placed in the esky with the samples.

Address for samples:

Envirolab Services
12 Ashley St
Chatswood NSW 2067
Phone: 02 9910 6200
Fax: 02 9910 6201
Aileen Hie (Client contact)

11.4.4 Sample Holding Times

Table 7 shows the hold times for each sample type. The laboratory must receive and analyse the samples within these time to ensure accuracy of the results.

Table 7 Sample holding times

Bottle Label	Tests	Bottle	Volume mL	Preservation	Holding Time
Green	TSS, TDS, anions, cations, hardness, DOC, TOC	Plastic	500	Cool to 4°C	TSS, TDS 7 d Others 28 d
Blue	WAD cyanide and Cr VI	Plastic	100	pH >12 (NaOH), cool to 4°C, dark	14 d (WAD CN) 40 d (Cr VI)
Red	Metals Dissolved and Total	Plastic	60	pH <2 (HNO ₃)	Metals 6 m Hg 28 d
Green	TRH	Glass	200	Cool to 4°C	7 d
Green	NO ₃ and PO ₄	Plastic	100	Filter and Freeze	28 d

12. Quality Assurance/Quality Control

To ensure the reliability and interpretability of the collected data, appropriate documentation has been incorporated into the monitoring program that records sample movement from collection to data reporting and ensures that analytical data is ascribed to the correct location (Chain of Custody documentation). Appropriate chain of custody information for collected samples commences with the completion of a "Field Sample Collection Sheet".

Once collected, samples are stored, handled, and transported in such a manner as to:

- prevent damage to containers or labels,
- minimise or eliminate degradation of the sample, and
- prevent contamination of the sample.

Upon delivery to the analytical laboratory, information relating to the time between sample receipt and analysis, storage and preservation methodology employed at the laboratory, and analytical technique is documented in the returned Chain of Custody, a Sample Receipt Advice and Certificate of Analysis documentation.

Quality Assurance (QA) practices applied during SW sample collection and analysis include:

- Field notes including *in situ* water quality parameters;
- Field equipment in-house calibration sheet;
- Sample holding times;
- Field blind duplicates (1 in 10);
- The use of NATA accredited laboratory;
- COC documentation. The Chain of Custody form tracks samples by label data. The completed form must accompany the SW samples from the field to the laboratory; and
- Laboratory internal analytical QA/QC procedures (where appropriate) including:
 - Laboratory duplicates;
 - NATA approved analytical methods;
 - Sample holding times;
 - Sample preservation (as recorded on CoC); and
 - Laboratory limit of reporting.

13. Document Control

The following information is to be saved in hard copy in the Surface Water Monitoring folder in the site office:

- The equipment calibration sheet.
- A photocopy of the signed CoC.
- The completed field data sheet.
- The laboratory results including laboratory QA/QC report.

The equipment calibration sheet, the signed CoC, and the field data sheet are all to be scanned and uploaded to the monthly results folder

14. WDL 178-2 Reporting

As specified in WDL 178-2, surface water monitoring reports are to be submitted to the Executive Director on a quarterly basis at the end of April, July, October and January. These quarterly submissions will present tabulated data from the surface water monitoring program, including river heights at time and point of discharge and results from *in situ* and laboratory water quality parameters.

15. Responsibilities

Environment Manager

The Environment Managers is to ensure that the field staff undertaking testing are familiar with this procedure and briefed on any relevant community, ecological, environmental or other issues which might affect the sampling process on the given day of testing. They are also responsible for ensuring field staff are suitably trained.

Field Staff

Field staff using this procedure are to ensure that; equipment is arranged and serviceable, that access to sampling sites is confirmed, and that the sample collection and testing is conducted, documented and entered correctly. Any requirement for modification to this procedure should be communicated to the Environmental Manager, such that revision can occur.

16. Attachments

Appendix 1. Sample Locations for WDL-2

Daily Calibration Sheet

pH Meter Manual

EC Meter Manual

DO Meter Manual

Envirolab chain of custody monthly sampling

Envirolab chain of custody daily sampling

SW Field Data Sheet monthly sampling

SW Field Data Sheet daily sampling

Appendix A

Sample Locations for WDL 178 -2

SW2



SW3



SW4



SW10



Appendix D – Toxicity and Chemistry Data

Water Quality Data and Toxicity Data October 2014

Date	Site	pH	EC	SO4	TU	Al	TU	Cd	TU	Co	TU	Cu	TU
Jan-12	RP1	4.23	1370	910	7.1	17370	115.8	63	78.8	180	72	3700	1480
Oct-11	RP3		2600	1400	10.9	10	0.1	48	60.0	460	184	13	5.2
Apr-12	RP1	3.8	1660	620	4.8	20000	133.3	62	77.5	690	276	4300	1720
Oct-12	RP7	4.5	3680	2200	17.1	23000	153.3	130	162.5	1900	760	19000	7600
Jan-13	RP3	6.4	2590	1800	14.0	5	0.0	130	162.5	1300	520	3400	1360
Mar-13	RP3	8.9	2710	1700	13.2	5	0.0	0.3	0.4	2	0.8	0.5	0.2
Dec-13	RP3	7.7	2700	1900	14.7	5	0.0	51	63.8	510	204	0.5	0.2
Jan-14	RP1	3.8		1400	10.9	37000	246.7	100	125.0	1200	480	8800	3520
Apr-13	CHCK03	4.7	370	160	1.2	3800	25.3	0.4	0.5	93	37.2	83	33.2
Apr-13	CHCK05	4.3	2000	1200	9.3	11000	73.3	2.7	3.4	960	384	1100	440
Apr-13	BCSW16	6.6	280	100	0.8	10	0.1	2	2.5	58	23.2	6	2.4
Apr-13	BCSW12	6.8	210	64	0.5	32	0.2	0.1	0.1	17	6.8	4	1.6
Apr-13	PCPWD	5	852	330	2.6	690	4.6	8.4	10.5	180	72	21	8.4
Apr-13	PCCK04	6.4	140	43	0.3	41	0.3	1.1	1.4	12	4.8	5	2
Mar-10	PCPWD			2140	16.6	14100	94.0	77	96.3	1260	504	189	75.6
Mar-10	TGEP			2090	16.2	62600	417.3	147	183.8	614	245.6	1110	444
Mar-10	CHCK05			2720	21.1	199	1.3	0.82	1.0	238	95.2	25.2	10.08
Jun-14	Treated	6.5	5000	3100	24.0	180	1.2	0.4	0.5	123	49.2	80	32
			Median		10.9		3.0		35.3		139.6		32.6
			Min		0.3		0.0		0.1		0.8		0.2
			Max		24.0		417.3		183.8		760.0		7600.0

Water Quality Data and Toxicity Data October 2014

Pb	TU	Mg	TU	Mn	TU	Ni	TU	Zn	TU	Total TU	Dilution	Ref
30	3.2	120	48	7600	2.1	640	37.65	13000	419.4	2264	1219	NTEPA 2012
0.5	0.1	200	80	17000	4.7	290	17.06	3400	109.7	472	58	Treated Pilot
40	4.3	1200	480	6600	1.8	690	40.59	16000	516.1	3254	1000	VG (2013)
11	1.2	280	112	22000	6.1	1800	105.88	33000	1064.5	9983	4545	VG (2013)
65	6.9	220	88	19000	5.3	1300	76.47	38000	1225.8	3459	1123	VG (2013)
0.5	0.1	160	64	2.5	0.0	13	0.76	6	0.2	80	20	VG (2013)
0.5	0.1	200	80	6000	1.7	500	29.41	4400	141.9	536	132	VG (2014)
57	6.1	240	96	15000	4.2	1300	76.47	30000	967.7	5533	1666	VG (2014)
1	0.1	33	13.2	1700	0.5	130	7.65	56	1.8	121	29.4	CGAO Reports
3	0.3	270	108	18000	5.0	1000	58.82	610	19.7	1102	435	CGAO Reports
0.5	0.1	24	9.6	2100	0.6	74	4.35	380	12.3	56	15.3	CGAO Reports
0.5	0.1	13	5.2	580	0.2	6	0.35	33	1.1	16	2.5	CGAO Reports
6	0.6	70	28	6200	1.7	120	7.06	7900	254.8	390	238	CGAO Reports
0.5	0.1	9	3.6	370	0.1	12	0.71	540	17.4	31	25	CGAO Reports
49	5.2	346	138.4	33400	9.3	829	48.76	63300	2041.9	3030	1000	ERISS 2010
4.46	0.5	245	98	19300	5.4	2610	153.53	14900	480.6	2045	900	ERISS 2010
1	0.1	342	136.8	6100	1.7	219	12.88	121	3.9	284	30	ERISS 2010
0.5	0.1	400	160	6200	1.7	52	3.06	17	0.5	272	31	CHBC Report
	0.2		84.0		1.8		23.2		125.8			
	0.1		3.6		0.0		0.4		0.2			
	6.9		480.0		9.3		153.5		2041.9			

Appendix E – Independent Technical Review



REVIEW OF THE DILUTION ALGORITHM FOR VISTA GOLD



October 10, 2014
ROSS A JEFFREE
Camborne Manor, 45 Casuarina Road, Alfords Point, NSW

Introduction

This report provides an independent review of a dilution algorithm that has been developed by GHD (2014) for Vista Gold Australia Pty Ltd (Vista Gold) in relation to mine waste water discharges from the Mt Todd Gold Mine (Mt Todd).

This dilution algorithm has been specifically developed by GHD to achieve the following inter-related objectives;

- i) Manage and minimise environmental impacts on the Edith River of multiple contaminants present in water-borne discharges from Mt Todd,
- ii) Reduce the on-site inventory of waste waters, and
- iii) Alleviate the risks of uncontrolled discharges from sites, for Retention Ponds 1, 7 & 3.

More specifically, the dilution algorithm has been developed to solve the problem posed by discharge waters that can change so rapidly and frequently in quality during the Wet season, due to various factors, that;

- a) Dry season-based direct toxicity assessments (DTAs) are not applicable for determination of appropriate dilutions, and
- b) Their assessment by DTAs is impractical because of their much longer turn-around time, compared to these daily changes in water chemistry.

Evaluation of the dilution algorithm

The algorithm

The proposed dilution algorithm has been developed to protect 80 percent of resident species from reductions in growth or reproduction in the Edith River for the 2014/2015 wet season. It has been derived as a statistical linear regression relationship between the following:

- i) x variable; toxicity units (TUs) based on historical ecotoxicology testing by various groups using those contaminants chemicals identified as contributing most to measured toxicity.
- ii) y variable; dilution factors required to meet certain Site Specific Trigger Values to protect 80% of species in the receiving waters within the mixing zone.

The 18 sets of data pairs used to derive the algorithm were generated between March 2010 and June 2014 among a variety of waters from sites in close geographical proximity and whose natural waters contain similar communities of organisms. Data for both variables range over more than 3 orders of magnitude in their values.

The plot of dilution as a function of toxic units given in Fig. 2 (GHD, 2014) indicates the following;

- The data are right-skewed in their frequency distributions, making the two higher data points disproportionately influential in the determination of the slope of the derived regression equation that is the basis of the dilution algorithm.
- However, visual inspection of the majority of data points which occur at lower values suggest that the regression line is still a good representation of the overall relationship between the two variables.

Employment of the algorithm to determine environmentally acceptable dilution rates

Confidence in the use of this regression equation for determination of dilution values, based on calculated toxic units, would be acceptable for toxicity units that lie within the range of the values presented in the GHD report, and particularly for TU's up to c. 2500. Beyond TU values of 2500 lower levels of confidence could be placed in the predicted dilution values, as the 95% confidence limits for the slope of the regression line could be expected to expand. The use of this regression relationship to determine dilution values beyond TU values of 8500-9000 by statistical extrapolation would be unwarranted, based on the current dataset.

However, the report also indicates that the following factors of conservatism are incorporated into the derivation and application of the dilution algorithm, using the cumulative criterion unit approach (CCU);

- The retention pond waters are expected to have qualities in their physico-chemistry that would ameliorate their toxicity and that are not included in the dilution algorithm. These include Ca^{2+} , Mg^{2+} and indirectly pH and alkalinity, as well as DOC, Chloride and Sulphate ions (Schmidt et al., 2010). The degrees of amelioration that could be expected by their incorporation into the calculation of the TUs have not been presented. So the question arises: how conservative is the dilution algorithm?

Validation of the dilution algorithm

The application of the dilution algorithm to determine a suitable dilution factor, which must be achieved in the rates of flow of receiving waters before release of waste effluents, is proposed to be validated by a) a full direct toxicity assessment (of water in Retention Pond 3, and b) post-release water sampling at a downstream site (SW4, within the mixing zone). These methods of validation of the dilution algorithm are valuable. It would also be useful to clarify *a priori* the statistical testing

procedure that will be used to assess whether the results of the planned full DTA either validate or refute the dilution algorithm, as it currently stands.

Subsequent toxicity assessment which is planned by Vista Gold using other sites in the receiving waters will also be valuable in the evaluation of dilution algorithm.

Operational methods

During the period of waste water releases into the Edith River it is planned to use the local Pine Creek laboratory to provide same-day analytical results of the levels of contaminants in waste water which are then to be used in the calculation of the dilution factor. This rapid analytical back-up would be essential to both meet the 80% species protection site specific trigger values (SSTVs) and thus comply with the Water Discharge Licence, within a changeable environment for water quality in the RP3, which has been identified in the GHD report (GHD, 2014).

There is thus a risk associated with the reliability of the timely delivery of chemical analytical results, upon which the dilution factor will be calculated. This risk would be exacerbated when;

- i) on-site water management conditions make it crucial to release in order to avoid uncontrolled spillages of waste waters and,
- ii) waste waters are changing both rapidly and by high percentages in those contaminants of most ecotoxicological concern, as identified for the determination of the TUs.

Conclusions

- The development of the dilution algorithm, based on site-specific and local regional data, is a scientifically valid and practical solution to the problem of determining environmentally safe releases of waste waters to the receiving waters of the Edith River, and the avoidance of uncontrolled releases of waste waters from Mt Todd.
- Moreover, its subsequent testing and validation with planned ecotoxicity and water quality evaluation in receiving waters will permit its continual improvement as a tool for on-site water management.
- In the further development of this dilution algorithm it would be valuable to determine the degree of conservatism that it currently incorporates, as the CCU methodology does not include various water quality parameters which are well known from the scientific literature to ameliorate toxicity.

- Such assessment of the level of amelioration in toxicity may be valuable if the need arises for dilution factors which rely upon extrapolation beyond the data used in the current regression relationship [(Fig 2, GHD, 2014)]. This information would also be valuable for decision-making if there are delays in the provision of the analyses for waste waters which are required for determination of dilution factors, prior to their release.

References

Schmidt T.S., Clements W.H., Mitchell K.A., Church S.E., Wanty R.B., Fey D.L., Verplanck P.L. and San Juan C.A. (2010). Development of a new toxic-unit model for the bioassessment of metals in streams. *Environmental Toxicology and Chemistry*. 29(11):2432-2442.

GHD (2014). Vista Gold Australia. Mt Todd Gold Mine. Algorithm calculations 2014/15.

Appendix F – Mixing Zone Study

1. Flow Rate Analysis

This Appendix summarises the results obtained for the mixing zone study conducted following the methodology outlined in GHD (2012a).

1.1 Available Flow Data

The best source of flow rate data for the site is a long term gauging station on the Edith River between the Stuart Highway crossing and the Vista Gold mine site (Site ID: G8140152). A record of flow from June 1962 at this site is available. This record is not continuous with the gaps between measurements extending up to four years (Figure 1). These gaps, although significant in length, do not prevent the use of this data to obtain a reasonable range of flows for mixing zone analysis.

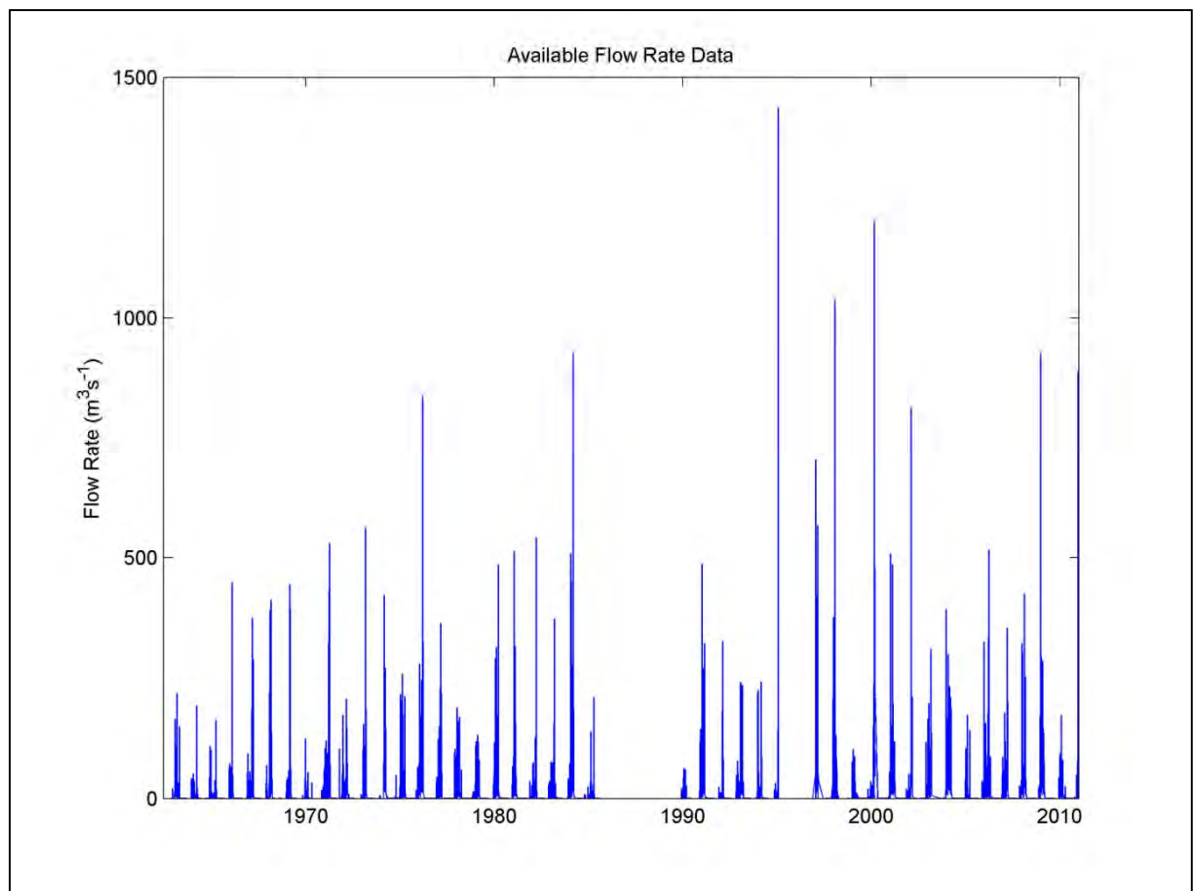


Figure 1 Available Flow Rate Data

Some flow can be expected to enter the Edith River between the long term monitoring station and the Vista Gold site. This has been estimated as 15% of the total flow (Austin Brandis, pers. Comms) and largely enters the creek through a tributary that discharge to the river around 500 m upstream of the gauging site.

1.2 Selection of Mixing Zone Analysis Flows

The instantaneous extent of the mixing zone is dependent on the effluent quality, flow rate, and the flow rate of the river and can be expected to change over time. The mixing zone (from an environmental management perspective) is the maximum of the instantaneous mixing zone extents. As such, the size of the mixing zone must be evaluated over a range of flows.

In order to calculate an appropriate range of flows, an analysis of the available flow rate data was undertaken. The wet season data (November to April, inclusive) was extracted from the full record and flow values corresponding to specific percentile exceedence values were calculated. The flow rate in terms of percentage exceedence is shown in Figure 2 (note the logarithmic vertical scale) and selected values are tabulated in Table 1. This data can be interpreted according to the following example: the flow is higher than $0.006 \text{ m}^3\text{s}^{-1}$ 99% of the time, but higher than $400 \text{ m}^3\text{s}^{-1}$ only 1% of the time.

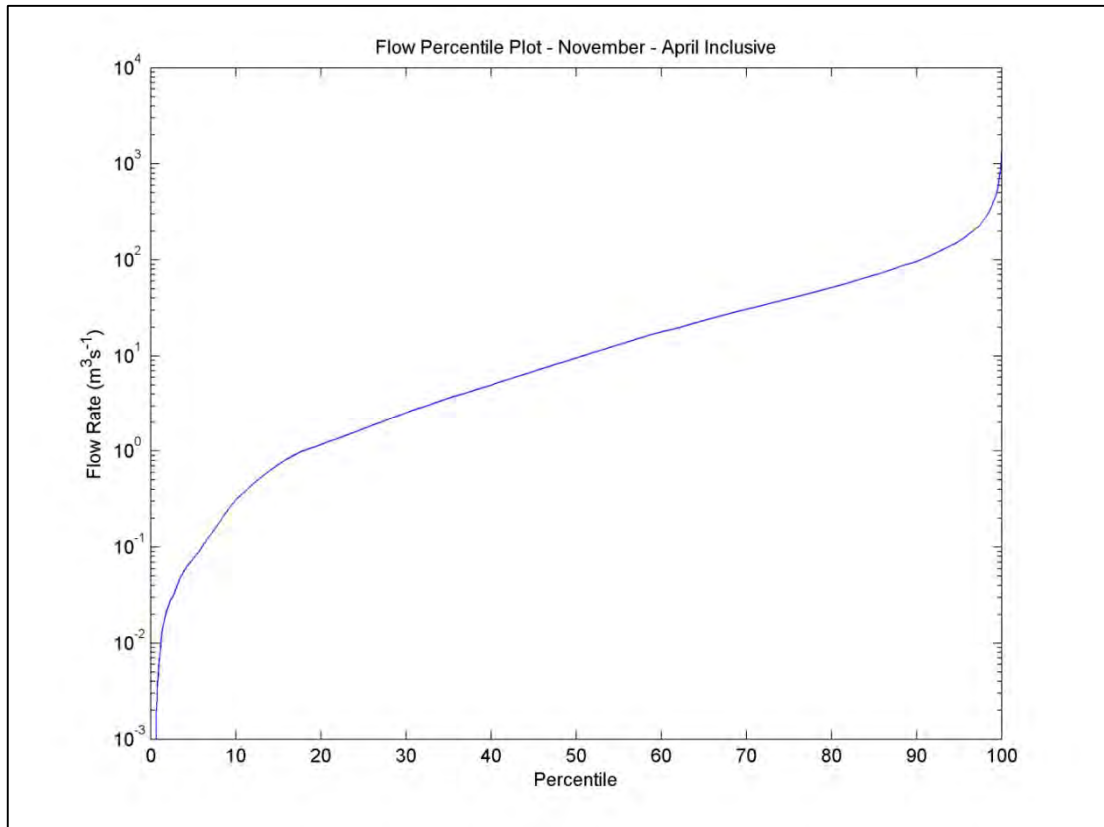


Figure 2 Wet Season Flow Exceedence Plot at Station G8140152

The estimated flow rate at station SW4 is also shown in Table 1. As previously discussed, the flow at station SW4 is assumed to be 85% of that measured at station G8140152.

Table 1 Selected Percentage Exceedence Values

Percentage Exceedance	Flow Rate (m³s⁻¹) G8140152	Flow Rate (m³s⁻¹) SW4 Estimate
99	0.0060	0.0051
95	0.076	0.064
90	0.31	0.24
80	1.2	0.99
65	3.6	3.1
50	9.5	8.1
35	23	19
20	52	44
10	97	82
5	160	130
1	400	340

1.3 Physical River Conditions

Transverse mixing in rivers is controlled by a number of factors, including the width and depth of the river, flow velocity, and river turbulence. In order to calculate the transverse mixing characteristics, an understanding of the way that these parameters change with river flow is required.

No rating curve (which relates flow rate to water level) is currently available at station SW4. A flow rating curve is available at station G8140152 downstream. A localised rating curve for SW4 is currently being developed for ongoing operational use however was not available for use in this investigation.

In order to estimate the flow conditions in the area of interest (SW4), a hydraulic model of the site was created using HEC-RAS. This covered the Edith River from station G8140152 at the downstream end to a location approximately two kilometres upstream of the area of interest. River cross sections for the model were created using available LIDAR topographic data for the site and limited observations of the river bathymetry. The rating curve at station G8140152 was used as the downstream boundary condition. The flows described in Table 2 were modelled using HEC-RAS and a rating curve and other river data was extracted at station SW4. This data is summarised in Table 2.

Table 2 Modelled River Conditions at SW4

Percentage Exceedance	Flow Rate (m ³ s ⁻¹) SW4	Water Surface Elevation (m AHD)	Main Channel River Flow Velocity (m s ⁻¹)	Total River Flow Area (m ²)
99	0.0051	107.474	0.00070	8.4
95	0.064	107.504	0.0085	9.0
90	0.24	107.548	0.032	9.8
80	0.99	107.637	0.10	12
65	3.1	107.825	0.23	16
50	8.1	108.133	0.40	24
35	19	108.563	0.63	37
20	44	109.045	0.94	55
10	82	109.625	1.2	81
5	130	110.162	1.5	110
1	340	111.499	2.1	230

A comparison of the modelled rating curve developed for station SW4 and the existing rating curve for station G8140152 is shown in Figure 3. The flow characteristics with depth for the two sites are similar, with minor variations likely resulting from small differences in river slope and river bank slope between the two sites.

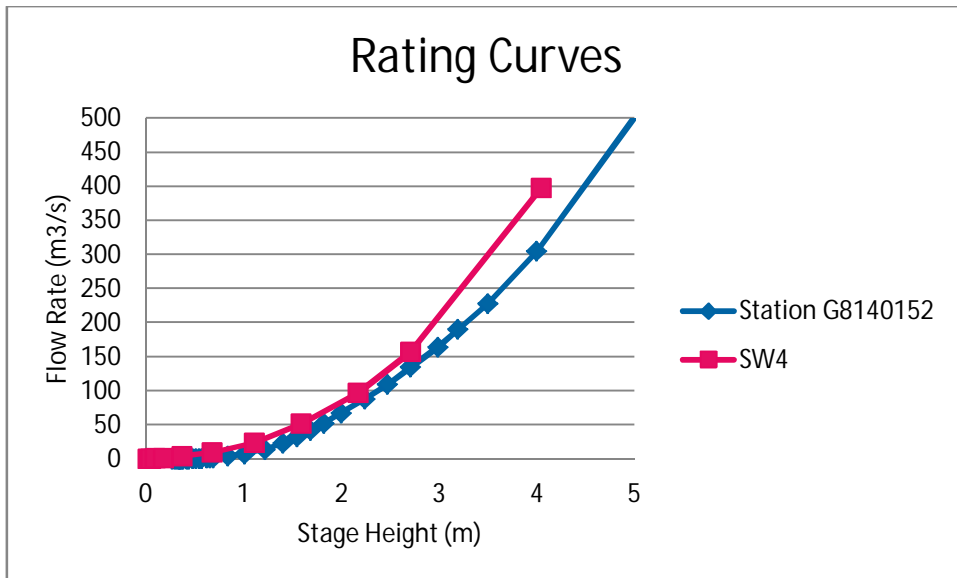


Figure 3 Existing and Modelled Rating Curve Comparison

1.4 Mixing Zone Calculations

The longitudinal extent of the mixing zone was calculated using the Gaussian diffusion modelling method described in Fischer et. al., 1979 using parameter values from this reference as well as more recent studies. The first step in this process is the calculation of the shear velocity, a parameter which describes the amount of bed shear:

$$u^* = \sqrt{gdS}$$

Where:

g is acceleration due to gravity

d is the average depth

S is the bed slope

For all cases analysed, an individual depth value was calculated, based upon the HEC-RAS modelling results. The slope used in all calculations corresponds to the overall slope of this section of the Edith River.

The second parameter calculated using this method is the transverse mixing coefficient, which is calculated as follows:

$$\epsilon_T = C_T du^*$$

Where:

C_T is a mixing coefficient

d is the average depth

u^* is the friction velocity, calculated previously

The value of C_T is site specific and depends on the cross section and topology of the channel. A study by Rutherford (1994) found that straight, rectangular channels generally had a C_T value of around 0.13, in meandering channels C_T varied from 0.3 to 0.9, and curved channels C_T varied from 1 to 3. Selection of an appropriate value of C_T is the primary source of uncertainty in this analysis and as such a range of values were modelled, for comparative purposes. A midrange value at for meandering rivers (0.6) and midrange curved channel value (2) were selected to form an appropriate range. Results are presented for both the lower and upper bound estimate.

Two distances were calculated for each flow scenario and parameter value case. These correspond to the distance where the maximum transverse concentration is 20% higher than the average concentration (qualitatively described as well mixed) and the distance where the maximum concentration is just 5% higher than the background concentration (qualitatively described as effectively fully mixed). These distances represent the longitudinal extent of the mixing zone under two different mixing criteria. Setting the mixing zone size criteria according to relative effluent concentration means that these results are independent of the final effluent concentration or discharge rate (as long as the volume of the effluent is insignificant compared the flow rate of the river). The results of the mixing zone analysis for the two parameter estimates and mixing criteria are shown in Table 3 and Table 4.

Table 3 Mixing Zone Extent Estimates, $C_T = 0.6$

Percentage Exceedance	Flow Rate (m ³ s ⁻¹) SW4	Mixing Zone Size as defined by 'Maximum 20% Above Average' Criteria (m)	Mixing Zone Size as defined by 'Maximum 5% Above Average' Criteria (m)
99	0.0051	7	12
95	0.064	82	134
90	0.24	291	474
80	0.99	810	1321
65	3.1	1484	2419
50	8.1	1826	2977
35	19	1913	3119
20	44	2146	3499
10	82	1995	3253
5	130	2064	3366
1	340	2194	3578

Table 4 Mixing Zone Extent Estimates, $C_T = 2$

Percentage Exceedance	Flow Rate (m ³ s ⁻¹) SW4	Mixing Zone Size as defined by 'Maximum 20% Above Average' Criteria (m)	Mixing Zone Size as defined by 'Maximum 5% Above Average' Criteria (m)
99	0.0051	2	4
95	0.064	25	40
90	0.24	87	142
80	0.99	243	396
65	3.1	445	726
50	8.1	548	893
35	19	574	936
20	44	644	1050
10	82	599	976
5	130	619	1010
1	340	658	1073

The mixing zone distance for the very smallest flows are extremely low, especially the flows with an exceedance less than 90%. At these very low flows it is unlikely that effluent would be discharged, making these results irrelevant. They are included for completeness only.

The results indicate that the size of the mixing zone stabilises at higher flow rates, reaching a plateau around the median flow rate.

In all cases the distance to reach the 5% above average criteria is around double that taken to reach the 20% threshold. The mixing zone results for the larger C_T mixing parameter (around 1000 m to meet the 5% criteria) are significantly smaller than those for the lower bound estimate (around 3500 m to reach the 5% criteria).

Given the curved river path and the variability in channel cross section (both factors that promote transverse mixing) it is possible that mixing could occur more rapidly than predicted in these results. In situ mixing measurements would be required to further refine these mixing zone estimates. This analysis has assumed that the flow is discharged on one bank of the river, which is effectively the worst case scenario for transverse mixing. Improvements to transverse mixing can be made, if needed, through the use of a diffuser.

Appendix H – Risk Assessment Matrix

Common

Duration							
	3	0	1	1	2	3	4
	2	0	1	1	1	2	3
	1	0	1	1	1	1	2
	0	0	0	0	0	1	1
		0	1	2	3	4	5
		Magnitude					

Significance

Common	0
State	1
National	2

Association

Low
Medium
High

State

Duration							
	3	0	1	2	3	4	5
	2	0	1	1	2	3	4
	1	0	1	1	1	2	3
	0	0	0	0	1	1	2
		0	1	2	3	4	5
		Magnitude					

Load Risk/benefit

		Load contribution					
		0	1	2	3	4	5
Risk/benefit	VH	NC	M	H	VH	VH	VH
	H	NC	L	M	H	VH	VH
	M	NC	L	M	M	H	H
	L	NC	L	L	L	M	M
	NA	NC	NC	NC	NC	NC	NC

National

Duration							
	3	0	2	3	4	5	5
	2	0	1	2	3	4	5
	1	0	1	1	2	3	4
	0	0	0	1	1	2	3
		0	1	2	3	4	5
		Magnitude					

Low

Threat							
	5	NA	L	L	M	H	VH
	4	NA	L	L	L	M	H
	3	NA	L	L	L	L	M
	2	NA	L	L	L	L	L
	1	NA	L	L	L	L	L
	0	NA	NA	NA	NA	NA	NA
		0	1	2	3	4	5
		Consequence					

Medium

Threat							
	5	NA	L	M	H	VH	VH
	4	NA	L	L	M	H	VH
	3	NA	L	L	L	M	H
	2	NA	L	L	L	L	L
	1	NA	L	L	L	L	L
	0	NA	NA	NA	NA	NA	NA
		0	1	2	3	4	5
		Consequence					

High

Threat							
	5	NA	M	H	VH	VH	VH
	4	NA	L	M	H	VH	VH
	3	NA	L	L	M	H	H
	2	NA	L	L	L	L	L
	1	NA	L	L	L	L	L
	0	NA	NA	NA	NA	NA	NA
		0	1	2	3	4	5
		Consequence					

Appendix I – 2014 Discharge Report



Vista Gold Australia P/L
Mt Todd Mine Site
Waste Discharge Licence 178-3

**Monthly Discharge Report
February 2014**





Executive Summary

This report presents results and information pursuant to Condition 30 of WDL 178-2 that requires Vista Gold submit a periodic report to the NT EPA for each calendar month during which a discharge has occurred.

One controlled discharge compliant with the conditions of WDL 178-3 occurred over six days in February 2014. 217 ML of treated RP3 water discharged at a target dilution ratio of 1:132, derived from Direct Toxicity Assessment performed on RP3 water sampled on the 25 November 2013.

Findings were as follows:

- No analytes exceeded the Australian Drinking Water Guidelines 6, 2011, Table 10.5.
- All discharge activities were compliant with Waste Discharge Licence 178-3

1. Introduction

Condition 30 of WDL 178-3 states that:

"The Licensee must submit a periodic report to the NT EPA for each calendar month during which a discharge has occurred no later than 10 Business days after the last day of the relevant calendar month.

The periodic report must

30.1. include, for each day of the month where a discharge occurred, tabulated data including

- the factors used to assess the Dilution Factor at SW4;*
- surface water monitoring results required under condition 21;*
- a comparison of surface water monitoring results for monitoring point SW4 with Monitoring Values determined under condition 14;*
- a comparison of surface water monitoring results for monitoring points SW2 and SW10 with applicable health guideline values from Australian Drinking Water Guidelines 6, 2011, Table 10.5; and*

30.2. be made available on the Licensee's Australian website within 10 Business days of providing the report to the NT EPA.

This report presents the Edith River hydrological data, RP3 discharge data as well analytical surface water monitoring results for discharges from Mt Todd conducted in accordance with Vista Gold's Discharge Plan and pursuant to the conditions of WDL 178-3 during the month of February 2014.

2. Discharge Summary

Table 1 and 2 summarise the discharges for February 2014.

Table 1 - February 2014 Discharge

Discharge	Date	Start Time (hrs)	Stop Time (hrs)	Duration (hrs & min)	Dilution Rate	Volume Discharged (ML)
1	01:02:2014	0841				
	06:02:2014		1149	5 Days 3 hrs 7 min	1:162	217.26

Table 2 - Daily flow readings

Date	Hours	SW4 Flow Rate (m ³ /s)	Edith Volume (m ³)	Theoretical Flow Rate at 1:132 (m ³ /s)	Actual RP3 Discharge Rate (m ³ /s)	Daily Discharge Volume (m ³)	Actual Daily Dilution Ratio
01-February-2014	14.5	149	7,756,506	1.13	0.80	41,685	186
02-February-2014	24.0	118	10,217,592	0.90	0.64	54,876	186
03-February-2014	24.0	77	6,619,446	0.58	0.57	48,841	136
04-February-2014	24.0	63	5,406,300	0.47	0.44	37,843	143
05-February-2014	24.0	45	3,868,794	0.34	0.32	27,512	141
06-February-2014	12.0	30	1,286,928	0.23	0.15	6,271	205
	122.5	80	35,155,566	0.60	0.49	217,029	162

Figure 1 below graphically shows the discharge flow rate from RP3 as well as the theoretical discharge rate calculated from the flow in the Edith River and based on a dilution ratio of 1 part RP3 water to 132 diluent – this is derived from the direct toxicity assessment.

The rate of flow from RP3 is measured via an inline magnetic flow meter which is automatically measured every 30 seconds. Flow from the Edith River is determined by measurement of water level at the SW4 Gauging Station and conversion via the established rating for the site.

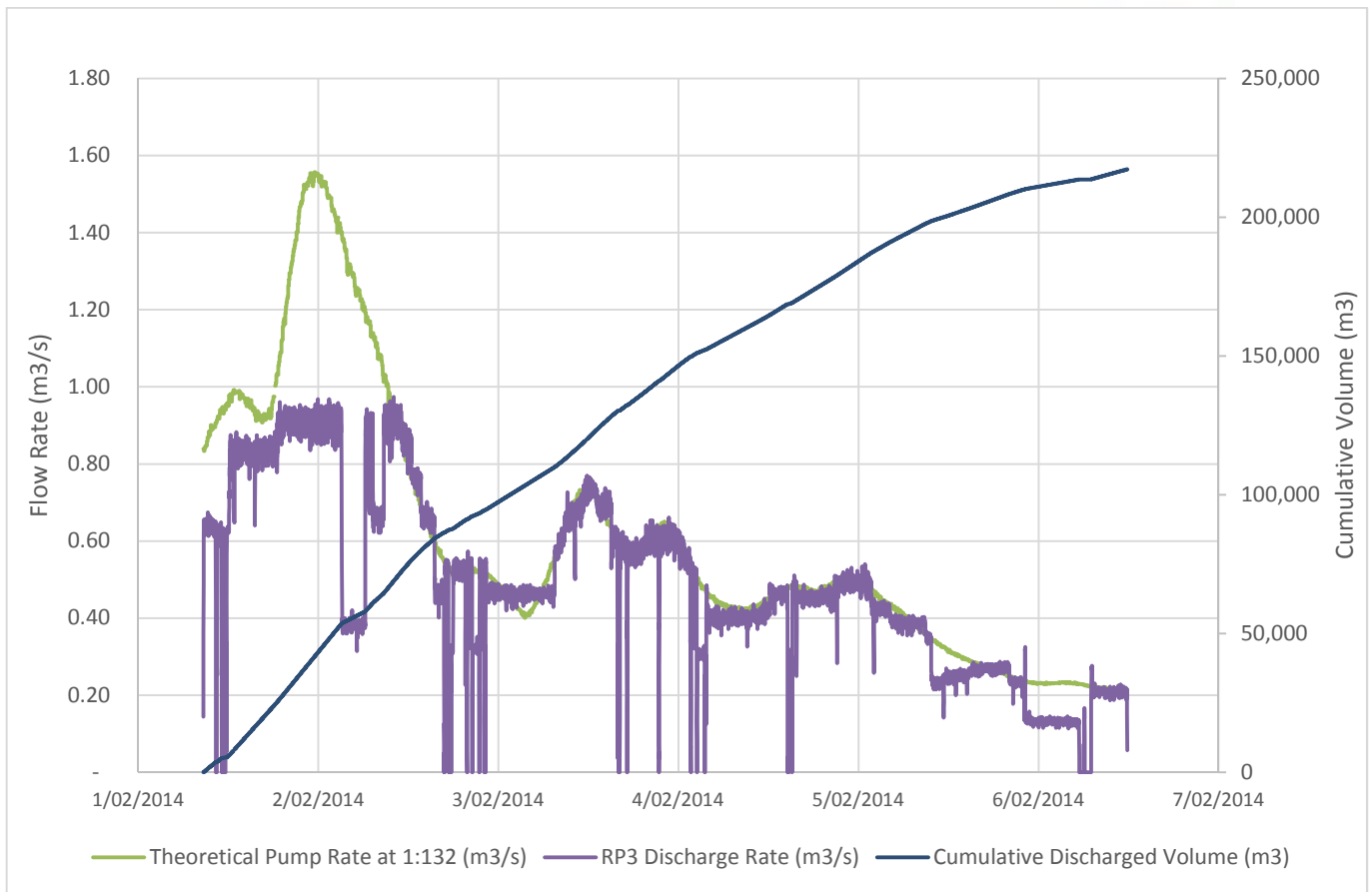


Figure 1 - RP3 treated water discharge rate during February 2014

3. Monitoring Summary

The monitoring analytes at SW4 from the November 2013 Direct Toxicity Assessment on RP3 are listed as

- Zinc - 33µg/L
- Cadmium 0.4 µg/L

Table 3 is an excerpt of these elements from Appendix B. Three exceedances of the monitoring values were detected. An exceedance occurred for both Cadmium and Zinc on the second day of discharge and 7 days after discharge had ceased.

Comparisons of other element concentrations between RP3 and SW2 & SW4 on the 2nd clearly evidence the additional concentrations of Zinc and Cadmium on that day at were not as a result of exceeding the reported dilution rate during discharge from RP3. Raw data and field sampling procedures on this day were reviewed for error, however all investigations indicate the increased concentrations measured on the 2/2/2014 are due to an unknown source between SW2 and SW4. The increased Zinc concentrations on the 13/2/2014 are also of unknown origin and are unlikely to be related to any discharge activities.

Table 3 – Measured concentrations of Zinc and Cadmium during discharge and one week following cessation of discharge

	01/02/2014	02/02/2014	03/02/2014	04/02/2014	05/02/2014	06/02/2014	13/02/2014
Cadmium-(0.45µm filtered) (µg/L)							
RP3	44	43	44	43	44	47	27
SW10	0.05	0.05	0.05	0.05	0.1	0.05	0.1
SW2	0.05	0.05	0.05	0.05	0.05	0.05	0.05
SW4	0.05	1.4	0.1	0.05	0.2	0.1	0.1
Cadmium-Total (µg/L)							
RP3	47	44	44	44	44	43	27
SW10	0.05	0.05	0.05	0.05	0.1	0.05	0.2
SW2	0.05	0.05	0.05	0.05	0.05	0.05	0.05
SW4	0.05	1.5	0.1	0.1	0.2	0.1	0.1
Zinc-(0.45µm filtered) (µg/L)							
RP3	2700	2700	2800	2800	2800	3000	6100
SW10	2	3	9	4	10	8	30
SW2	1	0.5	2	2	0.5	0.5	0.5
SW4	9	340	24	13	16	12	37
Zinc-Total (µg/L)							
RP3	3000	2900	2900	2900	3300	3100	5900
SW10	5	5	13	7	14	11	38
SW2	9	3	5	3	2	2	7
SW4	13	350	27	17	19	16	44

The elements from the Australian Drinking Water guidelines which have published health values comparable to the elements sampled during discharge are listed in Table 4. All samples from the Edith River (SW2, SW4, SW10) during and post discharge returned concentrations below the specified guidelines.

Table 4 - ADWG Elements available for comparison to discharge samples

Element	Health Guideline (ug/L)
Mercury	1.00
Cadmium	2.00
Lead	10.00
Nickel	20.00
Chromium	50.00
Cyanide	80.00
Manganese	500.00
Copper	2,000.00
Sulphate	500,000.00

The full tabulation of chemical results applicable to this report is presented in Appendix A



4. Conclusion

The controlled discharge of treated water from RP3 that occurred in February complied with the conditions of WDL 178-3. It is suspected that other catchments on site (i.e. Horseshoe and Batman Creeks) may be sources of elements to explain the unexpected and irregular elevated concentrations in certain parameters. This is why the WDL adopts the application of a 7 day rolling average to determine if the 80% species protection values have been met.

Appendix A – Tabulated chemical and physical results

	01/02/2014	02/02/2014	03/02/2014	04/02/2014	05/02/2014	06/02/2014	13/02/2014
Aluminium-(0.45µm filtered) (µg/L)							
RP3	16	35	72	82	110	97	4500
SW10	270	490	81	120	76	43	87
SW2	160	120	69	98	50	60	59
SW4	290	110	120	91	55	75	48
Aluminium-Total (µg/L)							
RP3	100	130	170	170	290	220	4300
SW10	750	740	300	370	540	610	190
SW2	270	40	190	200	470	310	190
SW4	370	310	40	300	810	360	230
Bicarbonate Alkalinity as (mg/L)							
RP3	38	36	36	35	38	40	6
SW10	9	11	9	11	11	10	8
SW2	7	7	8	8	8	10	10
SW4	10	5	8	10	11	9	8
Cadmium-(0.45µm filtered) (µg/L)							
RP3	44	43	44	43	44	47	27
SW10	0.05	0.05	0.05	0.05	0.1	0.05	0.1
SW2	0.05	0.05	0.05	0.05	0.05	0.05	0.05
SW4	0.05	1.4	0.1	0.05	0.2	0.1	0.1
Cadmium-Total (µg/L)							
RP3	47	44	44	44	44	43	27
SW10	0.05	0.05	0.05	0.05	0.1	0.05	0.2
SW2	0.05	0.05	0.05	0.05	0.05	0.05	0.05
SW4	0.05	1.5	0.1	0.1	0.2	0.1	0.1
Calcium - Dissolved (mg/L)							
RP3	430	440	440	410	410	420	84
SW10	0.7	0.9	1.3	1.1	1.9	1.7	0.7
SW2	0.6	0.25	0.5	0.7	0.6	0.25	0.25
SW4	0.25	5.3	1.9	1.5	2.5	1.9	0.8
Calcium - Total (mg/L)							
RP3	400	390	390	380	430	420	82
SW10	0.8	1	1.3	1.1	2.2	1.7	0.8
SW2	0.6	0.25	0.6	0.7	0.5	0.5	0.25
SW4	0.5	4	1.9	1.4	2.5	1.9	0.8
Carbonate Alkalinity as (mg/L)							
RP3	2.5	2.5	2.5	2.5	2.5	2.5	2.5
SW10	2.5	2.5	2.5	2.5	2.5	2.5	2.5
SW2	2.5	2.5	2.5	2.5	2.5	2.5	2.5
SW4	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Chloride, Cl (mg/L)							



RP3	5	5	31	75	6	5	3
SW10	0.5	0.5	1	2	1	0.5	0.5
SW2	0.5	0.5	0.5	0.5	0.5	1	1
SW4	0.5	1	0.5	67	1	1	1
Chromium-(0.45µm filtered) (µg/L)							
RP3	0.5	0.5	0.5	0.5	1	1	0.5
SW10	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SW2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SW4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Chromium-Total (µg/L)							
RP3	0.5	0.5	1	0.5	1	0.5	0.5
SW10	1	0.5	0.5	0.5	0.5	0.5	0.5
SW2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SW4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Cobalt-(0.45µm filtered) (µg/L)							
RP3	380	370	370	370	400	430	280
SW10	0.5	0.5	0.5	0.5	0.5	0.5	1
SW2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SW4	0.5	16	1	0.5	2	1	1
Cobalt-Total (µg/L)							
RP3	390	380	380	360	390	380	280
SW10	0.5	1	0.5	0.5	1	0.5	2
SW2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SW4	0.5	16	1	0.5	2	1	2
Copper-(0.45µm filtered) (µg/L)							
RP3	4	13	23	26	49	36	1400
SW10	67	81	17	58	2	1	7
SW2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SW4	2	50	4	4	2	1	8
Copper-Total (µg/L)							
RP3	11	21	34	38	65	46	1400
SW10	100	130	26	78	2	2	11
SW2	2	0.5	2	0.5	0.5	0.5	0.5
SW4	4	65	4	5	3	2	10
Hardness (mgCaCO3/L)							
RP3	1900	1900	1900	1800	1800	1800	540
SW10	1.5	5	8	6	11	10	6
SW2	4	1.5	4	4	4	1.5	1.5
SW4	4	35	11	10	14	12	6
Hydroxide Alkalinity (OH-) (mg/L)							
RP3	2.5	2.5	2.5	2.5	2.5	2.5	2.5
SW10	2.5	2.5	2.5	2.5	2.5	2.5	2.5
SW2	2.5	2.5	2.5	2.5	2.5	2.5	2.5
SW4	2.5	2.5	2.5	2.5	2.5	2.5	2.5



Iron-(0.45µm filtered) (µg/L)							
RP3	5	5	5	5	5	5	39
SW10	140	200	120	110	140	120	150
SW2	230	150	130	150	130	150	170
SW4	230	80	140	170	110	120	150
Iron-Total (µg/L)							
RP3	130	87	92	82	67	63	62
SW10	900	730	390	490	500	510	560
SW2	640	99	360	400	460	470	600
SW4	500	240	95	550	490	510	550
Lead-(0.45µm filtered) (µg/L)							
RP3	0.5	0.5	0.5	0.5	0.5	0.5	26
SW10	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SW2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SW4	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Lead-Total (µg/L)							
RP3	0.5	0.5	0.5	0.5	1	0.5	26
SW10	1	1	0.5	0.5	0.5	0.5	0.5
SW2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SW4	1	0.5	0.5	0.5	0.5	0.5	0.5
Magnesium - (0.45µm filtered) (mg/L)							
RP3	190	190	190	180	180	180	81
SW10	0.25	0.6	1.2	0.7	1.5	1.5	1
SW2	0.5	0.25	0.5	0.6	0.5	0.5	0.25
SW4	0.9	5.2	1.6	1.5	1.9	1.7	1.1
Magnesium - Total (mg/L)							
RP3	200	190	190	190	190	190	76
SW10	0.25	0.7	1.2	0.7	1.7	1.6	1.1
SW2	0.6	0.25	0.6	0.6	0.6	0.6	0.25
SW4	1	5	1.6	1.4	2	1.7	1.1
Manganese-(0.45µm filtered) (µg/L)							
RP3	4400	4400	4500	4300	4600	4900	3600
SW10	14	20	15	18	34	35	25
SW2	8	2.5	2.5	5	6	6	2.5
SW4	12	200	28	23	63	61	29
Manganese-Total (µg/L)							
RP3	4600	4400	4400	4300	4500	4400	3500
SW10	20	26	26	21	42	44	36
SW2	17	2.5	9	9	11	10	9
SW4	17	210	29	26	69	70	32
Mercury-(0.45µm filtered) (µg/L)							
RP3	0.025	0.025	0.025	0.025	0.025	0.025	0.025
SW10	0.025	0.025	0.025	0.025	0.025	0.025	0.025
SW2	0.025	0.025	0.025	0.025	0.025	0.025	0.025

SW4	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Mercury-Total (µg/L)							
RP3	0.025	0.025	0.025	0.025	0.025	0.025	0.025
SW10	0.025	0.025	0.025	0.025	0.025	0.025	0.025
SW2	0.025	0.025	0.025	0.025	0.025	0.025	0.025
SW4	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Nickel-(0.45µm filtered) (µg/L)							
RP3	350	350	350	340	380	400	260
SW10	0.5	0.5	0.5	0.5	1	1	2
SW2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SW4	0.5	17	2	1	2	1	2
Nickel-Total (µg/L)							
RP3	370	350	350	340	370	360	250
SW10	0.5	0.5	0.5	0.5	2	1	2
SW2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SW4	0.5	17	2	1	2	1	2
Sodium - Total (mg/L)							
RP3	59	56	57	56	60	58	14
SW10	1.6	1.9	1.6	2.3	2.1	2.4	1.8
SW2	1.1	0.8	1.1	1.1	1.2	1.3	1.3
SW4	1.5	2.1	1.7	1.7	2.3	2.5	1.9
Sulphate, SO4 (mg/L)							
RP3	1600	1500	1500	1500	1700	1800	550
SW10	0.5	1	4	2	8	7	3
SW2	0.5	0.5	0.5	0.5	0.5	0.5	0.5
SW4	0.5	26	6	11	8	9	3
Total Alkalinity (mg/L)							
RP3	38	36	36	35	38	40	6
SW10	9	11	9	11	11	10	8
SW2	7	7	8	8	8	10	10
SW4	10	5	8	10	11	9	8
Total Cyanide (mg/L)							
RP3	0.002	0.002	0.002	0.002	0.002	0.002	0.002
SW10	0.002	0.002	0.002	0.002	0.002	0.002	0.002
SW2	0.002	0.002	0.002	0.002	0.002	0.002	0.002
SW4	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Total Dissolved Solids (mg/L)							
RP3	2100	2700	2600	2600	2900	2900	670
SW10	70	76	46	80	84	54	60
SW2	48	56	40	100	26	38	30
SW4	82	100	92	90	50	54	20
Total Solids (mg/L)							
RP3	2100	2700	2700	2600	2900	3000	670
SW10	110	100	77	89	97	62	88



SW2	65	66	54	120	33	38	36
SW4	92	120	110	99	59	64	29
Total Suspended Solids (mg/L)							
RP3	2.5	5	14	2.5	2.5	2.5	2.5
SW10	35	25	31	9	13	8	28
SW2	17	10	14	19	7	2.5	6
SW4	10	12	19	9	9	10	9
Zinc-(0.45µm filtered) (µg/L)							
RP3	2700	2700	2800	2800	2800	3000	6100
SW10	2	3	9	4	10	8	30
SW2	1	0.5	2	2	0.5	0.5	0.5
SW4	9	340	24	13	16	12	37
Zinc-Total (µg/L)							
RP3	3000	2900	2900	2900	3300	3100	5900
SW10	5	5	13	7	14	11	38
SW2	9	3	5	3	2	2	7
SW4	13	350	27	17	19	16	44
Temperature (degrees celcius)							
RP3	30.5	30.8	29.7	28.9	29.5	27.9	33
SW10	29.1	30.3	28.5	29.3	28.7	28.4	28.3
SW2	27.8	28.5	28.9	27.9	28.4	28.3	29.1
SW4	29.8	30.3	30	28	29.1	28.2	31.4
Electrical Conductivity (uS/cm)							
RP3	3032	3009	3939	2800	2960	2863	1298
SW10	753.9	28.1	30.6	29.5	43.2	41.8	26.1
SW2	752.2	11.9	13.9	15	14.8	15.2	14.3
SW4	752.6	100.9	39.1	34.1	52.4	45.7	28.2
pH							
RP3	7.14	6.61	6.39	6.67	6.57	6.78	4.86
SW10	6.01	5.63	5.65	5.8	5.78	5.92	6.34
SW2	5.91	5.3	5.79	5.49	5.68	5.82	6.11
SW4	6.05	5.28	5.93	5.52	5.69	5.87	6.03
Dissolved Oxygen (% Sat)							
RP3	96.1	96.5	67.7	97.2	94.2	93.9	73.3
SW10	94.5	91.5	63.5	95.1	92.3	31.9	68.4
SW2	101.5	98.8	75.7	96.2	95.9	92.9	82.2
SW4	94.5	89	67.3	89.7	91.9	91.1	83.1

Appendix J – Metal Speciation

SPECIATION MODELLING OF METALS IN SURFACE WATERS OF THE EDITH RIVER DURING WET SEASON DISCHARGE OF WASTEWATER FROM THE MOUNT TODD MINE

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SUMMARY

Geochemical speciation modelling was used to calculate the distributions, or physico-chemical forms, of dissolved (0.45 µm filtered) cadmium (Cd), cobalt (Co), copper (Cu), manganese (Mn), nickel (Ni) and zinc (Zn) in main wet season Edith River surface water (at control site SW2) receiving treated wastewater (retention pond 3) from the Mount Todd mine site. The free metal ion (M^{2+}), generally considered to be a good predictor of the bioavailable metal fraction, was calculated to be the major proportion of dissolved Cd (84%), Co (91%), Mn (94%), Ni (84%), and Zn (91%), but accounted for only a relatively small proportion of Cu (8.4%). The speciation of dissolved Cu was dominated by binding with dissolved organic matter (DOM; 91%), in the form of humic substances (fulvic acid). In contrast, Cd, Co, Mn, Ni and Zn formed relatively weak complexes with DOM (i.e. 2.5-12%). After adjusting the dissolved concentrations of the selected metals for the percentage of the calculated free ion (i.e. the “bioavailable fraction”), Zn was the only metal likely to exceed its trigger value (by a factor of 1.7), based on an 80% species protection in freshwater ecosystems. These data should be interpreted in the context of an equilibrium model, and do not consider kinetic and/or biological processes, which may be important for some metals, such as Mn.

INTRODUCTION

The speciation of trace metals in natural freshwaters plays a crucial role in determining their reactivity, mobility, bioavailability and toxicity (Markich et al., 2001). Trace metals in fresh surface waters are partitioned between different physico-chemical forms, such as dissolved, complexed or associated phases with colloids and particles (Ure and Davidson, 2001). The distribution between these physico-chemical forms determines potential metal bioavailability, and hence toxicity. Measurements of “dissolved” (e.g. typically following 0.45 µm filtration) metal concentrations provide little insight to potential ecotoxicological impacts in aquatic systems. A convincing body of experimental evidence supports the biotic ligand model (BLM; McGeer et al., 2010; Figure 1) - stemming from the free ion activity model and its extensions (Campbell, 1995; Brown and Markich, 2000) - which postulates that the bioavailability and toxicity of a dissolved trace metal is best predicted by the activity of the free ion (e.g. Zn^{2+}), rather than the dissolved concentration. The use of BLMs in a compliance-based regulatory framework is an area which has received substantial attention. The United States Environmental Protection Agency (USEPA) and the European Union (EU) has either adopted, or are in the process of adopting, a BLM-based approach for Cu, Zn or Ni as part of a tiered approach for protecting freshwater organisms (USEPA, 2007; EU, 2008; DeForest and Van Genderen, 2012) – it accounts for metal speciation reactions and interactions with organisms under a wide range of water quality conditions. A BLM-based approach is being considered as part of the current revision of the Australian water quality guidelines for protecting freshwater organisms.

Many analytical techniques, both physical and chemical, are available to measure metal speciation in aquatic systems (Batley et al. 2004; Pesavento et al., 2009; Hamilton-Taylor et al., 2011), although rarely can a complete distribution of all species be determined. A complementary approach, which is more cost effective and time efficient, is the application of chemical speciation models, which estimate metal distributions on the basis of known or postulated chemical reactions. A number of chemical speciation models are currently available (Bethke, 2008), and are used to ascertain the speciation of a particular metal(s) in water under specified conditions (e.g. local measured ion concentrations, pH and temperature). Chemical speciation modelling may be employed as an integral part of a risk-based “decision-tree” approach (Figure 2) for determining metal bioavailability in freshwater ecosystems (ANZECC and ARMCANZ, 2000).

This study reports on speciation calculations for six key metals (Cd, Co, Cu, Mn, Ni and Zn) of potential ecotoxicological concern in the surface waters of the Edith River (control site

SW2; Figure 3) that may receive wastewaters (Retention Pond (RP) 3; Figure 3) from the Mount (Mt) Todd mine site during the wet season, via controlled discharge. The calculated “bioavailable fraction” of the dissolved concentrations of Cd, Co, Cu, Mn, Ni and Zn is also compared with trigger values at 80% protection for local freshwater species inhabiting the Edith River.

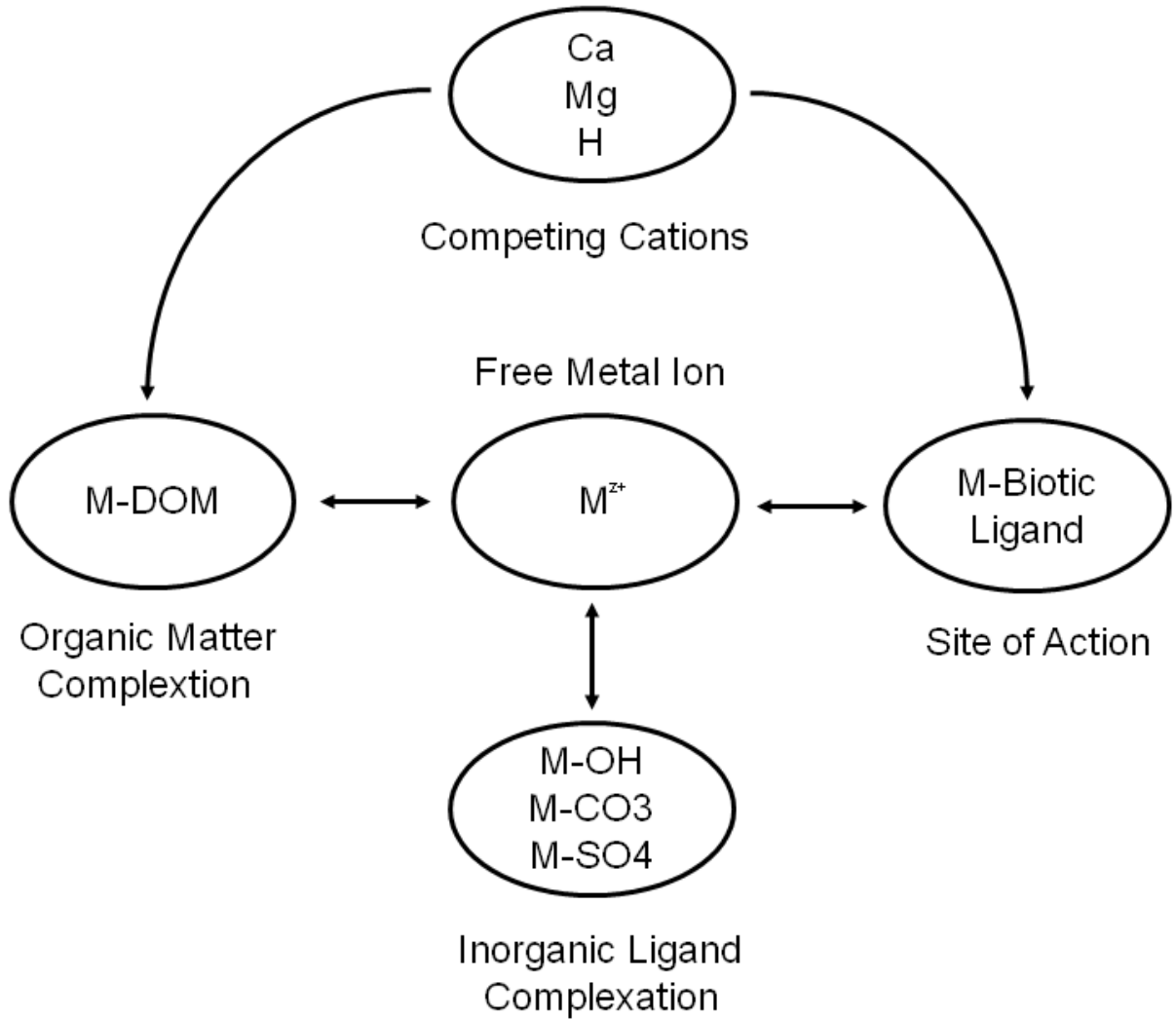


Figure 1. Schematic diagram of the biotic ligand model (BLM).

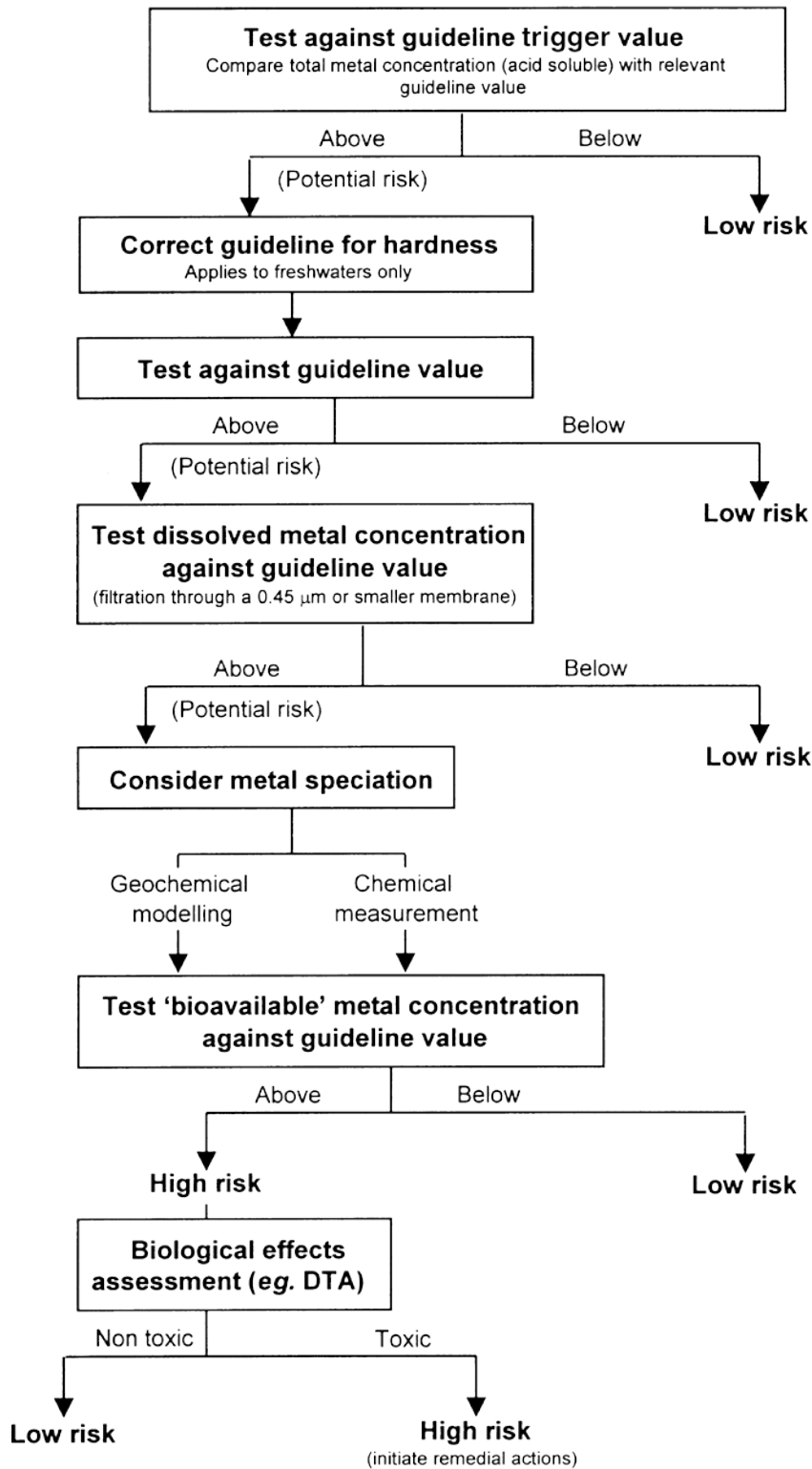


Figure 2. Risk-based decision-tree approach (ANZECC and ARMCANZ, 2000), incorporating metal speciation (modelling) for adjusting dissolved metal concentrations.

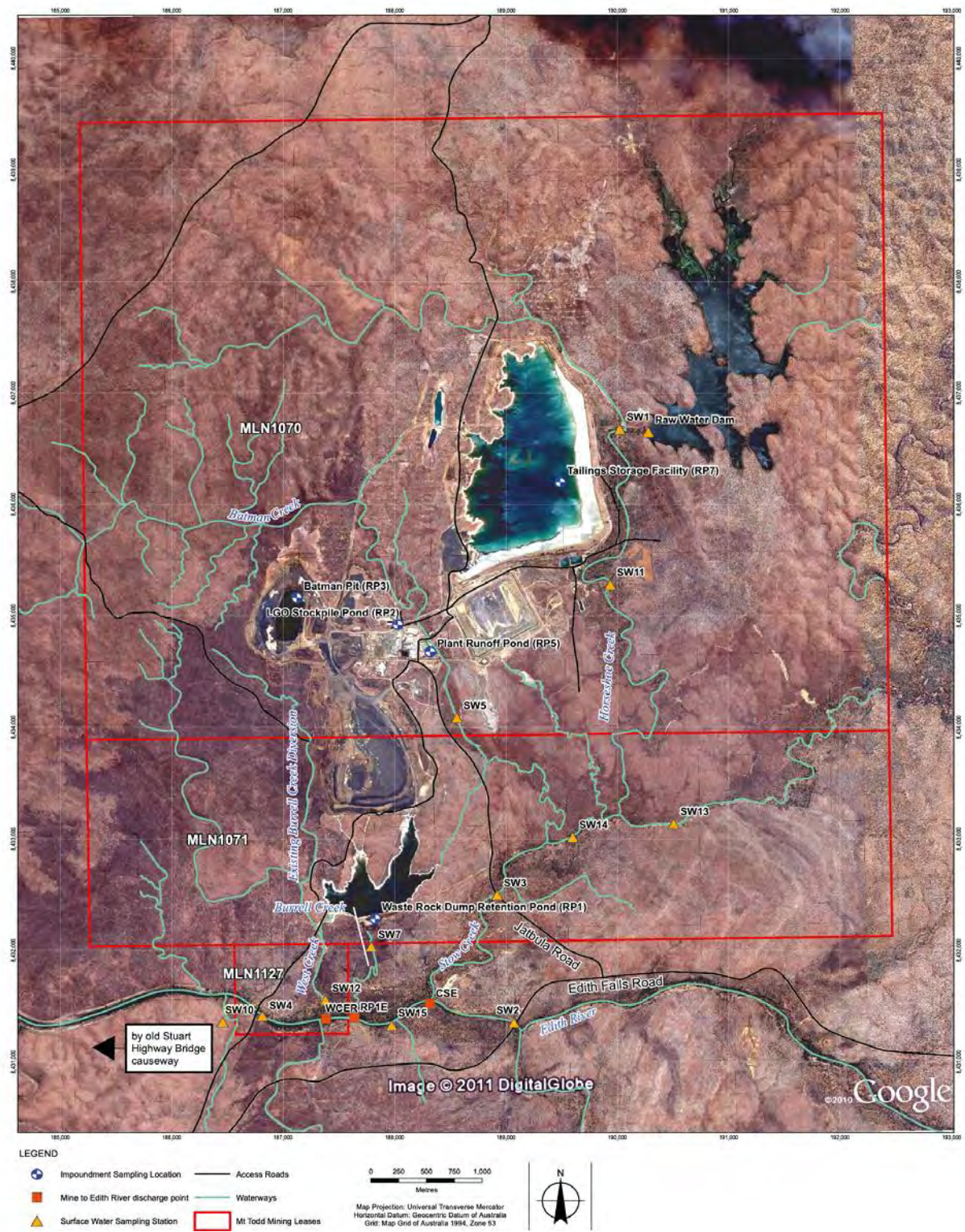


Figure 3. Location map of the Mount Todd mine site in relation to the Edith River – showing the RP3 and SW2 sampling sites.

METHODS

Water Chemistry

Baseline surface water chemistry of the Edith River (site SW2) during the 2011-2012 main wet season (Table 1; excluding “first flush” events) was compiled from water monitoring data made available by Vista Gold Australia and the Northern Territory Department of Natural Resources, Environment, Arts and Sport. Surface water chemistry for treated RP3 water from the Mt Todd mine was based on two samples (8/7/2011 and 24/8/2011; Table 1). Dissolved (operationally defined as 0.45 µm filtered) concentrations of trace metals (Al, Cd, Co, Cu, Fe, Ni, Mn and Zn) were used for all speciation modelling calculations. A 1:58 dilution ratio of baseline Edith River / treated RP3 water was used to calculate the likely surface water chemistry of the Edith River during controlled discharge of RP3 water during the main wet season (Table 1) - if required, as part of the water management strategy at the Mt Todd mine site. Mean (and standard deviation) values were calculated for the above waters using Statistica (version 7).

Chemical Speciation Modelling

The speciation of Cd, Co, Cu, Mn, Ni and Zn in the Edith River (at discharge) was calculated using both WHAM (version 7.0; Tipping et al., 2011) and Visual MINTEQ (version 3.0; Gustafsson, 2011). The inorganic equilibrium constants used in both models were derived from Markich (2012). Metal binding with dissolved organic matter (DOM) was calculated using three independent sub-models (Humic Ion-Binding Model VII (HIBM) – incorporated into WHAM, the Stockholm Humic Model (SHM) and the NICA Donnan Model (NICA) – both incorporated into Visual MINTEQ). The HIBM and SHM use a discrete-site approach for calculating proton- and metal-binding; however, there are important technical differences in their calculations. In contrast, the NICA uses a bimodal continuous distribution of affinities approach for calculating proton- and metal-binding. A more detailed description of each model is available within the references given above.

It was assumed that the ratio of active DOM / DOC was 1.4 and that 100% of the active DOM was fulvic acid (which forms ~90% of freshwater humic substances) – this is based on DOM containing 50% carbon (DOC) by mass with a 70% fulvic acid composition (a mean value based on reviews by Bryan et al. (2002) and Sjostedt et al. (2010)). The generic acid-base properties and proton binding constants of fulvic acid used in the NICA model were

Table 1. Water chemistry for the Edith River (baseline), Retention Pond (RP) 3, the Edith River at time of RP3 discharge and the calculated bioavailable concentrations of selected metals relative to water quality guideline trigger values for ecosystem protection.

	Edith River (baseline) ^a	Treated RP3 ^b	Edith River (discharge) ^c	Bioavailable Metal ^d	WQG ^e
pH	6.0 (0.5)	7.8	6.1	—	—
Conductivity (µS/cm)	18 (1.0)	2700 (140)	62	—	—
Suspended solids (mg/L)	5.1 (4.5)	< 5	5	—	—
Hardness (mg/L as CaCO ₃)	3.6 (1.0)	1775 (25)	34	—	—
Na (mg/L)	1.3 (0.4)	44 (2)	2.0	—	—
K (mg/L)	0.2 (0.1)	6.8 (0.2)	0.31	—	—
Ca (mg/L)	0.45 (0.11)	385 (7)	7.1	—	—
Mg (mg/L)	0.60 (0.15)	200 (2)	4.0	—	—
Fe (µg/L)	195 (85)	10 (2)	192	—	—
Al (µg/L)	60 (31)	15 (7)	59	—	—
Mn (µg/L)	5.4 (3.3)	15500 (2100)	270	253	3600
Cu (µg/L)	0.3 (0.1)	24 (15)	0.70	0.06	2.8 ^f
Zn (µg/L)	0.3 (0.1)	3700 (420)	64	58	34 ^f
Ni (µg/L)	0.3 (0.1)	390 (140)	7.0	5.9	19 ^f
Co (µg/L)	0.3 (0.1)	535 (100)	9.5	8.7	—
Cd (µg/L)	0.035 (0.02)	52 (6)	0.93	0.78	0.89 ^f
HCO ₃ (mg/L)	7.2 (2.7)	159 (2)	9.8	—	—
Si(OH) ₄ (mg/L)	19 (4)	—	19	—	—
Cl (mg/L)	1.2 (0.4)	5.5 (1)	1.3	—	—
SO ₄ (mg/L)	0.2 (0.1)	1550 (210)	27	—	—
NO ₃ (µg/L)	10 (3)	—	10	—	—
PO ₄ (µg/L)	5 (2)	—	5	—	—
Organic carbon (mg/L)	3 (1)	2 (1)	3	—	—

^a Mean (and standard deviation) measured values for surface waters of the Edith River during the 2011/2012 main wet season 2011/2012 (n=6–45). Values represent dissolved (0.45 µm filtered) concentrations for trace metals.

^b Mean (and standard deviation) measured values (n=2) for treated water. Values represent dissolved (0.45 µm filtered) concentrations for trace metals.

^c Calculated values based on a 1:58 dilution of RP3 water with baseline Edith River water. Values represent dissolved (0.45 µm filtered) concentrations for trace metals.

^d Calculated values based on results from geochemical speciation modelling (see Table 2), where the free metal ion (e.g. Cd²⁺) is a proxy for the bioavailable metal fraction (e.g. Cd: 0.93 x 0.844 [84.4% as Cd²⁺ from Table 2] = 0.78).

^e Water quality guideline (WQG) trigger values for disturbed freshwater ecosystems (80% protection level) ANZECC and ARMCANZ, 2000).

^f Corrected for a water hardness of 34 mg/L as CaCO₃ (using the algorithms given in ANZECC and ARMCANZ, 2000).

Table 2. Speciation calculations for selected metals in surface waters of the Edith River, receiving RP3 discharge.

Metal species ^a	Distribution (%) ^b
Cadmium	
Cd ²⁺	84.4 (4.3)
CdSO ₄	3.8 (0.2)
Cd-DOM ^c	11.5 (3.8)
Cobalt	
Co ²⁺	91.3 (1.9)
CuSO ₄	4.1 (0.1)
Co-DOM	4.5 (2.1)
Copper	
Cu ²⁺	8.4 (2.2)
CuSO ₄	0.4 (0.1)
Cu-DOM	90.8 (6.2)
Manganese	
Mn ²⁺	93.8 (1.2)
MnSO ₄	3.3 (0.1)
Mn-DOM	2.5 (0.8)
Nickel	
Ni ²⁺	84.4 (5.0)
NiSO ₄	3.5 (0.2)
Ni-DOM	12.0 (4.8)
Zinc	
Zn ²⁺	91.0 (2.7)
ZnSO ₄	3.3 (0.1)
Zn-DOM	5.1 (2.2)

^a Each metal species is shown as a percentage of its measured dissolved (0.45 µm filtered) concentration. Metal species comprising <0.2% were excluded for clarity.

^b Mean (and standard deviation).

^c DOM, Dissolved organic matter.

revised according to Lenoir et al. (2010). In addition, revised binding constants of Mn and Zn with fulvic acid were used in the WHAM model, based on “in house” research and development work. The speciation models also account for any minerals that may precipitate or any metal binding/adsorption to iron and/or aluminium (oxy)hydroxides, if applicable. The

input parameters for both speciation models were based on measured water chemistry data (pH and ion concentrations) given in Table 1. Mean (and standard deviation) values were calculated (using Statistica, version 7), based on the results of the three different metal-DOM binding sub-models.

RESULTS AND DISCUSSION

A summary of the surface water chemistry for (i) the Edith River (baseline), (ii) treated RP3 water and (iii) the Edith River (at discharge), is presented in Table 1. The results of speciation calculations (i.e. distribution of species) for Cd, Co, Cu, Mn, Ni and Zn are reported in Table 2. The free metal ion, generally considered to be a good predictor of the bioavailable metal fraction, was calculated to be the major proportion of dissolved (0.45 μm) Cd (84%), Co (91%), Mn (94%), Ni (84%), and Zn (91%), but accounted for only a relatively small proportion of Cu (8.4%). The speciation of dissolved Cu was dominated by binding with dissolved organic matter (91%), whereas Cd, Co, Mn, Ni and Zn formed relatively weak complexes with DOM (i.e. 2.5-12.0%). Given that sulphate is a major anion, by concentration, in the Edith River during discharge of RP3 water from the mine site (Table 1), metal sulphate complexes make-up the ionic charge balance / proportion for Cd, Co, Mn, Ni and Zn (i.e. 3.3-4.1%; Table 2).

Following the current risk-based decision-tree approach of ANZECC and ARMCANZ (2000), the dissolved (0.45 μm filtered) concentrations of Cd, Co, Cu, Mn, Ni and Zn in the Edith River (discharge; Table 1) were adjusted for their respective percentage of calculated free ion (i.e. the best predictor of the “bioavailable fraction”; Table 1). In addition, the default trigger values for Cd, Cu, Ni and Zn, based on an 80% species protection in freshwater ecosystems (ANZECC and ARMCANZ, 2000), were corrected for water hardness (i.e. 34 mg/L as CaCO_3 in Edith River (discharge)) using established algorithms (ANZECC and ARMCANZ, 2000). The results indicate that the “bioavailable fraction” of Cd, Cu, Mn and Ni is less than their respective trigger values (Table 1) - there is no reliable trigger value for Co. However, the “bioavailable fraction” of Zn exceeds the corrected trigger value by a factor of 1.7 (Table 1). Based on this result, ecotoxicological testing with Zn is warranted using relevant freshwater organisms, as the next stage in the decision-tree approach (Figure 2).

While there are limitations in using geochemical speciation models, the general consensus is that they can provide useful results if applied correctly with an understanding of the differences between simulated and real systems (Bethke, 2008). Speciation modelling typically assumes chemical (pseudo-) equilibrium exists in the system. However, due to

biological and geochemical processes in natural waters, chemical equilibrium may not always be attained (Millero, 2000). Of the trace metals most relevant to this study, only Mn has a more complex aquatic chemistry than the equilibrium calculations suggest, due to kinetically slow redox reactions, where soluble Mn^{2+} is oxidised to Mn^{4+} , as insoluble oxides (MnO_2) and oxyhydroxides ($MnOOH$), which form colloidal suspensions, coatings on other minerals and amorphous solid particles mixed with iron oxides (WHO, 2004). Transition between these two forms occurs via oxidation and reduction reactions that may be abiotic or microbially mediated (WHO, 2004). Based on results of the present study, the bioavailability of soluble Mn^{2+} is expected to be high, whereas the bioavailability of insoluble Mn^{4+} is expected to be very low.

On-going water chemistry monitoring of both the Edith River and RP3 may benefit from routine analyses of nitrate (NO_3), phosphate (PO_4) and dissolved organic carbon (filtered with 0.4 μm polysulfone membrane filters). Of these, PO_4 and DOC may bind strongly to trace metals, where the proportion of complexed metal-phosphate or metal-DOM increases with increasing PO_4 or DOC concentration, and thus, a decrease in the proportion of the free metal ion (or the “bioavailable fraction”).

REFERENCES

- ANZECC, ARMCANZ. 2000. *Australian Water Quality Guidelines for Fresh and Marine Waters*. Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.
- Batley, G.E., Apte, S.C., Stauber, J.L. 2004. Speciation and bioavailability of trace metals in water: Progress since 1982. *Aust. J. Chem.* 57, 903–919.
- Bethke, C.M. 2008. *Geochemical and Biogeochemical Reaction Modeling*. Cambridge University Press, London.
- Brown, P.L., Markich, S.J. 2000. Evaluation of the free ion activity model of metal-organism interaction: Extension of the conceptual model. *Aquat. Toxicol.* 51, 177–194.
- Bryan, S.E., Tipping, E., Hamilton-Taylor, J. 2002. Comparison of measured and modelled copper binding by natural organic matter in freshwater. *Comp. Biochem. Physiol.* 133C, 37–49.
- Campbell, P.G.C. 1995. Interactions between trace metals and aquatic organisms: A critique of the free-ion activity model. In: Tessier, A., Turner, D.R. (Eds), *Metal Speciation and Bioavailability in Aquatic Systems*. John Wiley and Sons, Chichester. pp. 45–102.

- DeForest, D.K., Van Genderen, E.J. 2012. Application of U.S. EPA guidelines in a bioavailability-based assessment of ambient water quality criteria for zinc in freshwater. *Environ. Toxicol. Chem.* 31, 1264–1272.
- EC. 2008. EU Directive 2008/105/EC of the European Parliament and of the Council on environmental quality standards in the field of water policy, amending and subsequently repealing council directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council. *Off. J. European Union* 348, 84–97.
- Gustafsson, J.P. 2011. Visual MINTEQ (Version 3.0): A Windows version of MINTEQA2. <http://www2.lwr.kth.se/English/OurSoftware/vminteq/>
- Hamilton-Taylor, J., Ahmed, I.A., Davison, W., Zhang, H. 2011. How well can we predict and measure metal speciation in freshwaters. *Environ. Chem.* 8, 461–465.
- Lenoir, T., Matynia, A., Manceau, A. 2010. Convergence-optimised procedure for applying the NICA-Donnan model to potentiometric titrations of humic substances. *Environ. Sci. Technol.* 44, 6221–6227.
- Markich, S.J. 2012. *Thermochemical Data (log K) for Environmentally-Relevant Elements*, 2nd Ed. ASI C1/12. Aquatic Solutions International, Sydney.
- Markich, S.J., Brown, P.L., Batley, G.E., Apte, S.C., Stauber, J.L. 2001. Incorporating metal speciation and bioavailability into water quality guidelines for protecting aquatic ecosystems. *Australas. J. Ecotoxicol.* 7, 109–122.
- McGeer, J.C., Clifford, M., Janssen, C.R., De Schampelaere, K.A. 2010. Modeling the toxicity of metals to aquatic biota using the biotic ligand approach. In: Bury, N.R., Handy, R.D. (Eds), *Surface Chemistry, Bioavailability and Metal Homeostasis in Aquatic Organisms: An Integrated Approach*. SEB Press, London, pp. 205–231.
- Millero, F. 2000. *The Physical Chemistry of Natural Waters*. Wiley, New York.
- Pesavento, M., Albertini, G., Biesuz, R. 2009. Analytical methods for the determination of free metal ion concentration, labile species fraction and metal complexation capacity of environmental waters: A review. *Anal. Chim. Acta* 631, 129–141.
- Sjöstedt, C.S., Gustafsson, J.P., Kohler, S.J. 2010. Chemical equilibrium modelling of organic acids, Ph, aluminium and iron in Swedish surface waters. *Environ. Sci. Technol.* 44, 8587–8593.
- Tipping, E., Lofts, S., Sonke, J.E. 2011. Humic ion-binding model VII: A revised parameterisation of cation-binding by humic substances. *Environ. Chem.* 8, 225–235.

- Ure, A.M., Davidson, C.M. 2001. *Chemical Speciation in the Environment*. 2nd Ed. Blackwell Science, London.
- USEPA. 2007. *Aquatic Life Ambient Freshwater Quality Criteria – Copper*. EPA-822-R-07-001. United States Environmental Protection Agency, Washington DC.
- WHO. 2004. *Manganese and its Compounds: Environmental Aspects*. World Health Organisation, Geneva.

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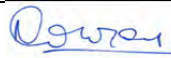
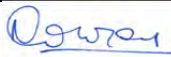
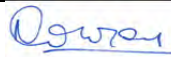
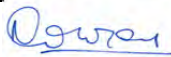
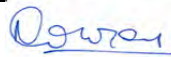
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