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Scott Hayes-Stanley
Director
Wulguru Technical Services
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559 Flinders Street
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Dear Mr Hayes-Stanley,

C&R Consulting Pty Ltd (C&R) recently completed a waste rock characterisation report (C&R, 2022[1]) for the Wirralie Gold Mine (WGM), for Wulguru Technical Services (WTS), to support WGM's progressive rehabilitation and closure plan (PRCP). It is understood that – following the review of this document by the Department of Environment and Science (DES) – a number of issues were raised around the salinity levels of material within the tailings storage facility (TSF), and whether these levels should be categorised as hypersaline. Therefore, this letter aims to provide additional information/explanation of the findings discussed within the C&R (2022) report with respect to the risk from the levels of salinity observed.

The salinity of waste rock (including tailings) was determined through two different methods within the C&R (2022) report. The first method employed the standard 1:5 water/soil mixture (paste) to determine the electrical conductivity (EC; as a proxy for salinity) of the soils/waste rock themselves, whereas the second method used a kinetic leach column test from which the resultant waters were tested (refer to Section 3.2 of C&R [2022] for further discussion of the methods).

The kinetic leach column test aims to provide an indication of the quality of runoff/infiltration waters after extended contact with the waste rock. There are no Queensland guidelines that provide definitions for the various ranges/categories of salinity in waters and the associated risks. Therefore, when assessing the results from the WGM waste rock testing, C&R compared the water quality values from the kinetic leach tests to the categories detailed by the US Geological Survey (refer to https://www.usgs.gov/special-topics/water-science-school/science/saline-water-and-salinity).

The salinity ranges detailed by the US Geological Survey are (once converted to µS/cm by a simple multiplying factor):

- Fresh water = <1,560 µS/cm;
- Slightly saline = 1,560 – 4,680 µS/cm;
- Moderately saline = 4,680 – 15,600 µS/cm; and

[1] C&R (2022). *Wirralie Gold Mine: Waste Rock Characterisation*. Report prepared for Wulguru Technical Services.

- Highly saline = 15,600 – 56,000 µS/cm.

There is no allocation/definition for hypersaline within the US Geological Survey criteria for waters. However, the Wetland Info website of DES refers to hypersaline waters as '*denoting or relating to an aquatic environment that is saltier than typical seawater*' (https://wetlandinfo.des.qld.gov.au/wetlands/resources/glossary.html#q=). Further, the attached Queensland Government document (*Science Notes – Land series – L137*) also states that seawater is typically about 55,000 µS/cm. Based on this, hypersaline would be any EC value greater than the *highly saline* category stipulated by the US Geological Survey (see above). Further, under these definitions, the potential runoff from the WGM waste rock/tailings material would not be considered hypersaline.

C&R only recorded one kinetic leach sample that was in the US Geological Survey *highly saline* category (but was still <20,000 µS/cm when the tests were completed). All other results were less than 12,000 µS/cm, which (in the attached Queensland Government document) is considered brackish water.

Notably, the attached Queensland Government document (*Science Notes – Land series – L137*) does provide salinity classes for soils (i.e. the results of the C&R static [1:5] tests). The mean EC value of static (i.e. using a 1:5 water mix) tailings material samples was 1,592 µS/cm (based on 50 samples). This value is deemed as slightly saline *soils* by the Queensland Government (refer to document attached). The maximum static value of 4,860 µS/cm is classed as moderately saline under the attached document for soils. This means that the '*yield of salt sensitive plants*' would be *'restricted*'. However, in no circumstances are any of the results detailed within the C&R (2022) report considered hypersaline in accordance with available US Geological Survey criteria or Queensland Government definitions.

Based on the above assessment, it is suggested that the risk associated with salinity from the waste rock (including tailings material) at WGM is considered low to moderate, with the potential of brackish runoff/infiltration and a restricted yield of salt-sensitive plants.

Regards,

Dr Christopher Cuff

Principal Scientist/Geochemist – Director
C&R Consulting Pty Ltd

Measuring salinity

Salinity is the accumulation of salt in soil and water. High salt levels can adversely affect plant growth, soil structure, water quality and infrastructure.

High salt levels occur naturally in many parts of the Australian landscape but in many cases have been exacerbated where human activities accelerate the mobilisation and accumulation of salt.

Methods for measuring salinity

It is important to identify saline areas so they can be appropriately managed. There are a range of methods for measuring salinity. Two common ways are by using an electrical conductivity (EC) meter or by measuring how much salt is in a solution of soil or water.

An EC meter measures how much electricity moves through a solution—the saltier the solution, the more electricity moves through it and the higher the conductivity reading. EC can be easily measured in the field or in a laboratory. A wide range of EC meters are available, ranging in price and size.

Electrical conductivity can be expressed in different units—for soil, EC is measured in dS/m (deci-Siemens/metre), while water is measured in µS/cm (micro-Siemens/centimetre). It is important to always calibrate the EC meter before use.

Another way to detect salinity is by measuring how much salt is in a solution—this measurement is called total dissolved solids (TDS) or total dissolved ions (TDI). It is measured in units of mg/l (milligrams/litre) or ppm (parts per million). Higher readings mean more salt is present in the solution.

Measuring salinity in water

Salinity in surface water and groundwater can be easily measured in the field by collecting a water sample, inserting an EC probe into the sample and reading the value shown on the meter.

Alternatively, a water sample can be collected and forwarded to a laboratory for testing of salinity and chemical composition. The container should be entirely filled with the water sample to exclude air. Samples for laboratory analysis should be forwarded as quickly as possible. Delays and high temperatures will change the composition of salts in the sample, affecting the results. Typical salinity values for water are given in Table 3.

Measuring salinity in soil

EC is usually measured in the field using a 1:5 soil:water suspension (EC1:5), or in a laboratory using a soil saturation extract EC (ECse) or a 1:5 solution.

To measure EC1:5 in the field, put approximately 10 millilitres of distilled water, rainwater or tank water into a jar, container or tube. Add small soil particles until the contents of the container increase by 5 millilitres to bring the volume to 15 millilitres. Add additional water to bring the total volume to 30 millilitres. Shake intermittently for five minutes and allow it to settle for five minutes. Dip an EC probe into the solution and take a reading. Remember to wash the EC probe after using it.

The interpretation of EC values to determine soil salinity levels depends on the texture of the soil. Salts are readily dissolved out of sandy soils whereas salts are more tightly held by clay soils. This means that the same amount of salt will have a greater impact on sandy soils then it will on clay soils. As a guide, sandy or loamy

soils are moderately saline if EC1:5 is above 0.3 deci- Siemens/metre, and clay soils are moderately saline if EC1:5 is above 0.6 deci- Siemens/metre.

As the EC1:5 is measured on a diluted sample, a more realistic measurement of the actual salt levels that a plant will encounter can be measured on a saturated extract (ECse). This can be done by some laboratories. As a guide, soils are generally considered saline if their ECse is greater than 2– 4 deci- Siemens/metre.

Salinity tolerance ratings for soils are usually based on ECse values, rather than EC1:5. To convert EC1:5 to ECse, identify the texture of the soil, and use the guide in Table 1

Table. 1. Conversion of EC1:5 to ECse for a range of soil textures

Soil type	Multiply EC1:5 by
Sand	23
Sandy loam	14
Loam	10
Clay loam	9
Light clay	7.5
Heavy clay	6

For example, sand with an EC1:5 of 0.3 dS/m is equivalent to an ECse of 6.9 dS/m, while a heavy clay with an EC1:5 of 0.3 dS/m is equivalent to an ECse of 1.8 dS/m. Soil salinity classes are shown in Table 2.

Table 2. Approximate soil salinity classes

Salinity rating	EC_{se} (dS/m)	
Slightly saline	1.5—2	Salinity effects usually minimal
Moderately saline	2—6	Yield of salt sensitive plants restricted
Highly saline	6—15	Only salt tolerant plants yield satisfactorily
Extremely saline	>15	Few salt tolerant plants yield satisfactorily

Salinity tolerance of crops

As a general guide, salt tolerant crops include barley, canola, cotton, beetroot, soybean, wheat, olives and sorghum. Moderately salt tolerant crops include lucerne, tomato, cabbage, potato and carrots. Low salt tolerant crops include maize, sugar cane, celery, lettuce and pumpkin.

Table 3. Guide to typical salinity limits for waters. It is important to also check other water quality parameters (e.g. chemical composition, sodium adsorption ration, metals etc) before use.

		Electrical conductivity (EC)		TDS
		(µS/cm)	(dS/m)	(mg/l or ppm)
Distilled water		1	0.001	0.67
Rainfall		30	0. 03	20
Sewage effluent		840	0.84	565
Freshwater		0-1500	0-1.5	0-1000
Great Artesian Basin Water		700-1000	0.7-1.0	470-670
Brackish water		1500-15000	1.5-15	1000-10050
Upper limit recommended for drinking		1600	1.6	1070
Tolerances of livestock to salinity in drinking water (at these values, animals may have an initial reluctance to drink, but stock should adapt without loss of production)	Beef cattle	5970-7460	5.9-7.5	4000-5000
	Dairy cattle	3730-5970	3.7-5.9	2500-4000
	Sheep	7460-14925	7.5-14.9	5000-10000
	Horses	5970-8955	5.9-8.9	4000-6000
	Pigs	5970-8955	5.9-8.9	4000-6000
	Poultry	2985-4475	2.9-4.4	2000-3000
General limits for irrigation	Salt sensitive crops	650	0.65	435
	Moderately salt sensitive crops	1300	1.3	870
	Salt tolerant crops	5200	5.2	3485
	Generally too saline for crops	8100	8.1	5430
Salt water swimming pool		5970-8955	5.9-8.9	4000-6000
Seawater		55000	55	36850
Dead sea		110000	110	73700

Note: To convert from µS/cm to dS/m, divide by 1000. To approximately convert from µS/cm to mg/l, multiply by 0.67.

References

- ANZECC (2000). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. ANZECC and ARMCANZ.
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- Foth HD (1990). Fundamentals of Soil Science, 8th Edition. John Wiley & Sons, New York, USA.
- Price G (ed) (2006). Australian Soil Fertility Manual, 3rd Edition. CSIRO Publishing and Fertilizer Industry Federation of Australia, Collingwood.
- Salcon (1997). Salinity Management Handbook. Department of Natural Resources, Indooroopilly.

Further information

This and other science notes are available from the Queensland Government website www.qld.gov.au – search 'science notes'. For further information about this science notes series phone **13 QGOV** (13 74 68) – ask for science notes – Land series L137.

For further information about salinity visit < http://www.qld.gov.au/environment/land/soil/salinity/> or email soils@qld.gov.au.