APPENDIX L

EXCAVATED ROCK PLACEMENT ASSESSMENT

ANNEXURE C – ENVIRONMENTAL CHARACTERISATIONS OF EXCAVATED ROCKS
ANNEXURE D – ECOTOXICOLOGY ASSESSMENT OF EXCAVATED ROCK AND
ANNEXURE E – DISSOLVED ALUMINIUM ASSESSMENT FOR TALBINGO RESERVOIR

Annexure C Environmental Characterisations of Excavated Rocks

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Snowy 2.0 Assignment P4: Environmental Categorisation of Excavated Rock Interactions with and Potential Impacts on Reservoir Waters and Sediments

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Foreword and Assignment Summary

CSIRO was requested by Snowy Hydro Limited (SHL) in November 2017 to provide scientific expertise and capability in relation to identifying and assessing the environmental risks associated with the placement of excavated rocks from the development and operations of the proposed Snowy 2.0 scheme. EMM Consulting (EMM) will be preparing the Environmental Impact Statement (EIS) on behalf of SHL, and CSIRO will undertake a series of assignments to provide scientific information for the environmental risk assessment (ERA) associated with the handling of excavated rock materials from the proposed works. In December 2017, CSIRO worked with EMM to develop conceptual models of the proposed works (source, fate and receptors) to provide information to the ERA. As a result, CSIRO was commissioned to undertake an initial series of four assignments.

In March 2018, Haskoning Australia (HKA) was engaged to provide additional capability, specifically to take the role of leading the project entitled: "Engineering Option for Placement of Excavated Rocks". The draft work assignments that CSIRO had previously provided to SHL and EMM (in late January 2018) were subsequently updated to ensure that they would fulfil the needs of EIS requirements and HKA's "Engineering Option for Placement of Excavated Rocks" project. These updated assignment(s) have been executed and are providing relevant input into the ERA. This report details the results and findings of Assignment P4: Environmental Categorisation of Excavated Rock Interactions with and Potential Impacts on Reservoir Waters and Sediments.

Disclaimer

This Assignment Subcontract and all documents and information provided by CSIRO to HKA under this Assignment Subcontract are prepared (i) as inputs for further scientific services to be performed for HKA by CSIRO under separate Assignment Subcontracts that has been agreed; and (ii) to assist HKA in its development of a excavated rock disposal and management plan as part of the environmental impact assessment process for the proposed Snowy 2.0 Pumped Hydro Electric Scheme("Purpose"), and for no other purpose. This Assignment Subcontract does not involve the provision of advice or recommendations in relation to specific risks or mitigations associated with Excavated Rock disposal and management or design and construction of the Snowy 2.0 project however it is understood that the inputs provided by CSIRO are for the Purpose and are based on CSIRO's professional skill, care and~~,~~ diligence in performing this Assignment Subcontract. In the course of performing this Assignment Subcontract, CSIRO may rely on stated assumptions and/or information provided by HKA or third parties which is not within the control of CSIRO, and this Assignment does not involve CSIRO verifying such assumptions or information except to the extent expressly stated herein. If CSIRO provides any forecasts or projections, CSIRO does not represent that they will be realised as forecast or projected and actual outcomes may vary materially from forecast or projected outcomes. Documents and information provided to HKA under this Assignment Subcontract are to be read as a whole, and if reproduced must be reproduced in full and no part should be read or relied upon out of context. CSIRO does not accept responsibility for, or liability arising from, any error in, or omission in connection with, stated assumptions or third party-supplied information, or reliance on documents or information provided under this Assignment by HKA other than for the Purpose, or by any other person.

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Common Abbreviations/Acronyms

Abbreviation / Acronym	Description
µg	Microgram
AEM	Dilute-acid extractable metal (or other element e.g. metalloid)
COPC	Contaminant of potential concern
CRM	Certified reference material
d	Day
DGV	Default guideline value
DO	Dissolved oxygen
DOC	Dissolved organic carbon
Eh	Redox potential
EIS	Environmental impact statement
ERA	Environmental risk assessment
GV	Guideline Value, replaces term ‘trigger value’ (TV) in water quality guidelines (ANZG, 2018)
h	Hour
kg	Kilogram
L	Litre
L/S	Liquid/solid ratio
LoE	Line of evidence
M	Molar = mol per litre (mol/L)
mg	Milligram
Milli-Q	High purity deionised water
mL	millilitre
mm	Millimetre
NTU	Nephelometric Turbidity Unit
PC95(50)	Concentration that is protective of 95% of species (with 50% confidence)
QA/QC	Quality assurance/quality control
SD	Standard deviation
SE	Standard error
SQGV	Sediment quality guideline value
SOPC	Stressor of potential concern
TOC	Total organic carbon
TRM	Total recoverable metal (or other element e.g. metalloid)
TSS	Total suspended solids
WoE	Weight of evidence
WQGV	Water quality guideline value

Chemical symbols and Acronyms

Ag	Silver	F^-	Fluoride ion	Ni	Nickel	Sn	Tin
Al	Aluminium	Fe	Iron	NO_3^-	Nitrate ion	SO_4^{2-}	Sulphate ion
As	Arsenic	Hg	Mercury	P	Phosphorus	Sr	Strontium
Ba	Barium	K	Potassium	Total-P	Total phosphorus	Ti	Titanium
Be	Beryllium	Li	Lithium	Pb	Lead	Tl	Thallium
Ca	Calcium	Mg	Magnesium	S	Sulphur	Th	Thorium
Cd	Cadmium	Mn	Manganese	Total-S	Total sulphur	U	Uranium
Cl^-	Chloride	Mo	Molybdenum	Sb	Antinomy	V	Vanadium
Co	Cobalt	N	Nitrogen	Se	Selenium	Zn	Zinc
Cr	Chromium	Na	Sodium	Si	Silicon		
Cu	Copper						
dAl	Dissolved aluminium (<0.45 µm filtered)						

Acknowledgments

CSIRO would like to acknowledge the support from Haskoning Australia (HKA) and Snowy Hydro Limited (SHL) for their assistance in acquiring information for this report. We thank Ali Watters and Greg Britton of HKA and Ellen Porter of SHL for discussions to refine the study design, and provision of water and sediment samples. We thank Ryan Fraser (CSIRO) and Grant Douglas (CSIRO) for advice and provision of excavated rock samples and preliminary data. John Gouzos (CSIRO) is thanked for undertaking analyses of selected rock and sediments materials. We thank Graeme Batley (CSIRO) for internal review of the report.

Executive summary

Snowy Hydro Limited (SHL) are exploring options for the placement of excavated rock within the two reservoirs Talbingo and Tantangara, as part of a proposed Snowy 2.0 Pumped Hydro Electric Scheme (Snowy 2.0). The excavated rock placement should not compromise, within reasonable parameters, the ecological, chemical, physiochemical, or physical state of the environment in the reservoirs.

CSIRO were engaged by Haskoning Australia (HKA) on behalf of SHL to provide four studies involving tests and data analysis to help inform an Environmental Impact Statement (EIS) for Snowy 2.0. These studies are:

- Assignment P1: Comprehensive Geochemistry Examination;
- Assignment P2: Environmental Risk Categorisation of Rock Materials;
- Assignment P4: Environmental Categorisation of Excavated Rock Interactions with and Potential Impacts on Reservoir Waters and Sediments; and
- Assignment P5: Ecotoxicological Assessment of Excavated Rock Leachates in Water and Excavated Rock-Sediment Mixtures.

This report specifically relates to Assignment P4 - Environmental Categorisation of Excavated Rock Interactions with and Potential Impacts on Reservoir Waters and Sediments.

Assignment P4 provides scientific information to help assess the potential impacts of the excavated rock materials on water and sediment quality within the reservoirs. Rock materials for testing were sourced from seven geological units based on findings from Assignment P2: Environmental Risk Categorisation of Rock Materials (Douglas et al., 2018). Fourteen excavated rock composite materials were prepared to be representative of the possible range of materials being considered for placement in the reservoirs. These comprised two rock composites for each of the seven geological units, for which individual rock materials had been categorised as 'baseline' or 'enriched' based on concentration of sulphur (total S) as described in Assignment P2. The waters and sediments used were from locations where excavated rock placement may potentially occur (Talbingo and Tantangara Reservoirs). A range of exposure scenarios and conditions (i.e. temperature) were evaluated for the interaction of the rock materials with the reservoir waters and sediments, and analyses of changes to water quality associated with the release/attenuation of substances from the rock materials. Here the term 'substances' refers to any elements, ions and chemical compounds that may become classified as contaminants of potential concern (COPCs) or modify water and sediment quality.

Assignment P4 provides information on the lines of evidences (LoEs) relating to stressors of potential concern (SOPCs) that should be considered within the weight of evidence (WoE) assessment framework. The waters of the Talbingo and Tantangara Reservoirs can be classified as having neutral pH (6.9-7.3), low conductivity (26-30 µS/cm), and low turbidity (0.2-0.6 NTU). The background/baseline waters contained no COPCs when compared to Australian national water quality guideline values (ANZG, 2018). Rock materials were available for seven geological units anticipated to be encountered during tunnelling, with fourteen composite samples prepared from <75-µm sized rock materials and used in the majority of the tests. . The reservoir sediments had similar fine particle size. The rock composites and sediments materials contained few metals at concentrations that exceeded the Australian national sediment quality guideline values (SQGVs). For one rock composite material, the concentrations of Ag, Cr, Ni, Pb and Zn exceeded the SQGVs.

During the anticipated period of time the placement of excavated rock will occur within the reservoirs, significant amounts of fine rock material may remain present in the water column, and the finest fractions may take many days or weeks to settle after the placement activities cease. The release of substances from the rock materials was assessed using a series of elutriate tests that involved mixing and leaching rock materials with reservoir water and covered a wide range of mixing-leaching scenarios and conditions. The tests characterised differences in substance release that may occur due to differences in the concentration of solids in the water (liquid/solid ratio; L/S), time, repeat/successive leaching, rock particle size, temperature, and attenuation of substances released due to interactions with sediments. Substance release was observed to be very similar for rock materials in Talbingo and Tantangara Reservoir waters.

The mixing of excavated rock materials with reservoir waters resulted in increased pH (from approximately pH 7 to 9.5) and conductivity (from approximately 30 to 150 µS/cm). Turbidity was increased in these tests with the <75 µm rock composites in proportion to the L/S ratio. There were no significant increases in nitrate concentrations and small and variable increases in total-P concentrations. When mixed at high solid concentrations (100 g fine rock/L reservoir water; liquid/solid ratios (L/S) = 10), the concentrations of dissolved (<0.45 µm filterable) aluminium (Al) exceeded the default guideline value (DGV) for water quality of 55 µg/L. Dissolved As and Cr exceeded DGVs in some L/S=10 tests. Truly dissolved Al (<0.003 µm) rather than colloidal forms comprised the majority of the <0.45 µm filterable water fraction, with the aluminate ion, $Al(OH)_4^-$ predicted to be the dominate Al species. Increases in water pH, conductivity and dissolved Al were identified as the primary SOPCs, and were the focus of the subsequent tests. Al was identified as a COPC, where exceeding the DGV may cause toxicity to a range of aquatic organisms.

The concentrations of fine solids in the reservoir waters will be influenced by the properties of the rock (e.g. density, particle size) and the water conditions and the placement procedure. The concentrations of rock materials should decrease with increasing distance from the placement site, with materials of larger particle size settling more rapidly to become sediments, and materials of finer particle size remaining in the reservoir water column for longer and dispersing and becoming diluted with reservoir water (L/S lower in deeper waters and closer to the placement area). The DGV for dissolved Al was exceeded at L/S ≤1000 (≥1 g rock solids /L reservoir water, 1 part per thousand) after durations of 18 h, and were exceeded within 0.5 h at a L/S=30. The total-P concentrations were <10 µg/L when the reservoir waters contained <3.3 g/L fine rock materials.

The size of the excavated rock material is expected to range from boulder (>200 mm) to clay (<0.002 mm). The vast majority of the excavated rock, by mass, will be larger in size than coarse-sand (>2 mm) and should settle rapidly to form sediments. When mixed with reservoir water, rock materials with particle size ≥2 mm had negligible impact on water quality. For smaller sized rock materials (e.g. <0.21 mm) mixed with reservoir waters, the pH, conductivity and dissolved Al concentrations increased by a larger extent as the rock particle size decreased, confirming the higher risks of adverse effects to water quality from the finer rock size fractions.

Some portion of the fine rock particles may potentially disperse beyond the target placement area and the release of substances from the solids may continue during this process. Dissolved Al concentrations increased steadily during 1-2 weeks of contact with reservoir water, then decreased and the pH also decreased from pH 9 to 9.5 range (depending on L/S) to nearer pH 8.

The water temperatures of both reservoirs vary between approximately 6°C and 21°C, with significant changes over depth and season. Release of Al from fine rock materials occurred significantly more slowly at 6°C than at 21°C, resulting in fewer elutriate waters exceeding the DGV for dissolved Al.

Greater release of substances may occur from the fine rock materials if they remain in the water column within the placement area or as they disperse away from the placement area. The successive leaches indicated that the Al available for release into solution was not quickly exhausted, with successive leaches often having similar or increased Al concentrations.

Existing benthic sediments in the reservoirs may be resuspended during and following the placement of excavated rock materials in the reservoirs. Tests found that sediments may both release substances and adsorb substances that have been released from the rock materials, with the resuspended sediment concentration and duration of resuspension influencing whether they will act as a sink or a source.

Substance release from excavated rock resulting in stressors of potential concern

The following observations are made with regards to substance release from excavated rock materials in reservoir water that may result in potentially adverse changes to water quality:

(i) Increases in water pH and conductivity are expected due to rapid release of ions that occur via ion solubility and exchange reactions.

- Both high pH (e.g. > pH 9) and high conductivity (e.g. >60 µS/cm) may be classified as SOPCs for some sensitive aquatic organisms.

(ii) Dissolved Al was the only substance consistently identified as a COPC.

- Dissolved Al concentrations may exceed the DGV.
- Sustained release of Al may occur from excavated rock materials.
- Dissolved Al release was negligible for rock materials >2 mm in size.
- Dissolved Al release increases significantly with decreasing particle size <0.21 mm.
- Dissolved Al release is markedly lower in waters with temperature of 6°C than at 21°C.

(iii) Dissolved As and Cr were infrequently identified as COPCs, but only when waters contained >20 g/L fine solids (L/S <50).

(iv) Resuspension of existing sediments within the reservoirs may buffer the pH closer to that of the reservoir waters, but significant attenuation of dissolved Al was not observed in tests.

Overall, Assignment P4 has identified changes in water pH, conductivity and dissolved Al concentrations as the primary SOPCs in both Talbingo and Tantangara Reservoirs, and that the risk of adverse impacts from these SOPCs will increase as concentrations of fine excavated rock materials increase and the duration the rock materials remaining suspended in the water column increases.

In the summary section of this report, greater discussion is provided on the use of the laboratory-derived data for predicting substance release under excavated rock placement conditions in the field. The technique used for the placement of the excavated rock materials is expected to strongly influence the extent of the potential impacts, and aspects of a range of possible placement techniques are discussed that were outside the scope of the study. Field trials of rock placement techniques at a larger scale would greatly benefit the environmental risk assessment. During field trials, field monitoring should include continuous monitoring of general water quality parameters such as pH, conductivity, temperature and turbidity, and in situ monitoring of dissolved Al to provide time-average concentrations that can be better compared to water quality guidelines when assessing risks.

The summary section also identifies a number of knowledge gaps and provides recommendations for future study to fill knowledge gaps.

1 Introduction

1.1 Background

Snowy Hydro Limited (SHL) are embarking on the development of the landmark Snowy 2.0 Pumped Hydro Electric Scheme (Snowy 2.0). As part of Snowy 2.0, options are being identified and assessed for the management and ultimately disposal of excavated rock as part of an Environmental Impact Statement (EIS) and practical engineering options for its management. There are several challenges that are associated with this expansion and a suitable, extensive but ultimately urgent environmental assessment is necessary. To accomplish Snowy 2.0, SHL will require “drill-out” of 27 km of tunnels between the two reservoirs Talbingo and Tantangara and in the process generate approximately 10 million m^3 of excavated rock that will need to be disposed of primarily within these two reservoirs as land-based disposal of significant quantities of excavated rock is not possible within the National Park, nor is it practical to remove it from site.

Haskoning Australia (HKA) have been appointed lead consultant to manage and deliver an Engineering Option Assessment for Excavated Rock Placement for Snowy 2.0. CSIRO has been requested to provide scientific insight into the environmental impacts associated with the excavated rock placement options.

As the subsurface geology was largely unknown, a geological study complemented by a geochemical and mineralogical characterisation was required to determine the composition of the materials to be extracted in the construction phase. The excavated rock will eventually need to be disposed of within the reservoirs, however, initially the excavated rock will be temporarily stockpiled on land and then relocated, along with other materials, into the reservoirs. It is required that the excavated rock be deemed chemically stable now and into the future so the ecological, chemical, physiochemical, and physical state of the environment is not compromised. Further the placement of the excavated rock must:

- not compromise existing reservoir operations during the expansion construction;
- not compromise existing environmental flows;
- ensure extreme and “1 in a 100” year weather events do not impact the long-term stability of the excavated rock placed within either Talbingo or Tantangara Reservoirs, as well as remaining stable under pumping loads of approximately 350 cubic metres per second (cumecs) during expanded hydro operations (intake / outflow); or
- not adversely impact threatened species (both terrestrial and aquatic).

Finally, ensuring all the above, a social licence to operate must be maintained.

1.2 CSIRO work assignments

A series of work assignments were undertaken by CSIRO to inform the EIS:

Assignment P1: Mineralogy and geochemistry characterisation of excavated rock.

Assignment P2: Excavated rock reactivity, leachability, and risk categorisation.

Assignment P4: Environmental characterisation of excavated rock addition to reservoir waters and sediments.

Assignment P5: Effects of excavated rock addition on biota in reservoirs (waters and sediments).

This report relates to Assignment P4 and is provided to HKA to inform their work-programs, considering both the needs of the EIS and the longer-term ecological risk assessment (ERA). Information from baseline studies (primarily from consultancy firm EMM) and from Assignments P1 and P2 (CSIRO) was used to select a subset of materials (excavated rock, waters and sediments) and exposures.

1.2.1 Context for Assignment P4

For the purpose of Assignment P4, the context for the EIS and ERA was informed by the conceptual site model (CSM) and identification of pathways among pressures, stressors, and likely biological receptors and their responses (Appendix A). In the CSM, placement of excavated rock material was envisaged to occur into deep waters within the reservoirs, possibly via dumping from hopper barges near the water surface that result in rock material dropping through the water column with the intent of depositing within a specific placement depth. The CSM incorporates the services for protection, which, for Snowy 2.0, will include the power assets, ecosystem, and recreational services. The CSM thus enables management aims and goals, community values, and required levels of protection to be defined. The services for protection being considered in Assignment P4 are broadly described as 'water quality', of which sediment quality is a component. The SOPCs may be physical (e.g. suspended solids), physico-chemical (e.g. pH, conductivity, dissolved oxygen (DO)) and chemical (e.g. contaminants released from excavated rock or sediments) and the interactions of these multiple stressors. Based on the CSM and SOPCs, the relevant required LoEs can be determined and the analysis of these LoEs then takes place as part of the monitoring and assessment framework (i.e. considered in the EIS and evaluated in the ERA).

For Snowy 2.0, the assessment issue may be broadly categorised as a 'proposed development in a greenfields (undisturbed) location' or a more general 'development approval' (partly or moderately disturbed). For a greenfields location in advance of future development, the assessment issue relates to the gathering of baseline (pre-disturbance) data and information that enables prediction of potential impacts. Typically, following development of the CSM of existing and future pressures, the assessment should seek to provide an adequate baseline characterisation for defining the water quality and ecological health and potential organism sensitivities (and assessing other baseline pressures). In the case of the EIS, EMM indicated that baseline information on water quality (spatial and temporal) and ecosystem status (i.e. what species and functions require protecting) was being gathered. Establishing the pre-development background conditions is necessary to determine the potential additive effects from additional stressors that might be introduced to the water body as a consequence of the proposed development.

The SOPCs are identified in the CSM (Appendix A). In relation to Snowy 2.0, physical and physico-chemical stressors may be of greater concern (may have a greater impact) than the chemical contaminant stressors (e.g. COPCs for which water and sediment quality guideline values exist). The waters within the reservoirs (in which excavated rock placement may occur) are generally quite clear (low suspended solids), low conductivity (low salts), and have low buffering capacity (low alkalinity). The existing ecosystem will be developed around these conditions, noting that the background studies by EMM will determine and describe these conditions and the existing ecosystem in the EIS. The CSM indicated that important physico-chemical stressors within the Reservoirs waters may include fine crushed rock materials or resuspended sediments, acidity (from potential acid generating rock materials), and salts (that increase water conductivity). Unless significant acidity is generated, it would be unlikely that significant concentrations of COPCs (metals or metalloids) would be released from the excavated rock materials to the reservoir waters.

The quality of the LoEs is an important consideration for the assessment (EIS/ERA), and this is strongly influenced by the type of assessment. In the case of Snowy 2.0 (development approval/greenfield site), use of chemistry and physical stressor data alone may frequently be considered of low quality LoE, and need to be integrated with a biological effects LoE that has been designed to assess potential impacts of stressors on water and sediment biota after development has occurred. For Snowy 2.0, it is unlikely that any baseline toxicity exists at the site(s) (i.e. the baseline ecosystem), but Assignment P5 (Ecotoxicological Assessment of Excavated Rock Leachates in Water and Excavated Rock-Sediment Mixtures) will need to establish the potential for toxicity at the operating site due to excavated rock placement. This cannot rely on the chemistry and physical stressor information from the baseline and Assignment P4 studies alone, but needs to be supported by site-specific testing to determine the potential sensitivity of the local ecosystem.

Establishing the baseline for the Ecology LoE is important for identifying the key receptors (sensitive species and functions - biodiversity indicators; highlighting key potential sensitivities of the reservoir ecosystem) that should represent the reference/control and potential impact sites (for which risks of adverse effects are to be assessed). This information will assist in identifying classes/types of organisms and habitats that should be considered in more detail during assessment components that seek to predict potential adverse effects from the proposed development (i.e. potential stressors identified in Assignment P4). Thus, the Ecology LoE for the Snowy 2.0 EIS/ERA assists but does not enable a suitable prediction of impacts unless species sensitivity to the stressors has been pre-established. Assignment P5 provides this information through direct assessment of potential effects using toxicity tests on representative and sensitive species/endpoints under conditions (stressor extremes) predicted to potentially exist from Assignment P4. Assignment P5 thus enables a multiple (added) stressor assessment.

Together, information from Assignments P1, P2, P4 and P5, supported by the baseline information is expected to provide the multiple LoEs to enable a WoE assessment to be undertaken (in accordance with current National Water Quality Management Strategy (NWQMS) assessment guidance: http://www.waterquality.gov.au/anz-guidelines). Based on the CSM, an assessment of the potential for elevated bioaccumulation by local organisms seems unlikely to aid the WoE assessment at this stage.

1.3 Environmental characterisation of excavated rock interactions with and potential impacts on reservoir waters and sediments

Assignment P4 intends to address requirements to assess the potential impacts of the excavated rock materials on water and sediment quality within the reservoirs. The project utilises excavated rock materials, and leachates (attenuation study) arising from excavated rock, selected to be representative of the proposed range of excavated rock placement operations. The waters and sediments used for the study will be from locations / depths where excavated rock placement sites may eventually be selected (i.e. most likely locations/sites). This is expected to provide materials suitable for assessing excavated rock/leachate-water-sediment mixing scenarios that cover an adequate range and enable identification of the potential dominant stressors (physical, physico-chemical and chemical).

Within the WoE assessment framework (Appendix A, Figure A3), Assignment P4 will provide information on the LoEs relating to SOPCs. The project will provide information on the potential for the waters and sediments within the reservoir to attenuate (or exacerbate) the stressors (generally indicated by parameter levels or concentration of substances) released from excavated rock material upon mixing with reservoir waters and sediments (i.e. interactions of excavated rock with water alone and with sediments during resuspension and following deposition).

Assignment P4 involved a range of tests designed to provide information on the types, forms, and behaviour of stressors (physical, physico-chemical and chemical) released from excavated rock material upon mixing with reservoir waters and sediments. There were four main work components:

- Physical and chemical characterisation of excavated rock materials.
- Physical and chemical characterisation of waters and sediments used in elutriate tests.
- Substances[a] release from excavated rock materials to waters.
- Attenuation of substances released from excavated rock by sediments.

[a] Substances include elements, ions and chemical compounds that may become classified as contaminants of potential concern (COPCs) or modify water and sediment quality.

2 Methods

2.1 Waters, sediments and excavated rock materials

The excavated rock samples used in the study were selected based on results from Assignment P2 (Douglas et al., 2018). A total of fourteen composite samples (Appendix B, Tables B1 to B5) were used to represent 'baseline' and 'enriched' materials and seven geological units:

i. Ravine Group – geology of western portion of the tunnel transect and surge shaft (13 km with (ii));

ii. Byron/Boraig Group – geology of western portion of the tunnel transect and surge shaft (13 km with (i));

iii. Shaw Hill Gabbro – in the tunnel transect and constitutes (approximately 1 km);

iv. Gooandra Volcanics – in the tunnel transect (approximately 5 km);

v. Peppercorn/Tantangara/Temperance Formations – in the tunnel transect (approximately 9 km). Based on the available information these could not be readily differentiated, but has a mostly similar geology and form a contiguous sequence along the tunnel transect so have been aggregated;

vi. Kellys Plain Volcanics – in the intake area at the Tantangara Reservoir (approximately 2 km of the tunnel). Note: this material was only available from late in the study and was used in fewer of the tests;

vii. Felsic/Granite/Gneiss/Ignimbrite – compilation of granitic/extrusive equivalents present at various places along the tunnel transect.

For each of these geological units there were between four and nine individual excavated rock materials available to prepare composites (Table 1). For each sample there were 50 g (<75-µm) and also core pieces available. The composites for each geological unit were prepared by weighing equal amounts of each individual <75-µm excavated rock material available for that geological unit and homogenising thoroughly.

Larger pieces of rock (e.g. 3-15 cm length, 2-3 cm thickness) were provided of many of the materials and were used in the laboratory tests investigating the effect of particle size on substance release. Rock samples of varying size categories were prepared using a jaw crusher and sieves to create the following size fractions: 10-25 mm; 2-10 mm, 0.21-2 mm, <0.21 mm. Separate subsamples of rock material were used to also prepare a series of size fractions of 150-210 µm, 63-150 µm and <63 µm.

The reservoir waters (Table 2) and sediments (Table 3) used in the study were provided by HKA and were from locations near the anticipated placement areas for the excavated rock.

Twelve sediment samples (approximately 4 kg each) were collected from 3 sites in the Tantangara Reservoir and 9 sites in Talbingo Reservoir, and transported to CSIRO in Eskys with ice. Seven water samples were collected (approximately 15 L each) in 20-L plastic carboys. For one sample (TAL_PL1B), the carboy was compromised resulting in a leak and it only contained approximately 4 L upon arrival, and was not used for the remainder of the project.

Table 1. Individual <75 µm excavated rock samples used to prepare the composite excavated rock materials.

Composite name (individual samples in corresponding column)											
1B	1E	2B	2E	3B	3E	4B	4E	5B	5E	7B	7E
BH6105-R-0063	BH6102-R-0045	BH5104-R-0122	BH5104-R-0138	BH4106-R-0270	BH4106-R-0273	BH4103-R-0001	BH4103-R-0008	BH3101-R-0257	BH3102-R-0329	BH4102-R-0315	BH5105-R-0147
BH4105-R-0362	BH7105-R-0039	BH5104-R-0133	BH5104-R-0114	BH4106-R-0271	BH4106-R-0274	BH4103-R-0003	BH3110-R-0409	BH3101-R-0259	BH3101-R-0263	BH4102-R-0316	BH5103-R-0066
BH6105-R-0061	BH7105-R-0396	BH5101-R-0055	BH5104-R-0109	BH4106-R-0272	BH4106-R-0276	BH4103-R-0011	BH4103-R-0026	BH3101-R-0261	BH3102-R-0331	BH4102-R-0318	BH5103-R-0080
BH4105-R-0356	BH4104-R-0294	BH5104-R-0116	BH5104-R-0113	BH4106-R-0281	BH4106-R-0278	BH4103-R-0012	BH3110-R-0413	BH3106-R-0353	BH3102-R-0320	BH4105-R-0370	BH5105-R-0146
BH4104-R-0291	BH4105-R-0371	BH5105-R-0143	BH8106-R-0406			BH4103-R-0014	BH3110-R-0407	BH3104-R-0395	BH3102-R-0322	BH5104-R-0115	
BH4105-R-0363	BH6101-R-0226	BH5104-R-0120	BH5104-R-0110			BH4103-R-0018	BH3110-R-0408	BH3101-R-0254	BH3102-R-0321	BH5103-R-0079	
BH7105-R-0036	BH7105-R-0038	BH5104-R-0108	BH5115-R-0388			BH4103-R-0019	BH3110-R-0411	BH3106-R-0352	BH3101-R-0255	BH7104-R-0234	
BH6105-R-0060						BH4102-R-0312	BH4103-R-0017	BH2102-R-0345	BH3102-R-0319		

Additional details provided in Appendix B, Tables B1 to B5. B =– baseline; E = enriched.
For each individual sample, the "R-00XX" identifier tracks the individual samples described in Appendix A7 of Assignment P1.

Table 2. Water samples provided by HKA

Tantangara Reservoir	Date	Time
TAN-TN2A	3/07/2018	11:30
TAN-TN3A	3/07/2018	11:00
TAN-TN1A	3/07/2018	12:05
Talbingo Reservoir	**Date**	**Time**
TAL-PL2A	4/07/2018	13:50
TAL-PL1A	4/07/2018	14:00
TAL-PL1B (leaked / contaminated)	4/07/2018	14:00
TAL-PL2B	4/07/2018	13:50

* Sampling notes and locations in Appendix B

Table 3. Sediment samples provided by HKA

Tantangara Reservoir			
Sample I.D.	Depth (m)	Date	Time
TN2_P4	19	3/07/2018	11.15
TN1_P4	16.5	3/07/2018	11.45
TN3_P4	18.5	3/07/2018	10.40
Talbingo Reservoir			
Sample I.D.	Depth (m)	Date	Time
RA1_P4	31.5	4/07/2018	10.20
RA2_P4	29	4/07/2018	10:45
RA3_P4	28.5	4/07/2018	11:20
PL1_P4	33.5	4/07/2018	14:20
PL2_P4	26.5	4/07/2018	13:15
PL3_P4	27	4/07/2018	12:35
CA1_P4	30	5/07/2018	11:20
CA2_P4	42	5/07/2018	10:15
CA3_P4	48	5/07/2018	9:45

* Sampling notes and locations in Appendix B.

2.2 General analytical procedures

The CSIRO laboratories at Lucas Heights, Sydney, are accredited by the National Association of Testing Authorities (NATA) for all analyses performed for this project. The analysis of trace metals at sub-µg/L concentrations is acknowledged to be technically challenging and necessitates the application of rigorous protocols for container preparation, sample collection and analysis to ensure the accuracy of results. State-of-the-art protocols, as outlined by USEPA (1996) and Angel et al. (2010) were used throughout this work. Plasticware used for metals analyses was either new or acid-washed prior to use with a minimum soak for 24 h in analytical reagent (AR) or Tracepur nitric acid (Merck). Deionised water used was from a Milli-Q system (18 MΩ.cm, Millipore, Australia).

2.2.1 Quality control: general procedures and analysis acceptance criteria

For all analyses, at least three analytical blanks were measured per batch of samples for the determination of mean blank metal concentrations and limits of detection (3 × standard deviation (3σ)).

For all analyses, at least 10% of the samples had method duplicates analysed to confirm the precision of analytical procedures.

To assess the potential matrix interferences during metals analyses, spike recoveries were performed for at least 10% of the samples.

To confirm the analytical accuracy, aliquots of certified reference materials were analysed with each batch of samples whenever a suitable reference material was available. Reference standards have certified concentrations of elements for a range of sample matrices such as freshwater and sediment, allowing the performance of the analytical procedures to be assessed by a comparison of the results obtained with the certified concentrations. The following reference materials were used: TM-24.4 and TMDA-64.3 waters from Environment and Climate Change Canada), ERM-CC018 (European sandy soil reference material) and OREAS-25a (Australian reference soil).

The general acceptance criteria for the analyses included:

- Method duplicates; relative standard deviation is 100% for concentrations ≤5 times limit of detection (LOD), 50% for concentrations between 5 to 10 times the LOD, and 20% for concentrations ≥10 times the LOD;
- Spike recoveries; within 85-115%. Spike recoveries are investigated if outside this range. A common cause of poor spike recoveries is the metal spike is low relative to the concentration in the sample (i.e. spike less than a quarter of the measured concentration). For a batch of samples, if spike recoveries are acceptable for all samples other than ones where the spike is low relative to the measured concentration, the poor spike recoveries are treated as not being representative and are ignored; and,
- Certified reference materials (CRMs); within 85-115% of the certified value specified by certifying authority or within the certified concentration range. CRM material recoveries are investigated if outside this range. Common causes of poor CRM recoveries are the concentrations are low and near the LOD, or are not homogenous for particulate matter.

2.3 Waters

2.3.1 Water sample filtration

For the purpose of sample filtration for measurement of dissolved metals and metalloids, acid-washed (10% v/v nitric acid) plastic syringes (Terumo) fitted with 25 mm 0.45-µm cellulose nitrate capsule filters (Sartorius Minisart) were used (Angel et al., 2015). Before filtering the samples, a 12 mL volume of deionised water followed by 3 mL of sample was passed through each filter to waste to precondition. Then 10-30 mL of sample was filtered into acid-washed polycarbonate filtrate receiving vials. The filtered samples for dissolved metals analysis were preserved by acidifying with 0.2% v/v nitric acid (Merck, Tracepur) immediately after filtration. The samples requiring measurement of anions were not acidified and were placed into a refrigerator to minimise any chemical changes before measurement.

Ultra-filtration of waters to <0.003 µm

For the test investigating the size fractionation of Al described below (Section 3.4.9), ultrafiltration was used to measure truly dissolved metal concentrations and determine whether the <0.45 µm fraction comprised a significant concentration of metals are associated with colloidal species. The method used was similar to that described in Angel et al. (2013), and used Macrosep Advance 3K Omega ultrafiltration centrifugal devices (Pall-Gellman, Port Washington, USA) that had a 3 kDa molecular weight cutoff (equivalent to filtration membrane of approximately 0.003 µm). Each solution added to the devices was centrifuged at 1500 g for 20 min to filter it through the 3 kDa membrane. The ultrafiltration devices were pre-conditioned with 20 mL of Talbingo or Tantangara Reservoir waters (discarded), followed by 20 mL of the treatment solutions. The filtered treatment solutions were subsampled for individual analysis.

In order to verify that the Al did not adsorb to the filter membrane, a dissolved Al control solution (25 µg/L), prepared by addition of $AlCl_3.6H_2O$ to synthetic freshwater (Angel et al., 2013), was subsampled and analysed before and after ultrafiltration (n=3). The Al recovery (mean ± standard deviation) after ultrafiltration of 101±7% confirmed all of the dissolved Al passed through the ultrafiltration membrane without significant adsorption/loss occurring.

2.3.2 General water quality measurements

The pH, conductivity and DO in waters were measured using an Orion Star A329 meter (Thermo Scientific). The pH was measured using a Thermo Scientific Orion Gel-Filled ROSS pH Ultra Triode Electrode (8107UWMMD) that was calibrated using pH 4.00, 7.00 and 10.00 buffers. The conductivity was measured using a Thermo Scientific Orion Conductivity Cell (013010MD) that was calibrated using potassium chloride (KCl) conductivity standards. The DO was measured using a Thermo Scientific Orion RDO optical DO sensor (087010MD) calibrated with water saturated air within its calibration sleeve.

The alkalinity (as total $CaCO_3$) of samples was measured via titration of each sample with standardised sulphuric acid to an end point at pH 4.5 (Method 2320B, APHA 2015).

Dissolved ammonia was analysed colourmetrically using an ammonia test kit (API) and a refined method based on the manufacturer’s instructions. The sediment porewaters analysed for ammonia were isolated from the sediment by completely filling a 50 mL centrifuge tube with sediment (zero head space) then centrifuging at 1000 g for 3-5 min.

Dissolved concentrations of major and minor anions and cations (including most metal(loid)s and rare earth elements) were quantified using a combination of inductively coupled plasma atomic emission spectrometry (ICPAES) (Varian730 ES, in-house method C-229) and inductively coupled plasma-mass spectrometry (ICPMS) (Agilent, 8800, in-house method C-209). Major cations (Ca, K, Mg, Na, Al, Fe, Si) and

Sr were measured by ICPAES. The Ag, As, Ba, Be, Cd, Co, Cr, Cu, Li, Mn, Mo, Ni, Pb, Sb, Se, Sn, Th, Ti, U, V and Zn were measured by ICPMS. The spectrometers were calibrated using matrix-matched standards and operated under the standard operating conditions recommended by the manufacturer.

The major anions Cl^-, F^-, NO_3^- and SO_4^{2-} were measured by suppressed ion chromatography based on APHA Method-4110B using a Shimadzu HPLC system with Merck Sequant Suppressor and conductivity detection. A Shodex IC SI-90 4E column was used with a 12 mM Na carbonate buffer. The HPLC system was calibrated using certified anion standards and samples were diluted (if need) using Milli-Q water to within the linear calibration range. Total-P was analysed by ICPAES, and used to provide an upper limit estimate for reactive phosphate (PO_4^{3-}).

The total organic carbon (TOC) in filtered samples (i.e. dissolved organic carbon (DOC)) was analysed using a Shimadzu TOC-LCSH Total Organic Carbon Analyser following the method APHA 5310B (APHA, 2015). In brief, the total organic carbon (TOC) was calculated from the difference of total carbon (TC) and inorganic carbon (IC) measurements (i.e. TC-IC). The TC was analysed following catalytic oxidation to CO_2 at 680ºC, followed by measurement by non-dispersive infrared analysis (NDIR). The IC was analysed by measuring the CO_2 after purging the sample with phosphoric acid to convert carbonates to CO_2.

2.4 Sediment and rock samples

2.4.1 General analyses

Laser particle size analyses were made using a Malvern Mastersizer 3000, and operating conditions recommended by the manufacturer. In brief, the sediment and excavated rock material were homogenised and approximately 2 g transferred into a 30 mL plastic vial that had been rinsed with deionised water to remove any dust contamination, followed by the addition of approximately 25 mL of deionised water and mixing. A plastic pasteur pipette was then used to draw in and out the sample five times to mix without the addition of air bubbles, after which an aliquot was added to the wet cell of the instrument and sonicated at 100% power for 30 s before measurement of laser diffraction. The international scales are used when referring to particle size (ISO 14688-1:2002): clay (<0.002 mm), fine silt (0.002-0.0063 mm), medium silt (0.0063-0.02 mm), coarse silt (0.02-0.063 mm), fine sand (0.063-0.2 mm), medium sand (0.2-0.63 mm), coarse sand (0.63-2.0 mm), gravel (fine to coarse; 2-63 mm), cobble (63-200 mm), boulder >200 mm).

The moist solid pH was determined using a 1:5 solid/water extract, as described by Rayment and Lyons (2011a). Approximately 10 g of air dried solid was shaken with 50 mL water for one hour and then left to settle for 20 min. The pH was then determined using a Metrohm 815 Robotic Processor and Metrohm 854 glass electrode.

Total carbon was determined by high temperature combustion in an atmosphere of oxygen using a Leco TruMAC (Matejovic, 1997). Carbon was converted to CO_2 and determined by infrared detection. The Inorganic carbon was determined by reacting the sample with acid in a sealed container and measuring the pressure increase (Sherrod et al., 2002; Rayment and Lyons, 2011b). Sufficient finely ground sample to contain no more than 0.8 g $CaCO_3$ equivalent was weighed into a 250 mL glass bottle, a tube containing 8 mL of 3-M hydrochloric acid (HCl) and 3% $Fe(II)Cl_2$ was added and the bottle sealed. The contents were mixed intermittently during a 1 h period and the pressure in the bottle measured by piercing the septum with a needle attached to a pressure transducer. Organic carbon content was determined by difference.

The cation exchange capacity (CEC) was determined using ammonium chloride (NH_4Cl) solution at either pH 7.0 or pH 8.5 dependent on solid pH (Rayment and Lyon, 2011c). Non-calcareous solids use extraction solution pH 7.0 and alkaline solids use extraction solution pH 8.5. Samples were pre-treated for soluble salts prior to extraction, and analysed using a Flow Injection Analyser.

2.4.2 Elemental analyses

Total recoverable metals (TRM)

The total recoverable metals (and other elements) in the sediment and rock materials (<75 µm) were extracted within pre-cleaned Teflon digestion vessels using aqua regia in a microwave-assisted reaction system (CEM, MARS). The Teflon vessels were extensively cleaned using in-house method C-226. In brief, the sediments were freeze-dried (Christ Alpha 1-2 LDplus) and ground to a powder using a mortar and pestle before the strong concentrated acid extraction. The sediments and rock samples were weighed into the pre-cleaned MARS Teflon vessels to which 9 mL of concentrated nitric acid (HNO_3, Merck Tracepur) and 3 mL of concentrated hydrochloric acid (HCl, Merck Tracepur) were added. The MARS Teflon vessels were capped and inverted 2-3 times to ensure that all the solid material is contained in the acid. The CEM MARS system was operated at 1600 Watts and the samples were heated to 175±5ºC over a ramp time of 12 min. Once the samples reached 175±5ºC the samples were held for 4.5 min at this temperature. Following the microwave heating program the vessels were allowed to cool for 30 min in the CEM MARS system and then uncapped to vent the toxic chlorine and nitrogen oxide gases. 40 mL of deionised water was added to each vessel and the vessel stoppered and mixed well by inversion. The digests were left to stand overnight so that the fine solid material settled to the bottom of the vessel. Approximately 20-30 mL of digest was transferred to an acid-washed polycarbonate vial. The digest solutions were subsequently diluted 10-fold using deionised water and analysed using a combination of ICPAES (Varian730 ES) and ICPMS (Agilent 8800 CE) with matrix-matched calibration standards.

Dilute-acid extractable metals (AEM)

Dilute-acid extractable metals (AEM) were determined for each sediment and rock material using an extraction in 1 M HCl (prepared by diluting 36% HCl, 12 M, Merch Tracepur) for 60 min, followed by filtration (<0.45 µm) (in-house method C-241). The extraction treatments (~10 g/L) were shaken for 20 min over the 60 min extraction duration. The 1 M HCl sample extracts were subsequently diluted 10-fold using deionised water and analysed using a combination of ICPAES (Varian730 ES) and ICPMS (Agilent 8800 CE) with matrix-matched calibration standards.

2.5 Substance release from excavated rock materials to waters

Mixing-leaching tests (forms of elutriate tests) were performed on the excavated rock materials to gain an understanding of the release of substances following mixing with reservoir waters. The mixing test methods used were selected following consideration of a range of methods developed in Europe and the USA for the purpose of providing information on the concentrations and potential loads of substances released from the rock materials over time. Leaching for a range of liquid/solid ratios (L/S) were used to develop relationships between the load of substance released and mass of rock (fraction of substance available for leaching). The L/S ratios tested were intended to cover scenarios from worst case (e.g. L/S=10 = 100 g/L) to those representing solids concentration in the water column after sedimentation/settling (e.g. L/S = 3000 = 0.33 g/L). The fraction of a substance released from a rock material generally varies widely between elements, and generally there is a poor correlation between total and potentially leachable concentrations. Replicates were generally performed for 10% of tests.

The leaching kinetics were studied to provide information on changes in dissolved concentrations over time, the release mechanism (ion exchange, dissolution) and available substance load. The effect of rock particle size was investigated to enable relationships to be developed between rock fractions (surface area) and substance load. Successive leaches were undertaken to provide information on available load of the substance being released. The effect of water temperature on substance release was also investigated as the water temperature exhibits substantial variation over seasons and reservoir depth, as well as to provide information on the substance release mechanism (e.g. dissolution kinetics). Analyses were made of pH and conductivity and dissolved substances (<0.45 µm filterable concentrations of substances). The analyses focussed primarily on inorganic substances (e.g. metals, metalloids and major cations), with alkalinity and anions being analysed in some of the tests. Al was identified early within the testing as the principal substance of interest (COPC) and additional analyses were made to investigate the significance of colloids. The influence of sediments on attenuation of substance released from rock materials was also investigated.

Talbingo Reservoir water was used for most tests as Talbingo Reservoir was anticipated at the time of undertaking the testing to be the location where most of the excavated rock material could be placed (Greg Britton, personal communication).

2.5.1 Elutriate tests

The rock-water elutriate (mixing-leaching) tests were undertaken as bottle-rolling tests, in which a pre-determined amount of the rock material were resuspended in a known volume of test water, after which samples were taken for analyses after set periods of time. Unless otherwise specified, tests were conducted at room temperature (21±2°C) in closed containers (acid-washed polycarbonate (PC) vials or low density polyethylene (LDPE) bottles) and DO measurements indicated that samples remained well oxygenated (e.g. approximately 8 mg/L DO). When considering all the tests, a wide range of mixing-leaching scenarios were investigated and the exact description is provided in the corresponding results section. In brief:

- Liquid to solid ratios (L/S) tested included L/S = 10, 30, 300, 500, 1000, 3000, 5000 and 10000; being equivalent to 100, 33, 3.3, 2, 1, 0.33, 0.2 and 0.1 g/L, respectively, where S = excavated rock.
- Mixing periods prior to measuring substance release generally included times of 0.5, 1, 3, 4, 6, 18, 24, 48 and 120 h, with a longer-term test that investigating substance release being run for 8 weeks.
- The primary rock materials had been milled to <75-µm size as part of Assignment P1. Tests were also conducted on different size fractions of excavated rock materials that had size categories 10-25 mm; 2-10 mm, 0.21-2 mm and <0.21 mm (composite fine material). The core samples received were ground using a jaw crusher plant to create rock materials of size ranges that were then separated using sieves. This plant created a wide range of uneven shapes but were generally more flat than square. The crushed materials were sieved through plastic sieves to create the following size fractions: >10 mm; 2-10 mm, 0.21-2 mm and <0.21 mm (fine material). Owing to the varied shapes, the different size ranges included fractions that were able to pass through the sieve in a single direction but would not pass if perpendicular (e.g. long thin piece could pass). This was considered when selecting fractions for the tests, where the aim was to have pieces that were more ‘square’ than flat or thin. For a small number of rock materials tests were conducted on a finer particle size range prepared by sieving the <210 µm material to create size categories of 150-210, 63-150 and <63 µm (composite fine material).
- The effect of temperature was investigated by tests undertaken at both 21±2°C and 6±1°C (conducted in a refrigerator).
- Repeated mixing-leaching of rock materials was undertaken, and included three successive leaches lasting time period of 0.5 and 18 h at several L/S ratios.
- The effect of the presence of sediments (PL2) on substance attenuation was investigated using elutriates created at L/S = 500 (2 g rock/L reservoir water) and sediment at L/S = 50 and 500 (20 and 2 g/L, respectively).
- The effect of resuspended sediment concentration on substance attenuation was investigated using an elutriate created by adding 4 g of composites 1B, 2B, 5B, 5E and 7E (i.e. 20 g of solids) to 2

L of Talbingo water and mixing for 24 h. An aliquot of elutriate was mixed with sediments CA3, PL2, RA1 at sediment TSS concentrations of 1, 5 and 25 mg/L for 30 s, and subsampled after 1 and 24 h.

- The effect of deposited sediment (approximately 2 cm on bottom of 50 mL tube) on substance attenuation was investigated using the above elutriate composite and subsampling after 1, 6, 24 and 96 h.

3 Results

For the majority of the tests and analyses undertaken in the project, summaries of what we considered to be key results were reported to HKA and SHL via a series of Memos (13) and Presentations (3) as the results became available. The memos contained preliminary data and some values have been updated in preparing the report sections below. Each Memo is provided in the appendices together with final data summaries.

3.1 Characterisation of Talbingo and Tantangara Reservoir waters

These results were described in Memo 1 (25 September 2018) (Appendix C).

The pH, conductivity, DO, turbidity, alkalinity and DOC measured in the Talbingo and Tantangara Reservoir waters are shown in Table 4. The pH, conductivity, DO and alkalinity were similar in both reservoirs and ranged from 6.93 to 7.27, 26.5 to 29.4 µS/cm, 9.19 to 10.1 mg/L, and 11.5 to 12.5 mg $CaCO_3$/L, respectively. The turbidity in the Tantangara Reservoir was in the range 0.51-0.60 NTU, which was relatively low but slightly higher than that measured in Talbingo Reservoir of 0.20-0.34 NTU. The DOC ranged from 1.2-2.3 mg/L, with the Tantangara Reservoir having nearly double the concentration as the Talbingo Reservoir. The hardness of the Talbingo and Tantangara Reservoir waters based on the concentrations of Ca and Mg is shown in Table 5. The hardness was in the range 7.47-8.05 mg $CaCO_3$/L, with the Talbingo Reservoir being slightly less hard than the Tantangara Reservoir.

The concentrations of major cations are shown in Table 5. The dissolved Ca, K, Mg and Na were in the range 1.63-1.91, 0.426-0.569, 0.755-0.967 and 1.44-1.57 mg/L, respectively. Talbingo Reservoir had a slightly higher concentration of dissolved Ca, while Tantangara Reservoir had slightly higher concentrations of K and Mg, and Na was of a similar concentration in both reservoirs.

The concentrations of Ag, Al, As, Ba, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Sb, Se, Sn, Sr, Th, U, V, Zn are shown in Table 6. The concentrations of dissolved Ag, Be, Cd, Li, Mo, Sb, Se, Sn, Sr and Tl were similar in both reservoirs. The concentrations of dissolved Al, As, Ba, Co, Cr, Fe, Mn, Ni, Pb, Th and V were higher in Tantangara Reservoir than Talbingo Reservoir. The dissolved Al, Fe and Mn concentrations were a factor of 6, 15 and 10 times higher in Tantangara Reservoir waters, and were subsequently found to be predominantly comprised of colloidal phases using measurements size fractionation (0.45 µm vs 0.003 µm, Appendix D8). The concentrations of dissolved Ag, Al, As, Ba, Be, Cd, Co, Cr, Fe, Li, Mn, Mo, Ni, Pb, Sb, Se, Sn, Sr, Th, Tl and V exhibited little intra-reservoir variability for the multiple sites sampled in each reservoir, indicating surface waters are well mixed throughout each reservoir. The concentrations of dissolved Cu, U and Zn were generally higher in Talbingo Reservoir than Tantangara Reservoir, however, site TAL-PL1B contained over 5 µg/L of Cu, attributed to likely contamination during collection and transport; this carboy was damaged and had a leak.

The concentrations were compared to the corresponding guideline values (GVs) for water quality ANZG (2018), representing the 95 and 99% of species protection concentrations Table 6 when values were available. The only exceedance of the default guideline values (DGV) was for Cu in sample TAL-PL1B, and that was attributed to the aforementioned potential contamination. All sites exceeded the 99% guideline value (99% GV) for dissolved Cr, however, it should be noted that the only value available for comparison was for hexavalent Cr being in the hexavalent form, which is unlikely due its' stability. The dissolved Al concentration exceeded the 99% GV in Tantangara Reservoir waters, with approximately 80% of the dissolved (<0.45 µm) speciation subsequently being found to be in colloidal forms (Appendix D8).

Table 4. The pH, alkalinity conductivity, DO, turbidity, and DOC in Talbingo and Tantangara Reservoir waters

Site Code	Reservoir	pH	Alkalinity (mg $CaCO_3$/L)	Conductivity (µS/cm)	DO (mg/L)	Turbidity (NTU)	DOC[a] (mg/L)
TAL-PL1A	Talbingo	7.2	12	26.5	9.7	0.20	1.3
TAL-PL2A	Talbingo	6.9	12	27.3	9.6	0.34	1.2
TAL-PL1B	Talbingo	7.3	12	28.9	9.5	0.26	1.3
TAL-PL2B	Talbingo	7.2	12	28.3	9.5	0.22	1.3
TAN-TN1A	Talbingo	7.2	13	28.4	9.2	0.51	2.2
TAN-TN2A	Tantangara	7.2	12	29.4	10	0.60	2.2
TAN-TN3A	Tantangara	7.1	12	28.7	9.9	0.54	2.3

Table 5. The concentrations of major cations and water hardness in Talbingo and Tantangara Reservoir waters

Site Code	Hardness (mg $CaCO_3$/L)	Na (mg/L)	K (mg/L)	Mg (mg/L)	Ca (mg/L)
TAL-PL1A	7.5	1.51	0.43	0.81	1.88
TAL-PL2A	7.5	1.5	0.43	0.82	1.87
TAL-PL1B	8.0	1.62	0.45	0.87	2.00
TAL-PL2B	7.5	1.51	0.43	0.82	1.87
TAN-TN1A	8.1	1.65	0.57	1.04	1.73
TAN-TN2A	8.0	1.64	0.56	1.04	1.74
TAN-TN3A	8.0	1.63	0.57	1.04	1.72

Table 6. The concentrations of metals and metalloids in Talbingo and Tantangara Reservoir waters

Site Code	Ag (µg/L)	Al (µg/L)	As (µg/L)	Ba (µg/L)	Cd (µg/L)	Co (µg/L)	Cr (µg/L)	Cu (µg/L)	Fe (µg/L)	Mn (µg/L)
TAL-PL1A	<0.002	7	0.17	4.5	<0.01	<0.01	0.06	0.65	24	0.3
TAL-PL2A	<0.002	8	0.18	4.5	<0.01	<0.01	0.06	0.63	27	0.3
TAL-PL1B	<0.002	7	0.16	4.6	<0.01	<0.01	0.06	5.2	25	0.4
TAL-PL2B	<0.002	7	0.15	4.4	<0.01	<0.01	0.05	0.74	26	0.3
TAN-TN1A	<0.002	43	0.31	6.2	<0.01	0.03	0.10	0.48	396	3.2
TAN-TN2A	<0.002	43	0.23	6.3	<0.01	0.03	0.09	0.41	399	3.2
TAN-TN3A	0.017	42	0.33	6.2	<0.01	0.03	0.10	0.39	394	3.3
DVG [a]	0.05	55	13	-	0.2	-	1.0	1.4	-	1900
99% GV [b]	0.02	27	0.8	-	0.06	-	0.01	1.0	-	1200

Site Code	Mo (µg/L)	Ni (µg/L)	Pb (µg/L)	Sb (µg/L)	Se (µg/L)	Sn (µg/L)	Sr (µg/L)	Th (µg/L)	U (µg/L)	V (µg/L)	Zn (µg/L)
TAL-PL1A	<0.1	0.08	<0.01	0.01	0.03	<0.02	15	0.004	0.017	0.10	2.5
TAL-PL2A	<0.1	0.10	<0.01	<0.01	0.02	<0.02	15	0.004	0.014	0.10	1.1
TAL-PL1B	<0.1	0.11	0.03	0.01	0.02	<0.02	16	0.004	0.015	0.11	2.0
TAL-PL2B	<0.1	0.12	<0.01	0.01	0.02	<0.02	15	0.003	0.016	0.11	0.7
TAN-TN1A	<0.1	0.19	0.08	0.01	0.02	<0.02	15	0.016	0.008	0.21	1.7
TAN-TN2A	<0.1	0.20	0.06	<0.01	0.02	<0.02	15	0.014	0.008	0.21	1.0
TAN-TN3A	<0.1	0.18	0.05	<0.01	0.03	<0.02	15	0.012	0.009	0.21	0.4
DGV [a]	-	11	3.4	-	11	-	-	-	-	-	8.0
99% GV[b]	-	8	1.0	-	5	-	-	-	-	-	2.4

[a] http://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/. DGV = default guideline value (water quality guideline value (WQGV), representing the 95% species protection guideline values (95%GV) for freshwater. [b] 99% species protection guideline values (99%GV) for freshwater. Values for As are for As(V), Cr are for Cr(VI), and tin are for inorganic tin

The concentrations of major anions (Cl^-, F^-, NO_3^-, SO_4^{2-}) and total-P and Si are shown in Table 7. The concentrations of most anions were near the limit of reporting and generally similar for both reservoirs. Nitrate and Si concentrations were higher in the Talbingo Reservoir waters. The C, N, P and Si concentrations are reported due to their potential influence on algal growth (phytoplankton and diatoms). The concentrations of nitrate were greater than the default guideline value of 0.01 mg N/L for NOx in the Talbingo Reservoir samples. Total-P concentrations were below the DGV (freshwater lakes and reservoirs in south-east Australia).

Table 7. The concentrations of major anions and total-P and Si in Talbingo and Tantangara Reservoir waters

Site Code	Chloride (mg/L)	Fluoride (mg/L)	Nitrate (mg/L)	Sulphate (mg/L)	Total-P (mg/L)	Si (mg/L)
TAL-PL1A	<1	<0.1	0.1	<1	<0.010	2.20
TAL-PL2A	<1	<0.1	0.1	<1	<0.010	2.20
TAL-PL1B	1	<0.1	0.2	<1	<0.010	2.10
TAL-PL2B	<1	<0.1	0.1	<1	<0.010	2.10
TAN-TN1A	<1	<0.1	<0.1	<1	<0.010	0.64
TAN-TN2A	<1	<0.1	<0.1	<1	<0.010	0.63
TAN-TN3A	<1	<0.1	<0.1	<1	<0.010	0.65
DGV	-	-	0.01	-	0.010	

[a] http://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/.

DGV = default guideline values for nitrate (NOx as mg N/L) and total-P are for freshwater lakes and reservoirs in south-east Australia.

Reservoir Waters Summary

The reservoir waters had neutral pH (6.9-7.3), low conductivity (26-30 µS/cm), and low turbidity (0.2-0.6 NTU). Most parameters measured in the waters were in a similar concentration range in both reservoirs and there was little variability between sites in each reservoir. The concentrations of dissolved Al, As, Ba, Co, Cr, Fe, Mn, Ni, Pb, Th and V were higher in Tantangara Reservoir than Talbingo Reservoir. Dissolved Al, Fe and Mn concentrations were a factor of 6, 15 and 10 times higher in Tantangara than Talbingo Reservoir, and were subsequently found to be predominantly in colloidal forms (Appendix D8). These colloidal species contribute significantly to the dissolved Al concentration exceeding the 99% GV in the Tantangara waters. In relation to water quality guidelines (ANZG, 2018), the waters contained no contaminants of potential concern (COPCs), i.e. concentrations were less than the corresponding DGV. Nutrient concentrations were generally within acceptable ranges, with care to note that the limit of detection for nitrate analyses was greater than the DGV.

3.2 Characterisation of Talbingo and Tantangara Reservoir sediments

These results were described in Memo 2 (25 September 2018) (Appendix C).

3.2.1 Reservoir sediment pore waters

The pH, conductivity and redox potential of the sediment pore waters in the Talbingo and Tantangara Reservoirs are shown in Table 8. There was little difference in each parameter between the different sites in Talbingo Reservoir. The porewater pH was marginally lower in Talbingo Reservoir than the Tantangara Reservoir, while the conductivity and redox potential were marginally higher. The higher redox potential indicates slightly more oxic conditions prevailed in the Tantangara Reservoir sediment porewaters.

The major anions, total-P and Si and ammonia in the Talbingo and Tantangara Reservoir sediment porewaters are shown in Table 8. The concentration of SO_4^{2-} was variable between sites at the same general location (i.e. CA, PL or RA), whereas, Cl^-, NO_3^- and ammonia concentrations were generally similar between the different sites in the Talbingo Reservoir. The sediment pore water of the Tantangara Reservoir had higher concentrations of ammonia than the Talbingo sites. Total-P concentrations were several orders of magnitude higher in the pore waters than both the reservoir surface waters (Table 7). Total ammonia concentrations were similar within a factor of two, and higher in Tantangara Reservoir sediments than Talbingo Reservoir sediments.

The concentrations of metals, metalloids and major cations in the sediment pore water of Talbingo and Tantangara Reservoir sediments are shown in Table 9. Many of the metals, metalloids and major cations exhibited substantial variability between sites, probably due to differences in micro-environmental parameter conditions, such as redox potential.

When comparing sediment porewater concentrations with the DGVs for surface water (Table 6), the Al and Cu exceeded the corresponding DGV in some pore waters. The dissolved (<0.45 µm filterable) Al was the most variable, probably due to differences in colloidal fractions between sites. Copper is likely to be complexed by organic ligands, resulting in the labile (and potentially bioavailable) concentration being below the DGV. The pore waters of the Talbingo Reservoir sediments from location RA had a dissolved As concentration that exceeded the DGV. It should be noted that the DGVs are designed for risk minimisation in surface waters and the exceedances observed for sediment pore waters may occur naturally for some substances, in which case they are not usually classified as COPCs.

Table 8. pH, redox potential, conductivity, major anions and ammonia of the reservoir sediment pore waters

Site Code	Reservoir	pH	Redox, Eh (mV)	Conductivity (µS/cm)	Cl^- (mg/L)	NO_3^- (mg/L)	SO_4^{2-} (mg/L)	Total-P (mg/L)	Total Si (mg/L)	Total ammonia (mg NH_3/L)
CA1	Talbingo	7.30	-175	23.5	<4	<0.5	<3	0.34	11	2.4
CA2	Talbingo	7.60	-180	26.5	<4	<0.5	5	0.33	10	2.8
CA3	Talbingo	7.45	-170	19.0	<4	0.7	<3	0.23	12	2.6
PL1	Talbingo	7.05	-140	20.0	<4	0.6	<3	0.50	12	2.6
PL2	Talbingo	7.30	-125	15.7	<4	0.5	<3	0.34	10	2.3
PL3	Talbingo	7.40	-160	18.9	<4	0.6	<3	0.38	11	2.2
RA1	Talbingo	7.25	-160	22.7	<4	0.5	<3	0.08	11	2.8
RA2	Talbingo	7.30	-185	24.0	<4	0.5	<3	0.37	14	3.3
RA3	Talbingo	7.50	-190	21.6	<4	<0.5	<3	0.38	15	4.3
TN1	Tantangara	6.70	-105	33.0	<4	0.6	<3	0.14	16	5.6
TN2	Tantangara	7.10	-140	36.0	6	<0.5	<3	0.32	14	5.7
TN3	Tantangara	7.00	-155	36.7	<4	<0.5	<3	0.71	16	7.5

Table 9. Concentrations of major ions, metals and metalloids in the reservoir sediment pore waters

	Na	K	Mg	Ca	Fe	Mn		Ag	Al	As	Ba	Cd	Co
Site code			(mg/L)							(µg/L)			
CA1	2.9	1.0	1.84	6.08	25.9	7.3		0.063	10	6.2	68	<0.021	9.2
CA2	3.4	1.4	6.36	10.5	37.1	10.5		<0.005	8	7.9	107	0.033	8.8
CA3	2.0	1.1	1.30	5.50	17.9	15.6		<0.005	67	8.9	72	0.080	7.7
PL1	2.9	1.2	2.01	6.10	27.5	7.4		0.006	278	11.7	75	<0.021	10.5
PL2	2.2	1.0	1.83	6.54	18.6	9.8		0.008	600	6.7	62	<0.021	7.1
PL3	2.8	1.8	3.37	7.65	36.8	12.9		0.007	32	7.5	108	0.027	11.0
RA1	2.1	1.1	1.23	5.40	15.6	8.1		0.006	144	10.3	89	<0.021	7.0
RA2	2.5	1.2	1.55	8.19	22.4	14.0		<0.005	51	17.7	133	<0.021	7.5
RA3	2.5	1.2	2.14	13.3	30.6	28.8		<0.005	6	18.3	260	0.035	9.3
TN1	3.6	1.4	2.26	3.66	28.1	2.7		0.005	180	4.6	107	<0.021	7.2
TN2	3.5	1.2	2.12	3.39	32.1	2.6		0.004	179	5.1	95	<0.021	5.2
TN3	1.9	0.9	1.84	3.09	37.4	3.4		<0.005	59	8.6	111	<0.021	5.7
Minimum	**1.92**	**0.917**	**1.230**	**3.09**	**15.6**	**2.56**		**<0.005**	**5.5**	**4.63**	**62.1**	**<0.021**	**5.25**
Maximum	**3.56**	**1.77**	**6.36**	**13.3**	**37.4**	**28.8**		**0.063**	**600**	**18.3**	**260**	**0.080**	**11.0**

	Cr	Cu	Mo	Ni	Pb	Sb	Se	Sn	Sr	Th	U	V	Zn
Site code							(µg/L)						
CA1	0.39	0.24	0.9	1.7	<0.046	0.10	0.12	<0.028	51.9	0.058	0.059	1.6	1.5
CA2	0.57	0.31	0.8	1.7	<0.046	0.10	0.14	<0.028	121.7	0.080	0.096	1.9	3.5
CA3	0.44	0.91	1.3	2.1	0.306	0.13	0.12	<0.028	45.3	0.117	0.105	2.5	3.1
PL1	0.83	1.62	0.6	2.5	0.660	0.23	0.13	<0.028	47.8	0.163	0.137	2.8	2.6
PL2	0.68	1.39	1.3	2.1	0.622	0.20	0.10	<0.028	44.8	0.149	0.137	2.6	6.2
PL3	0.38	0.68	1.9	1.6	0.157	0.28	0.14	<0.028	71.4	0.079	0.112	1.6	4.2
RA1	0.43	1.47	1.0	2.0	0.716	0.13	0.09	<0.028	35.7	0.132	0.152	1.8	4.0
RA2	0.45	0.46	1.2	2.4	0.134	0.06	0.12	<0.028	49.9	0.093	0.105	1.9	1.9
RA3	0.37	0.30	2.0	2.6	0.001	0.12	0.15	<0.028	69.9	0.078	0.260	2.0	2.2
TN1	0.69	0.65	0.2	1.1	0.140	0.28	0.18	<0.028	36.7	0.140	0.053	3.6	1.6
TN2	0.73	0.53	0.2	0.8	0.150	0.28	0.17	<0.028	34.8	0.133	0.035	2.9	2.2
TN3	0.76	0.27	0.1	0.9	<0.046	0.17	0.23	<0.028	31.9	0.103	0.033	3.4	1.4
Minimum	**0.373**	**0.238**	**0.12**	**0.784**	**<0.046**	**0.064**	**0.094**	**<0.028**	**31.9**	**0.058**	**0.033**	**1.59**	**1.42**
Maximum	**0.835**	**1.62**	**2.03**	**2.62**	**0.716**	**0.283**	**0.235**	**0.013**	**122**	**0.163**	**0.260**	**3.62**	**6.23**

3.2.2 Reservoir benthic sediments

The particle size distributions of the Talbingo and Tantangara Reservoir sediments are shown in Table 10. Cumulative distribution plots and tables are shown in Appendix C. The mean diameter of the sediments was in the range 23.1 to 77.6 µm. The Dv (50) (50% of particles had lower diameter than this value) were all less than 30 µm, indicating the sediments were predominantly silt and clay. Tantangara Reservoir sediments had a larger particle size-range, which influenced its slightly larger mean particle size.

The total N, total-P, inorganic and organic carbon in benthic reservoir sediments are shown in Table 11. For Talbingo reservoir, the RA sites had lower concentrations of many of the parameters than the CA and PL sites. Tantangara Reservoir sediments had similar or higher concentrations of each parameter than those in Talbingo Reservoir sediments. The concentrations of each parameter varied by approximately two-fold between the different sites in the two reservoirs.

The total Ca, K, Mg, Na, S in the benthic sediments and the sediment cation exchange capacity (CEC) is shown in Table 11. For Talbingo Reservoir sediments, Ca was the only major cation that varied between the sites, with lower concentrations being measured in the RA site sediments than the CA or PL sediments. The concentrations of Ca, Mg, K and Na were generally lower in Tantangara Reservoir sediments than Talbingo

Reservoir sediments. The S concentrations were higher in Tantangara Reservoir sediments and the CEC was similar for both reservoir sediments.

Table 10. Particle size distribution of Talbingo and Tantangara Reservoir benthic sediments

Site Code	Reservoir	Dv (10) (µm)	Dv (50) (µm)	Dv (90) (µm)	Mean diameter (µm)
CA1	Talbingo	4.40	15.7	70.6	31.2
CA2	Talbingo	4.30	18.0	113	45.5
CA3	Talbingo	4.36	17.2	103	44.7
PL1	Talbingo	4.67	18.0	81.6	36.5
PL1 Dup	Talbingo	4.73	17.4	73.9	32.7
PL1 mean	Talbingo	**4.70**	**17.7**	**77.8**	**34.6**
PL2	Talbingo	4.41	16.3	90.6	42.1
PL3	Talbingo	4.24	16.0	103	49.6
RA1	Talbingo	3.94	13.7	62.0	30.7
RA1 dup	Talbingo	3.93	13.5	60.8	28.8
RA1 mean	Talbingo	**3.94**	**13.6**	**61.4**	**29.8**
RA2	Talbingo	3.66	11.5	43.9	23.1
RA3	Talbingo	3.75	12.0	47.7	24.2
TN1	Tantangara	5.57	27.4	223	77.6
TN2	Tantangara	4.84	20.1	132	50.5
TN3	Tantangara	4.63	20.3	133	48.7

Note: Dv (x) refers to 10, 50 and 90th percentiles of particle diameters (on spherical volume basis).

Table 11. Concentration of total N, total-P, TIC, TOC, Ca, K, Mg, Na, S and CEC of Talbingo and Tantangara Reservoir sediments

Site Code	Reservoir	Total N (%)	Total-P (mg/kg)	TIC (%)	TOC (%)	Ca	K	Mg (mg/kg)	Na	S	CEC (NH4) cmol (+/-)/kg
CA1	Talbingo	0.43	1340	0.2	5.8	1900	7150	5310	175	475	34
CA2	Talbingo	0.39	1170	0.1	5.5	2080	8670	6210	174	432	33
CA3	Talbingo	0.36	1140	0.1	4.5	1790	8580	7770	179	395	30
PL1	Talbingo	0.39	1080	0.1	5.5	2450	7280	6680	177	436	32
PL2	Talbingo	0.41	1030	0.2	6.0	1900	8800	6190	192	409	29
PL3	Talbingo	0.40	1130	0.2	5.4	1620	7790	6100	174	448	32
RA1	Talbingo	0.37	945	0.1	4.4	1480	8970	6630	163	395	27
RA2	Talbingo	0.36	945	0.1	4.2	1490	10230	7040	175	386	30
RA3	Talbingo	0.32	916	0.1	3.7	1450	8690	6570	146	338	26
TN1	Tantangara	0.54	1040	0.2	6.4	714	6650	3320	140	650	34
TN2	Tantangara	0.56	1500	0.2	5.7	783	7700	3490	150	742	36
TN3	Tantangara	0.54	1310	0.2	5.8	653	7480	3520	134	773	36
Minimum		**0.32**	**916**	**0.1**	**3.7**	**653**	**6650**	**3320**	**134**	**338**	**26**
Maximum		**0.56**	**1500**	**0.2**	**6.4**	**2450**	**10230**	**7770**	**192**	**773**	**36**

TIC is total inorganic carbon, TOC is total organic carbon, CEC is cation exchange capacity

The TRM concentrations (total recoverable metal, metalloid, and other major ions) in Talbingo and Tantangara Reservoir sediments are shown in Table 12. There was generally higher concentrations of Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Sb, Sn, Sr, Th and U in Talbingo Reservoir sediments and a higher concentration of S in Tantangara Reservoir sediments.

These concentrations reflect the background surface sediment concentrations. The concentrations of Ni exceed the corresponding sediment quality guideline value (SQGV) (Simpson et al., 2013; ANZG, 2018) that is considered an overly conservative value (Vangheluwe et al., 2013; Simpson and Batley 2016).

A significant portion of the TRM concentration (extracted using concentrated acids) may release inert (not easily released) fractions of metals that exhibit very low bioavailability to organisms. For most metals, the ‘maximum bioavailable concentration’ can be estimated by AEM analyses, as commonly achieved by extracting the solid in 1-M HCl for 1 h (Simpson and Batley, 2016). AEM data can also be useful for interpreting the partitioning behaviour of elements between the dissolved and particulate phases, and the potential availability of reactive binding phases.

The AEM concentrations (metal, metalloid, and other major ions) in Talbingo and Tantangara Reservoir sediments are shown in Table 13. There was generally little variation in the AEM concentrations between the different sites in Talbingo Reservoir sediments. However, the K, Mg and V were marginally lower for the RA sites than the CA and PL sites. A comparison between the two reservoirs showed that the AEM concentrations of As, Ba, Ca, Cr, Cu, K, Mg, Mn, Na, Ni, Th and U from Talbingo Reservoir sediments were generally higher than those measured in Tantangara Reservoir, while a higher concentration of S was extracted from Tantangara Reservoir sediments.

No AEM concentrations exceeded their respective SQGVs.

Reservoir Sediment Summary

The concentrations of many of the parameters often differed between the two reservoirs. There were no exceedances of SQGVs for the AEM concentrations, and few based on TRM.

Table 12. Total recoverable concentrations (TRM) metals, metalloids and other elements in Talbingo and Tantangara Reservoir sediments

Sediment ID	Reservoir	Al (mg/kg)	Ag (mg/kg)	As (mg/kg)	Ba (mg/kg)	Cd (mg/kg)	Ca (mg/kg)	Co (mg/kg)	Cr (mg/kg)	Cu (mg/kg)
CA1	Talbingo	23000	0.14	9.2	250	0.24	1800	30	56	41
CA2	Talbingo	23000	0.13	8.6	270	0.17	1900	23	56	37
CA3	Talbingo	42000	0.15	12	300	0.27	1900	30	78	51
PL1	Talbingo	31000	0.11	8.8	220	0.15	1800	28	72	46
PL2	Talbingo	35000	0.14	11	250	0.23	2200	26	61	52
PL3	Talbingo	36000	0.14	12	240	0.26	1600	30	62	51
PL3 duplicate	Talbingo	36000	0.15	12	240	0.21	1600	30	61	51
PL3 Mean	**Talbingo**	**36000**	**0.14**	**12**	**240**	**0.23**	**1600**	**30**	**61**	**51**
RA1	Talbingo	20000	0.14	10	240	0.27	1400	24	48	46
RA2	Talbingo	36000	0.16	14	280	0.22	1700	25	59	49
RA3	Talbingo	26000	0.15	15	320	0.23	1700	25	52	48
TN1	Tantangara	17000	0.12	5.4	180	0.27	720	15	27	26
TN2	Tantangara	31000	0.16	6.7	230	0.25	840	23	37	28
TN3	Tantangara	23750	0.15	8.2	240	0.25	1150	26	41	32
Minimum		**17000**	**0.11**	**5.4**	**180**	**0.15**	**720**	**15**	**27**	**26**
Maximum		**42000**	**0.16**	**15**	**320**	**0.28**	**2200**	**30**	**78**	**52**
SQGV			**1**	**20**	**NA**	**1.5**	**NA**	**NA**	**80**	**65**

Sediment ID	Reservoir	Fe (mg/kg)	Hg (mg/kg)	K (mg/kg)	Mg (mg/kg)	Mn (mg/kg)	Mo (mg/kg)	Na (mg/kg)	Ni (mg/kg)	Pb (mg/kg)
CA1	Talbingo	49000	<0.1	2200	4400	2200	0.60	58	44	25
CA2	Talbingo	44000	<0.1	3400	5400	1900	0.63	51	43	24
CA3	Talbingo	56000	<0.1	6000	8000	4000	0.60	120	68	26
PL1	Talbingo	45000	<0.1	3100	6400	1900	0.56	83	64	22
PL2	Talbingo	45000	<0.1	3100	5700	3000	0.99	100	56	28
PL3	Talbingo	57000	<0.1	3400	5900	2400	0.67	120	54	27
PL3 duplicate	Talbingo	73000	<0.1	3500	5800	2500	0.65	92	54	27
PL3 Mean	**Talbingo**	**65000**	**<0.1**	**3400**	**5800**	**2400**	**0.66**	**100**	**54**	**27**
RA1	Talbingo	37000	<0.1	1600	5400	2100	0.49	27	48	28
RA2	Talbingo	42000	<0.1	4000	6400	2800	0.40	85	60	32
RA3	Talbingo	45000	<0.1	2500	6000	4000	0.39	48	56	30
TN1	Tantangara	25000	<0.1	1200	2200	540	0.45	44	13	23
TN2	Tantangara	39000	<0.1	2400	2600	740	0.36	70	19	28
TN3	Tantangara	41700	<0.1	3180	4590	2390	0.45	45	27	27
Minimum		**25000**	**<0.1**	**1200**	**2200**	**540**	**0.36**	**26**	**13**	**22**
Maximum		**73000**	**<0.1**	**6000**	**8000**	**4000**	**0.99**	**120**	**68**	**32**
SQGV			**0.15**	**NA**	**NA**	**NA**	**NA**	**NA**	**21**	**50**

Sediment ID	Reservoir	Sb (mg/kg)	Se (mg/kg)	Sn (mg/kg)	Sr (mg/kg)	Th (mg/kg)	U (mg/kg)	V (mg/kg)	Zn (mg/kg)	P (mg/kg)	S (mg/kg)
CA1	Talbingo	0.43	0.47	1.3	27	12	3.8	66	79	1400	650
CA2	Talbingo	0.47	0.44	1.4	35	10	3.2	63	81	1300	600
CA3	Talbingo	0.51	0.57	1.9	33	14	4.2	85	109	1300	550
PL1	Talbingo	0.52	0.48	1.4	28	11	3.2	66	92	1200	630
PL2	Talbingo	0.56	0.58	1.7	31	12	4.3	65	110	1100	570
PL3	Talbingo	0.57	0.56	1.7	29	12	3.9	67	99	1300	630
PL3 duplicate	Talbingo	0.52	0.54	1.6	29	12	3.9	66	99	1300	640
PL3 Mean	**Talbingo**	**0.54**	**0.55**	**1.6**	**29**	**12**	**3.9**	**67**	**99**	**1300**	**640**
RA1	Talbingo	0.62	0.47	1.2	15	10	3.6	47	91	1000	510
RA2	Talbingo	0.75	0.50	1.9	22	13	3.5	53	113	1000	510
RA3	Talbingo	0.74	0.45	1.4	17	12	3.0	43	99	1100	480
TN1	Tantangara	0.28	0.43	0.83	11	6.0	1.2	49	85	1200	880
TN2	Tantangara	0.31	0.46	1.3	18	9.2	1.5	59	102	1700	940
TN3	Tantangara	0.37	0.49	1.3	17	10	2.1	65	104	1305	762
Minimum		**0.28**	**0.43**	**0.8**	**11**	**6.0**	**1.2**	**43**	**79**	**1000**	**480**
Maximum		**0.76**	**0.58**	**1.9**	**35**	**14**	**4.3**	**85**	**114**	**1700**	**940**
SQGV		**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**200**	**NA**	**NA**

SQGV = the sediment quality guideline values (Simpson e al., 2013). Values are bold underline where the default GV is exceeded.

Table 13. Dilute-acid extractable concentrations (AEM) metals, metalloids and other elements in Talbingo and Tantangara Reservoir sediments

Sediment ID	Reservoir	Ag (mg/kg)	Al (mg/kg)	As (mg/kg)	Ba (mg/kg)	Ca (mg/kg)	Cd (mg/kg)	Co (mg/kg)	Cr (mg/kg)	Cu (mg/kg)
CA1	Talbingo	0.068	4740	3.85	205	1630	0.161	19.0	8.57	21.2
CA2	Talbingo	0.046	4280	3.12	208	1660	0.096	13.6	7.40	18.6
CA3	Talbingo	0.065	5020	3.82	210	1420	0.194	16.7	7.89	23.3
PL1	Talbingo	0.047	4550	3.04	168	1360	0.077	16.5	7.19	20.7
PL2	Talbingo	0.071	4590	3.27	174	1650	0.187	15.2	6.46	24.4
PL3	Talbingo	0.074	4600	4.45	169	1160	0.187	19.0	7.08	23.0
RA1	Talbingo	0.061	4280	3.92	205	1340	0.179	15.6	5.74	26.8
RA2	Talbingo	0.045	3910	4.58	213	1410	0.251	16.2	6.68	24.5
RA3	Talbingo	0.061	3460	6.60	260	1520	0.215	16.8	6.04	25.2
TN1	Tantangara	0.039	3620	1.81	141	661	0.192	7.19	3.05	13.0
TN2	Tantangara	0.085	3980	2.09	164	760	0.229	13.3	5.84	14.3
TN3	Tantangara	0.074	4460	2.81	158	649	0.310	15.6	6.30	14.8
Minimum		**0.039**	**3460**	**1.81**	**141**	**649**	**0.077**	**7.19**	**3.05**	**13**
Maximum		**0.085**	**5020**	**6.6**	**260**	**1660**	**0.31**	**19**	**8.57**	**26.8**
SQGV		**1**	**NA**	**20**	**NA**	**NA**	**1.5**	**NA**	**80**	**65**

Sediment ID	Reservoir	Fe (mg/kg)	Hg (mg/kg)	K (mg/kg)	Mg (mg/kg)	Mn (mg/kg)	Mo (mg/kg)	Na (mg/kg)	Ni (mg/kg)	Pb (mg/kg)
CA1	Talbingo	23500	<0.008	248	356	1910	<0.071	70.7	8.97	17.4
CA2	Talbingo	17300	<0.008	389	560	1630	<0.071	77.2	8.01	16.0
CA3	Talbingo	16800	<0.008	467	488	3360	<0.071	58.7	10.3	17.3
PL1	Talbingo	17000	<0.008	263	463	1690	<0.071	71.6	9.33	15.4
PL2	Talbingo	15900	<0.008	245	336	2490	0.084	56.6	8.50	19.4
PL3	Talbingo	25100	<0.008	294	384	2110	0.12	68.7	7.11	17.5
RA1	Talbingo	14400	<0.008	217	246	1920	<0.071	63.3	8.05	21.3
RA2	Talbingo	14700	<0.008	209	239	2540	<0.071	59.5	9.33	22.1
RA3	Talbingo	17800	<0.008	193	201	3640	0.098	76.8	8.83	21.0
TN1	Tantangara	12400	<0.008	154	189	470	<0.071	55.8	2.40	15.0
TN2	Tantangara	20200	<0.008	208	195	646	0.079	<41.8	3.42	18.5
TN3	Tantangara	21900	<0.008	163	172	753	<0.071	47.2	3.93	19.5
Minimum		**12400**	**<0.008**	**154**	**172**	**470**	**0.079**	**47.2**	**2.4**	**15**
Maximum		**25100**	**<0.008**	**467**	**560**	**3640**	**0.12**	**77.2**	**10.3**	**22.1**
SQGV		**NA**	**0.15**	**NA**	**NA**	**NA**	**NA**	**NA**	**21**	**50**

Sediment ID	Reservoir	Sb (mg/kg)	Se (mg/kg)	Sn (mg/kg)	Sr (mg/kg)	Th (mg/kg)	U (mg/kg)	V (mg/kg)	Zn (mg/kg)	P (mg/kg)	S (mg/kg)
CA1	Talbingo	<0.024	0.044	0.238	16.6	0.324	1.97	32.7	32.3	921	<43.6
CA2	Talbingo	<0.024	0.034	0.209	26.3	0.165	1.27	28.5	27.4	771	62.5
CA3	Talbingo	0.047	0.032	0.201	12.5	0.347	2.65	29.8	34.6	708	45.5
PL1	Talbingo	0.034	0.044	0.160	11.8	0.218	1.52	29.7	30.4	686	43.8
PL2	Talbingo	0.039	0.043	0.089	15.1	0.250	2.35	30.7	37.3	583	<43.6
PL3	Talbingo	0.028	0.032	0.152	13.3	0.299	2.23	28.4	33.0	705	<43.6
RA1	Talbingo	0.037	0.028	0.170	10.1	0.284	2.19	24.4	36.6	573	<43.6
RA2	Talbingo	0.034	0.034	0.191	10.9	0.160	1.20	22.2	30.9	584	<43.6
RA3	Talbingo	0.039	0.043	0.210	10.8	0.254	1.38	19.2	28.2	638	<43.6
TN1	Tantangara	0.029	0.023	0.107	7.72	0.070	0.451	30.8	49.1	545	76.7
TN2	Tantangara	<0.024	0.033	0.282	8.43	0.057	0.688	33.4	43.4	1090	104
TN3	Tantangara	0.033	0.038	0.219	7.2	0.113	0.638	37.1	54.6	890	124
Minimum		**0.028**	**0.023**	**0.089**	**7.2**	**0.057**	**0.451**	**19.2**	**27.4**	**545**	**43.8**
Maximum		**0.047**	**0.044**	**0.282**	**26.3**	**0.347**	**2.65**	**37.1**	**54.6**	**1090**	**124**
SQGV		**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**200**	**NA**	**NA**

SQGV = the sediment quality guideline values (Simpson e al., 2013). Values are bold underline where the default GV is exceeded.

3.3 Characterisation of excavated rock material

These results were described in Memo 3 (28 September 2018) (Appendix C3). Note, the materials 6B and 6E (Kellys Plain Volcanics) were available after the other rock materials and therefore results additional to those presented in Memo 3 are discussed here.

The particle size distribution (PSD), and wet pH and redox potential of the fine excavated rock composites are shown in Table 14. Cumulative distribution plots and tables are shown in Appendix C. The mean diameter of the composites were in the range 21.0 to 41.3 µm. The Dv (10) (10% of particles had lower diameter than this value) had mean±SD of 2.6±0.4 µm), where clay-size is <2 µm. The Dv (50) (50% of particles had lower diameter than this value) were all less than 19 µm (mean±SD = 15±3 µm), indicating the sediments were predominantly silt. The Dv (90) (90% of particles had lower diameter than this value) were between 52 and 110 µm (mean±SD = 82±15 µm), indicating some components of the 75-µm-milled excavated rock samples underwent aggregation and increased above the milled size range or were irregular shaped that affected the PSD reporting of the instrument on a spherical volume basis. In relation to clay and fine silt factions of the milled material (mean±SD), 28±3% was <6.3 µm (clay and fine silt), 18±3% was <4 µm, and 6.3±2% was <2 µm (clay) (Appendix C).

The particle size distribution of the milled excavated rock samples overlapped most of the particle size distribution of Talbingo and Tantangara Reservoir benthic sediments. In order to measure the pH and redox potential of excavated rock material, the samples remaining after the initial 10/1 L/S elutriate test were subsampled (following 48 h mixing of excavated rock material with composite Talbingo Reservoir water and syringe filtration that removed most of the solution (Memo 4) were allowed to stand for ten days, after which the pH and redox potential were measured by inserting probes directly into each wet solid material. The porewater pH after the 10 d was in the range 8.50-9.55, which had decreased from that measured in the elutriate solution following 48 h mixing (shown in brackets in Table 14). The redox potentials indicated that oxic conditions prevailed in the pore waters.

Table 14. Particle size distribution, pH and redox potential of the composite excavated rock material

Rock ID	Dv (10) (µm)	Dv (50) (µm)	Dv (90) (µm)	Mean diameter (µm)	pH	Redox, Eh (mV)
1B composite	2.71	11.6	72.2	26.4	8.75 (9.20)	180
1E composite	2.53	18.6	97.2	41.3	8.85 (9.29)	160
2B composite	2.44	17.3	76.4	30.1	8.85 (9.33)	160
2E composite	2.43	18.3	87.3	34.0	8.55 (8.88)	115
3B composite	2.47	12.8	80.3	28.7	8.50 (9.35)	20
3E composite	2.98	12.7	84.3	30.4	9.55 (9.58)	165
3E composite duplicate	2.95	12.7	81.0	28.9	9.05 (9.81)	150
4B composite	3.72	15.0	110	38.4	8.80 (9.67)	165
4E composite	2.87	10.6	62.9	23.7	8.61 (9.37)	180
5B composite	2.24	12.9	52.2	21.0	8.55 (9.31)	165
5E composite	2.41	18.8	105	39.5	8.85 (9.57)	80
5E composite duplicate	2.30	16.5	93.2	33.9	8.75 (9.39)	-20
6B composite	2.72	19.7	82.0	32.5	NA	NA
6E composite	2.45	15.7	76.3	29.3	NA	NA
7B composite	2.69	14.7	80.4	29.9	9.00 (9.56)	160
7E composite	2.00	16.5	69.5	27.4	8.75 (9.38)	70

Note: Dv (x) refers to 10, 50 and 90th percentiles of particle diameters (on spherical volume basis). The pH and Eh values were determined on solids mixed with Talbingo Reservoir water for 48 h and allowed to stand for 10 days. The pH values in brackets is the pH of the elutriate water after 48-h mixing.

The TRM concentrations measured in the milled rock composites are shown in Table 15. The concentrations of most metals were below the corresponding SQGVs. There was one exceedance for Pb and Zn, two exceedances As and Cr, three exceedances for Cu, and eight for Ni. Of the excavated rock composites, 1E had the most SQGV-exceedances; Ag, Cr, Ni, Pb and Zn. It should be noted that the Ni SQGV is considered an overly conservative value and it is not surprising that it exceeded the SQGV for many of the excavated rock composites (Vangheluwe et al., 2013; Simpson and Batley 2016).

As noted above, a significant portion of the TRM may not be bioavailable to organisms, and AEM analyses provide a better estimate of the maximum potentially bioavailable concentration (Simpson and Batley, 2016). The AEM concentrations measured in the milled rock composites are shown in Table 16. The AEM concentrations were found to be below their respective SQGVs (where available) except for Pb in composite 1E.

For most of the excavated rock composites, the percent of total recoverable elements in dilute-acid extractable fraction was generally <30% for Ag, Al, As, Co, Cr, Cu, Fe, Mg, Ni, S, Sb, Sn, U, V and Zn (Appendix C, Memo 3). The percentage of dilute-acid extractable Ba, Pb and Sr was generally >50%.

Excavated Rock Compositions Summary

The fine excavated rock composites used for testing were predominantly silt-sized (<63 µm), with only a small fraction of the samples having diameters larger than this size range. The particle size distributions of the milled excavated rock samples were similar to the Talbingo and Tantangara Reservoir sediments.

The porewater pH of the excavated rock samples mixed with Talbingo Reservoir water and allowed to stand for 10 days was in the range 8.50-9.55 and had decreased from that measured in the elutriate solution following 48 h mixing. This pH range is significantly greater than that of the waters from Talbingo (pH 7.05-7.60) and Tantangara (pH 6.70-7.10) Reservoir.

Composite 1E had the greatest number of metals with TRM concentrations exceeding sediment quality guideline values (SQGVs). When considering the AEM concentrations, there was only one exceedance; lead for composite 1E (197 mg Pb/kg).

Table 15. Total recoverable concentrations (TRM) of metals, metalloids and other elements in the rock composites

Rock ID	Ag (mg/kg)	Al (mg/kg)	As (µg/g)	Ba (mg/kg)	Ca (mg/kg)	Cd (mg/kg)	Co (mg/kg)	Cr (mg/kg)	Cu (mg/kg)
Composite 1B mean	0.051	16500	6.1	45	7450	0.030	18	65	27
Composite 1E	**2.4**	24900	13	82	7790	1.0	21	**113**	51
Composite 2B	0.13	16100	5.3	97	6000	0.034	12	66	8.2
Composite 2E	0.27	11200	14	65	11000	0.044	14	29	28
Composite 3B	0.029	24600	0.93	11	21100	0.031	29	**118**	59
Composite 3E	0.045	16800	2.2	19	9980	0.019	20	76	62
Composite 4B	0.072	11300	5.6	32	12200	0.042	8.8	13	15
Composite 4E	0.38	19200	**39**	66	20200	0.238	21	12	**90**
Composite 5B	0.052	9200	3.4	53	5440	0.014	6.3	20	6.1
Composite 5E	0.20	18800	12	37	11200	0.121	19	25	**338**
Composite 6B	0.11	15500	12	46.7	2010	0.007	9.3	30	19
Composite 6E	0.11	18700	**25**	85.4	6120	0.16	15	27	33
Composite 7B	0.060	11600	2.7	64	13100	0.043	6.5	19	11
Composite 7E	0.18	9960	6.5	2086	8080	0.025	6.3	13	**88**
MIN	**0.029**	**9200**	**0.93**	**10.9**	**5440**	**0.014**	**6.27**	**11.7**	**6.10**
MAX	**2.352**	**24900**	**38.5**	**2086**	**21100**	**1.045**	**28.54**	**118**	**338**
SQGV	**1**	**NA**	**20**	**NA**	**NA**	**1.5**	**NA**	**80**	**65**

Rock ID	Fe (mg/kg)	Hg (mg/kg)	K (mg/kg)	Mg (mg/kg)	Mn (mg/kg)	Mo (mg/kg)	Na (mg/kg)	Ni (mg/kg)	P (mg/kg)
Composite 1B mean	29800	<0.03	2240	17900	638	0.14	200	**93**	487
Composite 1E	46400	<0.03	2600	22400	1316	0.21	240	**134**	640
Composite 2B	28600	<0.03	3190	8520	602	0.31	160	**28**	423
Composite 2E	27300	<0.03	3070	7110	413	0.23	110	**31**	537
Composite 3B	39000	<0.03	1840	26400	727	0.10	400	**42**	422
Composite 3E	24900	<0.03	1080	15000	577	0.08	330	**39**	459
Composite 4B	18200	<0.03	1020	8020	464	0.33	190	13	490
Composite 4E	41800	<0.03	2060	10400	588	1.6	310	16	901
Composite 5B	15900	<0.03	1880	6310	336	2.1	360	16	516
Composite 5E	43500	<0.03	1550	9680	644	1.3	700	**25**	856
Composite 6B	19700	<0.02	3910	7770	269	0.49	334	17	414
Composite 6E	31600	<0.02	4120	8660	295	0.62	140	**37**	527
Composite 7B	18800	<0.03	2760	6340	525	0.13	370	10	378
Composite 7E	15600	<0.03	3310	5500	253	0.14	160	11	469
MIN	**15600**	**<0.03**	**1020**	**5500**	**253**	**0.08**	**110**	**10.0**	**378**
MAX	**46400**	**<0.03**	**3310**	**26400**	**1316**	**2.11**	**700**	**134**	**901**
SQGV	**NA**	**0.15**	**NA**	**NA**	**NA**	**NA**	**NA**	**21**	**NA**

Rock ID	Pb (mg/kg)	S (mg/kg)	Sb (mg/kg)	Se (mg/kg)	Sn (mg/kg)	Sr (mg/kg)	Th (mg/kg)	U (mg/kg)	V (mg/kg)	Zn (mg/kg)
Composite 1B mean	10	78	0.38	0.08	0.55	28	10	0.86	38	76
Composite 1E	**214**	756	0.92	0.12	0.59	33	7.9	0.75	71	**543**
Composite 2B	5.2	160	0.45	0.04	0.86	18	10	1.2	44	58
Composite 2E	11	3790	2.2	0.18	0.65	48	9.1	1.1	23	45
Composite 3B	0.61	15	0.03	0.02	0.35	30	0.67	0.10	70	66
Composite 3E	2.3	13	0.10	0.03	0.40	13	5.3	0.33	34	62
Composite 4B	17	17	0.17	0.04	0.55	26	11	0.79	14	52
Composite 4E	9.8	5410	0.63	0.30	0.41	50	4.7	1.3	71	104
Composite 5B	2.7	260	0.10	0.03	0.38	21	7.5	0.99	22	22
Composite 5E	8.0	6050	0.21	1.0	1.0	51	5.3	0.84	80	76
Composite 6B	17	1070	0.31	0.032	1.6	8.24	16	2.8	36	44
Composite 6E	23	7530	1.3	0.18	0.62	51.5	13	1.8	21	109
Composite 7B	8.8	54	0.37	0.03	0.74	73	11	1.4	19	35
Composite 7E	8.6	1010	1.2	0.03	2.0	63	8.8	1.2	14	32
MIN	**0.6**	**13**	**0.029**	**<0.01**	**0.35**	**13.1**	**0.67**	**0.10**	**13.5**	**79**
MAX	**214**	**6050**	**2.17**	**1.03**	**1.98**	**73**	**11.5**	**1.38**	**79.5**	**114**
SQGV	**50**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**200**

Table 16. Dilute-acid extractable concentrations (AEM) of metals, metalloids and other elements in the rock composites

Rock ID	Ag (mg/kg)	Al (mg/kg)	As (mg/kg)	Ba (mg/kg)	Ca (mg/kg)	Cd (mg/kg)	Co (mg/kg)	Cr (mg/kg)	Cu (mg/kg)
Composite 1B mean	0.015	2420	2.0	31	7500	0.018	2.6	6.3	3.4
Composite 1E	0.085	3270	2.3	57	8430	0.180	2.0	12	2.3
Composite 2B	0.033	2960	0.63	84	6620	0.015	4.3	12	1.3
Composite 2E	0.084	2100	1.3	43	11700	0.020	1.2	4.6	3.1
Composite 3B	0.004	2920	0.57	7.4	15100	0.013	3.4	13	18
Composite 3E	0.017	2540	1.5	12	8840	0.012	2.1	8.8	21
Composite 4B	0.015	1160	1.6	21	12400	0.029	0.40	1.9	2.9
Composite 4E	0.074	2750	1.9	27	20100	0.079	1.2	2.8	4.9
Composite 5B	0.049	2800	0.76	30	6570	0.026	1.1	3.8	22
Composite 5E	0.015	1810	0.68	36	5340	0.007	0.82	4.3	1.4
Composite 6B	0.033	1270	1.0	37	1990	0.006	0.88	4.3	1.6
Composite 6E	0.012	2040	3.7	37	6070	0.034	2.0	3.3	2.0
Composite 7B	0.010	1630	0.74	45	14000	0.019	0.48	4.3	0.80
Composite 7E	0.042	2110	1.4	1836	8770	0.011	0.61	2.7	4.1
MIN	**0.004**	**1160**	**0.57**	**7.4**	**5340**	**0.007**	**0.40**	**1.9**	**0.80**
MAX	**0.085**	**3270**	**2.3**	**1836**	**20100**	**0.184**	**4.27**	**13**	**22**
SQGV	**1**	**NA**	**20**	**NA**	**NA**	**1.5**	**NA**	**80**	**65**

Rock ID	Fe (mg/kg)	Hg (mg/kg)	K (mg/kg)	Mg (mg/kg)	Mn (mg/kg)	Mo (mg/kg)	Na (mg/kg)	Ni (mg/kg)	P (mg/kg)
Composite 1B	4610	<0.02	1100	3060	343	0.08	143	8.7	523
Composite 1B duplicate	4580	<0.02	1130	3050	345	0.06	140	8.3	512
Composite 1B mean	4600	<0.02	1120	3060	344	0.07	141	8.5	518
Composite 1E	6460	<0.02	1050	3510	679	0.07	136	13	664
Composite 2B	5570	<0.02	1100	2080	514	0.08	83	5.4	359
Composite 2E	6310	<0.02	1440	1400	298	0.08	82	3.1	545
Composite 3B	3830	<0.02	1420	3120	203	<0.02	189	5.3	483
Composite 3E	2780	<0.02	643	1720	119	0.04	220	4.3	501
Composite 4B	1850	<0.02	552	674	263	0.05	110	0.6	519
Composite 4E	5470	<0.02	765	1260	319	0.08	146	1.1	952
Composite 5B	5820	<0.02	755	1330	131	0.08	246	1.5	919
Composite 5E	4250	<0.02	930	1400	172	0.30	206	1.8	546
Composite 6B	4970	0.085	760	1050	124	0.19	129	1.4	401
Composite 6E	2820	0.063	1150	632	115	0.12	62.6	3.2	525
Composite 7B	4150	<0.02	1080	705	452	0.05	192	0.8	400
Composite 7E	3140	<0.02	1920	686	198	0.07	119	0.9	479
MIN	**1850**	**<0.02**	**552**	**674**	**119**	**0.04**	**82**	**0.6**	**359**
MAX	**6460**	**<0.02**	**1920**	**3510**	**679**	**0.30**	**246**	**13**	**952**
SQGV	**NA**	**0.15**	**NA**	**NA**	**NA**	**NA**	**NA**	**21**	**NA**

Rock ID	Pb (µg/g)	S (µg/g)	Sb (µg/g)	Se (µg/g)	Sn (µg/g)	Sr (µg/g)	Th (µg/g)	U (µg/g)	V (µg/g)	Zn (µg/g)
Composite 1B	7.2	<30	0.10	<0.01	0.17	28	4.2	0.26	5.3	14
Composite 1B duplicate	7.3	<30	0.13	0.01	0.17	27	4.4	0.27	5.2	14
Composite 1B mean	7.2	<30	0.12	0.01	0.17	28	4.3	0.27	5.2	14
Composite 1E	197	38	0.21	0.01	0.22	33	3.1	0.24	9.1	86
Composite 2B	3.7	<30	0.093	<0.01	0.20	17	2.7	0.27	8.2	15
Composite 2E	7.1	<30	0.67	0.01	0.23	44	3.3	0.38	4.5	8.0
Composite 3B	0.14	<30	0.005	<0.01	0.03	5.8	0.17	0.01	8.3	8.9
Composite 3E	1.1	<30	0.024	<0.01	0.06	7.0	1.4	0.07	3.4	7.1
Composite 4B	11	<30	0.030	<0.01	0.09	20	4.7	0.19	1.1	3.8
Composite 4E	6.9	<30	0.086	<0.01	0.06	44	1.5	0.28	9.7	14
Composite 5B	4.8	45	0.075	0.01	0.09	13	3.0	0.19	9.4	16
Composite 5E	1.9	<30	0.052	<0.01	0.14	13	4.5	0.29	2.9	3.8
Composite 6B	118	24.3	0.049	0.004	0.15	5.0	8.6	0.94	3.6	6.8
Composite 6E	17	137	0.77	0.018	0.14	56.4	4.1	0.39	2.3	19
Composite 7B	6.3	<30	0.082	<0.01	0.16	71	3.9	0.26	3.0	3.7
Composite 7E	4.4	413	0.21	0.01	0.63	62	2.2	0.40	2.6	6.0
MIN	**0.1**	**38**	**0.005**	**<0.01**	**0.03**	**5.8**	**0.17**	**0.01**	**1.1**	**79**
MAX	**197**	**413**	**0.67**	**0.01**	**0.63**	**71**	**4.7**	**0.40**	**9.7**	**114**
SQGV	**50**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**200**

3.4 Release of substances from excavated rock materials in reservoir water

This section summarises the results from a large range of tests. The majority of the data is summarised in Appendix D with the accompanying Memo that provided early reporting. The memos also provide further details of the methods. The data included and results discussed here are those considered useful for informing the EIS of potential risk-factors related to the placement of the excavated rock materials in the reservoirs.

3.4.1 Release of substances from <75-µm composite excavated rock materials in reservoir water at low L/S ratio

The vast majority of the excavated rock, by mass, is expected to be larger than sand size and should settle rapidly, whereas the finest fractions (clay to low-silt size range) of the excavated rock materials may remain suspended in the waters in the main disposal area for a considerable period of time. While the placement of excavated rock occurs, considerable amounts of fine rock material may remain present in the waters and not settle for many days after the placement activities cease. Consequently the bottom waters may contain a very high concentration of suspended fine excavated rock material for the duration of the placement activities and potentially for weeks beyond the date placement is deemed complete. Such conditions may allow for prolonged release from those excavated rock materials.

Initial elutriate tests were conducted with the <75-µm composite excavated rock materials at a liquid/solid ratio (L/S) of 10 (100 g/L) over a duration of 48 h with the intension of providing a worst case scenario for concentrations of fine rock materials suspended within the reservoir water column for prolonged periods. These results were described in Memo 4 (28 September 2018) (Appendix D1).

Note: at the time of these test the materials 6B and 6E (Kellys Plain Volcanics) were not available for testing. Results for these materials are provided in later sections at different L/S ratio, after determining more relevant information would be achieved at higher L/S ratios. In general, the magnitude of substance release for 6B and 6E were quite similar to the results for the other 12 materials.

At the end of 48-h L/S=10 tests on the <75-µm rock composites, the pH, conductivity and DO were in the range 8.88-9.81, 107-203 and 7.14-8.49 (Table 17). The pH and conductivity in the elutriate samples were substantially higher than in Talbingo Reservoir water without added rock, while the DO was not affected other than for the lower value measured for composite 5E.

Table 17. Water pH, conductivity and DO for <75-µm rock composites at L/S = 10 after 48 h

Elutriate	pH	Conductivity (µS/cm)	DO (mg/L)
Talbingo composite A (water, no added rock)	7.12	29.1	8.26
Talbingo composite B (water, no added rock)	6.99	28.9	8.22
Talbingo composite C (water, no added rock)	7.05	29.0	8.16
Talbingo composite D (water, no added rock)	7.03	29.0	8.19
1B composite	9.20	154	8.21
1B composite duplicate	9.29	153	8.15
1B composite MEAN	9.25	154	8.18
1E composite	9.33	166	8.26
2B composite	8.88	160	8.36
2E composite	9.35	173	8.22
3B composite	9.58	120	8.23
3E composite	9.81	120	8.47
4B composite	9.67	107	8.32
4E composite	9.37	141	8.49
4E composite duplicate	9.31	143	8.35
4E composite MEAN	9.34	142	8.42
5B composite	9.57	150	8.25
5E composite	9.39	162	7.14
7B composite	9.56	150	8.36
7E composite	9.38	203	8.27

Note: The Talbingo composites A-D had no added rock materials.

The concentrations of anions released from <75-µm rock composites are shown in Table 18, and major cations, metals and metalloids in Table 19. The concentrations of each parameter were all higher than the corresponding values in the Talbingo Reservoir water except for a few values for SO_4^{2-} which were similar, and NO_3^- which was below the limit of detection.

The metals, metalloids and major cations released from the <75-µm composite rock composites are shown in Table 19. When compared to WQGVs, the main exceedances occurred for Al, As and Cr, where the majority of composites had concentrations of one or more of these elements that exceeded the DGV or 99% species protection concentrations (99% GV). The 95% WQGV for Al was exceeded by the largest factor; over 14-fold higher. There were also six exceedances of DGV for total-P. The inorganic speciation of Al, As and Cr is influenced by anionic complexes at basic pH's and it is likely that higher dilutions (i.e. higher L/S ratios) and/or mixing durations effect solubility. These parameters were investigated in subsequent tests.

Summary for low L/S-elutriate tests on <75-µm composite excavated rock materials

The mixing of the <75-µm composite excavated rock materials in Talbingo Reservoir water (L/S = 10) resulted in an increase in the pH of 2-2.8 pH units, and a 3-7-fold increase in the conductivity.

The Cl^-, F^-, SO_4^{2-}, total-P and total-S increased relative to the original Talbingo Reservoir water, with the total-P being the only parameter that increased above the DGV for water quality.

Most of the metals, metalloids and major cations in the excavated rock elutriates increased relative to the control Talbingo Reservoir water. The As, Cr and, in particular, the Al increased above the DGVs and are identified COPCs.

As described in the introduction, this initial test was performed to assess what we consider to be a worst case scenario for fine excavated rock material remaining in the water column. The results of this test indicate that under such conditions the pH of the waters is likely to increase to levels that result in high concentrations of dissolved Al within the waters. These waters are likely to cause toxicity to a range of aquatic organisms.

The results of this test were used for selection of composites to test in more detail in subsequent tests. Due to the higher concentrations of substances, particularly Al, released from excavated rock composites 1B, 2B, 5B, 5E, and 7E, these materials were often used in these tests.

Table 18. The anions, nitrate, and total-S, -P and -Si released from rock composites in L/S=10 elutriate test

Elutriate water	F^- (mg/L)	Cl^- (mg/L)	Br^- (mg/L)	SO_4^{2-} (mg/L)	S (mg/L)	Nitrate (mg/L)	Total-P (mg/L)	Total Si (mg/L)
Talbingo composite A	0.015	0.92	<0.5	0.44	0.16	0.5	<0.0044	2.1
Talbingo composite B	0.025	0.94	<0.5	0.49	0.15	<0.3	<0.0044	2.1
Talbingo composite C	0.03	0.93	<0.5	0.46	0.16	<0.3	<0.0044	2.1
Talbingo composite D	0.02	0.93	<0.5	0.53	0.16	0.3	<0.0044	2.1
1B composite	0.42	1.59	<0.5	0.79	0.33	1.5	**0.010**	3.1
1B duplicate	0.42	1.60	<0.5	0.75	0.32	<0.3	**0.010**	3.1
1B mean	0.42	1.59	<0.5	0.77	0.32	<1	**0.010**	3.1
1E composite	0.47	2.53	<0.5	3.40	1.43	0.6	0.006	1.5
2B composite	0.45	1.95	<0.5	0.96	0.45	1.0	**0.039**	4.1
2E composite	0.54	1.65	<0.5	9.35	5.8	<0.3	0.008	2.9
3B composite	0.16	1.31	<0.5	0.46	0.18	<0.3	<0.0044	2.1
3E composite	0.60	1.34	<0.5	0.52	0.18	0.4	0.006	1.7
4B composite	0.48	1.56	<0.5	0.69	0.29	0.4	0.005	3.0
4E composite	0.14	2.15	<0.5	5.14	3.5	0.4	0.007	1.4
4E duplicate	0.16	2.12	<0.5	5.08	3.5	<0.3	<0.0044	1.4
4E mean	0.15	2.13	<0.5	5.11	3.5	0.3	0.006	1.4
5B composite	0.32	2.41	<0.5	1.27	0.75	<0.3	**0.038**	4.3
5E composite	0.33	1.75	<0.5	7.45	8.5	<0.3	**0.021**	2.0
7B composite	0.72	1.51	<0.5	1.10	0.52	<0.3	0.005	3.8
7E composite	0.53	1.94	<0.5	11.5	4.3	<0.3	0.005	4.2
Minimum	**0.14**	**1.31**	**<0.5**	**0.46**	0.18		0.005	**1.4**
Maximum	**0.72**	**2.53**	**<0.5**	**11.5**	8.5		0.039	**4.3**
DGV					-	**0.010**	**0.010**	

[a] http://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/.

DGV = default guideline values for nitrate (NOx) and total-P are for freshwater lakes and reservoirs in south-east Australia

Table 19. The metals, metalloids and major cations released into the dissolved phase from composite excavated rock materials in L/S=10 elutriate test

Elutriate water	Na (mg/L)	K (mg/L)	Mg (mg/L)	Ca (mg/L)	Al (µg/L)	Fe (µg/L)	Mn (µg/L)	Ag (µg/L)	As (µg/L)	Ba (µg/L)	Cd (µg/L)	Co (µg/L)
Talbingo composite A	1.43	0.40	0.70	1.70	3.8	16	0.22	<0.004	0.13	4.1	0.029	0.01
Talbingo composite B	1.48	0.42	0.73	1.76	3.1	17	0.21	<0.004	0.16	4.3	0.008	0.01
Talbingo composite C	1.43	0.41	0.71	1.76	3.1	17	0.22	<0.004	0.15	4.1	<0.004	<0.01
Talbingo composite D	1.47	0.40	0.72	1.73	3.4	17	0.22	<0.004	0.19	4.4	<0.004	<0.01
1B composite	7.63	20.3	2.09	5.05	208	0.6	1.5	<0.004	15	3.6	<0.004	0.03
1B duplicate	7.59	20.2	2.11	5.03	212	0.7	1.6	<0.004	15	3.6	<0.004	0.02
1B mean	7.61	20.3	2.10	5.04	210	0.6	1.5	<0.004	15	3.6	<0.004	0.03
1E composite	7.72	20.7	2.51	5.61	300	0.7	3.2	<0.004	21	20	<0.004	0.06
2B composite	4.80	13.1	6.36	6.85	73	0.3	2.3	<0.004	3.8	15	0.005	0.04
2E composite	4.33	27.8	1.52	6.75	231	0.8	1.7	<0.004	9.4	9.8	<0.004	0.04
3B composite	9.33	8.60	2.59	4.17	417	1.2	0.43	<0.004	0.49	0.33	<0.004	0.02
3E composite	9.71	11.1	1.90	4.64	779	2.7	0.46	<0.004	0.74	0.42	<0.004	0.01
4B composite	5.90	10.6	0.89	5.30	409	0.9	1.0	<0.004	10	1.1	<0.004	0.01
4E composite	6.60	15.4	1.50	7.00	701	3.2	1.2	<0.004	10	2.1	<0.004	0.02
4E duplicate	6.58	15.4	1.53	6.96	705	3.3	1.2	<0.004	10	1.9	<0.004	0.02
4E mean	6.59	15.4	1.52	6.98	703	3.3	1.2	<0.004	10	2.0	<0.004	0.02
5B composite	9.48	15.5	1.39	4.62	263	1.9	0.88	<0.004	12	4.0	<0.004	0.04
5E composite	9.74	11.0	1.96	8.01	404	1.7	1.6	<0.004	2.4	6.2	<0.004	0.02
7B composite	9.68	19.9	0.62	4.08	300	1.0	3.4	<0.004	5.8	6.4	<0.004	0.01
7E composite	6.19	34.5	0.92	4.16	128	1.9	0.74	<0.004	24	181	<0.004	0.03
MIN elutriate	4.33	8.60	0.62	4.08	73.2	0.3	0.43	<0.004	0.49	0.33	<0.07	0.011
MAX elutriate	9.74	34.50	6.36	8.01	779	3.31	3.45	<0.004	24.1	181	<0.07	0.063
DGV or 95% GV	-	-	-	-	**55**	-	**1900**	**0.05**	**13**	-	**0.2**	-
99% GV	-	-	-	-	27	-	1200	0.02	0.8	-	0.06	-

[a] http://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/.

DGV = default guideline value, representing the 95% species protection guideline values (95%GV) for freshwater.

99% species protection guideline values (99%GV) for freshwater. Values for As are for As(V), Cr are for Cr(VI), and tin are for inorganic tin

Table 19 (continued). The metals, metalloids, and major cations released into the dissolved phase from composite excavated rock materials in L/S=10 elutriate test

Elutriate water	Cr (µg/L)	Cu (µg/L)	Mo (µg/L)	Ni (µg/L)	Pb (µg/L)	Sb (µg/L)	Se (µg/L)	Sn (µg/L)	Sr (µg/L)	V (µg/L)	Zn (µg/L)
Talbingo composite A	<0.04	0.542	0.02	0.085	<0.01	<0.02	0.02	<0.02	14	0.10	1.36
Talbingo composite B	<0.04	0.578	0.03	0.078	0.01	<0.02	0.02	<0.02	14	0.10	1.33
Talbingo composite C	0.04	0.554	0.03	0.068	<0.01	<0.02	0.02	<0.02	14	0.09	1.47
Talbingo composite D	0.05	0.567	0.03	0.233	<0.01	<0.02	0.02	<0.02	15	0.11	1.18
1B composite	0.48	0.197	1.30	0.057	<0.01	3.7	0.43	<0.02	52	14	0.115
1B duplicate	0.48	0.188	1.27	0.052	<0.01	3.7	0.45	<0.02	52	15	<0.1
1B mean	0.48	0.193	1.29	0.054	<0.01	3.7	0.44	<0.02	52	15	<0.1
1E composite	<0.04	0.095	1.84	0.276	0.16	11	0.54	<0.02	82	6.6	<0.1
2B composite	1.5	0.125	3.76	0.061	<0.01	4.1	0.36	<0.02	28	6.0	0.124
2E composite	0.07	0.162	2.21	0.048	<0.01	14	0.81	<0.02	36	8.6	0.129
3B composite	4.3	0.369	0.116	0.032	<0.01	0.07	0.02	<0.02	5.7	9.1	<0.1
3E composite	2.9	0.691	0.125	0.032	<0.01	0.20	0.05	<0.02	10	5.6	<0.1
4B composite	0.07	0.586	0.250	0.045	<0.01	0.49	0.12	<0.02	20	5.2	<0.1
4E composite	0.07	0.342	2.49	0.072	<0.01	2.1	0.66	<0.02	26	8.6	<0.1
4E duplicate	0.07	0.369	2.51	0.054	<0.01	2.0	0.66	<0.02	25	8.6	<0.1
4E mean	0.07	0.356	2.50	0.063	<0.01	2.1	0.66	<0.02	25	8.6	<0.1
5B composite	0.08	0.272	15.46	0.147	<0.01	0.79	0.16	<0.02	19	13	0.149
5E composite	0.05	0.983	1.45	0.026	<0.01	1.6	1.4	<0.02	26	6.5	<0.1
7B composite	0.06	0.318	1.24	0.057	<0.01	3.1	0.22	<0.02	46	19	0.169
7E composite	0.05	0.537	1.89	0.052	<0.01	6.3	0.18	<0.02	52	15	0.227
MIN	<0.04	0.095	0.116	0.026	<0.01	0.068	0.020	<0.02	5.66	5.23	<0.1
MAX	4.30	0.983	15.5	0.276	0.160	14.0	1.39	<0.02	81.9	18.7	0.227
DVG or 95% GV	**1.0**	**1.4**	-	**11**	**3.4**	-	**11**	-	-	-	**8.0**
99% GV	0.01	1.0	-	8	1.0	-	5	-	-	-	2.4

3.4.2 Effect of L/S ratio on substance release from <75-µm composite rock materials

The concentrations of fine solids in the water column following placement of excavated rock materials in the reservoirs will be influenced by the properties of the rock (e.g. density, particle size), the water conditions, and the placement procedure. In relation to the suspended concentrations of fine rock materials, the L/S ratios are anticipated to lower in deeper waters (higher concentrations of solids in deeper waters) and expected to increase with increasing distance from the placement site as fine particles disperse and become diluted with reservoir water. As the placement activities will occur over a considerable period of time, fine rock concentrations may be at elevated levels for many days to weeks, and potentially much longer in the bottom waters.

This section describes the results of tests undertaken to characterise the influence of liquid-to-solid (L/S) ratio on substance release from the rock materials. The tests also provide data on the release kinetics that are discussed in Section 3.4.3. Tests were performed on the <75-µm composite rock materials 1B, 2B, 5B, 5E and 7E and reported in Memo 11 (9 November 2018) (Appendix D2). An additional series of tests were performed on the 6B/6E rock materials that were provided later in the project, and these are included in this results section. The primary aim of the tests was to investigate the effect of L/S ratio on pH, conductivity, and the dissolved metal concentrations. The tests were performed at L/S = 30, 300, 1000, 3000 [being 33, 3.3, 1 and 0.33 g/L, respectively] and measurements were made at times of 0.5, 3, 18 and 120 h (Memo 11).

Results

The pH, conductivity and dissolved Al concentrations measured in the elutriate solutions for all composites combined for each L/S ratio over time are shown in Figure 1 (mean±standard error for all results). Appendix D2_Memo 11 provides figures with the data for the individual composites 1B, 2B, 5B, 5E, 6B, 6E and 7E, respectively. For 6B, the conductivity was initially 1.3 mS/cm then dropped to 0.3-0.6 mS/cm range after 3 h, and that data is not shown on the scale of Figure 1 (Figures D2.1 and D2.2 in Appendix D2). In general, the individual composites displayed similar behaviour.

In general, as the L/S ratio decreased (increased solids concentration) the pH and conductivity were higher for leaching times ≤18 h. Note, for the 120 h elutriates there were only two results for L/S =1000 and 3000 tests and no clear relationship was observed between L/S and pH or conductivity. Dissolved Al concentrations increased as the L/S ratio decreased for all leaching times. Dissolved As and Cr concentrations did not exceed DGVs when L/S ≥ 30 (Data in Appendix D2), and would not be categorised as COPCs in reservoir waters containing <33 g/L fine rock (L/S>30). Infrequently, dissolved Zn exceeded the DGV of 8 µg/L and was attributed to contamination owing to the infrequency and difficulties in avoiding low levels zinc contamination arising as part of the test methodology (i.e. not attributed to release from the rock materials).

The initial contact of the solids with the water resulted in a rapid increase in pH and conductivity. The pH generally decreased marginally over the duration of the tests, although increases occurred for 6B and 6E The pH was nearly always higher for a lower L/S ratio at any given time point, whereas, for the conductivity, this relationship was not quite as clear, with similar values often observed for the 300 and 1000 L/S ratios. Conductivity marginally increased with time, but deceased for 6B L/S=30 tests. Appendix D2 also provides figures with major salt cation concentrations, indicating K > Ca > Na > Mg.

The dissolved Al concentrations were in the range 30-439, 9-445, 6-175, 6.5-42 µg/L for the 30:1 (33 g/L), 300:1 (3.3 g/L), 1000:1 (1 g/L) and 3000:1 (0.33 g/L) L/S ratios, respectively. The dissolved Al concentrations increased over the duration of all tests, with the degree of increase generally being higher for lower L/S ratios. For all composite samples tested except 6B, the dissolved Al exceeded the default guideline value (DGV) of 55 µg/L after 3 h for the 30 and 300 L/S ratios, and exceeded the DGV after 18 h (3 h not tested) for the 1000 L/S ratio. For 6B the DGV for Al was only exceeded for LS/=30 treatment at 18 h and 120 h. The Al DGV was not exceeded for any composites at the 3000 L/S ratio.

The total-P concentrations decreased with increasing L/S ratio, with mean concentrations (±standard deviation, maximum-minimum) of 16±13 (3-44), 7±4 (3-17), and 5±1 (3-7) and 3±1 (3-4) µg total-P/L for the tests with L/S ratio of 30:1 (33 g/L), 300:1 (3.3 g/L), 1000:1 (1 g/L) and 3000:1 (0.33 g/L), respectively (Appendix D2.1). For 3 of the 5 rock composites tested (2B, 5B, 5E) at L/S of 30 (33 g/L) the total-P concentration ranged from 10-44 µg/L (exceeding the DGV of 10 µg/L) for measurements made between 0.5 to 120 h. For the same rock composites at L/S of 300 (3.3 g/L), the DGV was exceeded infrequently (4 of 20 measurements), by a lower amount (10-17 µg/L). No exceedances of the DGV occurred at L/S of 1000 (1 g/L).

Significant observation from L/S ratio tests

When reservoir waters contain ≥1 g/L fine rock (part per thousand), the dissolved Al concentrations are predicted to exceed the DGV for durations of ≥18 h. When the reservoir waters contain <3 g/L fine rock materials, total-P concentrations are predicted to be below the DGV of 10 µg/L. Dissolved concentrations of other metals or metalloids (including As and Cr) should not exceed DGVs when reservoir waters contain <33 g/L fine rock (L/S>30). The water pH and conductivity increased significantly with increasing amount of fine solids (lower L/S), and generally pH >9 when L/S ≥300 and conductivity >60 µS/cm when L/S ≥1000.

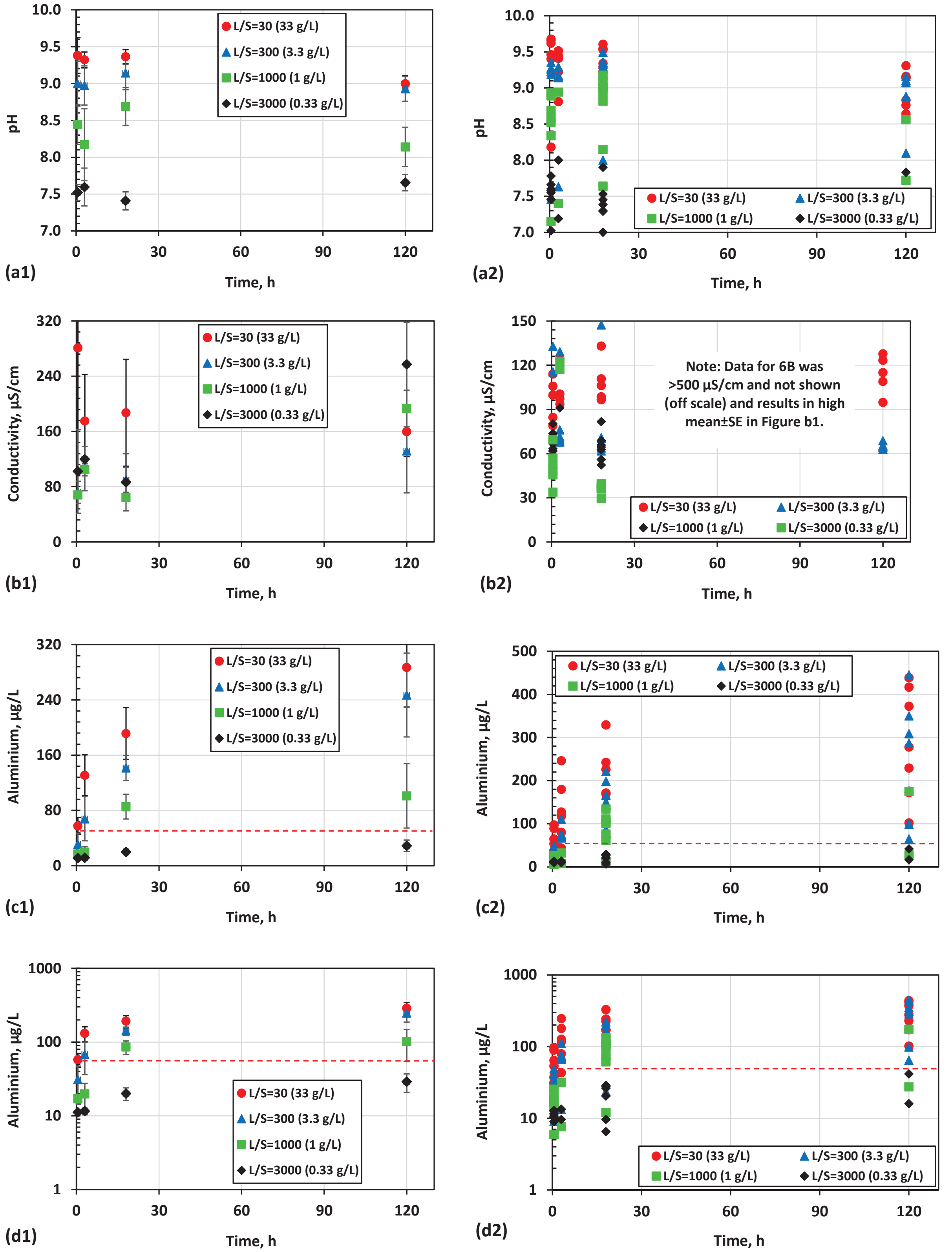

Figure 1. The pH, conductivity and dissolved Al concentration after elutriate times of 0.5, 3, 18 and 120 h for all excavated rock composite samples at liquid to solid ratios (L/S) of 30, 300, 1000 and 3000 (d1, d2 = log scale). The figures on the left (a1-d1) show the mean values (error bars are standard errors), and the figures on the right (a2-d2) show the values measured for each composite material at each duration. A red dashed line at 55 µg/L indicates the DGV for dissolved Al.

3.4.3 Effect of mixing duration on substance release from <75-µm composite rock materials

The time the rock solids spend entrained in the water column before settling as sediments will be influenced by the properties of the rock (e.g. density, particle size), the water conditions (hydrodynamic forces), and the placement procedure. Fine rock particles within the water column may be transported greater distances from the original placement location and may potentially release greater amounts of substances.

This section describes the results of tests undertaken to characterise the influence that the duration the rock materials spend in the water column has on substance release into the water. The tests were performed with those investigating the effect of L/S ratio on substance release (3.4.2). Tests were performed on the <75-µm composite rock material 4E initially (Memo 5, 18 October 2018) to assist in determining the appropriate test conditions/treatment for the other <75-µm composite rock materials (Meno 11, 9 November 2018) (Appendix D3). The primary aim of the test was to investigate the effect of duration on pH, conductivity, and the dissolved Al concentrations. All tests were conducted using the composite Talbingo Reservoir water.

In tests with rock composite 4E, measurements of water quality and substance release were made at times of 0.5, 2, 6 and 24 h for L/S = 100, 1000, and 10000 [being 10, 1 and 0.1 g/L, respectively] (Memo 5). This material was selected owing to the high level of Al release observed in the initial elutriate test (Section 3.4.1).

In tests with rock composites 1B, 2B, 5B, 5E and 7E, measurements of water quality and substance release were made at times of 0.5, 3, 18 and 120 h for L/S = 30, 300, 1000, 3000 [being 33, 3.3, 1 and 0.33 g/L, respectively] (Memo 11).

Also discussed are tests designed specifically to assess changes in water alkalinity (Memo 7, 2 November 2018). These tests were undertaken on eight rock composites (the enriched (E)-samples of 7 geological zones, and also Kelly Plains 6B), measurements of water quality and substance release were made 0.5 and 6 h for L/S = 500 and also for one material (4E) tests were conducted for L/S = 500, 2000, 5000 and 10000 and compared with the alkalinity of the Talbingo Reservoir water.

Results

The initial contact of the <75-µm rock composite 4E solids with the water resulted in a rapid increase in pH and conductivity (Figure 2). Similar observations were made for the subsequent tests with rock composites 1B, 2B, 5B, 5E and 7E (Figure 1). The pH generally decreased marginally over the duration of the tests while the conductivity marginally increased. The pH was nearly always higher for a lower L/S ratio (higher concentrations of solids) at any given time point, whereas, for the conductivity, this relationship was not quite as clear, with similar values often observed at the L/S ratios of 300 and 1000. Appendix D3 also provides figures with major salt cations, shown concentrations Ca > K > Na > Mg contributing to increased conductivity for this material (Figure D3.1).

The dissolved Al generally exhibited a relatively linear increase as the duration in Talbingo Reservoir water increased. The changes in the dissolved Al concentrations with time indicate dissolution of rock solids is occurring and higher pH promotes continued dissolution through the formation of the highly soluble aluminate ion, $Al(OH)_4^-$. The degree of increase in dissolved Al concentration was generally higher for lower L/S ratios (greater concentrations of fine solids). As noted in section 3.4.2 (Figures 1c and d), the dissolved Al exceeded the default guideline value (DVG) of 55 µg/L after 3 h for all composite samples tested at L/S of 30 and 300, and after 18 h at a L/S of 1000, but not for a L/S of 3000 over any duration tested. Infrequently, dissolved Zn exceeded the DGV of 8 µg/L (Appendix D7), and was attributed to contamination arising as part of the methodology as noted in the previous section. No other metal or metalloid concentrations exceeded DGVs.

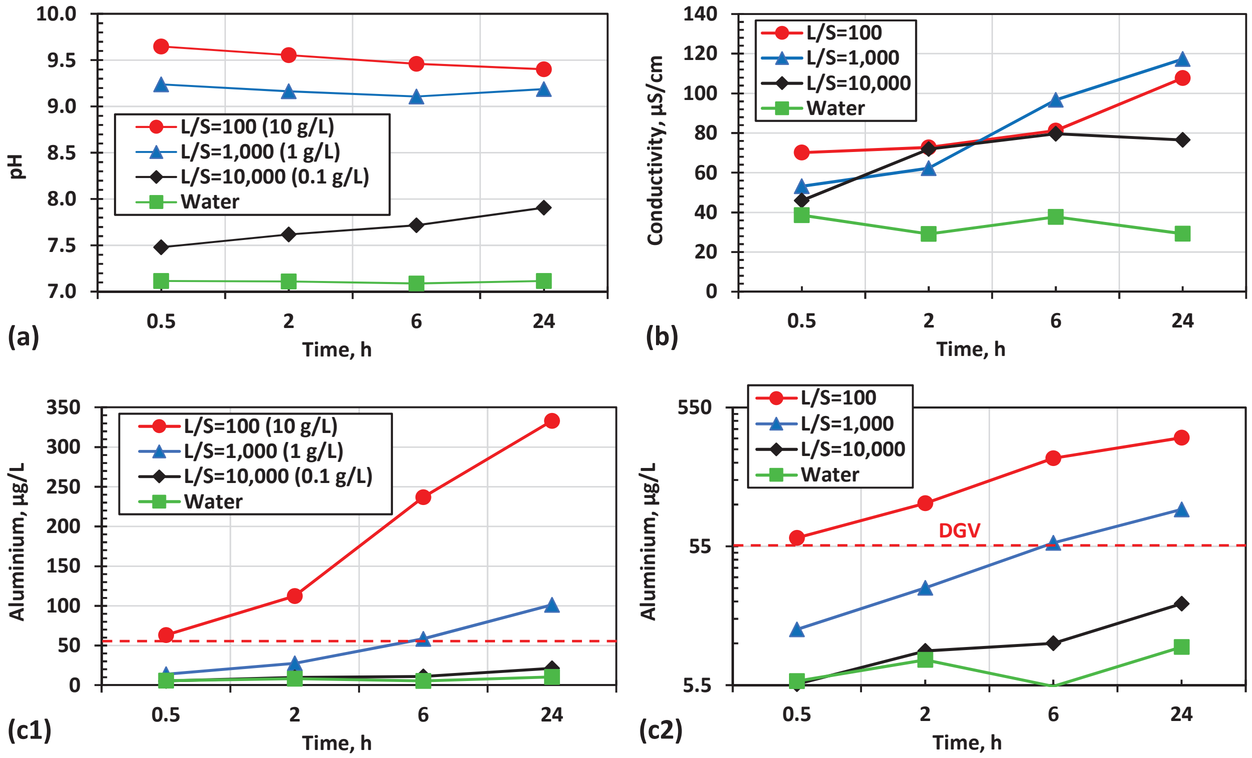

Figure 2. Rock composite material 4E. Elutriate water (a) pH, (b) conductivity and (c1, c2) dissolved Al concentrations. A red dashed line at 55 µg/L indicates the DGV.

Water alkalinity changes

For waters with low pH-buffering capacity, measurements of water pH provide limited information on the acidity or alkalinity changes caused by the addition of the rock materials. For that reason, additional tests were undertaken to characterise changes in alkalinity (Memo 7, Appendix D3). The Talbingo Reservoir water had neutral pH (7.0), low conductivity (25-40 µS/cm) and alkalinity of 13-14 mg $CaCO_3$/L. The alkalinity of elutriates at L/S of 500 were 50-100% higher than the original Talbingo Reservoir water, and similar after 0.5 and 6 h (Table 20). The increases in pH, conductivity and alkalinity were considerably lower at higher L/S ratios (Table 20).

Significant observations from mixing-duration tests

The kinetics of the changes in pH, conductivity and the dissolved Al concentrations indicate increased dissolution of rock solids occur with time. For Al, the increase with time is consistent with the high pH acting to increase dissolution through formation of the highly soluble aluminate ion, $Al(OH)_4^-$.

Both the concentration of fine rock materials and duration within the water column should be considered when predicting the risks posed by dissolved Al. No other released metal concentrations exceeded DGVs.

Increases in alkalinity due to the presence of fine rock materials within the waters were generally modest and are unlikely to result in impacts to aquatic organisms.

Table 20. The pH, conductivity and alkalinity for elutriate test of the fine excavated rock composites

Test water and fine-rock composite	L/S	Time h	pH	Conductivity (µS/cm)	Alkalinity (mg $CaCO_3$/L)
Talbingo water only	∞	0.5	7.0	39.9	14
Talbingo water only	∞	6	7.0	24.5	13
1E	500	0.5	8.4	76.9	23
1E	500	6	7.1	40.4	22
2E	500	0.5	9.1	78.8	25
2E	500	6	8.7	48.1	25
3E	500	0.5	9.2	52.1	25
3E	500	6	9.1	51.3	25
4E	500	0.5	9.2	55.6	27
4E	500	6	9.1	130	26
5E	500	0.5	9.2	54.6	25
5E	500	6	8.9	49.0	27
6E	500	0.5	8.8	58.6	21
6E	500	6	8.6	47.2	24
7E	500	0.5	9.1	58.0	24
7E	500	6	8.4	49.3	17
6B	500	0.5	7.4	62.0	15
6B	500	6	7.5	32.0	22
Test water and fine-rock composite	**L/S**	**Time h**	**pH**	**Conductivity (µS/cm)**	**Alkalinity as $CaCO_3$ mg/L**
Talbingo water only	∞	0.5	7.0	39.9	14
Talbingo water only	∞	6	7.0	24.5	13
4E	10,000	0.5	7.3	42.2	16
4E	10,000	6	7.4	32.5	18
4E	5,000	0.5	8.0	45.1	18
4E	5,000	6	7.7	36.4	19
4E	2,000	0.5	8.9	46.9	22
4E	2,000	6	8.7	45.2	22
4E	500	0.5	9.2	55.6	27
4E	500	6	9.1	130	26

3.4.4 Effect of rock particle size on substance release

Owing to the greater surface area and therefore reactivity, finer particle size materials are expected to represent the greatest environmental risk with respect to transport and release of substances. The size of the excavated rock material is expected to range from the large boulder to powder size. The vast majority of the excavated rock, by mass, will be larger than sand size and should settle rapidly. While it is important to understand the worst case scenario for impacts to the receiving water, to make realistic calculations of loads of substances that may be released from the rock during placement operations it is important to understand differences in substance release from larger particle size materials that may comprise the majority of the material by mass.

This section describes the results of tests undertaken to characterise the influence of rock particle size on substance release to the reservoir waters. Tests were performed on excavated rock materials that had been mechanically crushed to provide materials with the size categories 10-25 mm; 2-10 mm, 0.21-2 mm and <0.21 mm (composite fine material) (Memo 6, 26 October 2018) (Appendix D4). Elutriate tests were undertaken at L/S of 25 (40 g/L) and measurements made at time periods of 1, 4 and 24 h after mixing then settling in Talbingo Reservoir water. As fine dust was on the surface of large rock pieces, the three larger rock fraction underwent a 10-s leach (add Talbingo Reservoir water, shake, then decant to waste) immediately before the test water was added.

Following these tests, further investigation was made into the finer particle-size fraction of materials and size categories 150-210, 63-150 and <63 µm (composite fine material) were prepared for three rock materials (1E, 4B, 5E). Elutriate tests were undertaken at a L/S of 1000 (1 g/L) represent a scenario where considerably settling of fine materials has occurred and measurement made 24 h after mixing then settling in Talbingo Reservoir water (Memo 8, 5 November 2018) (Appendix D4). The <210 µm composite was also tested at L/S = 1000 for comparison with previous experiments on the 75-µm rock composites, and these data are provided in Appendix D4.1).

Results

The pH, conductivity and dissolved Al concentrations are shown function of the size of the larger (0.21-25 mm) rock materials in Figure 3 for the 24-h time period. The relationships were similar at 1 and 4 h, and those Figures are provided in Appendix D4 (Memo 6). The concentrations of dissolved major ions (Na, K, Mg, Ca), are provided for 24 h (Figure 4) and for 1 and 4 h in Appendix D4 (Figures D3.3 and D3.4). For different visualisation, the effect of time is shown for individual rock size fractions in Figure 5. The particle size distributions of the <0.21 mm size fractions are provided in Appendix D4. Key observations from tests on the larger size fractions of rock materials include:

- For both pH and conductivity, the values were higher than the Talbingo Reservoir water across the full range of rock material sizes.
- Dissolved Al exceeded the DVG of 55 µg/L by a factor of 4 to 15 within 1 h for the <0.21 mm size fraction, and was below the DGV for the 0.21-2 mm size fraction initially before increasing to exceed the DGV for longer elutriate durations.
- pH kinetics: For the 0.21-2 mm size fraction, pH of 24-h elutriates was significantly lower than 1-h and 4-h elutriates.
- Conductivity varied greatly between different fine rock fractions, and increased with time for the <0.21 mm fraction. Major initial increases (1 h) then variable increases, potentially doubling conductivity over 4 h, with less change through to 24 h.
- The <0.21 mm samples had particle diameters that generally spanned the <0.001-0.21 mm range. Sample 4B (<0.21 mm) was the finest with 50% of the sample being <21.5 µm. The other samples comprised approximately 50% silt i.e. approximately 50% <63 µm.
- For the tests undertaken with L/S = 25 (40 g/L), dissolved As, Cr and/or Zn concentrations frequently exceeded the DGVs (13 µg As(V)/L, 1.0 µg Cr(VI)/L) and 8 µg Zn/L) in elutriates, including elutriates of larger rock fractions over longer durations (Appendix D4). No other metal concentrations exceeded DGVs.

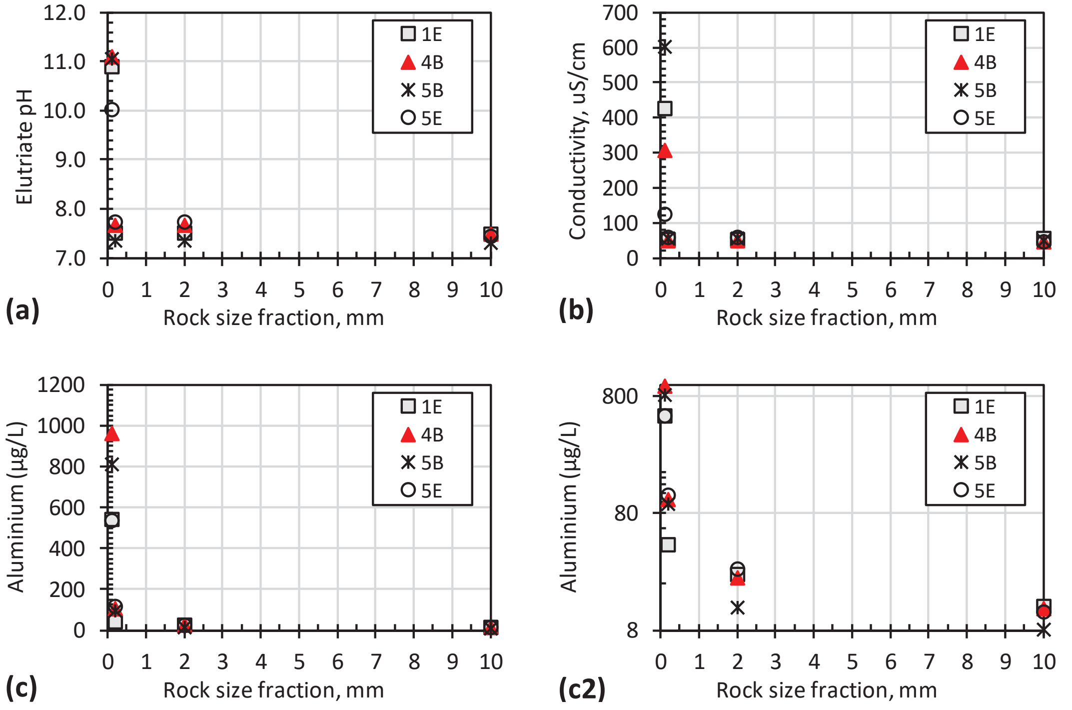

Figure 3. The pH, conductivity and dissolved Al after elutriate time of 24 h (c2 = log scale). Note that the <0.21, 0.21-2, 2-10 and 10-25 mm grain size treatments are plotted on the x-axis of figures at 0.1, 0.21, 2 and 10 mm, respectively.

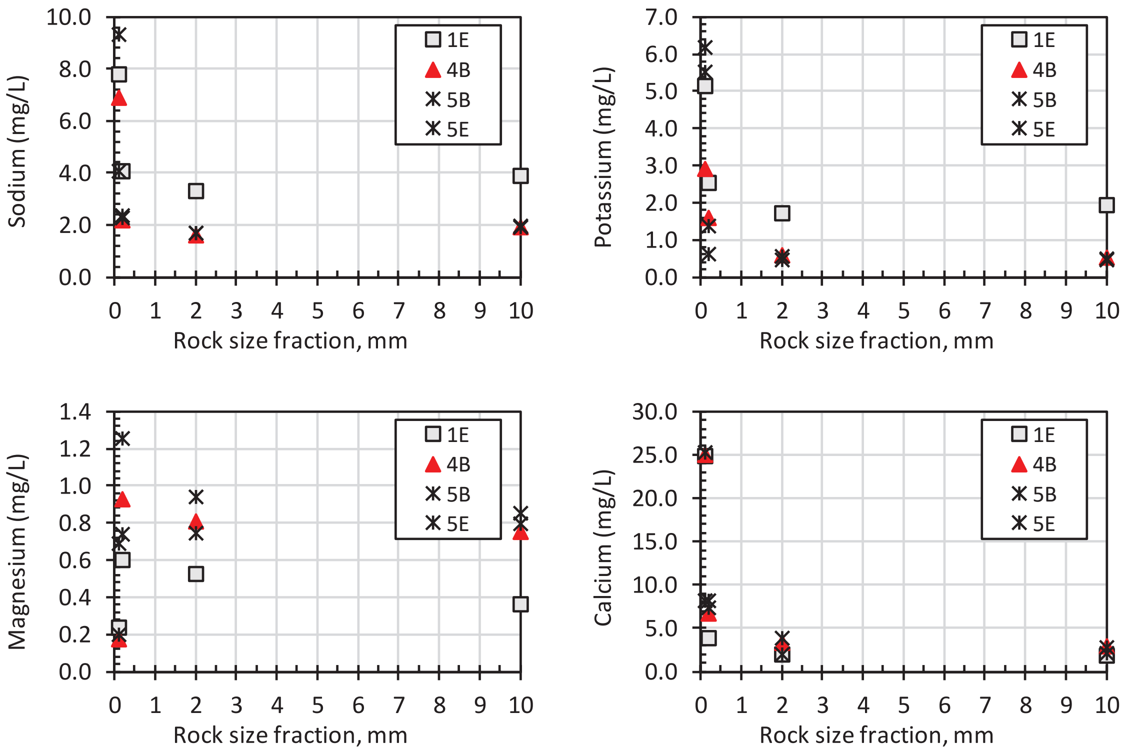

Figure 4. Dissolved major ions (Na, K, Mg, Ca) after elutriate time of 24 h. Note that the <0.21, 0.21-2, 2-10 and 10-25 mm grain size treatments are plotted on the x-axis of figures at 0.1, 0.21, 2 and 10 mm, respectively.

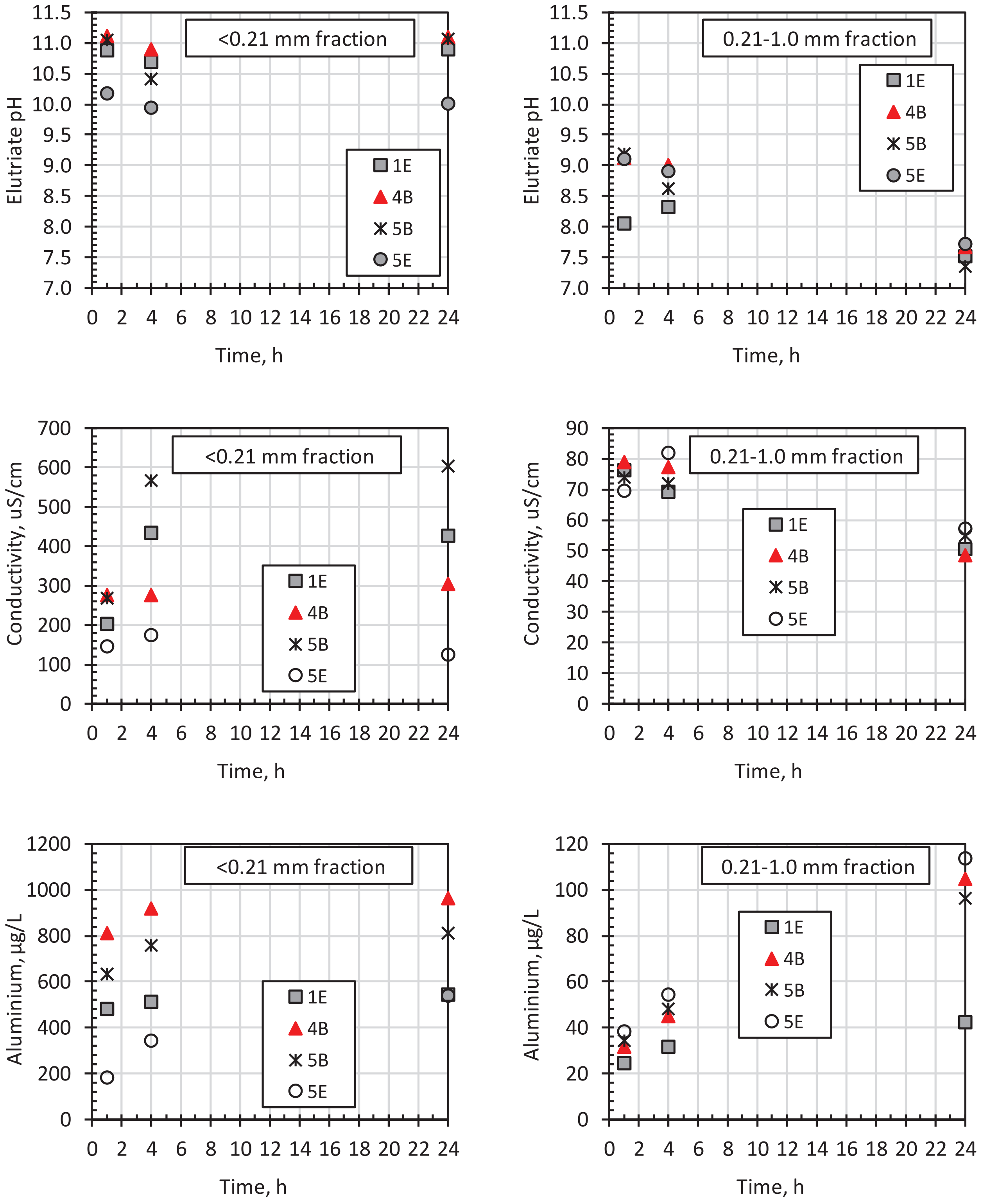

Figure 5. Effect of elutriate time on pH, conductivity and dissolved Al for the two smaller rock size fractions (<0.21 mm and 0.21-2 mm) (L/S=25)

For the <63, 63-150 and 150-210 µm size fractions (L/S=1000), the particle size relationships for pH, conductivity and dissolved Al concentrations are in Figure 6 and Figure 7 for major ions (Na, K, Mg, Ca) (24 h elutriates). Key observations from tests on these smaller particle-size rock materials include:

- The dissolved Al exceeded the DVG of 55 µg/L by a factor of 4.2 to 1.1 for the <63 and 63-150 µm size fractions, and was below the DGV for the 150-210 µm size fraction (Figure 7).
- The dissolved Ca and K decreased as the size fraction increased, but the decreases were not as steep as for dissolved Al, while the dissolved Mg and Na were generally similar for the different size fractions (Figure 8).

Significant observations from particle size tests

- Substance release is low, trends towards negligible, for rock materials >2 mm.
- The finer <0.21 mm rock fraction is likely to have an impact on water quality that is an order of magnitude greater than that of rock fractions >2 mm in size.
- For the finer rock materials, pH, conductivity and dissolved Al concentrations decrease as the particle size increases from <63 µm to 150-210 µm, however, the decrease was essentially linear compared to the more exponential decrease observed as size increased for the larger particle size fractions.
- For a L/S of 1000 (1 g/L), the dissolved Al released from the <63 µm size fraction exceeded the DGV after 24 h. For the 63-150 µm, there was a much smaller exceedance of the DGV.
- Dissolved As and/or Cr concentrations frequently exceeded the DGVs in tests with L/S = 25 (40 g/L)

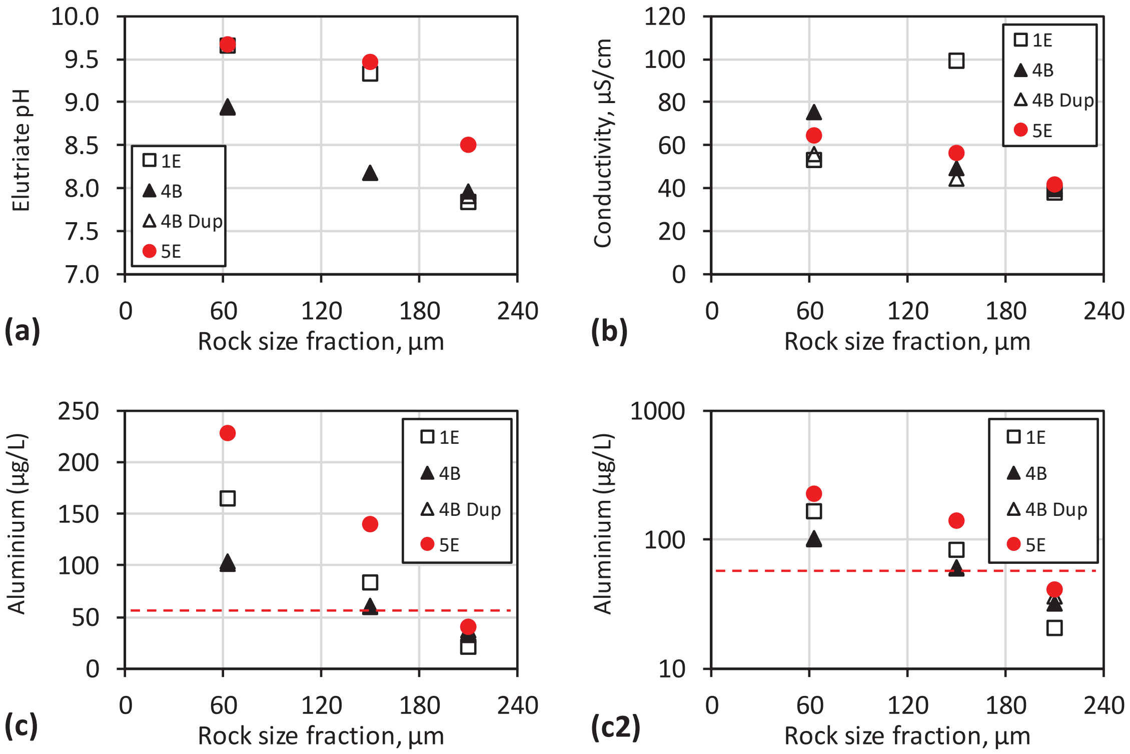

Figure 6. pH (a), conductivity (b) and dissolved Al (c, c2) after an elutriate time of 24 h (c2 = log scale) for <63, 63-150 and 150-210 µm size fractions (L/S=1000). A red dashed line at 55 µg/L indicates the DGV. Note that the <63, 63-150, and 150-210 µm grain size treatments are plotted on the x-axis of figures at 63, 150 and 210 µm, respectively.

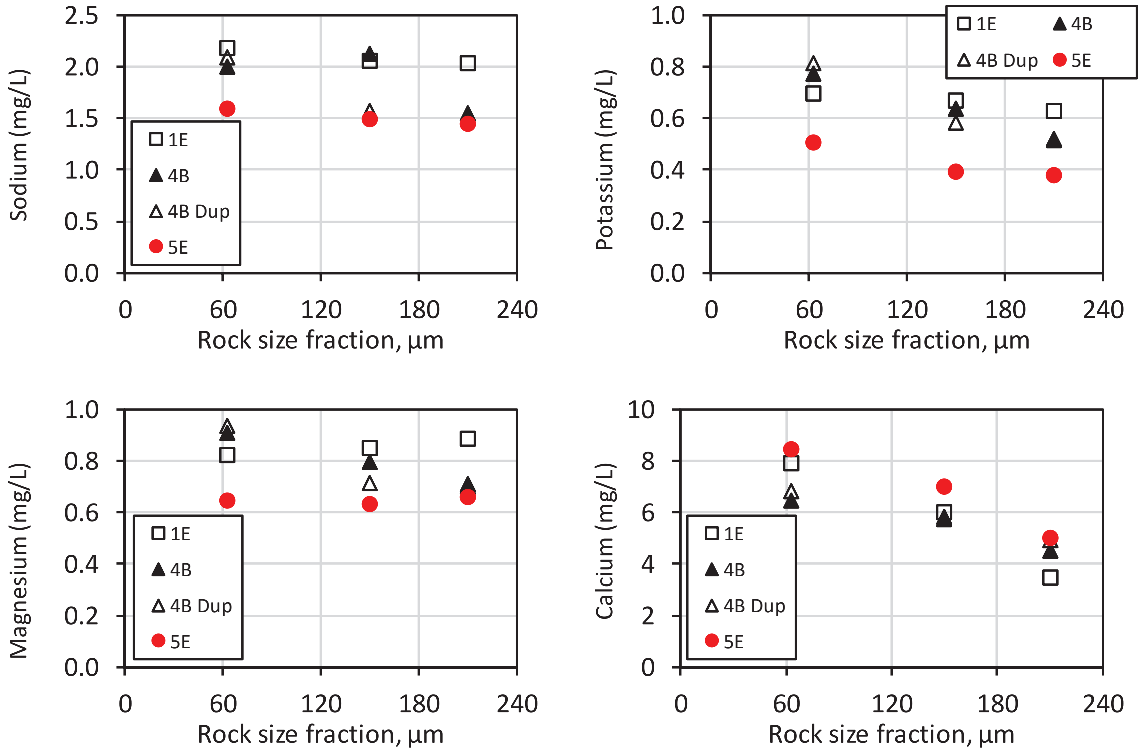

Figure 7. Major ions (Na, K, Mg, Ca) after an elutriate time of 24 h for <63, 63-150 and 150-210 µm size fractions. Note that the <63, 63-150, and 150-210 µm grain size treatments are plotted on the x-axis of figures at 63, 150 and 210 µm, respectively.

3.4.5 Comparison between leaching in Talbingo and Tantangara Reservoir waters

Talbingo Reservoir water was used for most of the elutriate tests as this was anticipated at the time the tests were undertaken to be the location where most of the excavated rock material may be placed (Greg Britton, personal communication). For comparison, elutriate tests were performed in Tantangara Reservoir water and with <75-µm composite rock materials 1B, 2B, 5B, 5E and 7E (Memo 13, 26 November 2018) (Appendix D5). The tests were performed at L/S of 300 and 1000 (3.3 and 1 g/L) with measurements made at 3 and 18 h, enabling comparison with results for Talbingo Reservoir water (Memo 11, Appendix D2). Comparisons of elutriate results for Tantangara and Talbingo Reservoir waters are shown for pH, conductivity and dissolved Al concentrations with composite 2B in Figure 8 and the dissolved Al concentrations for composites 1B, 5B, 5E and 7E are shown in Figure 9, with results for other substances provided in Appendix D5.

For Tantangara Reservoir water treatments, the concentration of dissolved Al was below the DGV of 55 µg/L for the 1000-L/S treatments at 3-h and 18-h, and exceeded the DGV for the 300 L/S treatments at 3 and 18 h. The lower pH of Tantangara 18-h_1000-L/S treatments compared to the corresponding Talbingo treatments indicates the Tantangara Reservoir water had a greater ability to buffer pH increases than the Talbingo Reservoir water. In turn, the lower dissolved Al released from the Tantangara 18-h_1000-L/S treatments than the corresponding Talbingo treatments is likely influenced by the lower pH resulting in slower mineral dissolution and release of Al as the aluminate ion, which is favoured at higher pH values. No other metal or metalloid concentrations exceeded DGVs.

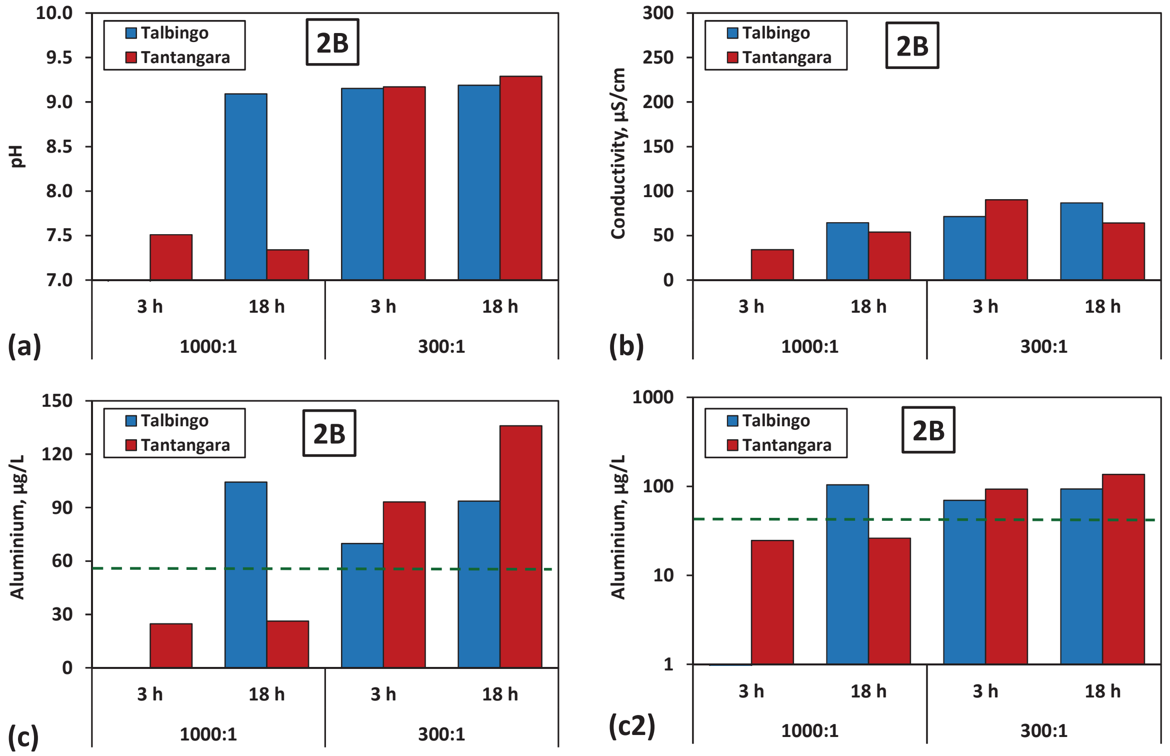

Figure 8. Comparison between the pH, conductivity and dissolved Al concentration measured in Talbingo and Tantangara Reservoir waters following elutriate tests with excavated rock composite 2B (c2 = log scale)

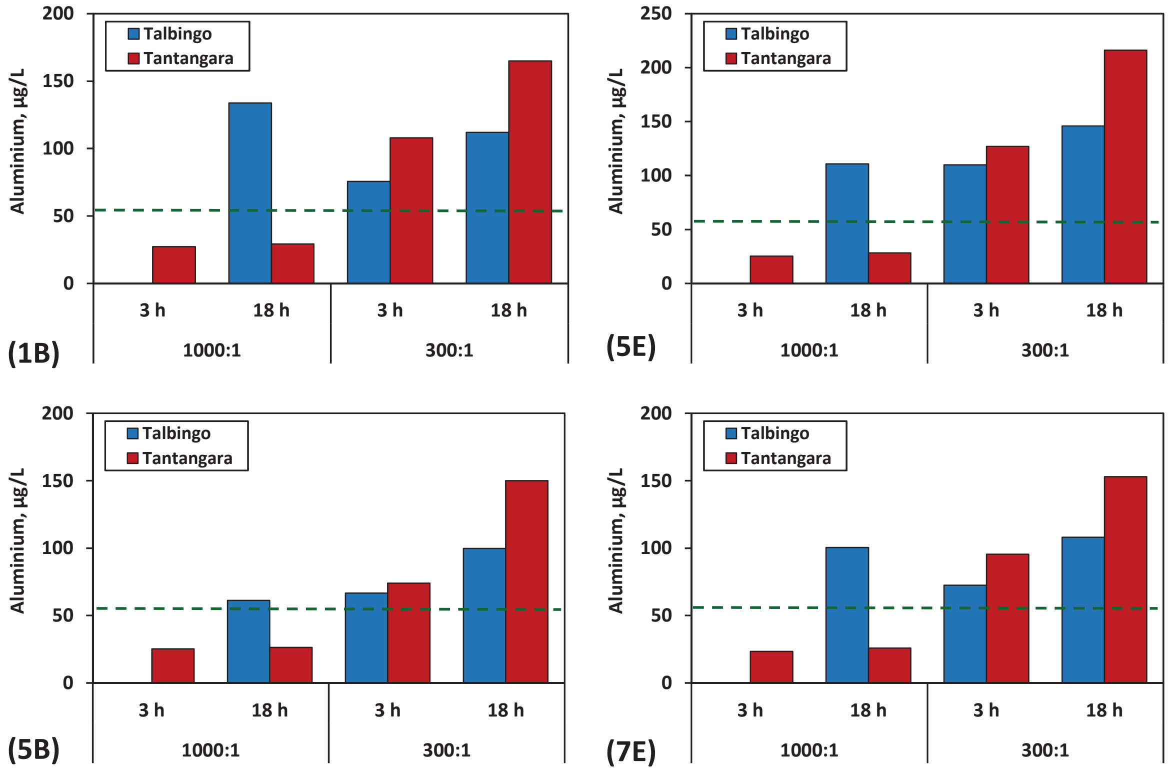

Figure 9. Comparison between the dissolved Al concentration measured in Talbingo and Tantangara Reservoir waters following elutriate tests with excavated rock composites 1B, 5B, 5E and 7E. A green dashed line at 55 µg/L indicates the DGV.

Significant observations from comparison of substance release in Talbingo and Tantangara Reservoir waters

The elutriate water pH was similar in the Tantangara and Talbingo Reservoir water treatments for the 300-L/S tests, but lower in the Tantangara Reservoir treatments for the 1000-L/S_18-h tests, probably due to this water having a greater ability to buffer pH increases. The conductivities were generally in a similar range for the two reservoir waters except for a few Tantangara Reservoir treatments having higher values.

The concentration of dissolved Al was in the range 23.5-216 µg/L in the Tantangara Reservoir elutriate treatments, which was in a similar range to corresponding Talbingo Reservoir treatments conducted in previous tests. Small differences were observed for corresponding treatments, with the Talbingo elutriate treatments having higher concentrations than the Tantangara treatments for the 1000-L/S_18-h tests, and the Tantangara elutriate treatments having higher concentrations than the Talbingo treatments for the 300-L/S_3-h and 300-L/S_18-h tests.

The concentration of dissolved Al in the 1000-L/S Tantangara Reservoir water treatments was below the DGV of 55 µg/L for the 1000-L/S treatments, and exceeded the DGV for the 300-L/S treatments.

3.4.6 Effect of water temperature on substance release

Substance release from solids to waters is usually greater at higher temperatures and to provide a worst-case scenario for substance release the elutriate tests were conducted at a temperature of 21°C. The temperature of the reservoirs varies between approximately 6 and 21°C, with significant changes over depth and season. Lower temperatures may substantially slow the kinetics of reactions that effect the release of pollutants from excavated rock material into the reservoirs.

Elutriate tests (L/S of 300 and 1000) with the <75-µm composite rock materials 1B, 2B, 5B, 5E and 7E were performed at 6°C Memo 9 (7 November 2018) (Appendix D6), and compared with results from corresponding tests performed at 21°C in Talbingo Reservoir water (Memo 11, Appendix D2). The kinetics of substance release at 6 °C was monitored at time periods of 6, 18 and 48 h, while the 21±2°C treatments to which they were compared were sampled after 0.5 and 18 h, with the 3.3 g/L (300/1 L/S) also being sampled after 3 and 120 h. Therefore, the 18-h time point was directly comparable and trends over time were also compared to investigate the effect of temperature on water quality. Comparisons of composite 2B elutriate pH, conductivity and dissolved Al concentrations for water temperatures of 6 °C and 21 °C are shown in Figure 10, and the dissolved Al concentrations for composites 1B, 5B, 5E and 7E are shown in Figure 11. All of the results are provided in Appendix D6, including figures for major cations.

The concentrations of major cations were generally similar for the 1 g/L (1000 L/S) at both temperatures, whereas for the 3.3 g/L (300 L/S), marginally higher concentrations were generally measured for the 21°C than the 6°C (data in Appendix D6).

For the 6°C treatments, only the 3.3 g/L (300 L/S) had dissolved Al concentrations that exceeded the DGV of 55 µg/L (dotted red line in graphs), which occurred for the 48 h sampling time for all but composite 5E, for which the DGV was exceeded for all durations tested. The dissolved Al increased continuously over the 48 h test period for all 6°C treatments and would presumably continue to increase for some time if the test was run longer (i.e. the concentration did not plateau after 48 h). No other metal or metalloid concentrations exceeded DGVs.

A comparison between the 6 and 21°C values for dissolved Al concentrations is shown for all the composite materials together at 18 h in Figure 12. Conductivity was similar for both temperatures (Appendix D6). Water pH and dissolved Al concentrations were mostly higher at 21°C than at 6°C.

Significant observations from comparison of substance release at low water temperature

The release of Al occurred significantly more slowly in the 6°C treatments than the 21°C treatments. As such, after 18 h, the concentration of dissolved Al (and pH) were generally substantially lower for the lower temperature treatment. The dissolved Al continued to increase over the 48-h period of the 6°C test and did not plateau. After 48-h, the dissolved Al exceeded the DGV of 55 µg/L for all 6°C treatments at 3.3 g/L (300 L/S), but did not exceed the DGV for any 1 g/L (1000 L/S) treatments.

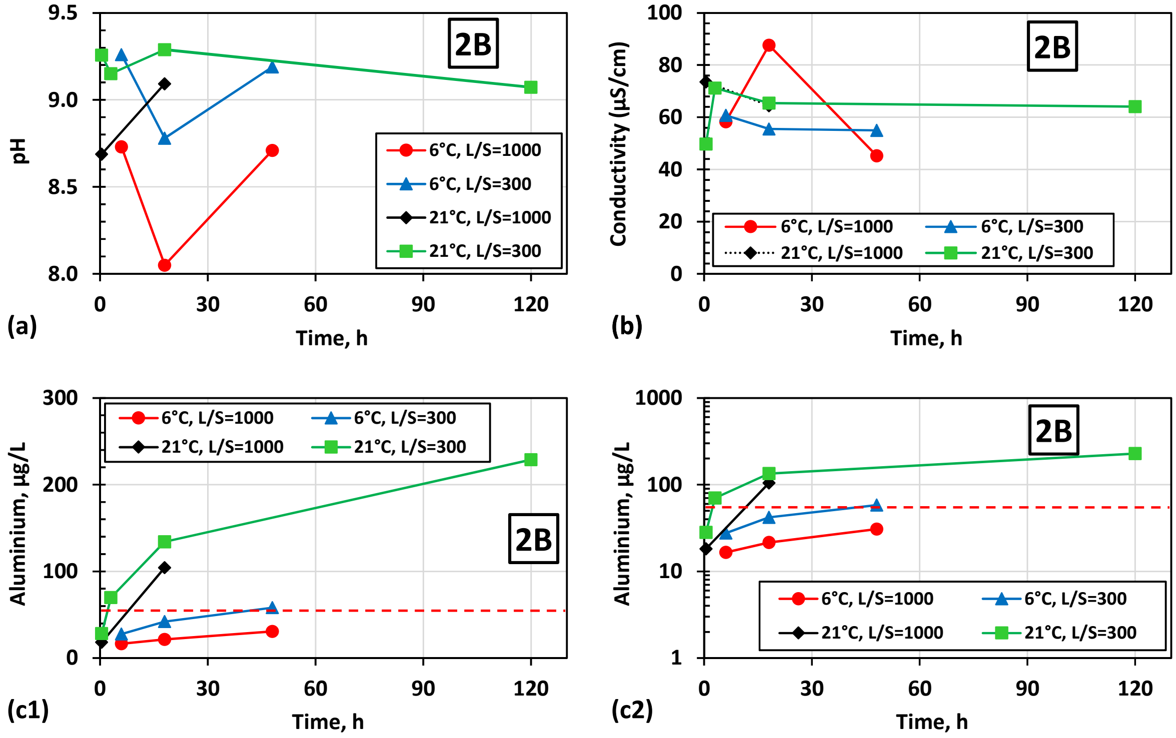

Figure 10. The pH, conductivity and dissolved Al over time for composite 2B (c2 = log scale)

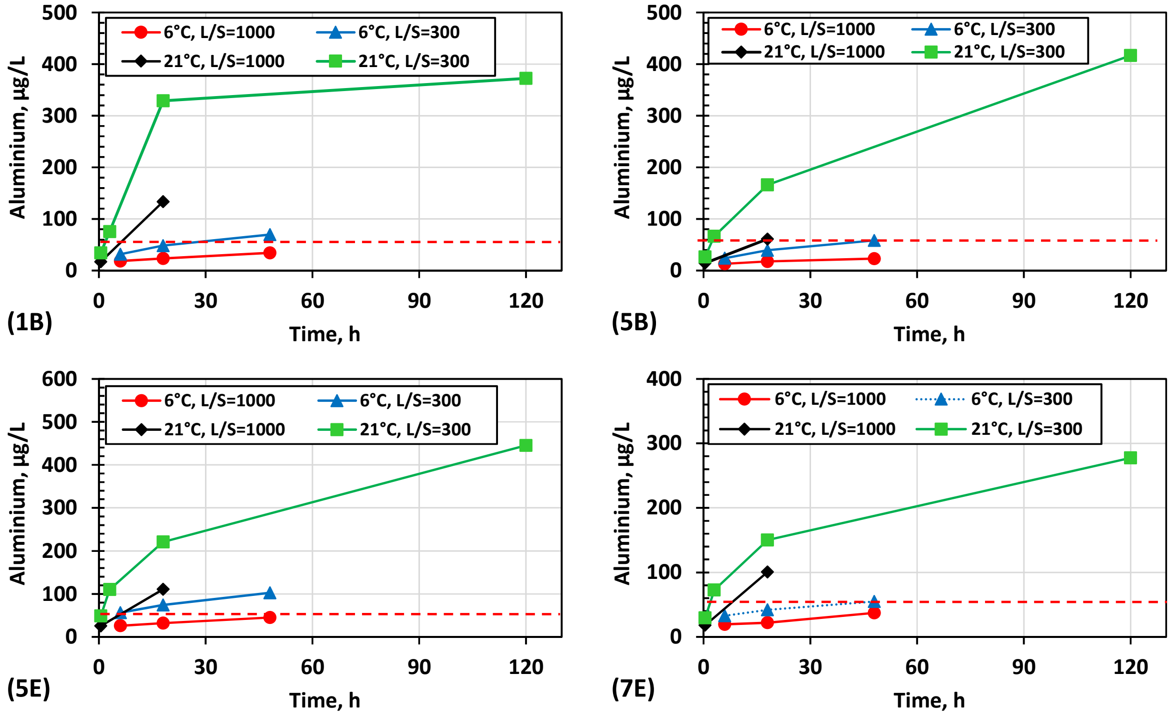

Figure 11. Dissolved Al concentrations at 6°C and 21°C at L/S 300 and 1000 for elutriate tests with excavated rock composites 1B, 5B, 5E and 7E. A red dashed line at 55 µg/L indicates the DGV.

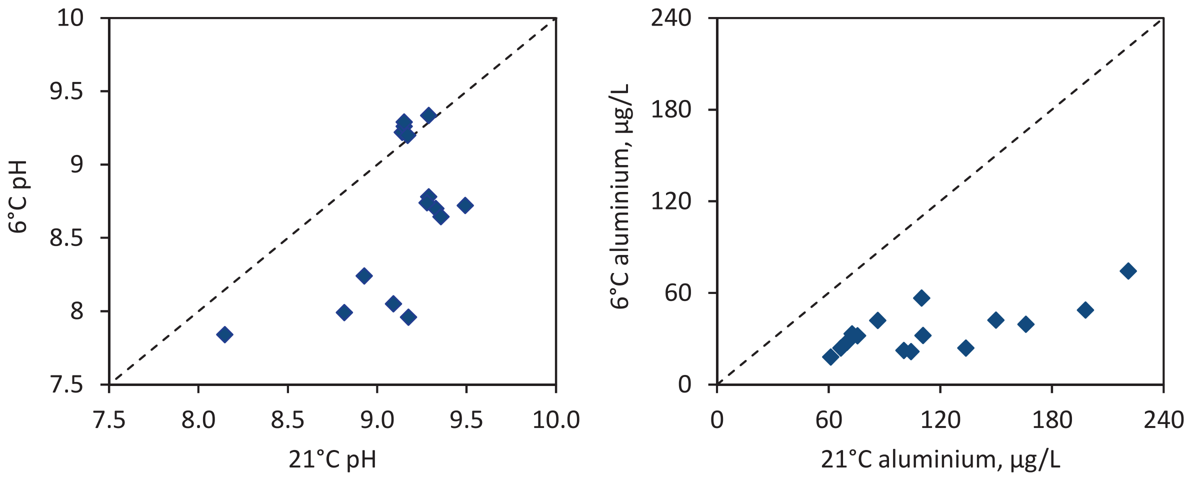

Figure 12. Comparison between temperatures of 6 and 21°C on the pH and dissolved Al for 1B, 2B, 5B, 5E and 7E composites after 18 h in Talbingo Reservoir water. The dotted unity line indicates a 1:1 relationship.

3.4.7 Effect of repeat leaching on substance release

Greater release of substances may occur from the fine rock materials if they remain in the water column, either within the placement area or as they disperse away from the placement area. To assist in predictions of long-term leaching, a series of repeat/successive leach tests was performed on the same rock materials (Memo 12, 26 November 2018) (Appendix D7).

Two series of successive elutriate tests (3 leaches each) were performed on the <75-µm composite rock materials 1B, 2B, 5B, 5E and 7E. The first successive leach test series investigated the effect of two mixing durations (0.5 or 18 h) at L/S of 30 and 300 at 21°C. Key relationships are shown in Figure 13 (pH, conductivity and dissolved Al for 2B) and Figure 14 (dissolved Al concentrations for all other treatments, with other figures provided in Memo 12 and Appendix D7. The second successive leach test series investigated the effect of temperature (6°C and 21°C) for the two L/S (30 and 300) and had a duration of 18 h (further method details are provided in Memo 12). Key relationships shown in Figure 15 (pH, conductivity and dissolved Al for 2B) and Figure 16 (dissolved Al concentrations for all other treatments, with other figures provided in Memo 12 and Appendix D7.

Results from first test series - L/S of 30 or 300, 21°C, 0.5 or 18 h mixing

In the first test series, the pH was generally higher for a lower L/S ratio and longer mixing duration and decreased in each successive leach. The conductivity was more variable than pH, but was generally marginally higher for the lower L/S, and for the L/S=300, was higher for the longer mixing duration. Apart from a few treatments, the conductivity generally decreased in each successive leach. Figures are provided for major cations in Appendix D7.

For all excavated rock samples at each L/S ratio and mixing duration, the concentration of dissolved Al in the leach 1, 2 and 3 solutions were in the range 26.6-329, 26.7-416, and 26.5-512 µg/L, respectively. The concentration of dissolved Al was generally similar or increased over successive leaches, despite the water pH successively decreasing.

The dissolved Al exceeded the default guideline value (DVG) of 55 µg/L for each of the three leaches for each material after a mixing duration of 18 h. The DGV was never exceeded for the L/S=300, 0.5-h treatments, with the dissolved Al remaining at a similar concentration for each successive leach, i.e. the short 0.5-h mixing duration at this L/S was not adequate to either release enough Al to exceed the DGV or exhaust the pool of Al in the samples, so the concentration remained steady. The concentration of dissolved Al released in the L/S=30, 0.5 h treatments always increased over successive leaches, with the initial leach often being below the DGV and the later leaches being above the DGV. No other metal or metalloid concentrations exceeded DGVs, noting here that a single value of 42 µg/L Zn (exceeding the DGV of 8 µg/L) was attributed to contamination not associated with the rock (Appendix D7).

In the first test series, the pH was generally similar or marginally lower over successive leaches with L/S=30, while for those with L/S=300 the pH was generally similar between the first two leaches then decreased for the third leach. There were no discernible trends for the conductivity in successive leach test series 2, i.e. temperature had no clear effect on conductivity. The conductivity was in the range 35-402 µS/cm.

Results from second test series - L/S of 30 or 300, 6°C and 21°C, 0.5 h mixing and 17.5 h standing in water

For all excavated rock samples at each L/S ratio at 6°C, the concentration of dissolved Al in the leach 1, 2 and 3 solutions were in the range 23.1-109, 27.9-129, and 16.8-137 µg/L, respectively, and at 21°C, the concentration of dissolved Al in the leach 1, 2 and 3 solutions were in the range 93.6-299, 125-403, and 65.0-384 µg/L, respectively. Less Al was released in the 6°C than the 21°C treatments at each L/S ratio, and more Al was released by treatments with a lower L/S ratio. For the 21°C treatments, the dissolved Al was generally steady or decreased over the successive leaches, whereas, for the 6°C treatments the dissolved Al was steady or increased over the successive leaches. The dissolved Al exceeded the default guideline value (DVG) of 55 µg/L for all of the leaches of the 21°C treatments and most leaches of 6°C, L/S=30 treatments, while the DGV was not exceeded by any of the 6°C, L/S=300 treatments.

A comparison of the 21°C treatments that were in contact with the reservoir water for 18 h, 0.5-h mixing (successive leach test series 2) and 18-h mixing (successive leach test series 1) indicated that longer physical mixing often caused an increase in the release of dissolved Al (Figure 17); most evident for the 2nd and 3rd leaches. This is likely to be the cause of the difference in trends over successive leaches between the first and second test series for the 21°C treatments, i.e. generally similar or increased concentrations in test series 1 and generally similar or decreased in test series 2. However, even the short mixing durations (0.5 h) generally resulted in considerable release of dissolved Al when monitored over the same time period, which is a result of the slow settling of the fine rock material (i.e. a considerable portion remain suspended in solution for next 24 h) that are the dominant source of most Al released.

Data were gathered on total-P leaching in these tests and figures are provided in Appendix D7. For successive elutriates at L/S of 30, the total-P concentrations were within the range of 10-40 µg/L (exceeding the DGV of 10 µg/L) for each of the successive elutriates for rock composites 2B, 5B and 5E, but not for rock composites 1B and 7E. Significant observations relating to long term substance release (repeat/sucessive leaches)

The successive leaches indicated that the Al available for release into solution was not quickly exhausted. Many treatments had similar or increased Al concentrations in the 2nd and 3rd successive leaches. Consistent with results from Section 3.4.6, the lower temperatures resulted in substantially lower concentration of Al being released into reservoir waters. These results suggest a dissolution process is responsible for the release of Al, which is dependent on the duration of contact with water and the temperature. Longer durations of physical mixing also generally increased the release of dissolved Al. The DGV for Al, 55 µg/L, was exceeded by most treatments in the successive leach tests. No other metal or metalloid concentrations exceeded DGVs.

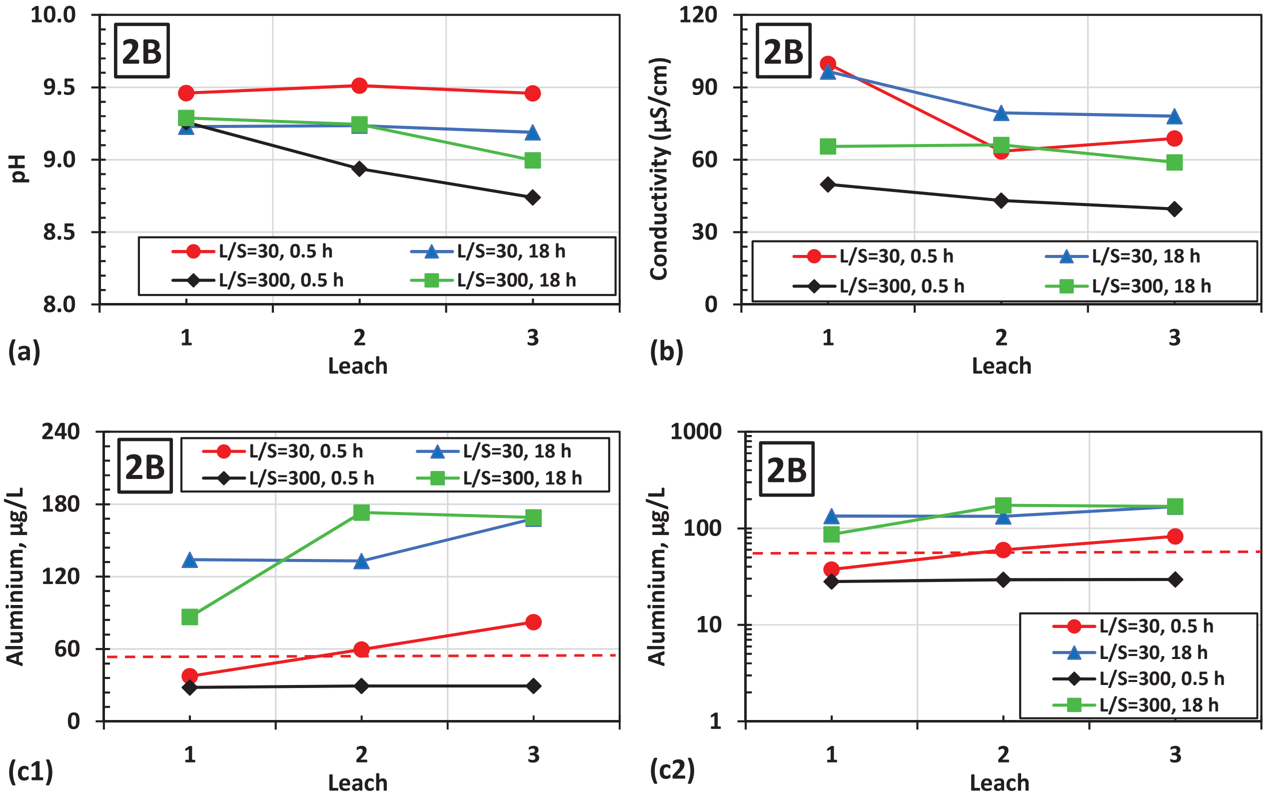

Figure 13. The pH, conductivity and dissolved Al concentration after three successive leach cycles at 21±2°C for excavated rock sample 5B (successive leach test 1), where the effect of mixing duration and L/S ratio was investigated (c2 = log scale).

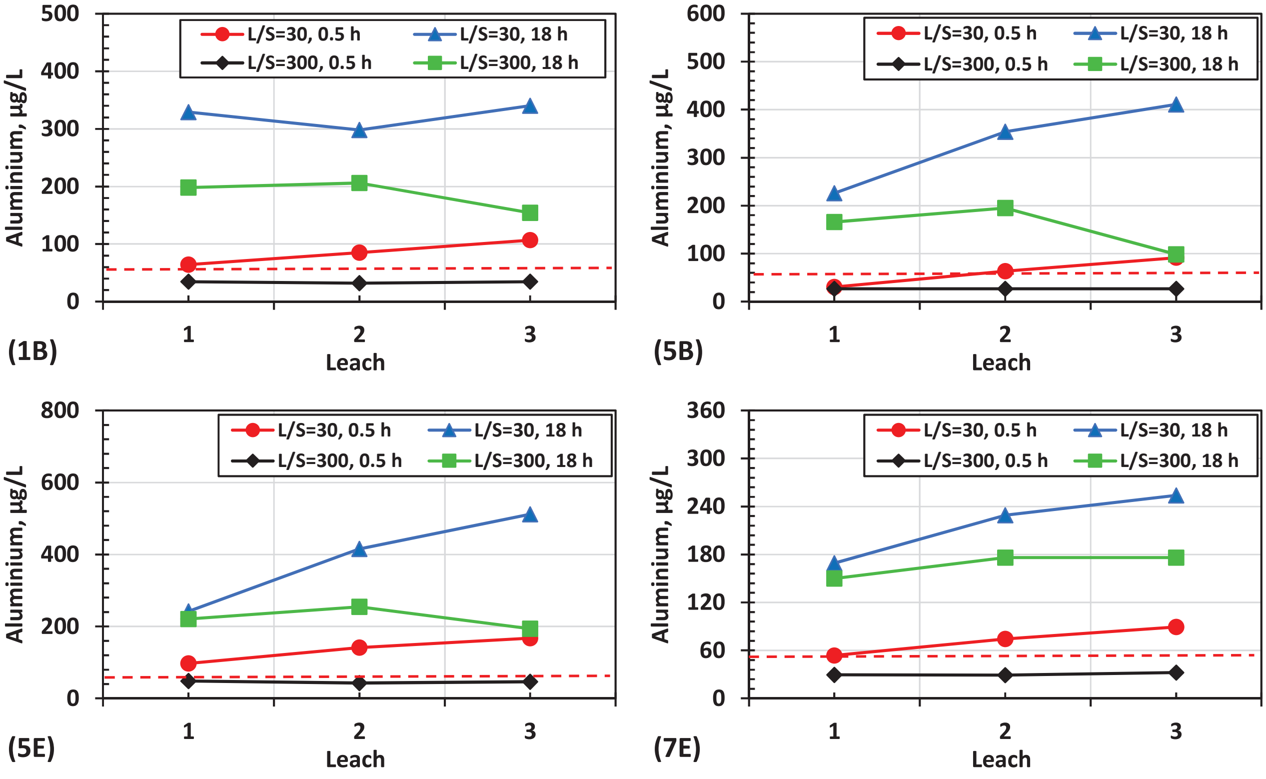

Figure 14. Dissolved Al concentrations for three successive leaches at L/S 30 and 300 after 0.5 h and 18 h for elutriate tests with excavated rock composites 1B, 5B, 5E and 7E. A red dashed line at 55 µg/L indicates the DGV.

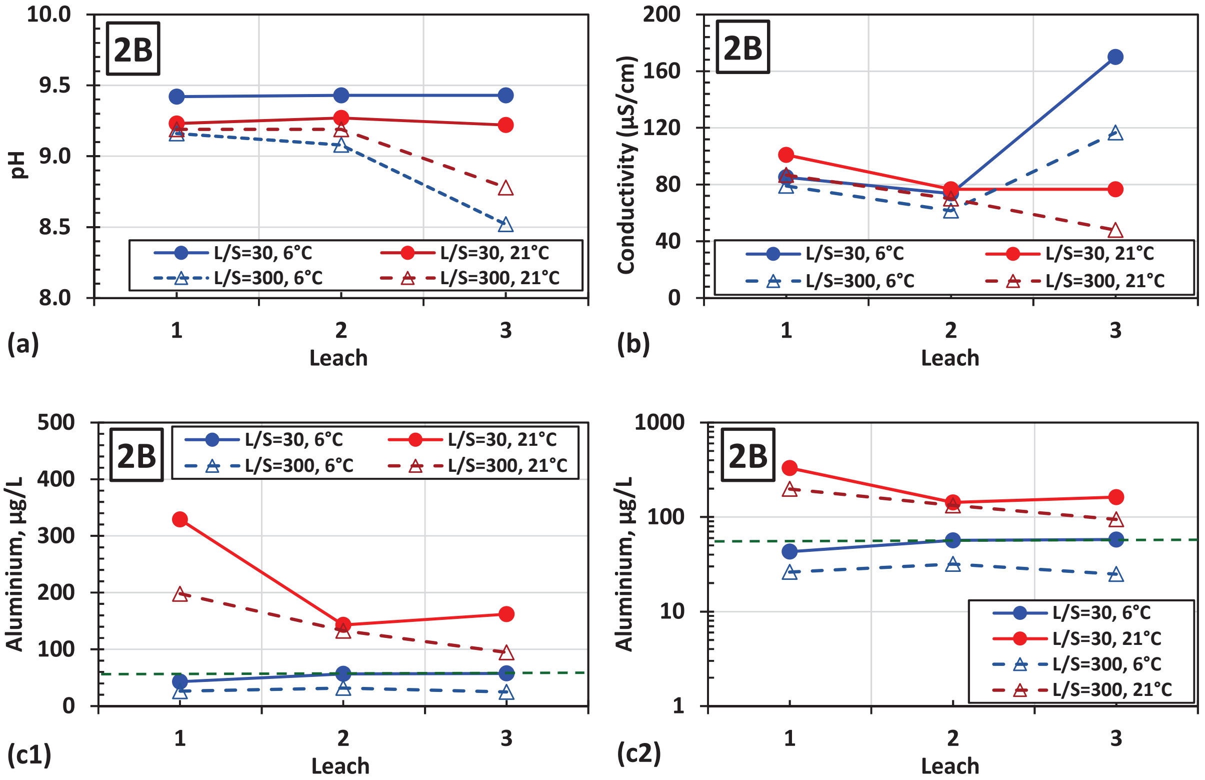

Figure 15. The effect of temperature on the pH, conductivity and dissolved Al concentration after three successive leach cycles at 6±1°C and 21±2°C for excavated rock sample 2B (successive leach test 2), (c2 = log scale)

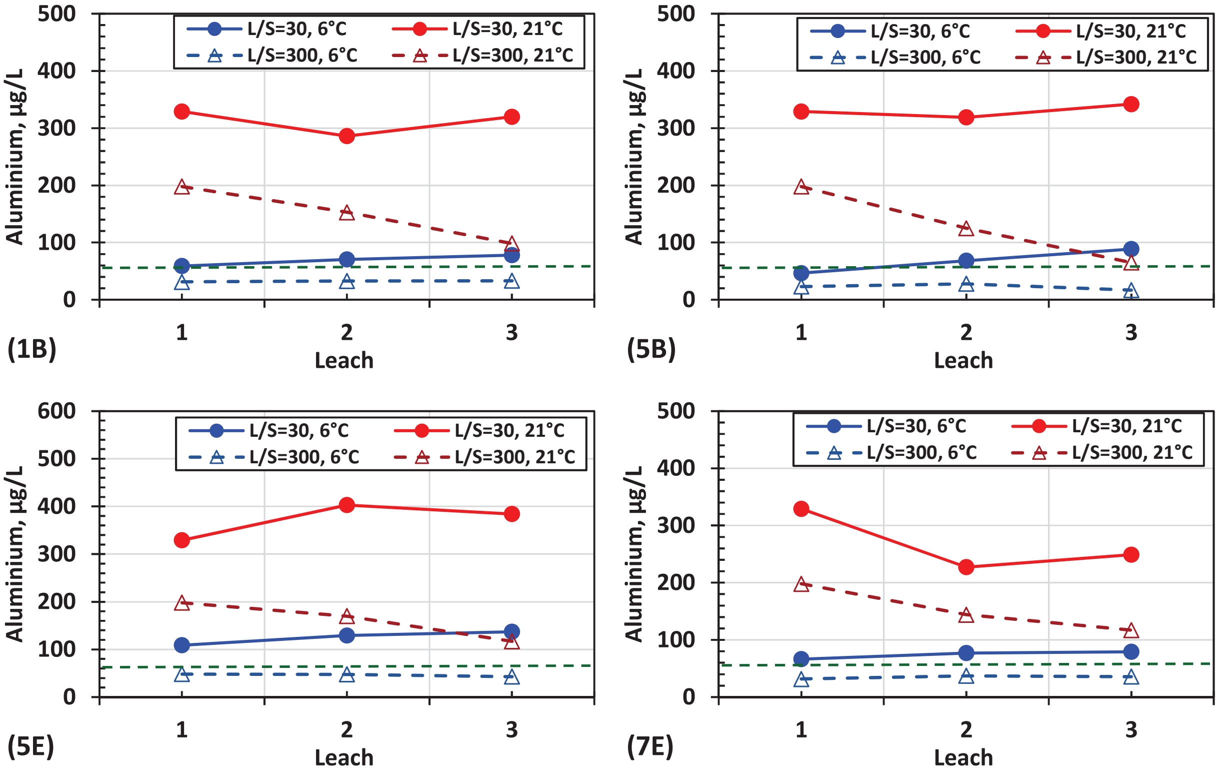

Figure 16. Dissolved Al concentrations for three successive leaches at of 6 and 21°C and L/S 30 and 300 for elutriate tests with excavated rock composites 1B, 5B, 5E and 7E. A green dashed line at 55 µg/L indicates the DGV

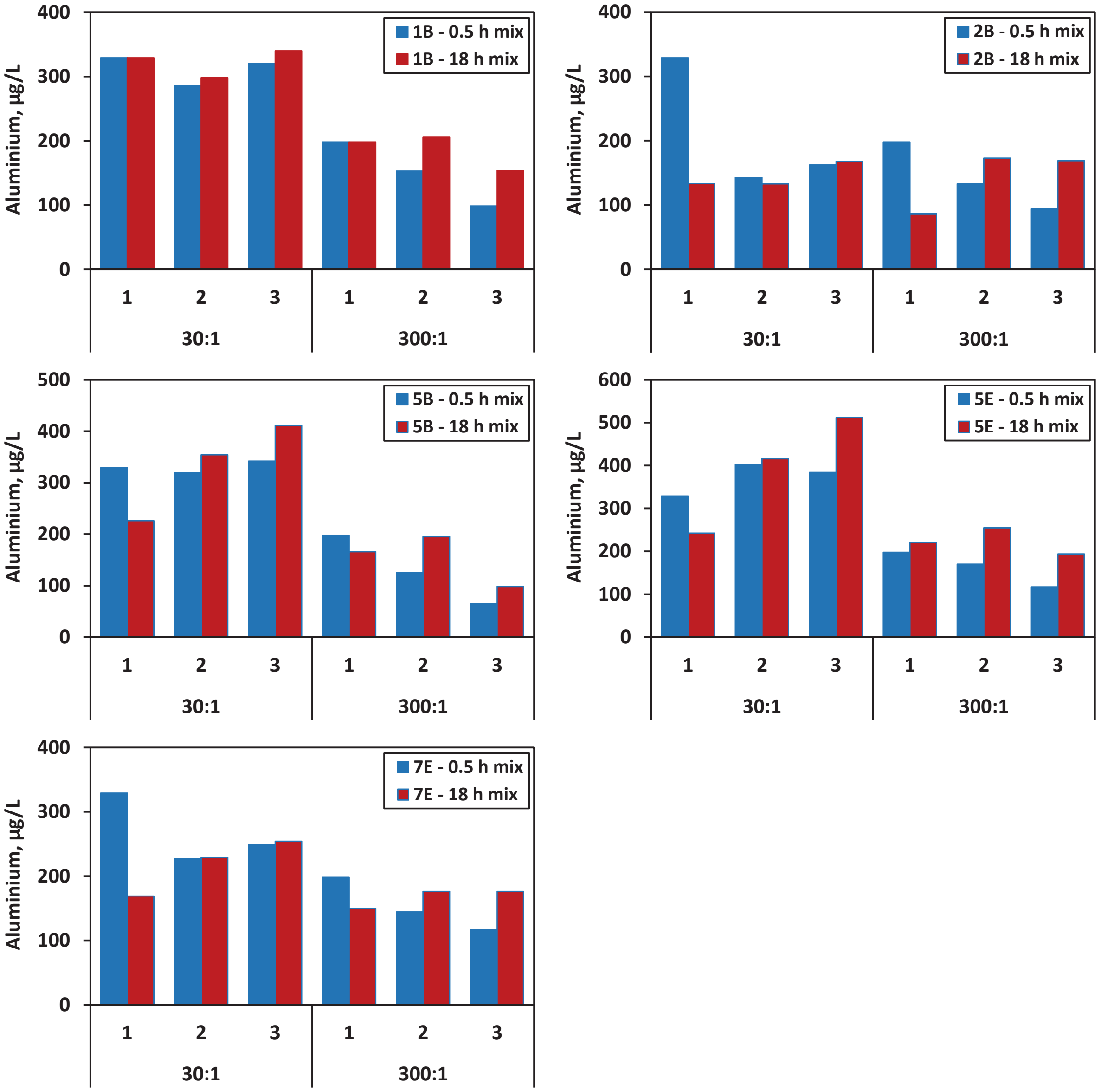

Figure 17. Comparison between the dissolved Al released from excavated rock material at L/S ratios of 30 and 300 in Talbingo Reservoir water after 18 h contact with water between successive leach test 1 (18 h mixing, red bars) and leach test 2 (0.5 h mixing, 17.5 h standing, blue bars) at 21°C to assess the effect of mixing vs standing for each successive leach (1, 2 and 3)

3.4.9 Significance of colloidal forms of Al with <0.45 µm filtered water

A significant portion of Al is often found to exist in colloidal forms in natural waters, and these forms are often predicted to be less bioavailable than truly dissolved forms. It is well recognised that the filtration of waters through a 0.45 µm filter (i.e. the standard filter size) does not completely separate dissolved and colloidal forms of metals (Gundersen and Steinnes, 2003; Wilkinson and Lead, 2007; Simpson et al., 2014). Colloids have sizes in the range of approximately 0.001–1 µm (Wilkinson and Lead, 2007) and may be less bioavailable to some aquatic organisms.

Tests were performed in Talbingo and Tantangara Reservoir waters with <75-µm composite rock materials at L/S of 300 (3.3 g/L) that were filtered (0.45 µm, dissolved and colloidal substances) and ultrafiltered (0.003 µm, dissolved substances) after 18 and 120 h (Appendix D8). The Al concentrations were similar in the <0.45 µm and <0.003 µm fractions of each treatment, and indicated that the <0.45 µm filterable water fraction of the <75-µm composite elutriates contained predominantly dissolved (<0.003 µm) (Figure 18) rather than colloidal forms of aluminium, which is consistent with the dominant aluminium species (ion) in the basic pH waters being the aluminate ion ($Al(OH)_4^-$).

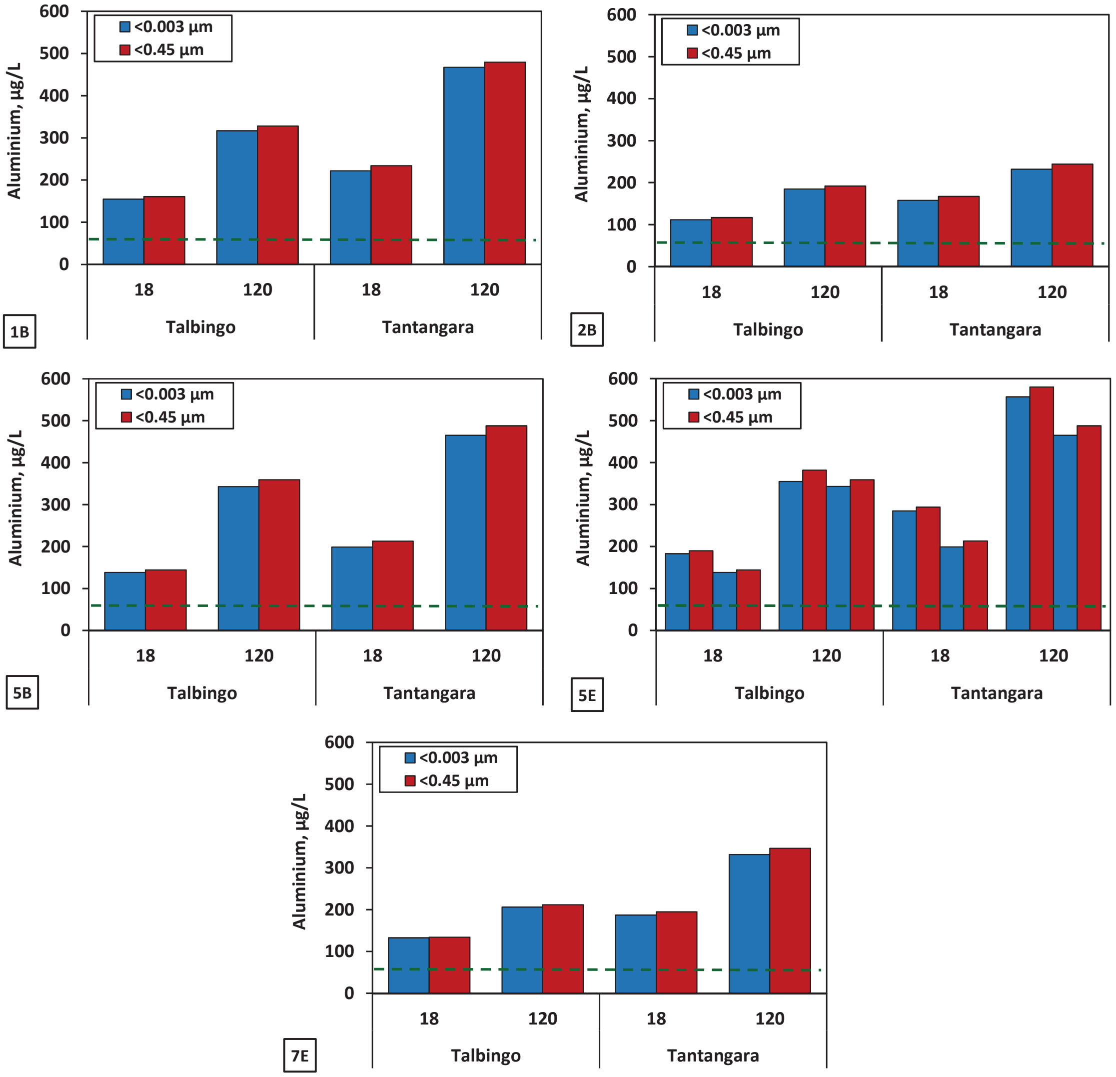

Figure 18. Comparison between the Al concentrations measured in leachate waters generated from a 300 L/S after filtering through 0.45 µm (dissolved and colloidal substances) and 0.003 µm (dissolved substances) filters. 5E has replicate treatments shown.

Significant observations relating to Al colloids

The <0.45 µm filterable elutriates waters prepared with Talbingo Reservoir waters contains predominantly truly dissolved forms of Al, which are predicted to be the aluminate ion, $Al(OH)_4^-$.

3.4.10 Longer-term substance release

A portion of the finest rock particle size fractions (e.g. clay to fine silt (<2 µm to 6.3 µm)) may remain suspended in the bottom waters for months to years. The hydro-pumping operations of Snowy 2.0 may also generate hydrodynamic forces that result in repeated mixing (resuspension) of rock solids within their vicinity. To investigate long-term changes in water quality, two <75-µm composite rock materials (1B and 5B) were resuspended in Talbingo Reservoir water at L/S of 300 (3.3 g/L) and 1000 (1 g/L) at 6 and 21 °C, and measurements made after durations up to 56 days (Appendix D9). In these tests, each test treatment was initially shaken for 0.5 h to suspend the solids and then allowed to stand at each temperature until next sampled, when they were shaken for 10 s and subsampled for analyses. These longer-duration tests indicated the following (Figure 19):

- Following the initial immediate pH increase to pH 9.5, the pH decreased and exhibited a plateau within the range of pH 7.7-8.2 after approximately 30 days.
- The conductivity increased considerably over the 56 days, although any trends were obscured by variability, with values of 400-600 µS/cm range being reached. In particular, Ca concentrations in the L/S=300 treatments were markedly higher after 14 days (Appendix D9).
- Dissolved Al concentrations generally increased during the first 1-2 weeks then decreased, and indicated potential removal of dissolved Al due to changes in speciation, decreased solubility with decreasing pH, and/or increased adsorption. Over the pH range measured in the treatments of this test, the aluminate ion ($Al(OH)_4^-$) would remain the dominate dissolved ion in solution.
    - At 21°C, the dissolved Al exceeded the DGV for all rock composite treatments; by a factor of 2-5 for the entire 56 d duration at L/S=300, and by a factor of 1-3 for the entire 56-d duration at L/S=1000, except the initial 18 h duration for 1B.
    - At 6°C, the dissolved Al marginally exceeded the DGV in the mid-duration subsamples of each treatment except the 1000 L/S, 1B treatment that never exceeded the DGV.
- No other metal or metalloid concentrations exceeded DGVs.
- Total-P concentrations remained below the DGV of 10 µg/L over the 56-day period (Appendix D9).

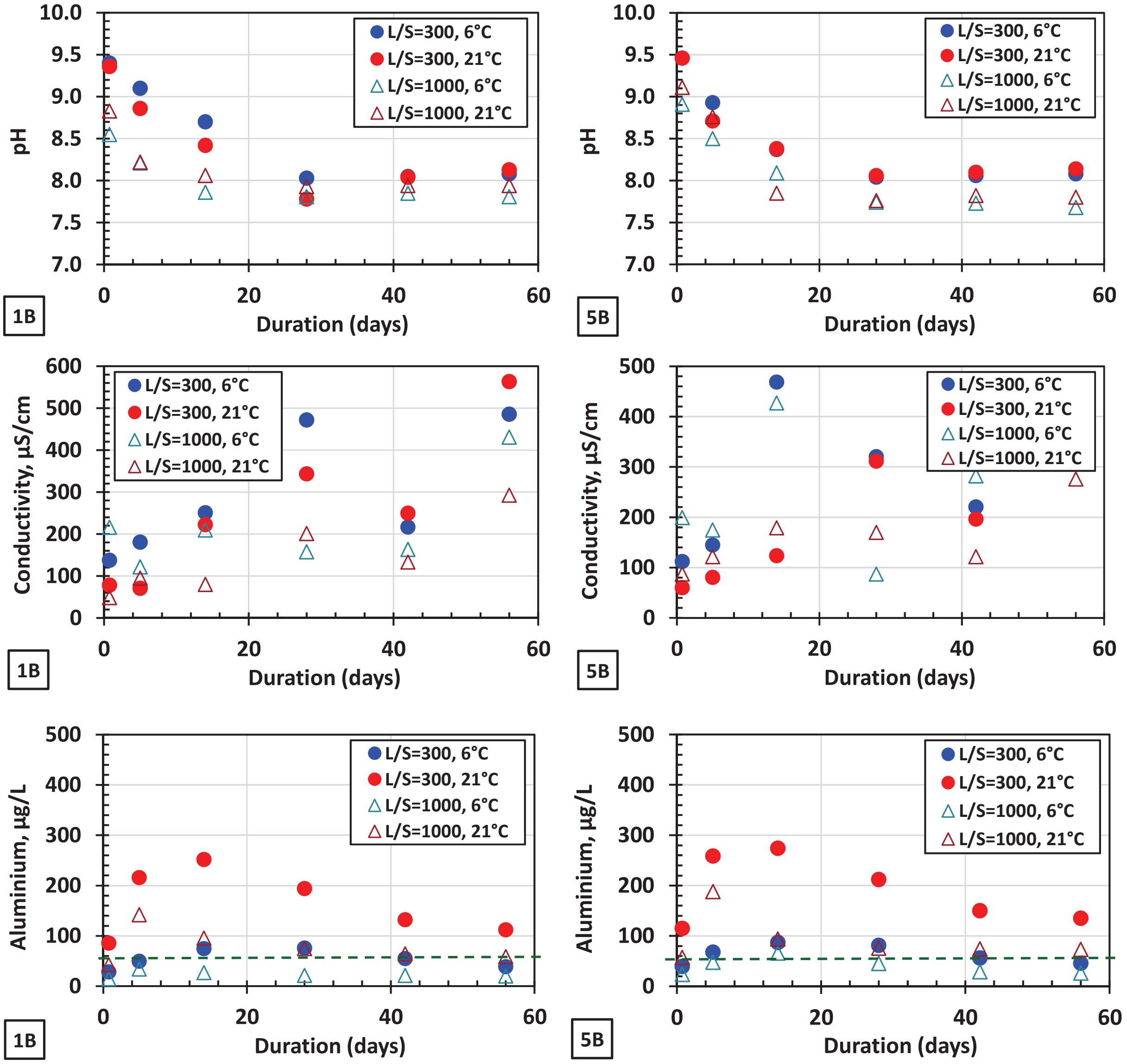

Figure 19. Longer term changes in water quality after water-rock mixing durations of up to 56 days for <75-µm rock composites 1B and 5Bd in Talbingo Reservoir water at L/S of 300 (3.3 g/L) and 1000 (1 g/L) at 6 and 21 ºC. A green dashed line at 55 µg/L indicates the DGV.

Significant observations from long term mixing tests

After long durations (56 days) of mixing (suspension) of <75-µm rock composites in Talbingo Reservoir water the pH decreased to plateau, conductivity continued to increase and dissolved Al concentrations decreased, but dissolved Al concentrations remained above the Al DGV in tests performed at 21°C and L/S=300. Total-P concentrations remained below the DGV of 10 µg/L over the 56-day period.

3.4.12 Effect of resuspended sediment in attenuation of substances released from rock materials

Benthic sediments may be resuspended during and following the placement of excavated rock materials in the reservoirs. The sediment may release additional substances or adsorb substances that have been released from the rock materials. Sediment resuspension may attenuate dissolved concentrations of substances, including Al, through adsorption onto these solids. To investigate whether such attenuation reactions occur and the magnitude and rate of any attenuation, a series of tests were undertaken using resuspended and deposited sediments, and the first of these tests was reported in Memo 10 (8 November 2018) (Appendix D10).

First attenuation test – Effect of sediment concentration on attenuation

The first sediment resuspension-attenuation test used the remaining treatment solutions of composites 1E, 2E, 3E, 4E, 5E and 7E after the alkalinity test (Memo 7, 2 November 2018) was completed, and allowed them to equilibrate with the atmosphere for an additional 6 days before the sediment attenuation test was started. These waters had elevated dissolved Al concentrations and were mixed with the Talbingo Reservoir sediment PL2 (Section 3.2) at L/S of 50 and 500 [L-E/Sed=500 and L-E/Sed=50 (L-E=elutriate and Sed=sediment 2 and 20 g/L of PL2, respectively] and compared with treatments having no added sediment. Each treatment was shaken to disperse the sediment then allowed to settle for 24 h before measurements. The results are compared with treatments containing no added sediment (Figure 20). The pH and conductivity of the elutriate waters decreased with increasing amounts of resuspended sediment. The dissolved Al concentrations in the 2 g/L added sediment treatments were substantially lower than the elutriate treatments with no added sediment, indicating the presence of the sediment contributed to the attenuation of dissolved Al. However, for the 20 g/L added sediment treatments, variable results were observed; the addition of 20 g/L PL2 sediment resulted in lower concentrations of dissolved Al for elutriates 3E and 4E, similar concentrations for elutriate 2E, and higher concentrations for elutriates 1E, 5E and 7E.

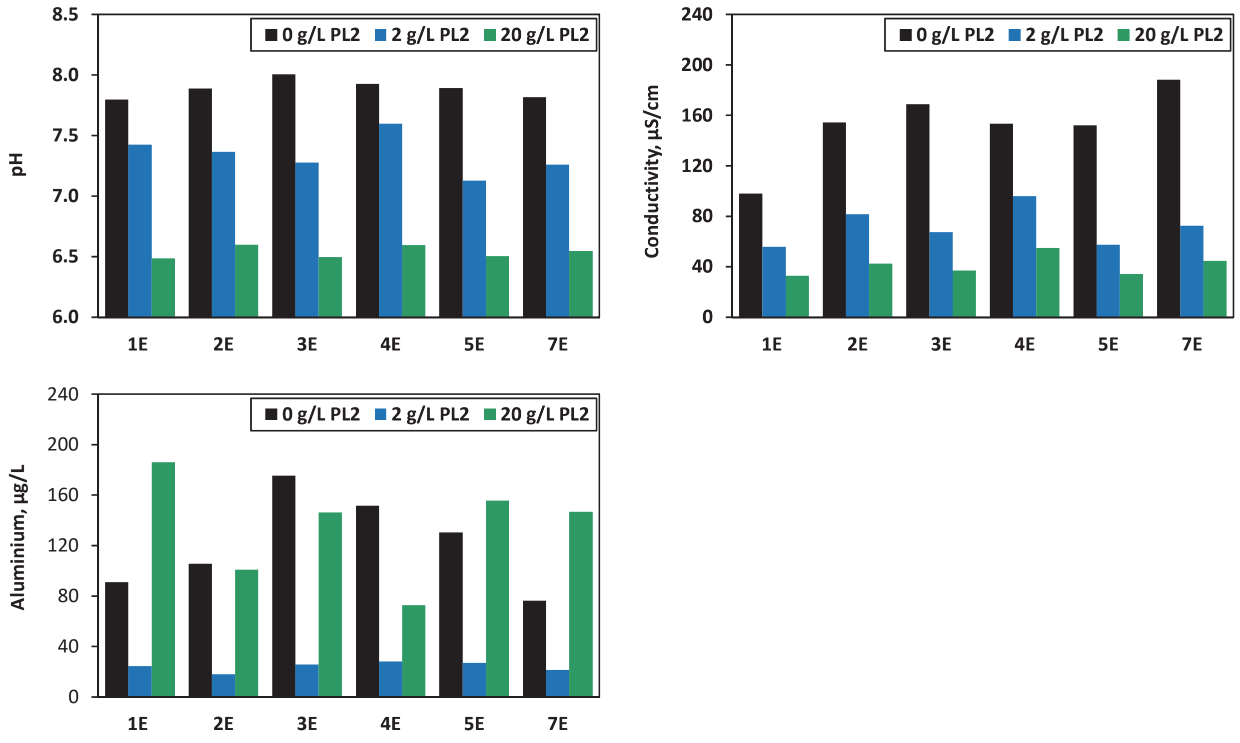

Figure 20. The pH, conductivity and dissolved Al after 0, 2 and 20 g/L of Talbingo Reservoir sediment PL2 was mixed for 10 s with 4-d old composite (1E, 2E, 3E, 4E, 5E and 7E) elutriates then allowed to stand for 24 h before measurement.

The dissolved Al ranges for the L-E/Sed = 500 and 50 sediment resuspension-attenuation tests were 18-28 µg/L and 73-186 µg/L, respectively, compared to the range for the initial waters of 76-176 µg/L, and that of the Talbingo Reservoir water of ca. 5 µg/L.

The PL2 sediment was used for these tests because it had the highest porewater Al concentration of 600 µg/L (Table 13), and should represent a worst case scenario for assessing risks. Based on the mass of sediment and volumes of test solutions, the maximum contribution of porewater Al from the addition of 20 g/L PL2 would be less than 10 µg/L. Increases of up to 100 µg/L dissolved Al were observed in the 20 g/L PL2 treatments, indicating the sediment particulate phase was likely the cause rather than pore water. Significant amounts of colloidal Al may be included in this filterable Al measurement, and the lower pH of 6.5 created by the presence of 20 g/L sediment would favour colloid formation.

Second attenuation test – Effect of resuspended sediment TSS concentration on attenuation

The second and third attenuation tests used a freshly prepared composite bulk elutriate water and Talbingo Reservoir sediments CA3, PL2, RA1, chosen because they had the largest differences in properties such as total organic carbon, particulate Fe etc. The bulk composite elutriate water was prepared by combining <75 µm masses of rock composites 1B, 2B, 5B, 5E and 7E (4 g per composite) to 2 L of Talbingo Reservoir water to achieve a L/S of 100, and was mixed for 24 h before use. This water had a dissolved Al concentration of 150 µg/L and pH 9.52 for attenuation test 2, while for attenuation test 3 that commenced a day later the dissolved Al concentration had decreased to 111 µg/L (same pH). The second attenuation test investigated the effect of resuspended sediment TSS concentration and involved combining an aliquot of elutriate with sediments CA3, PL2, RA1 at sediment TSS concentrations of 1, 5 and 25 mg/L, mixing for 30 min, and subsampling after 1 and 24 h.

These tests indicated that attenuation of dissolved Al concentrations by the presence of such small amounts of suspended sediment was low (<10%) (Figure 21) (Appendix D10.2). For the pH and dissolved Al, there was a general trend of slightly decreasing values as the TSS increased. There was also a general trend of slightly higher pH or concentration of dissolved Al in the 24 h subsamples compared to the 1 h subsamples for any given treatment. The slightly higher dissolved Al in the 24 h than the 1 h subsamples probably indicates release of Al from the suspended sediment. No discernible trend in conductivity was observed for the different parameters tests; TSS concentration, duration, sediment type. There was little difference in the pH, conductivity and concentration of dissolved Al between sediments CA3, PL2 and RA1.

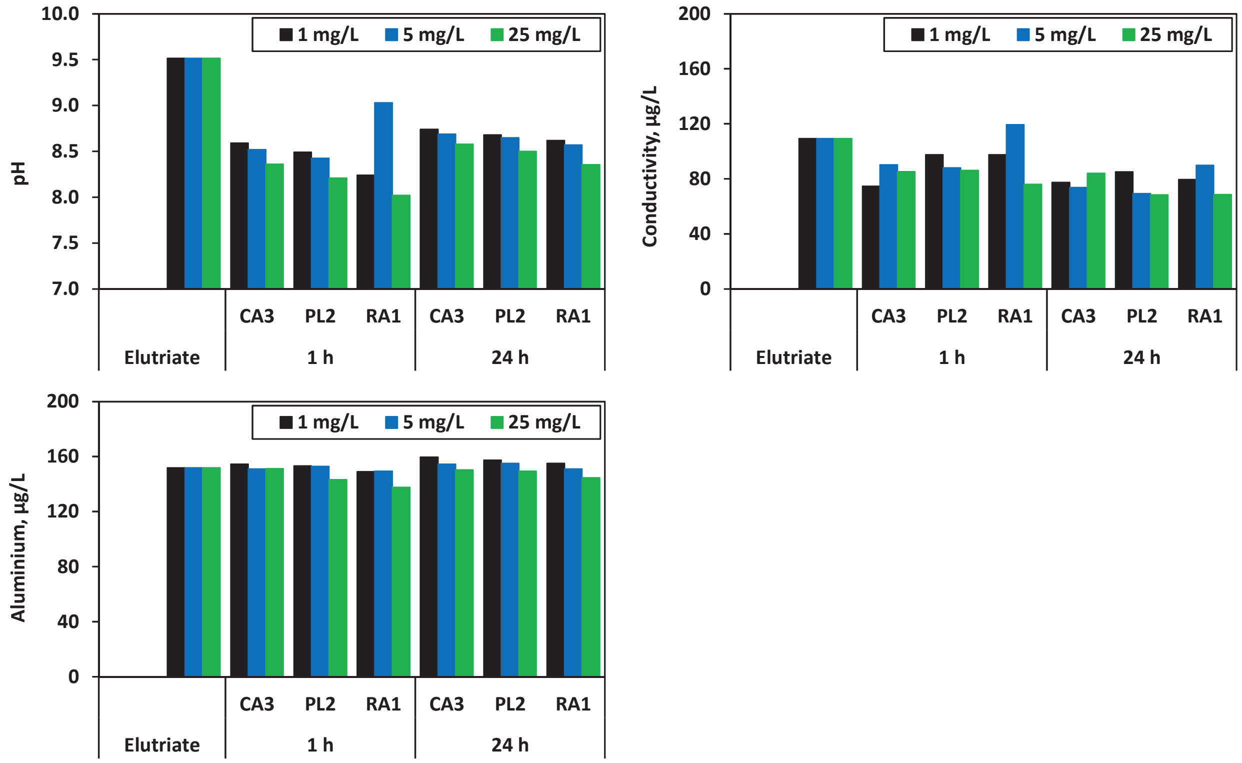

Figure 21. The effect of Talbingo Reservoir sediment TSS concentration on the composite elutriate pH conductivity and dissolved Al

Third attenuation test – Effect of deposited sediment and duration on attenuation

Attenuation test 3 investigated the effect of deposited sediments (CA3, PL2 and RA1) on the attenuation of substances present in the elutriate composite described above in the second attenuation test. Sediment (approximately 2 cm) was deposited on the bottom of 50 mL centrifugation tubes to represent the bottom of the reservoir. An aliquot of the composite elutriate was carefully added to minimise sediment resuspension, and subsamples were taken after 1, 6, 24 and 96 h. Each treatment was performed in duplicate.

The deposited sediments alone (no rock material) released 20-42 µg Al/L to the overlying water after 24 h (Appendix D10.3). In the presence of the deposited sediments the pH and dissolved Al concentration in the overlying elutriates waters decreased over time (Figure 22) to concentrations that were similar to the 24 h control values; the dissolved Al decreased substantially from the initial concentration of 112 µg/L. There was little difference in the attenuation of dissolved Al between the sediments CA3, PL2 and RA1. For each sediment the dissolved Al concentration had decreased below the DGV-dAl after 12 h (Figure 22, Appendix D10.3). No other metal or metalloid concentrations exceeded DGVs. No discernible trend in conductivity was observed for the different parameters tests; TSS concentration, duration, sediment type.

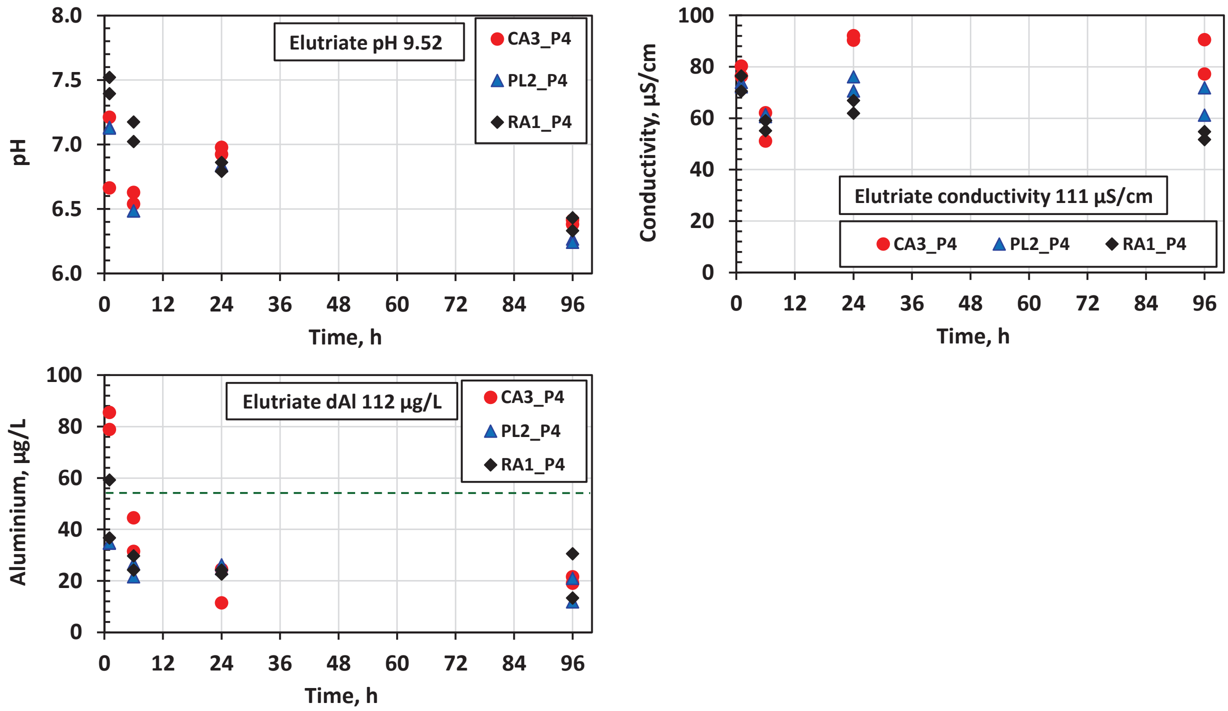

Figure 22. The pH, conductivity and dissolved Al concentrations in elutriate waters (initially pH 8.15, 110 µg Al/L) overlying three Talbingo Reservoir sediments (deposited, not resuspended)

Significant observations relating to sediment resuspension – attenuation tests

The presence of sediments may both lower (attenuate) or increase (release) dissolved substances. For Al, the particulate matter contains adsorption surfaces that decrease the concentration, but also act as a source of Al, possibly in colloidal forms, that can increase the concentration. The pH is also likely to influence the attenuation. Higher pHs (as measured in attenuation test 2) result in greater proportions of the dissolved Al being present as the aluminate ion, which probably has a low affinity for the negatively charged sediment surfaces. As the pH decreases, Al speciation will favour neutral and positively charged Al species (e.g. $Al(OH)_3$ and $Al(OH)_2^+$) that probably have a higher adsorptive affinity for sediment surface binding sites.

4 Test Summary and Identification of SOPCs

An intent of Assignment *P4 was to provide information on the lines of evidences (LoEs) relating to stressors of potential concern (SOPCs) that should be considered within the WoE assessment framework.*

The waters of the Talbingo and Tantangara Reservoirs can be classified as having neutral pH (6.9-7.3), low conductivity (26-30 µS/cm), low turbidity (0.2-0.6 NTU). There was little variability between sites in each reservoir. The concentrations of some dissolved elements were higher in Tantangara Reservoir than Talbingo Reservoir. In relation to water quality GVs (ANZG, 2018), the waters contained no COPCs. Talbingo and Tantangara Reservoir sediments were characterised as being silty (mean particle size 20-20 µm range), with significant amounts of organic matter (3.7-6.4% TOC) and having no COPCs, when considering relevant SQGVs.

Rock composites that had been milled to a size <75 µm were used for the majority of the tests. The rock composites had particle size distributions that were similar to the reservoir sediments. When wet with reservoir water the pH range was 8.5-9.6, which was significantly greater than that of the waters from the reservoir. A large portion of most elements were present in forms considered relatively inert (not easily released) and predicted to exhibit low bioavailability to organisms. The concentrations of most metals were below the corresponding SQGVs, with some exceedances. For the dilute-acid extractable metal concentrations, the SQGVs were only exceeded for lead in one composite.

Release of Substances from Excavated Rock Materials in Reservoir Water

During the period of time the placement of excavated rock occurs within the reservoirs, significant amounts of fine rock material may remain present in the waters, and the finest fractions (e.g. clay to fine silt (<2 µm to 6.3 µm)) may take many months to years settle after the placement activities cease. The release of substances from the rock materials was assessed using a series of elutriate tests that involved mixing and leaching rock with reservoir water and covered a wide range of mixing-leaching scenarios and conditions. The tests characterised differences in substance release that may occur due to differences in the concentration of solids in the water (liquid/solid ratio; L/S), time (up to 56 days), repeat/successive leaching, rock particle size, temperature, and attenuation of substances released due to interactions with sediments. Substance release was observed to be very similar for rock materials in Talbingo and Tantangara Reservoir waters.

Immediate release of substances and changes in water quality

The vast majority of the excavated rock, by mass, is expected to be larger than sand size and should settle rapidly, whereas the finest fractions of the excavated rock materials may remain suspended in the waters in the main disposal area for a considerable period of time. Consequently the bottom waters may contain very high concentration of suspended fine excavated rock material for the duration of the placement activities and beyond the date that placement is deemed complete.

The initial elutriate test was undertaken to represent a potential worst case scenario for immediate water quality impacts, with waters containing high concentrations of fine solids (100 g/L). The mixing of <75-µm rock composites with Talbingo Reservoir water at L/S=10 (100 g/L) resulted in the pH and conductivity increasing considerably, e.g. from approximately pH 7 to 9.5 and 30 to 150 µS/cm. There were no significant increases in nitrate concentrations and small and variable increases in total-P concentrations. When mixed at liquid/solid ratios (L/S) of 10, the concentrations of As, Cr and, in particular, the dissolved Al concentration increased to levels that exceeded water quality GVs (default GV, DGVs). Al was identified as the most significant COPC, and the waters from tests with L/S=10 would be predicted to cause toxicity to a range of aquatic organisms.

As increases in water pH, conductivity and dissolved Al were identified as the primary SOPCs concern, these were the focus of the subsequent tests. The test gathered data on other potential COPCs, but the different test conditions did not reveal any additional stressors. Increases in alkalinity due to the presence of fine rock materials within the waters (from 14 to 25 mg $CaCO_3$/L at L/S=500) were generally modest and considered unlikely to result in impacts to aquatic organisms. The major ions contributing to the increased conductivity were primarily K and Ca, with lesser contributions from Na and Mg.

<u>Comparison of Talbingo and Tantangara Reservoir elutriate tests</u>

Comparison of elutriate tests performed in Tantangara and Talbingo Reservoir waters indicated that the elutriate water pH was similar in each water for the 300-L/S tests, but lower in Tantangara Reservoir treatments for the 1000-L/S_18-h tests, probably due to this water having a greater ability to buffer pH increases. The conductivities were generally in a similar range for the two reservoir waters except for a few Tantangara Reservoir treatments having higher values.

The concentration of dissolved Al was in the range 23.5-216 µg/L in the Tantangara Reservoir elutriate treatments, which was in a similar range to corresponding Talbingo Reservoir treatments. Small differences were observed for corresponding treatments, with the Talbingo elutriate treatments having higher concentrations than the Tantangara treatments for the 1000-L/S_18-h tests, and the Tantangara elutriate treatments having higher concentrations than the Talbingo treatments for the 300-L/S_3-h and 300-L/S_18-h tests. The concentration of dissolved Al in the 1000-L/S Tantangara Reservoir water treatments was below the DGV of 55 µg/L for the 1000-L/S treatments, and exceeded the DGV for the 300-L/S treatments.

<u>Influence of concentration of rock in waters</u>

The concentrations of fine solids in the reservoir waters will be influenced by the properties of the rock (e.g. density, particle size) and the water conditions and the placement procedure. The concentrations of rock materials are anticipated to be greater in deeper waters and should decrease with increasing distance from the placement site as fine particles disperse and become diluted with reservoir water (L/S lower in deeper waters and closer to the placement area).

The <75-µm rock composites were mixed with Talbingo Reservoir water at L/S= 30, 300, 1000, 3000 [33, 3.3, 1 and 0.33 g/L] and monitored for 5 days. The water pH and conductivity increased significantly with increasing amount of fine solids (lower L/S), and generally pH >9 when L/S ≥300 and conductivity >60 µS/cm when L/S ≥1000. The DGV for dissolved Al (DGV-dAl) was exceeded at L/S ≤1000 (≥1 g/L solids, 1 part per thousand) after durations of 18 h, and were exceeded within 0.5 h at a L/S=30. Dissolved concentrations of other metals or metalloids (including As and Cr) should not exceed DGVs when reservoir waters contain <33 g/L fine rock (L/S>30). The total-P concentrations were <10 µg/L when the reservoir waters contained <3.3 g/L fine rock materials.

<u>Influence of water-rock mixing duration</u>

The duration the rock solids will remain suspended in the water column before depositing as sediments will be influenced by the properties of the rock (e.g. density, particle size) and the water conditions (movement) and the placement procedure. Some portion of the fine rock particles may potentially disperse beyond the target placement area and the release of substances from the solids may continue during this process.

Measurements of changes in water quality made over 5 days mixing of the <75-µm rock composites and Talbingo Reservoir water indicated that increased dissolution of rock solids occurs with increased mixing duration. Increases in dissolved Al were consistent with the higher pH (9.1-9.7 range) acting to increase dissolution through formation of the highly soluble aluminate ion, $Al(OH)_4^-$.

Over longer durations (56 days) of suspension of <75-µm rock composites in Talbingo Reservoir water the pH decreased to a plateau within the range of pH 7.7-8.2, while the conductivity continued to increase (400-600 µS/cm range). Dissolved Al concentrations generally increased during the first 1-2 weeks then decreased, and indicated potential removal of dissolved Al due to changes in speciation, decreased solubility with decreasing pH, and/or increased adsorption. At the warmer water temperature of 21 °C, the Al DGV was exceeded by a factor of 2-5 for the entire 56 day duration for both rock composites at L/S=300, and by a factor of 1-3 for the entire 56 d duration at L/S=1000, except the initial 18 h duration for 1B. At 6 °C, the dissolved Al marginally exceeded the DGV in the mid-duration subsamples of each treatment except the 1000 L/S, 1B treatment, where the DGV was never exceeded. Total-P concentrations remained below the DGV of 10 µg/L over the 56 day period.

Effect of rock particle size in on substance release

The size of the excavated rock material is expected to range from boulder to clay size. The vast majority of the excavated rock, by mass, will be larger than sand size and should settle rapidly. Rock materials with a smaller particle size are expected to represent the greatest environmental risk with respect to transport and release of substances. The release of substances was characterised for excavated rock materials of seven size categories ranging from 1-2.5 cm to <0.00063 cm (<63 µm) diameter. Key observations were that substance release is low, trends towards negligible, for rock materials >2 mm. Based on dissolved Al concentrations, the finer <0.21 mm rock fraction is likely to have an impact on water quality that is an order of magnitude greater than that of rock fractions >2 mm in size. For the <210 µm rock sizes, pH, conductivity and dissolved Al concentrations decrease as size categories increased <63 to <63-150 to 150-210 µm. Dissolved As and/or Cr concentrations frequently exceeded the DGVs in tests with L/S = 25 (40 g/L)

Effect of water temperature on substance release

Substance release from solids to waters is usually greater at higher temperatures, and warmer water conditions of 21°C were used in most tests to provide a worst-case scenario for substance release. The temperature of the reservoirs varies between approximately 6 and 21°C, with significant changes over depth and season. Test revealed that the release of Al occurs significantly more slowly in the 6°C treatments than the 21°C treatments, resulting in fewer elutriate waters having dissolved Al concentrations that exceed the DGV.

Effect of repeat leaching on substance release

Greater release of substances may occur from the fine rock materials if they remain in the water column within the placement area or as they disperse away from the placement area. To assist in predictions of long-term leaching, a series of repeat/successive leach tests were performed on the same rock materials. The successive leaches indicated that the Al available for release into solution was not quickly exhausted. Many treatments had similar or increased Al concentrations in the second and third successive leaches. The results suggest a dissolution process is responsible for the release of Al, which is dependent on the duration of contact with water and the temperature. Longer durations of physical mixing also generally increased the release of dissolved Al.

Release of dissolved or colloidal forms of Al

A significant portion of Al is often found to exist in colloidal forms in natural waters, and these forms are often predicted to be less bioavailable than truly dissolved forms. It is well recognised that the filtration of waters through a 0.45 µm filter (i.e. the standard filter size) does not completely separate dissolved and colloidal forms of metals. Filtration through 0.45 µm (dissolved and colloidal substances) and 0.003 µm (truly dissolved) membranes was used to distinguish dissolved and colloidal substances. For the <75 µm composite rock elutriate waters, the concentration of dissolved Al measured in subsamples filtered through the two filter sizes was similar, indicating that the <0.45 µm filterable water fraction contains predominantly dissolved (<0.003 µm), rather than colloidal forms of Al. This is consistent with the dominant Al species (ion) being the aluminate ion ($Al(OH)_4^-$).

Effect of resuspended sediment in attenuation of substances released from rock materials

Benthic sediments may be resuspended during and following the placement of excavated rock materials in the reservoirs. Tests were undertaken to characterise how sediment resuspension may influence dissolved Al concentrations released from rock materials. The pH and conductivity of the elutriate waters decreased with increasing amounts of resuspended sediment. Dissolved Al concentrations decreased in tests with 2 g/L resuspended sediments. At 20 g/L sediment loads the pH decreased to 6.5 and Al concentrations varied greatly between sediments, with several treatments increasing 50-100 µg/L compared to treatments with no sediment. Contributions of colloidal Al forms from the sediment were considered the likely cause of the increased Al concentrations at this pH. When sediments were deposited there was less Al released, indicating that the mixing of sediments increases the release of Al. The dissolved Al also decreased over time in the attenuation test using deposited sediment. In the attenuation test with low (1, 5, 25 mg/L TSS) of resuspended sediment concentrations, there was little attenuation. The water pH is likely to influence the magnitude of attenuation, with water pH 6-8 facilitating greater attenuation via adsorption of Al to sediment binding sites than water with a higher pH>8. The overall finding of the attenuation tests was that sediments may both release substances and adsorb substances that have been release from the rock materials, with the resuspended sediment concentration and duration of resuspension influencing whether they will act as a sink or a source.

Substance Release resulting in Contaminants of Potential Concern

Based on the collective elutriate test results (broad range of conditions-scenarios), the following observations are made with regards to substance release from the excavated rock materials that may result in potentially adverse changes to water quality and/or COPCs being present in the reservoir waters:

- Increases in water pH and conductivity are expected due to rapid release of ions that occur via ion exchange reactions.
    - Water pH was generally pH >9 when L/S ≥300 (3.3 g fine solids/L)
    - Conductivity was generally >60 µS/cm when L/S ≥1000 (1 g fine solids/L).
    - Over a duration of multiple days/weeks the water pH may decrease back to close to that of the original reservoir water as equilibration reactions proceed.
- Al is the only substance consistently identified as a COPC.
    - Sustained release of Al may occur from excavated rock dissolution processes.
    - The rate of Al release may result in dissolved Al concentrations that exceed the default water quality guideline value of 55 µg/L (DGV-dAl).
    - Al release is predicted to be negligible for rock materials >2 mm in size, and the rate of Al release may increase proportionally with decreasing particle size <210 µm (equivalent mass of rock).
    - Al release is markedly lower in waters with temperature of 6°C than at 21°C. The DGV-dAl should not be exceeded when waters at 6°C contain less than 1 g/L of fine excavated rock materials (<0.21 mm particle size)
- When predicting the risks posed by dissolved Al released from the excavated rock materials, particular consideration should be given to the concentration of rock materials that are <210 µm in size, duration within the water column, and water temperature.

- The resuspension of sediments is expected to cause the pH to drop, and potentially result in an increase in the concentration of colloidal Al, through release from the sediments and precipitation and/or adsorption of dissolved Al that had been released from waste rock materials.
- Other potential COPCs
    - Dissolved As and/or Cr concentrations frequently exceeded the DGVs of 13 µg As(V)/L and 1.0 µg/L Cr(VI)/L in elutriates of some rock materials tested with L/S ≤30 (≥33 g/L), including those with larger rock fractions over longer durations.
    - Total-P and nitrate concentrations should not be released at such high rates that they adversely impact water quality. However we cannot discard possible scenarios where concentrations of these substances reach elevated levels if waste rock placement creates regions of shallow waters that do not adequately mix with the greater reservoir.

Overall, Assignment P4 has identified changes in water pH, conductivity and dissolved Al as the primary SOPCs, and that adverse impacts from these SOPCs are predicted when the water contains greater concentrations of the fine excavated rock materials for long durations.

5 Discussion

The tests described in this report were undertaken to provide information to assist in assessing the potential impacts of the placement of excavated rock materials on water and sediment quality within the reservoirs.

The DGV for Al (55 µg/L, applied to water pH >6.5) is classified as moderate reliability (ANZG, 2018). The USEPA uses chronic criterion of 87 µg/L, that is based on no-effect concentrations from a 60-d brook trout study and a 7-d striped bass study (USEPA, 1988). The risk of adverse effects to aquatic organisms from elevated dissolved Al concentrations is influenced by its bioavailability, as well as the exposure paths and sensitivity of the organisms (Gensemer and Playle, 1999). The bioavailability of Al is influence by its speciation, forms of Al that change with pH, complexation with natural organic matter, and also be concentrations of competing ions (e.g. Ca^{2+}, Mg^{2+} - hardness) (Gensemer et al., 2018; Campbell, 1994; Paquin et al., 2002). Based on a review of Al toxicity for freshwater organisms and accompanying data relating to speciation/bioavailability by DeForest et al. (2018), there may be data available that is suitable for developing a site-specific guideline value for dissolved Al that is more appropriate for the assessment of risks of toxicity within the reservoir waters.

There is no DGV for conductivity, however an increasing number of studies indicate that even relatively small increases in water conductivity may impact some freshwater aquatic organisms (Cormier et al., 2011; Cormier et al., 2018; Kefford, 2018). The species present in many freshwater environments may exhibit a wide range of sensitivities to conductivity, and the literature generally indicates that waters with conductivities greater than 300 µS/cm frequently cause adverse effects to a significant number of species, and particularly mayflies.

One of the challenges of using data from the laboratory tests is that the particle size distribution may differ between the laboratory and field. Milled rock materials were used in most tests in this laboratory study, and approximately 50% of the rock particles had size <20 µm (medium silt) and little less than 10% being <2 µm (clay). Excavated rock disposed into reservoirs in the field may have substantially different size distribution. The results from the current study indicate the material with size of medium silt or smaller (<210 µm size fraction in the present study) will be the most important, with the smaller size fractions predicted to release greater amounts of substances into the water (in proportion to mass of the size fraction). The rock fractions ranging in size from fine silt (2-6.3 µm) and clay (<2 µm) may remain entrained in the reservoir waters for months to years, while larger sized material will settle to form sediment more quickly (e.g. minutes to days). Consideration of the proportion of fine silt and clay in the excavated rock relative to the milled rock used in the tests may be important when extrapolating the results from this study to predict substance release from the rock material entrained in reservoir waters during disposal operations. No tests were undertaken on milled rock separated into fractions smaller than <63 µm (coarse silt).

Another difficulty in making predictions of substance release in the field using laboratory test data is that turbidity plumes of disposed rock material fines will comprise a continuous spectrum of material from freshly added to that suspended for days to weeks. Substances released from materials will undergo dilution by reservoir water. Results from this study indicate dissolution will continue over time, so the concentrations of dissolved substances in water such as Al will be controlled by competing processes of dissolution and dilution. Another factor to consider is the pH and how it effects substances release i.e. greater release of Al for higher pH. The pH increases were driven by ion exchange reactions that occurred rapidly. If the disposal results in great enough concentrations of freshly added fine material being resuspended, the pH may remain as high, or potentially higher, than values measured in this study, which could result in higher concentrations of Al being released from rock material than measured in this study.

Laboratory-based testing programs can be used to simulate processes that may be expected to occur in the field, but cannot match field conditions. Consequently, validation of the observations from this testing program using field tests and measurements is recommended, particularly should the opportunity for a field trial of rock placement occur. Based on the results of this study, we would expect field monitoring to include continuous monitoring of general water quality parameters such as pH, conductivity, temperature and turbidity, and in situ monitoring of dissolved Al to provide time-average concentrations that can be better compared to water quality guidelines when assessing risks.

The technique used for the placement of the excavated rock materials is expected to strongly influence the extent of the potential impacts. The placement scenario considered in the conceptual site model (CSM) (Appendix A), placement of excavated rock material was envisaged to occur into relative deep waters within the reservoirs (e.g. >10 m), possible via dumping from hopper barges that results in rock material dropping through the water column with the intent of depositing below within a specific placement area and remaining at depth (<3 m). During the period of the project, discussions with HKA/SHL (phone conversation with Greg Britton, and during meetings at CSIRO) considered possible changes to the CSM. Based on early results, the possible benefits of using a fall-pipe to release the materials not far above the sediments were discussed. The possible benefits would include minimising surface and subsurface plumes of fine materials within the upper waters than may be more difficult to contain within the target placement area, and also the lower temperatures of the deeper waters reducing dissolved Al release from fine solids.

Later in the project, the possibility was raised of shoreline disposal that created areas that may become beaches, or inter-shoreline zones that may cycle from being above and below the water shoreline as the water intake and outflow processes occur for the Snowy Hydro-electric operation. This scenario was not part of the CSM used in the design tests used in Assignment P4, and tests were not undertaken to assess substance release from the excavated rock materials for this scenario. For inter-shoreline zones of excavated rock material, the assessment would benefit from testing the effect of ‘inundation and draining, and ‘wetting and drying’, that were not evaluated in Assignment P4. Shoreline environments may be occupied by a great range of benthic and aquatic species (fauna and flora), including microalgae that may be stimulated if nutrient releases occur in shallow waters that are not diluted within the broader reservoir environment. The sequential leaching of rock materials within shallow near-shore water environments may also occur with waters that may have already been impacted by previous water-rock interactions, and potentially resulting in successively larger changes in water quality (e.g. higher pH, conductivity and dissolved Al concentrations and possibly other COPCs such as As) than were simulated in the present project (CSM based on placement in deeper waters with dilution and successive leaching with fresh reservoir water).

During the reporting stage of the project, other shoreline placement scenarios were raised in discussions (primarily internal to CSIRO), and included a scenario where placement of excavated rock may be proposed to occur via side-casting from the reservoir bank, and building outwards either new landforms (higher land, beaches or structures extending into the reservoirs such as breakwalls closer to the Snowy 2.0 outfall). Assignment P4 did not undertake tests to evaluate longer-term substance release for side-casting placement scenarios.

Owing to the short timeframe of Assignment P4, a range of possible longer-term tests were not undertaken. Owing to the size of Snowy 2.0, it is envisaged that the excavated rock placement activities may need to occur over a period of several months to years. Assignment P4 primarily assessed placement of rock in new reservoir water, and the concentrations of substances in waters may become significantly higher if the waters in which placement occurs already contain elevated concentrations of fine rock materials and are already impacted by previous cycles of rock placement that have resulted in elevated pH, conductivity and COPCs. The finest fractions of the excavated rock material (e.g. clay to fine silt size) may remain in the water column for months to years. Assignment P4 did not undertake tests to assess such long-term substance release and impacts to water quality.

5.1 Recommendations

The tests undertaken identified changes in water pH, conductivity and dissolved Al as the primary SOPCs, and that adverse impacts from these SOPCs are predicted in reservoir waters containing higher concentrations of the fine excavated rock materials for prolonged durations. The technique used for the placement of the excavated rock materials is expected to strongly influence the concentrations of fine rock materials within the water column and the extent of substance release. Based on the result of Assignment P4 (Summarised in Section 4) and Discussion (Section 5), recommendations are provided below to fill knowledge gaps that have been identified during the course of this project.

Subject to confirmation of the disposal method and particle size distribution of the excavated rock, the following testing is recommended to fill knowledge gaps:

1. Testing of the longer-term release of substances from the clay to fine silt sized (<2 µm to 6.3 µm) excavated rock materials that are predicted to remain suspended within the reservoir water for periods of many months;
2. Testing of the effects of cycling water exposure to excavated rock materials, representing inundation/draining, and wetting/drying that may occur at shorelines;
3. Testing of longer term effects of water pH on attenuation of dissolved Al release, including potential cycling from dissolved and precipitated forms if pH cycles up and own, and
4. Field trials of rock placement scenarios that may be used, potentially including:
    - placement within deeper waters using a form of fall pipe (expected to minimize duration of high concentrations of fine rock in water column);
    - placement into surface water to deposit through the water column (potentially resulting in elevated concentrations of fine rock in surface waters, and subsurface plumes dispersing);
    - placement from shoreline (fine rock dispersion dependent on method, but subject to surface water cycling processes).

As noted in the discussion, field monitoring should include continuous monitoring of general water quality parameters such as pH, conductivity, temperature and turbidity, and in situ monitoring of dissolved Al to provide time-average concentrations that can be better compared to water quality guidelines when assessing risks.

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Glossary

Alkaline: Description of a substance with a pH greater than 7 when dissolved in or mixed with water.

Anaerobic: Lacking in oxygen.

Anoxic: An environment where oxygen is intrinsically rare or absent.

ANZECC/ARMCANZ: Australian and New Zealand Environment and Conservation Council/Agriculture and Resource Management Council of Australia and New Zealand.

Aquatic environment: The geochemical environment in which dredged material is submerged under water and remains water saturated after disposal is completed.

Aqueous: Composed of or pertaining to water.

Attenuation: A reduction in concentration of a contaminant with increasing distance from the source. Attenuation is specifically used in this document to describe reductions in leachate concentrations as a result of mixing with groundwater, adsorption of contaminants in foundation soils, degradation, volatilisation, and precipitation.

Background: Environmental conditions that commonly occur, or concentration of a substance (ASS or contaminant) that is commonly found, in the local concentration environment at the site being considered.

Buffering capacity: The ability of a mixture or solution to resist pH change – in an ASS context, this may refer to surface or groundwaters, or to the soil solution, or to the soil itself.

COC: Contaminant of concern.

Constituent of potential concern (COPC): A chemical species of interest, which may or may not be regulated, but may be characteristic of release-controlling properties of the sample geochemistry.

Contaminants: Biological or chemical substances or entities, not normally present in a system, capable of producing an adverse effect in a biological system, seriously injuring structure or function

Contaminated: A material (e.g. water or solid) containing chemical substances at concentrations above background concentrations and above the guideline values.

Control: Part of an experimental procedure that is ideally exactly like the treated part except that it is not subject to the test conditions. It is used as a standard of comparison, to check that the outcome of the experiment is a reflection of the test conditions and not of some unknown general factor.

COPC: Contaminant of potential concern.

Detection limit: Method detection limit is the concentration of a substance which, when processed through the complete analytical method, produces a signal that has a 99% probability of being different from the blank.

DGV: Default guideline value; usually the 95% species protection guideline value.

Diffusion: The transport of contaminants by random molecular motion and turbulence, usually from an area of high concentration to an area of low concentration.

Dissolution: In chemistry, the process by which a solid material forms a homogenous mixture with a solvent.

Dissolved solids: The weight of matter, including both organic and inorganic matter, in solution in a stated volume of water. The amount of dissolved solids is usually determined by filtering water through a glass or 0.45 µm pore-diameter micrometer filter, weighing the filtrate residue remaining after the evaporation of the water, and drying the salts to constant weight at 180°C.

DO: Dissolved oxygen.

DOC: Dissolved organic carbon.

Dry-mass equivalent: The mass of “as-tested” (i.e., “wet”) sample that equates to the mass of dry solids plus associated moisture, based on the moisture content of the “as- tested” material. The dry-mass equivalent is typically expressed in mass units of the “as-tested” sample (g).

Effluent: A material, usually a liquid waste, that is emitted by a source.

Eh: Redox potential.

Eluate: The solution collected as an extract from a leaching test that contains the eluent plus constituents leached from the solid phase2.

Eluent: The solution used to contact the solid material in a leaching test. The eluent is usually free of COPCs but may contain other species used to control the test conditions of the extraction.

Guideline framework: Narrative statement to support and maintain a designated water use.

Guideline value: Numerical concentration used to assist in identifying risks of adverse effects of water use.

Hydrolysis: The process of splitting the water molecule into separate components of hydrogen ions (H+) and hydroxide ions (OH-) that often react with other constituents present.

Impact: Environmental change (usually biological) that has occurred as a result of dredging activity. The extent of the change may be considered unacceptable and may require some intervention by regulatory authorities.

Leachate: Water or any other liquid that may contain dissolved (leached) soluble materials, such as organic salts and mineral salts, derived from a solid material.

Level of protection: The acceptable level of change from a defined reference condition.

Liquid-solid partitioning (LSP): The distribution of COPCs between the solid and liquid phases at the conclusion of the extraction.

Liquid-to-solid ratio (L/S): The fraction of the total liquid volume (including the moisture contained in the “as used” solid sample) to the dry mass equivalent of the solid material. L/S is typically expressed in volume units of liquid per dry mass of solid material (mL/g-dry).

Measurement parameter: Any parameter or variable that is measured to find something out about an environment or ecosystem.

Organism: Any living animal or plant; anything capable of carrying on life processes.

Overlying water: The water above the sediment at a collection site or in a test chamber.

pH: The intensity of the acidic or basic character of a solution, defined as the negative logarithm of the hydrogen ion concentration of a solution. Used as a measure of the acidity of alkalinity of a soil of water body on a logarithmic scale of 0 to 14; a pH <7 is acid, pH 7 is neutral, and pH >7 is alkaline. Note that one unit change in pH is a ten-fold change in acidity.

Phase: Distinct state of matter (solid, liquid or gas) which in aquatic systems comprises sediment, water and air.

Pore water: The water that occupies the space between and surrounding individual sediment particles in an aquatic sediment (often called interstitial water).

QA/QC: Quality assurance/quality control.

Quality assurance (QA): The implementation of checks on the success of quality control (e.g. replicate samples, analysis of samples of known concentration).

Quality control (QC): The implementation of procedures to maximise the integrity of monitoring data (e.g. cleaning procedures, contamination avoidance, sample preservation methods).

Redox potential: A measure of the oxidation–reduction potential (ORP) of sediments. The redox potential is often reported as Eh (versus the normal hydrogen electrode).

Redox: Simultaneous (chemical) reduction and oxidation; reduction is the transfer of electrons to an atom or molecule, whereas oxidation is the removal of electrons from an atom or molecule.

Release: The dissolution or partitioning of a constituent of potential concern (COPC) from the solid phase to the aqueous phase during laboratory testing (or under field conditions). In this method, mass release is expressed in units of mg COPC/kg dry solid material.

Risk: A statistical concept defined as the expected frequency or probability of undesirable effects resulting from a specified exposure to known or potential environmental concentrations of a material, organism or condition. A material is considered safe if the risks associated with its exposure are judged to be acceptable. Estimates of risk may be expressed in absolute or relative terms. Absolute risk is the excess risk due to exposure. Relative risk is the ratio of the risk in the exposed population to the risk in the unexposed population.

Salinity: The presence of soluble salts in water or soils.

Soil and sediment: The natural accumulation of unconsolidated mineral particles (derived from weathered rocks) and organic matter that covers much of the earth’s surface. The chemical and physical composition varies greatly between soil and sediment types.

Solubility: In chemistry, how easily a substance will dissolve into a homogeneous solution, and also how much of a substance can dissolve into a solvent before saturation is reached. Solubility in water is the most common measurement, and the most relevant to ASS management.

Speciation: Measurement of different chemical forms or species of an element in a solution or solid.

Species: Generally regarded as a group of organisms that resemble each other to a greater degree than members of other groups and that form a reproductively isolated group that will not normally breed with members of another group. (Chemical species are differing compounds of an element.).

Stressors: The physical, chemical or biological factors that can cause an adverse effect on an aquatic ecosystem as measured by the condition indicators.

TOC: Total organic carbon.

Toxicant: A chemical capable of producing an adverse response (effect) in a biological system, seriously injuring structure or function or producing death. Examples include pesticides, heavy metals and biotoxins.

Toxicity: The inherent potential or capacity of a material to cause adverse effects in a living organism.

WQGV: Water quality guideline value. Includes the DVG = default guideline value, representing the 95% species protection guideline values (95%GV). 99% species protection guideline values (99%GV).

Appendix A - Conceptual models [4 pages]

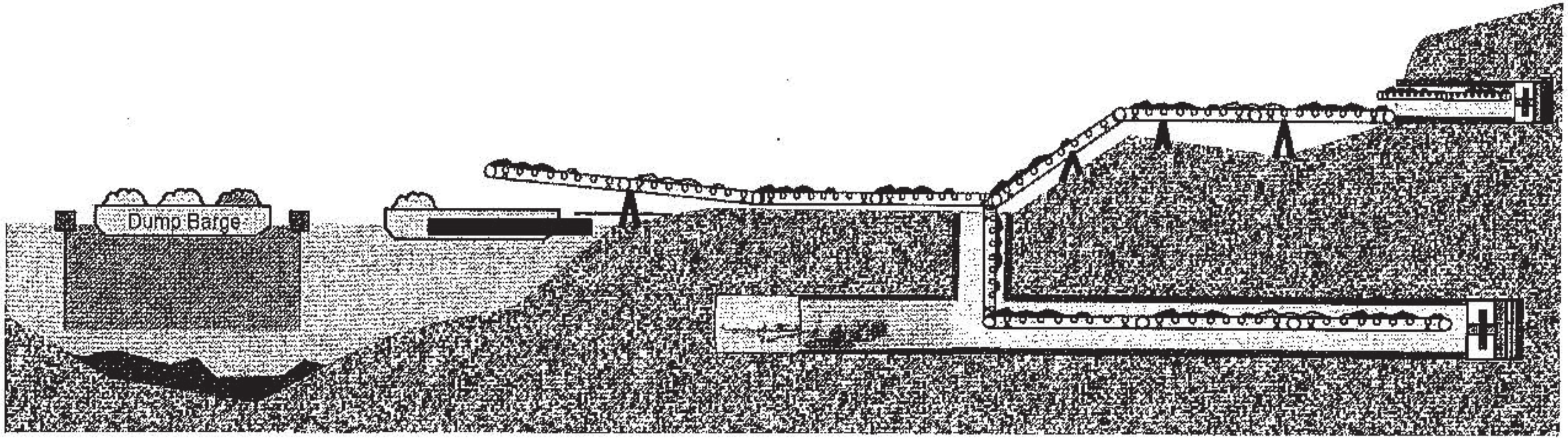

Figure A1. Depiction of excavated rosk placement by hopper barge (provided by EMM in early discussions (December 2017)

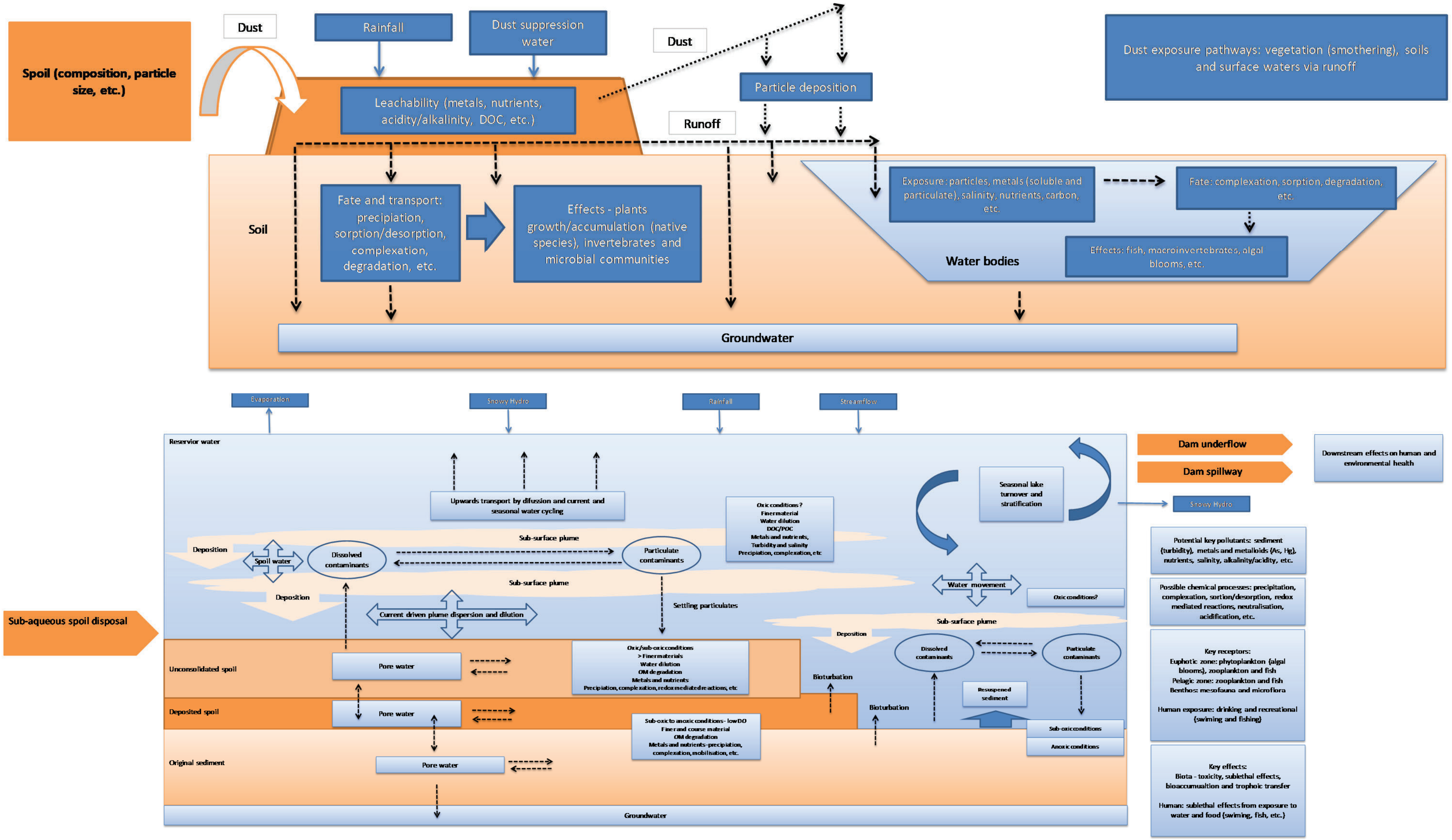

Figure A2. Conceptual Site Model – Outline of pressure-stressor-receptor pathways and connections (EMM and CSIRO in December 2017)

Table A1. Outline of pressure-stressor-receptor pathways and connections (EMM and CSIRO in December 2017)

Pathway	Natural	Extreme natural events	Spoil discharge (acute)	Spoil discharge (chronic)
Physical paths				
Lake water movement - general	Yes	Yes	Yes	Yes
Lake water movement - vertical mixing	Yes	Yes	Yes	Yes
Lake water movement - storm mixing	?	?	?	?
Rainfall	Yes	Yes	Yes	Yes
Evaporation	Yes	Yes	Yes	Yes
Stream flow - water	Yes	Yes	Yes	Yes
Stream flow - sediments	Yes	Yes	Yes	Yes
Snowy Hydro - water release to lake	Yes	Yes	Yes	Yes
Snowy Hydro - water take	Yes	Yes	Yes	Yes
Dam underflow	Yes	Yes	Yes	Yes
Dam spillway	No	Yes	?	?
Release of spoil water	No	No	Yes	No
Particle settling of natural particles	Yes	Yes	Yes	Yes
Particle settling of suspended/resuspended spoil	No	No	Yes	Yes
Particle settling - initial spoil deposition	No	No	Yes	No
Particle resuspension due to water movement	?	?	?	?
Sediment resuspension due to spoil addition	No	?	Yes	Yes
Surface plume formation	?	?	?	?
Sub-surface plume formation	?	?	?	?
Water 'ejected' during spoil consolidation	No	No	Yes	No
Smothering of benthos	No	?	?	No
Bioturbation	Yes	-	-	?
Slumping	?	?	?	?
Chemical paths				
Adsorption of contaminants in lake water onto suspended particles	Yes	Yes	Yes	Yes
Desorbtion of contaminants from suspended particles	Yes	Yes	Yes	Yes
Adsorption of contaminants from lake water onto spoil particles	No	No	Yes	Yes
Desorbtion of contaminants from spoil particles	No	No	Yes	Yes
Diffusion of contaminants from pore water to water column	Yes	Yes	Yes	Yes
Adsorption of contaminants in pore water onto natural sediment particles	Yes	Yes	Yes	Yes
Desorbtion of contaminants from natural sediment particles to pore water	Yes	Yes	Yes	Yes
Adsorption of contaminants in pore water onto spoil particles	No	No	Yes	Yes
Desorbtion of contaminants from spoil particles to pore water	No	No	Yes	Yes
Redox mediated chemical pathways (oxic, sub-oxic and anoxic conditions - spoil and sediments)	No	?	Yes	Yes
Biological paths				
Ingestion of suspended particulates	Yes	Yes	Yes	Yes
Ingestion of sediment particles on lake bed	Yes	Yes	Yes	Yes
Uptake of dissolved contaminants in water column	Yes	Yes	Yes	Yes
Uptake of dissolved contaminants in pore water	Yes	Yes	Yes	Yes
Ingestion of nekton	Yes	Yes	Yes	Yes
Ingestion of benthos	Yes	Yes	Yes	Yes
Human ingestion of fish	Yes	Yes	Yes	Yes
Human recreational contact	Yes	Yes	Yes	Yes

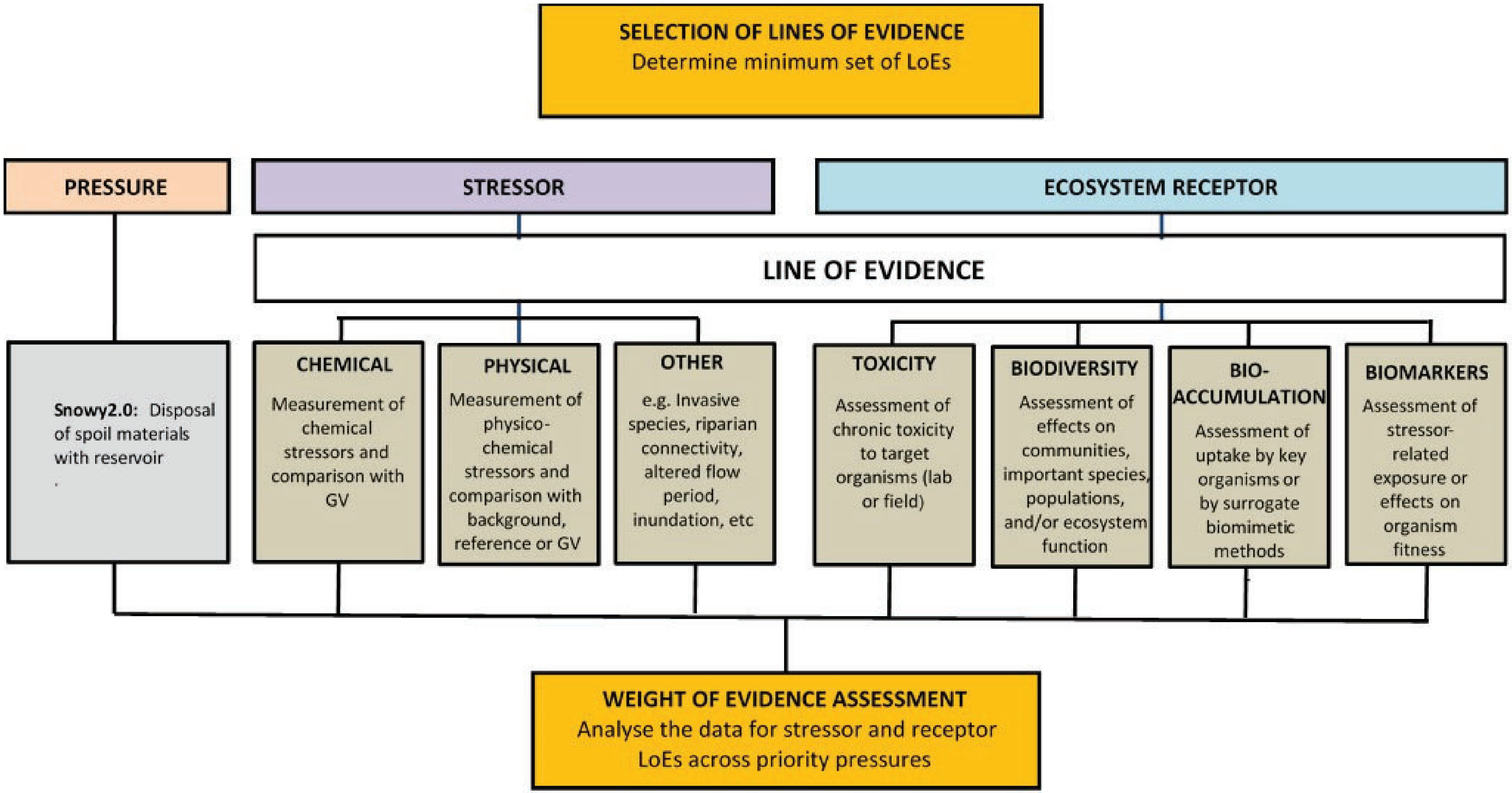

Figure A3. Selection of Lines of Evidence (LoE) in a pressure, stressor, ecosystem receptor within Weight of Evidence (WoE) Assessment framework

Appendix B - Test samples [14 pages]

- Water, Rock and Sediment Materials used in the study.

Table B1. Excavated rock materials - Ravine

Sample_ID	Depth (m) Top	Depth (m) Bottom	Lithology	Major Geology (Surface)/ Zone	Placement Option	Classification
Ravine – Baseline						
BH6105-R-0063	160.57	161.00	Siltstone with a sandstone band	Yarrangobilly Limestone/Palaeozoic	Talbingo	Tunnel/surge shaft/powerhouse
BH4105-R-0362	200.7	201	Phyllite	Ravine bed	Talbingo	Tunnel/surge shaft/powerhouse
BH6105-R-0061	177.00	177.26	Siltstone with a chert band	Yarrangobilly Limestone/Palaeozoic	Talbingo	Tunnel/surge shaft/powerhouse
BH4105-R-0356	18.1	18.5	Siltstone	Ravine bed	Talbingo	Tunnel/surge shaft/powerhouse
BH4104-R-0291	376.61	377	Siltstone	Yarrangobilly Limestone/Palaeozoic	Talbingo	Tunnel/surge shaft/powerhouse
BH4105-R-0363	225.7	226	Interbedded phyllite/schist	Ravine bed	Talbingo	Tunnel/surge shaft/powerhouse
BH7105-R-0036	49.00	49.30	Siltstone	Yarrangobilly Limestone/Palaeozoic	Talbingo	Tunnel/surge shaft/powerhouse
BH6105-R-0060	*147.00*	*147.33*	*Siltstone*	*Yarrangobilly Limestone/Palaeozoic*	*Talbingo*	Tunnel/surge shaft/powerhouse
Ravine – Enriched						
BH6102-R-0045	162.00	162.15	Interbedded siltstone/sandstone	Yarrangobilly Limestone/Palaeozoic	Talbingo	Tunnel/surge shaft/powerhouse
BH7105-R-0039	15.00	15.30	Siltstone	Yarrangobilly Limestone/Palaeozoic	Talbingo	Tunnel/surge shaft/powerhouse
BH7105-R-0396	23	23.25	Siltstone	Ravine bed	Talbingo	Tunnel/surge shaft/powerhouse
BH4104-R-0294	871.56	871.82	Siltstone	Yarrangobilly Limestone/Palaeozoic	Talbingo	Tunnel/surge shaft/powerhouse
BH4105-R-0371	445.7	446	Interbedded phyllite/gneiss	Ravine bed	Talbingo	Tunnel/surge shaft/powerhouse
BH6101-R-0226	161	161.3	Sandstone/Siltstone	Yarrangobilly Limestone/Palaeozoic	Talbingo	Tunnel/surge shaft/powerhouse
BH7105-R-0038	*25.60*	*26.00*	*Conglomerate*	*Yarrangobilly Limestone/Palaeozoic*	*Talbingo*	Tunnel/surge shaft/powerhouse

Table B2. Excavated rock - Byron/Boraig and Shaw Hill Gabbro

	Depth (m)					
Sample_ID	Top	Bottom	Lithology	Major Geology (Surface)/ Zone	Placement Option	Classification
Byron/Boraig – Baseline						
BH5104-R-0122	472	472.3	Sandstone	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH5104-R-0133	727.63	727.83	Sandstone	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH5101-R-0055	*283.73*	*283.87*	*Siltstone*	*Yarrangobilly Limestone/Palaeozoic*	*Talbingo*	Top of surge shaft
BH5104-R-0116	282.53	282.8	Felsic ignimbrite	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH5105-R-0143	36	36	Sandstone	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH5104-R-0120	409	409.3	Conglomerate/sandstone	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH5104-R-0108	119.4	119.75	Mudstone	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
Byron/Boraig - Enriched						
BH5104-R-0138	822.7	823	Siltstone	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH5104-R-0114	239.15	239.4	Sandstone	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH5104-R-0109	131.1	131.35	Mudstone	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH5104-R-0113	227.4	227.67	Conglomerate	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH8106-R-0406	640.7	641	Interbedded sandstone/siltstone	Byron range group/ravine bed	Talbingo	Top of surge shaft
BH5104-R-0110	142.17	142.43	Conglomerate	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH5115-R-0388	261.35	261.6		Byron range group/boraig group/ravine bed	Talbingo	Top of surge shaft
Shaw Hill Gabbro - Baseline						
Sample_ID	**Top**	**Bottom**	**Lithology**	**Major Geology (Surface)/ Zone**	**Placement Option**	**Classification**
BH4106-R-0270	96.75	97	Schist	Shaw Hill Gabbro	Talbingo	Tunnel alignment/headrace
BH4106-R-0271	124.75	125	Schist	Shaw Hill Gabbro	Talbingo	Tunnel alignment/headrace
BH4106-R-0272	162	162.2	Schist	Shaw Hill Gabbro	Talbingo	Tunnel alignment/headrace
BH4106-R-0281	76.71	77	Schist	Shaw Hill Gabbro	Talbingo	Tunnel alignment/headrace
Shaw Hill Gabbro - Enriched						
BH4106-R-0273	198.1	198.4	Diorite	Shaw Hill Gabbro	Talbingo	Tunnel alignment/headrace
BH4106-R-0274	230.37	230.78	Diorite	Shaw Hill Gabbro	Talbingo	Tunnel alignment/headrace
BH4106-R-0276	312.42	312.72	Diorite	Shaw Hill Gabbro	Talbingo	Tunnel alignment/headrace
BH4106-R-0278	383.15	383.5	Diorite	Shaw Hill Gabbro	Talbingo	Tunnel alignment/headrace

Table B3. Excavated rock - Gooandra Volcanics

Sample_ID	Depth (m) Top	Bottom	Lithology	Major Geology (Surface)/ Zone	Placement Option	Classification
Gooandra Volcanics - Baseline						
BH4103-R-0001	360.30	360.60	Greenschist	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
BH4103-R-0003	*76.40*	*76.60*	*Schist*	*Gooandra Volcanics*	*Talbingo*	Tunnel alignment/headrace
BH4103-R-0011	325.00	325.40	Metasiltstone	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
BH4103-R-0012	246.16	246.56	Metasiltstone	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
BH4103-R-0014	173.62	173.90	Greenschist	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
BH4103-R-0018	*155.20*	*155.47*	*Greenschist*	*Gooandra Volcanics*	*Talbingo*	Tunnel alignment/headrace
BH4103-R-0019	318.15	318.47	Metasiltstone	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
BH4102-R-0312	472.25	472.55	Schist	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
Gooandra Volcanics - Enriched						
BH4103-R-0008	383.72	384.00	Greenschist	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
BH3110-R-0409	115.7	116	Metasandstone	Gooandra volcanics	Talbingo	Tunnel alignment/headrace
BH4103-R-0026	*117.65*	*117.93*	*Greenschist*	*Gooandra Volcanics*	*Talbingo*	Tunnel alignment/headrace
BH3110-R-0413	215	215.27	Metasandstone	Gooandra volcanics	Talbingo	Tunnel alignment/headrace
BH3110-R-0407	64.7	65	Interlaminated metasiltstone/metasandstone	Gooandra volcanics	Talbingo	Tunnel alignment/headrace
BH3110-R-0408	92	92.25	Metasiltstone	Gooandra volcanics	Talbingo	Tunnel alignment/headrace
BH3110-R-0411	172.75	173	Metasiltstone	Gooandra volcanics	Talbingo	Tunnel alignment/headrace
BH4103-R-0017	*82.37*	*82.68*	*Schist*	*Gooandra Volcanics*	*Talbingo*	Tunnel alignment/headrace

Table B4. Excavated rock - Peppercorn/Tantangara/Temperance formations

Sample_ID	Depth (m) Top	Depth (m) Bottom	Lithology	Major Geology (Surface)/ Zone	Placement Option	Classification
Peppercorn/Tantangara/Temperance Formations - Baseline						
BH3101-R-0257	110.35	110.65	meta sandstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3101-R-0259	170.3	170.6	Meta Siltstone/Meta Sandstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3101-R-0261	201	201.3	Meta Siltstone/Meta Sandstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3106-R-0353	154	154.3	Interbedded sandstone/siltstone	Tantangara formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3104-R-0395	319	319.45	Silstone	Tantangara formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3101-R-0254	38	38.3	Meta Siltstone/Meta Sandstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3106-R-0352	129.39	129.69	Interbedded sandstone/siltstone	Tantangara formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH2102-R-0345	47.7	48	Interbedded sandstone/siltstone	Tantangara formation	Tantangara/Talbingo	Tunnel alignment/Headrace
Peppercorn/Tantangara/Temperance Formations - Enriched						
BH3102-R-0329	247.35	247.67	Meta Siltstone/Meta Sandstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3101-R-0263	253	253.3	Meta Siltstone/Meta Sandstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3102-R-0331	268	268.3	Meta Siltstone/Meta Sandstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3102-R-0320	67.6	67.9	meta siltstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3102-R-0322	116	116.28	meta siltstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3102-R-0321	81.7	82	meta siltstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3101-R-0255	61	61.3	Meta Siltstone/Meta Sandstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3102-R-0319	35.25	35.55	meta siltstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
Kellys Plain Volcanics - Not available until late in study testing period						
BH5102-R-0009, BH5102-R-0011, BH5102-R-0013					Tantangara/Talbingo	
BH1115-R-0003, BH1116-R-0005, BH1117-R-0007					Tantangara/Talbingo	

Table B5. Excavated rock - Felsics/granitoids/gniess/ignimbrites

	Depth (m)					
Sample_ID	**Top**	**Bottom**	**Lithology**	**Major Geology (Surface)/ Zone**	**Placement Option**	**Classification**
Felsics/granitoids/gniess/ignimbrites - Baseline						
BH4102-R-0315	524	524.3	Gneiss	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
BH4102-R-0316	546.4	546.7	Gneiss	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
BH4102-R-0318	599	599.3	Gneiss	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
BH4105-R-0370	430.7	431	Gneiss	Ravine bed	Talbingo	Tunnel alignment/headrace
BH5104-R-0115	256	256.3	Felsic ignimbrite	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Tunnel alignment/headrace
BH5103-R-0079	*512.57*	*512.80*	*Felsic volcanics*	*Sandstone/Shale/Limestone/Palaeozoic*	*Talbingo*	Tunnel alignment/headrace
BH7104-R-0234	86.4	86.65	Ignimbrite	Yarrangobilly Limestone/Palaeozoic	Talbingo	Tunnel alignment/headrace
Felsics/granitoids/gniess/ignimbrites - Enriched						
BH5105-R-0147	69	69.3	Ignimbrite	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Tunnel alignment/headrace
BH5103-R-0066	*342.40*	*342.61*	*Felsic volcanics*	*Sandstone/Shale/Limestone/Palaeozoic*	*Talbingo*	Tunnel alignment/headrace
BH5103-R-0080	*348.37*	*348.58*	*Felsic volcanics*	*Sandstone/Shale/Limestone/Palaeozoic*	*Talbingo*	Tunnel alignment/headrace
BH5105-R-0146	64.7	65	Ignimbrite	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Tunnel alignment/headrace
BH5105-R-0148	93.5	93.8	Ignimbrite	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Tunnel alignment/headrace

Centre for Enviromental Contaminants Research
CSIRO Land and Water
Locked Bag 2007, Kirrawee, NSW, 2234, Australia
Telephone: (02) 9710 6822
Fax: (02) 9710 6800
Email: Chad.Jarolimek@csiro.au

CHAIN OF CUSTODY

Batch No:	CE491

Laboratory I.D. No.:	Sample I.D.:		Date Received:	Date Sampled:	Time:	Sample Preservation	Analyses Requested	Storage Location:	Comments:
CE491-1	59918111	TAL-PL2A	11/07/2018	4/07/2018	13:50			2J	15Litres
CE491-2	59918111	TAL-PL1A		4/07/2018	14:00				15Litres
CE491-3	59918111	TAN2A		3/07/2018	11:30				15Litres
CE491-4	59918111	TN3_A		3/07/2018	11:00				15Litres
CE491-5	59918111	TN1_A		3/07/2018	12:05				15Litres
CE491-6	59918111	TAL_PL1B		4/07/2018	14:00				Estimated as 5Litres
CE491-7	59918100	TAL_P22B		4/07/2018	13:50				15Litres

Client:	Cardno		**Received By (*Print Name*):**	Chad Jarolimek
Client Contact Person:	via Simon Apte/Brad Angel		**Date and Time:**	11/07/18 at 15:00
Client Contact Tel/Fax:			**Condition (i.e. Temperature):**	Ambient
Client Contact Email:			**Signature:**	
Method of Shipment:			**Comments:**	All contained in Carboys
Con Note No.:			**NATA Report Required:**	

CSIRO

Centre for Enviromental Contaminants Research
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Email: Chad.Jarolimek@csiro.au

CHAIN OF CUSTODY

Batch No:	CE491

Laboratory I.D. No.:	Sample I.D.:		Date Received:	Date Sampled:	Time Sampled:	Sample Preservation	Storage Location:	Comments:
CE491-8	TAN_P4	19 metres	11/07/2018	3/07/2018		Ice in esky	2J	Blue esky -TAN-P4
CE491-9	TN1_P4	16.5 metres		3/07/2018				Blue esky -TAN-P4
CE491-10	TN3_P4	18.5 metres		3/07/2018				Blue esky -TAN-P4
CE491-11	CA3_P4	48 metres		5/07/2018	9:45			Red esky -TAL-P4
CE491-12	RA1_P4	31.5 metres		4/07/2018	10.15			Red esky -TAL-P4
CE491-13	PL1_P4	33.5 metres		4/07/2018	14:20			Red esky -TAL-P4
CE491-14	CA1_P4	30 metres		5/07/2018	11:20			Red esky -TAL-P4
CE491-15	PL3_P4	27 metres		4/07/2018	12:35			Red esky -TAL-P4
CE491-16	RA3_P4	28.5 metres		4/07/2018	11:20			Red esky -TAL-P4
CE491-17	PL2_P4	26.5 metres		4/07/2018	13:15			Red esky -TAL-P4
CE491-18	CA2_P4	42 metres		5/07/2018	10:15			Red esky -TAL-P4
CE491-19	RA2_P4	29 metres		4/07/2018	10:45			Red esky -TAL-P4

Client:	Cardno	**Received By (*Print Name*):**	Chad Jarolimek
Client Contact Person:	via Simon Apte/Brad Angel	**Date and Time:**	11/07/18 at 15:00
Client Contact Tel/Fax:		**Condition (i.e. Temperature):**	Chilled (ice had melted but still cold)
Client Contact Email:		**Signature:**	
Method of Shipment:		**Comments:**	All contained in Carboys
Con Note No.:		**NATA Report Required:**	

Simpson, Stuart (L&W, Lucas Heights)

Subject: FW: CSIRO Project P4 - Water and Sediment samples

Water and Sediment samples from HKA

From: Ali Watters [mailto:ali.watters@rhdhv.com]
Sent: Monday, 9 July 2018 6:05 PM
To: Simpson, Stuart (L&W, Lucas Heights) <Stuart.Simpson@csiro.au>; Adams, Merrin (L&W, Lucas Heights) <Merrin.Adams@csiro.au>; Apte, Simon (L&W, Lucas Heights) <Simon.Apte@csiro.au>; Angel, Brad (L&W, Lucas Heights) <Brad.Angel@csiro.au>; Fraser, Ryan (Mineral Resources, Kensington WA) <Ryan.Fraser@csiro.au>
Cc: Ellen Porter (ellen.porter@snowyhydro.com.au) <ellen.porter@snowyhydro.com.au>; Greg Britton <greg.britton@rhdhv.com>
Subject: RE: CSIRO Project P4 - Water and Sediment samples

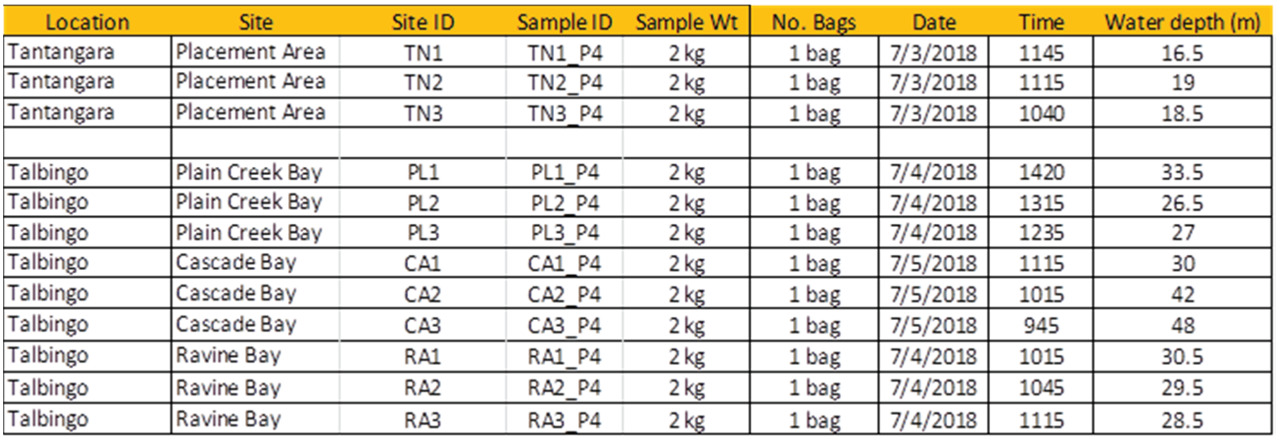
Ryan , Simon

The following 10 items have been shipped today and should arrive in Lucas Heights tomorrow (Tuesday) –

Water containers
3 x 15 L Tantangara water – 30 x 30 x 30 cm, 15 kg each, total 45L
4 x 15 L Talbingo Water – 30 x 30 x 30 cm, 15 kg each, total 60L

Eskies with sediment
1 esky 45 x 45 x 30 cm
2 eskies 40 x 60 x30 cm

The sediment in the eskies comprises the following bagged samples – total 18 kg. Plans showing the sample locations and coordinates are attached.



Location	Site	Site ID	Sample ID	Sample Wt	No. Bags	Date	Time	Water depth (m)
Tantangara	Placement Area	TN1	TN1_P4	2 kg	1 bag	7/3/2018	1145	16.5
Tantangara	Placement Area	TN2	TN2_P4	2 kg	1 bag	7/3/2018	1115	19
Tantangara	Placement Area	TN3	TN3_P4	2 kg	1 bag	7/3/2018	1040	18.5
Talbingo	Plain Creek Bay	PL1	PL1_P4	2 kg	1 bag	7/4/2018	1420	33.5
Talbingo	Plain Creek Bay	PL2	PL2_P4	2 kg	1 bag	7/4/2018	1315	26.5
Talbingo	Plain Creek Bay	PL3	PL3_P4	2 kg	1 bag	7/4/2018	1235	27
Talbingo	Cascade Bay	CA1	CA1_P4	2 kg	1 bag	7/5/2018	1115	30
Talbingo	Cascade Bay	CA2	CA2_P4	2 kg	1 bag	7/5/2018	1015	42
Talbingo	Cascade Bay	CA3	CA3_P4	2 kg	1 bag	7/5/2018	945	48
Talbingo	Ravine Bay	RA1	RA1_P4	2 kg	1 bag	7/4/2018	1015	30.5
Talbingo	Ravine Bay	RA2	RA2_P4	2 kg	1 bag	7/4/2018	1045	29.5
Talbingo	Ravine Bay	RA3	RA3_P4	2 kg	1 bag	7/4/2018	1115	28.5

Please note we asked Cardno to recover bulk sediment samples from three locations within the 3 potential Talbingo placement areas. Similarly 3 bulk samples at the Tantangara placement area. The intention of the three locations within a placement area was to see if any variation within a placement area was observed. This is not expected and we thought it likely that CSIRO Sydney & Adelaide labs will end up compositing their requested volume of sediment from the 3 locations within a placement area into one large bulk sample for use in the P4 & P5 testing.

Regards

Ali

8:15 → LEAVE JINDABYNE FOR TALBINGO
SPILLWAY VIA MIDDLINGBANK RD.

10:20 → PIT STOP IN TALBINGO.

10:40 → TALBINGO DAM VIEW POINT NEAR BOAT
RAMP. PHOTOS OF SPILLWAY FROM ACROSS DAM.

11:00 → ARRIVED AT TALBINGO SPILLWAY &
TOOK PHOTOS.
PUT ON WELLIES & COLLECTED APPROX. 22L OF
RESERVOIR WATER FROM MOST OUTER POINT
NE OF PROPOSED WHARF AREA.
WATER VESSEL WAS TRIPLE RINSED WITH
RESERVOIR WATER.

11:30 → LEFT THE SPILLWAY TO TRY AND ACCESS
MIDDLE BAY AREA.

11:50 → ~~COULD NOT FIND ACCESS TRACK~~ → EP.

WARNING: CALLED BY SAFETY OFFICER & WAS
INFORMED OF AERIAL SHOOTING AT LOBS
HOLE. AVOID LOBS HOLE RAVINE ROAD.
∴ NO PICS OF YARRANGOBILLY RIVER WHARF
AREA.

BRIEF STOP FOR LUNCH.

12:05 → SET OFF FOR TANTANGARA RESERVOIR.

13:45 → ARRIVED AT TANTANGARA.
AND HAD A LOOK/DRIVE AROUND.

14:15 → COLLECTED APPROX. 20L OF TANTANGARA
RESERVOIR WATER.
TRIPLE WASHED VESSLES WITH RESERVOIR
WATER.
P.N.B. WIND HAD GOTTEN UP & TANTANGARA
RESERVOIR WAS FAIRLY TURBID. SEE PICS.

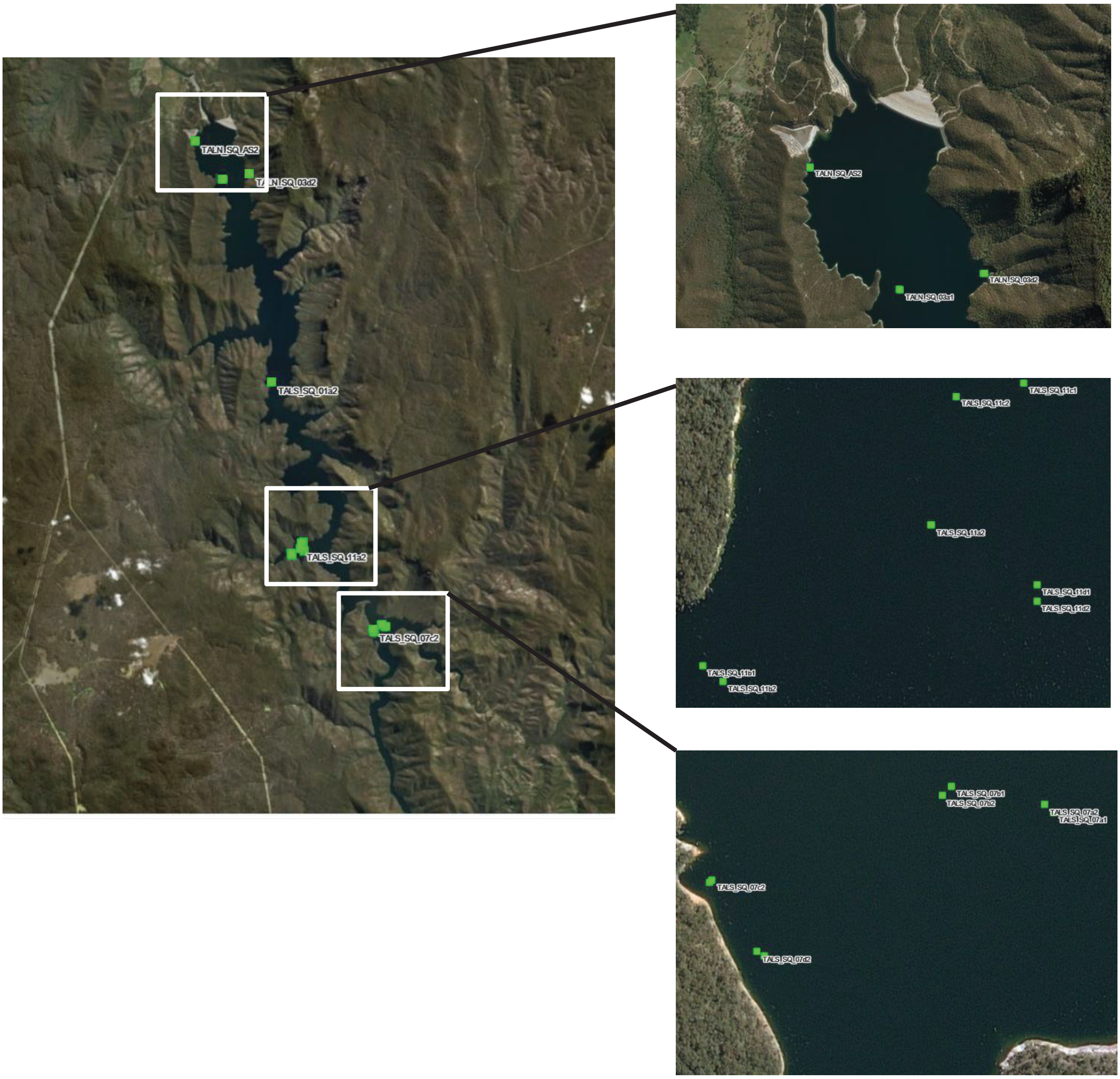
THIS MADE IT MORE DIFFICULT TO COLLECT
WATER. (THE WATER WENT OVER THE TOP OF
MY WELLIES & IT WAS COLD!)

14:40 → HEADED BACK TO COOMA FROM
TANTANGARA.

16:00 → ARRIVED BACK IN COOMA & FUELLED UP.

16:10 → ARRIVED BACK AT COOMA OFFICE, UNLOADED
& CLEANED CAR.

E Porter
14/6/18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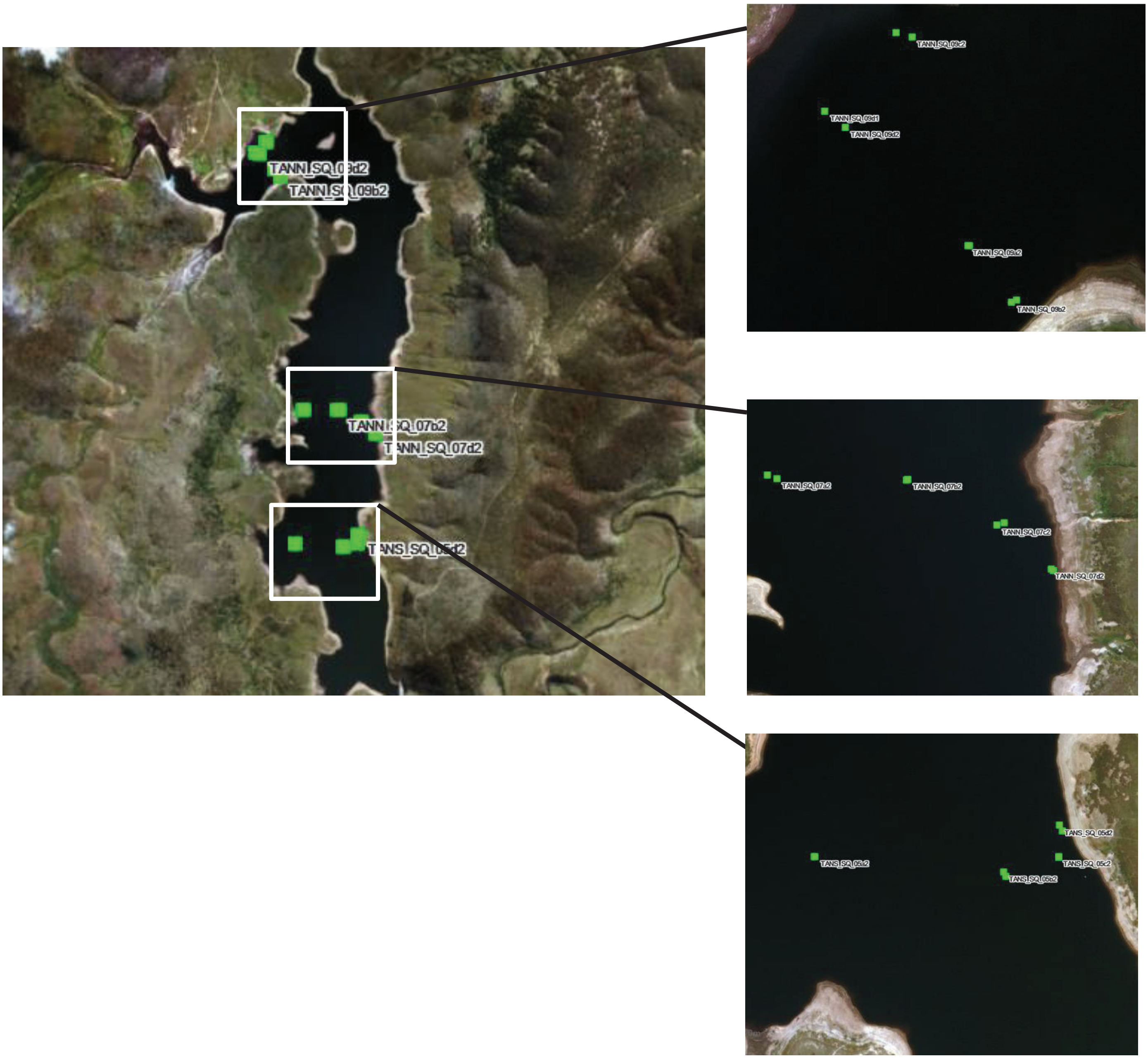
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TANN_SQ_07c2
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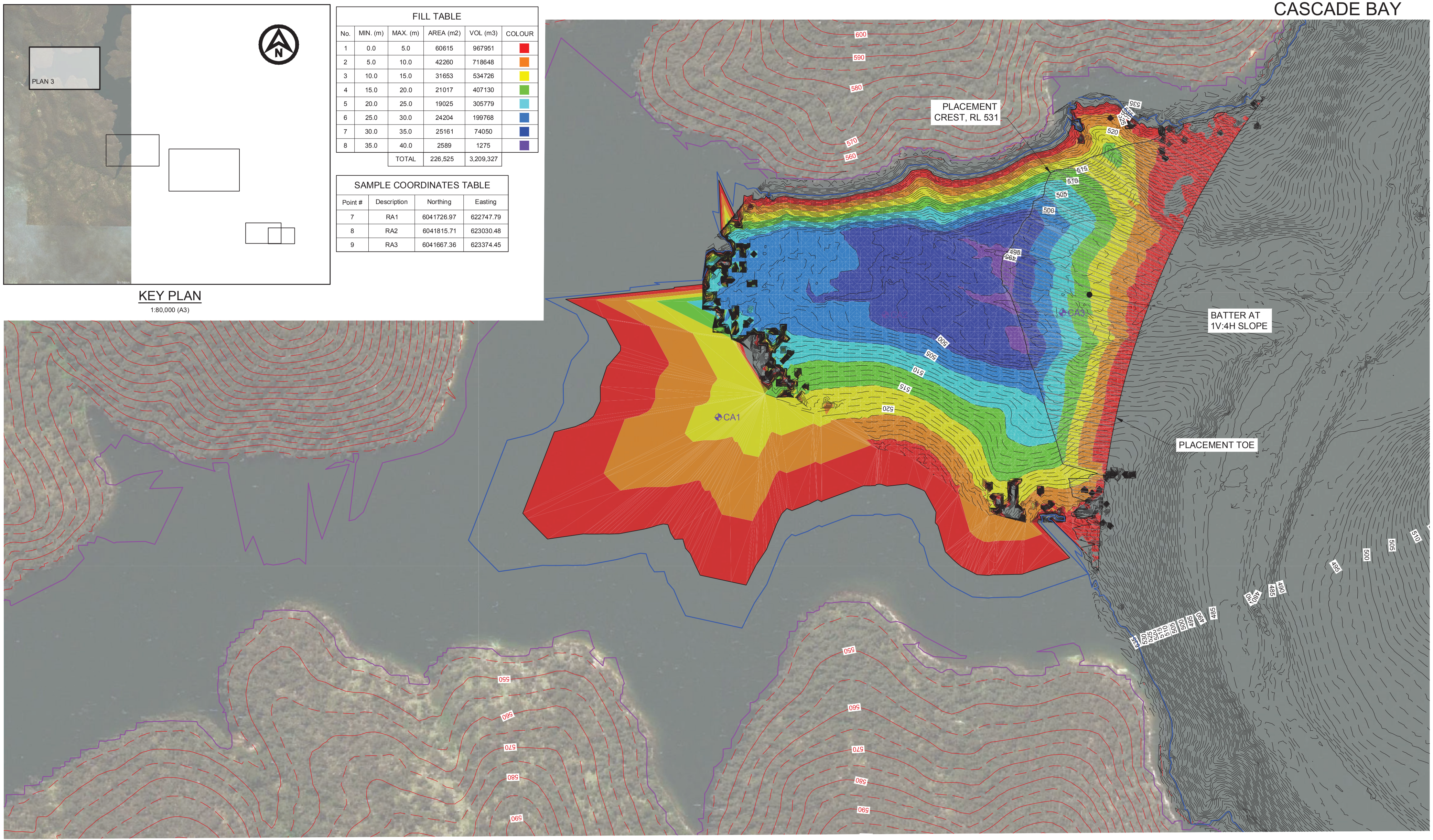
TANS_SQ_05b2

TALBINGO - PLACEMENT
CASCADE BAY



KEY PLAN
1:80,000 (A3)

PLAN 3
1:3,000 (A3)

FILL TABLE					
No.	MIN. (m)	MAX. (m)	AREA (m2)	VOL (m3)	COLOUR
1	0.0	5.0	60615	967951	🟥
2	5.0	10.0	42260	718648	🟧
3	10.0	15.0	31653	534726	🟨
4	15.0	20.0	21017	407130	🟩
5	20.0	25.0	19025	305779	🟦
6	25.0	30.0	24204	199768	🟦
7	30.0	35.0	25161	74050	🟦
8	35.0	40.0	2589	1275	🟪
		TOTAL	226,525	3,209,327	

SAMPLE COORDINATES TABLE			
Point #	Description	Northing	Easting
7	RA1	6041726.97	622747.79
8	RA2	6041815.71	623030.48
9	RA3	6041667.36	623374.45

NOTES

1. BATHYMETRIC SURVEY DATED 26/02/2018, LEVELS TO AHD.
2. FILL TO RL 529mAHD

LEGEND

— — —	LIDAR CONTOUR
— — —	HYDROSURVEY CONTOUR (26/02/2018)
——	FULL SUPPLY LEVEL (FSL) = RL 543.19mAHD
——	MIN. OPERATING LEVEL (MOL) = RL 534.35mAHD
⊕RA1	PROPOSED SEDIMENT & WATER SAMPLE

30 0 30 60 90 120 150m
1:3000 (A3) 1:1500 (A1)

NOT FOR CONSTRUCTION

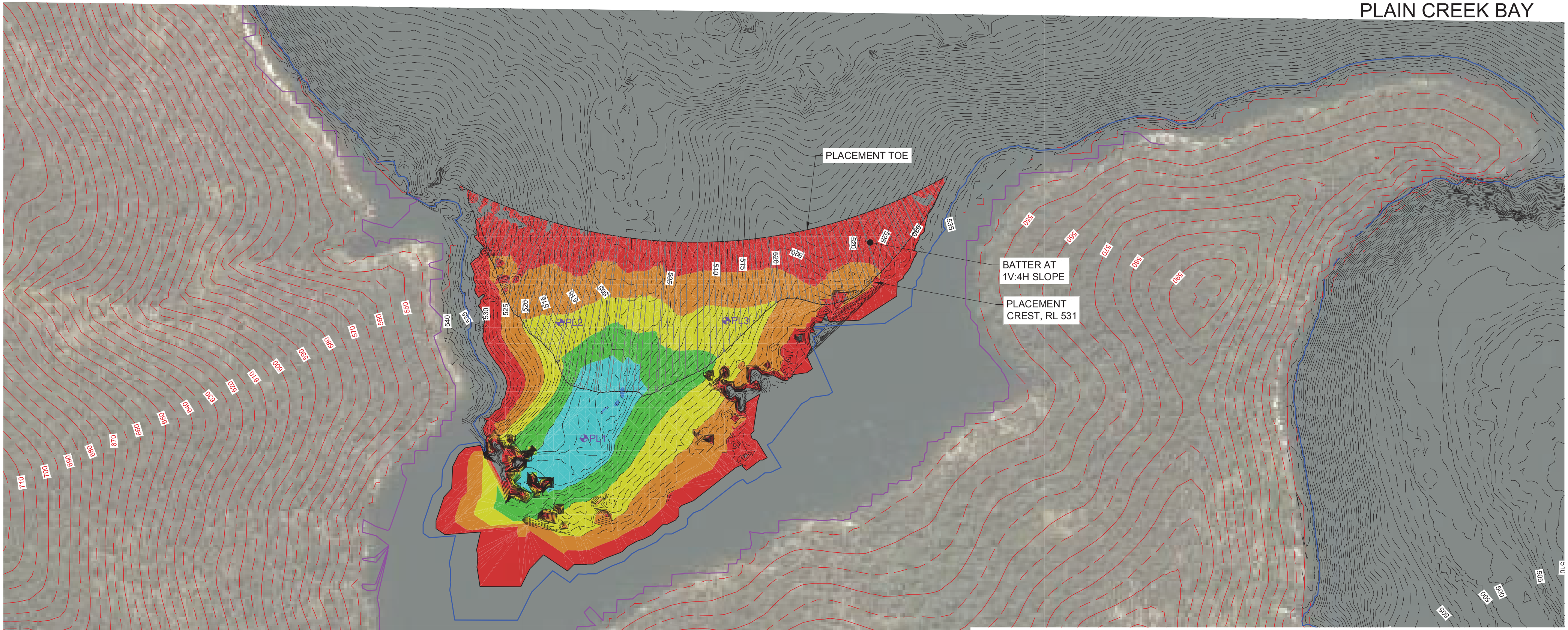
AUSTRALIAN HEIGHT DATUM

SNOWY HYDRO 2.0
D:\RHDHV\JOBS\~PA1804 - Snowy Hydro Dams\E02 Working Drawings\PA1804-RHD-TAL-MA-C3D - Talbingo Placement.dwg

SAVED: 2-Jul-18

Royal HaskoningDHV
Enhancing Society Together

TALBINGO - PLACEMENT
PLAIN CREEK BAY

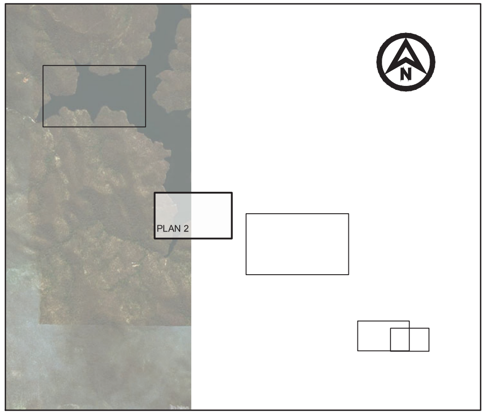


PLAN 2

1:3,000 (A3)

FILL TABLE					
No.	MIN. (m)	MAX. (m)	AREA (m2)	VOL (m3)	COLOUR
1	0.0	5.0	20584	234667	🟥
2	5.0	10.0	15044	147826	🟧
3	10.0	15.0	10917	83092	🟨
4	15.0	20.0	6810	39257	🟩
5	20.0	25.0	4789	10389	🟦
6	25.0	30.0	42	9	🟦
		TOTAL	58,187	515,239	

SAMPLE COORDINATES TABLE			
Point #	Description	Northing	Easting
4	PL1	6042236.53	621482.06
5	PL2	6042323.17	621464.15
6	PL3	6042324.42	621588.56



KEY PLAN

1:80,000 (A3)

NOTES

1. BATHYMETRIC SURVEY DATED 26/02/2018, LEVELS TO AHD.
2. FILL TO RL 529mAHD.

LEGEND

— — —	LIDAR CONTOUR
— — —	HYDROSURVEY CONTOUR (26/02/2018)
——	FULL SUPPLY LEVEL (FSL) = RL 543.19mAHD
——	MIN. OPERATING LEVEL (MOL) = RL 534.35mAHD
RA1	PROPOSED SEDIMENT & WATER SAMPLE

30 0 30 60 90 120 150m

1:3000 (A3) 1:1500 (A1)

NOT FOR CONSTRUCTION

AUSTRALIAN HEIGHT DATUM

SNOWY HYDRO 2.0
D:\RHDHV\JOBS\~PA1804 - Snowy Hydro Dams\E02 Working Drawings\PA1804-RHD-TAL-MA-C3D - Talbingo Placement.dwg

SAVED: 2-Jul-18

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TALBINGO - PLACEMENT
RAVINE BAY

FILL TABLE

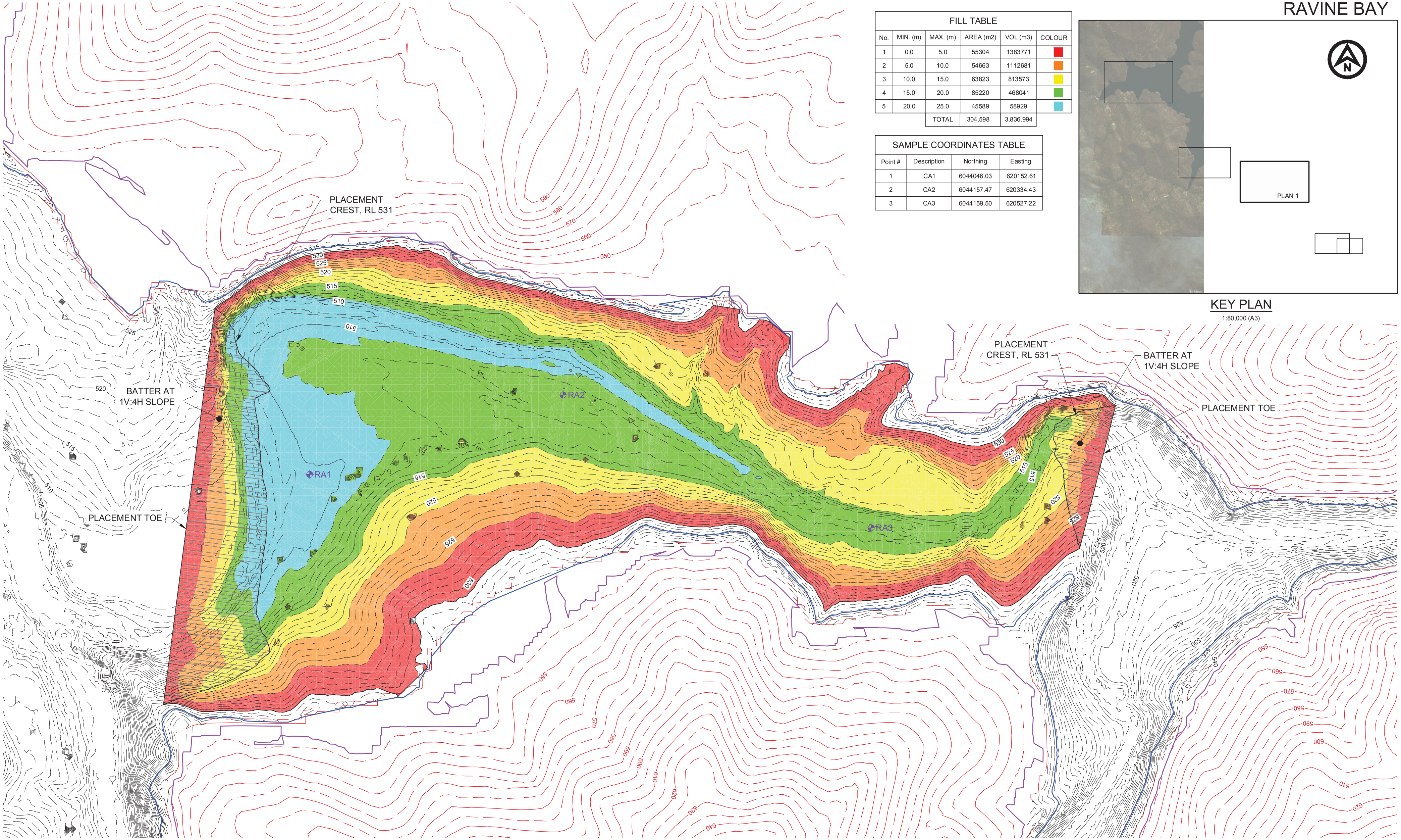
No.	MIN. (m)	MAX. (m)	AREA (m2)	VOL (m3)	COLOUR
1	0.0	5.0	55304	1383771	🟥
2	5.0	10.0	54663	1112681	🟧
3	10.0	15.0	63823	813573	🟨
4	15.0	20.0	85220	468041	🟩
5	20.0	25.0	45589	58929	🟦
		TOTAL	304,598	3,836,994	

SAMPLE COORDINATES TABLE

Point #	Description	Northing	Easting
1	CA1	6044046.03	620152.61
2	CA2	6044157.47	620334.43
3	CA3	6044159.50	620527.22

KEY PLAN

1:80,000 (A3)



PLAN 1

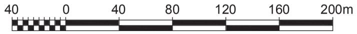
1:3,000 (A3)

NOTES

1. BATHYMETRIC SURVEY DATED 26/02/2018, LEVELS TO AHD.

LEGEND

- — — LIDAR CONTOUR
- — — HYDROSURVEY CONTOUR (26/02/2018)
- —— FULL SUPPLY LEVEL (FSL) = RL 543.19mAHD
- —— MIN. OPERATING LEVEL (MOL) = RL 534.35mAHD
- ⌖RA1 PROPOSED SEDIMENT & WATER SAMPLE



1:4000 (A3) 1:2000 (A1)

NOT FOR CONSTRUCTION

AUSTRALIAN HEIGHT DATUM

SNOWY HYDRO 2.0

D:\RHDHV\JOBS\~PA1804 - Snowy Hydro Dams\E02 Working Drawings\PA1804-RHD-TAL-MA-C3D - Talbingo Placement.dwg

SAVED: 2-Jul-18

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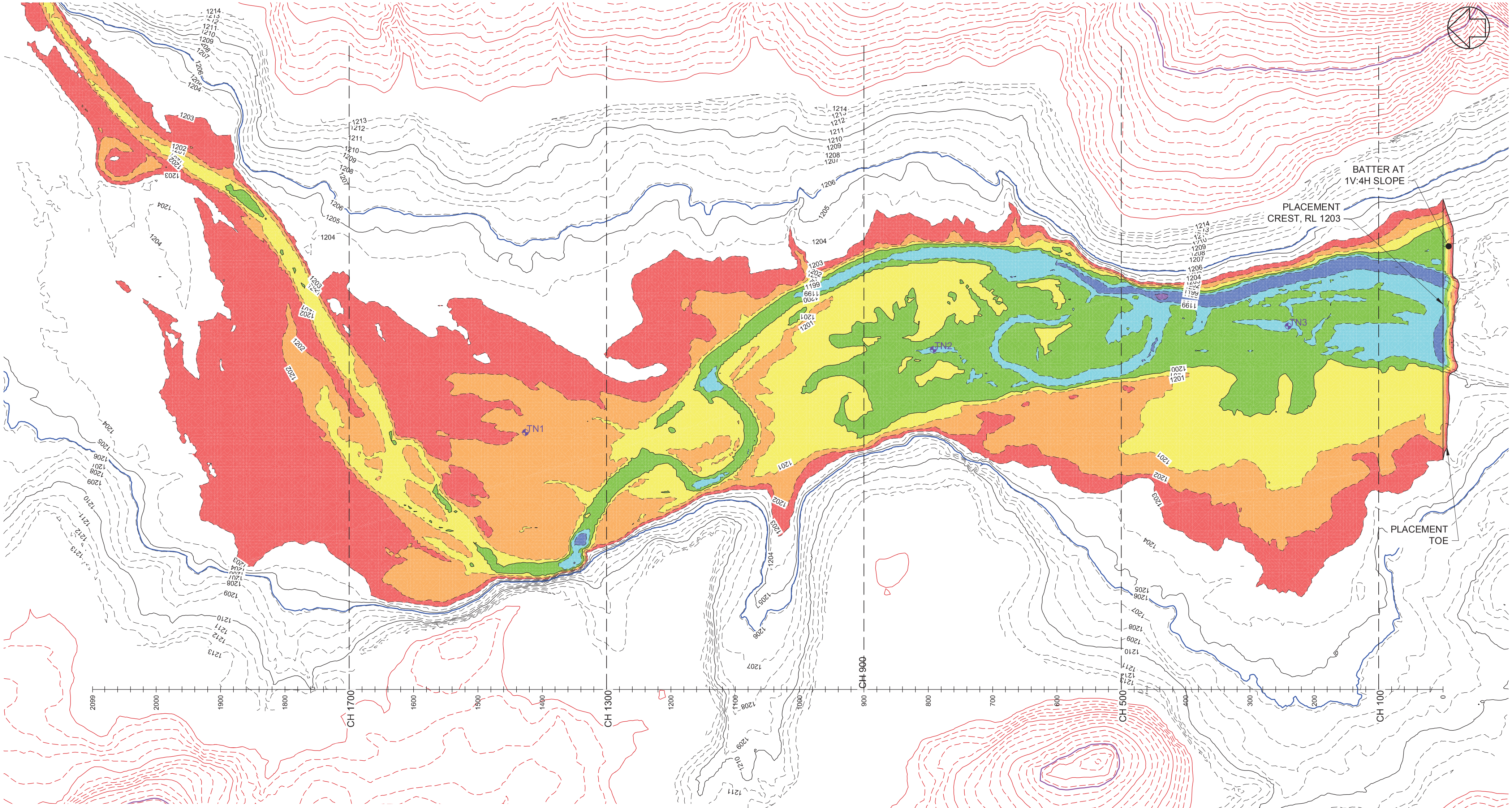
TANTANGARA - PLACEMENT - INSET A



FILL TABLE					
No.	MIN. (m)	MAX. (m)	AREA (m2)	VOL (m3)	COLOUR
1	0.00	1.00	289852	655171	🟥
2	1.00	2.00	184681	425773	🟧
3	2.00	3.00	164685	252263	🟨
4	3.00	4.00	124142	107728	🟩
5	4.00	5.00	38708	20769	🟦
6	5.00	6.00	8777	4335	🟦
7	6.00	7.00	147	25	🟪
		TOTAL	810,992	1,466,064	

SAMPLE COORDINATES TABLE			
Point #	Description	Northing	Easting
1	TN1	6040072.60	649606.34
2	TN2	6039438.74	649735.20
3	TN3	6038887.06	649771.54

LEGEND

- LIDAR CONTOURS
- HYDROSURVEY CONTOURS
- FULL SUPPLY LEVEL (FSL) = RL 1228.69mAHD
- MIN. SUPPLY LEVEL (MOL) = RL 1205.88mAHD
- TN1 PROPOSED SEDIMENT & WATER SAMPLE

NOTES

1. BATHYMETRIC SURVEY DATED 2017, LEVELS TO AHD.
2. FILL TO RL 1203mAHD

AUSTRALIAN HEIGHT DATUM

NOT FOR CONSTRUCTION

60 0 100 200 300m

1:6000 (A3) 1:3000 (A1)

SNOWY HYDRO 2.0
D:\RHDHV\JOBS\~PA1804 - Snowy Hydro Dams\E02 Working Drawings\PA1804-RHD-TAN-MA-C3D - Tantangara Placement.dwg

SAVED: 2-Jul-18

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Appendix C - Characterisation of the Water, Rock and Sediments [67 pages]

The preliminary results were summarised as Memos 1, 2 and 3, and updated data provided here.

Memo 1 – Reservoir Waters, and data files

Memo 2 - Reservoir Sediments, and data files

Memo 3 – Rock materials, and data files

Note/Memo	CSIRO P4 Project Investigations
To:	Ali Watters (HKA)
From:	Brad Angel, Lucas Heights, NSW
Date:	25 September 2018
Copy:	Ryan Fraser, Stuart Simpson and Ellen Porter (SHL)
Our reference:	CSIRO P4 – Memo 1
Classification:	Internal use only
Subject:	Chemical characterisation of the Talbingo and Tantangara reservoirs

Chemical formulas and acronyms

Ag	Silver	Mo	Molybdenum
Al	Aluminium	Na	Sodium
As	Arsenic	Ni	Nickel
Ba	Barium	NO_3^-	Nitrate
Ca	Calcium	Pb	Lead
Cd	Cadmium	Sb	Antinomy
Cl^-	Chloride	Se	Selenium
Co	Cobalt	Sn	Tin
Cr	Chromium	SO_4^{2-}	Sulfate
Cu	Copper	Sr	Strontium
DOC	Dissolved organic carbon	Th	Thorium
F^-	Fluoride	U	Uranium
Fe	Iron	V	Vanadium
Mg	Magnesium	Zn	Zinc
Mn	Manganese		

Background

The CSIRO was engaged by Haskoning Australia Pty Ltd (RHDHV) to undertake an investigation of the pollutant release from excavated rock disposal into the Talbingo and Tantangara reservoirs. The first phase of the work involved chemical characterisation of the reservoir waters.

This technical memo describes the preliminary results.

pH, conductivity, dissolved oxygen, turbidity, alkalinity, DOC and hardness

The pH, electrical conductivity (EC), dissolved oxygen, turbidity, alkalinity and dissolved organic carbon (DOC) measured in the Talbingo and Tantangara reservoir waters are shown in Table 1. The pH, conductivity, dissolved oxygen and alkalinity were similar in both reservoirs and ranged from 6.93 to 7.27, 26.5 to 29.4 µS/cm, 9.19 to 10.1 mg/L, and 11.5 to 12.5 mg $CaCO_3$/L, respectively. The turbidity in the Tantangara reservoir was in the range 0.51-0.60 NTU, which was relatively low but slightly higher than that measured in Talbingo reservoir of 0.20-0.34 NTU. The DOC ranged from 1.2-2.3 mg/L, with the Tantangara reservoir having nearly double the concentration as the Talbingo reservoir. The hardness of the Talbingo and Tantangara reservoir water based on the concentrations of calcium and magnesium is shown in Table

2. The hardness was in the range 7.47-8.05 mg $CaCO_3$/L, with the Talbingo water being slightly less hard than the Tantangara water.

Table 1. The pH, conductivity, dissolved oxygen, turbidity and alkalinity of the Talbingo and Tantangara reservoirs

Sample ID	Reservoir	pH	Conductivity (µS/cm)	Dissolved O_2 (mg/L)	Turbidity (NTU)	Alkalinity (mg $CaCO_3$/L)	DOC[a] (mg/L)
TAL-PL1A	Talbingo	7.20	26.5	9.71	0.20	11.9	1.3
TAL-PL2A	Talbingo	6.93	27.3	9.64	0.34	11.7	1.2
TAL-PL1B	Talbingo	7.27	28.9	9.45	0.26	11.7	1.3
TAL-PL2B	Talbingo	7.18	28.3	9.65	0.22	11.5	1.3
TAL-PL2B duplicate	Talbingo	7.16	28.3	9.41	0.21	-	-
TAN-TN1A	Tantangara	7.20	28.4	9.19	0.51	12.5	2.2
TAN-TN2A	Tantangara	7.17	29.4	10.1	0.60	12.0	2.2
TAN-TN3A	Tantangara	7.14	28.7	9.86	0.54	11.6	2.3

[a] Dissolved organic carbon

Dissolved major cations, metals and metalloids

The concentrations of major cations are shown in Table 2. The dissolved Ca, K, Mg and Na were in the range 1.63-1.91, 0.426-0.569, 0.755-0.967 and 1.44-1.57 mg/L, respectively. The Talbingo reservoir had a slightly higher concentration of dissolved calcium, while the Tantangara reservoir had slightly higher concentrations of potassium and magnesium, and sodium was of a similar concentration in both reservoirs.

The concentrations of Ag, Al, As, Ba, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Sb, Se, Sn, Sr, Th, U, V, Zn are shown in Table 3. The concentrations of dissolved Ag, Be, Bi, Cd, Li, Mo, Sb, Se, Sn, Sr and Tl were similar in both reservoirs. The concentrations of dissolved Al, As, Ba, Co, Cr, Fe, Mn, Ni, Pb, Th and V were higher in the Tantangara reservoir than the Talbingo reservoir, with the mean dissolved iron having the greatest difference, being over 16 times higher. The concentrations of dissolved Ag, Al, As, Ba, Be, Bi, Cd, Co, Cr, Fe, Li, Mn, Mo, Ni, Pb, Sb, Se, Sn, Sr, Th, Tl and V exhibited little intra-reservoir variability for the multiple sites sampled in each reservoir, indicating surface waters are well mixed throughout each reservoir. The concentrations of dissolved copper, uranium and zinc were generally higher in the Talbingo reservoir than the Tantangara reservoir, however, site TAL-PL1B contained over 5 µg/L of copper and was obviously contaminated, and the dissolved zinc was spotty, probably due to contamination during sampling.

The concentrations were compared to ANZECC / ARMCANZ default water quality guideline values for the protection of 95 and 99% of species in Table 3, when values were available. The only exceedance of the 95% default guideline values (DGV) was for copper in sample TAL-PL1B that had leaked and potentially been contaminated during collection and transport. All sites exceeded the 99% guideline value for dissolved chromium, however, it should be noted that the only value available for comparison was for hexavalent chromium being in the hexavalent form, which is unlikely due its' stability.

Table 2. The concentrations major cations and water hardness in the Talbingo and Tantangara reservoirs

Sample I.D.	**Hardness (mg CaCO3/L)**	**Ca (mg/L)**	**K (mg/L)**	**Mg (mg/L)**	**Na (mg/L)**
TAL-PL1A	7.50	1.78	0.431	0.756	1.45
TAL-PL2A	7.47	1.77	0.426	0.755	1.44
TAL-PL1B	8.03	1.91	0.451	0.807	1.57
TAL-PL2B	7.51	1.78	0.431	0.757	1.45
TAN-TN1A	8.05	1.65	0.568	0.967	1.57
TAN-TN2A	8.00	1.64	0.563	0.962	1.55
TAN-TN3A	7.99	1.63	0.569	0.964	1.55

Table 3. The concentrations of metals and metalloids in the Talbingo and Tantangara reservoirs

Client I.D.	**Ag (µg/L)**	**Al (µg/L)**	**As (µg/L)**	**Ba (µg/L)**	**Be (µg/L)**	**Bi (µg/L)**	**Cd (µg/L)**	**Co (µg/L)**	**Cr (µg/L)**	**Cu (µg/L)**	**Li (µg/L)**	**Fe (µg/L)**	**Mn (µg/L)**
TAL-PL1A	<0.002	3.93	0.166	4.44	<0.005	<0.028	<0.005	<0.007	**0.060**	0.649	0.095	23.9	0.287
TAL-PL2A	0.002	4.99	0.184	4.42	<0.005	<0.028	<0.005	0.007	**0.058**	0.629	0.091	26.7	0.348
TAL-PL1B	<0.002	4.86	0.16	4.52	<0.005	<0.028	<0.005	<0.007	**0.064**	**5.22**	0.116	24.9	0.386
TAL-PL2B	<0.002	4.16	0.153	4.38	<0.005	<0.028	<0.005	<0.007	**0.051**	0.739	0.093	26.3	0.282
TAN-TN1A	<0.002	26.2	0.314	6.13	<0.005	<0.028	<0.005	0.025	**0.100**	0.483	0.107	396	2.30
TAN-TN2A	<0.002	24.3	0.228	6.19	<0.005	<0.028	<0.005	0.028	**0.089**	0.41	0.104	399	2.17
TAN-TN3A	0.017	23.6	0.326	6.15	0.007	<0.028	<0.005	0.032	**0.095**	0.386	0.104	394	2.36
95% GV[a]	**0.05**	**55**	**13**	-	-	-	**0.2**	-	**0.4**	**1.4**	-	-	**1900**
99% GV[b]	**0.02**	**27**	**0.8**	-	-	-	**0.06**	-	**0.01**	**1.0**	-	-	**1200**

Client I.D.	**Mo (µg/L)**	**Ni (µg/L)**	**Pb (µg/L)**	**Sb (µg/L)**	**Se (µg/L)**	**Sn (µg/L)**	**Sr (µg/L)**	**Th (µg/L)**	**Tl (µg/L)**	**U (µg/L)**	**V (µg/L)**	**Zn (µg/L)**
TAL-PL1A	<0.073	0.078	<0.02	0.012	0.026	<0.021	14.7	0.0035	<0.006	0.017	0.097	2.15
TAL-PL2A	<0.073	0.102	<0.02	0.007	0.020	<0.021	14.7	0.0039	<0.006	0.014	0.102	0.929
TAL-PL1B	<0.073	0.111	0.033	0.01	0.015	<0.021	15.1	0.0043	<0.006	0.015	0.106	1.67
TAL-PL2B	<0.073	0.117	<0.02	0.01	0.024	<0.021	14.8	0.0025	<0.006	0.016	0.114	0.605
TAN-TN1A	<0.073	0.188	0.079	0.012	0.024	<0.021	14.7	0.0158	<0.006	0.008	0.211	1.44
TAN-TN2A	<0.073	0.205	0.06	0.007	0.022	<0.021	14.6	0.0143	<0.006	0.008	0.206	0.750
TAN-TN3A	<0.073	0.179	0.04	0.009	0.029	<0.021	14.8	0.0122	<0.006	0.009	0.209	0.425
95% GV	-	**11**	**3.4**	-	**11**	-	-	-	-	-	-	**8.0**
99% GV	-	**8**	**1.0**	-	**5**	-	-	-	-	-	-	**2.4**

[*] TAL-PL1B sample container had leaked most of its content due to a loose lid or hole in container and sample contamination resulting from this is considered the likely reason for the elevated copper concentration

[a] http://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/. 95% species protection guideline values (95%GV) for freshwater. Values for Arsenic are for As(V), chromium are for Cr(VI), and tin are for inorganic tin

[b] http://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/. 99% species protection guideline values (99%GV) for freshwater. Values for Arsenic are for As(V), chromium are for Cr(VI), and tin are for inorganic tin

The concentrations of dissolved organic carbon, major anions and total sulfur

The concentrations of dissolved organic carbon (DOC), fluoride, chloride, nitrate, sulfate and total sulfur measured in the Talbingo and Tantangara reservoir samples are shown in Table 4. There was little intra-site variability in each parameter in each given reservoir. The concentrations of fluoride and chloride were similar in the two reservoirs, whereas nitrate, sulfate and total sulfur were marginally higher in the Talbingo reservoir than the Tantangara reservoir. The concentration of DOC measured in the Tantangara reservoir was nearly double the concentration in the Talbingo reservoir.

Table 4. The concentrations of metals and metalloids in the Talbingo and Tantangara reservoirs.

Client I.D.	DOC (mg/L)	F^- (mg/L)	Cl^- (mg/L)	NO_3^- (mg/L)	SO_4^{2-} (mg/L)	Total S (mg/L)
TAL-PL1A	1.3	0.024	0.912	0.140	0.431	0.170
TAL-PL2A	1.2	0.023	0.911	0.129	0.421	0.165
TAL-PL1B	1.3	0.032	1.154	0.151	0.513	0.192
TAL-PL2B	1.3	0.023	0.910	0.142	0.428	0.161
TAN-TN1A	2.2	0.022	0.926	0.058	0.346	0.145
TAN-TN2A	2.2	0.025	0.910	0.039	0.343	0.155
TAN-TN3A	2.3	0.014	0.900	0.055	0.324	0.157

* Phosphate to be measured in the near future

Summary

Most parameters measured in the waters were in a similar concentration range in both reservoirs and there was little variability between sites in each reservoir. The concentrations of dissolved Al, As, Ba, Co, Cr, Fe, Mn, Ni, Pb, Th and V were higher in the Tantangara reservoir than the Talbingo reservoir, with the mean dissolved iron having the greatest difference, being over 16 times higher.

Note. For sample collection the containers used were not acid-washed, and the concentrations of metals such as Cu and Zn may also reflect minor contamination owing to the sampling procedures. This is not considered a particular concern for their intended use in later parts of the P4 investigations.

Appendix C: Elements/substances in reservoir water

		pH	Alkalinity	Conductivity	DO	Turbidity	mg/L						
Laboratory I.D. No.:	Client description:		mg/L $CaCO_3$	µS/cm	mg/L	NTU	DOC	Chloride	Fluoride	Nitrate	Sulphate	Total P	Silicon
CE491-2	TAL-PL1A 59918111	7.2	12	26.5	9.7	0.20	1.3	<1	<0.1	0.1	<1	<0.010	2.20
CE491-1	TAL-PL2A 59918111	6.9	12	27.3	9.6	0.34	1.2	<1	<0.1	0.1	<1	<0.010	2.20
CE491-6	TAL-PL1B 59918111	7.3	12	28.9	9.5	0.26	1.3	1	<0.1	0.2	<1	<0.010	2.10
CE491-7	TAL-P22B 59918100	7.2	12	28.3	9.5	0.22	1.3	<1	<0.1	0.1	<1	<0.010	2.10
CE491-5	TAN-1A 59918111	7.2	13	28.4	9.2	0.51	2.2	<1	<0.1	<0.1	<1	<0.010	0.64
CE491-3	TAN-2A 59918111	7.2	12	29.4	10	0.60	2.2	<1	<0.1	<0.1	<1	<0.010	0.63
CE491-4	TAN-3A 59918111	7.1	12	28.7	9.9	0.54	2.3	<1	<0.1	<0.1	<1	<0.010	0.65
LOD 3σ	---	---	10	---	---	---	1	1	0.1	0.1	1	0	0
Method code	---	C-240	C-257	C-255	C-255	C-256	C-260	C-261	C-261	C-261	C-261	C-229	C-229

		Dissolved Metals (µg/L)																							
Laboratory I.D. No.:	Client description:	Na	K	Mg	Ca	Ag	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Sb	Se	Sn	Sr	Th	U	V	Zn
CE491-2	TAL-PL1A 59918111	1510	431	813	1880	<0.002	7	0.17	4.5	<0.01	<0.01	0.06	0.65	24	0.3	<0.1	0.08	<0.01	0.01	0.03	<0.02	15	0.004	0.017	0.10	2.5
CE491-1	TAL-PL2A 59918111	1500	426	817	1870	<0.002	8	0.18	4.5	<0.01	<0.01	0.06	0.63	27	0.3	<0.1	0.10	<0.01	<0.01	0.02	<0.02	15	0.004	0.014	0.10	1.1
CE491-6	TAL-PL1B 59918111	1620	451	872	2000	<0.002	7	0.16	4.6	<0.01	<0.01	0.06	5.2	25	0.4	<0.1	0.11	0.03	0.01	0.02	<0.02	16	0.004	0.015	0.11	2.0
CE491-7	TAL-P22B 59918100	1510	431	816	1870	<0.002	7	0.15	4.4	<0.01	<0.01	0.05	0.74	26	0.3	<0.1	0.12	<0.01	0.01	0.02	<0.02	15	0.003	0.016	0.11	0.7
CE491-5	TAN-1A 59918111	1650	568	1040	1730	<0.002	43	0.31	6.2	<0.01	0.03	0.10	0.48	396	3.2	<0.1	0.19	0.08	0.01	0.02	<0.02	15	0.016	0.008	0.21	1.7
CE491-3	TAN-2A 59918111	1640	563	1040	1740	<0.002	43	0.23	6.3	<0.01	0.03	0.09	0.41	399	3.2	<0.1	0.20	0.06	<0.01	0.02	<0.02	15	0.014	0.008	0.21	1.0
CE491-4	TAN-3A 59918111	1630	569	1040	1720	0.017	42	0.33	6.2	<0.01	0.03	0.10	0.39	394	3.3	<0.1	0.18	0.05	<0.01	0.03	<0.02	15	0.012	0.009	0.21	0.4
LOD 3σ	---	10	5	4	1	0.002	1	0.02	0.1	0.01	0.01	0.01	0.02	1	0.1	0.1	0.001	0.01	0.01	0.01	0.02	0.1	0.001	0.002	0.01	0.1
Method code	---	C-229	C-229	C-229	C-229	C-209	C-229	C-209	C-229	C-209	C-209	C-209	C-209	C-229	C-229	C-209	C-209	C-209	C-209	C-209	C-209	C-229	C-209	C-209	C-209	C-209

Quality control

Replicate analysis

		pH		Conductivity	DO	Turbidity		mg/L			
Laboratory I.D. No.:	Client description:			µS/cm	mg/L	NTU		Chloride	Fluoride	Nitrate	Sulphate
CE491-7	TAL-P22B 59918100	7.2		28.3	9.7	0.22		<1	<0.1	0.1	<1
CE491-7 dup	TAL-P22B 59918100 dup	7.2		28.3	9.4	0.21		<1	<0.1	0.1	<1
CE491-7 avg	**TAL-P22B 59918100 avg**	**7.2**		**28.3**	**9.5**	**0.22**		**<1**	**<0.1**	**0.1**	**<1**
LOD 3σ	---	---		---	---	---		1	0.1	0.1	1
Method code	---	C-240		C-255	C-255	C-256		C-261	C-261	C-261	C-261

		Dissolved Metals (µg/L)																									
Laboratory I.D. No.:	Client description:	Na	K	Mg	Ca	Ag	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Sb	Se	Sn	Sr	Th	U	V	Zn	P	Si
CE491-5	TAN-1A 59918111	1660	570	1050	1730	<0.002	42	0.29	6.3	<0.01	0.03	0.10	0.49	397	3.3	<0.1	0.20	0.07	0.01	0.03	<0.02	15	0.016	0.008	0.20	1.7	<10	640
CE491-5 dup	TAN-1A 59918111 dup	1650	566	1040	1730	<0.002	43	0.34	6.3	<0.01	0.02	0.10	0.48	396	3.3	<0.1	0.17	0.08	0.01	0.02	<0.02	15	0.016	0.009	0.22	1.8	<10	640
CE491-5 avg	**TAN-1A 59918111 avg**	**1650**	**568**	**1040**	**1730**	**<0.002**	**43**	**0.31**	**6.2**	**<0.01**	**0.03**	**0.10**	**0.48**	**396**	**3.2**	**<0.1**	**0.19**	**0.08**	**0.01**	**0.02**	**<0.02**	**15**	**0.016**	**0.008**	**0.21**	**1.7**	**<10**	**640**
LOD 3σ	---	10	5	4	1	0.002	1	0.02	0.1	0.01	0.01	0.01	0.02	1	0.1	0.1	0.001	0.01	0.01	0.01	0.02	0.1	0.001	0.002	0.01	0.1	10	10
Method code	---	C-229	C-229	C-229	C-229	C-209	C-229	C-209	C-229	C-209	C-209	C-209	C-209	C-229	C-229	C-209	C-209	C-209	C-209	C-209	C-209	C-229	C-209	C-209	C-209	C-209	C-229	C-229

[a]Reference Materials

		Dissolved Metals (µg/L)																
Laboratory I.D. No.:	Client description:	Ag	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Sr	V	U	Zn
TM-24.4	---	---	43.9	5.09	15.7	3.83	6.51	5.06	6.32	16.7	8.41	6.30	4.93	5.44	117	7.24	4.21	---
Certified Value	---	---	32.9 ± 4.5	5.30 ± 0.53	15.0 ± 1.0	3.96 ± 0.34	6.27 ± 0.57	5.00 ± 0.59	6.31 ± 0.60	16.0 ± 2.3	8.24 ± 0.73	6.30 ± 0.56	5.03 ± 0.53	5.60 ± 0.52	113 ± 8	7.00 ± 0.58	4.24 ± 0.34	---
TMDA-64.3	---	12.2	302	164	300	213	267	296	264	309	299	299	258	257	655	298	126	297
Certified Value	---	12.6 ± 1.3	291 ± 23	164 ± 15	287 ± 18	258 ± 21	250 ± 16	283 ± 17	261 ± 18	298 ± 21	292 ± 17	286 ± 21	252 ± 18	280 ± 22	628 ± 34	279 ± 18	135 ± 11	320 ± 23
Method code	---	C-209	C-229	C-209	C-229	C-209	C-209	C-209	C-209	C-229	C-229	C-209	C-209	C-209	C-229	C-209	C-209	C-209

[a] TM-24.4 and TMDA-64.3 are certified reference materials from Environment and Climate Change Canada

[b]Spike Recovery

		Spike Recovery (%)																									
Laboratory I.D. No.:	Client description:	Na	K	Mg	Ca	Ag	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Sb	Se	Sn	Sr	Th	U	V	Zn	P	Si
CE491-2	TAL-PL1A 59918111	109	97	97	101	96	103	95	104	97	96	96	100	106	100	97	95	93	96	97	98	101	98	98	99	104	104	101
Method code	---	C-229	C-229	C-229	C-229	C-209	C-229	C-209	C-229	C-209	C-209	C-209	C-209	C-229	C-229	C-209	C-209	C-209	C-209	C-209	C-209	C-229	C-209	C-209	C-209	C-209	C-229	C-229

[b] analyte of interest added to sample prior to analysis

Miscellaneous information:
Dup.= duplicate
Avg.=average of replicate analysis in laboratory

Method codes:
C-209 Inductively Coupled Plasma - Mass Spectrometry (ICP-MS)
C-229 Inductively Coupled Plasma - Atomic Emission Spectrometry (ICP-AES)
C-261 Anions by Ion Chromatography

Method codes:
C-240 Determination of pH
C-255 Conductivity and dissolved oxygen (DO) meter
C-260 Dissolved Organic Carbon (DOC) by combustion and catalytic oxidation

Method codes:
C-256 Turbidity by light scattering
C-257 Alkalinity by titration

Note/Memo	CSIRO P4 Project Investigations
To:	Ali Watters (HKA)
From:	Brad Angel, Lucas Heights, NSW
Date:	25 September 2018
Copy:	Ryan Fraser, Stuart Simpson and Ellen Porter (SHL)
Our reference:	CSIRO P4 – Memo 2
Classification:	Internal use only
Subject:	Chemical characterisation of Talbingo and Tantangara reservoir sediments

Chemical formulas and acronyms

Ag	Silver	Mo	Molybdenum
Al	Aluminium	Na	Sodium
As	Arsenic	Ni	Nickel
Ba	Barium	NO_3^-	Nitrate
Ca	Calcium	Pb	Lead
Cd	Cadmium	Sb	Antinomy
Cl^-	Chloride	Se	Selenium
Co	Cobalt	Sn	Tin
Cr	Chromium	SO_4^{2-}	Sulfate
Cu	Copper	Sr	Strontium
DOC	Dissolved organic carbon	Th	Thorium
F^-	Fluoride	U	Uranium
Fe	Iron	V	Vanadium
Mg	Magnesium	Zn	Zinc
Mn	Manganese		

Background

The CSIRO was engaged by Haskoning Australia Pty Ltd (RHDHV) to undertake an investigation of the pollutant release from excavated rock placed in Talbingo and Tantangara reservoirs (a map of the sample sites will be prepared at a later date for incorporation into an interpretive report). The second phase of the work involved chemical characterisation of the reservoir sediments.

This technical memo describes the preliminary results to date.

Reservoir benthic sediment porewater pH, conductivity and redox potential

The pH and redox potential of the porewaters of the Talbingo and Tantangara reservoir sediments were measured directly in the sediments (not extracted porewater) Table 1. An inadequate volume of porewater was extracted in this initial work for conductivity measurements and instead conductivity was measured on sediment:deionised water suspension (1:10) that had been allowed to equilibrate for two weeks.

Table 1. The pH, conductivity and redox potential of the Talbingo and Tantangara reservoir sediment porewaters.

Sediment ID	Reservoir	pH	Conductivity (µS/cm)	Redox, Eh (mV)
CA1	Talbingo	7.30	23.5	-175
CA2	Talbingo	7.60	26.5	-180
CA3	Talbingo	7.45	19.0	-170
PL1	Talbingo	7.05	20.0	-140
PL2	Talbingo	7.30	15.7	-125
PL3	Talbingo	7.40	18.9	-160
RA1	Talbingo	7.25	22.7	-160
RA2	Talbingo	7.30	24.0	-185
RA3	Talbingo	7.50	21.6	-190
TN1	Tantangara	6.70	33.0	-105
TN2	Tantangara	7.10	36.0	-140
TN3	Tantangara	7.00	36.7	-155

There was little difference in each parameter between the different sites in the Talbingo reservoir.

The pH was marginally lower in the porewaters from the Talbingo sediments than the Tantangara sediments, while the redox potential were marginally higher. The higher redox potential indicates slightly more oxic conditions prevailed in the Tantangara sediment proewaters.

- The pH of the porewaters was within a similar range to that measured in the reservoir waters (Memo 1), having generally a slightly higher range than the reservoir waters.
- The conductivity of the waters equilibrated with the Talbingo sediments was a little lower than the reservoir water (26-30 µS/cm range, Memo 1), whereas, the conductivity of the waters equilibrated with the Tantangara sediments was a little higher than the reservoir waters, indicating a minor release of major ions.

Sediment pore water major anions and ammonia

The major anions in the porewater extracted (0.45 µm filtered) from the Talbingo and Tantangara sediments are shown in Table 2. The concentration of sulfate was variable between sites at the same general location (i.e. CA, PL or RA), whereas, chloride, nitrate and ammonia concentrations were generally similar between the different sites in the Talbingo reservoir. The sediment porewater of the Tantangara reservoir had higher concentrations of ammonia than the Talbingo sites.

Table 2. The concentrations of major anions and ammonia in the reservoir sediment porewater.

Sediment ID	Cl^- (mg/L)	NO_3^- (mg/L)	SO_4^{2-} (mg/L)	Total ammonia (mg NH_3/L)
CA1_P4	1.27	0.43	1.40	2.4
CA2_P4	1.73	0.46	5.10	2.8
CA3_P4	1.74	0.73	2.55	2.6
PL1_P4	1.76	0.56	0.36	2.6
PL2_P4	1.24	0.53	1.28	2.3
PL3_P4	2.49	0.63	0.89	2.2
RA1_P4	1.39	0.51	1.34	2.8
RA2_P4	1.36	0.51	0.83	3.3
RA3_P4	1.69	0.48	0.39	4.3
TN1_P4	1.94	0.61	2.11	5.6
TN2_P4	5.94	0.44	2.78	5.7
TN3_P4	1.89	0.49	1.75	7.5

Metals, metalloids and major cations in the porewater of Talbingo and Tantangara reservoirs sediments

The concentrations of metals, metalloids and major cations in the porewater of Talbingo and Tantangara reservoir sediments are shown in Table 3. Many of the metals, metalloids and major cations exhibited substantial variability between sites, probably due to differences in micro-environmental parameter conditions in the porewaters from different sites, such as redox potential.

The default guideline values (DGVs) for water are shown in Table 3, with aluminium and copper exceeding the corresponding DGV in some porewaters. The dissolved (<0.45 µm filterable) aluminium was the most variable, probably due to differences in colloidal fractions between sites. Copper is likely to be complexed by organic ligands, resulting in the labile concentration being below the DGV. The porewaters of the Talbingo sediments from location RA had arsenic concentration that exceed the DGV.

Table 3. The concentrations of metals and metalloids in the sediment porewaters of the Talbingo and Tantangara reservoirs.

Sediment ID	Ag (µg/L)	Al (µg/L)	As (µg/L)	Ba (µg/L)	Ca (mg/L)	Cd (µg/L)	Co (µg/L)	Cr (µg/L)	Cu (µg/L)
CA1	0.063	10	6.2	68	6.08	<0.021	9.2	0.39	0.24
CA2	<0.005	8	7.9	107	10.5	0.033	8.8	0.57	0.31
CA3	<0.005	**67**	8.9	72	5.50	0.080	7.7	0.44	0.91
PL1	0.006	**278**	11.7	75	6.10	<0.021	10.5	0.83	**1.62**
PL2	0.008	**600**	6.7	62	6.54	<0.021	7.1	0.68	1.39
PL3	0.007	32	7.5	108	7.65	0.027	11.0	0.38	0.68
RA1	0.006	**144**	10.3	89	5.40	<0.021	7.0	0.43	**1.47**
RA2	<0.005	51	**17.7**	133	8.19	<0.021	7.5	0.45	0.46
RA3	<0.005	6	**18.3**	260	13.3	0.035	9.3	0.37	0.30
TN1	0.005	**180**	4.6	107	3.66	<0.021	7.2	0.69	0.65
TN2	0.004	**179**	5.1	95	3.39	<0.021	5.2	0.73	0.53
TN3	<0.005	**59**	8.6	111	3.09	<0.021	5.7	0.76	0.27
Minimum	**<0.005**	**5.5**	**4.63**	**62.1**	**3.09**	**<0.021**	**5.25**	**0.373**	**0.238**
Maximum	**0.063**	**600**	**18.3**	**260**	**13.3**	**0.080**	**11.0**	**0.835**	**1.62**
DGV	**0.05**	55	**13**	NA	NA	**0.2**	NA	**0.4**	**1.4**

	Fe (mg/L)	K (mg/L)	Mg (mg/L)	Mn (mg/L)	Mo (µg/L)	Na (mg/L)	Ni (µg/L)	Pb (µg/L)	Sb (µg/L)
CA1	25.9	1.0	1.84	7.3	0.9	2.9	1.7	<0.046	0.10
CA2	37.1	1.4	6.36	10.5	0.8	3.4	1.7	<0.046	0.10
CA3	17.9	1.1	1.30	15.6	1.3	2.0	2.1	0.306	0.13
PL1	27.5	1.2	2.01	7.4	0.6	2.9	2.5	0.660	0.23
PL2	18.6	1.0	1.83	9.8	1.3	2.2	2.1	0.622	0.20
PL3	36.8	1.8	3.37	12.9	1.9	2.8	1.6	0.157	0.28
RA1	15.6	1.1	1.23	8.1	1.0	2.1	2.0	0.716	0.13
RA2	22.4	1.2	1.55	14.0	1.2	2.5	2.4	0.134	0.06
RA3	30.6	1.2	2.14	28.8	2.0	2.5	2.6	0.001	0.12
TN1	28.1	1.4	2.26	2.7	0.2	3.6	1.1	0.140	0.28
TN2	32.1	1.2	2.12	2.6	0.2	3.5	0.8	0.150	0.28
TN3	37.4	0.9	1.84	3.4	0.1	1.9	0.9	<0.046	0.17
Minimum	**15.6**	**0.917**	**1.230**	**2.56**	**0.12**	**1.92**	**0.784**	**<0.046**	**0.064**
Maximum	**37.4**	**1.77**	**6.36**	**28.8**	**2.03**	**3.56**	**2.62**	**0.716**	**0.283**
DGV	NA	NA	NA	1900	NA	NA	**11**	**3.4**	NA

	Se (µg/L)	Sn (µg/L)	Sr (µg/L)	Th (µg/L)	U (µg/L)	V (µg/L)	Zn (µg/L)
CA1	0.12	<0.028	51.9	0.058	0.059	1.6	1.5
CA2	0.14	<0.028	121.7	0.080	0.096	1.9	3.5
CA3	0.12	<0.028	45.3	0.117	0.105	2.5	3.1
PL1	0.13	<0.028	47.8	0.163	0.137	2.8	2.6
PL2	0.10	<0.028	44.8	0.149	0.137	2.6	6.2
PL3	0.14	<0.028	71.4	0.079	0.112	1.6	4.2
RA1	0.09	<0.028	35.7	0.132	0.152	1.8	4.0
RA2	0.12	<0.028	49.9	0.093	0.105	1.9	1.9
RA3	0.15	<0.028	69.9	0.078	0.260	2.0	2.2
TN1	0.18	<0.028	36.7	0.140	0.053	3.6	1.6
TN2	0.17	<0.028	34.8	0.133	0.035	2.9	2.2
TN3	0.23	<0.028	31.9	0.103	0.033	3.4	1.4
Minimum	**0.094**	**<0.028**	**31.9**	**0.058**	**0.033**	**1.59**	**1.42**
Maximum	**0.235**	**0.013**	**122**	**0.163**	**0.260**	**3.62**	**6.23**
DGV	11	NA	NA	NA	NA	NA	**8.0**

DGV = the default guideline value (95% species protection), where GVs for arsenic are for As(V), chromium are for Cr(VI), and tin are for inorganic tin. http://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/.

Values are **bold underline** where the default GV is exceeded

Particle size distribution

The particle size distribution of the Talbingo and Tantangara reservoir sediments are shown in Table 4. The mean diameter of the sediments were in the range 23.1 to 77.6 µm. The Dv (50) (50% of particles had lower diameter than this value) were all less than 30 µm, indicating the sediments were predominantly silt. Tantangara had a larger sediment particle size-range, which influenced its' slightly larger mean particle size.

Table 4. The particle size distribution of benthic sediments collected from Talbingo and Tantangara reservoirs.

Sediment ID	Reservoir	Dv (10) (µm)	Dv (50) (µm)	Dv (90) (µm)	Mean diameter (µm)
CA1	Talbingo	4.40	15.7	70.6	31.2
CA2	Talbingo	4.30	18.0	113	45.5
CA3	Talbingo	4.36	17.2	103	44.7
PL1	Talbingo	4.67	18.0	81.6	36.5
PL1 Dup	Talbingo	4.73	17.4	73.9	32.7
PL1	Talbingo	**4.70**	**17.7**	**77.8**	**34.6**
PL2	Talbingo	4.41	16.3	90.6	42.1
PL3	Talbingo	4.24	16.0	103	49.6
RA1	Talbingo	3.94	13.7	62.0	30.7
RA1 dup	Talbingo	3.93	13.5	60.8	28.8
RA1	Talbingo	**3.94**	**13.6**	**61.4**	**29.8**
RA2	Talbingo	3.66	11.5	43.9	23.1
RA3	Talbingo	3.75	12.0	47.7	24.2
TN1	Tantangara	5.57	27.4	223	77.6
TN2	Tantangara	4.84	20.1	132	50.5
TN3	Tantangara	4.63	20.3	133	48.7

Note: Dv (x) refers to 10, 50 and 90th percentiles of particle diameters (on spherical volume basis)

The total nitrogen and phosphorous, inorganic and organic carbon in benthic sediments

The total nitrogen, phosphorous, inorganic and organic carbon in benthic reservoir sediments are shown in Table 5. For the Talbingo reservoir, the RA sites generally had lower concentrations of each parameter than the CA and PL sites. The Tantangara reservoir benthic sediments had similar or higher concentrations of each parameter than those in the Talbingo reservoir. The concentrations of each parameter varied by approximately two-fold between the different sites in the two reservoirs.

The total Ca, K, Mg, Na, S and the cation exchange capacity of benthic sediments

The total Ca, K, Mg, Na, S in the benthic sediments and the sediment cation exchange capacity (CEC) is shown in Table 5. For the Talbingo reservoir sediments, calcium was the only major cation that varied between the sites, with lower concentrations being measured in the RA site sediments than the CA or PL sediments. The concentrations of calcium, magnesium, potassium and sodium were generally lower in the Tantangara reservoir sediments than the Talbingo reservoir sediments. The sulfur was higher in the Tantangara sediments and the CEC was similar for both reservoir sediments.

Table 5. The concentration of N, P, TIC, TOC, Ca, K, Mg, Na, S and CEC in benthic reservoir sediments

Sediment ID	Reservoir	Total N	Total P	TIC	TOC	Ca	K	Mg	Na	S	CEC
		(%)	(mg/kg)	(%)	(%)			(mg/kg)			(NH4) cmol (+/-)/kg
CA1	Talbingo	0.43	1340	0.2	5.8	1900	7150	5310	175	475	34
CA2	Talbingo	0.39	1170	0.1	5.5	2080	8670	6210	174	432	33
CA3	Talbingo	0.36	1140	0.1	4.5	1790	8580	7770	179	395	30
PL1	Talbingo	0.39	1080	0.1	5.5	2450	7280	6680	177	436	32
PL2	Talbingo	0.41	1030	0.2	6.0	1900	8800	6190	192	409	29
PL3	Talbingo	0.40	1130	0.2	5.4	1620	7790	6100	174	448	32
RA1	Talbingo	0.37	945	0.1	4.4	1480	8970	6630	163	395	27
RA2	Talbingo	0.36	945	0.1	4.2	1490	10230	7040	175	386	30
RA3	Talbingo	0.32	916	0.1	3.7	1450	8690	6570	146	338	26
TN1	Tantangara	0.54	1040	0.2	6.4	714	6650	3320	140	650	34
TN2	Tantangara	0.56	1500	0.2	5.7	783	7700	3490	150	742	36
TN3	Tantangara	0.54	1310	0.2	5.8	653	7480	3520	134	773	36
Minimum		**0.32**	**916**	**0.1**	**3.7**	**653**	**6650**	**3320**	**134**	**338**	**26**
Maximum		**0.56**	**1500**	**0.2**	**6.4**	**2450**	**10230**	**7770**	**192**	**773**	**36**

Where, TIC is total inorganic carbon, TOC is total organic carbon, CEC is cation exchange capacity [a] C.E.C. = Cation exchange capacity, determined using NH_4Cl solution, as per Rayment and Lyons (2011).

Total recoverable concentrations of metals, metalloid, and major cations in benthic sediments

The total recoverable concentrations of metal, metalloid, and other major ions in Talbingo and Tantangara sediments are shown in Table 6. There was generally higher concentrations of antinomy, calcium, chromium, copper, iron, potassium, magnesium, manganese, nickel, sodium, strontium, tin, thallium, and uranium in the Talbingo sediments and a higher concentration of sulfur in the Tantangara sediments.

These concentrations reflect the background surface sediment concentrations, and not surprisingly the concentrations of nickel exceed the corresponding SQGV that is considered an overly conservative value (Vangheluwe et al., 2013; Simpson and Batley 2016).

Dilute-acid extractable concentrations of metals, metalloid, and major cations in benthic sediments

A significant portion of the total element concentration (extracted using concentrated acids) may release inert (not easily released) fractions of metals that exhibit very low bioavailability to organisms. For most metals, the ‘maximum bioavailable concentration’ can be determined by dilute-acid extractable metal (AEM) analyses, as commonly achieved by extracting the solid in 1 M hydrochloric acid for 1 h (Simpson and Batley 2016). AEM data can also be useful for interpreting the partitioning behaviour of elements between the dissolved and particulate phases, and the availability of reactive binding phases.

The dilute-acid extractable concentrations of metal, metalloid, and other major ions in Talbingo and Tantangara sediments are shown in Table 7. There was generally little variation in the concentrations between the different sites in the Talbingo reservoir. However, the K, Mg and V were marginally lower for the RA sites than the CA and PL sites. A comparison between the two reservoirs showed that the 1 M HCl-extractable concentrations of As, Ba, Ca, Cr, Cu, K, Mg, Mn, Na, Ni, Th and U from the Talbingo reservoir sediments were generally higher than those measured in the Tantangara reservoir, while a higher concentration of sulfur was extracted from the Tantangara reservoir sediments.

No concentrations of diluted acid-extractable metals, metalloids and major cations exceeded their respective SQGV’s.

Table 6. Total recoverable concentrations of metals, metalloids, and major ions in the sediments of the Talbingo and Tantangara reservoir waters

Sediment ID	Reservoir	Al (mg/kg)	Ag (mg/kg)	As (mg/kg)	Ba (mg/kg)	Cd (mg/kg)	Ca (mg/kg)	Co (mg/kg)	Cr (mg/kg)	Cu (mg/kg)
CA1	Talbingo	23000	0.14	9.2	250	0.24	1800	30	56	41
CA2	Talbingo	23000	0.13	8.6	270	0.17	1900	23	56	37
CA3	Talbingo	42000	0.15	12	300	0.27	1900	30	78	51
PL1	Talbingo	31000	0.11	8.8	220	0.15	1800	28	72	46
PL2	Talbingo	35000	0.14	11	250	0.23	2200	26	61	52
PL3	Talbingo	36000	0.14	12	240	0.26	1600	30	62	51
PL3 duplicate	Talbingo	36000	0.15	12	240	0.21	1600	30	61	51
PL3 Mean	**Talbingo**	**36000**	**0.14**	**12**	**240**	**0.23**	**1600**	**30**	**61**	**51**
RA1	Talbingo	20000	0.14	10	240	0.27	1400	24	48	46
RA2	Talbingo	36000	0.16	14	280	0.22	1700	25	59	49
RA3	Talbingo	26000	0.15	15	320	0.23	1700	25	52	48
TN1	Tantangara	17000	0.12	5.4	180	0.27	720	15	27	26
TN2	Tantangara	31000	0.16	6.7	230	0.25	840	23	37	28
TN3	Tantangara	23750	0.15	8.2	240	0.25	1150	26	41	32
Minimum		**17000**	**0.11**	**5.4**	**180**	**0.15**	**720**	**15**	**27**	**26**
Maximum		**42000**	**0.16**	**15**	**320**	**0.28**	**2200**	**30**	**78**	**52**
SQGV			**1**	**20**	**NA**	**1.5**	**NA**	**NA**	**80**	**65**

Sediment ID	Reservoir	Fe (mg/kg)	Hg (mg/kg)	K (mg/kg)	Mg (mg/kg)	Mn (mg/kg)	Mo (mg/kg)	Na (mg/kg)	Ni (mg/kg)	Pb (mg/kg)
CA1	Talbingo	49000	<0.1	2200	4400	2200	0.60	58	44	25
CA2	Talbingo	44000	<0.1	3400	5400	1900	0.63	51	43	24
CA3	Talbingo	56000	<0.1	6000	8000	4000	0.60	120	68	26
PL1	Talbingo	45000	<0.1	3100	6400	1900	0.56	83	64	22
PL2	Talbingo	45000	<0.1	3100	5700	3000	0.99	100	56	28
PL3	Talbingo	57000	<0.1	3400	5900	2400	0.67	120	54	27
PL3 duplicate	Talbingo	73000	<0.1	3500	5800	2500	0.65	92	54	27
PL3 Mean	**Talbingo**	**65000**	**<0.1**	**3400**	**5800**	**2400**	**0.66**	**100**	**54**	**27**
RA1	Talbingo	37000	<0.1	1600	5400	2100	0.49	27	48	28
RA2	Talbingo	42000	<0.1	4000	6400	2800	0.40	85	60	32
RA3	Talbingo	45000	<0.1	2500	6000	4000	0.39	48	56	30
TN1	Tantangara	25000	<0.1	1200	2200	540	0.45	44	13	23
TN2	Tantangara	39000	<0.1	2400	2600	740	0.36	70	19	28
TN3	Tantangara	41700	<0.1	3180	4590	2390	0.45	45	27	27
Minimum		**25000**	**<0.1**	**1200**	**2200**	**540**	**0.36**	**26**	**13**	**22**
Maximum		**73000**	**<0.1**	**6000**	**8000**	**4000**	**0.99**	**120**	**68**	**32**
SQGV			**0.15**	**NA**	**NA**	**NA**	**NA**	**NA**	**21**	**50**

Sediment ID	Reservoir	Sb (mg/kg)	Se (mg/kg)	Sn (mg/kg)	Sr (mg/kg)	Th (mg/kg)	U (mg/kg)	V (mg/kg)	Zn (mg/kg)	P (mg/kg)	S (mg/kg)
CA1	Talbingo	0.43	0.47	1.3	27	12	3.8	66	79	1400	650
CA2	Talbingo	0.47	0.44	1.4	35	10	3.2	63	81	1300	600
CA3	Talbingo	0.51	0.57	1.9	33	14	4.2	85	109	1300	550
PL1	Talbingo	0.52	0.48	1.4	28	11	3.2	66	92	1200	630
PL2	Talbingo	0.56	0.58	1.7	31	12	4.3	65	110	1100	570
PL3	Talbingo	0.57	0.56	1.7	29	12	3.9	67	99	1300	630
PL3 duplicate	Talbingo	0.52	0.54	1.6	29	12	3.9	66	99	1300	640
PL3 Mean	**Talbingo**	**0.54**	**0.55**	**1.6**	**29**	**12**	**3.9**	**67**	**99**	**1300**	**640**
RA1	Talbingo	0.62	0.47	1.2	15	10	3.6	47	91	1000	510
RA2	Talbingo	0.75	0.50	1.9	22	13	3.5	53	113	1000	510
RA3	Talbingo	0.74	0.45	1.4	17	12	3.0	43	99	1100	480
TN1	Tantangara	0.28	0.43	0.83	11	6.0	1.2	49	85	1200	880
TN2	Tantangara	0.31	0.46	1.3	18	9.2	1.5	59	102	1700	940
TN3	Tantangara	0.37	0.49	1.3	17	10	2.1	65	104	1305	762
Minimum		**0.28**	**0.43**	**0.8**	**11**	**6.0**	**1.2**	**43**	**79**	**1000**	**480**
Maximum		**0.76**	**0.58**	**1.9**	**35**	**14**	**4.3**	**85**	**114**	**1700**	**940**
SQGV		**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**200**	**NA**	**NA**

SQGV = the sediment quality guideline values (Simpson e al., 2013). **Values are bold underline where the default GV is exceeded.**

Table 6. Dilute-acid extractable concentrations of metals, metalloids, and major ions in the sediments of the Talbingo and Tantangara reservoir waters

Sediment ID	Reservoir	Ag (mg/kg)	Al (mg/kg)	As (mg/kg)	Ba (mg/kg)	Ca (mg/kg)	Cd (mg/kg)	Co (mg/kg)	Cr (mg/kg)	Cu (mg/kg)
CA1	Talbingo	0.068	4740	3.85	205	1630	0.161	19.0	8.57	21.2
CA2	Talbingo	0.046	4280	3.12	208	1660	0.096	13.6	7.40	18.6
CA3	Talbingo	0.065	5020	3.82	210	1420	0.194	16.7	7.89	23.3
PL1	Talbingo	0.047	4550	3.04	168	1360	0.077	16.5	7.19	20.7
PL2	Talbingo	0.071	4590	3.27	174	1650	0.187	15.2	6.46	24.4
PL3	Talbingo	0.074	4600	4.45	169	1160	0.187	19.0	7.08	23.0
RA1	Talbingo	0.061	4280	3.92	205	1340	0.179	15.6	5.74	26.8
RA2	Talbingo	0.045	3910	4.58	213	1410	0.251	16.2	6.68	24.5
RA3	Talbingo	0.061	3460	6.60	260	1520	0.215	16.8	6.04	25.2
TN1	Tantangara	0.039	3620	1.81	141	661	0.192	7.19	3.05	13.0
TN2	Tantangara	0.085	3980	2.09	164	760	0.229	13.3	5.84	14.3
TN3	Tantangara	0.074	4460	2.81	158	649	0.310	15.6	6.30	14.8
Minimum		**0.039**	**3460**	**1.81**	**141**	**649**	**0.077**	**7.19**	**3.05**	**13**
Maximum		**0.085**	**5020**	**6.6**	**260**	**1660**	**0.31**	**19**	**8.57**	**26.8**
SQGV		**1**	**NA**	**20**	**NA**	**NA**	**1.5**	**NA**	**80**	**65**

Sediment ID	Reservoir	Fe (mg/kg)	Hg (mg/kg)	K (mg/kg)	Mg (mg/kg)	Mn (mg/kg)	Mo (mg/kg)	Na (mg/kg)	Ni (mg/kg)	Pb (mg/kg)
CA1	Talbingo	23500	<0.008	248	356	1910	<0.071	70.7	8.97	17.4
CA2	Talbingo	17300	<0.008	389	560	1630	<0.071	77.2	8.01	16.0
CA3	Talbingo	16800	<0.008	467	488	3360	<0.071	58.7	10.3	17.3
PL1	Talbingo	17000	<0.008	263	463	1690	<0.071	71.6	9.33	15.4
PL2	Talbingo	15900	<0.008	245	336	2490	0.084	56.6	8.50	19.4
PL3	Talbingo	25100	<0.008	294	384	2110	0.12	68.7	7.11	17.5
RA1	Talbingo	14400	<0.008	217	246	1920	<0.071	63.3	8.05	21.3
RA2	Talbingo	14700	<0.008	209	239	2540	<0.071	59.5	9.33	22.1
RA3	Talbingo	17800	<0.008	193	201	3640	0.098	76.8	8.83	21.0
TN1	Tantangara	12400	<0.008	154	189	470	<0.071	55.8	2.40	15.0
TN2	Tantangara	20200	<0.008	208	195	646	0.079	<41.8	3.42	18.5
TN3	Tantangara	21900	<0.008	163	172	753	<0.071	47.2	3.93	19.5
Minimum		**12400**	**<0.008**	**154**	**172**	**470**	**0.079**	**47.2**	**2.4**	**15**
Maximum		**25100**	**<0.008**	**467**	**560**	**3640**	**0.12**	**77.2**	**10.3**	**22.1**
SQGV		**NA**	**0.15**	**NA**	**NA**	**NA**	**NA**	**NA**	**21**	**50**

Sediment ID	Reservoir	Sb (mg/kg)	Se (mg/kg)	Sn (mg/kg)	Sr (mg/kg)	Th (mg/kg)	U (mg/kg)	V (mg/kg)	Zn (mg/kg)	P (mg/kg)	S (mg/kg)
CA1	Talbingo	<0.024	0.044	0.238	16.6	0.324	1.97	32.7	32.3	921	<43.6
CA2	Talbingo	<0.024	0.034	0.209	26.3	0.165	1.27	28.5	27.4	771	62.5
CA3	Talbingo	0.047	0.032	0.201	12.5	0.347	2.65	29.8	34.6	708	45.5
PL1	Talbingo	0.034	0.044	0.160	11.8	0.218	1.52	29.7	30.4	686	43.8
PL2	Talbingo	0.039	0.043	0.089	15.1	0.250	2.35	30.7	37.3	583	<43.6
PL3	Talbingo	0.028	0.032	0.152	13.3	0.299	2.23	28.4	33.0	705	<43.6
RA1	Talbingo	0.037	0.028	0.170	10.1	0.284	2.19	24.4	36.6	573	<43.6
RA2	Talbingo	0.034	0.034	0.191	10.9	0.160	1.20	22.2	30.9	584	<43.6
RA3	Talbingo	0.039	0.043	0.210	10.8	0.254	1.38	19.2	28.2	638	<43.6
TN1	Tantangara	0.029	0.023	0.107	7.72	0.070	0.451	30.8	49.1	545	76.7
TN2	Tantangara	<0.024	0.033	0.282	8.43	0.057	0.688	33.4	43.4	1090	104
TN3	Tantangara	0.033	0.038	0.219	7.2	0.113	0.638	37.1	54.6	890	124
Minimum		**0.028**	**0.023**	**0.089**	**7.2**	**0.057**	**0.451**	**19.2**	**27.4**	**545**	**43.8**
Maximum		**0.047**	**0.044**	**0.282**	**26.3**	**0.347**	**2.65**	**37.1**	**54.6**	**1090**	**124**
SQGV		**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**200**	**NA**	**NA**

SQGV = the sediment quality guideline values (Simpson e al., 2013). **Values are bold underline where the default GV is exceeded.**

Summary

The concentrations of many of the parameters often differed between the two reservoirs.

There were no exceedances of diluted-extractable metal, metalloid or major cation concentrations above SQGV's.

References

Rayment, G.E and Lyons, D.J. (2011). Exchangeable bases and CEC (method 15D2). In 'Soil Chemical Methods - Australasia'. (CSIRO publishing, Melbourne). pp 318-321.

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Vangheluwe MLU, Verdonck FAM, Besser JM, Brumbaugh WG, Ingersoll CG, Schlekat CE, Garman ER (2013) Improving sediment-quality guidelines for nickel: Development and application of predictive bioavailability models to assess chronic toxicity of nickel in freshwater sediments. Environmental Toxicology and Chemistry 32, 2507–2519.

Sediment analyses *Total recoverable metals (TRM)*

		TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g
Sample ID	**Sample Description**	**Al**	**Ag**	**As**	**Au**	**B**	**Ba**	**Be**	**Bi**	**Cd**	**Ca**	**Ce**	**Co**	**Cr**	**Cu**	**Cs**	**Dy**	**Er**	**Eu**
CE491-8	TN2_P4 - 19 metres	31000	0.16	6.7	<0.003	2.5	230	1.8	0.42	0.25	840	71	23	37	28	5.4	4.6	2.3	1.3
CE491-9	TN1_P4 - 16.5 metres	17000	0.12	5.4	<0.003	0.4	180	1.5	0.35	0.27	720	57	15	27	26	2.6	3.9	2.0	1.1
CE491-10	TN3_P4 - 18.5 metres	22000	0.15	7.2	<0.003	0.8	210	1.7	0.42	0.26	680	67	25	31	28	3.7	4.3	2.2	1.2
CE491-10 dup	TN3_P4 - 18.5 metres dig dup	25000	0.14	10	<0.003	0.8	260	2.0	0.54	0.18	1600	78	28	63	46	6.0	4.8	2.3	1.4
CE491-10 average	**TN3_P4 - 18.5 metres avg**	**24000**	**0.15**	**8.7**	**<0.003**	**0.8**	**240**	**1.8**	**0.48**	**0.22**	**1100**	**72**	**27**	**47**	**37**	**4.8**	**4.6**	**2.3**	**1.3**
CE491-10	TN3_P4 - 18.5 metres	32000	0.16	7.5	<0.003	3.4	230	1.7	0.42	0.27	710	70	24	34	27	4.0	4.4	2.2	1.2
CE491-10 dup	TN3_P4 - 18.5 metres dig dup	39000	0.16	8.0	<0.003	5.1	240	1.8	0.43	0.27	730	74	25	37	28	4.5	4.6	2.4	1.3
CE491-10 average	**TN3_P4 - 18.5 metres avg**	**35000**	**0.16**	**7.7**	**<0.003**	**4.3**	**240**	**1.8**	**0.43**	**0.27**	**720**	**72**	**25**	**36**	**28**	**4.2**	**4.5**	**2.3**	**1.3**
CE491-11	CA3_P4 - 48 metres	42000	0.15	12	0.008	3.4	300	2.3	0.58	0.27	1900	92	30	78	51	8.4	5.4	2.7	1.6
CE491-12	RA1_P4 - 31.5 metres	20000	0.14	10	0.006	0.6	250	2.0	0.74	0.28	1400	75	24	48	46	7.8	4.5	2.3	1.4
CE491-12	RA1_P4 - 31.5 metres dil dup	20000	0.15	11	0.003	0.6	240	2.1	0.73	0.26	1400	75	24	48	46	7.8	4.6	2.3	1.4
CE491-12 average	**RA1_P4 - 31.5 metres avg**	**20000**	**0.14**	**10**	**0.004**	**0.6**	**240**	**2.0**	**0.73**	**0.27**	**1400**	**75**	**24**	**48**	**46**	**7.8**	**4.6**	**2.3**	**1.4**
CE491-13	PL1_P4 - 33.5 metres	31000	0.11	8.8	<0.003	2.3	220	1.9	0.48	0.15	1800	76	28	72	46	6.1	4.3	2.1	1.3
CE491-14	CA1_P4 - 30 metres	23000	0.14	9.2	<0.003	0.4	250	2.2	0.57	0.24	1800	85	30	56	41	5.2	5.5	2.7	1.6
CE491-15	PL3_P4 - 27 metres	36000	0.14	12	<0.003	3.3	240	2.1	0.62	0.26	1600	86	30	62	51	8.3	4.8	2.3	1.5
CE491-15 Dup	PL3_P4 - 27 metres dig dup	36000	0.15	12	<0.003	3.3	240	2.2	0.62	0.21	1600	85	30	61	51	8.2	4.7	2.4	1.5
CE491-15 average	**PL3_P4 - 27 metres avg**	**36000**	**0.14**	**12**	**<0.003**	**3.3**	**240**	**2.2**	**0.62**	**0.23**	**1600**	**85**	**30**	**61**	**51**	**8.3**	**4.7**	**2.4**	**1.5**
CE491-16	RA3_P4 - 28.5 metres	26000	0.15	15	<0.003	2.2	320	2.1	0.81	0.23	1700	83	25	52	48	10	4.9	2.4	1.5
CE491-17	PL2_P4 - 26.5 metres	35000	0.14	11	<0.003	2.9	250	2.2	0.64	0.23	2200	91	26	61	52	7.4	4.9	2.5	1.6
CE491-18	CA2_P4 - 42 metres	23000	0.13	8.6	<0.003	0.7	270	1.9	0.52	0.17	1900	78	23	56	37	5.1	4.7	2.3	1.5
CE491-19	RA2_P4 - 29 metres	36000	0.16	14	<0.003	5.7	280	2.4	0.84	0.25	1700	89	25	59	49	15	5.3	2.6	1.6
CE491-19	RA2_P4 - 29 metres dil dup	36000	0.16	14	<0.003	5.6	290	2.4	0.83	0.18	1700	89	25	60	49	15	5.3	2.7	1.6
CE491-19 average	RA2_P4 - 29 metres avg	**36000**	**0.16**	**14**	**<0.003**	**5.6**	**280**	**2.4**	**0.83**	**0.22**	**1700**	**89**	**25**	**59**	**49**	**15**	**5.3**	**2.7**	**1.6**
LOD 3σ	---	10	0.0003	0.01	0.003	0.1	0.03	0.001	0.004	0.01	5	0.004	0.01	0.1	0.02	0.01	0.001	0.0002	0.0001
Method Code:	---	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209

Method Codes: C-209: ICP-MS C-229: ICP-AES C-223 Total recoverable metals by Aqua Regia microwave digest

Certified Reference Materials

		TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g
Sample ID	**Sample Description**	**Al**	**Ag**	**As**	**Au**	**B**	**Ba**	**Be**	**Bi**	**Cd**	**Ca**	**Ce**	**Co**	**Cr**	**Cu**	**Cs**	**Dy**	**Er**	**Eu**
ERM-CC018-1		5100	2.1	20	0.041	5.8	370	0.52	1.1	5.5	18000	15	4.8	130	74	0.80	0.85	0.44	0.26
ERM-CC018-1		5100	2.1	21	0.040	5.9	370	0.52	1.2	5.2	18000	15	4.8	130	74	0.81	0.86	0.45	0.26
ERM-CC018-2		5200	2.1	21	0.038	6.0	380	0.53	1.1	5.5	18000	15	4.8	130	76	0.81	0.86	0.44	0.26
ERM-CC018 average		**5100**	**2.1**	**20**	**0.039**	**5.9**	**370**	**0.52**	**1.1**	**5.4**	**18000**	**15**	**4.8**	**130**	**75**	**0.81**	**0.86**	**0.44**	**0.26**
Certified Value		---	---	22.9 ± 1.3	---	---	---	---	---	5.4 ± 0.5	---	---	5.9 ± 0.4	129 ± 6	80 ± 4	---	---	---	---
OREAS-25a-1		68000	0.08	5.9	<0.003	8.3	64	0.76	0.31	0.04	1400	41	6.9	93	29	5.8	1.4	0.66	0.54
OREAS-25a-2		62000	0.08	5.5	<0.003	6.1	59	0.71	0.31	0.04	1400	38	6.4	88	27	5.3	1.3	0.60	0.50
OREAS-25a average		**65000**	**0.08**	**5.7**	**<0.003**	**7.2**	**61**	**0.74**	**0.31**	**0.04**	**1400**	**39**	**6.6**	**90**	**28**	**5.6**	**1.4**	**0.63**	**0.52**
Certified Value		58500	---	---	---	---	56	---	0.30	---	1500	33.1	5.72	73	24.9	4.45	---	---	---

ERM-CC018 is a European sandy soil reference material *OREAS-25a is an Australian reference soil. Certified values reported are for an Aqua Regia Digestion*

Spike Recoveries

		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Sample ID	**Sample Description**	**Al**	**Ag**	**As**	**Au**	**B**	**Ba**	**Be**	**Bi**	**Cd**	**Ca**	**Ce**	**Co**	**Cr**	**Cu**	**Cs**	**Dy**	**Er**	**Eu**
CE491-12	RA1_P4 - 31.5 metres	---	101	109	107	105	94	107	106	104	91	110	102	104	105	110	107	108	108
CE491-19	RA2_P4 - 29 metres	---	98	106	105	103	96	108	104	103	106	109	98	106	103	108	106	107	108

Analyte of interest added to sample prior to analysis

Sediment analyses ***Total recoverable metals (TRM)***

		TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g
Sample ID	**Sample Description**	**Fe**	**Ga**	**Gd**	**Ge**	**Hf**	**Hg**	**Ho**	**In**	**Ir**	**K**	**La**	**Li**	**Lu**	**Mg**	**Mn**	**Mo**	**Na**	**Nb**
CE491-8	TN2_P4 - 19 metres	39000	9.2	6.0	0.31	0.31	<0.1	0.85	0.043	<0.001	2400	32	19	0.24	2600	740	0.36	70	0.31
CE491-9	TN1_P4 - 16.5 metres	25000	6.0	4.9	0.24	0.18	<0.1	0.73	0.031	<0.001	1200	24	9.5	0.20	2200	540	0.45	44	0.25
CE491-10	TN3_P4 - 18.5 metres	38000	7.1	5.6	0.24	0.26	<0.1	0.82	0.036	<0.001	1700	28	13	0.23	2300	820	0.42	26	0.27
CE491-10 dup	TN3_P4 - 18.5 metres dig dup	49000	8.8	6.5	0.23	0.23	<0.1	0.89	0.044	<0.001	4600	36	24	0.24	6800	3900	0.55	53	1.2
CE491-10 average	**TN3_P4 - 18.5 metres avg**	**44000**	**7.9**	**6.1**	**0.24**	**0.25**	**<0.1**	**0.85**	**0.040**	**<0.001**	**3200**	**32**	**18**	**0.24**	**4600**	**2400**	**0.49**	**40**	**0.75**
CE491-10	TN3_P4 - 18.5 metres	37000	9.7	5.8	0.15	0.22	0.3	0.82	0.040	<0.001	2600	31	18	0.23	2800	810	0.42	67	0.33
CE491-10 dup	TN3_P4 - 18.5 metres dig dup	38000	11	6.0	0.15	0.25	0.2	0.87	0.046	<0.001	3500	34	20	0.25	3000	800	0.42	67	0.33
CE491-10 average	**TN3_P4 - 18.5 metres avg**	**38000**	**10**	**5.9**	**0.15**	**0.23**	**0.3**	**0.84**	**0.043**	**<0.001**	**3000**	**33**	**19**	**0.24**	**2900**	**810**	**0.42**	**67**	**0.33**
CE491-11	CA3_P4 - 48 metres	56000	12	7.5	0.36	0.35	<0.1	0.99	0.056	<0.001	6000	45	34	0.27	8000	4000	0.60	120	0.98
CE491-12	RA1_P4 - 31.5 metres	37000	6.6	6.2	0.28	0.24	<0.1	0.85	0.037	<0.001	1600	34	19	0.23	5400	2100	0.47	27	0.50
CE491-12	RA1_P4 - 31.5 metres dil dup	37000	6.7	6.2	0.23	0.24	<0.1	0.87	0.035	<0.001	1600	34	19	0.24	5400	2100	0.51	26	0.50
CE491-12 average	**RA1_P4 - 31.5 metres avg**	**37000**	**6.6**	**6.2**	**0.26**	**0.24**	**<0.1**	**0.86**	**0.036**	**<0.001**	**1600**	**34**	**19**	**0.23**	**5400**	**2100**	**0.49**	**27**	**0.50**
CE491-13	PL1_P4 - 33.5 metres	45000	9.2	5.9	0.26	0.20	<0.1	0.79	0.040	<0.001	3100	35	27	0.22	6400	1900	0.56	83	0.62
CE491-14	CA1_P4 - 30 metres	49000	7.5	7.0	0.25	0.26	<0.1	1.0	0.039	<0.001	2200	38	18	0.27	4400	2200	0.60	58	1.5
CE491-15	PL3_P4 - 27 metres	57000	10	6.6	0.23	0.31	<0.1	0.88	0.048	<0.001	3400	41	28	0.24	5900	2400	0.67	120	0.54
CE491-15 Dup	PL3_P4 - 27 metres dig dup	73000	10	6.7	0.23	0.26	<0.1	0.88	0.049	<0.001	3500	40	28	0.24	5800	2500	0.65	92	0.42
CE491-15 average	**PL3_P4 - 27 metres avg**	**65000**	**10**	**6.7**	**0.23**	**0.29**	**<0.1**	**0.88**	**0.048**	**<0.001**	**3400**	**40**	**28**	**0.24**	**5800**	**2400**	**0.66**	**100**	**0.48**
CE491-16	RA3_P4 - 28.5 metres	45000	7.8	6.9	0.28	0.29	<0.1	0.89	0.038	<0.001	2500	39	29	0.25	6000	4000	0.39	48	0.46
CE491-17	PL2_P4 - 26.5 metres	45000	10	7.0	0.26	0.28	<0.1	0.92	0.046	<0.001	3100	43	28	0.26	5700	3000	0.99	100	0.57
CE491-18	CA2_P4 - 42 metres	44000	7.7	6.5	0.28	0.23	<0.1	0.86	0.041	<0.001	3400	37	19	0.22	5400	1900	0.63	51	1.4
CE491-19	RA2_P4 - 29 metres	41000	10	7.3	0.27	0.26	<0.1	0.98	0.049	<0.001	4000	43	34	0.28	6400	2800	0.39	86	0.43
CE491-19	RA2_P4 - 29 metres dil dup	42000	10	7.3	0.33	0.25	<0.1	0.97	0.050	<0.001	4000	43	33	0.27	6400	2800	0.42	84	0.43
CE491-19 average	RA2_P4 - 29 metres avg	**42000**	**10**	**7.3**	**0.30**	**0.25**	**<0.1**	**0.97**	**0.050**	**<0.001**	**4000**	**43**	**33**	**0.27**	**6400**	**2800**	**0.40**	**85**	**0.43**
LOD 3σ	---	2	0.002	0.001	0.03	0.001	0.1	0.0003	0.001	0.001	20	0.002	0.01	0.0004	2	0.03	0.002	20	0.001
Method Code:	---	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-229	C-223/C-229	C-223/C-209	C-223/C-229	C-223/C-209

Certified Reference Materials

		TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g
Sample ID	**Sample Description**	**Fe**	**Ga**	**Gd**	**Ge**	**Hf**	**Hg**	**Ho**	**In**	**Ir**	**K**	**La**	**Li**	**Lu**	**Mg**	**Mn**	**Mo**	**Na**	**Nb**
ERM-CC018-1		9900	2.3	1.1	0.65	0.16	1.4	0.16	0.075	<0.001	---	7.1	6.3	0.052	1170	190	13	---	0.64
ERM-CC018-1		9800	2.4	1.1	0.65	0.15	1.4	0.16	0.073	<0.001	---	7.2	6.2	0.055	1157	190	13	---	0.64
ERM-CC018-2		10000	2.4	1.1	0.64	0.15	1.4	0.16	0.071	0.001	---	7.2	6.2	0.054	1174	190	14	---	0.64
ERM-CC018 average		**9900**	**2.4**	**1.1**	**0.65**	**0.15**	**1.4**	**0.16**	**0.073**	**<0.001**	**---**	**7.2**	**6.2**	**0.054**	**1167**	**190**	**13**	**---**	**0.64**
Certified Value		---	---	---	---	---	1.38 ± 0.06	---	---	---	---	---	---	---	---	---	---	---	---
OREAS-25a-1		60000	23	2.3	0.14	1.2	<0.1	0.24	0.092	0.002	2000	18	32	0.071	2283	440	1.6	---	0.24
OREAS-25a-2		59000	22	2.2	0.23	1.1	<0.1	0.23	0.089	0.002	1800	16	31	0.067	2121	430	1.6	---	0.28
OREAS-25a average		**60000**	**23**	**2.3**	**0.18**	**1.1**	**<0.1**	**0.24**	**0.090**	**0.002**	**1900**	**17**	**31**	**0.069**	**2202**	**440**	**1.6**	**---**	**0.26**
Certified Value		59900	---	---	---	---	---	---	---	---	1310	---	---	---	---	420	---	---	---

ERM-CC018 is a European sandy soil reference material

Spike Recoveries

		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Sample ID	**Sample Description**	**Fe**	**Ga**	**Gd**	**Ge**	**Hf**	**Hg**	**Ho**	**In**	**Ir**	**K**	**La**	**Li**	**Lu**	**Mg**	**Mn**	**Mo**	**Na**	**Nb**
CE491-12	RA1_P4 - 31.5 metres	---	105	107	100	106	---	108	106	105	106	110	104	108	---	93	104	104	106
CE491-19	RA2_P4 - 29 metres	---	99	106	95	105	---	107	105	104	129	107	105	108	---	115	103	102	101

Analyte of interest added to sample prior to analysis

Sediment analyses ***Total recoverable metals (TRM)***

		TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g
Sample ID	**Sample Description**	**Nd**	**Ni**	**Os**	**P**	**Pb**	**Pd**	**Pt**	**Pr**	**Rb**	**Re**	**Rh**	**Ru**	**S**	**Sb**	**Sc**	**Se**	**Sm**	**Sn**
CE491-8	TN2_P4 - 19 metres	31	19	<0.2	1700	28	0.26	<0.001	7.9	45	0.001	<0.01	<0.02	940	0.31	7.7	0.46	6.2	1.3
CE491-9	TN1_P4 - 16.5 metres	24	13	<0.2	1200	23	0.23	<0.001	6.2	26	0.001	<0.01	<0.02	880	0.28	5.8	0.43	5.1	0.83
CE491-10	TN3_P4 - 18.5 metres	28	16	<0.2	1400	27	0.26	<0.001	7.2	34	0.001	<0.01	<0.02	1000	0.33	6.7	0.47	5.9	1.0
CE491-10 dup	TN3_P4 - 18.5 metres dig dup	34	53	<0.2	1200	24	0.28	<0.001	8.8	58	0.001	<0.01	<0.02	520	0.45	9.7	0.47	6.8	1.4
CE491-10 average	**TN3_P4 - 18.5 metres avg**	**31**	**35**	**<0.2**	**1300**	**26**	**0.27**	**<0.001**	**8.0**	**46**	**0.001**	**<0.01**	**<0.02**	**760**	**0.39**	**8.2**	**0.47**	**6.4**	**1.2**
CE491-10	TN3_P4 - 18.5 metres	30	19	<0.2	1400	28	0.26	<0.001	7.6	48	<0.001	<0.01	<0.02		0.33	7.4	0.50	6.0	1.3
CE491-10 dup	TN3_P4 - 18.5 metres dig dup	32	21	<0.2	1500	29	0.27	<0.001	8.2	59	0.001	<0.01	<0.02		0.35	8.2	0.52	6.3	1.5
CE491-10 average	**TN3_P4 - 18.5 metres avg**	**31**	**20**	**<0.2**	**1450**	**28**	**0.26**	**<0.001**	**7.9**	**53**	**0.001**	**<0.01**	**<0.02**		**0.34**	**7.8**	**0.51**	**6.2**	**1.4**
CE491-11	CA3_P4 - 48 metres	40	68	<0.2	1300	26	0.30	0.001	11	79	0.001	<0.01	<0.02	550	0.51	11.9	0.57	8.0	1.9
CE491-12	RA1_P4 - 31.5 metres	33	48	<0.2	1000	28	0.26	<0.001	8.4	31	0.001	<0.01	<0.02	510	0.62	6.4	0.46	6.6	1.2
CE491-12	RA1_P4 - 31.5 metres dil dup	33	48	<0.2	1000	28	0.25	<0.001	8.4	30	0.001	<0.01	<0.02	510	0.63	7.1	0.47	6.7	1.2
CE491-12 average	**RA1_P4 - 31.5 metres avg**	**33**	**48**	**<0.2**	**1000**	**28**	**0.25**	**<0.001**	**8.4**	**30**	**0.001**	**<0.01**	**<0.02**	**510**	**0.62**	**6.7**	**0.47**	**6.6**	**1.2**
CE491-13	PL1_P4 - 33.5 metres	33	64	<0.2	1200	22	0.25	<0.001	8.4	47	0.001	<0.01	<0.02	630	0.52	9.3	0.48	6.4	1.4
CE491-14	CA1_P4 - 30 metres	36	44	<0.2	1400	25	0.30	0.001	9.3	37	0.001	<0.01	<0.02	650	0.43	8.5	0.47	7.3	1.3
CE491-15	PL3_P4 - 27 metres	37	54	<0.2	1300	27	0.28	<0.001	9.5	50	<0.001	<0.01	<0.02	630	0.57	8.9	0.56	7.2	1.7
CE491-15 Dup	PL3_P4 - 27 metres dig dup	37	54	<0.2	1300	27	0.27	<0.001	9.4	49	<0.001	<0.01	<0.02	640	0.52	9.3	0.54	7.2	1.6
CE491-15 average	**PL3_P4 - 27 metres avg**	**37**	**54**	**<0.2**	**1300**	**27**	**0.28**	**<0.001**	**9.5**	**49**	**<0.001**	**<0.01**	**<0.02**	**640**	**0.54**	**9.1**	**0.55**	**7.2**	**1.6**
CE491-16	RA3_P4 - 28.5 metres	37	56	<0.2	1100	30	0.27	0.001	9.6	41	<0.001	<0.01	<0.02	480	0.74	7.4	0.45	7.5	1.4
CE491-17	PL2_P4 - 26.5 metres	39	56	<0.2	1100	28	0.29	0.001	10	50	0.001	<0.01	<0.02	570	0.56	8.7	0.58	7.7	1.7
CE491-18	CA2_P4 - 42 metres	35	43	<0.2	1300	24	0.28	<0.001	9.0	44	<0.001	<0.01	<0.02	600	0.47	7.9	0.44	6.9	1.4
CE491-19	RA2_P4 - 29 metres	40	60	<0.2	1000	32	0.29	0.001	10	55	<0.001	<0.01	<0.02	510	0.74	8.3	0.49	8.0	1.9
CE491-19	RA2_P4 - 29 metres dil dup	40	61	<0.2	1000	32	0.31	<0.001	10	58	<0.001	<0.01	<0.02	510	0.76	8.3	0.51	8.1	1.9
CE491-19 average	RA2_P4 - 29 metres avg	**40**	**60**	**<0.2**	**1000**	**32**	**0.30**	**<0.001**	**10**	**56**	**<0.001**	**<0.01**	**<0.02**	**510**	**0.75**	**8.3**	**0.50**	**8.0**	**1.9**
LOD 3σ	---	0.001	0.04	0.2	1	0.01	0.003	0.001	0.0004	0.02	0.001	0.01	0.02	10	0.001	0.0004	0.002	0.002	0.004
Method Code:	---	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209

Certified Reference Materials

		TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g
Sample ID	**Sample Description**	**Nd**	**Ni**	**Os**	**P**	**Pb**	**Pd**	**Pt**	**Pr**	**Rb**	**Re**	**Rh**	**Ru**	**S**	**Sb**	**Sc**	**Se**	**Sm**	**Sn**
ERM-CC018-1		6.1	23	<0.2	860	309	0.085	0.015	1.7	6.0	0.001	0.02	<0.02	1000	3.1	1.4	0.47	1.2	13
ERM-CC018-1		6.2	24	<0.2	860	310	0.087	0.013	1.7	6.5	0.002	0.01	<0.02	1000	3.0	1.3	0.52	1.2	13
ERM-CC018-2		6.3	24	<0.2	880	310	0.091	0.013	1.7	5.6	0.001	0.01	<0.02	1000	2.9	1.5	0.51	1.2	13
ERM-CC018 average		**6.2**	**24**	**<0.2**	**870**	**309**	**0.088**	**0.013**	**1.7**	**6.0**	**0.001**	**0.02**	**<0.02**	**1000**	**3.0**	**1.4**	**0.50**	**1.2**	**13**
Certified Value		---	25.8 ± 1.8	---	---	289 ± 10	---	---	---	---	---	---	---	---	---	---	---	---	---
OREAS-25a-1		15	39	<0.2	400	22	0.068	0.003	4.1	44	<0.001	<0.01	<0.02	480	0.34	12	1.7	2.9	3.1
OREAS-25a-2		14	35	<0.2	400	22	0.063	0.004	3.8	40	<0.001	<0.01	<0.02	470	0.31	10	1.5	2.7	3.0
OREAS-25a average		**15**	**37**	**<0.2**	**400**	**22**	**0.065**	**0.003**	**4.0**	**42**	**<0.001**	**<0.01**	**<0.02**	**480**	**0.32**	**11**	**1.6**	**2.8**	**3.0**
Certified Value		---	26.9	---	370	21	---	---	---	---	---	---	---	---	---	8.64	---	---	2.7

ERM-CC018 is a European sandy soil reference material

Spike Recoveries

		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Sample ID	**Sample Description**	**Nd**	**Ni**	**Os**	**P**	**Pb**	**Pd**	**Pt**	**Pr**	**Rb**	**Re**	**Rh**	**Ru**	**S**	**Sb**	**Sc**	**Se**	**Sm**	**Sn**
CE491-12	RA1_P4 - 31.5 metres	107	104	105	95	106	102	105	108	111	105	103	105	107	104	105	104	109	104
CE491-19	RA2_P4 - 29 metres	107	104	104	111	105	102	103	109	109	104	103	104	107	103	103	99	108	103

Analyte of interest added to sample prior to analysis

Sediment analyses *Total recoverable metals (TRM)*

		TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g
Sample ID	**Sample Description**	**Sr**	**Ta**	**Tb**	**Te**	**Th**	**Ti**	**Tl**	**Tm**	**U**	**V**	**W**	**Y**	**Yb**	**Zn**	**Zr**
CE491-8	TN2_P4 - 19 metres	18	0.003	0.84	0.03	9.2	92	0.40	0.30	1.5	59	0.079	23	1.8	102	12
CE491-9	TN1_P4 - 16.5 metres	11	0.004	0.71	0.02	6.0	40	0.26	0.25	1.2	49	0.092	20	1.5	85	5.3
CE491-10	TN3_P4 - 18.5 metres	12	0.003	0.81	0.02	9.0	47	0.32	0.28	1.4	57	0.10	22	1.7	97	9.0
CE491-10 dup	TN3_P4 - 18.5 metres dig dup	23	0.005	0.92	0.05	11	416	0.51	0.30	3.9	73	0.34	23	1.7	93	11
CE491-10 average	**TN3_P4 - 18.5 metres avg**	**18**	**0.004**	**0.87**	**0.03**	**10**	**232**	**0.42**	**0.29**	**2.6**	**65**	**0.22**	**23**	**1.7**	**95**	**10**
CE491-10	TN3_P4 - 18.5 metres	17	0.010	0.81	0.02	9.5	116	0.39	0.28	1.6	63	0.08	22	1.7	110	9.9
CE491-10 dup	TN3_P4 - 18.5 metres dig dup	19	0.006	0.85	0.03	10	184	0.44	0.30	1.7	67	0.08	23	1.8	115	12
CE491-10 average	**TN3_P4 - 18.5 metres avg**	**18**	**0.008**	**0.83**	**0.03**	**9.9**	**150**	**0.42**	**0.29**	**1.6**	**65**	**0.08**	**22**	**1.7**	**113**	**11**
CE491-11	CA3_P4 - 48 metres	33	0.006	1.1	0.06	14	894	0.61	0.33	4.2	85	0.17	26	1.9	109	17
CE491-12	RA1_P4 - 31.5 metres	15	0.005	0.87	0.03	10	94	0.29	0.29	3.6	47	0.39	23	1.7	90	8.0
CE491-12	RA1_P4 - 31.5 metres dil dup	14	0.005	0.89	0.05	10	93	0.30	0.29	3.6	46	0.37	22	1.7	92	8.1
CE491-12 average	**RA1_P4 - 31.5 metres avg**	**15**	**0.005**	**0.88**	**0.04**	**10**	**94**	**0.29**	**0.29**	**3.6**	**47**	**0.38**	**22**	**1.7**	**91**	**8.1**
CE491-13	PL1_P4 - 33.5 metres	28	0.003	0.83	0.03	11	302	0.36	0.27	3.2	66	0.18	21	1.6	92	9.2
CE491-14	CA1_P4 - 30 metres	27	0.008	1.0	0.03	12	231	0.37	0.34	3.8	66	0.33	26	2.0	79	11
CE491-15	PL3_P4 - 27 metres	29	0.002	0.93	0.03	12	279	0.37	0.30	3.9	67	0.19	23	1.7	99	14
CE491-15 Dup	PL3_P4 - 27 metres dig dup	29	0.003	0.92	0.02	12	258	0.37	0.30	3.9	66	0.13	23	1.8	99	12
CE491-15 average	**PL3_P4 - 27 metres avg**	**29**	**0.003**	**0.92**	**0.03**	**12**	**268**	**0.37**	**0.30**	**3.9**	**67**	**0.16**	**23**	**1.8**	**99**	**13**
CE491-16	RA3_P4 - 28.5 metres	17	0.002	0.95	0.03	12	159	0.35	0.30	3.0	43	0.25	23	1.8	99	13
CE491-17	PL2_P4 - 26.5 metres	31	0.004	0.96	0.02	12	262	0.40	0.31	4.3	65	0.22	24	1.8	110	13
CE491-18	CA2_P4 - 42 metres	35	0.006	0.92	0.02	10	307	0.36	0.28	3.2	63	0.31	23	1.6	81	10
CE491-19	RA2_P4 - 29 metres	22	0.003	1.0	0.02	13	312	0.47	0.34	3.4	53	0.15	25	2.0	112	13
CE491-19	RA2_P4 - 29 metres dil dup	22	0.003	1.0	0.03	13	315	0.46	0.33	3.5	53	0.15	26	2.0	114	13
CE491-19 average	RA2_P4 - 29 metres avg	**22**	**0.003**	**1.0**	**0.03**	**13**	**313**	**0.46**	**0.34**	**3.5**	**53**	**0.15**	**25**	**2.0**	**113**	**13**
LOD 3σ	---	0.01	0.001	0.0001	0.01	0.002	0.2	0.004	0.0001	0.001	0.3	0.001	0.001	0.001	1	0.01
Method Code:	---	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209

Certified Reference Materials

		TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g	TRM µg/g
Sample ID	**Sample Description**	**Sr**	**Ta**	**Tb**	**Te**	**Th**	**Ti**	**Tl**	**Tm**	**U**	**V**	**W**	**Y**	**Yb**	**Zn**	**Zr**
ERM-CC018-1		73	0.009	0.16	0.03		134	0.18	0.060		15	2.0	5.9	0.37	261	14
ERM-CC018-1		72	0.008	0.16	0.02	1.92	133	0.18	0.058	0.98	15	2.0	5.7	0.37	264	14
ERM-CC018-2		74	0.007	0.16	0.03	1.95	132	0.17	0.061	0.99	15	1.9	5.8	0.38	270	13
ERM-CC018 average		**73**	**0.008**	**0.16**	**0.03**	**1.94**	**133**	**0.18**	**0.060**	**0.99**	**15**	**2.0**	**5.8**	**0.37**	**265**	**14**
Certified Value		---	---	---	---	---	---	---	---	---	19.4 ± 1.0	---	---	---	313 ± 13	---
OREAS-25a-1		19	0.001	0.30	0.03	12.3	682	0.28	0.084	1.55	122	0.045	6.0	0.51	37	36
OREAS-25a-2		17	0.004	0.28	0.04	12.2	513	0.25	0.075	1.51	118	0.045	5.4	0.50	34	34
OREAS-25a average		**18**	**0.002**	**0.29**	**0.04**	**12.3**	**597**	**0.27**	**0.080**	**1.53**	**120**	**0.045**	**5.7**	**0.51**	**36**	**35**
Certified Value		17.3	---	---	---	10.7	---	0.20	---	1.49	117	---	4.56	---	30.1	---

ERM-CC018 is a European sandy soil reference material

Spike Recoveries

		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
Sample ID	**Sample Description**	**Sr**	**Ta**	**Tb**	**Te**	**Th**	**Ti**	**Tl**	**Tm**	**U**	**V**	**W**	**Y**	**Yb**	**Zn**	**Zr**
CE491-12	RA1_P4 - 31.5 metres	98	111	108	103	---	102	108	108	97	96	105	107	107	113	104
CE491-19	RA2_P4 - 29 metres	97	91	107	101	---	100	105	107	104	96	105	106	107	108	102

Analyte of interest added to sample prior to analysis

Sediment analyses *Dilute-acid extractable metals (AEM)*

Sample ID	Sample Description	Ca	K	Mg	Na	Ag	Al	As	Au	B	Ba	Be	Bi	Cd	Ce	Co	Cr	Cs	Cu	Dy	Er	Eu	Fe
		(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
CE491-8	TN2_P4	760	208	195	<41.8	0.085	3980	2.09	<0.005	1.08	164	1.16	0.273	0.229	41.9	13.3	5.84	0.149	14.3	3.61	1.86	0.911	20200
CE491-9	TN1_P4	661	154	189	55.8	0.039	3620	1.81	<0.005	<0.816	141	0.956	0.193	0.192	32.4	7.19	3.05	0.093	13	2.87	1.42	0.702	12400
CE491-10	TN3_P4	649	163	172	47.2	0.074	4460	2.81	<0.005	0.927	158	1.18	0.267	0.31	42	15.6	6.3	0.141	14.8	3.55	1.84	0.888	21900
CE491-11	CA3_P4	1420	467	488	58.7	0.065	5020	3.82	<0.005	1.07	210	1.25	0.339	0.194	54.3	16.7	7.89	0.502	23.3	3.77	1.87	1.05	16800
CE491-12	RA1_P4	1340	217	246	63.3	0.061	4280	3.92	<0.005	0.874	205	1.36	0.479	0.179	46.2	15.6	5.74	0.615	26.8	3.65	1.84	0.954	14400
CE491-13	PL1_P4	1360	263	463	71.6	0.047	4550	3.04	0.01	1.24	168	1.14	0.293	0.077	44.2	16.5	7.19	0.391	20.7	3.13	1.56	0.851	17000
CE491-14	CA1_P4	1630	248	356	70.7	0.068	4740	3.85	0.006	1.3	205	1.41	0.327	0.161	60.8	19	8.57	0.407	21.2	4.31	2.12	1.17	23500
CE491-15	PL3_P4	1160	294	384	68.7	0.074	4600	4.45	<0.005	1.1	169	1.26	0.363	0.187	48.2	19	7.08	0.569	23	3.38	1.7	0.929	25100
CE491-16	RA3_P4	1520	193	201	76.8	0.061	3460	6.6	<0.005	0.961	260	1.28	0.492	0.215	41.6	16.8	6.04	0.817	25.2	3.61	1.82	0.953	17800
CE491-17	PL2_P4	1650	245	336	56.6	0.071	4590	3.27	<0.005	0.991	174	1.34	0.375	0.187	50.8	15.2	6.46	0.509	24.4	3.6	1.8	0.956	15900
CE491-18	CA2_P4	1660	389	560	77.2	0.046	4280	3.12	<0.005	1.08	208	1.2	0.279	0.096	47.3	13.6	7.4	0.341	18.6	3.49	1.72	0.984	17300
CE491-19	RA2_P4	1410	209	239	59.5	0.045	3910	4.58	<0.005	0.945	213	1.48	0.46	0.251	47.5	16.2	6.68	0.767	24.5	3.94	1.95	1.02	14700

Lab ID	Client ID	Ca	K	Mg	Na	Ag	Al	As	Au	B	Ba	Be	Bi	Cd	Ce	Co	Cr	Cs	Cu	Dy	Er	Eu	Fe
		(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
LOD 3σ	**Avg AEM-28 Blk**	**2.16**	**-0.988**	**2.46**	**13.4**	**0.000**	**1.53**	**0.000**	**0.000**	**0.000**	**0.058**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**1.28**
Method Code:	**LOD (3 x S.D.)**	**7.08**	**16.2**	**13.5**	**41.8**	**0.001**	**2.53**	**0.023**	**0.005**	**0.816**	**0.123**	**0.002**	**0.004**	**0.039**	**0.002**	**0.004**	**0.145**	**0.003**	**0.065**	**0.000**	**0.000**	**0.001**	**2.9**

Certified Reference Materials

Lab ID	Client ID	Ca	K	Mg	Na	Ag	Al	As	Au	B	Ba	Be	Bi	Cd	Ce	Co	Cr	Cs	Cu	Dy	Er	Eu	Fe
		(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
ERM-CCO18-1		17900	405	640	85.2	1.51	2460	16.5	0.005	3.71	276	0.295	1.01	5.48	8.12	2.47	41.3	0.173	62.6	0.52	0.275	0.158	3140
ERM-CCO18-2		18000	402	647	88.3	1.64	2420	15.8	0.003	4.25	281	0.314	1.14	5.46	8.61	2.46	41.7	0.18	61.7	0.548	0.292	0.172	3140
ERM-CCO18 Mean		**17950**	**404**	**644**	**86.8**	**1.57**	2440	**16.2**	**0.004**	**3.98**	**279**	**0.304**	**1.07**	**5.47**	**8.37**	**2.47**	**41.5**	**0.177**	**62.2**	**0.534**	**0.284**	**0.165**	3140
In-house mean						**1.446**	**2470**	**17.2**			**277**			**5.5**		**2.8**	**44.0**		**61.8**				**3270**
% recovery (%)						**109**	**99**	**94**			**101**			**99**		**89**	**94**		**101**				**96**

Spike Recoveries

Lab ID	Client ID	Ca	K	Mg	Na	Ag	Al	As	Au	B	Ba	Be	Bi	Cd	Ce	Co	Cr	Cs	Cu	Dy	Er	Eu	Fe
		(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
CE491-12	RA1_P4	**104**	**103**	**101**	**103**	**108**	**93**	**108**	**103**	**101**	**98**	**110**	**111**	**108**	**116**	**108**	**107**	**112**	**107**	**110**	**109**	**109**	**71**
CE491-19	RA2_P4	**100**	**102**	**97**	**99**	**103**	**96**	**107**	**91**	**100**	**99**	**106**	**106**	**106**	**107**	**103**	**104**	**108**	**104**	**105**	**105**	**105**	**77**
CE491-10	TN3_P4	612	162	165	<41.8	0.085	4430	2.69	<0.005	0.879	158	1.15	0.281	0.218	42.4	15.8	6.31	0.141	15.4	3.58	1.83	0.884	21800
CE491-10 Dup	TN3_P4	687	164	179	66.1	0.064	4480	2.94	<0.005	0.974	159	1.21	0.252	0.402	41.6	15.4	6.3	0.141	14.3	3.52	1.85	0.892	21900
CE491-10 Mean	**TN3_P4**	**649**	**163**	**172**	**47.2**	**0.074**	**4460**	**2.81**	**<0.005**	**0.927**	**158**	**1.18**	**0.267**	**0.31**	**42**	**15.6**	**6.3**	**0.141**	**14.8**	**3.55**	**1.84**	**0.888**	**21900**
CE491-15	PL3_P4	1170	303	384	69.5	0.084	4610	4.65	<0.005	1	170	1.22	0.356	0.22	48.4	19.4	7.16	0.574	23.7	3.42	1.71	0.937	25100
CE491-15 Dup	PL3_P4	1160	284	383	67.9	0.065	4590	4.25	<0.005	1.2	167	1.3	0.37	0.154	48	18.6	7.01	0.564	22.2	3.35	1.68	0.92	25000
CE491-15 Mean	**PL3_P4**	**1160**	**294**	**384**	**68.7**	**0.074**	**4600**	**4.45**	**<0.005**	**1.1**	**169**	**1.26**	**0.363**	**0.187**	**48.2**	**19**	**7.08**	**0.569**	**23**	**3.38**	**1.7**	**0.929**	**25100**

Sediment analyses *Dilute-acid extractable metals (AEM)*

Sample ID	Sample Description	Ga	Gd	Ge	Hf	Hg	Ho	In	Ir	La	Li	Lu	Mn	Mo	Nb	Nd	Ni	Os	P	Pb	Pd	Pr	Pt	Rb
		(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
CE491-8	TN2_P4	1.05	4.13	<0.086	0.086	<0.008	0.692	0.029	<0.004	15.2	0.144	0.191	646	0.079	<0.055	17.8	3.42	<0.098	1090	18.5	0.176	4.35	<0.006	1.86
CE491-9	TN1_P4	0.897	3.24	<0.086	0.044	<0.008	0.544	0.018	<0.004	12.1	0.118	0.14	470	<0.071	<0.055	14	2.4	<0.098	545	15	0.128	3.38	<0.006	2.4
CE491-10	TN3_P4	1.26	4.03	<0.086	0.078	<0.008	0.686	0.021	<0.004	15	0.135	0.189	753	<0.071	<0.055	17.5	3.93	<0.098	890	19.5	0.185	4.23	<0.006	2.35
CE491-11	CA3_P4	1.28	4.65	<0.086	0.053	<0.008	0.71	0.017	<0.004	22.2	1.03	0.192	3360	<0.071	0.085	22.2	10.3	<0.098	708	17.3	0.186	5.63	<0.006	4.1
CE491-12	RA1_P4	1.02	4.54	<0.086	0.047	<0.008	0.693	0.018	<0.004	18.8	0.451	0.184	1920	<0.071	<0.055	20	8.05	<0.098	573	21.3	0.173	4.97	<0.006	2.55
CE491-13	PL1_P4	1.21	3.83	<0.086	0.05	<0.008	0.593	0.023	<0.004	17.5	0.631	0.162	1690	<0.071	<0.055	17.7	9.33	<0.098	686	15.4	0.159	4.43	<0.006	1.7
CE491-14	CA1_P4	1.18	5.24	<0.086	0.052	<0.008	0.805	0.02	<0.004	25	0.448	0.207	1910	<0.071	0.09	24.9	8.97	<0.098	921	17.4	0.199	6.33	<0.006	3.12
CE491-15	PL3_P4	1.11	4.16	<0.086	0.054	<0.008	0.635	0.017	<0.004	18.7	0.496	0.17	2110	0.12	<0.055	19.7	7.11	<0.098	705	17.5	0.162	4.85	<0.006	2.82
CE491-16	RA3_P4	0.829	4.53	<0.086	0.043	<0.008	0.692	0.015	<0.004	17.5	0.466	0.187	3640	0.098	<0.055	19.5	8.83	<0.098	638	21	0.157	4.78	<0.006	3.53
CE491-17	PL2_P4	1.13	4.45	<0.086	0.05	<0.008	0.679	0.018	<0.004	19.6	0.474	0.183	2490	0.084	<0.055	20.4	8.5	<0.098	583	19.4	0.172	5.08	<0.006	3.17
CE491-18	CA2_P4	1.1	4.38	<0.086	0.044	<0.008	0.65	0.014	<0.004	20.3	0.663	0.167	1630	<0.071	0.078	20.5	8.01	<0.098	771	16	0.174	5.14	<0.006	3.33
CE491-19	RA2_P4	1.01	4.94	<0.086	0.048	<0.008	0.751	0.016	<0.004	19.5	0.55	0.206	2540	<0.071	0.056	21.5	9.33	<0.098	584	22.1	0.182	5.22	<0.006	3.45

Lab ID	Client ID	Ga	Gd	Ge	Hf	Hg	Ho	In	Ir	La	Li	Lu	Mn	Mo	Nb	Nd	Ni	Os	P	Pb	Pd	Pr	Pt	Rb
		(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
LOD 3σ	**Avg AEM-28 Blk**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.04**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**-0.385**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Method Code:	**LOD (3 x S.D.)**	**0.002**	**0.001**	**0.086**	**0.010**	**0.008**	**0.000**	**0.003**	**0.004**	**0.001**	**0.011**	**0.001**	**0.148**	**0.1**	**0.055**	**0.002**	**0.116**	**0.098**	**8.25**	**0.037**	**0.003**	**0.000**	**0.006**	**0.150**

Certified Reference Materials

Lab ID	Client ID	Ga	Gd	Ge	Hf	Hg	Ho	In	Ir	La	Li	Lu	Mn	Mo	Nb	Nd	Ni	Os	P	Pb	Pd	Pr	Pt	Rb
		(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
ERM-CCO18-1		0.875	0.656	0.721	0.172	0.079	0.101	0.054	0	3.62	1.82	0.031	134	7.91	0.123	3.33	13.7	-0.046	759	289	0.058	0.845	0.001	2.03
ERM-CCO18-2		0.853	0.718	0.617	0.19	0.085	0.108	0.053	0.002	3.85	1.93	0.035	133	7.99	0.171	3.48	13.4	-0.029	757	308	0.059	0.898	0.003	1.8
ERM-CCO18 Mean		**0.864**	**0.687**	**0.669**	**0.181**	**0.082**	**0.104**	**0.053**	**0.001**	**3.73**	**1.87**	**0.033**	**133**	**7.95**	**0.147**	**3.4**	**13.5**	**-0.037**	758	**298**	**0.059**	**0.872**	**0.002**	**1.92**
In-house mean						**0.090**							**137**	**7.8**			**13.8**			**266.5**				
% recovery (%)						**92**							**98**	**102**			**98**			**112**				

Spike Recoveries

Lab ID	Client ID	Ga	Gd	Ge	Hf	Hg	Ho	In	Ir	La	Li	Lu	Mn	Mo	Nb	Nd	Ni	Os	P	Pb	Pd	Pr	Pt	Rb
		(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
CE491-12	RA1_P4	**113**	**110**	**113**	**110**	-	**112**	**111**	**111**	**113**	**109**	**110**	**90**	**108**	**112**	**110**	**105**	**126**	**100**	**111**	**108**	**113**	**109**	**102**
CE491-19	RA2_P4	**111**	**104**	**111**	**106**	-	**108**	**105**	**106**	**107**	**105**	**107**	**93**	**105**	**106**	**104**	**100**	**121**	**100**	**104**	**104**	**110**	**104**	**99**
CE491-10	TN3_P4	1.25	4.05	<0.086	0.08	<0.008	0.687	0.02	<0.004	15	0.137	0.191	754	<0.071	<0.055	17.7	4.07	<0.098	889	19.6	0.176	4.24	<0.006	2.45
CE491-10 Dup	TN3_P4	1.28	4	<0.086	0.075	<0.008	0.685	0.023	<0.004	14.9	0.133	0.187	751	<0.071	<0.055	17.4	3.8	<0.098	891	19.4	0.195	4.22	<0.006	2.25
CE491-10 Mean	**TN3_P4**	**1.26**	**4.03**	**<0.086**	**0.078**	**<0.008**	**0.686**	**0.021**	**<0.004**	**15**	**0.135**	**0.189**	**753**	**<0.071**	**<0.055**	**17.5**	**3.93**	**<0.098**	**890**	**19.5**	**0.185**	**4.23**	**<0.006**	**2.35**
CE491-15	PL3_P4	1.13	4.18	<0.086	0.06	<0.008	0.637	0.018	<0.004	18.9	0.487	0.171	2130	0.12	<0.055	19.8	7.26	<0.098	705	17.3	0.165	4.85	<0.006	3.15
CE491-15 Dup	PL3_P4	1.08	4.13	<0.086	0.048	<0.008	0.634	0.017	<0.004	18.6	0.504	0.169	2090	0.12	<0.055	19.5	6.96	<0.098	704	17.6	0.16	4.85	<0.006	2.5
CE491-15 Mean	**PL3_P4**	**1.11**	**4.16**	**<0.086**	**0.054**	**<0.008**	**0.635**	**0.017**	**<0.004**	**18.7**	**0.496**	**0.17**	**2110**	**0.12**	**<0.055**	**19.7**	**7.11**	**<0.098**	**705**	**17.5**	**0.162**	**4.85**	**<0.006**	**2.82**

Sediment analyses *Dilute-acid extractable metals (AEM)*

Sample ID	Sample Description	Re	Rh	Ru	S	Sb	Sc	Se	Sm	Sn	Sr	Ta	Tb	Te	Th	Ti	Tl	Tm	U	V	W	Y	Yb	Zn	Zr
		(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
CE491-8	TN2_P4	<0.004	<0.007	<0.004	104	<0.024	0.854	0.033	4	0.282	8.43	<0.534	0.63	<0.026	0.057	42.1	0.088	0.24	0.688	33.4	0.029	16.5	1.4	43.4	1.41
CE491-9	TN1_P4	<0.004	<0.007	<0.004	76.7	0.029	0.482	0.023	3.07	0.107	7.72	<0.534	0.497	<0.026	0.07	37.5	0.054	0.185	0.451	30.8	<0.015	15.2	1.04	49.1	0.869
CE491-10	TN3_P4	<0.004	<0.007	<0.004	124	0.033	0.852	0.038	3.9	0.219	7.2	<0.534	0.619	<0.026	0.113	48.1	0.07	0.234	0.638	37.1	0.042	17.5	1.38	54.6	1.42
CE491-11	CA3_P4	<0.004	<0.007	<0.004	45.5	0.047	1.13	0.032	4.72	0.201	12.5	<0.534	0.688	<0.026	0.347	122	0.126	0.24	2.65	29.8	0.133	18	1.38	34.6	1.24
CE491-12	RA1_P4	<0.004	<0.007	<0.004	<43.6	0.037	0.706	0.028	4.42	0.17	10.1	<0.534	0.663	<0.026	0.284	60.2	0.091	0.23	2.19	24.4	0.139	18.8	1.36	36.6	0.974
CE491-13	PL1_P4	<0.004	<0.007	0.005	43.8	0.034	0.676	0.044	3.74	0.16	11.8	<0.534	0.564	<0.026	0.218	88.3	0.062	0.199	1.52	29.7	0.098	15.9	1.17	30.4	0.773
CE491-14	CA1_P4	<0.004	<0.007	<0.004	<43.6	<0.024	0.918	0.044	5.24	0.238	16.6	<0.534	0.791	<0.026	0.324	114	0.082	0.269	1.97	32.7	0.106	20.8	1.57	32.3	1.33
CE491-15	PL3_P4	<0.004	<0.007	<0.004	<43.6	0.028	0.864	0.032	4.17	0.152	13.3	<0.534	0.621	<0.026	0.299	70.7	0.072	0.214	2.23	28.4	0.145	17.2	1.28	33	1.02
CE491-16	RA3_P4	<0.004	<0.007	<0.004	<43.6	0.039	0.553	0.043	4.43	0.21	10.8	<0.534	0.675	<0.026	0.254	46.7	0.1	0.23	1.38	19.2	0.126	20	1.34	28.2	0.958
CE491-17	PL2_P4	<0.004	<0.007	0.004	<43.6	0.039	0.709	0.043	4.33	0.089	15.1	<0.534	0.654	<0.026	0.25	69.3	0.095	0.23	2.35	30.7	0.143	18.3	1.38	37.3	0.902
CE491-18	CA2_P4	<0.004	<0.007	0.008	62.5	<0.024	0.541	0.034	4.29	0.209	26.3	<0.534	0.644	<0.026	0.165	101	0.055	0.214	1.27	28.5	0.109	19.5	1.22	27.4	1.02
CE491-19	RA2_P4	<0.004	0.008	0.004	<43.6	0.034	0.387	0.034	4.78	0.191	10.9	<0.534	0.722	<0.026	0.16	56.9	0.088	0.255	1.2	22.2	0.133	21.3	1.45	30.9	0.816

Lab ID	Client ID	Re	Rh	Ru	S	Sb	Sc	Se	Sm	Sn	Sr	Ta	Tb	Te	Th	Ti	Tl	Tm	U	V	W	Y	Yb	Zn	Zr
		(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
LOD 3σ	**Avg AEM-28 Blk**	**0.000**	**0.000**	**0.000**	**16.8**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.072**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**2.5**	**0.000**
Method Code:	**LOD (3 x S.D.)**	**0.004**	**0.007**	**0.004**	**43.7**	**0.024**	**0.012**	**0.007**	**0.001**	**0.065**	**0.044**	**0.534**	**0.000**	**0.026**	**0.003**	**0.364**	**0.001**	**0.000**	**0.000**	**0.113**	**0.015**	**0.025**	**0.001**	**5.71**	**0.015**

Certified Reference Materials

Lab ID	Client ID	Re	Rh	Ru	S	Sb	Sc	Se	Sm	Sn	Sr	Ta	Tb	Te	Th	Ti	Tl	Tm	U	V	W	Y	Yb	Zn	Zr
		(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
ERM-CCO18-1		0.002	0.008	0	703	1.11	0.396	0.148	0.671	7.99	55.6	-0.041	0.092	0.007	0.204	53.6	0.068	0.037	0.699	7.63	0.982	4.2	0.227	244	6.25
ERM-CCO18-2		0	0.011	0.001	664	1.34	0.43	0.115	0.69	7.97	56.3	0.063	0.099	0.019	0.201	53.4	0.077	0.038	0.775	7.72	1.08	4.15	0.243	235	6.58
ERM-CCO18 Mean		**0.001**	**0.009**	**0.001**	683	**1.23**	**0.413**	**0.132**	**0.681**	**7.98**	**55.9**	**0.011**	**0.095**	**0.013**	**0.202**	**53.5**	**0.073**	**0.038**	**0.737**	**7.67**	**1.03**	**4.18**	**0.235**	**240**	**6.41**
In-house mean						**1.199**		**0.12**		**7.5**	**57.4**					**53.1**	**0.065**		**0.654**	**7.6**				**241**	
% recovery (%)						**102**		**113**		**106**	**97**					**101**	**111**		**113**	**100**				**100**	

Spike Recoveries

Lab ID	Client ID	Re	Rh	Ru	S	Sb	Sc	Se	Sm	Sn	Sr	Ta	Tb	Te	Th	Ti	Tl	Tm	U	V	W	Y	Yb	Zn	Zr
		(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
CE491-12	RA1_P4	**109**	**109**	**110**	**102**	**104**	**110**	**112**	**110**	**108**	**113**	**160**	**113**	**109**	**111**	**102**	**111**	**112**	**110**	**108**	**111**	**111**	**109**	**103**	**110**
CE491-19	RA2_P4	**105**	**105**	**106**	**99**	**103**	**107**	**110**	**105**	**104**	**106**	**151**	**107**	**104**	**106**	**102**	**106**	**107**	**106**	**102**	**107**	**109**	**105**	**102**	**105**
CE491-10	TN3_P4	<0.004	<0.007	<0.004	96.9	0.035	0.971	0.028	3.94	0.264	6.89	<0.534	0.631	<0.026	0.104	48.6	0.075	0.237	0.714	37	0.042	17.8	1.37	56.9	1.47
CE491-10 Dup	TN3_P4	<0.004	<0.007	<0.004	152	0.03	0.733	0.047	3.87	0.174	7.5	<0.534	0.606	<0.026	0.122	47.6	0.066	0.231	0.563	37.2	0.042	17.2	1.38	52.3	1.37
CE491-10 Mean	**TN3_P4**	**<0.004**	**<0.007**	**<0.004**	**124**	**0.033**	**0.852**	**0.038**	**3.9**	**0.219**	**7.2**	**<0.534**	**0.619**	**<0.026**	**0.113**	**48.1**	**0.07**	**0.234**	**0.638**	**37.1**	**0.042**	**17.5**	**1.38**	**54.6**	**1.42**
CE491-15	PL3_P4	<0.004	<0.007	<0.004	<43.6	0.035	0.963	0.037	4.26	0.173	13.3	<0.534	0.628	<0.026	0.343	71.5	0.074	0.215	2.36	28.5	0.149	17.6	1.3	33.9	1.04
CE491-15 Dup	PL3_P4	<0.004	<0.007	0.004	<43.6	<0.024	0.765	0.027	4.07	0.131	13.3	<0.534	0.615	<0.026	0.255	69.9	0.07	0.212	2.11	28.2	0.141	16.9	1.27	32.1	1
CE491-15 Mean	**PL3_P4**	**<0.004**	**<0.007**	**<0.004**	**<43.65**	**0.028**	**0.864**	**0.032**	**4.17**	**0.152**	**13.3**	**<0.534**	**0.621**	**<0.026**	**0.299**	**70.7**	**0.072**	**0.214**	**2.23**	**28.4**	**0.145**	**17.2**	**1.28**	**33**	**1.02**

Analysis

CSIRO

Measurement Details

Operator Name CSIRO Mastersizer
Sample Name Average of 'CE491-8_TN2'
SOP File Name Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time 29/08/2018 3:27:56 PM
Measurement Date Time 29/08/2018 3:27:56 PM
Result Source Averaged

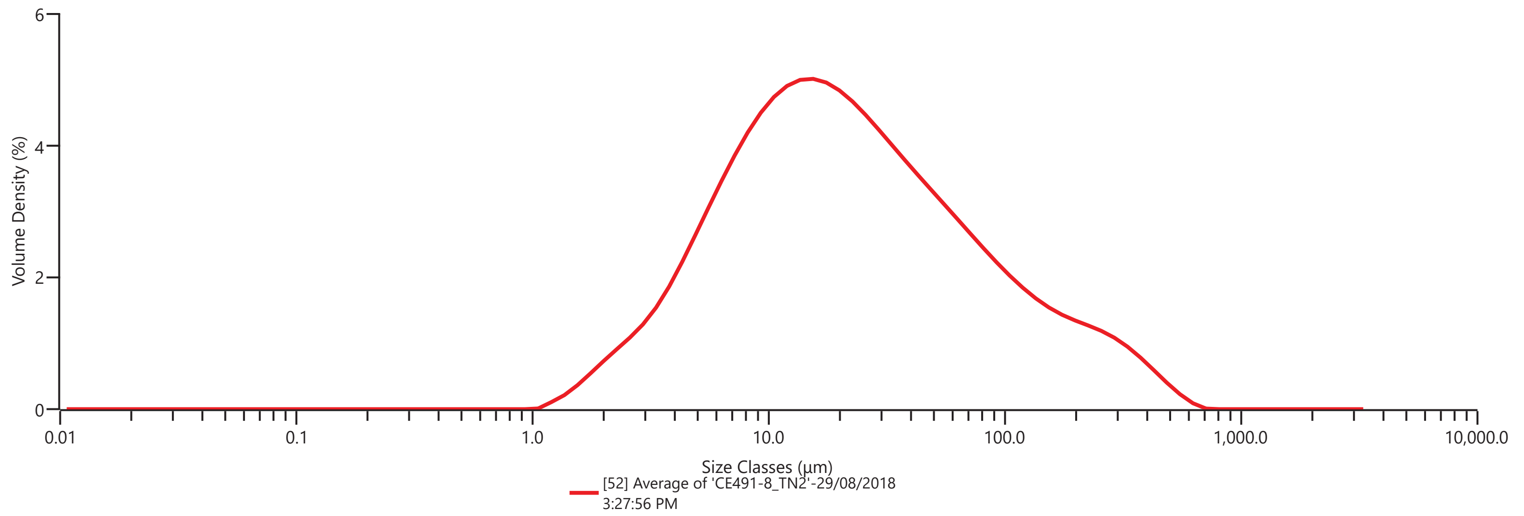
Analysis

Particle Name China Clay
Particle Refractive Index 1.555
Particle Absorption Index 0.010
Dispersant Name Water
Dispersant Refractive Index 1.330
Scattering Model Mie
Analysis Model General Purpose
Weighted Residual 0.32 %
Laser Obscuration 13.08 %

Result

Concentration 0.0185 %
Span 6.363
Uniformity 2.031
Specific Surface Area 517.0 m^2/kg
D [3,2] 11.6 µm
D [4,3] 50.5 µm
Dv (10) 4.84 µm
Dv (50) 20.1 µm
Dv (90) 132 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	1.63	12.7	35.22	76.0	82.39	454	99.41	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	2.39	14.5	39.39	86.4	84.42	516	99.74	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	3.29	16.4	43.58	98.1	86.28	586	99.93	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	4.36	18.7	47.72	111	87.97	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	5.64	21.2	51.76	127	89.51	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	7.19	24.1	55.65	144	90.91	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.00	4.58	9.05	27.4	59.38	163	92.19	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.00	5.21	11.25	31.1	62.92	186	93.39	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.00	5.92	13.80	35.3	66.27	211	94.51	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.00	6.72	16.69	40.1	69.42	240	95.57	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.09	7.64	19.90	45.6	72.38	272	96.56	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.26	8.68	23.41	51.8	75.16	310	97.47	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.56	9.86	27.17	58.9	77.75	352	98.26	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	1.02	11.2	31.12	66.9	80.16	400	98.91	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-9_TN1'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	29/08/2018 3:19:29 PM
Measurement Date Time	29/08/2018 3:19:29 PM
Result Source	Averaged

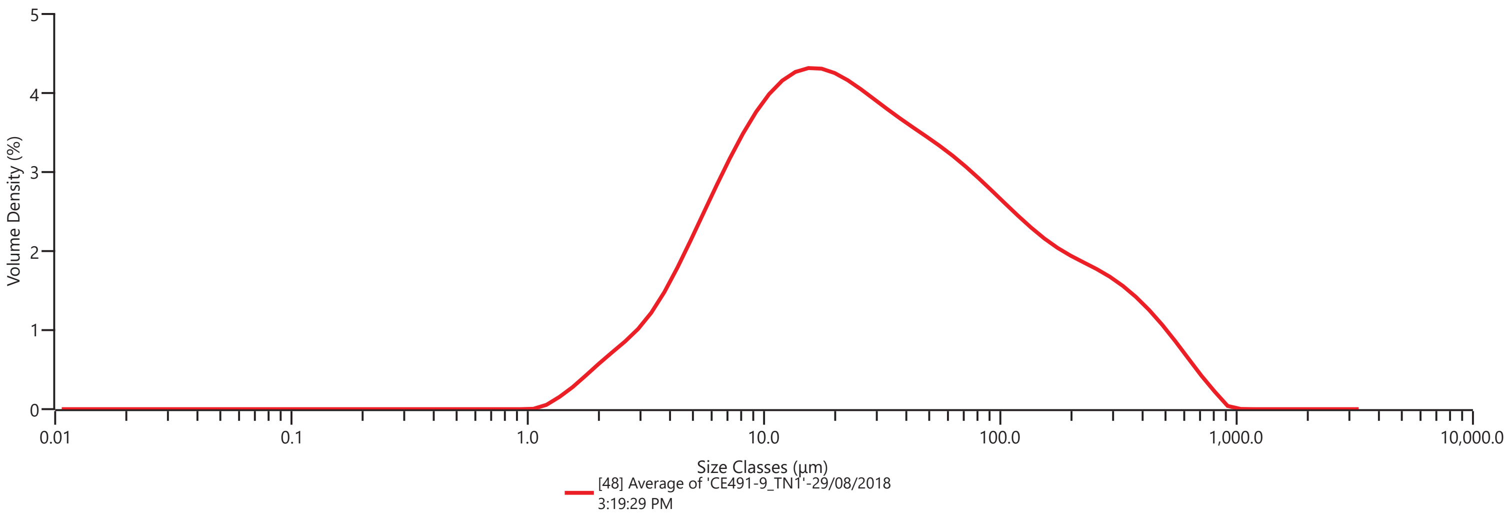
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.26 %
Laser Obscuration	13.66 %

Result

Concentration	0.0234 %
Span	7.936
Uniformity	2.388
Specific Surface Area	431.3 m^2/kg
D [3,2]	13.9 µm
D [4,3]	77.6 µm
Dv (10)	5.57 µm
Dv (50)	27.4 µm
Dv (90)	223 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	1.24	12.7	28.83	76.0	73.35	454	97.30	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	1.83	14.5	32.39	86.4	75.79	516	98.19	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	2.55	16.4	36.00	98.1	78.09	586	98.91	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	3.39	18.7	39.59	111	80.26	666	99.44		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	4.40	21.2	43.14	127	82.30	756	99.79		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	5.63	24.1	46.61	144	84.22	859	99.98		
0.0215	0.00	0.128	0.00	0.767	0.00	4.58	7.12	27.4	49.99	163	86.02	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.00	5.21	8.90	31.1	53.26	186	87.72	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.00	5.92	10.97	35.3	56.42	211	89.34	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.00	6.72	13.34	40.1	59.49	240	90.88	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.04	7.64	15.99	45.6	62.46	272	92.36	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.17	8.68	18.90	51.8	65.34	310	93.76	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.40	9.86	22.03	58.9	68.12	352	95.06	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	0.76	11.2	25.36	66.9	70.79	400	96.25	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-10_TN3'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	29/08/2018 3:35:38 PM
Measurement Date Time	29/08/2018 3:35:38 PM
Result Source	Averaged

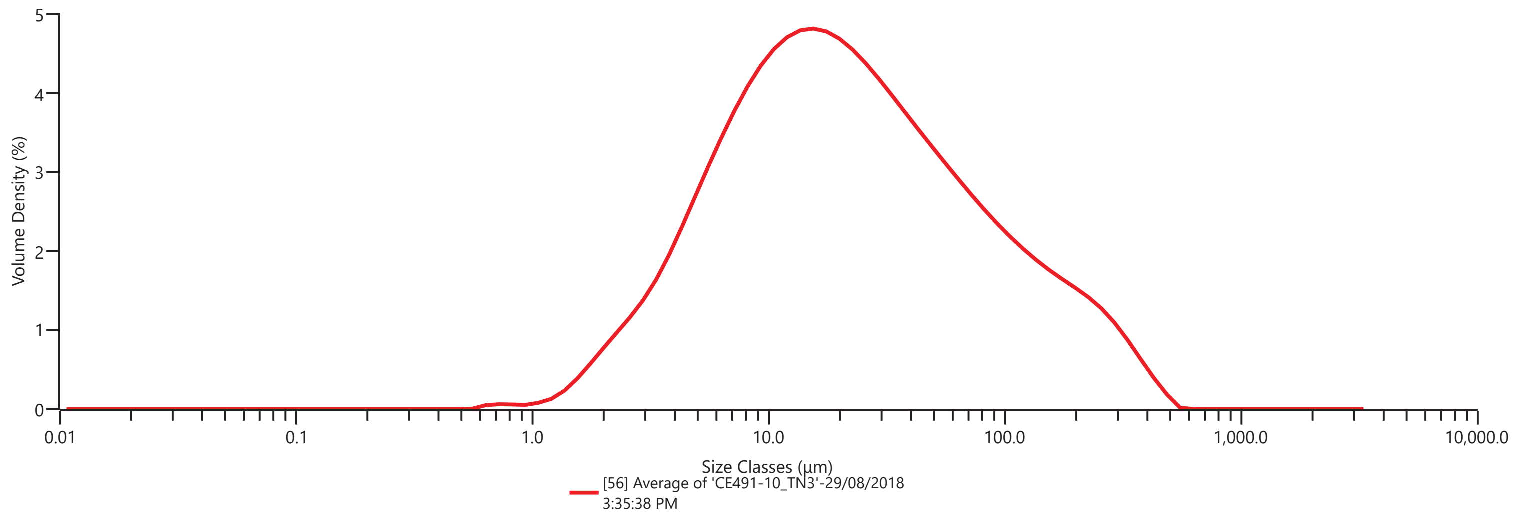
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.36 %
Laser Obscuration	14.15 %

Result

Concentration	0.0194 %
Span	6.323
Uniformity	1.926
Specific Surface Area	541.7 m^2/kg
D [3,2]	11.1 µm
D [4,3]	48.7 µm
Dv (10)	4.63 µm
Dv (50)	20.3 µm
Dv (90)	133 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	1.99	12.7	35.43	76.0	81.81	454	99.85	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	2.79	14.5	39.44	86.4	83.93	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	3.76	16.4	43.46	98.1	85.89	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	4.90	18.7	47.45	111	87.71	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	6.26	21.2	51.36	127	89.41	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.04	4.03	7.89	24.1	55.16	144	90.98	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.10	4.58	9.82	27.4	58.81	163	92.45	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.14	5.21	12.07	31.1	62.30	186	93.82	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.18	5.92	14.63	35.3	65.62	211	95.10	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.25	6.72	17.50	40.1	68.75	240	96.29	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.35	7.64	20.66	45.6	71.71	272	97.35	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.54	8.68	24.07	51.8	74.49	310	98.27	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.86	9.86	27.70	58.9	77.10	352	99.00	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	1.34	11.2	31.50	66.9	79.54	400	99.52	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-11_CA3'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	29/08/2018 3:07:32 PM
Measurement Date Time	29/08/2018 3:07:32 PM
Result Source	Averaged

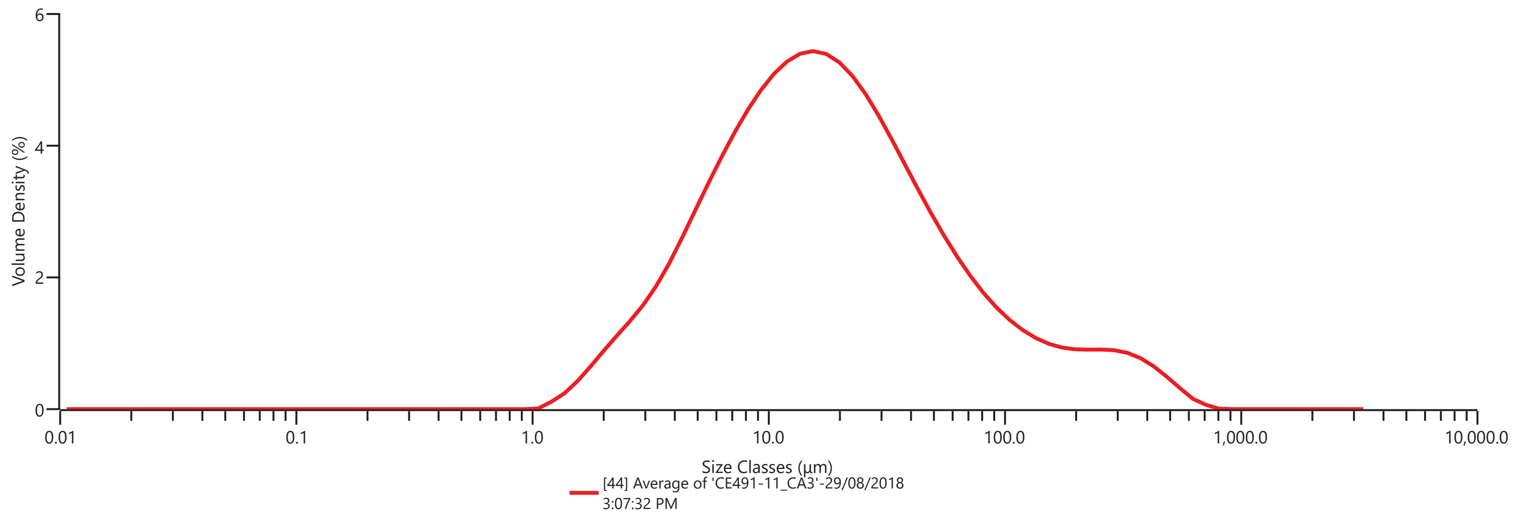
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.35 %
Laser Obscuration	12.59 %

Result

Concentration	0.0159 %
Span	5.724
Uniformity	2.099
Specific Surface Area	577.6 m²/kg
D [3,2]	10.4 μm
D [4,3]	44.7 μm
Dv (10)	4.36 μm
Dv (50)	17.2 μm
Dv (90)	103 μm

Frequency (compatible)



Result

Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	1.92	12.7	39.39	76.0	86.85	454	99.14	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	2.85	14.5	43.90	86.4	88.32	516	99.56	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	3.96	16.4	48.44	98.1	89.60	586	99.82	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	5.27	18.7	52.94	111	90.73	666	99.95		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	6.82	21.2	57.33	127	91.73	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	8.66	24.1	61.56	144	92.62	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.00	4.58	10.83	27.4	65.55	163	93.45	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.00	5.21	13.35	31.1	69.27	186	94.23	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.00	5.92	16.21	35.3	72.68	211	94.98	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.00	6.72	19.41	40.1	75.78	240	95.73	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.09	7.64	22.91	45.6	78.56	272	96.49	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.29	8.68	26.70	51.8	81.04	310	97.24	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.64	9.86	30.74	58.9	83.24	352	97.95	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	1.18	11.2	34.99	66.9	85.16	400	98.60	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-12_RA1 dup'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	29/08/2018 4:23:01 PM
Measurement Date Time	29/08/2018 4:23:01 PM
Result Source	Averaged

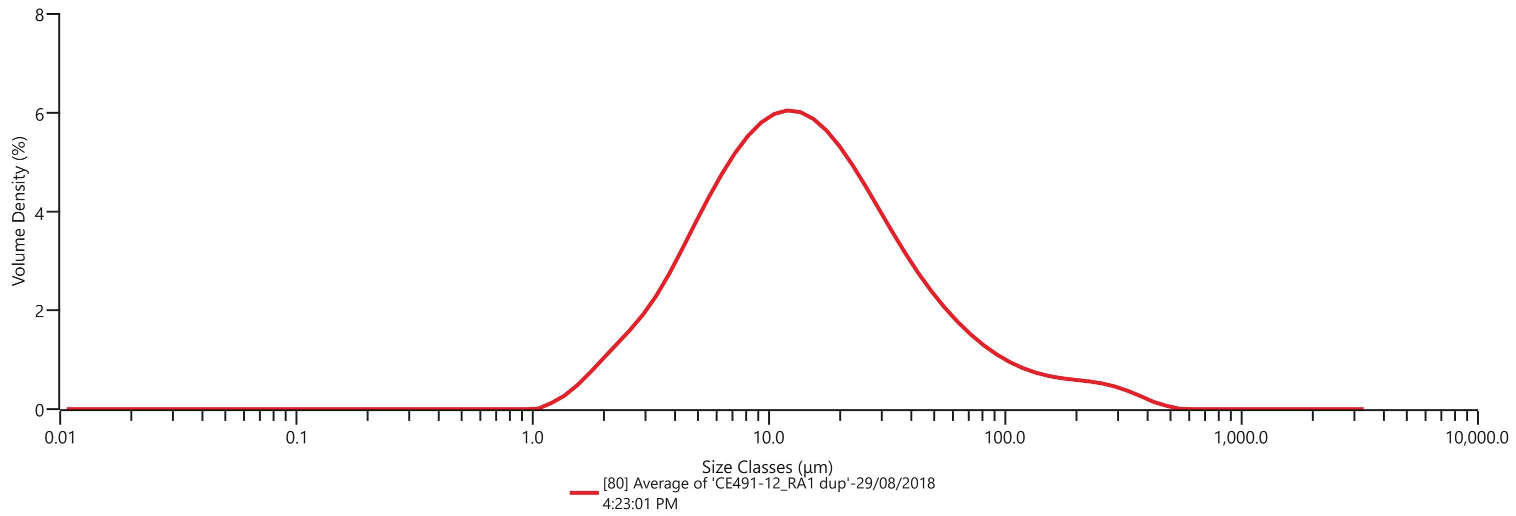
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.42 %
Laser Obscuration	12.62 %

Result

Concentration	0.0137 %
Span	4.213
Uniformity	1.602
Specific Surface Area	670.3 m^2/kg
D [3,2]	8.95 µm
D [4,3]	28.8 µm
Dv (10)	3.93 µm
Dv (50)	13.5 µm
Dv (90)	60.8 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	2.23	12.7	47.67	76.0	92.36	454	99.95	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	3.33	14.5	52.69	86.4	93.43	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	4.66	16.4	57.59	98.1	94.35	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	6.26	18.7	62.30	111	95.14	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	8.16	21.2	66.74	127	95.83	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	10.45	24.1	70.86	144	96.44	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.00	4.58	13.15	27.4	74.61	163	97.00	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.00	5.21	16.30	31.1	77.99	186	97.52	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.00	5.92	19.88	35.3	80.99	211	98.01	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.00	6.72	23.85	40.1	83.62	240	98.48	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.10	7.64	28.17	45.6	85.92	272	98.92	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.33	8.68	32.79	51.8	87.91	310	99.30	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.73	9.86	37.63	58.9	89.62	352	99.61	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	1.36	11.2	42.62	66.9	91.10	400	99.83	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-12_RA1'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	29/08/2018 4:15:21 PM
Measurement Date Time	29/08/2018 4:15:21 PM
Result Source	Averaged

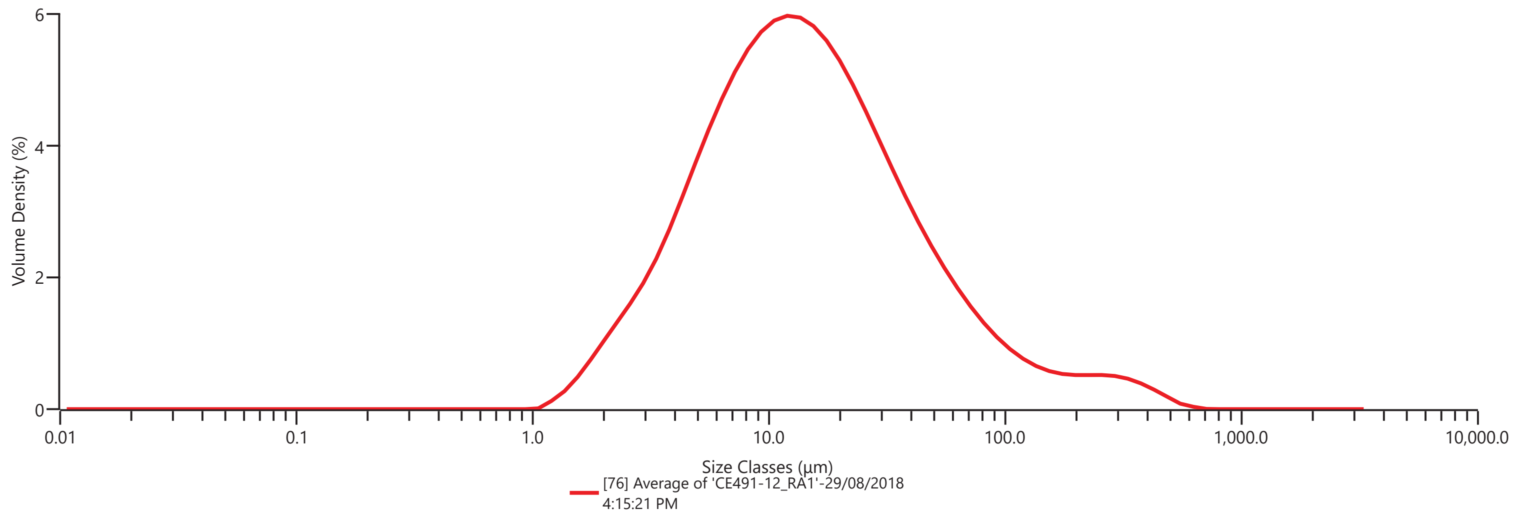
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.38 %
Laser Obscuration	12.49 %

Result

Concentration	0.0136 %
Span	4.247
Uniformity	1.717
Specific Surface Area	666.2 m²/kg
D [3,2]	9.01 µm
D [4,3]	30.7 µm
Dv (10)	3.94 µm
Dv (50)	13.7 µm
Dv (90)	62.0 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	2.22	12.7	47.21	76.0	92.21	454	99.75	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	3.32	14.5	52.18	86.4	93.30	516	99.91	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	4.65	16.4	57.03	98.1	94.21	586	99.97	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	6.24	18.7	61.70	111	94.97	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	8.14	21.2	66.12	127	95.60	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	10.41	24.1	70.23	144	96.15	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.00	4.58	13.10	27.4	74.01	163	96.62	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.00	5.21	16.22	31.1	77.42	186	97.07	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.00	5.92	19.76	35.3	80.47	211	97.50	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.00	6.72	23.69	40.1	83.16	240	97.93	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.10	7.64	27.96	45.6	85.53	272	98.36	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.33	8.68	32.52	51.8	87.60	310	98.79	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.73	9.86	37.30	58.9	89.38	352	99.17	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	1.36	11.2	42.23	66.9	90.91	400	99.50	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name CSIRO Mastersizer
Sample Name Average of 'CE491-13_PL1 Dup'
SOP File Name Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time 29/08/2018 3:52:16 PM
Measurement Date Time 29/08/2018 3:52:16 PM
Result Source Averaged

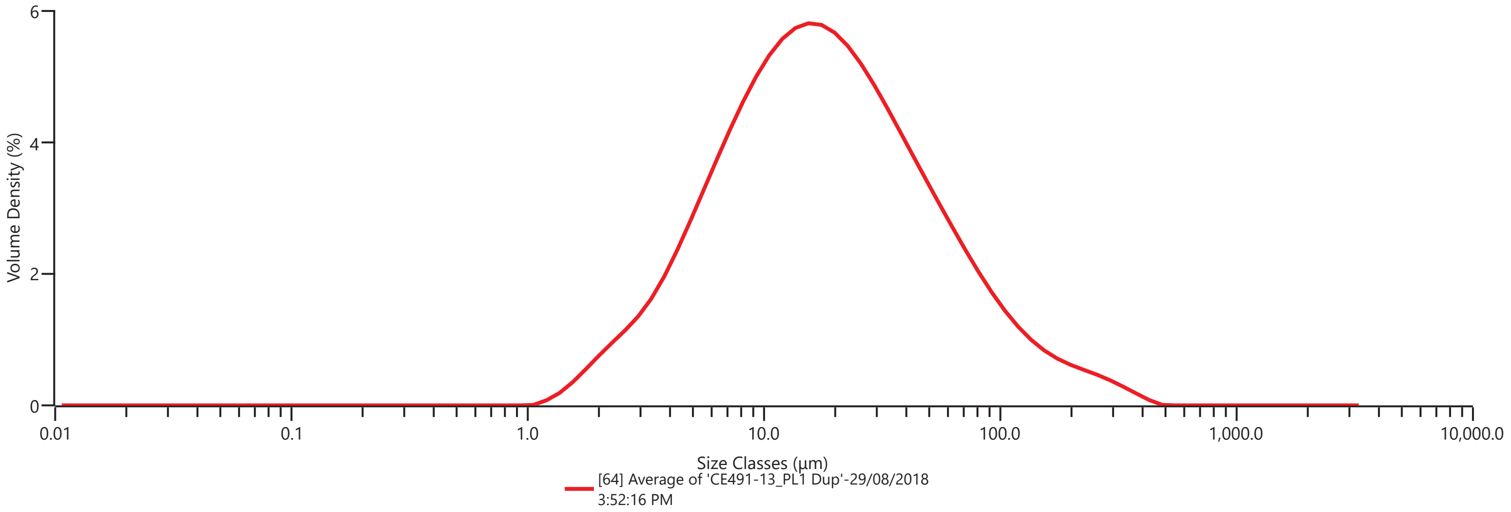
Analysis

Particle Name China Clay
Particle Refractive Index 1.555
Particle Absorption Index 0.010
Dispersant Name Water
Dispersant Refractive Index 1.330
Scattering Model Mie
Analysis Model General Purpose
Weighted Residual 0.34 %
Laser Obscuration 12.23 %

Result

Concentration 0.0162 %
Span 3.978
Uniformity 1.365
Specific Surface Area 554.0 m²/kg
D [3,2] 10.8 μm
D [4,3] 32.7 μm
Dv (10) 4.73 μm
Dv (50) 17.4 μm
Dv (90) 73.9 μm

Frequency (compatible)



Result

Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	1.59	12.7	38.22	76.0	90.44	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	2.39	14.5	43.01	86.4	92.13	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	3.34	16.4	47.87	98.1	93.55	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	4.46	18.7	52.70	111	94.75	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	5.81	21.2	57.43	127	95.75	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	7.44	24.1	61.99	144	96.58	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.00	4.58	9.41	27.4	66.33	163	97.27	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.00	5.21	11.76	31.1	70.40	186	97.86	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.00	5.92	14.49	35.3	74.18	211	98.38	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.00	6.72	17.60	40.1	77.65	240	98.83	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.06	7.64	21.10	45.6	80.81	272	99.22	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.22	8.68	24.95	51.8	83.67	310	99.54	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.51	9.86	29.12	58.9	86.22	352	99.78	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	0.96	11.2	33.57	66.9	88.47	400	99.93	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-13_PL1'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	29/08/2018 3:43:30 PM
Measurement Date Time	29/08/2018 3:43:30 PM
Result Source	Averaged

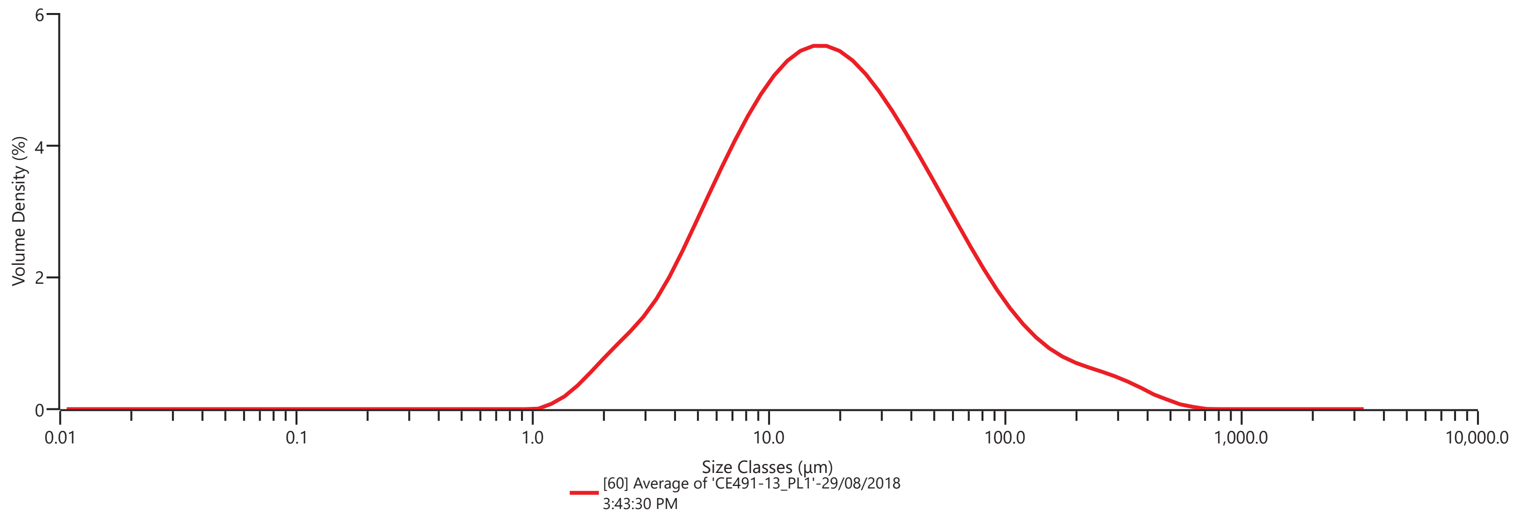
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.34 %
Laser Obscuration	12.38 %

Result

Concentration	0.0165 %
Span	4.270
Uniformity	1.522
Specific Surface Area	550.0 m^2/kg
D [3,2]	10.9 µm
D [4,3]	36.5 µm
Dv (10)	4.67 µm
Dv (50)	18.0 µm
Dv (90)	81.6 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	1.63	12.7	37.53	76.0	89.01	454	99.79	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	2.45	14.5	42.07	86.4	90.79	516	99.91	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	3.43	16.4	46.67	98.1	92.30	586	99.97	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	4.59	18.7	51.27	111	93.57	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	5.98	21.2	55.81	127	94.65	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	7.65	24.1	60.23	144	95.55	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.00	4.58	9.65	27.4	64.47	163	96.32	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.00	5.21	12.00	31.1	68.50	186	96.98	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.00	5.92	14.71	35.3	72.28	211	97.57	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.00	6.72	17.77	40.1	75.80	240	98.10	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.07	7.64	21.18	45.6	79.03	272	98.57	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.22	8.68	24.89	51.8	81.97	310	98.99	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.52	9.86	28.88	58.9	84.61	352	99.34	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	0.99	11.2	33.11	66.9	86.96	400	99.61	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-14_CA1'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	29/08/2018 2:50:39 PM
Measurement Date Time	29/08/2018 2:50:39 PM
Result Source	Averaged

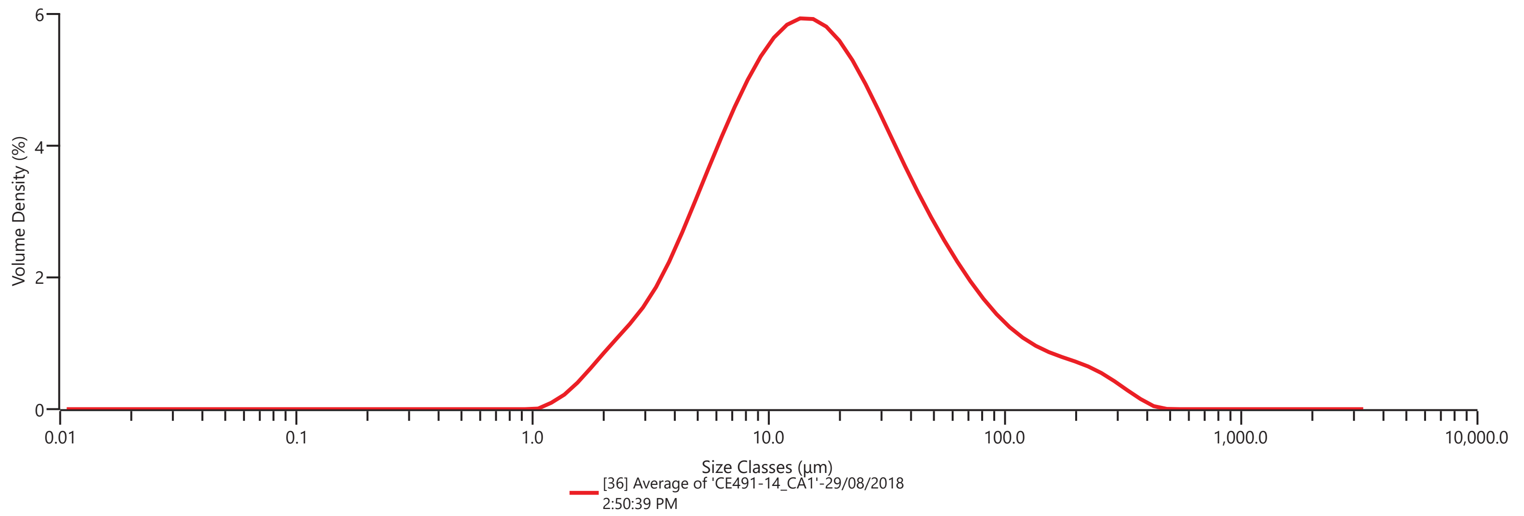
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.41 %
Laser Obscuration	12.16 %

Result

Concentration	0.0149 %
Span	4.222
Uniformity	1.467
Specific Surface Area	597.1 m^2/kg
D [3,2]	10.0 μm
D [4,3]	31.2 μm
Dv (10)	4.40 μm
Dv (50)	15.7 μm
Dv (90)	70.6 μm

Frequency (compatible)



Result

Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	1.82	12.7	41.89	76.0	90.93	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	2.71	14.5	46.84	86.4	92.33	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	3.79	16.4	51.79	98.1	93.52	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	5.07	18.7	56.64	111	94.56	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	6.61	21.2	61.31	127	95.46	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	8.47	24.1	65.73	144	96.26	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.00	4.58	10.71	27.4	69.85	163	96.98	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.00	5.21	13.34	31.1	73.63	186	97.64	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.00	5.92	16.39	35.3	77.06	211	98.25	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.00	6.72	19.84	40.1	80.14	240	98.79	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.08	7.64	23.66	45.6	82.88	272	99.25	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.26	8.68	27.84	51.8	85.31	310	99.60	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.59	9.86	32.31	58.9	87.45	352	99.84	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	1.11	11.2	37.02	66.9	89.31	400	99.97	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name CSIRO Mastersizer
Sample Name Average of 'CE491-15_PL3'
SOP File Name Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time 29/08/2018 4:07:48 PM
Measurement Date Time 29/08/2018 4:07:48 PM
Result Source Averaged

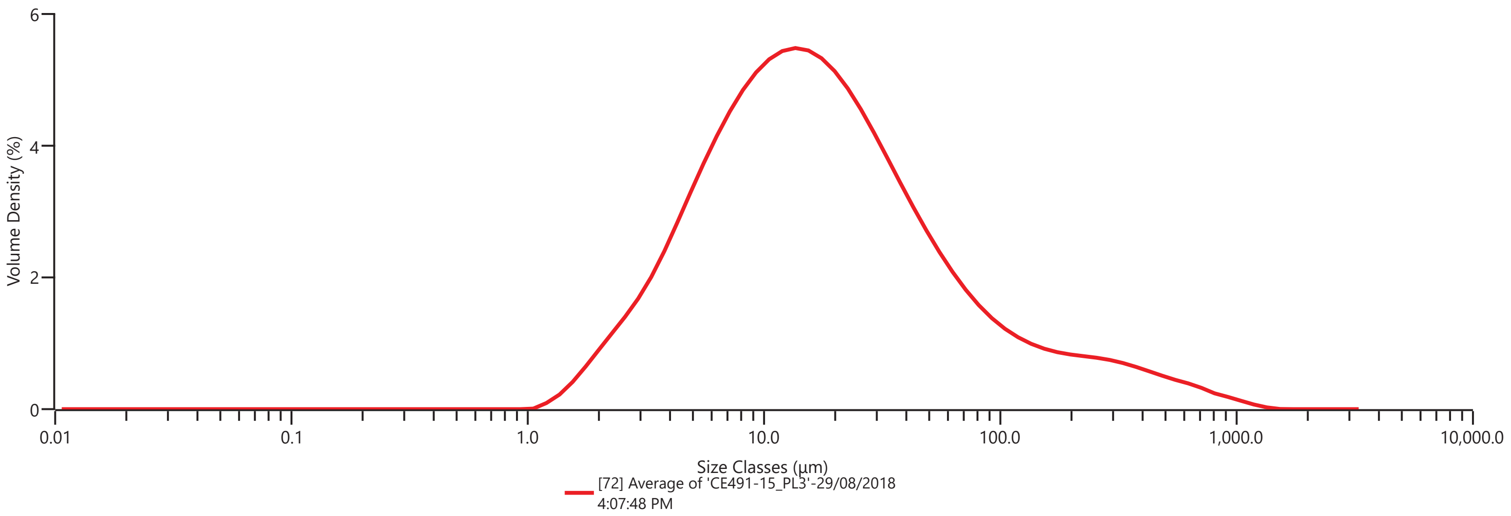
Analysis

Particle Name China Clay
Particle Refractive Index 1.555
Particle Absorption Index 0.010
Dispersant Name Water
Dispersant Refractive Index 1.330
Scattering Model Mie
Analysis Model General Purpose
Weighted Residual 0.35 %
Laser Obscuration 11.75 %

Result

Concentration 0.0142 %
Span 6.182
Uniformity 2.594
Specific Surface Area 598.8 m^2/kg
D [3,2] 10.0 µm
D [4,3] 49.6 µm
Dv (10) 4.24 µm
Dv (50) 16.0 µm
Dv (90) 103 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	1.89	12.7	41.82	76.0	87.14	454	98.07	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	2.85	14.5	46.39	86.4	88.45	516	98.49	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	4.02	16.4	50.94	98.1	89.60	586	98.86	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	5.41	18.7	55.39	111	90.62	666	99.19		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	7.08	21.2	59.67	127	91.53	756	99.46		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	9.08	24.1	63.73	144	92.35	859	99.66		
0.0215	0.00	0.128	0.00	0.767	0.00	4.58	11.44	27.4	67.53	163	93.11	976	99.81		
0.0244	0.00	0.146	0.00	0.872	0.00	5.21	14.19	31.1	71.04	186	93.83	1110	99.92		
0.0278	0.00	0.166	0.00	0.991	0.00	5.92	17.30	35.3	74.22	211	94.53	1260	99.98		
0.0315	0.00	0.188	0.00	1.13	0.00	6.72	20.76	40.1	77.09	240	95.20	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.08	7.64	24.53	45.6	79.65	272	95.85	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.26	8.68	28.58	51.8	81.91	310	96.47	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.60	9.86	32.84	58.9	83.89	352	97.06	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	1.14	11.2	37.28	66.9	85.63	400	97.59	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-16_RA3'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	29/08/2018 4:38:31 PM
Measurement Date Time	29/08/2018 4:38:31 PM
Result Source	Averaged

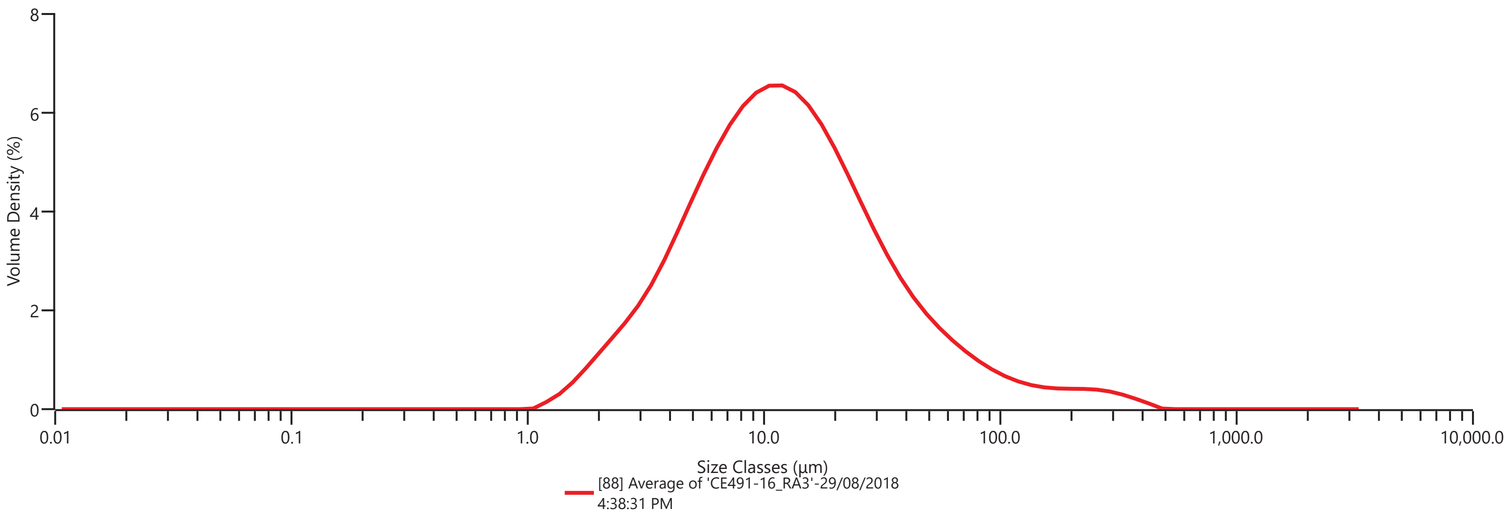
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.39 %
Laser Obscuration	12.45 %

Result

Concentration	0.0125 %
Span	3.662
Uniformity	1.463
Specific Surface Area	722.9 m^2/kg
D [3,2]	8.30 μm
D [4,3]	24.2 μm
Dv (10)	3.75 μm
Dv (50)	12.0 μm
Dv (90)	47.7 μm

Frequency (compatible)



Result

Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	2.45	12.7	52.52	76.0	94.55	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	3.65	14.5	57.89	86.4	95.36	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	5.10	16.4	63.02	98.1	96.03	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	6.84	18.7	67.83	111	96.58	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	8.94	21.2	72.25	127	97.05	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	11.45	24.1	76.21	144	97.45	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.00	4.58	14.44	27.4	79.70	163	97.82	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.00	5.21	17.92	31.1	82.73	186	98.17	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.00	5.92	21.89	35.3	85.33	211	98.51	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.00	6.72	26.31	40.1	87.55	240	98.85	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.12	7.64	31.11	45.6	89.44	272	99.18	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.37	8.68	36.23	51.8	91.05	310	99.48	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.82	9.86	41.58	58.9	92.42	352	99.73	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	1.51	11.2	47.05	66.9	93.57	400	99.90	2390	100.00		

Analysis

CSIRO

Malvern

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-17_PL2'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	29/08/2018 4:00:00 PM
Measurement Date Time	29/08/2018 4:00:00 PM
Result Source	Averaged

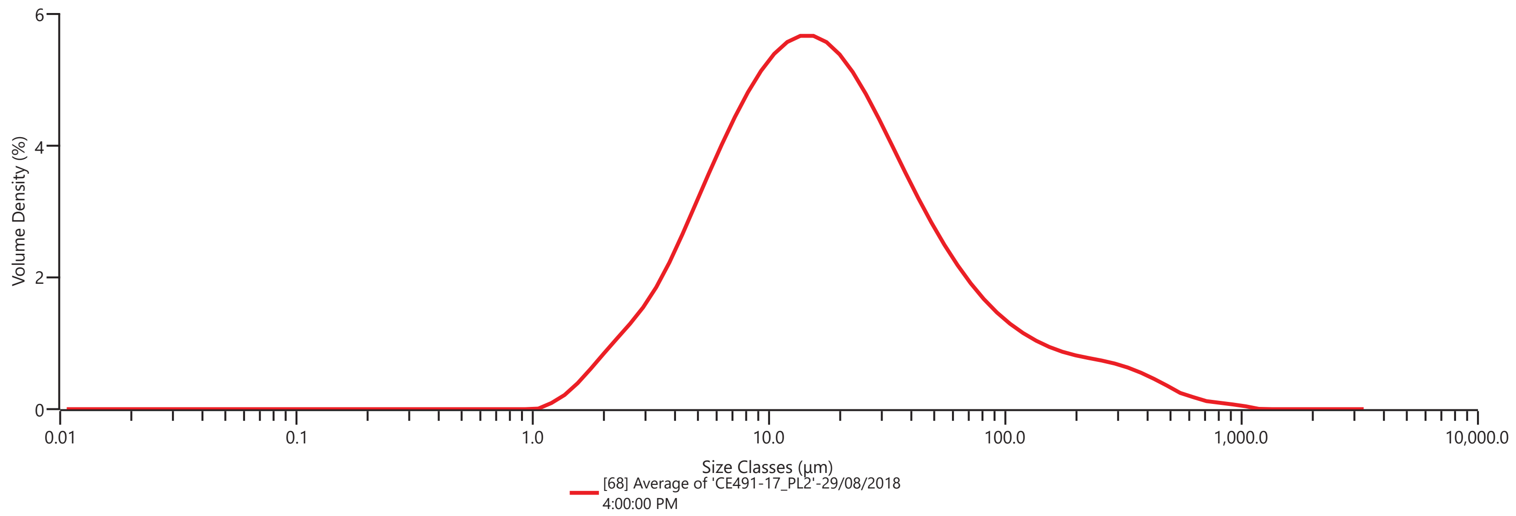
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.33 %
Laser Obscuration	12.82 %

Result

Concentration	0.0161 %
Span	5.276
Uniformity	2.061
Specific Surface Area	583.9 m²/kg
D [3,2]	10.3 µm
D [4,3]	42.1 µm
Dv (10)	4.41 µm
Dv (50)	16.3 µm
Dv (90)	90.6 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	1.79	12.7	40.74	76.0	88.15	454	99.07	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	2.69	14.5	45.47	86.4	89.54	516	99.37	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	3.77	16.4	50.20	98.1	90.76	586	99.57	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	5.05	18.7	54.85	111	91.84	666	99.72		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	6.59	21.2	59.35	127	92.80	756	99.82		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	8.44	24.1	63.62	144	93.67	859	99.90		
0.0215	0.00	0.128	0.00	0.767	0.00	4.58	10.65	27.4	67.61	163	94.45	976	99.96		
0.0244	0.00	0.146	0.00	0.872	0.00	5.21	13.25	31.1	71.29	186	95.18	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.00	5.92	16.23	35.3	74.63	211	95.86	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.00	6.72	19.58	40.1	77.63	240	96.51	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.08	7.64	23.28	45.6	80.30	272	97.12	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.25	8.68	27.29	51.8	82.66	310	97.70	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.58	9.86	31.58	58.9	84.74	352	98.23	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	1.09	11.2	36.08	66.9	86.56	400	98.69	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name CSIRO Mastersizer
Sample Name Average of 'CE491-18_CA2'
SOP File Name Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time 29/08/2018 2:58:58 PM
Measurement Date Time 29/08/2018 2:58:58 PM
Result Source Averaged

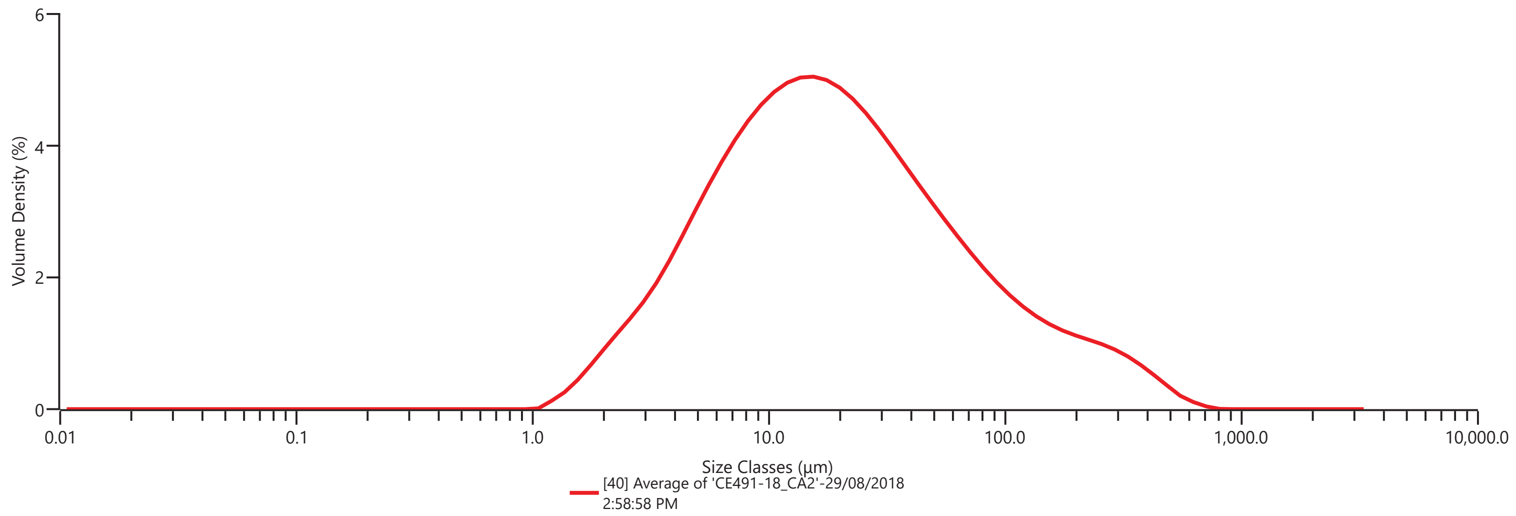
Analysis

Particle Name China Clay
Particle Refractive Index 1.555
Particle Absorption Index 0.010
Dispersant Name Water
Dispersant Refractive Index 1.330
Scattering Model Mie
Analysis Model General Purpose
Weighted Residual 0.36 %
Laser Obscuration 12.96 %

Result

Concentration 0.0164 %
Span 6.078
Uniformity 2.047
Specific Surface Area 573.6 m²/kg
D [3,2] 10.5 µm
D [4,3] 45.5 µm
Dv (10) 4.30 µm
Dv (50) 18.0 µm
Dv (90) 113 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	2.00	12.7	38.68	76.0	85.00	454	99.42	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	2.95	14.5	42.88	86.4	86.78	516	99.72	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	4.10	16.4	47.09	98.1	88.38	586	99.88	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	5.45	18.7	51.26	111	89.82	666	99.97		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	7.04	21.2	55.34	127	91.12	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	8.92	24.1	59.27	144	92.29	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.00	4.58	11.11	27.4	63.02	163	93.37	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.00	5.21	13.63	31.1	66.56	186	94.36	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.00	5.92	16.47	35.3	69.87	211	95.30	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.00	6.72	19.60	40.1	72.96	240	96.18	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.11	7.64	23.01	45.6	75.81	272	97.00	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.31	8.68	26.66	51.8	78.43	310	97.76	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.68	9.86	30.52	58.9	80.83	352	98.43	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	1.24	11.2	34.54	66.9	83.02	400	98.98	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-19_RA2'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	29/08/2018 4:30:45 PM
Measurement Date Time	29/08/2018 4:30:45 PM
Result Source	Averaged

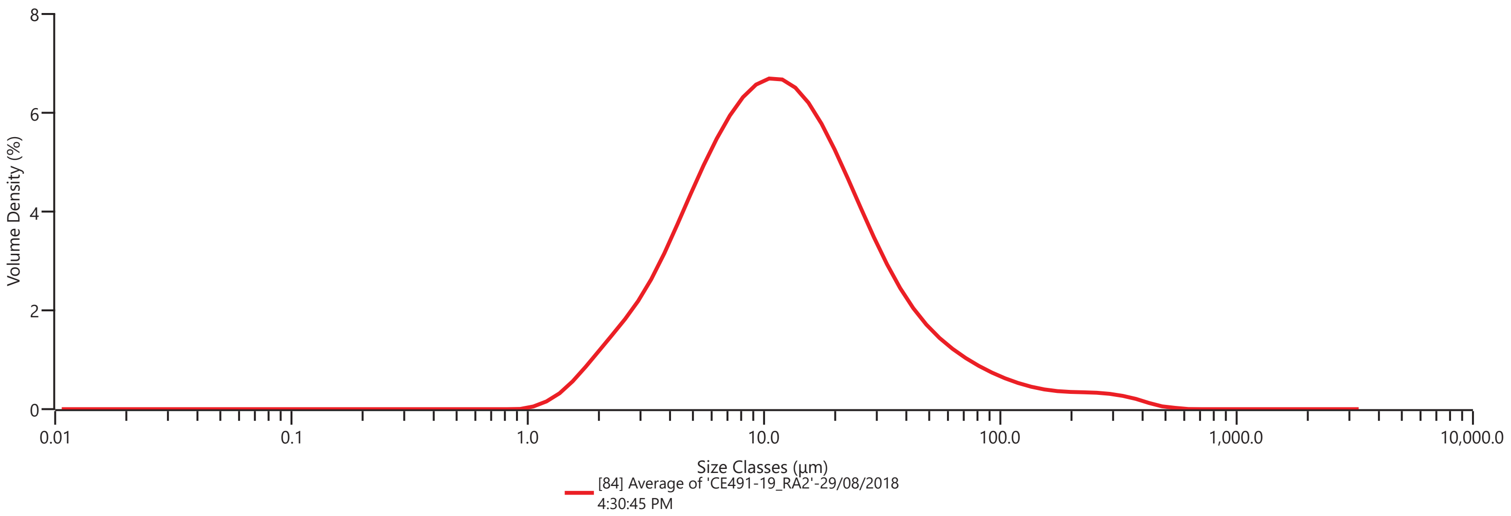
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.33 %
Laser Obscuration	13.06 %

Result

Concentration	0.0127 %
Span	3.491
Uniformity	1.449
Specific Surface Area	745.9 m²/kg
D [3,2]	8.04 µm
D [4,3]	23.1 µm
Dv (10)	3.66 µm
Dv (50)	11.5 µm
Dv (90)	43.9 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	2.59	12.7	54.32	76.0	95.00	454	99.93	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	3.84	14.5	59.75	86.4	95.73	516	99.98	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	5.36	16.4	64.93	98.1	96.35	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	7.17	18.7	69.75	111	96.87	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	9.36	21.2	74.14	127	97.31	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	11.99	24.1	78.04	144	97.69	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.00	4.58	15.11	27.4	81.43	163	98.02	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.00	5.21	18.74	31.1	84.33	186	98.32	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.00	5.92	22.86	35.3	86.77	211	98.61	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.04	6.72	27.43	40.1	88.81	240	98.89	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.17	7.64	32.39	45.6	90.51	272	99.17	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.43	8.68	37.66	51.8	91.93	310	99.43	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.89	9.86	43.15	58.9	93.13	352	99.66	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	1.61	11.2	48.74	66.9	94.14	400	99.83	2390	100.00		

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Note/Memo	CSIRO P4 Project Investigations
To:	Ali Watters (HKA)
From:	Brad Angel, Lucas Heights, NSW
Date:	28 September 2018
Copy:	Ryan Fraser, Stuart Simpson and Ellen Porter (SHL)
Our reference:	CSIRO P4 – Memo 3
Classification:	Internal use only
Subject:	Chemical characterisation of composite excavated rock samples

Background

The CSIRO was engaged by Haskoning Australia Pty Ltd (RHDHV) to undertake an investigation of the pollutant release from excavated rock placed in Talbingo and Tantangara reservoirs (a map of the sample sites will be prepared at a later date for incorporation into an interpretive report). The third phase of the work involved chemical characterisation of the composite excavated rock samples.

This technical memo describes the preliminary results to date.

Methodology for preparing excavated rock fine particle composites

The reasoning for the choice of excavated rock materials used to create composites is provided in the accompanying CSIRO study P2. In brief, there were available 50 g quantities of excavated rock materials (rock milled to a fine particle size, <75 µm) from six different geological zones, and for each zone samples were selected to represent baseline and enriched materials. Excavated rock composites were prepared by combining 50 g of each of the samples shown in each column of Table 1 and homogenising thoroughly. Between 4 and 8 individual samples comprised each composite.

Table 1. Individual <75 µm excavated rock samples that comprised each excavated rock composite tested.

Composite name (individual samples in corresponding column)											
1B	**1E**	**2B**	**2E**	**3B**	**3E**	**4B**	**4E**	**5B**	**5E**	**7B**	**7E**
BH6105-R-0063	BH6102-R-0045	BH5104-R-0122	BH5104-R-0138	BH4106-R-0270	BH4106-R-0273	BH4103-R-0001	BH4103-R-0008	BH3101-R-0257	BH3102-R-0329	BH4102-R-0315	BH5105-R-0147
BH4105-R-0362	BH7105-R-0039	BH5104-R-0133	BH5104-R-0114	BH4106-R-0271	BH4106-R-0274	BH4103-R-0003	BH3110-R-0409	BH3101-R-0259	BH3101-R-0263	BH4102-R-0316	BH5103-R-0066
BH6105-R-0061	BH7105-R-0396	BH5101-R-0055	BH5104-R-0109	BH4106-R-0272	BH4106-R-0276	BH4103-R-0011	BH4103-R-0026	BH3101-R-0261	BH3102-R-0331	BH4102-R-0318	BH5103-R-0080
BH4105-R-0356	BH4104-R-0294	BH5104-R-0116	BH5104-R-0113	BH4106-R-0281	BH4106-R-0278	BH4103-R-0012	BH3110-R-0413	BH3106-R-0353	BH3102-R-0320	BH4105-R-0370	BH5105-R-0146
BH4104-R-0291	BH4105-R-0371	BH5105-R-0143	BH8106-R-0406			BH4103-R-0014	BH3110-R-0407	BH3104-R-0395	BH3102-R-0322	BH5104-R-0115	
BH4105-R-0363	BH6101-R-0226	BH5104-R-0120	BH5104-R-0110			BH4103-R-0018	BH3110-R-0408	BH3101-R-0254	BH3102-R-0321	BH5103-R-0079	
BH7105-R-0036	BH7105-R-0038	BH5104-R-0108	BH5115-R-0388			BH4103-R-0019	BH3110-R-0411	BH3106-R-0352	BH3101-R-0255	BH7104-R-0234	
BH6105-R-0060						BH4102-R-0312	BH4103-R-0017	BH2102-R-0345	BH3102-R-0319		

The particle size distribution of the fine excavated rock composites

The particle size distribution of the fine excavated rock composites are shown in Table 2. Cumulative distribution plots and tables will be provided in the final report (but can be made available earlier if necessary). The mean diameter of the composites were in the range 21.0 to 41.3 µm. The Dv (50) (50% of particles had lower diameter than this value) were all less than 19 µm, indicating the sediments were predominantly silt. The Dv (90) (90% of particles had lower diameter than this value) were between 52 and 110 µm, indicating some components of the 75 µm-milled excavated rock samples underwent aggregation and increased above the milled size range. The particle size distribution of the milled excavated rock samples overlapped most of the particle size distribution of the Talbingo and Tantangara reservoir benthic sediments.

Table 2. The particle size distribution of the milled composite excavated rock samples.

Sediment ID	Dv (10) (µm)	Dv (50) (µm)	Dv (90) (µm)	Mean diameter (µm)
1B composite	2.71	11.6	72.2	26.4
1E composite	2.53	18.6	97.2	41.3
2B composite	2.44	17.3	76.4	30.1
2E composite	2.43	18.3	87.3	34.0
3B composite	2.47	12.8	80.3	28.7
3E composite	2.98	12.7	84.3	30.4
3E composite duplicate	2.95	12.7	81.0	28.9
4B composite	3.72	15.0	110	38.4
4E composite	2.87	10.6	62.9	23.7
5B composite	2.24	12.9	52.2	21.0
5E composite	2.41	18.8	105	39.5
5E composite duplicate	2.30	16.5	93.2	33.9
7B composite	2.69	14.7	80.4	29.9
7E composite	2.00	16.5	69.5	27.4

Note: Dv (x) refers to 10, 50 and 90th percentiles of particle diameters (on spherical volume basis)

Excavated rock porewater pH and redox potential (Eh)

In order to measure the excavated rock sample porewater pH and redox potential the composite materials were mixed with a composite mixture of the Talbingo reservoir water for 48 h. The majority of the overlying water was syringe filtered for analysis of dissolved analytes for an initial elutriate test (to be discussed in memo 4). The remaining water and excavated rock composite material was allowed to stand for ten days, after which the pH and redox potential were measured by inserting probes directly into each wet solid material.

The pH and redox potential of the porewaters of the excavated rock materials deposited in Talbingo water is shown in Table 3. The porewater pH was in the range 8.50-9.55 and had decreased from that measured in the elutriate solution following 48 h mixing (shown in brackets in Table 3). The redox potentials were all positive other than composite 5E, indicating oxic conditions prevailed in the porewaters.

Table 3. The pH and redox potential of the composite excavated rock material mixed with Talbingo reservoir water and allowed to stand for 10 days.

Sample ID	pH [a]	Redox, Eh (mV)
1B	8.75 (9.20)	180
1B duplicate	8.85 (9.29)	160
1E	8.85 (9.33)	160
2B	8.55 (8.88)	115
2E	8.50 (9.35)	20
3B	9.55 (9.58)	165
3E	9.05 (9.81)	150
4B	8.80 (9.67)	165
4E	8.61 (9.37)	180
4E duplicate	8.55 (9.31)	165
5B	8.85 (9.57)	80
5E	8.75 (9.39)	-20
7B	9.00 (9.56)	160
7E	8.75 (9.38)	70

[a] Value in brackets is the pH of the elutriate water after 48-h mixing

Total recoverable concentrations of metals, metalloid, and major cations in excavated rock composite

The total recoverable metal, metalloid, and major cation concentrations measured in the excavated rock composites are shown in Table 4. The concentrations of most metals were below the corresponding sediment quality guideline values (SQGVs). There was one exceedance for As, Pb and Zn, two exceedances for Cr, three exceedances for Cu, and nine for nickel. Of the excavated rock composites, 1E had the most SQGV-exceedances; Ag, Cr, Ni, Pb and Zn. It should be noted that the nickel value is considered an overly conservative value and it is not surprising that it exceeded the SQGV for many of the excavated rock composites (Vangheluwe et al., 2013; Simpson and Batley 2016).

Dilute-acid extractable concentrations of elements in the excavated rock composite

A significant portion of the total element concentration (extracted under pressure using hot concentrated acids) may release inert (not easily released) fractions of metals that exhibit very low bioavailability to organisms. For most metals, the ‘maximum bioavailable concentration’ can be determined by dilute-acid extractable metal (AEM) analyses, as commonly achieved by extracting the solid in 1 M hydrochloric acid for 1 h (Simpson and Batley 2016). AEM data can also be useful for interpreting the partitioning behaviour of elements between the dissolved and particulate phases, and the availability of reactive binding phases.

The 1 M HCl-extractable concentrations of metals, metalloids and major cations measured in the excavated rock composites are shown in Table 5. The concentrations of each parameter were all below the corresponding sediment quality guideline values (SQGVs) except for lead in composite 1E.

Table 4. Total recoverable concentrations of metals, metalloids, and major ions in the excavated rock composite

Sediment ID	Al (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Na (mg/kg)	K (mg/kg)	Mg (mg/kg)	Ca (mg/kg)	P (mg/kg)	S (mg/kg)
Composite 1B	15600	28700	636	180	2040	17600	7260	491	80
Composite 1B duplicate	17300	31000	640	220	2440	18300	7630	483	77
Composite 1B mean	**16500**	**29800**	**638**	**200**	**2240**	**17900**	**7450**	**487**	**78**
Composite 1E	24900	46400	1320	240	2600	22400	7790	640	756
Composite 2B	16100	28600	602	160	3190	8520	6000	423	160
Composite 2E	11200	27300	413	110	3070	7110	11000	537	3790
Composite 3B	24600	39000	727	400	1840	26400	21100	422	15
Composite 3E	16800	24900	577	330	1080	15000	9980	459	13
Composite 4B	11300	18200	464	190	1020	8020	12200	490	17
Composite 4E	19200	41800	588	310	2060	10400	20200	900	5410
Composite 5B	9200	15900	336	360	1880	6310	5440	516	260
Composite 5E	18800	43500	644	700	1550	9680	11200	856	6050
Composite 7B	11600	18800	525	370	2760	6340	13100	378	54
Composite 7E	9960	15600	253	160	3310	5500	8080	469	1010
Minimum	**9200**	**15600**	**253**	**110**	**1020**	**5500**	**5440**	**378**	**13**
Maximum	**24900**	**46400**	**1320**	**700**	**3310**	**26400**	**21100**	**900**	**6050**
SQGV	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Sediment ID	Ag (mg/kg)	As (mg/kg)	Ba (mg/kg)	Cd (mg/kg)	Co (mg/kg)	Cr (mg/kg)	Cu (mg/kg)	Hg (mg/kg)	Mo (mg/kg)
Composite 1B	0.046	6.1	42	0.03	18	63	27	<0.03	0.16
Composite 1B duplicate	0.055	6.1	49	0.029	18	67	27	<0.03	0.13
Composite 1B mean	**0.051**	**6.1**	**45**	**0.03**	**18**	**65**	**27**	**<0.03**	**0.14**
Composite 1E	**2.4**	13	82	1	21	**113**	51	<0.03	0.21
Composite 2B	0.13	5.3	97	0.034	12	66	8.2	<0.03	0.31
Composite 2E	0.27	14	65	0.044	14	29	28	<0.03	0.23
Composite 3B	0.029	0.93	11	0.031	29	**118**	59	<0.03	0.1
Composite 3E	0.045	2.2	19	0.019	20	76	62	<0.03	0.08
Composite 4B	0.072	5.6	32	0.042	8.8	13	15	<0.03	0.33
Composite 4E	0.38	**39**	66	0.238	21	12	**90**	<0.03	1.6
Composite 5B	0.052	3.4	53	0.014	6.3	20	6.1	<0.03	2.1
Composite 5E	0.2	12	37	0.121	19	25	**338**	<0.03	1.3
Composite 7B	0.06	2.7	64	0.043	6.5	19	11	<0.03	0.13
Composite 7E	0.18	6.5	2090	0.025	6.3	13	**88**	<0.03	0.14
Minimum	**0.029**	**0.93**	**10.9**	**0.014**	**6.27**	**11.7**	**6.1**	**<0.03**	**0.08**
Maximum	**2.4**	**38.5**	**2090**	**1.05**	**28.5**	**118**	**338**	**<0.03**	**2.11**
SQGV	**1**	**20**	**NA**	**1.5**	**NA**	**80**	**65**	**0.15**	**NA**

Sediment ID	Ni (mg/kg)	Pb (mg/kg)	Sb (mg/kg)	Se (mg/kg)	Sn (mg/kg)	Sr (mg/kg)	Th (mg/kg)	U (mg/kg)	V (mg/kg)	Zn (mg/kg)
Composite 1B	**92**	11	0.34	0.08	0.48	28	9.2	0.71	36	75
Composite 1B duplicate	**93**	9.9	0.43	0.08	0.62	29	11	1	39	76
Composite 1B mean	**93**	**10**	**0.38**	**0.08**	**0.55**	**28**	**10**	**0.86**	**38**	**76**
Composite 1E	**134**	**214**	0.92	0.12	0.59	33	7.9	0.75	71	**543**
Composite 2B	**28**	5.2	0.45	0.04	0.86	18	10	1.2	44	58
Composite 2E	**31**	11	2.2	0.18	0.65	48	9.1	1.1	23	45
Composite 3B	**42**	0.61	0.03	0.02	0.35	30	0.67	0.1	70	66
Composite 3E	**39**	2.3	0.1	0.03	0.4	13	5.3	0.33	34	62
Composite 4B	0.17	0.04	0.55	26	11	0.79	14	52	490	17
Composite 4E	0.63	0.30	0.41	50	4.7	1.3	71	104	900	5410
Composite 5B	0.10	0.03	0.38	21	7.5	0.99	22	22	516	260
Composite 5E	0.21	1.0	1.0	51	5.3	0.84	80	76	856	6050
Composite 7B	0.37	0.03	0.74	73	11	1.4	19	35	378	54
Composite 7E	1.2	0.03	2.0	63	8.8	1.2	14	32	469	1010
Minimum	**0.029**	**<0.01**	**0.35**	**13.1**	**0.67**	**0.10**	**13.5**	**79**	**378**	**13**
Maximum	**2.17**	**1.03**	**1.98**	**73**	**11.5**	**1.38**	**79.5**	**114**	**900**	**6050**
SQGV	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**200**	**NA**	**NA**

SQGV = the sediment quality guideline values (Simpson e al., 2013). **Values are bold underline where the SQGV is exceeded.**

Table 5. Dilute-acid extractable concentrations of metals, metalloids, and major ions in the rock composites.

Sediment ID	**Al (mg/kg)**	**Fe (mg/kg)**	**Mn (mg/kg)**	**Na (mg/kg)**	**K (mg/kg)**	**Mg (mg/kg)**	**Ca (mg/kg)**	**P (mg/kg)**	**S (mg/kg)**
Composite 1B	2410	4610	343	143	1100	3060	7490	523	<30
Composite 1B duplicate	2420	4580	345	140	1130	3050	7510	512	<30
Composite 1B mean	**2420**	**4600**	**344**	**141**	**1120**	**3060**	**7500**	**518**	**<30**
Composite 1E	3270	6460	679	136	1050	3510	8430	664	38
Composite 2B	2960	5570	514	83	1100	2080	6620	359	<30
Composite 2E	2100	6310	298	82	1440	1400	11700	545	<30
Composite 3B	2920	3830	203	189	1420	3120	15100	483	<30
Composite 3E	2540	2780	119	220	643	1720	8840	501	<30
Composite 4B	1160	1850	263	110	552	674	12400	519	<30
Composite 4E	2750	5470	319	146	765	1260	20100	952	<30
Composite 5B	2800	5820	131	246	755	1330	6570	919	45
Composite 5E	1810	4250	172	206	930	1400	5340	546	<30
Composite 7B	1630	4150	452	192	1080	705	14000	400	<30
Composite 7E	2110	3140	198	119	1920	686	8770	479	413
Minimum	**1160**	**1850**	**119**	**82**	**552**	**674**	**5340**	**359**	**38**
Maximum	**3270**	**6460**	**679**	**246**	**1920**	**3510**	**20100**	**952**	**413**
SQGV	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**

Sediment ID	**Ag (mg/kg)**	**As (mg/kg)**	**Ba (mg/kg)**	**Cd (mg/kg)**	**Co (mg/kg)**	**Cr (mg/kg)**	**Cu (mg/kg)**	**Hg (mg/kg)**	**Mo (mg/kg)**
Composite 1B	0.016	1.9	32	0.018	2.5	6.3	3.3	<0.02	0.08
Composite 1B duplicate	0.015	2	31	0.018	2.6	6.2	3.6	<0.02	0.06
Composite 1B mean	**0.015**	**2**	**31**	**0.018**	**2.6**	**6.3**	**3.4**	**<0.02**	**0.07**
Composite 1E	0.085	2.3	57	0.18	2	12	2.3	<0.02	0.07
Composite 2B	0.033	0.63	84	0.015	4.3	12	1.3	<0.02	0.08
Composite 2E	0.084	1.3	43	0.02	1.2	4.6	3.1	<0.02	0.08
Composite 3B	0.004	0.57	7.4	0.013	3.4	13	18	<0.02	<0.02
Composite 3E	0.017	1.5	12	0.012	2.1	8.8	21	<0.02	0.04
Composite 4B	0.015	1.6	21	0.029	0.4	1.9	2.9	<0.02	0.05
Composite 4E	0.074	1.9	27	0.079	1.2	2.8	4.9	<0.02	0.08
Composite 5B	0.049	0.76	30	0.026	1.1	3.8	22	<0.02	0.08
Composite 5E	0.015	0.68	36	0.007	0.82	4.3	1.4	<0.02	0.3
Composite 7B	0.01	0.74	45	0.019	0.48	4.3	0.8	<0.02	0.05
Composite 7E	0.042	1.4	1840	0.011	0.61	2.7	4.1	<0.02	0.07
Minimum	**0.004**	**0.57**	**7.4**	**0.007**	**0.4**	**1.9**	**0.8**	**<0.02**	**0.04**
Maximum	**0.085**	**2.3**	**1840**	**0.184**	**4.27**	**13**	**22**	**<0.02**	**0.3**
SQGV	**1**	**20**	**NA**	**1.5**	**NA**	**80**	**65**	**0.15**	**NA**

Sediment ID	**Ni (mg/kg)**	**Pb (mg/kg)**	**Sb (mg/kg)**	**Se (mg/kg)**	**Sn (mg/kg)**	**Sr (mg/kg)**	**Th (mg/kg)**	**U (mg/kg)**	**V (mg/kg)**	**Zn (mg/kg)**
Composite 1B	8.7	7.2	0.1	<0.01	0.17	28	4.2	0.26	5.3	14
Composite 1B duplicate	8.3	7.3	0.13	0.01	0.17	27	4.4	0.27	5.2	14
Composite 1B mean	**8.5**	**7.2**	**0.12**	**0.01**	**0.17**	**28**	**4.3**	**0.27**	**5.2**	**14**
Composite 1E	13	197	0.21	0.01	0.22	33	3.1	0.24	9.1	86
Composite 2B	5.4	3.7	0.093	<0.01	0.2	17	2.7	0.27	8.2	15
Composite 2E	3.1	7.1	0.67	0.01	0.23	44	3.3	0.38	4.5	8
Composite 3B	5.3	0.14	0.005	<0.01	0.03	5.8	0.17	0.01	8.3	8.9
Composite 3E	4.3	1.1	0.024	<0.01	0.06	7	1.4	0.07	3.4	7.1
Composite 4B	0.6	11	0.03	<0.01	0.09	20	4.7	0.19	1.1	3.8
Composite 4E	1.1	6.9	0.086	<0.01	0.06	44	1.5	0.28	9.7	14
Composite 5B	1.5	4.8	0.075	0.01	0.09	13	3	0.19	9.4	16
Composite 5E	1.8	1.9	0.052	<0.01	0.14	13	4.5	0.29	2.9	3.8
Composite 7B	0.8	6.3	0.082	<0.01	0.16	71	3.9	0.26	3	3.7
Composite 7E	0.9	4.4	0.21	0.01	0.63	62	2.2	0.4	2.6	6
Minimum	**0.6**	**0.1**	**0.005**	**<0.01**	**0.03**	**5.8**	**0.17**	**0.01**	**1.1**	**79**
Maximum	**13**	**197**	**0.67**	**0.01**	**0.63**	**71**	**4.7**	**0.4**	**9.7**	**114**
SQGV	**21**	**50**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**200**

SQGV = the sediment quality guideline values (Simpson e al., 2013). **Values are bold underline where the SQGV is exceeded.**

Ratio of concentrations: dilute-acid extractable/total recoverable (%).

The elemental ratios of the concentrations measured in dilute-acid extractable and total recoverable forms were calculated and expressed as a percentage in Table 6. As well as providing information on the extractability of the different elements, these calculations serve as a cross check of the analyses undertaken on different subsamples. It is not uncommon for the percentage to be a little greater than 100% when the elements are highly extractable by both methods, but where the percentage is considerably greater than 100% (e.g. >130%) this often reflects heterogeneity (composition or particle size) in the subsamples taken for each separate analysis despite the thorough homogenisation. For example, for Composite 5B the percentage is unexpectedly high for a number of elements.

Table 6. Ratio of concentrations: dilute-acid extractable/total recoverable (%).

Sediment ID	Al	Fe	Mn	Na	K	Mg	Ca	P	S
Composite 1B	15%	16%	54%	79%	54%	17%	103%	107%	ND
Composite 1B duplicate	14%	15%	54%	64%	46%	17%	98%	106%	ND
Composite 1B mean	**15%**	**15%**	**54%**	**71%**	**50%**	**17%**	**101%**	**106%**	**ND**
Composite 1E	13%	14%	51%	57%	40%	16%	108%	104%	5%
Composite 2B	18%	19%	85%	52%	34%	24%	110%	85%	ND
Composite 2E	19%	23%	72%	75%	47%	20%	106%	101%	ND
Composite 3B	12%	10%	28%	47%	77%	12%	72%	114%	ND
Composite 3E	15%	11%	21%	67%	60%	11%	89%	109%	ND
Composite 4B	10%	10%	57%	58%	54%	8%	102%	106%	ND
Composite 4E	14%	13%	54%	47%	37%	12%	100%	106%	ND
Composite 5B	30%	37%	39%	68%	40%	21%	121%	178%	17%
Composite 5E	10%	10%	27%	29%	60%	14%	48%	64%	ND
Composite 7B	14%	22%	86%	52%	39%	11%	107%	106%	ND
Composite 7E	21%	20%	78%	74%	58%	12%	109%	102%	41%

Sediment ID	Ag	As	Ba	Cd	Co	Cr	Cu	Hg	Mo
Composite 1B	35%	31%	76%	60%	14%	10%	12%	ND	50%
Composite 1B duplicate	27%	33%	63%	62%	14%	9%	13%	ND	46%
Composite 1B mean	**29%**	**33%**	**69%**	**60%**	**14%**	**10%**	**13%**	**ND**	**50%**
Composite 1E	4%	18%	70%	18%	10%	11%	5%	ND	33%
Composite 2B	25%	12%	87%	44%	36%	18%	16%	ND	26%
Composite 2E	31%	9%	66%	45%	9%	16%	11%	ND	35%
Composite 3B	14%	61%	67%	42%	12%	11%	31%	ND	ND
Composite 3E	38%	68%	63%	63%	11%	12%	34%	ND	50%
Composite 4B	21%	29%	66%	69%	5%	15%	19%	ND	15%
Composite 4E	19%	5%	41%	33%	6%	23%	5%	ND	5%
Composite 5B	94%	22%	57%	186%	17%	19%	361%	ND	4%
Composite 5E	8%	6%	97%	6%	4%	17%	0%	ND	23%
Composite 7B	17%	27%	70%	44%	7%	23%	7%	ND	38%
Composite 7E	23%	22%	88%	44%	10%	21%	5%	ND	50%

Sediment ID	Ni	Pb	Sb	Se	Sn	Sr	Th	U	V	Zn
Composite 1B	9%	65%	29%	ND	35%	100%	46%	37%	15%	19%
Composite 1B duplicate	9%	74%	30%	13%	27%	93%	40%	27%	13%	18%
Composite 1B mean	**9%**	**72%**	**32%**	**13%**	**31%**	**100%**	**43%**	**31%**	**14%**	**18%**
Composite 1E	10%	92%	23%	8%	37%	100%	39%	32%	13%	16%
Composite 2B	19%	71%	21%	ND	23%	94%	27%	23%	19%	26%
Composite 2E	10%	65%	30%	6%	35%	92%	36%	35%	20%	18%
Composite 3B	13%	23%	17%	ND	9%	19%	25%	10%	12%	13%
Composite 3E	11%	48%	24%	ND	15%	54%	26%	21%	10%	11%
Composite 4B	5%	65%	18%	ND	16%	77%	43%	24%	8%	7%
Composite 4E	7%	70%	14%	ND	15%	88%	32%	22%	14%	13%
Composite 5B	9%	178%	75%	33%	24%	62%	40%	19%	43%	73%
Composite 5E	7%	24%	25%	ND	14%	25%	85%	35%	4%	5%
Composite 7B	8%	72%	22%	ND	22%	97%	35%	19%	16%	11%
Composite 7E	8%	51%	18%	33%	32%	98%	25%	33%	19%	19%

Not calculated where values were <LOD (e.g. TR-S, TR-Hg), and marked ND**.**

For most of the excavated rock composites, the percent of total recoverable elements in dilute-acid extractable forms was generally <30% for Ag, Al, As, Co, Cr, Cu, Fe, Mg, Ni, S, Sb, Sn, U, V and Zn. The percentage of dilute-acid extractable Ba, Pb and Sr was generally >50%.

Summary

The fine excavated rock composites used for testing were predominantly silt-sized (<63 µm), with only a small fraction of the samples aggregating to larger diameters than this size range.

The porewater pH of the excavated rock samples mixed with Talbingo water and allowed to stand for 10 days was in the range 8.50-9.55 and had decreased from that measured in the elutriate solution following 48 h mixing. This pH range is significantly greater than that of the waters from Talbingo (7.05-7.60) and Tantangara (6.70-7.10).

Composite 1E had the greatest number of metals with total recoverable concentrations exceeding sediment quality guideline values (SQGVs). When considering the diluted-extractable metal concentrations, there was only one exceedance; lead for composite 1E (197 mg Pb/kg).

References

Simpson SL and Batley GE (2016) Sediment Quality Assessment: A Practical Guide. CSIRO Publishing, Melbourne, Victoria. 359 p. https://publications.csiro.au/rpr/download?pid=csiro:EP165955&dsid=DS1

Vangheluwe MLU, Verdonck FAM, Besser JM, Brumbaugh WG, Ingersoll CG, Schlekat CE, Garman ER (2013) Improving sediment-quality guidelines for nickel: Development and application of predictive bioavailability models to assess chronic toxicity of nickel in freshwater sediments. Environmental Toxicology and Chemistry 32, 2507–2519.

Rock analyses *Total recoverable metals (TRM)*

		Al	Ag	As	Au	B	Ba	Be	Bi	Cd	Ca	Ce	Co	Cr	Cu	Cs	Dy	Er	Eu
Sample ID	**Sample Description**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**
CE491-20	Rock composite 1B	15600	0.046	6.1	<0.001	2.0	42	0.70	0.26	0.030	7260	48	18	63	27	5.0	2.5	1.2	0.80
CE491-20 dig dup	Rock composite 1B dig dup	17300	0.055	6.1	0.003	2.8	49	0.77	0.26	0.029	7630	62	18	67	27	5.5	3.0	1.4	0.99
CE491-20 avg	Rock composite 1B avg	**16500**	**0.051**	**6.1**	**0.002**	**2.4**	**45**	**0.73**	**0.26**	**0.030**	**7450**	**55**	**18**	**65**	**27**	**5.3**	**2.7**	**1.3**	**0.90**
CE491-21	Rock composite 1E	24900	2.4	13	<0.001	3.1	82	0.89	0.40	1.0	7790	56	21	113	51	4.8	2.8	1.3	1.1
CE491-22	Rock composite 2B	16100	0.13	5.1	<0.001	2.5	97	0.98	0.19	0.039	6000	63	12	65	8.0	5.7	2.6	1.2	0.84
CE491-22 dil dup	Rock composite 2B dil dup	16100	0.13	5.5	<0.001	2.6	97	1.0	0.18	0.029	6010	63	12	67	8.3	5.9	2.6	1.2	0.85
CE491-22 avg	Rock composite 2B avg	**16100**	**0.13**	**5.3**	**<0.001**	**2.5**	**97**	**0.99**	**0.18**	**0.034**	**6000**	**63**	**12**	**66**	**8.2**	**5.8**	**2.6**	**1.2**	**0.84**
CE491-23	Rock composite 2E	11200	0.27	14	0.004	2.7	65	1.1	0.63	0.044	11000	48	14	29	28	5.8	2.4	1.0	0.82
CE491-24	Rock composite 3B	24600	0.029	0.93	<0.001	0.6	11	0.22	0.004	0.031	21100	4.6	29	118	59	0.75	1.5	1.1	0.24
CE491-25	Rock composite 3E	16800	0.045	2.2	<0.001	0.3	19	0.25	0.10	0.019	9980	14	20	76	62	0.58	1.2	0.69	0.23
CE491-26	Rock composite 4B	11300	0.072	5.6	<0.001	0.1	32	0.31	0.25	0.042	12200	52	8.8	13	15	0.95	2.5	1.2	0.63
CE491-27	Rock composite 4E	19200	0.38	39	<0.001	0.7	66	0.24	0.15	0.238	20200	36	21	12	90	0.50	2.6	1.5	0.81
CE491-28	Rock composite 5B	9200	0.052	3.4	<0.001	1.0	53	0.41	0.11	0.014	5440	43	6.3	20	6.1	0.94	1.9	0.93	0.61
CE491-29	Rock composite 5E	18800	0.20	12	<0.001	1.7	37	0.71	0.30	0.121	11200	37	19	25	338	1.6	2.6	1.3	0.82
CE491-30	Rock composite 7B	11600	0.060	2.7	<0.001	1.4	64	0.69	0.092	0.043	13100	53	6.5	19	11	4.0	2.9	1.5	0.72
CE491-31	Rock composite 7E	9940	0.18	6.4	<0.001	1.5	2081	1.3	3.1	0.030	8060	73	6.3	13	88	11	2.1	0.89	1.2
CE491-31 dil dup	Rock composite 7E dil dup	9990	0.18	6.5	<0.001	1.6	2092	1.3	3.1	0.019	8110	74	6.4	13	88	11	2.1	0.88	1.2
CE491-31 avg	Rock composite 7E avg	**9960**	**0.18**	**6.5**	**<0.001**	**1.6**	**2086**	**1.3**	**3.1**	**0.025**	**8080**	**74**	**6.3**	**13**	**88**	**11**	**2.1**	**0.89**	**1.2**
SED-43 LOD (3σ)	---	30	0.001	0.01	0.001	0.1	0.02	0.002	0.003	0.002	3	0.002	0.01	0.02	0.02	0.001	0.001	0.001	0.001
Method Code	---	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209

C-209: ICP-MS C-229: ICP-AES C-223 Total recoverable metals by Aqua Regia microwave digest

Certified Reference Materials

		Al	Ag	As	Au	B	Ba	Be	Bi	Cd	Ca	Ce	Co	Cr	Cu	Cs	Dy	Er	Eu
Sample ID	**Sample Description**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**
ERM-CC018-1	---	5360	2.2	22	0.036	5.9	378	0.58	1.1	5.9	16500	17	5.4	137	82	0.91	0.98	0.51	0.31
ERM-CC018-2	---	4670	2.2	21	0.037	4.8	372	0.52	1.2	6.0	16400	15	4.9	133	81	0.76	0.84	0.45	0.28
ERM-CC018 avg	---	5020	**2.2**	**21**	**0.037**	**5.4**	**375**	**0.55**	**1.2**	**6.0**	**16500**	**16**	**5.1**	**135**	**82**	**0.84**	**0.91**	**0.48**	**0.29**
Certified Value	---	---	---	22.9 ± 1.3	---	---	---	---	---	5.4 ± 0.5	---	---	5.9 ± 0.4	129 ± 6	80 ± 4	---	---	---	---
OREAS-25a-1	---	52400	0.092	5.4	0.015	5.2	51	0.71	0.32	0.071	1240	42	6.3	90	28	5.5	1.4	0.64	0.57
OREAS-25a-2	---	65200	0.11	6.2	0.005	7.1	57	0.79	0.33	0.063	1290	44	7.0	95	29	6.0	1.5	0.69	0.59
OREAS-25a avg		58800	**0.099**	**5.8**	**0.010**	**6.1**	**54**	**0.75**	**0.33**	**0.067**	**1260**	**43**	**6.7**	**92**	**29**	**5.8**	**1.5**	**0.66**	**0.58**
Certified Value	---	58500	---	---	---	---	56	---	0.30	---	1500	33.1	5.72	73	24.9	4.45	---	---	---

ERM-CC018 is a European sandy soil reference material *OREAS-25a is an Australian reference soil. Certified values reported are for an Aqua Regia Digestion*

Spike Recoveries

		Al	Ag	As	Au	B	Ba	Be	Bi	Cd	Ca	Ce	Co	Cr	Cu	Cs	Dy	Er	Eu
Sample ID	**Sample Description**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
CE491-22	Rock composite 2B	---	104	108	104	91	88	107	107	107	---	111	108	126	109	110	111	111	110
CE491-31	Rock composite 7E	86	127	113	105	95	96	109	108	108	87	112	109	113	114	114	111	111	111

Analyte of interest added to sample prior to analysis

Rock analyses *Total recoverable metals (TRM)*

		Fe	Ga	Gd	Ge	Hf	Hg	Ho	In	Ir	K	La	Li	Lu	Mg	Mn	Mo	Na	Nb
Sample ID	**Sample Description**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**
CE491-20	Rock composite 1B	28700	5.6	3.9	0.15	0.38	<0.03	0.43	0.021	<0.002	2040	23	43	0.13	17600	636	0.16	180	0.045
CE491-20 dig dup	Rock composite 1B dig dup	31000	6.2	4.7	0.16	0.53	<0.03	0.54	0.024	<0.002	2440	30	45	0.15	18300	640	0.13	220	0.075
CE491-20 avg	Rock composite 1B avg	**29800**	**5.9**	**4.3**	**0.15**	**0.46**	**<0.03**	**0.49**	**0.023**	**<0.002**	**2240**	**27**	**44**	**0.14**	**17900**	**638**	**0.14**	**200**	**0.060**
CE491-21	Rock composite 1E	46400	9.8	4.5	0.16	0.43	<0.03	0.51	0.075	<0.002	2600	28	56	0.14	22400	1320	0.21	240	0.021
CE491-22	Rock composite 2B	28500	5.6	4.3	0.16	0.45	<0.03	0.45	0.023	<0.002	3210	31	28	0.14	8520	602	0.31	170	0.018
CE491-22 dil dup	Rock composite 2B dil dup	28600	5.7	4.4	0.17	0.46	<0.03	0.46	0.023	<0.002	3180	31	28	0.15	8520	603	0.31	160	0.015
CE491-22 avg	Rock composite 2B avg	**28600**	**5.7**	**4.4**	**0.17**	**0.45**	**<0.03**	**0.46**	**0.023**	**<0.002**	**3190**	**31**	**28**	**0.14**	**8520**	**602**	**0.31**	**160**	**0.017**
CE491-23	Rock composite 2E	27300	4.1	3.9	0.13	0.47	<0.03	0.41	0.028	<0.002	3070	24	19	0.11	7110	413	0.23	110	0.027
CE491-24	Rock composite 3B	39000	7.0	1.1	0.10	0.36	<0.03	0.35	0.010	<0.002	1840	2.1	14	0.11	26400	727	0.10	400	0.110
CE491-25	Rock composite 3E	24900	5.2	1.3	0.07	0.27	<0.03	0.24	0.006	<0.002	1080	6.3	31	0.074	15000	577	0.08	330	0.119
CE491-26	Rock composite 4B	18200	3.7	4.0	0.12	0.44	<0.03	0.44	0.010	<0.002	1020	25	20	0.13	8020	464	0.33	190	0.119
CE491-27	Rock composite 4E	41800	6.5	3.4	0.12	0.77	<0.03	0.51	0.019	<0.002	2060	16	12	0.17	10400	588	1.6	310	0.121
CE491-28	Rock composite 5B	15900	3.7	3.1	0.11	0.50	<0.03	0.34	0.010	<0.002	1880	21	5.3	0.11	6310	336	2.1	360	0.094
CE491-29	Rock composite 5E	43500	8.2	3.5	0.22	0.59	<0.03	0.48	0.037	<0.002	1550	17	8.1	0.14	9680	644	1.3	700	0.154
CE491-30	Rock composite 7B	18800	4.6	4.2	0.12	0.74	<0.03	0.54	0.019	<0.002	2760	26	19	0.18	6340	525	0.13	370	0.030
CE491-31	Rock composite 7E	15600	3.4	4.5	0.11	0.69	<0.03	0.35	0.071	<0.002	3270	36	24	0.087	5480	251	0.14	160	0.006
CE491-31 dil dup	Rock composite 7E dil dup	15600	3.5	4.5	0.12	0.68	<0.03	0.35	0.071	<0.002	3340	36	24	0.087	5530	255	0.14	160	0.007
CE491-31 avg	Rock composite 7E avg	**15600**	**3.4**	**4.5**	**0.12**	**0.69**	**<0.03**	**0.35**	**0.071**	**<0.002**	**3310**	**36**	**24**	**0.087**	**5500**	**253**	**0.14**	**160**	**0.007**
SED-43 LOD (3σ)	---	1	0.002	0.001	0.01	0.001	0.03	0.001	0.002	0.002	2	0.001	0.01	0.001	1	0.02	0.01	30	0.004
Method Code	---	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-229	C-223/C-229	C-223/C-209	C-223/C-229	C-223/C-209

Reference Materials

		Fe	Ga	Gd	Ge	Hf	Hg	Ho	In	Ir	K	La	Li	Lu	Mg	Mn	Mo	Na	Nb
Sample ID	**Sample Description**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**
ERM-CC018-1	---	10100	2.9	1.3	0.84	0.26	1.4	0.19	0.075	<0.002	829	8.1	7.3	0.064	1180	185	14	210	0.801
ERM-CC018-2	---	9450	2.4	1.1	0.73	0.17	1.6	0.16	0.073	<0.002	681	6.8	6.1	0.055	1080	178	14	180	0.719
ERM-CC018 avg	---	**9780**	**2.7**	**1.2**	**0.79**	**0.22**	**1.5**	**0.17**	**0.074**	**<0.002**	**755**	**7.5**	**6.7**	**0.060**	**1130**	**182**	**14**	**200**	**0.760**
Certified Value	---	---	---	---	---	---	1.38 ± 0.06	---	---	---	---	---	---	---	---	---	---	---	---
OREAS-25a-1	---	54500	22	2.4	0.06	0.98	0.09	0.25	0.090	0.017	1280	18	28	0.071	1830	381	1.7	300	0.305
OREAS-25a-2	---	64700	24	2.6	0.16	1.3	0.04	0.26	0.096	0.002	1780	19	33	0.077	2080	402	1.9	330	0.356
OREAS-25a avg	---	**59600**	**23**	**2.5**	**0.11**	**1.1**	**0.07**	**0.25**	**0.093**	**0.009**	**1530**	**19**	**31**	**0.074**	**1960**	**392**	**1.8**	**320**	**0.330**
Certified Value	---	59900	---	---	---	---	---	---	---	---	1310	---	---	---	---	420	---	---	---

ERM-CC018 is a European sandy soil reference material *ERM-CC018 is a European sandy soil reference material*

Spike Recoveries

		Fe	Ga	Gd	Ge	Hf	Hg	Ho	In	Ir	K	La	Li	Lu	Mg	Mn	Mo	Na	Nb
Sample ID	**Sample Description**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
CE491-22	Rock composite 2B	---	107	111	104	110	111	111	109	107	129	110	115	111	---	86	108	104	107
CE491-31	Rock composite 7E	91	108	111	108	111	109	111	109	108	129	111	112	112	92	87	108	103	109

Analyte of interest added to sample prior to analysis *Analyte of interest added to sample prior to analysis*

Rock analyses *Total recoverable metals (TRM)*

		Nd	Ni	Os	P	Pb	Pd	Pt	Pr	Rb	Re	Rh	Ru	S	Sb	Sc	Se	Sm	Sn
Sample ID	**Sample Description**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**
CE491-20	Rock composite 1B	22	92	<0.1	491	11	0.18	0.003	5.6	13	<0.001	<0.002	<0.01	80	0.34	5.0	0.08	4.3	0.48
CE491-20 dig dup	Rock composite 1B dig dup	28	93	<0.1	483	9.9	0.22	0.003	7.2	17	<0.001	<0.002	<0.01	77	0.43	5.5	0.08	5.4	0.62
CE491-20 avg	Rock composite 1B avg	**25**	**93**	**<0.1**	**487**	**10**	**0.20**	**0.003**	**6.4**	**15**	**<0.001**	**<0.002**	**<0.01**	**78**	**0.38**	**5.3**	**0.08**	**4.8**	**0.55**
CE491-21	Rock composite 1E	26	134	<0.1	640	214	0.21	0.004	6.6	17	<0.001	0.004	<0.01	756	0.92	6.9	0.12	5.0	0.59
CE491-22	Rock composite 2B	26	28	<0.1	423	5.1	0.19	0.002	7.1	22	<0.001	<0.002	<0.01	159	0.45	8.6	0.04	5.0	0.84
CE491-22 dil dup	Rock composite 2B dil dup	27	29	<0.1	423	5.2	0.19	0.003	7.2	24	<0.001	<0.002	<0.01	161	0.44	8.1	0.05	5.1	0.88
CE491-22 avg	Rock composite 2B avg	**27**	**28**	**<0.1**	**423**	**5.2**	**0.19**	**0.003**	**7.2**	**23**	**<0.001**	**<0.002**	**<0.01**	**160**	**0.45**	**8.3**	**0.04**	**5.0**	**0.86**
CE491-23	Rock composite 2E	22	31	0.2	537	11	0.18	0.005	5.7	24	<0.001	0.002	<0.01	3790	2.2	3.4	0.18	4.3	0.65
CE491-24	Rock composite 3B	2.8	42	<0.1	422	0.61	0.14	0.002	0.62	9.9	0.001	<0.002	<0.01	15	0.03	6.0	0.02	0.79	0.35
CE491-25	Rock composite 3E	6.7	39	<0.1	459	2.3	0.10	0.003	1.7	4.7	<0.001	<0.002	<0.01	13	0.10	2.4	0.03	1.4	0.40
CE491-26	Rock composite 4B	23	13	<0.1	490	17	0.17	0.003	6.0	6.3	<0.001	<0.002	<0.01	17	0.17	1.8	0.04	4.4	0.55
CE491-27	Rock composite 4E	19	16	<0.1	901	9.8	0.23	0.005	4.6	6.6	0.002	<0.002	<0.01	5410	0.63	5.8	0.30	3.8	0.41
CE491-28	Rock composite 5B	18	16	<0.1	516	2.7	0.14	0.003	4.9	11	<0.001	<0.002	<0.01	260	0.10	1.5	0.03	3.5	0.38
CE491-29	Rock composite 5E	19	25	<0.1	856	8.0	0.21	0.007	4.6	11	0.005	<0.002	<0.01	6050	0.21	6.2	1.0	3.9	1.0
CE491-30	Rock composite 7B	23	10	<0.1	378	8.8	0.25	0.004	6.1	20	<0.001	<0.002	<0.01	54	0.37	3.5	0.03	4.6	0.74
CE491-31	Rock composite 7E	30	11	<0.1	467	8.6	0.16	0.004	8.2	24	<0.001	<0.002	<0.01	1010	1.2	2.3	0.04	5.6	2.0
CE491-31 dil dup	Rock composite 7E dil dup	30	11	<0.1	472	8.6	0.17	0.004	8.2	24	<0.001	<0.002	<0.01	1010	1.2	2.6	0.03	5.6	2.0
CE491-31 avg	Rock composite 7E avg	**30**	**11**	**<0.1**	**469**	**8.6**	**0.17**	**0.004**	**8.2**	**24**	**<0.001**	**<0.002**	**<0.01**	**1010**	**1.2**	**2.4**	**0.03**	**5.6**	**2.0**
SED-43 LOD (3σ)	---	0.001	0.01	0.1	4	0.01	0.002	0.001	0.001	0.01	0.001	0.002	0.01	12	0.01	0.03	0.01	0.001	0.003
Method Code	---	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209

Reference Materials

		Nd	Ni	Os	P	Pb	Pd	Pt	Pr	Rb	Re	Rh	Ru	S	Sb	Sc	Se	Sm	Sn
Sample ID	**Sample Description**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**
ERM-CC018-1	---	7.2	25	<0.1	830	331	0.13	0.018	1.9	6.6	0.002	0.025	<0.01	1010	3.0	1.8	0.56	1.4	13
ERM-CC018-2	---	6.1	24	<0.1	814	329	0.17	0.010	1.6	5.5	0.002	0.024	<0.01	987	3.0	1.3	0.54	1.2	14
ERM-CC018 avg	---	**6.6**	**25**	**<0.1**	**822**	**330**	**0.15**	**0.014**	**1.8**	**6.0**	**0.002**	**0.025**	**<0.01**	**1000**	**3.0**	**1.5**	**0.55**	**1.3**	**13**
Certified Value	---	---	25.8 ± 1.8	---	---	289 ± 10	---	---	---	---	---	---	---	---	---	---	---	---	---
OREAS-25a-1	---	16	32	<0.1	354	23	0.089	0.006	4.2	37	<0.001	0.055	---	431	0.22	12	1.5	3.0	2.9
OREAS-25a-2	---	17	39	<0.1	369	24	0.093	0.006	4.5	42	<0.001	0.005	<0.01	468	0.40	12	1.8	3.2	3.2
OREAS-25a avg	---	**16**	**35**	**<0.1**	**361**	**24**	**0.091**	**0.006**	**4.4**	**40**	**<0.001**	**0.030**	**<0.01**	**450**	**0.31**	**12**	**1.6**	**3.1**	**3.1**
Certified Value	---	---	26.9	---	370	21	---	---	---	---	---	---	---	---	---	8.64	---	---	2.7

ERM-CC018 is a European sandy soil reference material

ERM-CC018 is a European sandy soil reference material

Spike Recoveries

		Nd	Ni	Os	P	Pb	Pd	Pt	Pr	Rb	Re	Rh	Ru	S	Sb	Sc	Se	Sm	Sn
Sample ID	**Sample Description**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
CE491-22	Rock composite 2B	111	110	141	88	107	106	106	113	118	109	106	106	95	108	109	105	110	107
CE491-31	Rock composite 7E	110	111	144	92	108	107	107	116	113	110	108	109	96	109	113	107	112	109

Analyte of interest added to sample prior to analysis

Analyte of interest added to sample prior to analysis

Rock analyses *Total recoverable metals (TRM)*

		Sr	Ta	Tb	Te	Th	Ti	Tl	Tm	U	V	W	Y	Yb	Zn	Zr
Sample ID	**Sample Description**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**
CE491-20	Rock composite 1B	28	0.005	0.50	0.027	9.2	219	0.09	0.15	0.71	31	0.13	11	0.87	75	10
CE491-20 dig dup	Rock composite 1B dig dup	29	0.004	0.60	0.018	11	440	0.11	0.18	1.0	35	0.13	13	1.1	76	16
CE491-20 avg	Rock composite 1B avg	**28**	**0.005**	**0.55**	**0.022**	**10**	**329**	**0.10**	**0.16**	**0.86**	**33**	**0.13**	**12**	**0.98**	**76**	**13**
CE491-21	Rock composite 1E	33	0.004	0.58	0.028	7.9	42	0.14	0.16	0.75	61	0.12	12	0.99	543	10
CE491-22	Rock composite 2B	18	0.004	0.54	0.023	10	21	0.11	0.15	1.2	38	0.084	12	0.99	57	14
CE491-22 dil dup	Rock composite 2B dil dup	18	0.003	0.54	0.014	10	21	0.11	0.16	1.2	38	0.086	12	0.99	60	14
CE491-22 avg	Rock composite 2B avg	**18**	**0.004**	**0.54**	**0.018**	**10**	**21**	**0.11**	**0.16**	**1.2**	**38**	**0.085**	**12**	**0.99**	**58**	**14**
CE491-23	Rock composite 2E	48	0.017	0.50	0.027	9.1	20	0.17	0.13	1.1	20	0.18	10	0.78	45	13
CE491-24	Rock composite 3B	30	0.016	0.21	0.004	0.67	2210	0.064	0.16	0.10	62	0.077	8.3	0.96	66	8.9
CE491-25	Rock composite 3E	13	0.012	0.20	0.029	5.3	1230	0.026	0.097	0.33	30	0.12	5.7	0.59	62	7.4
CE491-26	Rock composite 4B	26	0.011	0.51	0.025	11	312	0.043	0.15	0.79	13	0.13	10	0.95	52	12
CE491-27	Rock composite 4E	50	0.014	0.47	0.011	4.7	1240	0.350	0.20	1.3	62	0.094	13	1.3	104	24
CE491-28	Rock composite 5B	21	0.008	0.39	0.010	7.5	96	0.057	0.12	0.99	19	0.20	8.5	0.76	22	13
CE491-29	Rock composite 5E	51	0.010	0.47	0.097	5.3	1100	0.071	0.18	0.84	67	0.32	12	1.1	76	16
CE491-30	Rock composite 7B	73	0.009	0.57	0.013	11	37	0.11	0.20	1.4	17	0.12	14	1.2	35	25
CE491-31	Rock composite 7E	63	0.007	0.49	0.016	8.8	7.8	0.14	0.10	1.2	12	0.052	9.0	0.61	31	20
CE491-31 dil dup	Rock composite 7E dil dup	63	0.006	0.49	0.017	8.8	8.2	0.14	0.10	1.2	12	0.053	8.9	0.61	32	20
CE491-31 avg	Rock composite 7E avg	**63**	**0.007**	**0.49**	**0.016**	**8.8**	**8.0**	**0.14**	**0.10**	**1.2**	**12**	**0.053**	**8.9**	**0.61**	**32**	**20**
SED-43 LOD (3σ)	---	0.002	0.001	0.001	0.001	0.01	0.1	0.004	0.001	0.002	0.1	0.001	0.001	0.001	1	0.01
Method Code	---	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-229	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209	C-223/C-209

Reference Materials

		Sr	Ta	Tb	Te	Th	Ti	Tl	Tm	U	V	W	Y	Yb	Zn	Zr
Sample ID	**Sample Description**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**	**TRM (µg/g)**
ERM-CC018-1	---	73	0.015	0.18	0.028	2.5	166	0.19	0.068	1.2	16	2.1	6.6	0.43	307	18
ERM-CC018-2	---	71	0.016	0.16	0.031	1.9	111	0.16	0.061	1.1	14	2.1	5.9	0.37	299	13
ERM-CC018 avg	---	**72**	**0.015**	**0.17**	**0.029**	**2.2**	**139**	**0.18**	**0.064**	**1.1**	**15**	**2.1**	**6.3**	**0.40**	**303**	**15**
Certified Value	---	---	---	---	---	---	---	---	---	---	19.4 ± 1.0	---	---	---	313 ± 13	---
OREAS-25a-1	---	15	0.005	0.30	0.024	13	357	0.27	0.081	1.8	110	0.027	5.7	0.51	36	36
OREAS-25a-2	---	17	0.004	0.33	0.041	13	690	0.29	0.089	1.8	117	0.038	5.9	0.54	39	39
OREAS-25a avg	---	**16**	**0.005**	**0.31**	**0.033**	**13**	**524**	**0.28**	**0.085**	**1.8**	**113**	**0.032**	**5.8**	**0.53**	**38**	**37**
Certified Value	---	17.3	---	---	---	10.7	---	0.20	---	1.49	117	---	4.56	---	30.1	---

ERM-CC018 is a European sandy soil reference material *ERM-CC018 is a European sandy soil reference material*

Spike Recoveries

		Sr	Ta	Tb	Te	Th	Ti	Tl	Tm	U	V	W	Y	Yb	Zn	Zr
Sample ID	**Sample Description**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
CE491-22	Rock composite 2B	93	112	111	106	112	96	108	111	109	91	108	111	110	112	110
CE491-31	Rock composite 7E	95	115	111	107	111	96	109	111	110	93	109	114	111	109	112

Analyte of interest added to sample prior to analysis *Analyte of interest added to sample prior to analysis*

Rock analyses *Dilute-acid extractable metals (AEM)*

		Ca	K	Mg	Na	Al	Ag	As	Au	B	Ba	Be	Bi	Cd	Ce	Co	Cr	Cu	Cs	Dy	Er	Eu	Fe
Sample ID	**Sample Description**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**
CE491-20	Rock composite 1B	7490	1100	3060	143	2410	0.016	1.9	<0.01	2.5	32	0.36	0.17	0.018	16	2.5	6.3	3.3	1.2	1.5	0.68	0.42	4610
CE491-20 Dig Dup	Rock composite 1B dig dup	7510	1130	3050	140	2420	0.015	2.0	<0.01	1.8	31	0.37	0.18	0.018	17	2.6	6.2	3.6	1.2	1.5	0.68	0.44	4580
CE491-20 avg	Rock composite 1B avg	7500	1120	3060	141	2420	0.015	2.0	<0.01	2.2	31	0.37	0.18	0.018	17	2.6	6.3	3.4	1.2	1.5	0.68	0.43	4600
CE491-21	Rock composite 1E	8430	1050	3510	136	3270	0.085	2.3	<0.01	2.2	57	0.49	0.26	0.18	13	2.0	12	2.3	0.75	2.0	0.90	0.53	6460
CE491-22	Rock composite 2B	6610	1090	2080	83	2950	0.034	0.62	<0.01	0.8	84	0.44	0.10	0.014	12	4.4	12	1.3	0.86	1.3	0.60	0.34	5600
CE491-22 dil dup	Rock composite 2B dil dup	6620	1100	2080	83	2960	0.032	0.64	<0.01	0.4	84	0.44	0.10	0.016	12	4.1	12	1.2	0.86	1.3	0.59	0.35	5540
CE491-22 avg	Rock composite 2B avg	6620	1100	2080	83	2960	0.033	0.63	<0.01	0.6	84	0.44	0.10	0.015	12	4.3	12	1.3	0.86	1.3	0.60	0.35	5570
CE491-23	Rock composite 2E	11700	1440	1400	82	2100	0.084	1.3	<0.01	1.1	43	0.60	0.32	0.020	11	1.2	4.6	3.1	0.71	1.5	0.62	0.44	6310
CE491-24	Rock composite 3B	15100	1420	3120	189	2920	0.004	0.57	<0.01	<0.2	7.4	0.078	<0.001	0.013	0.66	3.4	13	18	0.47	0.14	0.10	0.026	3830
CE491-25	Rock composite 3E	8840	643	1720	220	2540	0.017	1.5	0.04	5.7	12	0.13	0.027	0.012	3.4	2.1	8.8	21	0.19	0.33	0.17	0.038	2780
CE491-26	Rock composite 4B	12400	552	674	110	1160	0.015	1.6	0.02	1.7	21	0.15	0.096	0.029	25	0.40	1.9	2.9	0.35	1.2	0.48	0.29	1850
CE491-27	Rock composite 4E	20100	765	1260	146	2750	0.074	1.9	0.01	1.4	27	0.11	0.091	0.079	14	1.2	2.8	4.9	0.11	0.85	0.45	0.21	5470
CE491-28	Rock composite 5B	6570	755	1330	246	2800	0.049	0.76	<0.01	0.5	30	0.36	0.17	0.026	8.8	1.1	3.8	22	0.23	1.00	0.46	0.26	5820
CE491-29	Rock composite 5E	5340	930	1400	206	1810	0.015	0.68	<0.01	0.8	36	0.23	0.062	0.007	11	0.82	4.3	1.4	0.12	1.0	0.45	0.28	4250
CE491-30	Rock composite 7B	14000	1080	705	192	1630	0.010	0.74	<0.01	0.3	45	0.35	0.037	0.019	20	0.48	4.3	0.80	0.64	1.4	0.62	0.33	4150
CE491-31	Rock composite 7E	8760	1930	685	122	2090	0.040	1.4	<0.01	1.2	1836	0.83	1.3	0.011	17	0.61	2.6	4.0	1.8	1.3	0.48	0.55	3190
CE491-31 dil dup	Rock composite 7E dil dup	8780	1920	688	117	2130	0.043	1.4	<0.01	1.1	1836	0.81	1.3	0.010	17	0.60	2.7	4.2	1.8	1.3	0.50	0.56	3080
CE491-31 avg	Rock composite 7E avg	8770	1920	686	119	2110	0.042	1.4	<0.01	1.2	1836	0.82	1.3	0.011	17	0.61	2.7	4.1	1.8	1.3	0.49	0.56	3140
LOD (3σ)	---	5	2	4	10	30	0.001	0.03	0.01	0.2	0.1	0.002	0.001	0.001	0.001	0.01	0.1	0.3	0.003	0.001	0.001	0.001	1
Method Code	---	C-241/C-229		C-241/C-229		C-241/C-229		C-241/C-209		C-241/C-209		C-241/C-209		C-241/C-209		C-241/C-209		C-241/C-209		C-241/C-229		C-241/C-229	

C-209: ICP-MS C-229: ICP-AES C-241 Dilute Acid Extractable Metals (AEM) 1 M HCl

Certified Reference Materials

		Ca	K	Mg	Na	Al	Ag	As	Au	B	Ba	Be	Bi	Cd	Ce	Co	Cr	Cu	Cs	Dy	Er	Eu	Fe
Sample ID	**Sample Description**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**
ERM-CC018-1	---	15500	348	591	85	2190	1.3	14	0.02	7.9	226	0.30	0.98	5.0	7.2	2.2	38	58	0.14	0.47	0.25	0.14	2810
ERM-CC018-2	---	16600	369	617	89	2300	1.5	17	0.01	5.7	247	0.30	0.97	5.9	8.1	2.5	41	61	0.15	0.53	0.27	0.16	2990
Avg ERM-CC018	---	16000	358	604	87	2240	1.4	16	0.01	6.8	236	0.30	0.97	5.4	7.7	2.4	40	60	0.15	0.50	0.26	0.15	2900
In-house Value	---	---	---	---	---	2473	---	17	---	---	278	---	---	5.5	---	2.8	44	62	---	---	---	---	3278

Spike Recoveries

		Ca	K	Mg	Na	Al	Ag	As	Au	B	Ba	Be	Bi	Cd	Ce	Co	Cr	Cu	Cs	Dy	Er	Eu	Fe
Sample ID	**Sample Description**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
CE491-22	Rock composite 2B	89	96	95	101	90	38	112	111	119	95	110	113	110	115	107	108	107	112	112	111	113	86
CE491-31	Rock composite 7E	85	96	97	101	94	35	105	102	102	91	105	103	102	102	102	101	105	103	105	105	105	80

Analyte of interest added to sample prior to analysis

Rock analyses *Dilute-acid extractable metals (AEM)*

		Ga	Gd	Ge	Hf	Hg	Ho	In	Ir	La	Li	Lu	Mn	Mo	Nb	Nd	Ni	Os	P	Pb	Pd	Pt	Pr
Sample ID	**Sample Description**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**
CE491-20	Rock composite 1B	0.72	2.1	0.11	0.092	<0.02	0.26	0.010	<0.001	7.0	3.4	0.073	343	0.08	<0.02	8.9	8.7	<0.04	523	7.2	0.054	<0.001	2.1
CE491-20 Dig Dup	Rock composite 1B dig dup	0.72	2.2	0.13	0.11	<0.02	0.27	0.010	<0.001	7.4	3.4	0.077	345	0.06	<0.02	9.3	8.3	<0.04	512	7.3	0.054	<0.001	2.2
CE491-20 avg	Rock composite 1B avg	0.72	2.1	0.12	0.099	<0.02	0.27	0.010	<0.001	7.2	3.4	0.075	344	0.07	<0.02	9.1	8.5	<0.04	518	7.2	0.054	<0.001	2.1
CE491-21	Rock composite 1E	1.1	2.4	0.13	0.14	<0.02	0.35	0.033	<0.001	5.5	5.9	0.088	679	0.07	<0.02	7.7	13	<0.04	664	197	0.074	<0.001	1.7
CE491-22	Rock composite 2B	0.86	1.8	0.12	0.080	<0.02	0.23	0.010	<0.001	5.1	4.5	0.067	515	0.09	<0.02	6.4	5.4	<0.04	360	3.7	0.044	<0.001	1.5
CE491-22 dil dup	Rock composite 2B dil dup	0.88	1.8	0.12	0.087	<0.02	0.23	0.011	<0.001	5.1	4.5	0.066	513	0.06	<0.02	6.3	5.4	<0.04	358	3.7	0.048	<0.001	1.5
CE491-22 avg	Rock composite 2B avg	0.87	1.8	0.12	0.083	<0.02	0.23	0.010	<0.001	5.1	4.5	0.066	514	0.08	<0.02	6.4	5.4	<0.04	359	3.7	0.046	<0.001	1.5
CE491-23	Rock composite 2E	0.62	2.1	0.16	0.15	<0.02	0.26	0.015	<0.001	4.7	2.4	0.063	298	0.08	<0.02	6.5	3.1	<0.04	545	7.1	0.064	<0.001	1.4
CE491-24	Rock composite 3B	0.71	0.14	0.06	0.024	<0.02	0.032	0.001	<0.001	0.27	1.4	0.018	203	<0.02	<0.02	0.42	5.3	<0.04	483	0.14	0.007	<0.001	0.093
CE491-25	Rock composite 3E	0.64	0.42	0.06	0.060	<0.02	0.063	0.002	0.001	1.4	2.9	0.019	119	0.04	0.03	1.9	4.3	<0.04	501	1.1	0.014	<0.001	0.45
CE491-26	Rock composite 4B	0.33	2.0	0.16	0.087	<0.02	0.19	0.003	<0.001	14	0.78	0.056	263	0.05	0.02	13	0.6	<0.04	519	11	0.037	<0.001	3.3
CE491-27	Rock composite 4E	0.79	1.3	0.08	0.094	<0.02	0.16	0.008	<0.001	6.4	0.93	0.066	319	0.08	<0.02	7.5	1.1	<0.04	952	6.9	0.045	<0.001	1.8
CE491-28	Rock composite 5B	0.91	1.4	0.10	0.087	<0.02	0.18	0.004	<0.001	3.7	1.1	0.043	131	0.08	<0.02	5.9	1.5	<0.04	919	4.8	0.038	<0.001	1.2
CE491-29	Rock composite 5E	0.54	1.5	0.12	0.14	<0.02	0.18	0.006	<0.001	5.0	0.67	0.047	172	0.30	<0.02	5.7	1.8	<0.04	546	1.9	0.035	<0.001	1.3
CE491-30	Rock composite 7B	0.47	2.2	0.10	0.11	<0.02	0.25	0.006	<0.001	9.3	1.7	0.064	452	0.05	<0.02	10	0.8	<0.04	400	6.3	0.063	<0.001	2.5
CE491-31	Rock composite 7E	0.53	2.2	0.08	0.18	<0.02	0.21	0.026	<0.001	7.4	2.4	0.046	198	0.07	<0.02	9.2	0.9	<0.04	477	4.5	0.053	<0.001	2.2
CE491-31 dil dup	Rock composite 7E dil dup	0.53	2.2	0.08	0.18	<0.02	0.21	0.025	<0.001	7.3	2.3	0.044	198	0.07	<0.02	9.2	0.9	<0.04	480	4.4	0.051	<0.001	2.2
CE491-31 avg	Rock composite 7E avg	0.53	2.2	0.08	0.18	<0.02	0.21	0.025	<0.001	7.3	2.3	0.045	198	0.07	<0.02	9.2	0.9	<0.04	479	4.4	0.052	<0.001	2.2
LOD (3σ)	---	0.01	0.001	0.01	0.002	0.02	0.001	0.001	0.001	0.001	0.003	0.001	0.1	0.02	0.02	0.001	0.1	0.04	4	0.002	0.004	0.001	0.001
		C-241/C-209		C-241/C-209		C-241/C-209		C-241/C-209		C-241/C-209		C-241/C-209			C-241/C-209		C-241/C-209		C-241/C-209		C-241/C-209		

Certified Reference Materials

		Ga	Gd	Ge	Hf	Hg	Ho	In	Ir	La	Li	Lu	Mn	Mo	Nb	Nd	Ni	Os	P	Pb	Pd	Pt	Pr
Sample ID	**Sample Description**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**
ERM-CC018-1	---	0.77	0.59	0.59	0.15	0.07	0.091	0.041	0.002	3.2	1.6	0.031	120	7.1	0.12	2.9	13	<0.04	674	264	0.036	<0.001	0.75
ERM-CC018-2	---	0.82	0.65	0.67	0.16	0.08	0.10	0.044	0.002	3.6	1.7	0.035	128	8.0	0.12	3.3	14	<0.04	728	293	0.046	<0.001	0.86
Avg ERM-CC018	---	0.79	0.62	0.63	0.15	0.08	0.096	0.043	0.002	3.4	1.7	0.033	124	7.5	0.12	3.1	14	<0.04	701	278	0.041	<0.001	0.80
In-house Value	---	---	---	---	---	---	---	---	---	---	---	---	137	7.8	---	---	14	---	---	267	---	---	---

Spike Recoveries

		Ga	Gd	Ge	Hf	Hg	Ho	In	Ir	La	Li	Lu	Mn	Mo	Nb	Nd	Ni	Os	P	Pb	Pd	Pt	Pr
Sample ID	**Sample Description**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
CE491-22	Rock composite 2B	105	113	105	112	108	112	110	111	113	109	112	92	108	124	114	111	146	97	111	109	109	113
CE491-31	Rock composite 7E	100	105	100	105	102	105	104	102	103	102	105	96	107	113	104	107	138	98	103	99	100	103

Analyte of interest added to sample prior to analysis

Rock analyses *Dilute-acid extractable metals (AEM)*

		Rb	Re	Rh	Ru	S	Sb	Sc	Se	Sm	Sn	Sr	Ta	Tb	Te	Th	Ti	Tl	Tm	U	V	W	Y	Yb	Zn	Zr
Sample ID	**Sample Description**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**
CE491-20	Rock composite 1B	5.0	<0.002	<0.01	<0.001	<30	0.10	2.1	<0.01	2.1	0.17	28	<0.3	0.29	<0.02	4.2	15	0.034	0.083	0.26	5.3	0.066	6.6	0.53	14	2.2
CE491-20 Dig Dup	Rock composite 1B dig dup	5.6	<0.002	<0.01	<0.001	<30	0.13	2.1	0.01	2.2	0.17	27	<0.3	0.30	<0.02	4.4	16	0.032	0.085	0.27	5.2	0.072	6.4	0.52	14	2.6
CE491-20 avg	Rock composite 1B avg	5.3	<0.002	<0.01	<0.001	<30	0.12	2.1	0.01	2.2	0.17	28	<0.3	0.29	<0.02	4.3	15	0.033	0.084	0.27	5.2	0.069	6.5	0.52	14	2.4
CE491-21	Rock composite 1E	4.9	<0.002	<0.01	<0.001	38	0.21	3.3	0.01	2.1	0.22	33	<0.3	0.36	<0.02	3.1	13	0.043	0.11	0.24	9.1	0.085	8.6	0.65	86	2.7
CE491-22	Rock composite 2B	5.2	<0.002	<0.01	<0.001	<30	0.098	2.6	<0.01	1.6	0.20	17	<0.3	0.26	<0.02	2.7	6.5	0.022	0.075	0.28	8.3	0.021	6.1	0.47	15	1.6
CE491-22 dil dup	Rock composite 2B dil dup	4.6	<0.002	<0.01	<0.001	<30	0.088	2.5	<0.01	1.7	0.20	17	<0.3	0.25	<0.02	2.6	6.6	0.020	0.077	0.27	8.1	0.026	5.9	0.45	14	1.6
CE491-22 avg	Rock composite 2B avg	4.9	<0.002	<0.01	<0.001	<30	0.093	2.5	<0.01	1.6	0.20	17	<0.3	0.25	<0.02	2.7	6.5	0.021	0.076	0.27	8.2	0.024	6.0	0.46	15	1.6
CE491-23	Rock composite 2E	6.2	<0.002	<0.01	<0.001	<30	0.67	1.5	0.01	1.9	0.23	44	<0.3	0.30	<0.02	3.3	9.8	0.041	0.074	0.38	4.5	0.082	6.7	0.43	8.0	3.4
CE491-24	Rock composite 3B	7.3	<0.002	<0.01	<0.001	<30	0.005	0.32	<0.01	0.11	0.03	5.8	<0.3	0.023	<0.02	0.17	80	0.019	0.015	0.01	8.3	0.035	0.83	0.11	8.9	0.58
CE491-25	Rock composite 3E	2.1	<0.002	<0.01	<0.001	<30	0.024	0.36	<0.01	0.41	0.06	7.0	<0.3	0.057	<0.02	1.4	27	0.031	0.022	0.07	3.4	0.049	1.7	0.13	7.1	1.3
CE491-26	Rock composite 4B	2.5	<0.002	<0.01	<0.001	<30	0.030	0.37	<0.01	2.4	0.09	20	<0.3	0.24	<0.02	4.7	8.3	0.029	0.059	0.19	1.1	0.070	4.7	0.37	3.8	1.7
CE491-27	Rock composite 4E	1.5	<0.002	<0.01	<0.001	<30	0.086	0.95	<0.01	1.3	0.06	44	<0.3	0.16	<0.02	1.5	19	0.050	0.058	0.28	9.7	0.062	4.1	0.37	14	2.0
CE491-28	Rock composite 5B	2.9	<0.002	<0.01	<0.001	45	0.075	0.55	0.01	1.4	0.09	13	<0.3	0.19	<0.02	3.0	31	0.039	0.056	0.19	9.4	0.140	4.7	0.32	16	2.1
CE491-29	Rock composite 5E	3.1	<0.002	<0.01	<0.001	<30	0.052	0.42	<0.01	1.4	0.14	13	<0.3	0.20	0.02	4.5	11	0.024	0.057	0.29	2.9	0.070	4.4	0.32	3.8	2.5
CE491-30	Rock composite 7B	4.4	<0.002	<0.01	<0.001	<30	0.082	0.82	<0.01	2.2	0.16	71	<0.3	0.29	<0.02	3.9	7.7	0.038	0.071	0.26	3.0	0.057	6.4	0.43	3.7	2.3
CE491-31	Rock composite 7E	7.9	<0.002	<0.01	<0.001	418	0.21	0.90	0.01	2.2	0.64	62	<0.3	0.27	<0.02	2.2	6.9	0.040	0.056	0.40	2.6	0.028	5.6	0.31	5.7	4.0
CE491-31 dil dup	Rock composite 7E dil dup	7.8	<0.002	<0.01	<0.001	409	0.20	0.93	0.01	2.2	0.63	62	<0.3	0.27	<0.02	2.2	6.9	0.038	0.056	0.40	2.6	0.024	5.6	0.31	6.4	4.1
CE491-31 avg	Rock composite 7E avg	7.8	<0.002	<0.01	<0.001	413	0.21	0.91	0.01	2.2	0.63	62	<0.3	0.27	<0.02	2.2	6.9	0.039	0.056	0.40	2.6	0.026	5.6	0.31	6.0	4.0
LOD (3σ)	---	0.03	0.002	0.01	0.001	30	0.003	0.004	0.01	0.001	0.01	0.01	0.3	0.001	0.02	0.002	0.2	0.002	0.001	0.001	0.01	0.003	0.001	0.001	0.1	0.02
		C-241/C-209		C-241/C-209		C-241/C-209		C-241/C-209		C-241/C-209		C-241/C-209			C-241/C-209		C-241/C-209		C-241/C-209		C-241/C-209			C-241/C-209		

Certified Reference Materials

		Rb	Re	Rh	Ru	S	Sb	Sc	Se	Sm	Sn	Sr	Ta	Tb	Te	Th	Ti	Tl	Tm	U	V	W	Y	Yb	Zn	Zr
Sample ID	**Sample Description**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**	**(µg/g)**
ERM-CC018-1	---	1.7	<0.002	<0.01	<0.001	579	0.96	0.20	0.11	0.58	7.1	53	<0.3	0.083	<0.02	0.14	45	0.062	0.032	0.62	7.2	0.85	3.5	0.20	218	4.7
ERM-CC018-2	---	2.0	<0.002	<0.01	<0.001	617	1.0	0.20	0.11	0.66	7.5	56	<0.3	0.097	<0.02	0.15	49	0.070	0.036	0.67	7.7	0.97	4.2	0.23	248	5.1
Avg ERM-CC018	---	1.8	<0.002	<0.01	<0.001	598	1.0	0.20	0.11	0.62	7.3	54	<0.3	0.090	<0.02	0.14	47	0.066	0.034	0.64	7.5	0.91	3.9	0.21	233	4.9
In-house Value	---	---	---	---	---	---	---	---	---	---	7.6	58	---	---	---	---	53	---	---	0.65	7.7	---	---	---	241	---

Spike Recoveries

		Rb	Re	Rh	Ru	S	Sb	Sc	Se	Sm	Sn	Sr	Ta	Tb	Te	Th	Ti	Tl	Tm	U	V	W	Y	Yb	Zn	Zr
Sample ID	**Sample Description**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
CE491-22	Rock composite 2B	116	111	110	112	104	113	110	104	113	111	99	527	112	111	109	100	114	112	107	108	117	111	113	111	114
CE491-31	Rock composite 7E	107	105	100	101	97	104	105	100	104	103	98	522	104	103	104	99	102	105	103	105	109	107	106	104	104

Analyte of interest added to sample prior to analysis

Analysis

CSIRO

Measurement Details

Operator Name CSIRO Mastersizer
Sample Name Average of 'CE491-20 (1B composite) '
SOP File Name Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time 20/09/2018 8:41:02 AM
Measurement Date Time 20/09/2018 8:41:02 AM
Result Source Averaged

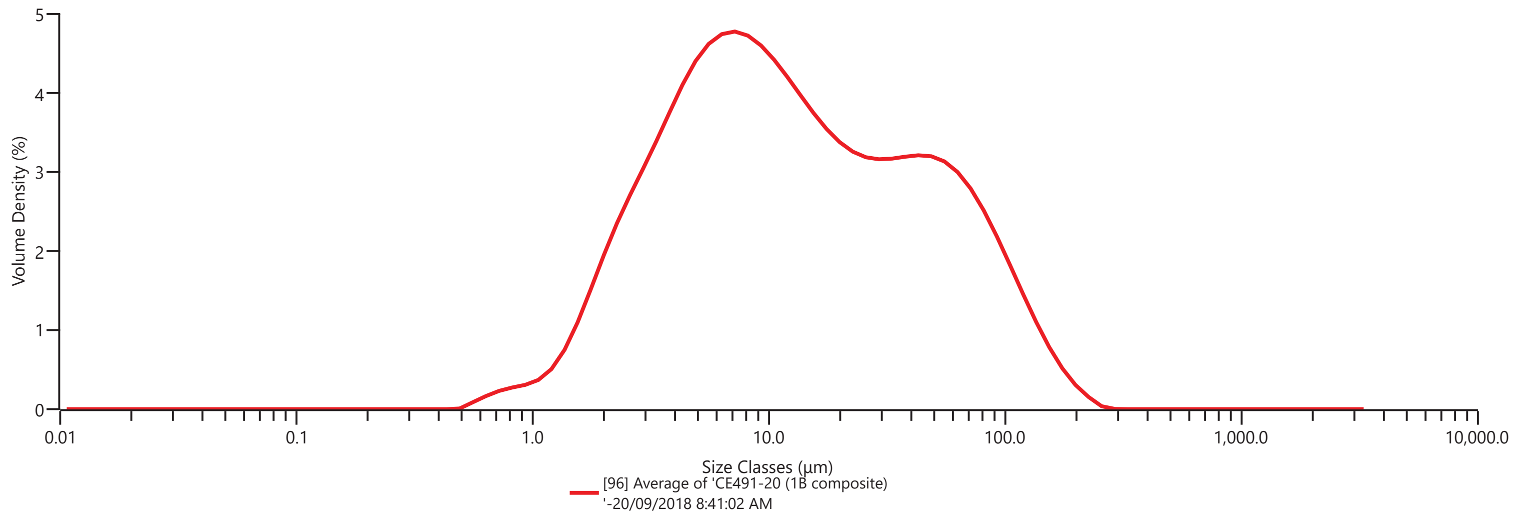
Analysis

Particle Name China Clay
Particle Refractive Index 1.555
Particle Absorption Index 0.010
Dispersant Name Water
Dispersant Refractive Index 1.330
Scattering Model Mie
Analysis Model General Purpose
Weighted Residual 0.49 %
Laser Obscuration 12.42 %

Result

Concentration 0.0098 %
Span 6.007
Uniformity 1.808
Specific Surface Area 910.8 m^2/kg
D [3,2] 6.59 µm
D [4,3] 26.4 µm
Dv (10) 2.71 µm
Dv (50) 11.6 µm
Dv (90) 72.2 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	6.03	12.7	52.63	76.0	90.95	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	7.99	14.5	55.94	86.4	93.05	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	10.25	16.4	59.07	98.1	94.87	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	12.79	18.7	62.02	111	96.39	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.07	3.55	15.61	21.2	64.83	127	97.60	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.21	4.03	18.74	24.1	67.55	144	98.52	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.41	4.58	22.16	27.4	70.20	163	99.17	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.64	5.21	25.84	31.1	72.83	186	99.60	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.89	5.92	29.70	35.3	75.48	211	99.85	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	1.19	6.72	33.66	40.1	78.14	240	99.98	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	1.61	7.64	37.65	45.6	80.82	272	100.00	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	2.23	8.68	41.60	51.8	83.49	310	100.00	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	3.14	9.86	45.44	58.9	86.11	352	100.00	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	4.40	11.2	49.12	66.9	88.61	400	100.00	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-21 (1E composite) '
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	20/09/2018 8:51:25 AM
Measurement Date Time	20/09/2018 8:51:25 AM
Result Source	Averaged

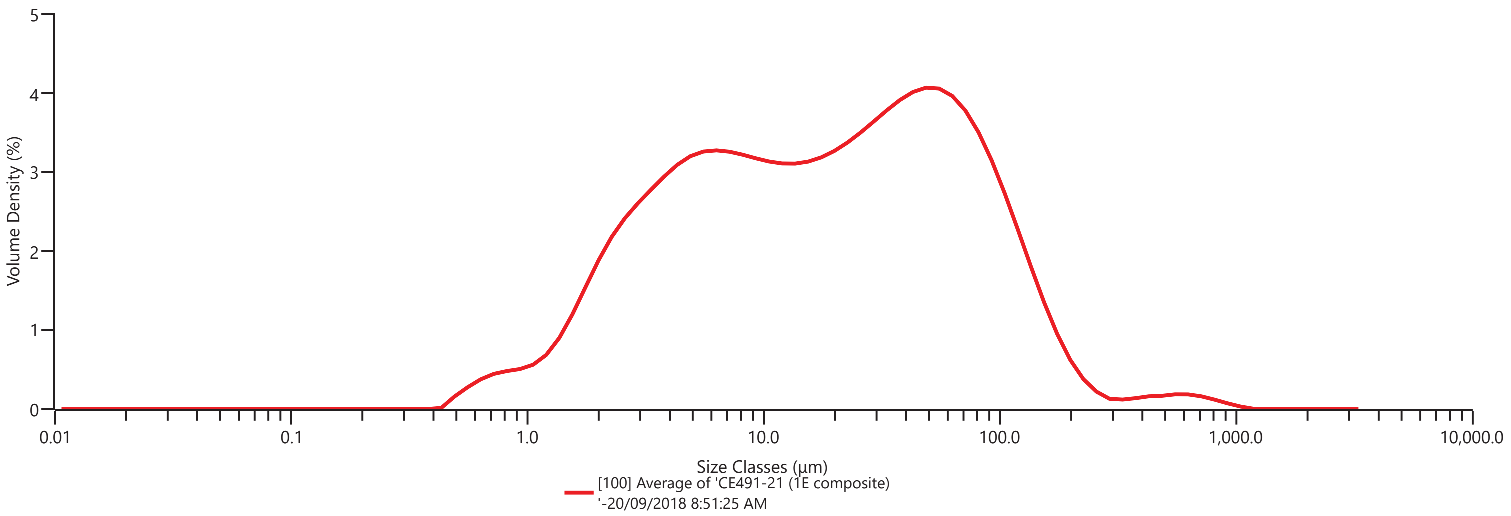
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.37 %
Laser Obscuration	12.73 %

Result

Concentration	0.0106 %
Span	5.102
Uniformity	1.853
Specific Surface Area	905.0 m²/kg
D [3,2]	6.63 µm
D [4,3]	41.3 µm
Dv (10)	2.53 µm
Dv (50)	18.6 µm
Dv (90)	97.2 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	7.51	12.7	42.25	76.0	84.63	454	99.23	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	9.33	14.5	44.84	86.4	87.55	516	99.37	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	11.35	16.4	47.45	98.1	90.18	586	99.52	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.14	3.12	13.52	18.7	50.11	111	92.46	666	99.68		
0.0167	0.00	0.0995	0.00	0.594	0.37	3.55	15.84	21.2	52.83	127	94.36	756	99.81		
0.0189	0.00	0.113	0.00	0.675	0.68	4.03	18.29	24.1	55.64	144	95.86	859	99.91		
0.0215	0.00	0.128	0.00	0.767	1.06	4.58	20.87	27.4	58.56	163	96.99	976	99.97		
0.0244	0.00	0.146	0.00	0.872	1.46	5.21	23.55	31.1	61.60	186	97.78	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	1.88	5.92	26.27	35.3	64.75	211	98.29	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	2.34	6.72	29.00	40.1	68.02	240	98.60	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	2.90	7.64	31.72	45.6	71.37	272	98.78	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	3.65	8.68	34.40	51.8	74.77	310	98.88	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	4.65	9.86	37.05	58.9	78.16	352	98.98	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	5.93	11.2	39.66	66.9	81.47	400	99.09	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name CSIRO Mastersizer
Sample Name Average of 'CE491-22 (2B composite) '
SOP File Name Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time 20/09/2018 9:00:24 AM
Measurement Date Time 20/09/2018 9:00:24 AM
Result Source Averaged

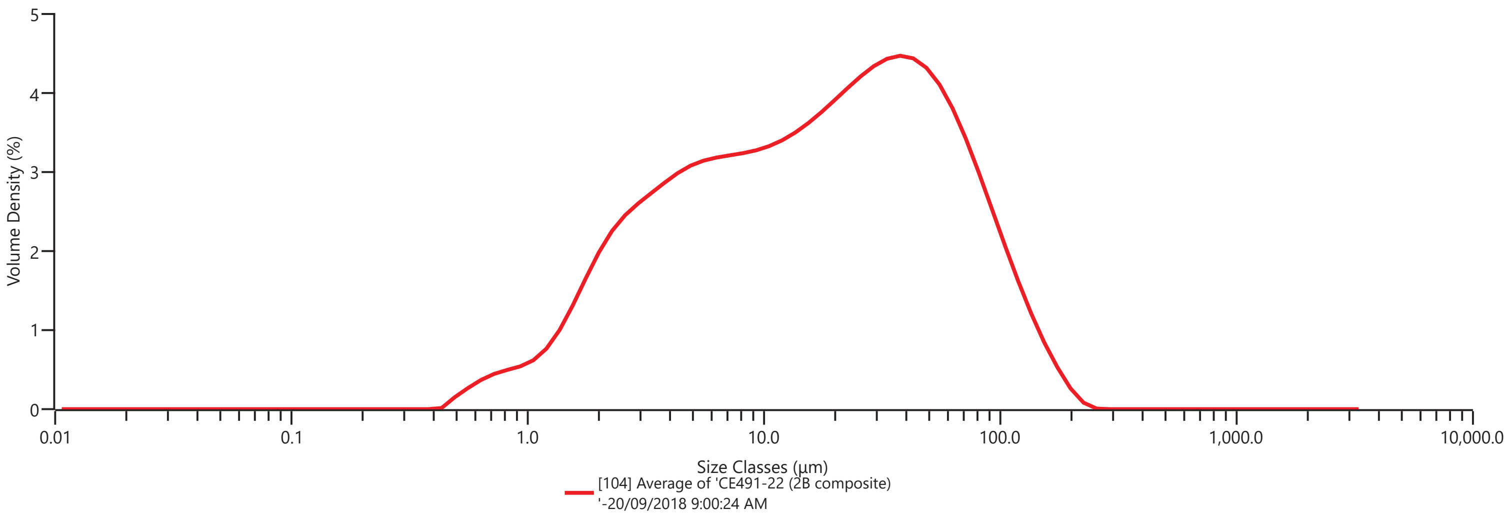
Analysis

Particle Name China Clay
Particle Refractive Index 1.555
Particle Absorption Index 0.010
Dispersant Name Water
Dispersant Refractive Index 1.330
Scattering Model Mie
Analysis Model General Purpose
Weighted Residual 0.52 %
Laser Obscuration 13.51 %

Result

Concentration 0.0109 %
Span 4.281
Uniformity 1.354
Specific Surface Area 933.7 m^2/kg
D [3,2] 6.43 µm
D [4,3] 30.1 µm
Dv (10) 2.44 µm
Dv (50) 17.3 µm
Dv (90) 76.4 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	8.00	12.7	42.82	76.0	89.89	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	9.88	14.5	45.74	86.4	92.39	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	11.93	16.4	48.75	98.1	94.50	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.13	3.12	14.10	18.7	51.89	111	96.23	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.35	3.55	16.38	21.2	55.15	127	97.58	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.66	4.03	18.77	24.1	58.54	144	98.59	859	100.00		
0.0215	0.00	0.128	0.00	0.767	1.03	4.58	21.26	27.4	62.05	163	99.29	976	100.00		
0.0244	0.00	0.146	0.00	0.872	1.45	5.21	23.83	31.1	65.67	186	99.72	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	1.90	5.92	26.45	35.3	69.37	211	99.94	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	2.41	6.72	29.11	40.1	73.11	240	100.00	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	3.04	7.64	31.78	45.6	76.81	272	100.00	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	3.87	8.68	34.48	51.8	80.42	310	100.00	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	4.96	9.86	37.21	58.9	83.85	352	100.00	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	6.34	11.2	39.99	66.9	87.03	400	100.00	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-23 (2E composite) '
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	20/09/2018 9:09:49 AM
Measurement Date Time	20/09/2018 9:09:49 AM
Result Source	Averaged

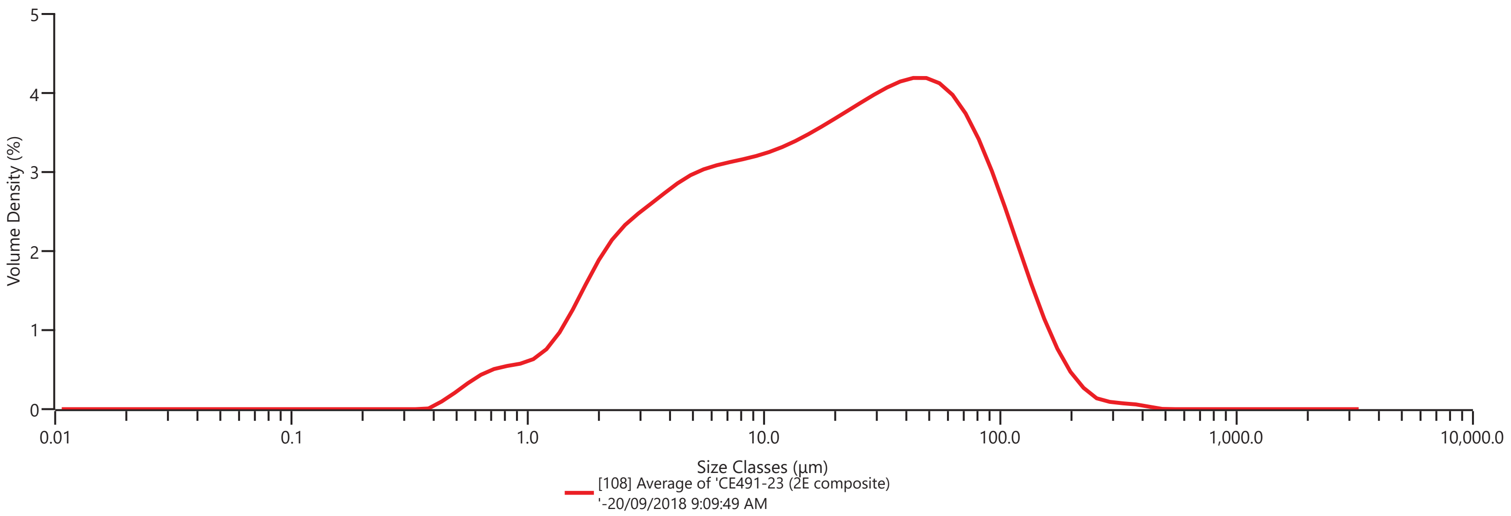
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.48 %
Laser Obscuration	12.50 %

Result

Concentration	0.0102 %
Span	4.632
Uniformity	1.478
Specific Surface Area	942.2 m²/kg
D [3,2]	6.37 µm
D [4,3]	34.0 µm
Dv (10)	2.43 µm
Dv (50)	18.3 µm
Dv (90)	87.3 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	8.14	12.7	41.74	76.0	86.94	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	9.93	14.5	44.56	86.4	89.79	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.08	2.75	11.88	16.4	47.46	98.1	92.31	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.25	3.12	13.94	18.7	50.44	111	94.44	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.53	3.55	16.11	21.2	53.51	127	96.17	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.89	4.03	18.39	24.1	56.65	144	97.49	859	100.00		
0.0215	0.00	0.128	0.00	0.767	1.32	4.58	20.77	27.4	59.89	163	98.44	976	100.00		
0.0244	0.00	0.146	0.00	0.872	1.77	5.21	23.24	31.1	63.20	186	99.07	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	2.25	5.92	25.78	35.3	66.60	211	99.46	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	2.77	6.72	28.35	40.1	70.06	240	99.68	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	3.40	7.64	30.96	45.6	73.55	272	99.79	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	4.20	8.68	33.59	51.8	77.05	310	99.86	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	5.25	9.86	36.26	58.9	80.50	352	99.92	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	6.57	11.2	38.97	66.9	83.82	400	99.97	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-24 (3B composite) '
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	20/09/2018 9:18:05 AM
Measurement Date Time	20/09/2018 9:18:05 AM
Result Source	Averaged

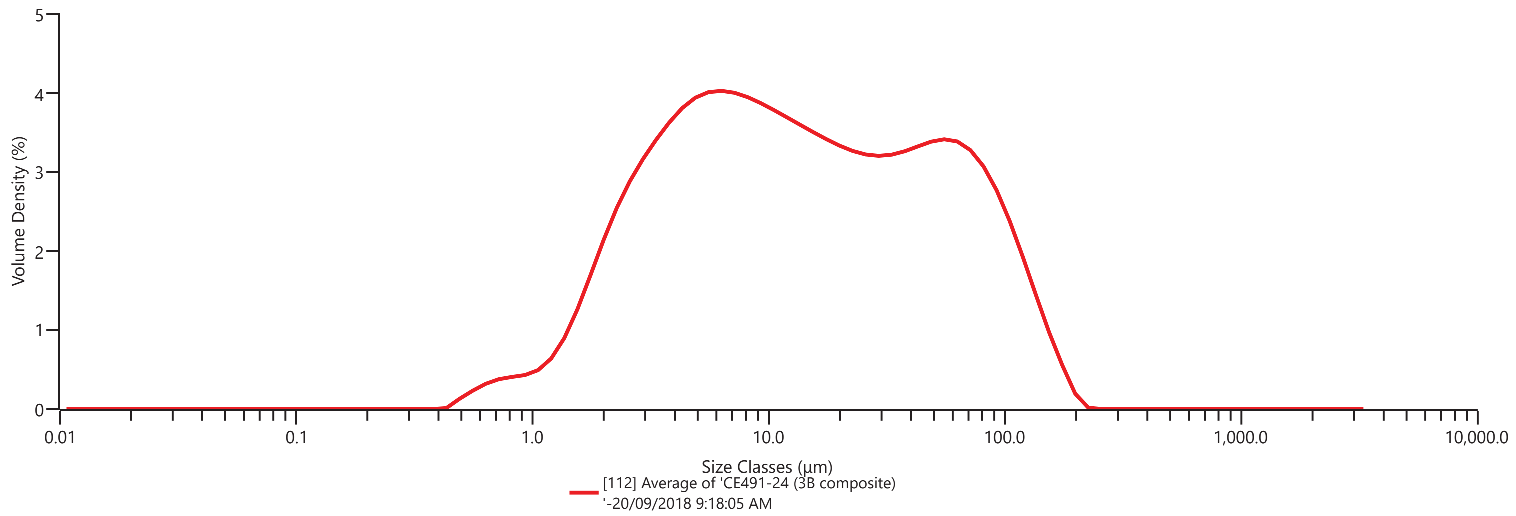
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.49 %
Laser Obscuration	12.93 %

Result

Concentration	0.0098 %
Span	6.073
Uniformity	1.810
Specific Surface Area	976.4 m^2/kg
D [3,2]	6.15 µm
D [4,3]	28.7 µm
Dv (10)	2.47 µm
Dv (50)	12.8 µm
Dv (90)	80.3 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	7.50	12.7	49.83	76.0	88.89	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	9.63	14.5	52.83	86.4	91.46	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	12.04	16.4	55.76	98.1	93.78	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.11	3.12	14.68	18.7	58.61	111	95.77	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.30	3.55	17.52	21.2	61.39	127	97.38	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.57	4.03	20.55	24.1	64.11	144	98.58	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.89	4.58	23.73	27.4	66.80	163	99.39	976	100.00		
0.0244	0.00	0.146	0.00	0.872	1.23	5.21	27.02	31.1	69.47	186	99.85	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	1.58	5.92	30.37	35.3	72.15	211	100.00	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	1.99	6.72	33.73	40.1	74.87	240	100.00	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	2.51	7.64	37.07	45.6	77.65	272	100.00	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	3.26	8.68	40.37	51.8	80.47	310	100.00	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	4.30	9.86	43.60	58.9	83.32	352	100.00	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	5.72	11.2	46.75	66.9	86.15	400	100.00	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name CSIRO Mastersizer
Sample Name Average of 'CE491-25 (3E composite) Duplicate'
SOP File Name Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time 20/09/2018 10:05:36 AM
Measurement Date Time 20/09/2018 10:05:36 AM
Result Source Averaged

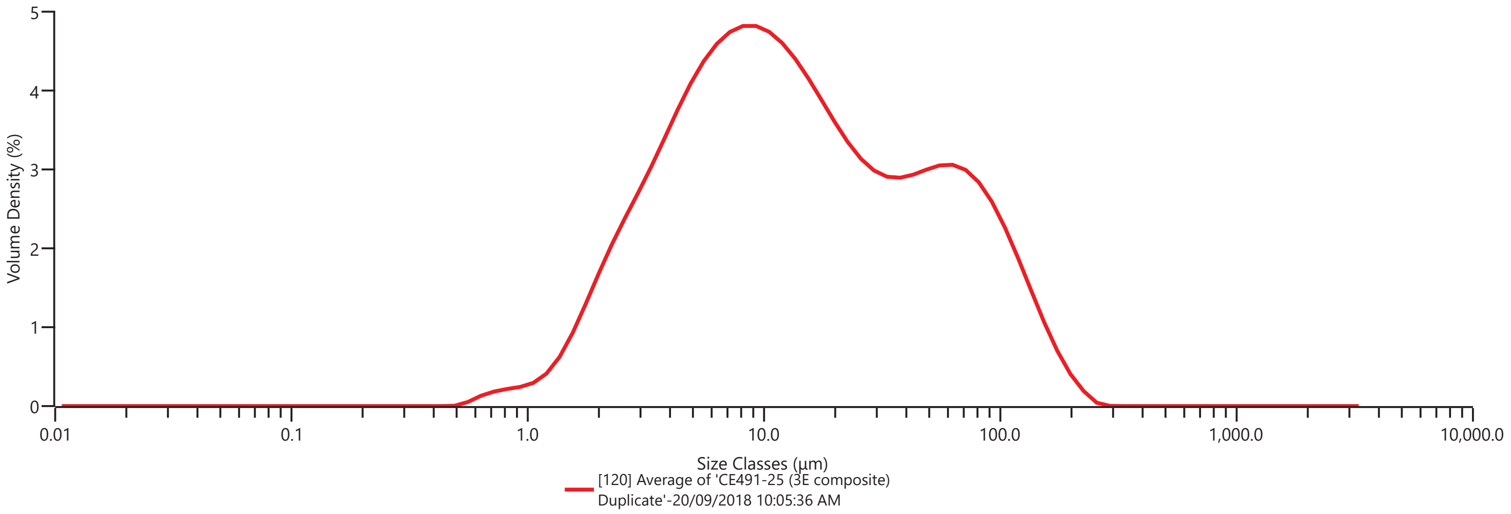
Analysis

Particle Name China Clay
Particle Refractive Index 1.555
Particle Absorption Index 0.010
Dispersant Name Water
Dispersant Refractive Index 1.330
Scattering Model Mie
Analysis Model General Purpose
Weighted Residual 0.42 %
Laser Obscuration 16.54 %

Result

Concentration 0.0147 %
Span 6.171
Uniformity 1.805
Specific Surface Area 833.2 m²/kg
D [3,2] 7.20 µm
D [4,3] 28.9 µm
Dv (10) 2.95 µm
Dv (50) 12.7 µm
Dv (90) 81.0 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	5.03	12.7	50.17	76.0	88.81	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	6.75	14.5	53.85	86.4	91.18	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	8.74	16.4	57.31	98.1	93.35	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	10.99	18.7	60.55	111	95.24	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.04	3.55	13.52	21.2	63.55	127	96.81	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.15	4.03	16.34	24.1	66.34	144	98.03	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.31	4.58	19.47	27.4	68.95	163	98.91	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.49	5.21	22.89	31.1	71.43	186	99.48	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.69	5.92	26.54	35.3	73.85	211	99.82	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.93	6.72	30.37	40.1	76.26	240	99.97	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	1.27	7.64	34.33	45.6	78.71	272	100.00	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	1.78	8.68	38.35	51.8	81.20	310	100.00	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	2.55	9.86	42.37	58.9	83.75	352	100.00	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	3.63	11.2	46.33	66.9	86.31	400	100.00	2390	100.00		

Analysis

CSIRO

Malvern

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-25 (3E composite) '
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	20/09/2018 9:28:06 AM
Measurement Date Time	20/09/2018 9:28:06 AM
Result Source	Averaged

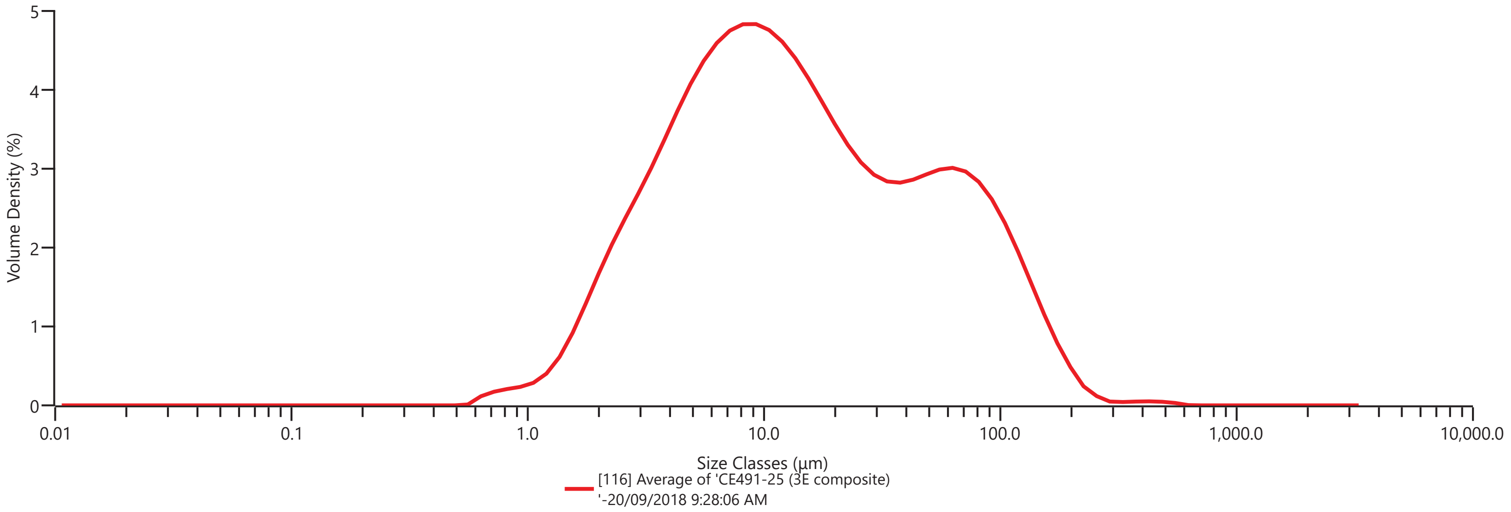
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.48 %
Laser Obscuration	13.26 %

Result

Concentration	0.0116 %
Span	6.386
Uniformity	1.911
Specific Surface Area	821.7 m^2/kg
D [3,2]	7.30 µm
D [4,3]	30.4 µm
Dv (10)	2.98 µm
Dv (50)	12.7 µm
Dv (90)	84.3 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	4.91	12.7	49.99	76.0	88.08	454	99.93	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	6.62	14.5	53.66	86.4	90.45	516	99.97	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	8.59	16.4	57.12	98.1	92.64	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	10.83	18.7	60.34	111	94.57	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	13.34	21.2	63.31	127	96.19	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.10	4.03	16.14	24.1	66.06	144	97.48	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.25	4.58	19.26	27.4	68.63	163	98.44	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.42	5.21	22.66	31.1	71.06	186	99.09	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.61	5.92	26.30	35.3	73.42	211	99.49	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.85	6.72	30.14	40.1	75.77	240	99.69	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	1.18	7.64	34.10	45.6	78.15	272	99.78	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	1.68	8.68	38.14	51.8	80.60	310	99.82	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	2.44	9.86	42.17	58.9	83.09	352	99.85	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	3.52	11.2	46.14	66.9	85.61	400	99.89	2390	100.00		

Analysis

CSIRO

Malvern

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-26 (4B composite)'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	20/09/2018 10:15:22 AM
Measurement Date Time	20/09/2018 10:15:22 AM
Result Source	Averaged

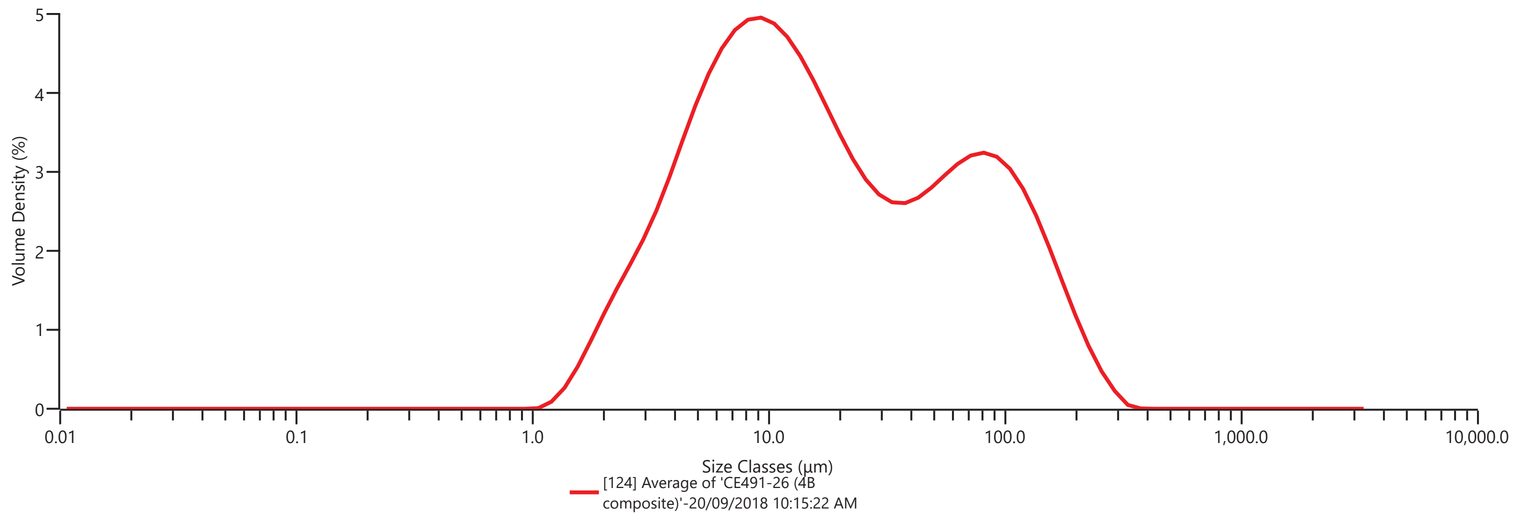
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.54 %
Laser Obscuration	12.60 %

Result

Concentration	0.0139 %
Span	7.041
Uniformity	2.070
Specific Surface Area	650.0 m²/kg
D [3,2]	9.23 μm
D [4,3]	38.4 μm
Dv (10)	3.72 μm
Dv (50)	15.0 μm
Dv (90)	110 μm

Frequency (compatible)



Result

Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	2.44	12.7	45.20	76.0	82.41	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	3.71	14.5	48.93	86.4	85.12	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	5.23	16.4	52.40	98.1	87.79	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	7.01	18.7	55.58	111	90.33	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	9.10	21.2	58.48	127	92.66	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	11.54	24.1	61.12	144	94.71	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.00	4.58	14.37	27.4	63.53	163	96.41	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.00	5.21	17.58	31.1	65.79	186	97.75	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.00	5.92	21.12	35.3	67.96	211	98.74	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.00	6.72	24.93	40.1	70.13	240	99.40	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.07	7.64	28.94	45.6	72.35	272	99.79	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.28	8.68	33.05	51.8	74.69	310	99.97	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.72	9.86	37.19	58.9	77.15	352	100.00	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	1.44	11.2	41.27	66.9	79.74	400	100.00	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-27 (4E composite)'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	20/09/2018 10:24:10 AM
Measurement Date Time	20/09/2018 10:24:10 AM
Result Source	Averaged

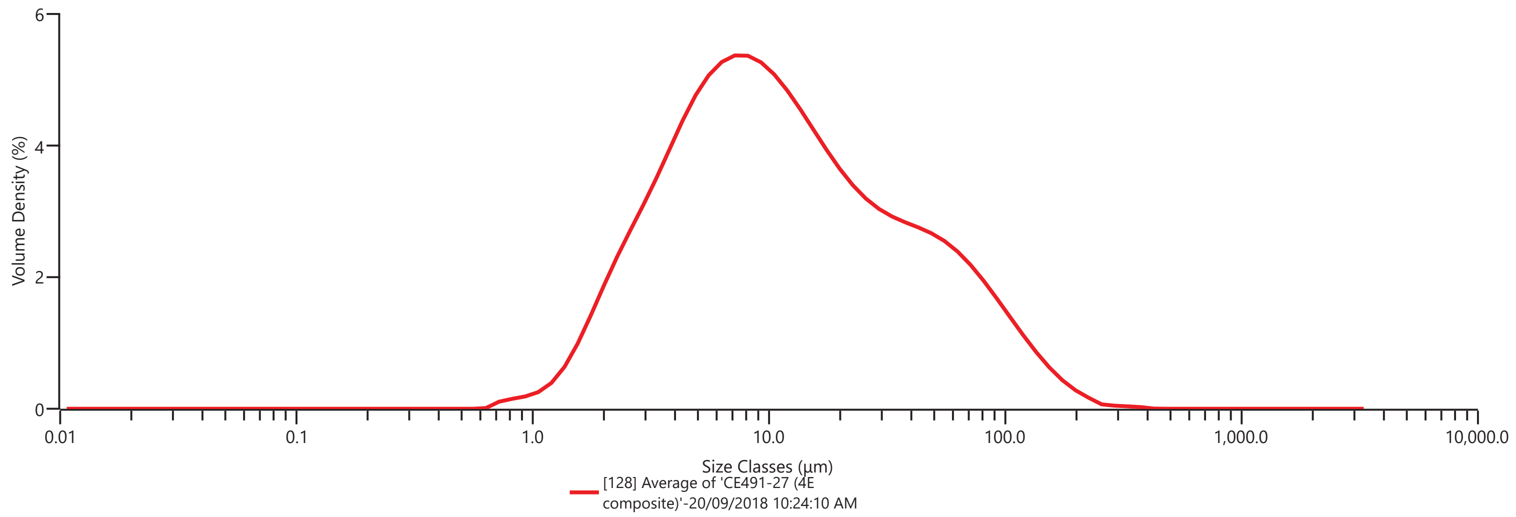
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.44 %
Laser Obscuration	12.55 %

Result

Concentration	0.0101 %
Span	5.663
Uniformity	1.724
Specific Surface Area	882.1 m²/kg
D [3,2]	6.80 µm
D [4,3]	23.7 µm
Dv (10)	2.87 µm
Dv (50)	10.6 µm
Dv (90)	62.9 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	4.98	12.7	55.84	76.0	92.77	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	6.91	14.5	59.63	86.4	94.40	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	9.16	16.4	63.17	98.1	95.79	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	11.74	18.7	66.45	111	96.96	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	14.66	21.2	69.49	127	97.89	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	17.94	24.1	72.32	144	98.61	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.10	4.58	21.59	27.4	74.98	163	99.13	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.22	5.21	25.57	31.1	77.51	186	99.49	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.38	5.92	29.80	35.3	79.94	211	99.72	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.58	6.72	34.20	40.1	82.30	240	99.86	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.90	7.64	38.68	45.6	84.60	272	99.91	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	1.42	8.68	43.16	51.8	86.83	310	99.95	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	2.24	9.86	47.56	58.9	88.96	352	99.98	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	3.42	11.2	51.80	66.9	90.95	400	100.00	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-28 (5B composite)'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	20/09/2018 10:35:33 AM
Measurement Date Time	20/09/2018 10:35:33 AM
Result Source	Averaged

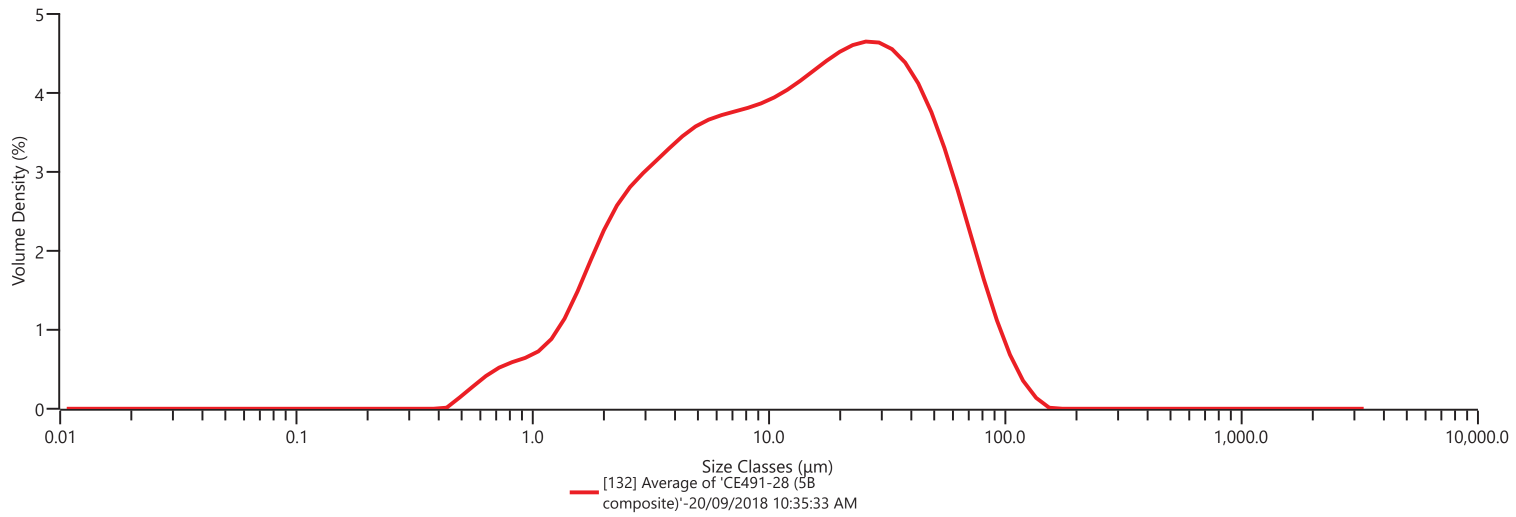
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.37 %
Laser Obscuration	12.12 %

Result

Concentration	0.0085 %
Span	3.886
Uniformity	1.216
Specific Surface Area	1060 m^2/kg
D [3,2]	5.66 μm
D [4,3]	21.0 μm
Dv (10)	2.24 μm
Dv (50)	12.9 μm
Dv (90)	52.2 μm

Frequency (compatible)



Result

Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	9.14	12.7	49.71	76.0	96.74	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	11.29	14.5	53.17	86.4	98.11	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	13.64	16.4	56.74	98.1	99.04	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.12	3.12	16.13	18.7	60.42	111	99.60	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.36	3.55	18.75	21.2	64.19	127	99.89	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.70	4.03	21.50	24.1	68.03	144	100.00	859	100.00		
0.0215	0.00	0.128	0.00	0.767	1.14	4.58	24.38	27.4	71.91	163	100.00	976	100.00		
0.0244	0.00	0.146	0.00	0.872	1.63	5.21	27.36	31.1	75.78	186	100.00	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	2.17	5.92	30.42	35.3	79.59	211	100.00	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	2.77	6.72	33.52	40.1	83.25	240	100.00	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	3.50	7.64	36.66	45.6	86.69	272	100.00	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	4.44	8.68	39.84	51.8	89.83	310	100.00	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	5.68	9.86	43.06	58.9	92.59	352	100.00	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	7.25	11.2	46.34	66.9	94.90	400	100.00	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-29 (5E composite) duplicate'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	20/09/2018 11:07:43 AM
Measurement Date Time	20/09/2018 11:07:43 AM
Result Source	Averaged

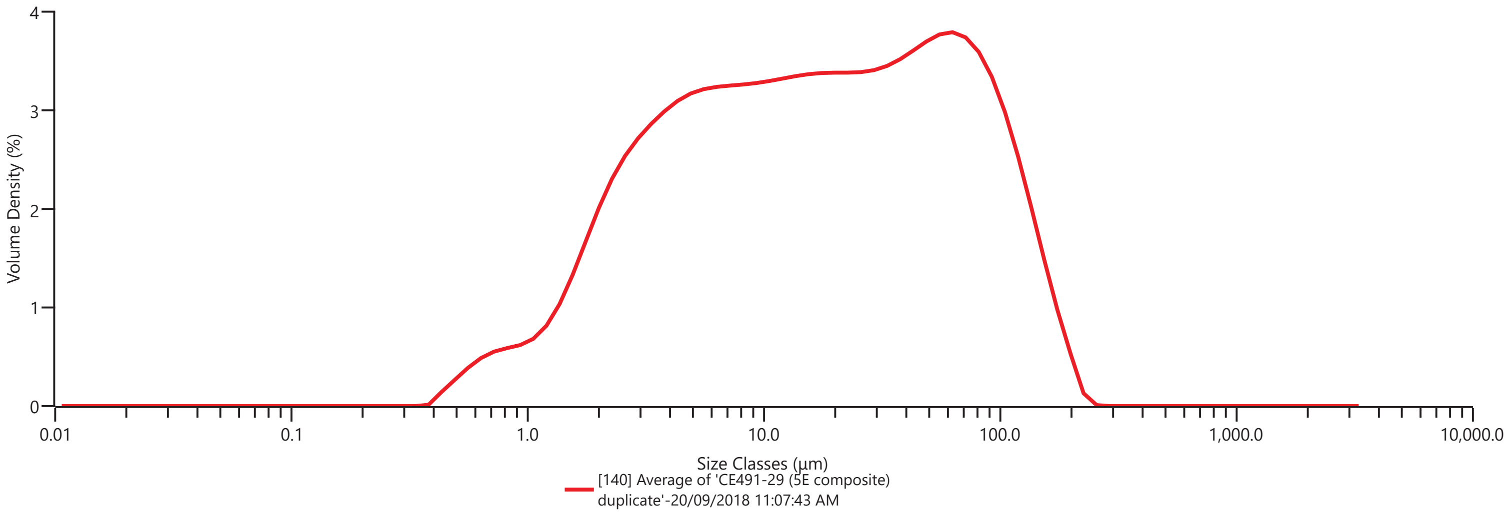
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.44 %
Laser Obscuration	13.17 %

Result

Concentration	0.0102 %
Span	5.504
Uniformity	1.676
Specific Surface Area	1008 m^2/kg
D [3,2]	5.95 µm
D [4,3]	33.9 µm
Dv (10)	2.30 µm
Dv (50)	16.5 µm
Dv (90)	93.2 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	8.82	12.7	44.29	76.0	85.34	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	10.74	14.5	47.08	86.4	88.34	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.12	2.75	12.86	16.4	49.89	98.1	91.13	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.34	3.12	15.13	18.7	52.71	111	93.62	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.67	3.55	17.52	21.2	55.52	127	95.74	756	100.00		
0.0189	0.00	0.113	0.00	0.675	1.08	4.03	20.01	24.1	58.34	144	97.42	859	100.00		
0.0215	0.00	0.128	0.00	0.767	1.54	4.58	22.59	27.4	61.17	163	98.66	976	100.00		
0.0244	0.00	0.146	0.00	0.872	2.03	5.21	25.23	31.1	64.00	186	99.47	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	2.54	5.92	27.92	35.3	66.88	211	99.91	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	3.11	6.72	30.62	40.1	69.81	240	100.00	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	3.78	7.64	33.33	45.6	72.82	272	100.00	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	4.64	8.68	36.04	51.8	75.90	310	100.00	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	5.74	9.86	38.78	58.9	79.05	352	100.00	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	7.14	11.2	41.52	66.9	82.21	400	100.00	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-29 (5E composite)'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	20/09/2018 10:59:03 AM
Measurement Date Time	20/09/2018 10:59:03 AM
Result Source	Averaged

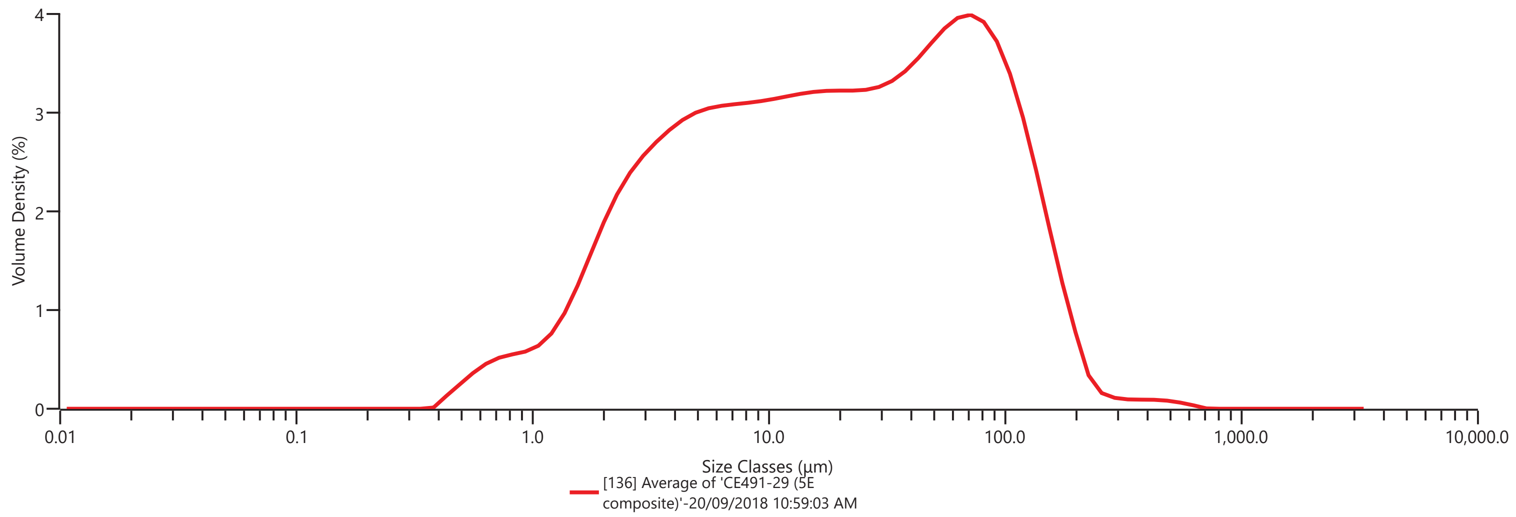
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.55 %
Laser Obscuration	12.97 %

Result

Concentration	0.0106 %
Span	5.445
Uniformity	1.738
Specific Surface Area	952.7 m^2/kg
D [3,2]	6.30 µm
D [4,3]	39.5 µm
Dv (10)	2.41 µm
Dv (50)	18.8 µm
Dv (90)	105 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	8.26	12.7	41.87	76.0	82.20	454	99.85	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	10.07	14.5	44.53	86.4	85.48	516	99.92	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.11	2.75	12.07	16.4	47.21	98.1	88.59	586	99.97	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.32	3.12	14.21	18.7	49.90	111	91.43	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.62	3.55	16.46	21.2	52.59	127	93.89	756	100.00		
0.0189	0.00	0.113	0.00	0.675	1.00	4.03	18.82	24.1	55.27	144	95.91	859	100.00		
0.0215	0.00	0.128	0.00	0.767	1.44	4.58	21.26	27.4	57.97	163	97.44	976	100.00		
0.0244	0.00	0.146	0.00	0.872	1.89	5.21	23.76	31.1	60.68	186	98.49	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	2.38	5.92	26.30	35.3	63.45	211	99.14	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	2.90	6.72	28.86	40.1	66.30	240	99.40	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	3.53	7.64	31.44	45.6	69.26	272	99.53	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	4.33	8.68	34.02	51.8	72.35	310	99.62	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	5.37	9.86	36.62	58.9	75.56	352	99.69	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	6.68	11.2	39.24	66.9	78.87	400	99.77	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name CSIRO Mastersizer
Sample Name Average of 'CE491-63_Composite 6B'
SOP File Name Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time 10/01/2019 1:48:31 PM
Measurement Date Time 10/01/2019 1:48:31 PM
Result Source Averaged

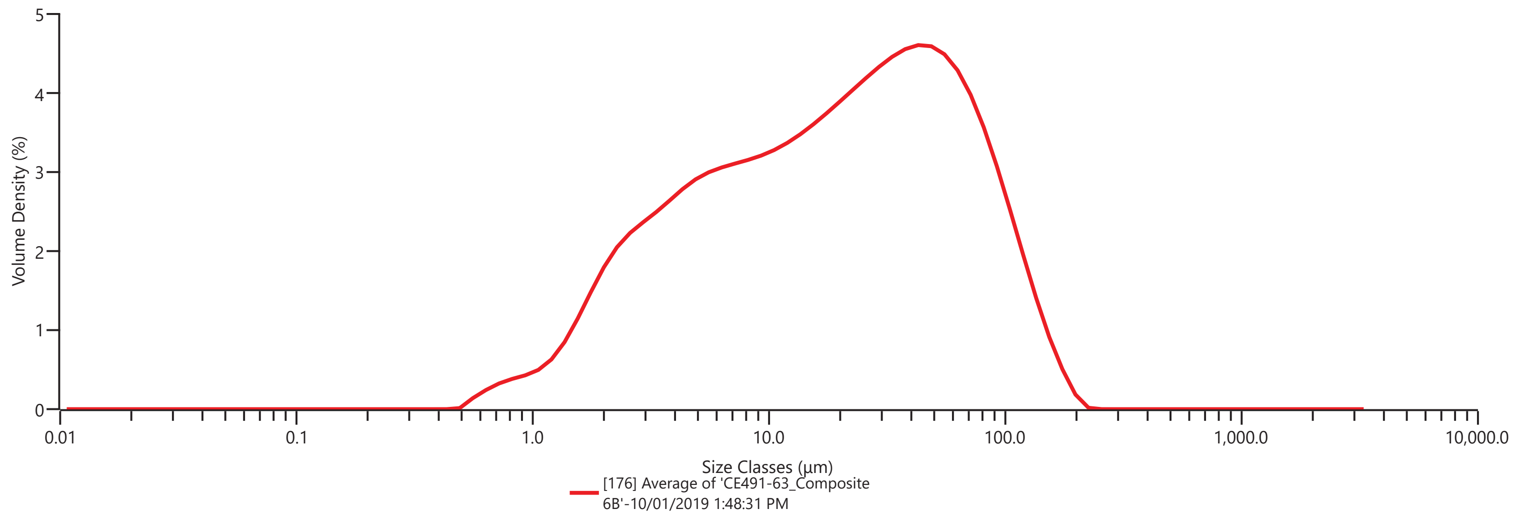
Analysis

Particle Name China Clay
Particle Refractive Index 1.555
Particle Absorption Index 0.010
Dispersant Name Water
Dispersant Refractive Index 1.330
Scattering Model Mie
Analysis Model General Purpose
Weighted Residual 0.52 %
Laser Obscuration 7.63 %

Result

Concentration 0.0066 %
Span 4.029
Uniformity 1.260
Specific Surface Area 817.8 m^2/kg
D [3,2] 7.34 µm
D [4,3] 32.5 µm
Dv (10) 2.72 µm
Dv (50) 19.7 µm
Dv (90) 82.0 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	6.59	12.7	39.64	76.0	88.23	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	8.30	14.5	42.54	86.4	91.21	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	10.16	16.4	45.54	98.1	93.78	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	12.13	18.7	48.66	111	95.88	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.12	3.55	14.21	21.2	51.91	127	97.51	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.32	4.03	16.41	24.1	55.27	144	98.68	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.60	4.58	18.73	27.4	58.77	163	99.44	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.92	5.21	21.16	31.1	62.38	186	99.85	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	1.27	5.92	23.66	35.3	66.10	211	100.00	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	1.68	6.72	26.21	40.1	69.90	240	100.00	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	2.20	7.64	28.80	45.6	73.74	272	100.00	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	2.90	8.68	31.43	51.8	77.58	310	100.00	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	3.85	9.86	34.10	58.9	81.33	352	100.00	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	5.09	11.2	36.83	66.9	84.91	400	100.00	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-64_Composite 6E'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	10/01/2019 1:57:46 PM
Measurement Date Time	10/01/2019 1:57:46 PM
Result Source	Averaged

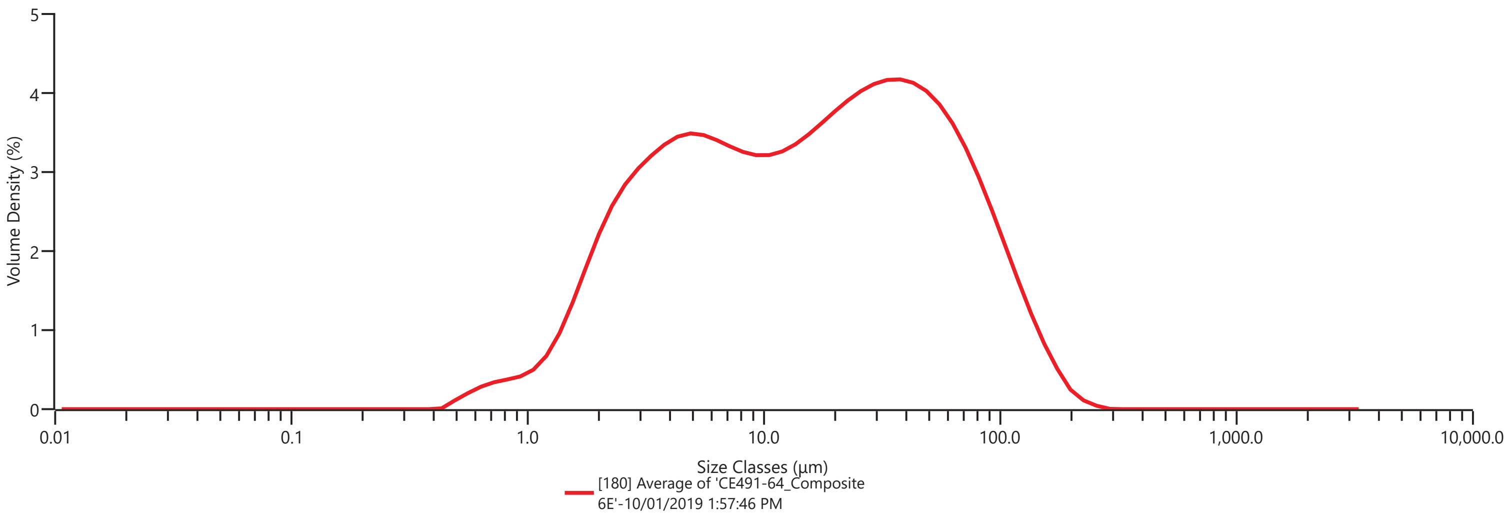
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.52 %
Laser Obscuration	7.94 %

Result

Concentration	0.0060 %
Span	4.689
Uniformity	1.475
Specific Surface Area	939.4 m²/kg
D [3,2]	6.39 µm
D [4,3]	29.3 µm
Dv (10)	2.45 µm
Dv (50)	15.7 µm
Dv (90)	76.3 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	7.66	12.7	45.27	76.0	89.93	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	9.81	14.5	48.06	86.4	92.38	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	12.19	16.4	50.96	98.1	94.48	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.09	3.12	14.73	18.7	53.98	111	96.21	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.26	3.55	17.40	21.2	57.12	127	97.57	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.50	4.03	20.19	24.1	60.37	144	98.58	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.79	4.58	23.07	27.4	63.73	163	99.26	976	100.00		
0.0244	0.00	0.146	0.00	0.872	1.10	5.21	25.99	31.1	67.16	186	99.68	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	1.44	5.92	28.88	35.3	70.64	211	99.88	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	1.85	6.72	31.72	40.1	74.12	240	99.97	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	2.40	7.64	34.49	45.6	77.57	272	100.00	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	3.20	8.68	37.20	51.8	80.93	310	100.00	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	4.32	9.86	39.88	58.9	84.15	352	100.00	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	5.81	11.2	42.56	66.9	87.17	400	100.00	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-30 (7B composite)'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	20/09/2018 11:15:25 AM
Measurement Date Time	20/09/2018 11:15:25 AM
Result Source	Averaged

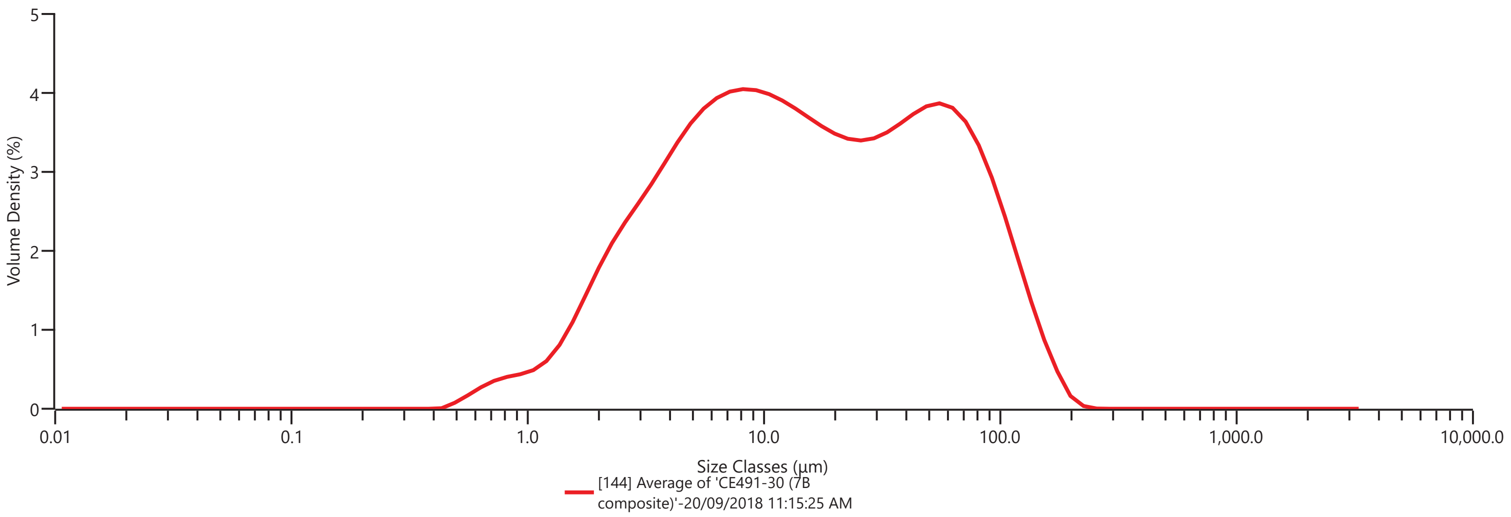
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.48 %
Laser Obscuration	12.06 %

Result

Concentration	0.0100 %
Span	5.283
Uniformity	1.607
Specific Surface Area	886.9 m^2/kg
D [3,2]	6.77 µm
D [4,3]	29.9 µm
Dv (10)	2.69 µm
Dv (50)	14.7 µm
Dv (90)	80.4 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	6.60	12.7	46.41	76.0	88.77	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	8.35	14.5	49.58	86.4	91.56	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	10.32	16.4	52.66	98.1	94.01	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.06	3.12	12.49	18.7	55.64	111	96.04	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.20	3.55	14.86	21.2	58.55	127	97.62	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.43	4.03	17.45	24.1	61.39	144	98.75	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.73	4.58	20.26	27.4	64.22	163	99.47	976	100.00		
0.0244	0.00	0.146	0.00	0.872	1.07	5.21	23.28	31.1	67.08	186	99.86	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	1.43	5.92	26.45	35.3	69.99	211	99.98	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	1.83	6.72	29.73	40.1	73.00	240	100.00	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	2.33	7.64	33.09	45.6	76.11	272	100.00	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	3.00	8.68	36.46	51.8	79.31	310	100.00	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	3.91	9.86	39.83	58.9	82.54	352	100.00	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	5.11	11.2	43.16	66.9	85.73	400	100.00	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-31 (7E composite)'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	20/09/2018 11:23:55 AM
Measurement Date Time	20/09/2018 11:23:55 AM
Result Source	Averaged

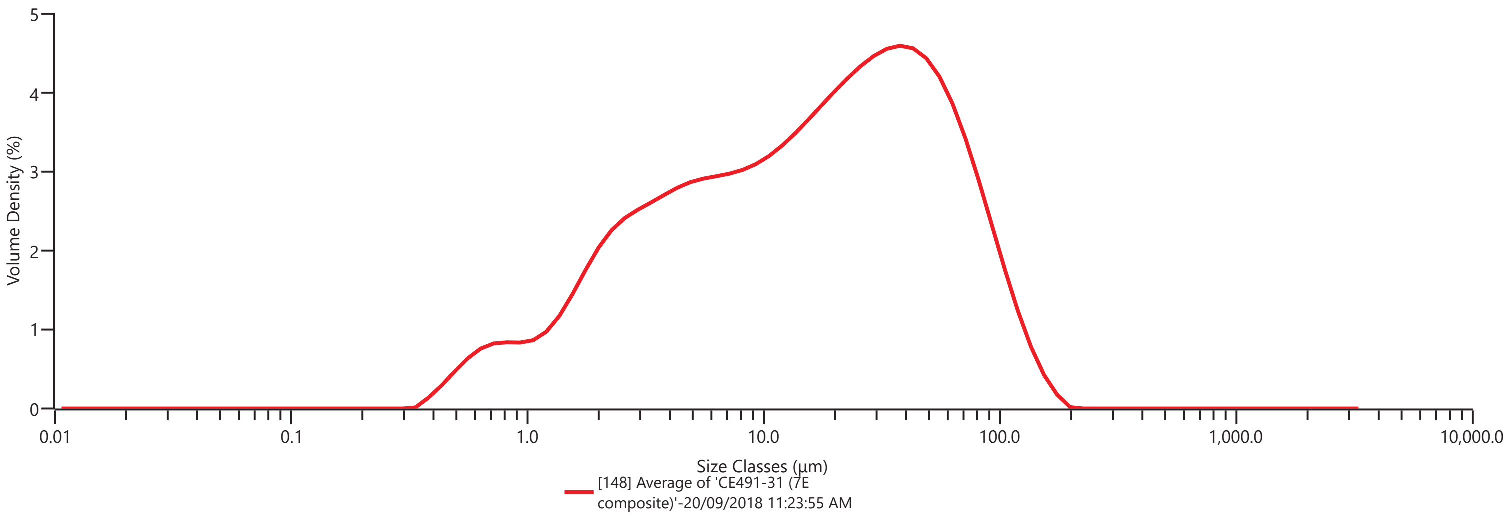
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.41 %
Laser Obscuration	12.35 %

Result

Concentration	0.0089 %
Span	4.087
Uniformity	1.286
Specific Surface Area	1161 m^2/kg
D [3,2]	5.17 µm
D [4,3]	27.4 µm
Dv (10)	2.00 µm
Dv (50)	16.5 µm
Dv (90)	69.5 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	10.86	12.7	43.91	76.0	92.00	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.11	2.42	12.75	14.5	46.82	86.4	94.42	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.35	2.75	14.76	16.4	49.86	98.1	96.37	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.74	3.12	16.86	18.7	53.06	111	97.84	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	1.27	3.55	19.04	21.2	56.41	127	98.86	756	100.00		
0.0189	0.00	0.113	0.00	0.675	1.91	4.03	21.29	24.1	59.90	144	99.51	859	100.00		
0.0215	0.00	0.128	0.00	0.767	2.60	4.58	23.63	27.4	63.52	163	99.86	976	100.00		
0.0244	0.00	0.146	0.00	0.872	3.30	5.21	26.02	31.1	67.24	186	100.00	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	4.00	5.92	28.45	35.3	71.04	211	100.00	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	4.71	6.72	30.90	40.1	74.88	240	100.00	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	5.52	7.64	33.38	45.6	78.69	272	100.00	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	6.49	8.68	35.90	51.8	82.40	310	100.00	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	7.69	9.86	38.48	58.9	85.91	352	100.00	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	9.16	11.2	41.14	66.9	89.14	400	100.00	2390	100.00		

Appendix C: Elements/substances in sediment pore waters

		Dissolved Metals (µg/L)																							
Laboratory I.D. No.:	**Client description:**	**Ag**	**Al**	**As**	**Ba**	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**Pb**	**Sb**	**Se**	**Sn**	**Sr**	**Th**	**U**	**V**	**Zn**
CE491-14PW	CA1_P4 - 30 metres	0.06	10	6.2	70	6110	0.02	9.2	0.39	0.24	26900	957	1930	7260	0.93	2890	1.7	<0.1	0.10	0.12	<0.03	52	0.058	0.059	1.6	1.5
CE491-18PW	CA2_P4 - 42 metres	<0.01	8	7.9	111	10500	0.03	8.8	0.57	0.31	38400	1380	3490	10500	0.81	3420	1.7	<0.1	0.10	0.14	<0.03	124	0.080	0.096	1.9	3.5
CE491-11PW	CA3_P4 - 48 metres	<0.01	67	8.9	74	5520	0.08	7.7	0.44	0.91	18200	1120	1350	15600	1.3	2030	2.1	0.3	0.13	0.12	<0.03	46	0.12	0.11	2.5	3.1
CE491-13PW	PL1_P4 - 33.5 metres	<0.01	278	12	78	6170	0.02	11	0.83	1.6	28400	1220	2110	7430	0.59	2870	2.5	0.7	0.23	0.13	<0.03	48	0.16	0.14	2.8	2.6
CE491-17PW	PL2_P4 - 26.5 metres	<0.01	599	6.7	66	6540	0.02	7.1	0.68	1.4	19300	1000	1900	9760	1.3	2160	2.1	0.6	0.20	0.10	<0.03	47	0.15	0.14	2.6	6.2
CE491-15PW	PL3_P4 - 27 metres	<0.01	32	7.5	112	7640	0.03	11	0.38	0.68	37900	1760	3390	12900	1.9	2820	1.6	0.2	0.28	0.14	<0.03	71	0.079	0.11	1.6	4.2
CE491-12PW	RA1_P4 - 31.5 metres	<0.01	144	10	91	5480	0.02	7.0	0.43	1.5	16000	1100	1310	8100	0.97	2130	2.0	0.7	0.13	0.09	<0.03	37	0.13	0.15	1.8	4.0
CE491-19PW	RA2_P4 - 29 metres	<0.01	51	18	137	8190	0.02	7.5	0.45	0.46	22700	1220	1610	14000	1.2	2500	2.4	0.1	0.06	0.12	<0.03	50	0.093	0.10	1.9	1.9
CE491-16PW	RA3_P4 - 28.5 metres	<0.01	6	18	289	13800	0.04	9.3	0.37	0.30	31400	1190	2290	28800	2.0	2450	2.6	<0.1	0.12	0.15	<0.03	75	0.078	0.26	2.0	2.2
CE491-9PW	TN1_P4 - 16.5 metres	<0.01	180	4.6	110	3720	<0.02	7.2	0.69	0.65	28900	1400	2390	2730	0.20	3560	1.1	0.1	0.28	0.18	<0.03	37	0.14	0.053	3.6	1.6
CE491-8PW	TN2_P4 - 19 metres	<0.01	179	5.1	98	3410	<0.02	5.2	0.73	0.53	33300	1150	2240	2560	0.19	3510	0.8	0.1	0.28	0.17	<0.03	35	0.13	0.035	2.9	2.2
CE491-10PW	TN3_P4 - 18.5 metres	<0.01	59	8.6	115	3140	0.02	5.7	0.76	0.27	38800	917	1960	3410	0.12	1920	0.9	<0.1	0.17	0.23	<0.03	33	0.10	0.033	3.4	1.4
LOD 3σ	---	0.01	5	0.01	0.2	3	0.02	0.01	0.01	0.04	5	20	20	1	0.01	60	0.1	0.1	0.01	0.01	0.03	0.2	0.004	0.001	0.01	0.1
Method code	---	C-209	C-229	C-209	C-229	C-229	C-209	C-209	C-209	C-209	C-229	C-229	C-229	C-229	C-209	C-229	C-209	C-209	C-209	C-209	C-209	C-229	C-209	C-209	C-209	C-209

		Other dissolved elements/ions (mg/L)				
Laboratory I.D. No.:	**Client description:**	**P**	**Si**	**Chloride**	**Nitrate**	**Sulphate**
CE491-14PW	CA1_P4 - 30 metres	0.34	11	<4	<0.5	<3
CE491-18PW	CA2_P4 - 42 metres	0.33	10	<4	<0.5	5
CE491-11PW	CA3_P4 - 48 metres	0.23	12	<4	0.7	<3
CE491-13PW	PL1_P4 - 33.5 metres	0.50	12	<4	0.6	<3
CE491-17PW	PL2_P4 - 26.5 metres	0.34	10	<4	0.5	<3
CE491-15PW	PL3_P4 - 27 metres	0.38	11	<4	0.6	<3
CE491-12PW	RA1_P4 - 31.5 metres	0.08	11	<4	0.5	<3
CE491-19PW	RA2_P4 - 29 metres	0.37	14	<4	0.5	<3
CE491-16PW	RA3_P4 - 28.5 metres	0.38	15	<4	<0.5	<3
CE491-9PW	TN1_P4 - 16.5 metres	0.14	16	<4	0.6	<3
CE491-8PW	TN2_P4 - 19 metres	0.32	14	6	<0.5	<3
CE491-10PW	TN3_P4 - 18.5 metres	0.71	16	<4	<0.5	<3
LOD 3σ	---	50	50	4	0.5	3
Method code	---	C-229	C-229	C-261	C-261	C-261

Quality control

[a]Reference Materials

		Dissolved Metals (µg/L)																		
Laboratory I.D. No.:	**Client description:**	**Ag**	**Al**	**As**	**Ba**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Mn**	**Mo**	**Ni**	**Pb**	**Se**	**Sn**	**Sr**	**V**	**U**	**Zn**
TM-24.4	---	---	32.5	5.02	15.0	3.75	6.33	4.99	6.33	16.2	8.06	6.21	4.89	5.52	3.26	3.50	109	7.03	4.26	---
Certified Value	---	---	32.9 ± 4.5	5.30 ± 0.53	15.0 ± 1.0	3.96 ± 0.34	6.27 ± 0.57	5.00 ± 0.59	6.31 ± 0.60	16.0 ± 2.3	8.24 ± 0.73	6.30 ± 0.56	5.03 ± 0.53	5.60 ± 0.52	3.56 ± 0.58	3.72 ± 0.39	113 ± 8	7.00 ± 0.58	4.24 ± 0.34	---
TMDA-64.3	---	---	247	---	228	---	---	---	---	245	231	---	---	---	---	---	533	---	---	---
Certified Value	---	---	291 ± 23	---	287 ± 18	---	---	---	---	298 ± 21	292 ± 17	---	---	---	---	---	628 ± 34	---	---	---
Method code	---	C-209	C-229	C-209	C-229	C-209	C-209	C-209	C-209	C-229	C-229	C-209	C-209	C-209	C-209	C-209	C-229	C-209	C-209	C-209

[a] *TM-24.4 and TMDA-64.3 are certified reference materials from Environment and Climate Change Canada*

[b]Spike Recovery

		Spike Recovery (%)																							
Laboratory I.D. No.:	**Client description:**	**Ag**	**Al**	**As**	**Ba**	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**Pb**	**Sb**	**Se**	**Sn**	**Sr**	**Th**	**U**	**V**	**Zn**
CE491-16PW	RA3_P4 - 28.5 metres	87	---	81	---	---	94	100	97	97	---	---	---	---	99	---	99	97	95	79	103	---	107	102	96	89
CE491-18PW	CA2_P4 - 42 metres	---	108	---	101	104	---	---	---	---	99	99	103	99	---	114	---	---	---	---	---	100	---	---	---	---
Method code	---	C-209	C-229	C-209	C-229	C-229	C-209	C-209	C-209	C-209	C-229	C-229	C-229	C-229	C-209	C-229	C-209	C-209	C-209	C-209	C-209	C-229	C-209	C-209	C-209	C-209

[b] *analyte of interest added to sample prior to analysis*

		Spike Recovery (%)				
Laboratory I.D. No.:	**Client description:**	**P**	**Si**	**Chloride**	**Nitrate**	**Sulphate**
CE491-16PW	RA3_P4 - 28.5 metres	---	---			
CE491-18PW	CA2_P4 - 42 metres	103	102	104	96	103
Method code	---	C-229	C-229	C-261	C-261	C-261

[b] *analyte of interest added to sample prior to analysis*

Miscellaneous information:
Samples received: 24/08/2018
Dup.= duplicate
Avg.=average of replicate analysis in laboratory
PW = pore water

Method codes:
C-209 Inductively Coupled Plasma - Mass Spectrometry (ICP-MS)
C-229 Inductively Coupled Plasma - Atomic Emission Spectrometry (ICP-AES)
C-261 Anions by Ion Chromatography

Appendix D - Release of substances excavated rock materials in reservoir water [100 pages]

Appendix D1. Release of substances from <75 µm composite excavated rock materials in reservoir water at low L/S ratio

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Note/Memo	CSIRO P4 Project Investigations
To:	Ali Watters (HKA)
From:	Brad Angel, Lucas Heights, NSW
Date:	28 September 2018
Copy:	Ryan Fraser, Stuart Simpson and Ellen Porter (SHL)
Our reference:	CSIRO P4 – Memo 4
Classification:	Internal use only
Subject:	Pollutant release from excavated rock composites

Chemical formulas and acronyms

Ag	Silver	F^-	Fluoride	Sb	Antimony
Al	Aluminium	Fe	Iron	Se	Selenium
As	Arsenic	Mg	Magnesium	Sn	Tin
Ba	Barium	Mn	Manganese	SO_4^{2-}	Sulfate
Ca	Calcium	Mo	Molybdenum	Sr	Strontium
Cd	Cadmium	Na	Sodium	Th	Thorium
Cl^-	Chloride	Ni	Nickel	U	Uranium
Co	Cobalt	NO_3^-	Nitrate	V	Vanadium
Cr	Chromium	Pb	Lead	Zn	Zinc
Cu	Copper				
DOC	Dissolved organic carbon	DGV	Default guideline value	L/S	Liquid/solid ratio

Background - Introduction

The CSIRO was engaged by Haskoning Australia Pty Ltd (RHDHV) to undertake an investigation of the pollutant release from excavated rock disposal into Talbingo and Tantangara reservoirs. This phase of the work involved investigating the release of pollutants from composite excavated rock samples in an initial elutriate test that had a liquid to solid (L/S) ratio of 10/1 and was run for 48 h. With respect to placement scenarios for the excavated rock, these tests were intended to assess a worst case scenario for impacts to the receiving water. It is envisaged that the design of the excavated rock placement will result in fast deposition of the majority of the excavated rock, and concentrations of fine materials within the waters will be managed to achieve considerably lower concentrations of suspended solids. The vast majority of the excavated rock, by mass, will be larger than sand size and should settle rapidly. The scenario assessed here is to represent predominantly fine excavated rock materials remaining suspended in the waters in the main disposal area. Daily excavated rock-placement activities at the site may potentially result in this material being disturbed and remaining in suspension for considerably longer than would occur without disturbance. Consequently the bottom waters may contain very high concentration of suspended fine excavated rock material for days, allowing for prolonged release from those excavated rock materials.

Further tests will evaluate scenarios of pollutant release for excavated rock materials at much higher L/S ratios (e.g. 100/1, 1000/1) and the release occurring over shorter durations to represent the scenario of more rapid settling and release within waters beyond the main placement area (where some fine material may potentially disperse to).

This technical memo describes the preliminary results.

pH, conductivity and dissolved oxygen

The final pH, conductivity and dissolved oxygen concentrations of the elutriates from the 12 excavated rock composites in Talbingo water (composite of four waters) are shown in Table 1 (liquid/solid (L/S) ratio = 10, 48 h).

Table 1. The pH, conductivity and dissolved oxygen in 48 h elutriate test of excavated rock composites @ L/S=10.

Sample ID	pH	Conductivity (µS/cm)	Dissolved oxygen (mg/L)
Talbingo water (composite), replicate 1	7.12	29.1	8.26
Talbingo water, replicate 2	6.99	28.9	8.22
Talbingo water, replicate 3	7.05	29.0	8.16
Talbingo water, replicate 4	7.03	29.0	8.19
1B composite	9.20	154	8.21
1B composite duplicate	9.29	153	8.15
1B composite MEAN	**9.25**	**154**	**8.18**
1E composite	9.33	166	8.26
2B composite	8.88	160	8.36
2E composite	9.35	173	8.22
3B composite	9.58	120	8.23
3E composite	9.81	120	8.47
4B composite	9.67	107	8.32
4E composite	9.37	141	8.49
4E composite duplicate	9.31	143	8.35
4E composite MEAN	**9.34**	**142**	**8.42**
5B composite	9.57	150	8.25
5E composite	9.39	162	7.14
7B composite	9.56	150	8.36
7E composite	9.38	203	8.27

The pH, conductivity and dissolved oxygen concentrations were in the ranges 8.88-9.81, 107-203 µS/cm and 7.14-8.49 mg/L. The pH and conductivity values were substantially higher than in the Talbingo composite water used in the tests (pH 7-7.1, 29 µS/cm), while the dissolved oxygen was not affected other than for the lower value measured for composite 5E.

The release of anions from excavated rock composites

The anions (mg/L), and total P and S (µg/L) released from excavated rock in elutriate test 1 is shown in Table 2. The concentrations of each parameter were all higher than the corresponding values in the Talbingo elutriate control water except for a few values for sulfate which were similar, and nitrate which was below the limit of detection.

Table 2. The anions, P and S released from excavated rock composites in elutriate test 1.[a]

Client I.D.	**F^- (mg/L)**	**Cl^- (mg/L)**	**Br^- (mg/L)**	**SO_4^{2-} (mg/L)**	**P (µg/L)**	**S (µg/L)**
Talbingo water composite A	0.015	0.92	<0.5	0.44	<4.4	156
Talbingo water composite B	0.025	0.94	<0.5	0.49	<4.4	154
Talbingo water composite C	0.03	0.93	<0.5	0.46	<4.4	156
Talbingo water composite D	0.02	0.93	<0.5	0.53	<4.4	161
Initial elutriate 1B	0.42	1.59	<0.5	0.79	10.1	327
Initial elutriate 1B duplicate	0.42	1.60	<0.5	0.75	9.5	320
Initial elutriate 1B mean	**0.42**	**1.59**	**<0.5**	**0.77**	9.8	324
Initial elutriate 1E	0.47	2.53	<0.5	3.40	5.7	1430
Initial elutriate 2B	0.45	1.95	<0.5	0.96	38.9	452
Initial elutriate 2E	0.54	1.65	<0.5	9.35	8	5780
Initial elutriate 3B	0.16	1.31	<0.5	0.46	<4.4	177
Initial elutriate 3E	0.60	1.34	<0.5	0.52	6.2	180
Initial elutriate 4B	0.48	1.56	<0.5	0.69	5	289
Initial elutriate 4E	0.14	2.15	<0.5	5.14	6.6	3510
Initial elutriate 4E duplicate	0.16	2.12	<0.5	5.08	<4.4	3540
Initial elutriate 4E mean	**0.15**	**2.13**	**<0.5**	**5.11**	5.5	3525
Initial elutriate 5B	0.32	2.41	<0.5	1.27	38	752
Initial elutriate 5E	0.33	1.75	<0.5	7.45	21	8510
Initial elutriate 7B	0.72	1.51	<0.5	1.10	4.8	516
Initial elutriate 7E	0.53	1.94	<0.5	11.5	5.1	4280
Minimum rock composite	**0.14**	**1.31**	**<0.5**	**0.46**	4.8	177
Maximum rock composite	**0.72**	**2.53**	**<0.5**	**11.5**	38.9	8510
DGV[b]		**3**			**10**	

[a] liquid/solid (L/S) ratio = 10, 48 h

[b] http://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/. 95% species protection guideline values (95%GV) for freshwater. Values for Arsenic are for As(V), chromium are for Cr(VI), and tin are for inorganic tin

The release of metals, metalloids and major cations from composite excavated rock samples in an initial elutriate test

The metals, metalloids and major cations released from the composite rock composites in elutriate test 1 are shown in Tables 3-5. When compared to water quality guideline values (WQGVs), the main exceedances occurred for aluminium, arsenic and chromium, where the majority of composites exceeded the 95% or 99% species protection WQGVs. The 95% WQGV for aluminium was exceeded by the largest factor; over 14-fold higher. There were also six exceedances of the total phosphorous WQGV. The inorganic speciation of Al, As and Cr is influenced by anionic complexes at basic pH's and it is likely that higher dilutions (i.e. higher L/S ratios) and/or mixing durations effect solubility. These parameters will be investigated in future tests.

Table 3. The Al, Fe, Mn and major cations released into the dissolved phase from excavated rocks in test 1.[a]

Site code	Al (µg/L)	Fe (µg/L)	Mn (µg/L)	Na (µg/L)	K (µg/L)	Mg (µg/L)	Ca (µg/L)
Talbingo water composite A	4.5	16	0.25	1640	402	704	1700
Talbingo water composite B	4.4	15.8	0.25	1660	417	725	1760
Talbingo water composite C	4.7	16.7	0.24	1660	414	711	1760
Talbingo water composite D	4.9	16.7	0.28	1660	404	724	1730
Initial elutriate 1B	249	<0.6	1.51	7680	20300	2090	5050
Initial elutriate 1B duplicate	252	<0.6	1.51	7680	20200	2110	5030
Initial elutriate 1B mean	251	<0.6	1.51	7680	20250	2100	5040
Initial elutriate 1E	286	<0.6	2.96	6390	20700	2510	5610
Initial elutriate 2B	85.3	<0.6	2.14	4930	13100	6360	6850
Initial elutriate 2E	274	<0.6	1.58	4520	27800	1520	6750
Initial elutriate 3B	467	0.8	0.4	9290	8600	2590	4170
Initial elutriate 3E	783	2.4	0.46	9540	11100	1900	4640
Initial elutriate 4B	457	<0.6	1.01	5930	10600	893	5300
Initial elutriate 4E	712	2.9	1.13	6620	15400	1500	7000
Initial elutriate 4E duplicate	719	2.9	1.17	6550	15400	1530	6960
Initial elutriate 4E mean	716	2.9	1.15	6585	15400	1515	6980
Initial elutriate 5B	304	1.6	0.86	9300	15500	1390	4620
Initial elutriate 5E	445	1.3	1.56	9470	11000	1960	8010
Initial elutriate 7B	343	0.7	3.2	9620	19900	617	4080
Initial elutriate 7E	149	1.2	0.68	6220	34500	917	4160
MIN	85	0.7	0.4	4520	8600	617	4080
MAX	783	2.93	3.2	9620	34500	6360	8010
95% DGV[b]	**55**	**700**	**1900**	-	-	-	-
99% DGV[c]	**27**	**400**	**1200**	-	-	-	-

[a] liquid/solid (L/S) ratio = 10, 48 h. [b] http://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/. 95% species protection guideline values (95%GV) for freshwater. [c].99% species protection guideline values (99%GV) for freshwater. Values for iron are from the final draft revision document, and are not expected to change before release in 2018.

Table 4. The metals and metalloids released into the dissolved phase from excavated rocks in test 1.[a]

Site code	Ag (µg/L)	As (µg/L)	Ba (µg/L)	Cd (µg/L)	Co (µg/L)	Cr (µg/L)	Cu (µg/L)	Mo (µg/L)
Talbingo water composite A	<0.36	<0.5	4.0	<0.07	<1.4	<0.4	<1.1	<1.5
Talbingo water composite B	<0.36	<0.5	4.0	<0.07	<1.4	<0.4	<1.1	<1.5
Talbingo water composite C	<0.36	<0.5	4.1	<0.07	<1.4	<0.4	1.2	<1.5
Talbingo water composite D	<0.36	<0.5	4.1	<0.07	<1.4	<0.4	<1.1	<1.5
Initial elutriate 1B	<0.36	14.9	3.2	<0.07	<1.4	0.5	<1.1	<1.5
Initial elutriate 1B duplicate	<0.36	14.8	3.3	<0.07	<1.4	<0.4	<1.1	<1.5
Initial elutriate 1B mean	<0.36	14.9	3.2	<0.07	<1.4	<0.4	<1.1	<1.5
Initial elutriate 1E	<0.36	17.4	16.6	<0.07	<1.4	<0.4	<1.1	<1.5
Initial elutriate 2B	<0.36	4.1	15.1	<0.07	<1.4	1.3	<1.1	3.9
Initial elutriate 2E	<0.36	8.5	9.2	<0.07	<1.4	<0.4	<1.1	2.0
Initial elutriate 3B	<0.36	<0.5	0.2	<0.07	<1.4	4.1	<1.1	<1.5
Initial elutriate 3E	<0.36	1.1	0.2	<0.07	<1.4	2.9	<1.1	<1.5
Initial elutriate 4B	<0.36	12.2	1.1	<0.07	<1.4	<0.4	<1.1	<1.5
Initial elutriate 4E	<0.36	10.8	1.9	<0.07	<1.4	<0.4	<1.1	2.5
Initial elutriate 4E duplicate	<0.36	11.4	1.9	<0.07	<1.4	<0.4	<1.1	2.1
Initial elutriate 4E mean	<0.36	11.1	1.9	<0.07	<1.4	<0.4	<1.1	2.3
Initial elutriate 5B	<0.36	13.4	3.8	<0.07	<1.4	<0.4	<1.1	14.5
Initial elutriate 5E	<0.36	2.8	5.8	<0.07	<1.4	<0.4	<1.1	1.7
Initial elutriate 7B	<0.36	5.8	6.0	<0.07	<1.4	<0.4	<1.1	<1.5
Initial elutriate 7E	<0.36	25.2	166	<0.07	<1.4	<0.4	<1.1	1.7
MIN	**<0.36**	**<0.5**	**0.2**	**<0.07**	**<1.4**	**<0.4**	**<1.1**	**1.7**
MAX	**<0.36**	**25.2**	**166**	**<0.07**	**<1.4**	**4.30**	**<1.1**	**14.5**
95% DGV[b]	**0.05**	**13**	**-**	**0.2**	**-**	**0.4**	**1.4**	**-**
99% DGV[c]	**0.02**	**0.8**	**-**	**0.06**	**-**	**0.01**	**1.0**	**-**

[a] liquid/solid (L/S) ratio = 10, 48 h. [b] http://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/. 95% species protection guideline values (95%GV) for freshwater. [c].99% species protection guideline values (99%GV) for freshwater. Values for Arsenic are for As(V) and chromium are for Cr(VI).

Table 5. The metals and metalloids released into the dissolved phase from excavated rocks in test 1.[a]

Site code	Ni (μg/L)	Pb (μg/L)	Sb (μg/L)	Sn (μg/L)	Sr (μg/L)	V (μg/L)	Zn (μg/L)
Talbingo water composite	<0.37	2.3	<50	<1.1	18	<0.3	1.0
Talbingo water composite	<0.37	5.2	<50	<1.1	18	<0.3	0.9
Talbingo water composite	<0.37	2.8	<50	<1.1	18	<0.3	1.2
Talbingo water composite	<0.37	3.3	<50	<1.1	18	<0.3	<0.9
Initial elutriate 1B	<0.37	<2.3	70	<1.1	58	14.0	<0.9
Initial elutriate 1B duplicate	<0.37	<2.3	<50	<1.1	57	13.8	<0.9
Initial elutriate 1B mean	<0.37	<2.3	~60	<1.1	57	13.9	<0.9
Initial elutriate 1E	<0.37	3.8	<50	<1.1	82	5.0	<0.9
Initial elutriate 2B	<0.37	6	<50	<1.1	33	5.9	<0.9
Initial elutriate 2E	<0.37	3.5	<50	<1.1	41	8.1	<0.9
Initial elutriate 3B	<0.37	4.7	<50	<1.1	6.3	8.2	<0.9
Initial elutriate 3E	<0.37	<2.3	<50	<1.1	12	5.3	<0.9
Initial elutriate 4B	<0.37	4.5	<50	<1.1	24	4.8	<0.9
Initial elutriate 4E	<0.37	<2.3	<50	<1.1	30	8.3	<0.9
Initial elutriate 4E duplicate	<0.37	<2.3	<50	<1.1	30	8.5	<0.9
Initial elutriate 4E mean	<0.37	<2.3	<50	<1.1	30	8.4	<0.9
Initial elutriate 5B	<0.37	3.5	<50	<1.1	23	12.2	<0.9
Initial elutriate 5E	<0.37	<2.3	<50	<1.1	31	5.8	<0.9
Initial elutriate 7B	<0.37	4.5	<50	<1.1	52	18.4	<0.9
Initial elutriate 7E	<0.37	3.2	<50	<1.1	58	14.0	<0.9
MIN	**<0.37**	**<0.2.3**	**<50**	<1.1	**6**	**4.8**	**<0.9**
MAX	**<0.37**	**6**	**70**	<1.1	**82**	**18.4**	**<0.9**
95% DGV[b]	**11**	**3.4**	**-**	**-**	**-**	**-**	**8.0**
99% DGV[c]	**8**	**1.0**	**-**	**-**	**-**	**-**	**2.4**

[a] liquid/solid (L/S) ratio = 10, 48 h. [b] http://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/. 95% species protection guideline values (95%GV) for freshwater. [c].99% species protection guideline values (99%GV) for freshwater. Value for tin is for inorganic tin.

Summary

The elutriate test with a solid to liquid (L/S) ratio of 10 undertaken to maintain the resuspension of materials for a duration of 48 h resulted in an increase in the pH of 2-2.8 pH units, and a 3-7-fold increase in the conductivity above that in the Talbingo control water.

The chloride, fluoride, sulfate, total phosphorous and sulfur increased relative to the control water, with the total phosphorous being the only parameter that increased above the 95% species protection water quality guideline value (WQGV).

Most of the metals, metalloids and major cations in the excavated rock elutriates increased relative to the control Talbingo water. The arsenic, chromium and, in particular, the aluminium increased above the DGVs.

As described in the introduction, this initial test was performed to assess what we consider to be a worst case scenario for fine excavated rock material remaining in the water column. The tests indicate that under such conditions the pH of the waters may increase to levels that result in high concentration of dissolved aluminium within the waters. These waters would be predicted to cause toxicity to a range of aquatic organisms.

Tests now underway (to be reported in future Memos) are evaluating scenarios of pollutant release for excavated rock materials at much higher L/S ratios (e.g. 100/1, 1000/1) and the release occurring over shorter durations to represent the scenario of more rapid settling and release within waters beyond the main placement area (where some fine material may potentially disperse to).

Successive leaching tests will be used to provide information on substance release from excavated rock materials transported within the water column.

Leach tests on composite materials of large particle sizes will provide information on how leaching from those materials compares to the fine solids.

Appendix D1. Release of substances from <75 µm composite excavated rock materials in reservoir water at low L/S ratic

Memo 4 (28 September 2018) (Appendix D1). Combination of ICP-MS and AES data. Not all data available when original (initial) Memo provided to HKA/SHL.

Notes **Composite Talbingo reservoir water used as leachate solution**

L/S of 10/1 tested i.e. 5 g solid and 50 mL Talbingo composite solution

Sample Labels	Treatment	pH	SEC (µS/cm)	DO (mg/L)	Al (µg/L)	Fe (µg/L)	Mn (µg/L)	Na (µg/L)	K (µg/L)	Mg (µg/L)	Ca (µg/L)
Tal Com A	Composite Talbingo water A	7.12	29.1	8.26	3.8	16	0.22	1430	402	704	1700
Tal Com B	Composite Talbingo water B	6.99	28.9	8.22	3.1	17	0.21	1480	417	725	1760
Tal Com C	Composite Talbingo water C	7.05	29.0	8.16	3.1	17	0.22	1430	414	711	1760
Tal Com D	Composite Talbingo water D	7.03	29.0	8.19	3.4	17	0.22	1470	404	724	1730
CE491-20	10/1 L/S composite 1B	9.20	154	8.21	208	0.6	1.5	7630	20300	2090	5050
CE491-20 dup	10/1 L/S composite 1B duplicate	9.29	153	8.15	212	0.7	1.6	7590	20200	2110	5030
	10/1 L/S composite 1B mean	9.25	154	8.18	**210**	**0.6**	**1.5**	**7610**	**20250**	**2100**	**5040**
CE491-21	10/1 L/S composite 1E	9.33	166	8.26	300	0.7	3.2	7720	20700	2510	5610
CE491-22	10/1 L/S composite 2B	8.88	160	8.36	73	0.3	2.3	4800	13100	6360	6850
CE491-23	10/1 L/S composite 2E	9.35	173	8.22	231	0.8	1.7	4330	27800	1520	6750
CE491-24	10/1 L/S composite 3B	9.58	120	8.23	417	1.2	0.43	9330	8600	2590	4170
CE491-25	10/1 L/S composite 3E	9.81	120	8.47	779	2.7	0.46	9710	11100	1900	4640
CE491-26	10/1 L/S composite 4B	9.67	107	8.32	409	0.9	1.0	5900	10600	893	5300
CE491-27	10/1 L/S composite 4E	9.37	141	8.49	701	3.2	1.2	6600	15400	1500	7000
CE491-27 dup	10/1 L/S composite 4E duplicate	9.31	143	8.35	705	3.3	1.2	6580	15400	1530	6960
	10/1 L/S composite 4E mean	9.34	142	8.42	**703**	**3.3**	**1.2**	**6590**	**15400**	**1515**	**6980**
CE491-28	10/1 L/S composite 5B	9.57	150	8.25	263	1.9	0.88	9480	15500	1390	4620
CE491-29	10/1 L/S composite 5E	9.39	162	7.14	404	1.7	1.6	9740	11000	1960	8010
CE491-30	10/1 L/S composite 7B	9.56	150	8.36	300	1.0	3.4	9680	19900	617	4080
CE491-31	10/1 L/S composite 7E	9.38	203	8.27	128	1.9	0.74	6190	34500	917	4160
	Min	8.9	107	7.1	73	0.3	0.43	4330	8600	617	4080
	Max	9.8	203	8.5	779	3.3	3.4	9740	34500	6360	8010

Sample Labels	Treatment	Ag (µg/L)	As (µg/L)	B (µg/L)	Ba (µg/L)	Be (µg/L)	Cd (µg/L)	Ce (µg/L)	Co (µg/L)	Cr (µg/L)	Cu (µg/L)	Li (µg/L)	Mo (µg/L)	Ni (µg/L)	Pb (µg/L)	Sb (µg/L)	Se (µg/L)	Sn (µg/L)	Sr (µg/L)	Th (µg/L)	Ti (µg/L)	Tl (µg/L)	U (µg/L)	V (µg/L)	Zn (µg/L)	P (µg/L)	S (µg/L)	P mg/L	S mg/L
Tal Com A	Composite Talbingo water A	<0.004	0.13	<0.66	4.1	<0.004	0.029	<0.42	0.01	<0.04	0.54	0.09	0.02	0.09	<0.01	<0.02	0.02	<0.02	14	0.014	<0.04	<0.01	0.014	0.10	1.4	<5	156	<0.005	0.16
Tal Com B	Composite Talbingo water B	<0.004	0.16	<0.66	4.3	<0.004	0.008	0.58	0.01	<0.04	0.58	0.09	0.03	0.08	0.01	<0.02	0.02	<0.02	14	0.011	<0.04	<0.01	0.014	0.10	1.3	<5	154	<0.005	0.15
Tal Com C	Composite Talbingo water C	<0.004	0.15	<0.66	4.1	<0.004	<0.004	<0.42	<0.01	0.04	0.55	0.09	0.03	0.07	<0.01	<0.02	0.02	<0.02	14	0.006	<0.04	<0.01	0.014	0.09	1.5	<5	156	<0.005	0.16
Tal Com D	Composite Talbingo water D	<0.004	0.19	<0.66	4.4	<0.004	<0.004	<0.42	<0.01	0.05	0.57	0.09	0.03	0.23	<0.01	<0.02	0.02	<0.02	15	0.006	<0.04	<0.01	0.013	0.11	1.2	<5	161	<0.005	0.16
CE491-20	10/1 L/S composite 1B	<0.004	15	30.3	3.6	<0.004	<0.004	<0.42	0.03	0.48	0.20	4.7	1.3	0.06	<0.01	3.7	0.43	<0.02	52	0.015	<0.04	0.04	0.12	14	0.1	10.1	327	0.010	0.33
CE491-20 dup	10/1 L/S composite 1B duplicate	<0.004	15	29.9	3.6	<0.004	<0.004	<0.42	0.02	0.48	0.19	4.7	1.3	0.05	<0.01	3.7	0.45	<0.02	52	0.005	<0.04	0.03	0.12	15	<0.1	9.5	320	0.010	0.32
	10/1 L/S composite 1B mean	**<0.004**	**15**	**30.1**	**3.6**	**<0.004**	**<0.004**	**<0.42**	**0.03**	**0.48**	**0.19**	**4.7**	**1.3**	**0.05**	**<0.01**	**3.7**	**0.44**	**<0.02**	**52**	**0.010**	**<0.04**	**0.03**	**0.12**	**15**	**<0.1**	**9.8**	**324**	**0.010**	**0.32**
CE491-21	10/1 L/S composite 1E	<0.004	21	16.8	20	<0.004	<0.004	<0.42	0.06	<0.04	0.09	6.2	1.8	0.28	0.16	11	0.54	<0.02	82	0.010	<0.04	0.04	0.039	6.6	<0.1	5.7	1430	0.006	1.4
CE491-22	10/1 L/S composite 2B	<0.004	3.8	10.9	15	<0.004	0.005	<0.42	0.04	1.5	0.12	7.8	3.8	0.06	<0.01	4.1	0.36	<0.02	28	0.007	<0.04	<0.01	0.070	6.0	0.1	38.9	452	0.039	0.45
CE491-23	10/1 L/S composite 2E	<0.004	9.4	17.6	9.8	<0.004	<0.004	<0.42	0.04	0.07	0.16	5.5	2.2	0.05	<0.01	14	0.81	<0.02	36	0.007	<0.04	0.04	0.52	8.6	0.1	8.0	5780	0.008	5.8
CE491-24	10/1 L/S composite 3B	<0.004	0.49	1.95	0.33	<0.004	<0.004	<0.42	0.02	4.3	0.37	0.18	0.12	0.03	<0.01	0.07	0.02	<0.02	5.7	<0.004	<0.04	<0.01	<0.003	9.1	<0.1	<5	177	<0.005	0.18
CE491-25	10/1 L/S composite 3E	<0.004	0.74	2.27	0.42	<0.004	<0.004	<0.42	0.01	2.9	0.69	0.88	0.12	0.03	<0.01	0.20	0.05	<0.02	10	0.027	0.04	<0.01	0.007	5.6	<0.1	6.2	180	0.006	0.18
CE491-26	10/1 L/S composite 4B	<0.004	10	<0.66	1.1	<0.004	<0.004	<0.42	0.01	0.07	0.59	0.68	0.25	0.04	<0.01	0.49	0.12	<0.02	20	0.021	<0.04	<0.01	0.690	5.2	<0.1	5.0	289	0.005	0.29
CE491-27	10/1 L/S composite 4E	<0.004	10	0.9	2.1	<0.004	<0.004	<0.42	0.02	0.07	0.34	0.26	2.5	0.07	<0.01	2.1	0.66	<0.02	26	0.005	<0.04	<0.01	0.090	8.6	<0.1	6.6	3510	0.007	3.5
CE491-27 dup	10/1 L/S composite 4E duplicate	<0.004	10	<0.66	1.9	<0.004	<0.004	<0.42	0.02	0.07	0.37	0.24	2.5	0.05	<0.01	2.0	0.66	<0.02	25	<0.004	<0.04	<0.01	0.089	8.6	<0.1	<5	3540	<0.005	3.5
	10/1 L/S composite 4E mean	**<0.004**	**10**	**<0.66**	**2.0**	**<0.004**	**<0.004**	**<0.42**	**0.02**	**0.07**	**0.36**	**0.25**	**2.5**	**0.06**	**<0.01**	**2.1**	**0.66**	**<0.02**	**25**	**0.004**	**<0.04**	**<0.01**	**0.089**	**8.6**	**<0.1**	**<5**	**3525**	**<0.005**	**3.5**
CE491-28	10/1 L/S composite 5B	<0.004	12	5.09	4.0	<0.004	<0.004	<0.42	0.04	0.08	0.27	0.41	15	0.15	<0.01	0.79	0.16	<0.02	19	0.012	<0.04	<0.01	0.80	13	0.1	38.0	752	0.038	0.75
CE491-29	10/1 L/S composite 5E	<0.004	2.4	6.64	6.2	<0.004	<0.004	<0.42	0.02	0.05	0.98	0.86	1.4	0.03	<0.01	1.6	1.4	<0.02	26	0.006	<0.04	<0.01	0.097	6.5	<0.1	21.0	8510	0.021	8.5
CE491-30	10/1 L/S composite 7B	<0.004	5.8	7.09	6.4	<0.004	<0.004	<0.42	0.01	0.06	0.32	3.2	1.2	0.06	<0.01	3.1	0.22	<0.02	46	0.012	<0.04	0.02	1.2	19	0.2	<5	516	<0.005	0.52
CE491-31	10/1 L/S composite 7E	<0.004	24	14.4	181	<0.004	<0.004	<0.42	0.03	0.05	0.54	8.9	1.9	0.05	<0.01	6.3	0.18	<0.02	52	0.013	<0.04	0.04	0.60	15	0.2	5.1	4280	0.005	4.3
	Min	<0.004	0.49	<0.66	0.33	<0.004	<0.07	<0.42	0.011	<0.04	0.09	0.18	0.12	0.03	<0.01	0.07	0.02	<0.02	5.7	<0.004	<0.04	<0.01	<0.003	5.2	<0.1	<5	177	<0.005	0.18
	Max	<0.004	24	30	181	<0.004	<0.07	<0.42	0.063	4.3	0.98	8.9	15	0.28	0.16	14	1.4	<0.02	82	0.027	0.040	0.04	1.2	19	0.2	39	8510	0.039	8.5

Appendix D1. Release of substances from <75 µm composite excavated rock materials in reservoir water at low L/S ratic

Memo 4 (28 September 2018) (Appendix D1). Combination of ICP-MS and AES data. Not all data available when original (initial) Memo provided to HKA/SHL.

Notes **Composite Talbingo reservoir water used as leachate solution**

L/S of 10/1 tested i.e. 5 g solid and 50 mL Talbingo composite solution

QA/QC.

Sample Labels	**Treatment**	**Al (µg/L)**	**Fe (µg/L)**	**Mn (µg/L)**		**Na (µg/L)**	**K (µg/L)**	**Mg (µg/L)**	**Ca (µg/L)**		**P (µg/L)**	**S (µg/L)**
LOD (3 x S.d.)		**0.2**	**0.1**	**0.01**		**15.0**	**15.9**	**42.6**	**20**		**5**	**10**
TM24.4		34.5	16.3	8.51		---	---	---	---		---	---
Certified TM24.4		32.9 ± 4.5	16.0 ± 2.3	8.24 ± 0.73		---	---	---	---		---	---
% recovery (TM24.4)		105	102	103		---	---	---	---		---	---
CE491-21+spike	10/1 L/S composite 1E	103	-	-		112	129	106	111		-	-
CE491-37+spike	Initial elutriate 3B	-	99	100		-	-	-	-		-	-
CE491-38+spike	10/1 L/S composite 3E	-	-	-		-	-	-	-		96	89
CE491-39+spike	10/1 L/S composite 4B	-	-	-		-	-	-	-		100	94
CE491-40+spike	Initial elutriate 4E	-	103	103		-	-	-	-		-	-
CE491-31+spike	10/1 L/S composite 7E	104	-	-		109	113	104	109		-	-

QA/QC.

Sample Labels	**Treatment**	**Ag (µg/L)**	**As (µg/L)**	**B (µg/L)**	**Ba (µg/L)**	**Be (µg/L)**	**Cd (µg/L)**	**Ce (µg/L)**	**Co (µg/L)**	**Cr (µg/L)**	**Cu (µg/L)**	**Li (µg/L)**	**Mo (µg/L)**	**Ni (µg/L)**	**Pb (µg/L)**	**Sb (µg/L)**	**Se (µg/L)**	**Sn (µg/L)**	**Sr (µg/L)**	**Th (µg/L)**	**Ti (µg/L)**	**Tl (µg/L)**	**U (µg/L)**	**V (µg/L)**	**Zn (µg/L)**
LOD (3 x S.d.)		**0.004**	**0.01**	**0.664**	**0.003**	**0.004**	**0.004**	**0.42**	**0.01**	**0.04**	**0.02**	**0.01**	**0.02**	**0.01**	**0.01**	**0.02**	**0.01**	**0.02**	**0.03**	**0.004**	**0.037**	**0.01**	**0.003**	**0.01**	**0.1**
TM24.4		8.74	5.16	10.2	15.3	1.98	3.97	<0.42	6.46	5.00	6.40	4.82	6.48	4.93	5.51	3.47	3.43	3.52	114	0.21	7.5	5.31	4.91	7.11	26.2
Certified TM24.4		---	5.30 ± 0.53		15.0 ± 1.0	2.06 ± 0.24	3.96 ± 0.34		6.27 ± 0.57	5.00 ± 0.59	6.31 ± 0.60	4.95 ± 0.42	6.30 ± 0.56	5.03 ± 0.53	5.60 ± 0.52	---	3.56 ± 0.58	3.72 ± 0.39	113 ± 8	---		4.20 ± 0.34	4.24 ± 0.34	7.00 ± 0.58	---
% recovery (TM24.4)		---	97		102	96	100		103	100	101	97	103	98	98	---	96	94	101	---		126	116	102	---
CE491-21+spike	10/1 L/S composite 1E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	98	-	-	-
CE491-37+spike	Initial elutriate 3B	93	97	-	103	100	94	-	103	105	101	99	100	100	97	101	95	98	106	128	-	117	107	108	96
CE491-38+spike	10/1 L/S composite 3E	99	-	95	-	-	-	99	-	-	-	-	-	-	-	-	-	-	-	-	103	-	-	-	-
CE491-39+spike	10/1 L/S composite 4B	99	-	98	-	-	-	101	-	-	-	-	-	-	-	-	-	-	-	-	106	-	-	-	-
CE491-40+spike	Initial elutriate 4E	72	98	-	100	89	97	-	100	98	98	90	102	97	93	97	95	90	104	135	-	111	109	103	97
CE491-31+spike	10/1 L/S composite 7E	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	103	-	-	-

Appendix D2. Effect of L/S ratio on substance release from <75 µm composite rock materials

Note/Memo	CSIRO P4 Project Investigations
To:	Ali Watters (HKA)
From:	Brad Angel, Lucas Heights, NSW
Date:	9 November 2018
Copy:	Ryan Fraser, Stuart Simpson and Ellen Porter (SHL)
Our reference:	CSIRO P4 – Memo 11
Classification:	Internal use only
Subject:	Pollutant release from excavated rock composites: effect of L/S and kinetics

Chemical formulas and acronyms

Al	Aluminium	DGV	Default guideline value	L/S	Liquid/solid ratio
SEC	Conductivity				

Background - Introduction

The CSIRO was engaged by Haskoning Australia Pty Ltd (RHDHV) to undertake an investigation of the pollutant release from excavated rock disposal into Talbingo and Tantangara reservoirs. Previous elutriate tests (Memo 4, 5, 6) investigating the release of pollutants from composite excavated rock samples have observed significant changes in water quality with respect to pH, conductivity (SEC) and the dissolved aluminium concentrations. The results in memo 5 for composite 4E detailed how the water quality is affected by the liquid to solid (L/S) ratio and duration of contact between the composite material and reservoir water.

This technical memo describes results of elutriate tests performed on excavated rock composites 1B, 2B, 5B, 5E and 7E investigating the effect of liquid- to-solid (L/S) ratio and duration of contact with Talbingo reservoir water on pH, conductivity (SEC), and the dissolved aluminium concentration. The tests were performed using the following conditions:

- L/S = 30, 300, 1000, 3000
    - [being 33, 3.3, 1 and 0.33 g/L, respectively]
- Measurements at times of 0.5, 3, 18 and 120 h
- Solids mixed in composite Talbingo control water for 0.5 h then allowed to stand for durations tested
- Tests performed at 21±2°C

Results

The pH, conductivity and dissolved aluminium concentrations measured in the elutriate solutions for all composites combined for each L/S ratio over time are shown in Figure 1. Figures 2, 3, 4, 5 and 6 show the pH, conductivity and dissolved aluminium concentrations for the individual composites 1B, 2B, 5B, 5E and 7E, respectively. There were generally higher pH, conductivity and concentrations of dissolved aluminium at each time as the L/S ratio increased.

The pH was in the range 8.76-9.67, 9.07-9.49, 8.15-9.18, 7.00-7.87 for the 30:1 (33 g/L), 300:1 (3.3 g/L), 1000:1 (1 g/L) and 3000:1 (0.33 g/L) L/S ratios, respectively.

The conductivity was in the range 78.9-133, 49.6-76.0, 52.2-81.7, 29.3-56.9 µS/cm for the 30:1 (33 g/L), 300:1 (3.3 g/L), 1000:1 (1 g/L) and 3000:1 (0.33 g/L) L/S ratios, respectively.

The dissolved aluminium concentrations were in the range 30.4-439, 26.6-445, 14.6-134, 6.5-28.9 µg/L for the 30:1 (33 g/L), 300:1 (3.3 g/L), 1000:1 (1 g/L) and 3000:1 (0.33 g/L) L/S ratios, respectively.

The initial contact of the solids with the water resulted in a rapid increase in pH and conductivity. The pH generally decreased marginally over the duration of the tests while the conductivity marginally increased. The pH was nearly always higher for a lower L/S ratio at any given time point, whereas, for the conductivity, this relationship was not quite as clear, with similar values often observed for the 300 and 1000 L/S ratios.

The dissolved aluminium increased over the duration of the tests, with the degree of increase generally being higher for lower L/S ratios. For all composite samples tested, the dissolved aluminium exceeded the default guideline value (DVG) of 55 µg/L after 3 h for the 30 and 300 L/S ratios, and exceeded the DGV after 18 h (3 h not tested) for the 1000 L/S ratio. The aluminium DGV was not exceeded for any composites at the 3000 L/S ratio.

Summary

The kinetics of the changes in pH, conductivity and the dissolved aluminium concentrations indicate increased dissolution of rock solids occur with time. For aluminium the increase with time is consistent with the high pH acting to increase dissolution through formation of the highly soluble aluminate ion, $Al(OH)_4^-$.

The aluminium DGV was exceeded for L/S ratios ≤1000 (i.e. ≥1 g/L) after composite durations of ≤18 h in Talbingo reservoir water.

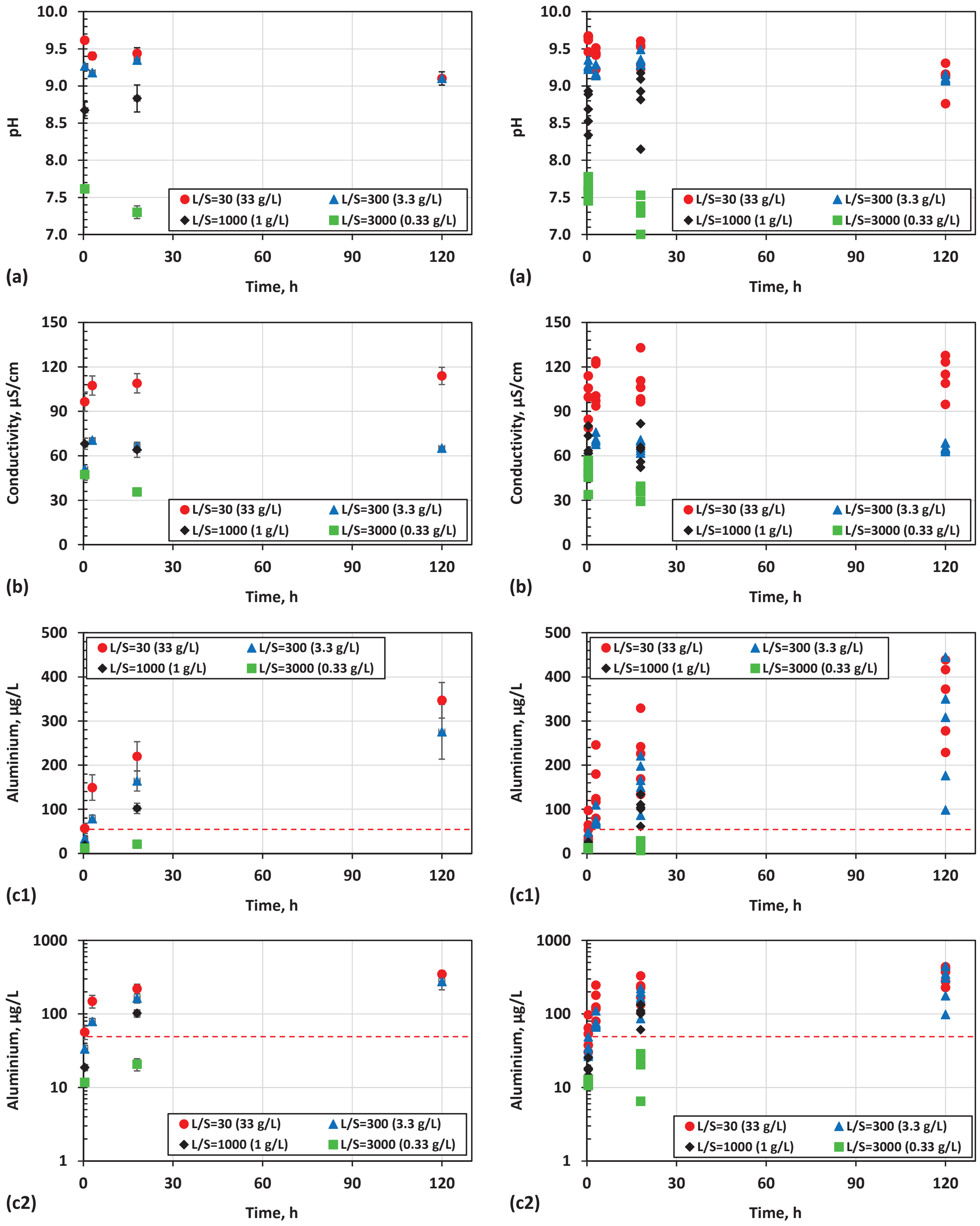

Figure 1. The pH, conductivity and dissolved aluminium concentration after elutriate times of 0.5, 3, 18 and 120 h for all excavated rock composite samples at liquid to solid ratios (L/S) of 30, 300, 1000 and 3000 (c2 = log scale). The figures on the left show the mean values (error bars are standard errors), and the figures on the right show the values measured for each composite materials at each duration.

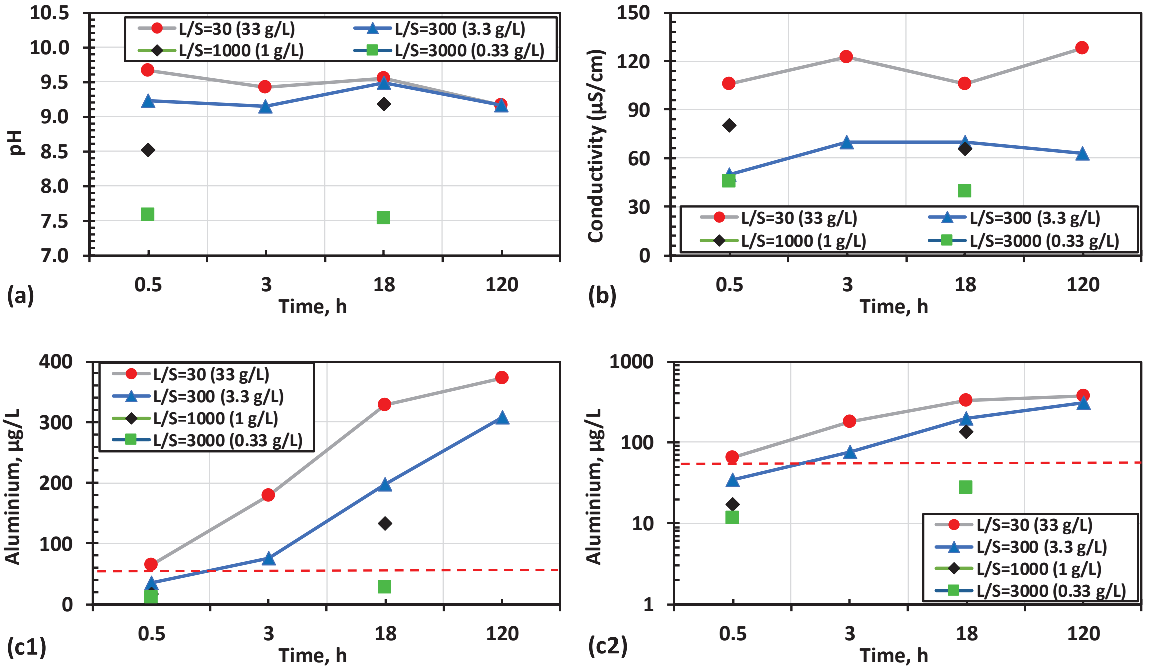

Figure 2. The pH, conductivity and dissolved aluminium concentration of composite 1B elutriate tests after times of 0.5, 3, 18 and 120 h for liquid to solid ratios (L/S) of 30, 300, 1000 and 3000 (c2 = log scale).

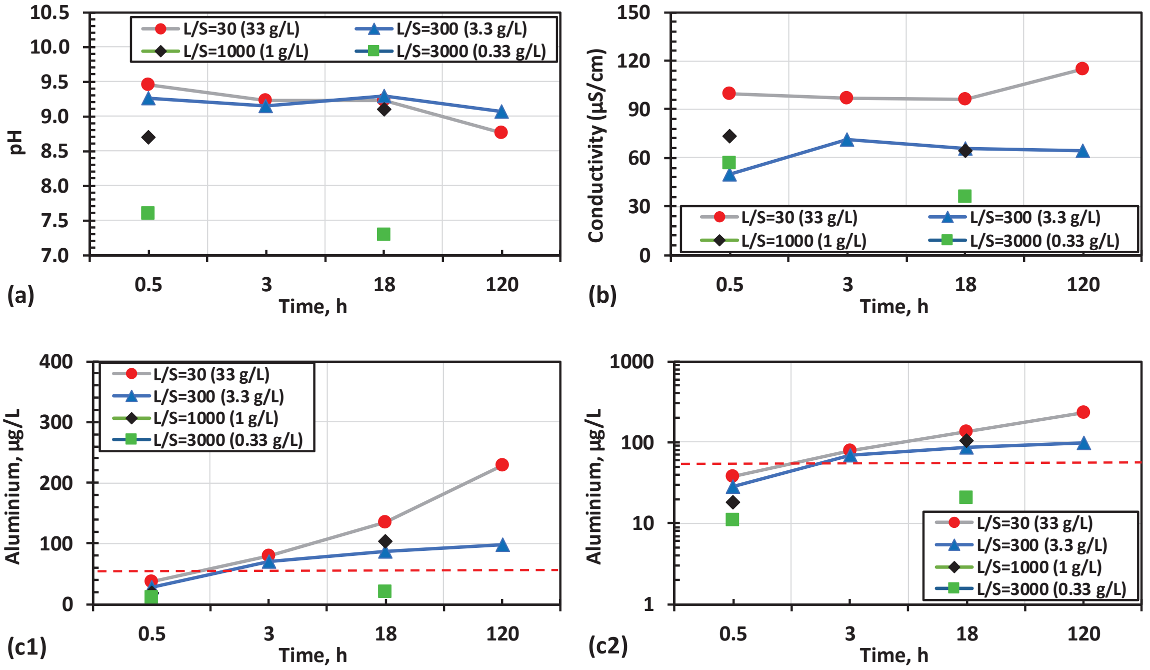

Figure 3. The pH, conductivity and dissolved aluminium concentration of composite 2B elutriate tests after times of 0.5, 3, 18 and 120 h for liquid to solid ratios (L/S) of 30, 300, 1000 and 3000 (c2 = log scale).

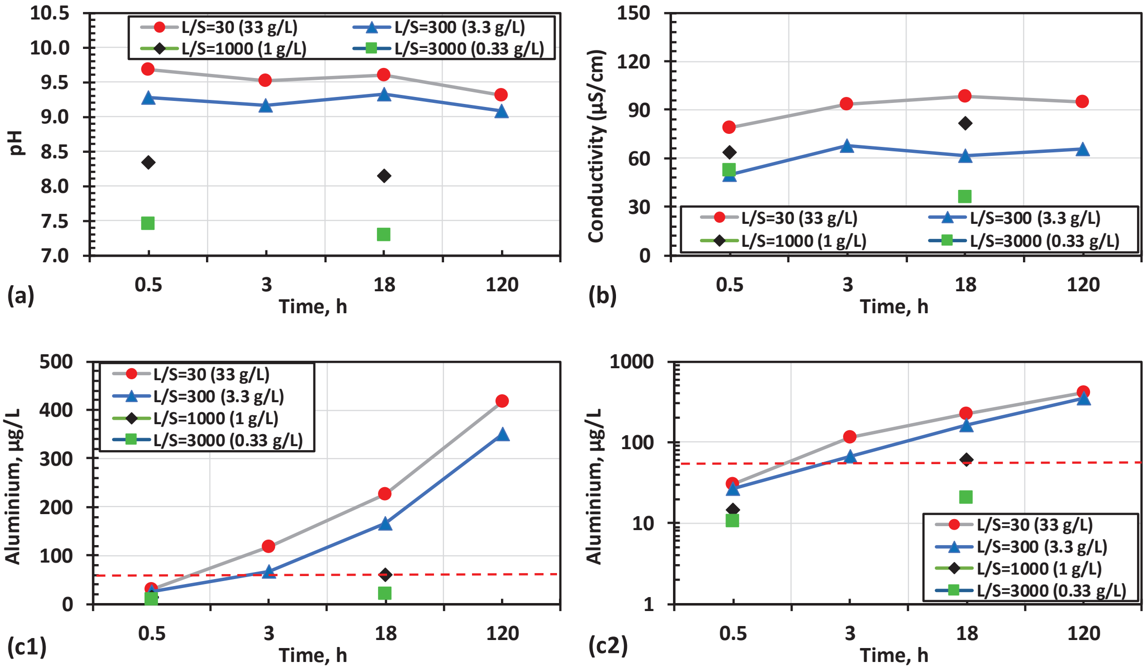

Figure 4. The pH, conductivity and dissolved aluminium concentration of composite 5B elutriate tests after times of 0.5, 3, 18 and 120 h for liquid to solid ratios (L/S) of 30, 300, 1000 and 3000 (c2 = log scale).

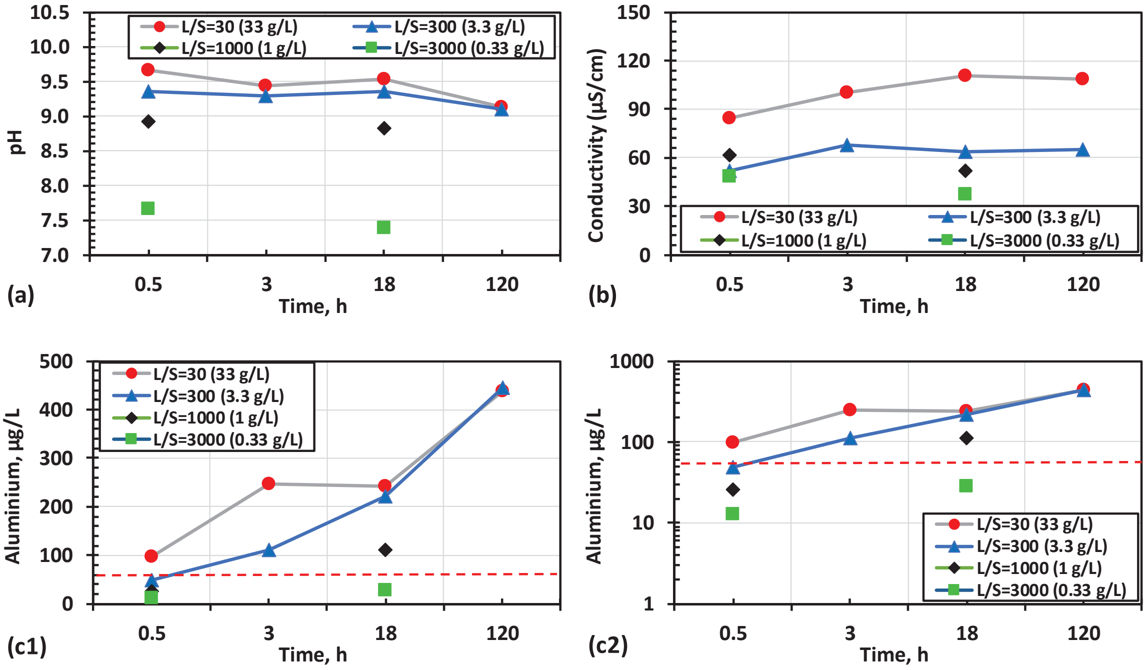

Figure 5. The pH, conductivity and dissolved aluminium concentration of composite 5E elutriate tests after times of 0.5, 3, 18 and 120 h for liquid to solid ratios (L/S) of 30, 300, 1000 and 3000 (c2 = log scale).

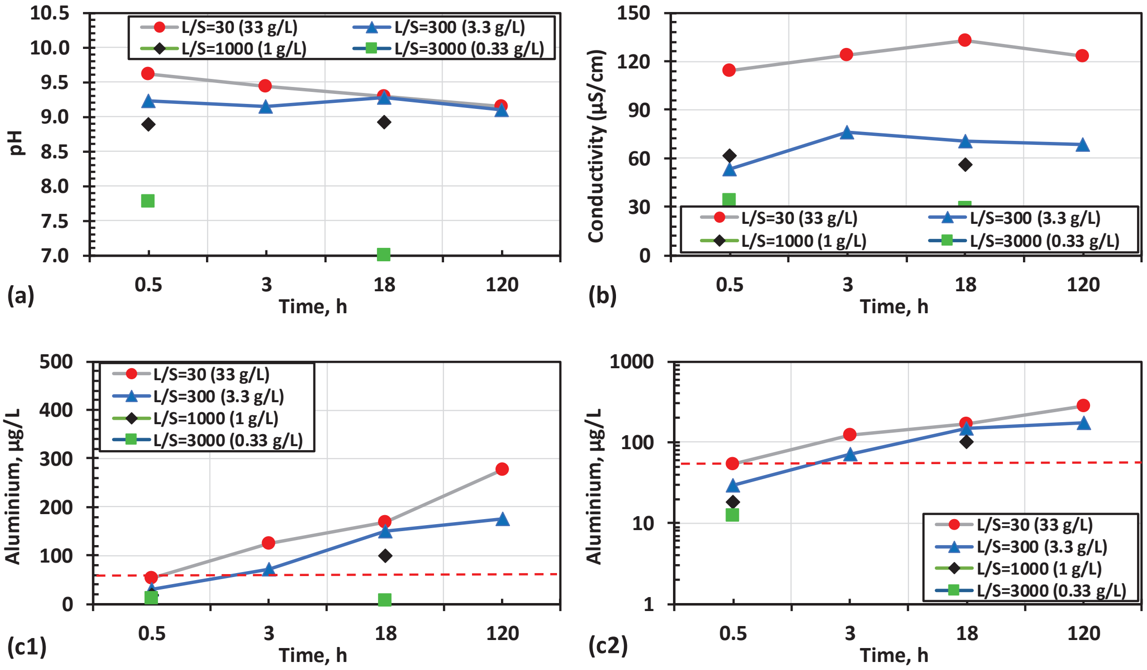

Figure 6. The pH, conductivity and dissolved aluminium concentration of composite 7E elutriate tests after times of 0.5, 3, 18 and 120 h for liquid to solid ratios (L/S) of 30, 300, 1000 and 3000 (c2 = log scale).

Appendix D2 Effect of L/S ratio on substance release from <75 µm composite rock materials

Samples re-analysed without dilution to provide different level of detection/reporting. New data for P (phosphorous) S (sulfur) and Si (silicon)

Sample Labels	Sample name	L/S ratio	Duration (h)	P (µg/L)	S (µg/L)	Si (µg/L)	Ag (µg/L)	Al (µg/L)	As (µg/L)	B (µg/L)	Ba (µg/L)	Be (µg/L)	Ca (µg/L)	Cd (µg/L)	Ce (µg/L)	Co (µg/L)	Cr (µg/L)	Cu (µg/L)	Fe (µg/L)	K (µg/L)	Li (µg/L)	Mg (µg/L)	Mn (µg/L)	Mo (µg/L)	Na (µg/L)	Ni (µg/L)	P (µg/L)	Pb (µg/L)	S (µg/L)	Sn (µg/L)	Sr (µg/L)	Ti (µg/L)	V (µg/L)	Zn (µg/L)
T3-1	1B	30/1	0.5	<3.4	202	2280	<0.5	66.1	<0.6	5	1.7	<0.05	4740	<0.1	<1.2	<1.3	0.15	0.7	2	8280	0.2	1510	2	0.5	3480	<0.6	<3.4	<1.3	202	<0.4	36	0.05	2.7	<0.2
T3-2	2B	30/1	0.5	22.8	224	2330	<0.5	37.8	<0.6	3	6.2	0.05	4130	<0.1	<1.2	<1.3	0.21	0.6	4	5570	0.1	3600	2	2.4	2470	<0.6	22.8	<1.3	224	<0.4	15	0.04	2.3	<0.2
T3-3	5B	30/1	0.5	14.7	284	2450	<0.5	28.9	<0.6	1	1.8	<0.05	5730	<0.1	<1.2	<1.3	<0.03	0.6	4	5970	0.5	1160	2	3.4	3650	<0.6	14.7	<1.3	284	<0.4	17	0.03	0.7	<0.2
T3-4	**5E**	**30/1**	**0.5**	**11.4**	**1260**	**2075**	**<0.5**	**106**	**<0.6**	**2**	**3.8**	**0.10**	**7740**	**<0.1**	**<1.2**	**<1.3**	**0.09**	**0.7**	**7**	**4375**	**0.6**	**1405**	**2**	**0.4**	**3730**	**<0.6**	**11.4**	**<1.3**	**1260**	**<0.4**	**21**	**0.28**	**1.1**	**<0.2**
T3-6	7E	30/1	0.5	4.5	1860	2430	<0.5	54.7	1.6	3	241	<0.05	4600	<0.1	<1.2	<1.3	<0.03	0.9	3	15700	<0.1	879	3	<0.3	3210	<0.6	4.5	3	1860	<0.4	56	0.04	2.2	<0.2
T3-7	1B	30:1	3 hr	9.1	269	2850	<0.5	215	3.5	9	2.5	0.07	5030	<0.1	<1.2	<1.3	0.35	0.7	83	8910	<0.1	1610	3	<0.3	3560	0.7	9.1	6.2	269	<0.4	37	1.41	5.1	1.3
T3-8	2B	30:1	3 hr	34.6	234	2910	<0.5	79	<0.6	4	6.8	0.09	4610	<0.1	<1.2	<1.3	0.28	<0.6	3	6070	<0.1	3550	1	2.6	2540	<0.6	34.6	<1.3	234	<0.4	16	0.06	4.2	<0.2
T3-9	5B	30:1	3 hr	17.9	288	3170	<0.5	116	<0.6	2	2.3	<0.05	5700	<0.1	<1.2	<1.3	0.06	<0.6	5	6500	0.5	1200	1	4.6	3910	<0.6	17.9	4.5	288	<0.4	18	0.07	2	<0.2
T3-10	**5E**	**30:1**	**3 hr**	**17.3**	**1380**	**2345**	**<0.5**	**255**	**<0.6**	**3**	**3.8**	**0.07**	**7600**	**<0.1**	**<1.2**	**<1.3**	**0.12**	**1.1**	**7**	**4740**	**0.5**	**1360**	**1**	**0.5**	**3995**	**0.9**	**17.3**	**<1.3**	**1380**	**<0.4**	**21**	**0.35**	**3.3**	**<0.2**
T3-12	7E	30:1	3 hr	4.9	2220	3230	<0.5	126	5.7	5	277	<0.05	4820	<0.1	<1.2	<1.3	<0.03	<0.6	1	16300	<0.1	862	2	0.5	3150	<0.6	4.9	5.4	2220	<0.4	63	<0.03	4.1	<0.2
T3-13	1B	30/1	18	5.6	213	3190	<0.5	207	7.2	12	1.9	<0.05	5390	<0.1	<1.2	<1.3	0.03	<0.6	1	9270	0.2	1640	1	0.4	3660	<0.6	5.6	5.8	213	<0.4	40	<0.03	8.2	<0.2
T3-14	2B	30/1	18	43.9	250	3530	<0.5	90.8	3.3	6	7	<0.05	5330	<0.1	<1.2	<1.3	0.44	<0.6	3	6370	<0.1	3670	1	2.8	2670	<0.6	43.9	4.7	250	<0.4	18	<0.03	5.9	<0.2
T3-15	5B	30/1	18	25.1	315	3940	<0.5	235	3.9	3	2.5	<0.05	5810	<0.1	<1.2	<1.3	<0.03	<0.6	3	7070	0.4	1270	1	4.9	4270	<0.6	25.1	3.3	315	<0.4	19	0.1	3.9	<0.2
T3-16	**5E**	**30/1**	**18**	**12.9**	**2000**	**3220**	**<0.5**	**255**	**6.0**	**6**	**136**	**<0.05**	**6415**	**<0.1**	**1.5**	**<1.3**	**<0.03**	**1.1**	**4**	**10715**	**0.3**	**1133**	**1**	**0.6**	**3805**	**<0.6**	**12.9**	**4.8**	**2000**	**<0.4**	**44**	**0.12**	**6.4**	**<0.2**
T3-18	7E	30/1	18	<3.4	172	2470	<0.5	181	1.7	2	1	<0.05	5810	<0.1	<1.2	<1.3	<0.03	<0.6	10	1850	0.4	1140	6	<0.3	1750	<0.6	<3.4	<1.3	172	<0.4	26	0.07	1.1	0.8
T3-19	1B	30:1	120 hr	<3.4	311	3430	<0.5	308	16.5	20	2.4	<0.05	6370	<0.1	1.3	<1.3	0.24	<0.6	4	10500	<0.1	2150	2	1.8	3980	<0.6	<3.4	4.4	311	0.5	49	0.11	13.5	0.3
T3-20	2B	30:1	120 hr	41.6	564	4850	<0.5	94.2	6.4	11	10.9	0.05	8850	<0.1	<1.2	<1.3	0.46	0.7	1	7750	<0.1	4060	2	2.7	2930	<0.6	41.6	5.8	564	<0.4	30	<0.03	8.6	<0.2
T3-21	5B	30:1	120 hr	23.9	764	4290	<0.5	344	12	6	3.3	<0.05	6500	<0.1	<1.2	<1.3	0.1	0.7	7	7800	0.4	1510	2	5.9	4750	<0.6	23.9	7.2	764	<0.4	22	0.13	6.9	0.5
T3-22	**5E**	**30:1**	**120 hr**	**14.2**	**3870**	**2575**	**<0.5**	**438**	**4.8**	**7**	**4.6**	**<0.05**	**10055**	**<0.1**	**<1.2**	**<1.3**	**0.05**	**2.0**	**16**	**5830**	**0.3**	**1745**	**2**	**1.6**	**4875**	**<0.6**	**14.2**	**3.9**	**3870**	**<0.4**	**28**	**0.79**	**7.1**	**<0.2**
T3-24	7E	30:1	120 hr	<3.4	3100	4440	<0.5	173	20.6	12	296	<0.05	7080	<0.1	<1.2	<1.3	0.21	1.3	2	18300	<0.1	1170	2	0.8	3550	<0.6	<3.4	2.2	3100	<0.4	88	<0.03	10.3	<0.2
T3-25	1B	300/1	0.5	3.8	183	2200	<0.5	31.3	1	1	0.9	<0.05	5250	<0.1	<1.2	<1.3	<0.03	0.9	15	1730	0.4	1050	11	<0.3	1790	<0.6	3.8	<1.3	183	<0.4	26	0.04	0.3	<0.2
T3-26	2B	300/1	0.5	6.1	179	2190	<0.5	28	<0.6	1	3.5	<0.05	4620	<0.1	<1.2	<1.3	0.17	0.9	17	1460	0.2	1670	11	1.1	1600	<0.6	6.1	<1.3	179	<0.4	15	0.06	0.4	<0.2
T3-27	5B	300/1	0.5	7.7	189	2220	<0.5	23.7	0.8	1	1.2	<0.05	5730	<0.1	<1.2	<1.3	<0.03	0.8	20	1270	0.3	905	6	0.4	1740	<0.6	7.7	<1.3	189	<0.4	18	0.14	<0.2	<0.2
T3-28	**5E**	**300/1**	**0.5**	**5.3**	**293**	**2190**	**<0.5**	**47.7**	**<0.6**	**1**	**2.2**	**<0.05**	**6490**	**<0.1**	**<1.2**	**<1.3**	**<0.03**	**1.1**	**25**	**1020**	**0.4**	**936**	**6**	**<0.3**	**1755**	**<0.6**	**5.3**	**<1.3**	**293**	**<0.4**	**18**	**0.51**	**<0.2**	**<0.2**
T3-30	7E	300/1	0.5	<3.4	496	2220	<0.5	28.7	0.9	1	312	<0.05	5430	<0.1	<1.2	<1.3	0.07	1.2	14	3060	0.3	885	19	<0.3	1710	<0.6	<3.4	<1.3	496	<0.4	47	<0.03	<0.2	<0.2
T3-31	1B	300:1	3 hr	6.2	184	2250	<0.5	79.4	<0.6	2	1	<0.05	5560	<0.1	<1.2	<1.3	<0.03	0.8	9	1810	0.2	1070	8	<0.3	1710	<0.6	6.2	<1.3	184	0.4	26	0.04	0.7	0.5
T3-32	2B	300:1	3 hr	9.7	186	2300	<0.5	71.9	1.1	1	3.7	0.08	5180	0.1	1.5	<1.3	<0.03	<0.6	10	1580	0.3	1630	6	<0.3	1620	0.9	9.7	<1.3	186	<0.4	16	<0.03	0.7	1.2
T3-33	5B	300:1	3 hr	7.8	188	2290	<0.5	64.2	1.1	1	1.4	<0.05	5980	<0.1	<1.2	<1.3	<0.03	0.8	13	1360	0.3	916	5	0.5	1740	1.7	7.8	<1.3	188	<0.4	18	0.09	<0.2	0.5
T3-34	**5E**	**300:1**	**3 hr**	**10.1**	**302**	**2235**	**<0.5**	**112**	**<0.6**	**1**	**2.2**	**<0.05**	**6755**	**<0.1**	**<1.2**	**<1.3**	**0.04**	**1.3**	**19**	**1085**	**0.6**	**932**	**4**	**<0.3**	**1755**	**<0.6**	**10.1**	**<1.3**	**302**	**<0.4**	**18**	**0.48**	**0.5**	**0.6**
T3-36	7E	300:1	3 hr	<3.4	612	2300	<0.5	73.4	1.6	1	425	<0.05	5730	<0.1	<1.2	<1.3	0.15	1.2	8	3200	0.3	874	13	<0.3	1700	<0.6	<3.4	<1.3	612	<0.4	56	<0.03	0.5	<0.2
T3-37	1B	300/1	18	17.4	1610	2510	<0.5	348	1.6	4	3.6	<0.05	7500	<0.1	<1.2	<1.3	0.11	1.5	5	5300	0.4	1380	1	0.4	4270	0.7	17.4	4.2	1610	<0.4	22	0.16	6.8	0.4
T3-38	2B	300/1	18	14	177	2530	<0.5	138	1.5	1	3.7	<0.05	5510	<0.1	<1.2	<1.3	0.08	0.6	8	1680	0.4	1640	2	<0.3	1640	<0.6	14	2.6	177	<0.4	17	<0.03	1.3	0.6
T3-39	5B	300/1	18	8.6	190	2580	<0.5	173	1	1	1.6	<0.05	6060	<0.1	<1.2	<1.3	0.04	1.5	13	1480	0.5	977	4	0.6	1790	<0.6	8.6	2.4	190	<0.4	19	0.09	0.6	<0.2
T3-40	**5E**	**300/1**	**18**	**11.5**	**318**	**2450**	**<0.5**	**232**	**<0.6**	**1**	**2.2**	**<0.05**	**6805**	**<0.1**	**<1.2**	**<1.3**	**0.15**	**1.3**	**20**	**1160**	**0.4**	**958**	**3**	**<0.3**	**1800**	**<0.6**	**11.5**	**3.0**	**318**	**<0.4**	**18**	**0.60**	**1.0**	**<0.2**
T3-42	7E	300/1	18	<3.4	663	2630	<0.5	154	0.8	1	457	<0.05	5990	<0.1	<1.2	<1.3	<0.03	1	7	3330	0.3	896	8	<0.3	1750	<0.6	<3.4	4.7	663	<0.4	60	<0.03	0.7	<0.2
T3-43	1B	300:1	120 hr	<3.4	183	2860	<0.5	375	2.5	3	1.4	<0.05	6750	<0.1	<1.2	<1.3	0.22	1.4	5	2110	0.2	1370	6	<0.3	1770	<0.6	<3.4	5.3	183	<0.4	30	0.05	2.6	<0.2
T3-44	2B	300:1	120 hr	12.5	232	3100	<0.5	236	3.4	2	5	<0.05	7530	<0.1	2.1	<1.3	<0.03	1	6	1920	0.2	1430	2	<0.3	1700	<0.6	12.5	5.7	232	<0.4	22	0.04	2.9	0.5
T3-45	5B	300:1	120 hr	<3.4	221	3090	<0.5	414	3.1	1	2.4	<0.05	7250	<0.1	<1.2	<1.3	0.08	1.1	22	1680	0.4	1120	6	0.6	1870	<0.6	<3.4	2	221	<0.4	22	0.51	1.1	<0.2
T3-46	**5E**	**300:1**	**120 hr**	**5.8**	**578**	**2745**	**<0.5**	**450**	**1.1**	**1**	**2.5**	**<0.05**	**8035**	**<0.1**	**<1.2**	**<1.3**	**<0.03**	**2.1**	**34**	**1280**	**0.5**	**1060**	**4**	**<0.3**	**1895**	**<0.6**	**5.8**	**<1.3**	**578**	**<0.4**	**20**	**0.93**	**2.3**	**0.3**
T3-48	7E	300:1	120 hr	<3.4	768	3090	<0.5	282	2.7	2	500	<0.05	7270	<0.1	<1.2	<1.3	0.06	1.2	4	3490	<0.1	949	7	<0.3	1770	<0.6	<3.4	3.6	768	<0.4	71	<0.03	1.4	<0.2
T5-1	1B	1000:1	0.5 hr	<3.4	176	2120	<0.5	15.5	<0.6	2	0.7	<0.05	3800	<0.1	<1.2	<1.3	<0.03	0.9	16	797	0.4	891	18	<0.3	1550	<0.6	<3.4	<1.3	176	<0.4	19	0.07	<0.2	0.8
T5-2	2B	1000:1	0.5 hr	<3.4	183	2120	<0.5	14.3	<0.6	1	2.6	<0.05	3820	<0.1	<1.2	<1.3	<0.03	0.8	17	719	0.4	1060	22	<0.3	1530	<0.6	<3.4	<1.3	183	<0.4	16	0.07	<0.2	0.7
T5-3	5B	1000:1	0.5 hr	4.5	308	2110	<0.5	12.8	<0.6	1	1.1	<0.05	3820	<0.1	1.8	1.9	<0.03	0.7	18	665	0.3	840	8	0.4	1570	<0.6	4.5	<1.3	308	<0.4	17	0.11	<0.2	<0.2
T5-4	**5E**	**1000:1**	**0.5 hr**	**5.3**	**350**	**2110**	**<0.5**	**22.2**	**0.8**	**1**	**2.1**	**<0.05**	**4955**	**<0.1**	**1.6**	**<1.3**	**0.10**	**1.2**	**20**	**587**	**0.5**	**838**	**9**	**<0.3**	**1590**	**<0.6**	**5.3**	**<1.3**	**350**	**<0.4**	**17**	**0.22**	**<0.2**	**0.6**
T5-6	7E	1000:1	0.5 hr	5.3	437	2100	<0.5	16.8	<0.6	<0.7	192	<0.05	4550	<0.1	<1.2	<1.3	<0.03	1	17	1220	0.5	822	35	<0.3	1580	<0.6	5.3	<1.3	437	<0.4	32	<0.03	0.2	0.3
T5-7	1B	1000:1	18 hr	<3.4	174	2340	<0.5	131	1.6	1	0.8	<0.05	5150	<0.1	<1.2	1.6	<0.03	0.6	12	891	0.5	969	13	<0.3	1560	<0.6	<3.4	<1.3	174	<0.4	22	0.1	0.4	0.2
T5-8	2B	1000:1	18 hr	6.4	190	2470	<0.5	103	<0.6	1	3.2	<0.05	5620	<0.1	<1.2	<1.3	0.1	0.7	11	871	0.6	1170	11	<0.3	1650	<0.6	6.4	<1.3	190	<0.4	19	0.06	0.5	0.7
T5-9	5B	1000:1	18 hr	<3.4	215	2620	<0.5	58.8	<0.6	1	1.7	<0.05	4920	<0.1	2.7	1.7	<0.03	0.8	20	822	0.5	1110	21	<0.3	1880	<0.6	<3.4	2.3	215	<0.4	20	0.21	<0.2	1.3
T5-10	**5E**	**1000:1**	**18 hr**	**6.7**	**258**	**2605**	**<0.5**	**112**	**1.3**	**1**	**2.3**	**<0.05**	**6440**	**<0.1**	**<1.2**	**<1.3**	**0.07**	**1.2**	**16**	**731**	**0.7**	**1000**	**9**	**<0.3**	**1895**	**<0.6**	**6.7**	**4.7**	**258**	**<0.4**	**20**	**0.36**	**0.3**	**1.5**
T5-12	7E	1000:1	18 hr	3.8	415	2660	<0.5	94.7	<0.6	1	404	<0.05	6510	<0.1	<1.2	1.7	<0.03	0.8	8	1450	0.4	992	36	<0.3	1870	1.1	3.8	5.9	415	<0.4	47	0.03	0.3	<0.2
T5-13	1B	3000:1	0.5 hr	3.7	202	2100	<0.5	9.9	0.8	<0.7	1.1	<0.05	2640	<0.1	<1.2	<1.3	0.07	0.7	17	557	0.3	849	14	<0.3	1520	<0.6	3.7	<1.3	202	<0.4	17	0.06	<0.2	0.5
T5-14	2B	3000:1	0.5 hr	<3.4	193	2160	<0.5	8.5	<0.6	1	3.2	<0.05	2670	<0.1	<1.2	<1.3	0.06	0.7	17	548	0.4	962	16	<0.3	1520	<0.6	<3.4	<1.3	193	<0.4	15	0.05	<0.2	0.7
T5-15	5B	3000:1	0.5 hr	3.9	185	2090	<0.5	7.8	<0.6	<0.7	1.5	<0.05	2560	<0.1	1.9	<1.3	0.09	1	17	506	0.4	816	6	<0.3	1510	1	3.9	<1.3	185	<0.4	16	0.07	<0.2	1.3
T5-16	**5E**	**3000:1**	**0.5 hr**	<3.4	**192**	**2100**	**<0.5**	**11.0**	**<0.6**	**<0.7**	**2.5**	**<0.05**	**3010**	**<0.1**	**<1.2**	**<1.3**	**0.06**	**<0.6**	**17**	**481**	**0.4**	**810**	**6**	**<0.3**	**1510**	**<0.6**	<3.4	**<1.3**	**192**	**<0.4**	**16**	**0.11**	**<0.2**	**0.8**
T5-18	7E	3000:1	0.5 hr	<3.4	235	2120	<0.5	9.4	<0.6	<0.7	149	<0.05	3240	<0.1	<1.2	<1.3	0.12	0.6	17	697	0.4	798	25	<0.3	1500	<0.6	<3.4	<1.3	235	<0.4	24	0.03	0.2	0.6
T5-19	1B	3000:1	18 hr	<3.4	193	2520	<0.5	23.8	<0.6	1	1.4	<0.05	3690	<0.1	2.5	<1.3	0.09	1	16	654	0.2	1150	37	<0.3	1780	0.8	<3.4	4.3	193	<0.4	21	0.05	<0.2	0.4
T5-20	2B	3000:1	18 hr	<3.4	208	2520	<0.5	18.9	1.3	1	4.1	0.07	3790	<0.1	<1.2	2.3	0.23	<0.6	15	668	0.3	1060	36	<0.3	1790	0.7	<3.4	2	208	<0.4	20	0.05	<0.2	1.6
T5-21	5B	3000:1	18 hr	<3.4	212	2520	<0.5	17.4	<0.6	2	2.4	<0.05	3290	<0.1	<1.2	<1.3	<0.03	1	19	616	0.3	1080	22	<0.3	1800	<0.6	<3.4	<1.3	212	<0.4	19	0.08	<0.2	1.2
T5-22	**5E**	**3000:1**	**18 hr**	**<3.4**	**216**	**2520**	**<0.5**	**26.2**	**<0.6**	**<0.7**	**2.9**	**0.09**	**3690**	**<0.1**	**<1.2**	**<1.3**	**<0.03**	**1.4**	**17**	**570**	**0.4**	**976**	**10**	**<0.3**	**1790**	**<0.6**	**<3.4**	**4.2**	**216**	**<0.4**	**19**	**0.14**	**<0.2**	**0.8**
T5-24	7E	3000:1	18 hr	<3.4	213	2480	<0.5	4.7	<0.6	<0.7	4.9	0.11	2160	<0.1	<1.2	<1.3	0.13	1.3	16	484	0.6	934	0	<0.3	1740	<0.6	<3.4	<1.3	213	<0.4	18	0.05	<0.2	3.3

Samples re-analysed without dilution to provide different level of detection/reporting. New data for P (phosphorous) S (sulfur) and Si (silicon)

Sample Labels	Sample name	L/S ratio	Duration (h)	P (µg/L)	S (µg/L)	Si (µg/L)	Ag (µg/L)	Al (µg/L)	As (µg/L)	B (µg/L)	Ba (µg/L)	Be (µg/L)	Ca (µg/L)	Cd (µg/L)	Ce (µg/L)	Co (µg/L)	Cr (µg/L)	Cu (µg/L)	Fe (µg/L)	K (µg/L)	Li (µg/L)	Mg (µg/L)	Mn (µg/L)	Mo (µg/L)	Na (µg/L)	Ni (µg/L)	P (µg/L)	Pb (µg/L)	S (µg/L)	Sn (µg/L)	Sr (µg/L)	Ti (µg/L)	V (µg/L)	Zn (µg/L)
Mean blank				2.1	3.1	-1.8	0.0	0.0	-1.2	-1.3	0.0	0.0	-4.6	0.0	0.6	-0.7	0.0	0.3	-0.1	0.7	-0.1	-1	0.0	0.0	-3	-0.1	2.1	-0.1	3.1	0.3	0.0	0.0	-0.1	-0.6
LOD (3 x S.d.)				3.4	8.1	1.2	0.5	0.1	0.6	0.7	0.0	0.0	0.2	0.1	1.2	1.3	0.0	0.6	0.2	0.8	0.1	4	0.0	0.3	0	0.6	3.4	1.3	8	0.4	0.0	0.0	0.2	0.2
Mean blank				3.7	-6.2	-4.2	0.1	0.3	-0.1	-3.4	0.0	0.0	-2	0.0	1.3	0.0	0.0	-0.4	0.0	0.3	-0.1	-1	0.0	0.0	-1	-0.2	3.7	-0.2	-6	0.4	0.0	0.0	0.0	-0.2
LOD (3 x S.d.)				4.7	8.9	0.2	0.5	0.2	0.6	0.9	0.0	0.0	1	0.1	4.1	1.3	0.2	1.4	0.3	0.7	0.3	1	0.0	0.1	0	0.4	4.7	0.1	9	1.6	0.0	0.0	0.3	0.1
TM-24.4				-2	5802	352	9	33	6	16	15	2		4	-1	7	5	7	16	1123	0	5409	8	6	9298	5	-2	7	5802	4	115	7	7	29
								32.9 ±	5.30 ±		15.0 ±			3.96 ±		6.27 ±	5.00 ±	6.31 ±	16.0 ±		4.95 ±					5.03 ±		5.60 ±			113 ±		7.00 ±	
Certified TM24.4							8.92	4.5	0.53		1.0			0.34		0.57	0.59	0.60	2.3		0.42					0.53		0.52			8		0.58	
% recovery (TM24.4)							102	101	113		97			102		111	104	110	98		4					103		116			101		102	
TMDA-64.3				3	5701	376	12	298	160	277	275	161		269		241	292	263	297	1169	126	5404	295	285	9538	262	3	286	5701	278	671	129	285	327
							12.6 ±	291 ±	164 ±		287 ±			258 ±		250 ±	283 ±	261 ±	298 ±		143 ±					252 ±		280 ±			628 ±		279 ±	320 ±
Certified TM63.4							1.3	23	15		18			21		16	17	18	21		15					18		22			34		18	23
% recovery (TMDA63.4)							99	102	97		96			104		96	103	101	100		88					104		102			107		102	102
TM-24.4				0.6	5864	351	8.9	32.7	4.5	16	15	2.2		4.2	1.3	7.0	5.1	7.2	16.2	1113	0.3	5408	8.2	6.0	9044	5.3	0.6	5.7	5864	3.6	115	7.4	7.2	29
								32.9 ±	5.30 ±		15.0 ±			3.96 ±		6.27 ±	5.00 ±	6.31 ±	16.0 ±		4.95 ±					5.03 ±		5.60 ±			113 ±		7.00 ±	
Certified TM24.4							8.92	4.5	0.53		1.0			0.34		0.57	0.59	0.60	2.3		0.42					0.53		0.52			8		0.58	
% recovery (TM24.4)							100	100	84		97			105		111	103	114	102		6					105		101			102		103	
TMDA-64.3				-1.6	5741	375	12.3	293	160	281	275	165		267	-2.8	257	288	264	299	1180	127	5396	290	285	9241	261	-1.6	286	5741	278	670	131	286	329
							12.6 ±	291 ±	164 ±		287 ±			258 ±		250 ±	283 ±	261 ±	298 ±		143 ±					252 ±		280 ±			628 ±		279 ±	320 ±
Certified TM63.4							1.3	23	15		18			21		16	17	18	21		15					18		22			34		18	23
% recovery (TMDA63.4)							98	101	98		96			104		103	102	101	100		89					103		102			107		103	103
T5-10 + Spike				97	93		97	96	97	97	96	96		95	97	93	96	98	96	101	92	84	95	99	95	96	97	95	93	100	96	97	97	95
T5-20 + Spike				95	94		96	95	97	98	96	95		95	97	95	96	98	96	99	93	82	95	99	96	96	95	95	94	99	96	97	97	95
T3-10 + Spike				97	74		95	91	97	97	95	96		94	94	94	96	97	95	97	90	77	95	98	81	94	97	94	74	99	95	97	97	95
T3-20 + Spike				100	92		97	96	99	97	96	99		99	98	97	98	98	97	60	94	59	97	98	99	96	100	95	92	98	97	99	99	97
T3-30 + Spike				100	92		99	?	99	97	97	100		98	99	96	98	99	98	90	95	86	98	99	96	98	100	98	92	99	98	99	99	98
T3-40 + Spike				99	95		98	97	99	97	98	100		99	99	98	99	99	98	101	96	87	99	100	96	98	99	97	95	99	98	99	100	99

Appendix D2 Effect of L/S ratio on substance release from <75 µm composite rock materials

Memo 11 (9 November 2018)

Notes **Composite Talbingo reservoir water used as leachate solution**
<75 µm composite rock materials
L/S = 30, 300, 1000, 3000 [being 33, 3.3, 1 and 0.33 g/L, respectively] and measurements at 0.5, 3, 18 and 120 h

Sample Name	Sample Description	L:S	Time	pH	SEC	Ag	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mn	Mo	V	Ni	Se	Sr	Sn	Sb	Pb	Th	U	Zn		Ca	K	Mg	Na
					(µS/cm)	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/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	mg/L
T3-7	CE491-20	30:1	3 hr	9.4	122	<0.01	180	3.5	2.4	<0.02	<0.1	0.19	0.28	41	2	0.4	5.2	0.8	0.22	35	0.15	0.3	0.05	0.03	0.02	4		4.6	9.2	1.5	3.5
T3-8	CE491-22	30:1	3 hr	9.2	97	<0.01	80	1.0	6.5	<0.02	<0.1	0.28	0.23	3	1	1.0	4.5	0.6	0.12	16	0.08	0.6	<0.03	<0.02	0.06	2		4.4	6.1	3.5	2.6
T3-9	CE491-28	30:1	3 hr	9.5	94	<0.01	117	1.1	2.5	<0.02	<0.1	<0.03	0.24	5	1	3.9	2.3	<0.1	0.05	17	0.05	<0.1	<0.03	<0.02	0.04	<1		5.2	6.2	1.2	3.8
T3-10	CE491-29	30:1	3 hr	9.5	101	<0.01	244	0.6	3.9	<0.02	<0.1	<0.03	0.39	6	1	0.5	4.1	<0.1	0.48	21	<0.03	0.2	<0.03	<0.02	<0.01	1		6.5	4.4	1.3	3.9
T3-11	CE491-29 Dup	30:1	3 hr	9.4	99	<0.01	248	0.9	4.0	<0.02	<0.1	<0.03	0.52	7	1	0.4	4.0	1.4	0.41	21	<0.03	0.3	<0.03	<0.02	0.01	3		6.7	4.5	1.3	3.9
T3-12	CE491-31	30:1	3 hr	9.4	124	<0.01	124	5.3	297	<0.02	<0.1	<0.03	0.38	1	2	0.5	4.5	<0.1	0.05	64	<0.03	0.8	<0.03	<0.02	0.18	3		4.5	17.4	0.9	3.1
T3-31	CE491-20	300:1	3 hr	9.1	70	<0.01	76	0.8	1.0	<0.02	<0.1	0.05	0.31	9	8	<0.1	0.8	0.2	0.03	24	<0.03	<0.1	<0.03	<0.02	0.06	3		6.1	10.9	2.1	4.1
T3-32	CE491-22	300:1	3 hr	9.2	71	<0.01	70	0.4	3.7	<0.02	<0.1	0.06	0.39	9	6	<0.1	1.1	0.8	0.05	15	<0.03	<0.1	<0.03	<0.02	0.07	<1		8.3	7.7	3.9	3.0
T3-33	CE491-28	300:1	3 hr	9.2	68	<0.01	67	0.1	1.4	<0.02	<0.1	<0.03	0.83	12	5	0.5	0.4	1.8	0.05	17	0.05	<0.1	<0.03	<0.02	0.06	6		6.0	7.6	1.5	4.7
T3-34	CE491-29	300:1	3 hr	9.3	67	<0.01	105	0.4	2.6	<0.02	<0.1	<0.03	0.76	14	4	<0.1	0.9	<0.1	0.07	18	<0.03	<0.1	<0.03	<0.02	0.03	5		8.9	5.6	1.7	4.8
T3-35	CE491-29 Dup	300:1	3 hr	9.3	69	0.01	115	0.3	2.3	<0.02	<0.1	0.07	1.95	21	4	0.1	0.8	1.4	0.07	19	0.30	0.2	0.06	0.02	0.03	2		9.3	5.6	1.7	4.9
T3-36	CE491-31	300:1	3 hr	9.2	76	<0.01	73	0.5	437	<0.02	<0.1	<0.03	0.67	8	13	<0.1	0.8	0.1	0.05	53	0.14	0.1	<0.03	<0.02	0.13	2		6.6	18.7	1.2	3.5
T3-19	CE491-20	30:1	120 hr	9.2	128	0.01	309	18.0	2.7	<0.02	<0.1	0.19	0.46	2	2	0.5	14.1	0.4	0.31	49	0.09	2.2	<0.03	<0.02	0.54	4		5.0	1.7	1.0	1.8
T3-20	CE491-22	30:1	120 hr	8.8	115	<0.01	99	7.7	12.0	<0.02	<0.1	0.44	0.34	2	2	1.7	9.6	0.4	0.25	31	0.06	2.2	<0.03	<0.02	0.42	4		4.7	1.5	1.5	1.7
T3-21	CE491-28	30:1	120 hr	9.3	95	<0.01	350	12.4	3.7	<0.02	<0.1	0.14	0.58	7	2	6.0	7.4	0.4	0.15	26	0.05	0.5	<0.03	<0.02	0.77	5		5.5	1.4	0.9	1.9
T3-22	CE491-29	30:1	120 hr	9.1	109	<0.01	438	4.8	5.1	<0.02	<0.1	0.10	1.99	16	2	0.7	8.4	0.4	1.1	26	<0.03	0.8	<0.03	<0.02	0.28	4		6.3	1.1	0.9	1.9
T3-23	CE491-29 Dup	30:1	120 hr	9.1	109	0.01	439	4.7	5.0	<0.02	<0.1	0.17	1.90	18	2	0.9	8.1	0.4	1.1	32	<0.03	1.0	<0.03	<0.02	0.28	2		6.3	1.1	0.9	1.9
T3-24	CE491-31	30:1	120 hr	9.1	123	<0.01	176	21.7	333	<0.02	<0.1	0.11	0.86	2	1	0.7	10.6	0.4	0.19	94	<0.03	3.8	<0.03	<0.02	1.15	8		5.5	3.3	0.9	1.8
T3-43	CE491-20	300:1	120 hr	9.2	63	0.01	372	2.9	1.2	<0.02	<0.1	0.11	0.59	6	5	0.1	2.9	0.6	0.13	30	0.24	0.3	<0.03	<0.02	0.12	31		6.3	2.1	1.4	1.9
T3-44	CE491-22	300:1	120 hr	9.1	64	<0.01	229	2.2	5.4	<0.02	<0.1	0.18	0.47	6	2	0.2	3.4	0.4	0.05	21	0.12	0.4	<0.03	<0.02	0.15	6		7.0	2.0	1.4	2.2
T3-45	CE491-28	300:1	120 hr	9.1	66	<0.01	417	1.6	2.6	<0.02	<0.1	0.08	0.84	21	6	0.8	1.7	0.5	0.05	22	0.07	0.2	0.08	<0.02	0.14	7		6.9	1.7	1.1	2.1
T3-46	CE491-29	300:1	120 hr	9.1	64	<0.01	446	1.3	2.5	<0.02	<0.1	0.09	2.28	34	4	0.2	2.7	0.9	0.16	20	0.07	0.1	0.09	<0.02	0.08	2		7.5	1.3	1.1	2.0
T3-47	CE491-29 Dup	300:1	120 hr	9.1	66	<0.01	444	1.0	2.7	<0.02	<0.1	0.06	2.29	32	4	<0.1	2.7	0.6	0.18	20	0.04	0.1	0.10	<0.02	0.08	2		7.5	1.3	1.0	2.1
T3-48	CE491-31	300:1	120 hr	9.1	69	<0.01	278	2.6	526	<0.02	<0.1	0.06	1.29	4	7	0.2	1.7	0.6	0.02	70	<0.03	0.5	0.09	<0.02	0.26	4		6.8	3.5	0.9	1.7
CE491-57	< 63 µm	1000:1	24 hr	8.9	361	<0.01	145	0.3	2.3	<0.02	<0.1	0.21	0.86	10	14	0.2	0.5	0.6	0.06	19	0.27	<0.1	<0.03	0.02	0.05	<1		5.9	0.6	0.7	1.4
CE491-58	< 63 µm dup	1000:1	24 hr	9.0	172	<0.01	139	0.7	2.4	<0.02	<0.1	0.17	0.80	10	15	0.2	0.5	0.2	<0.02	21	0.16	<0.1	<0.03	<0.02	0.05	<1		6.0	0.6	0.7	1.5
CE491-59	63 - 150 µm	1000:1	24 hr	8.2	57	<0.01	61	0.3	2.3	<0.02	<0.1	0.18	0.59	12	19	0.1	0.3	0.4	<0.02	17	0.09	<0.1	<0.03	<0.02	0.03	<1		4.6	0.5	0.7	1.4
CE491-60	63 - 150 µm Dup	1000:1	24 hr	8.2	61	<0.01	60	0.4	2.5	<0.02	<0.1	0.16	1.30	13	20	<0.1	0.3	0.3	<0.02	18	0.07	<0.1	<0.03	<0.02	0.04	<1		4.6	0.5	0.7	1.4
CE491-61	150-210 µm	1000:1	24 hr	8.0	75	<0.01	48	0.4	5.7	0.02	<0.1	0.16	0.65	13	25	0.1	0.3	0.2	<0.02	18	0.04	<0.1	<0.03	<0.02	0.03	<1		4.3	0.5	0.7	1.5
CE491-62	150-210 µm Dup	1000:1	24 hr	7.9	58	<0.01	42	0.6	2.3	<0.02	<0.1	0.21	0.63	19	22	<0.1	0.2	0.3	<0.02	17	<0.03	<0.1	<0.03	<0.02	0.03	<1		3.8	0.5	0.6	1.4
T5-1	CE491-20	1000:1	0.5 hr	8.5	80	<0.01	17	0.3	0.8	<0.02	<0.1	0.14	0.54	16	18	<0.1	0.2	0.4	0.04	19	0.19	0.1	<0.03	<0.02	0.03	1		3.5	0.8	0.9	1.7
T5-2	CE491-22	1000:1	0.5 hr	8.7	74	<0.01	18	0.2	2.7	<0.02	<0.1	0.11	0.55	17	21	<0.1	0.2	0.4	0.08	14	0.08	0.1	<0.03	<0.02	0.03	5		3.6	0.7	1.0	1.7
T5-3	CE491-28	1000:1	0.5 hr	8.3	63	<0.01	15	0.2	1.2	<0.02	<0.1	0.19	0.61	18	8	0.2	0.2	0.2	0.03	16	<0.03	<0.1	<0.03	<0.02	0.03	4		3.6	0.7	0.8	1.7
T5-4	CE491-29	1000:1	0.5 hr	8.9	64	<0.01	27	0.3	2.3	<0.02	<0.1	0.16	0.73	20	9	<0.1	0.3	0.6	0.04	18	<0.03	<0.1	<0.03	<0.02	0.03	27		4.5	0.6	0.8	1.7
T5-5	CE491-29 Dup	1000:1	0.5 hr	8.9	60	<0.01	24	0.1	2.2	<0.02	<0.1	0.14	0.58	19	9	<0.1	0.3	<0.1	<0.02	17	<0.03	<0.1	<0.03	<0.02	0.02	<1		4.5	0.6	0.8	1.7
T5-6	CE491-31	1000:1	0.5 hr	8.9	62	<0.01	18	0.1	206	<0.02	<0.1	0.16	0.59	16	34	<0.1	0.2	<0.1	0.05	31	<0.03	<0.1	<0.03	<0.02	0.06	<1		4.2	1.3	0.8	1.7
T5-7	CE491-20	1000:1	18 hr	9.2	66	<0.01	134	0.6	0.6	<0.02	<0.1	0.15	0.74	11	13	<0.1	0.8	0.7	<0.02	21	<0.03	<0.1	0.07	<0.02	0.04	9		4.8	0.9	0.9	1.8
T5-8	CE491-22	1000:1	18 hr	9.1	64	<0.01	104	0.8	3.3	<0.02	<0.1	0.11	0.81	11	10	<0.1	0.9	0.8	0.04	20	<0.03	0.1	<0.03	<0.02	0.05	14		5.1	0.9	1.1	1.8
T5-9	CE491-28	1000:1	18 hr	8.1	82	<0.01	61	0.6	1.5	<0.02	<0.1	0.13	0.93	19	20	0.1	0.3	0.8	0.05	21	<0.03	<0.1	0.07	<0.02	0.04	5		4.6	0.8	1.1	2.1
T5-10	CE491-29	1000:1	18 hr	8.8	52	<0.01	113	0.5	2.6	<0.02	<0.1	0.23	1.43	15	9	<0.1	0.7	0.6	<0.02	21	<0.03	<0.1	0.06	<0.02	0.03	5		5.9	0.7	1.0	2.0

Appendix D2 Effect of L/S ratio on substance release from <75 µm composite rock materials

Memo 11 (9 November 2018)

Sample Name	Sample Description	L:S	Time	pH	SEC	Ag	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mn	Mo	V	Ni	Se	Sr	Sn	Sb	Pb	Th	U	Zn	Ca	K	Mg	Na
					(µS/cm)	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/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	mg/L
T5-11	CE491-29 Dup	1000:1	18 hr	8.8	52	<0.01	109	0.4	2.1	<0.02	<0.1	0.18	1.39	16	9	0.1	0.8	0.5	0.03	20	0.08	<0.1	<0.03	<0.02	0.04	29	5.8	0.7	1.0	2.0
T5-12	CE491-31	1000:1	18 hr	8.9	56	<0.01	100	0.5	436	<0.02	<0.1	0.10	1.07	9	37	<0.1	0.5	1.3	0.04	49	<0.03	0.1	<0.03	<0.02	0.09	91	6.0	1.5	0.9	2.0
T5-13	CE491-20	3000:1	0.5 hr	7.6	46	0.02	12	0.4	1.1	<0.02	<0.1	0.27	0.64	18	14	<0.1	0.19	0.6	0.03	17	<0.03	<0.1	<0.03	<0.02	0.02	3	2.4	0.56	0.79	1.6
T5-14	CE491-22	3000:1	0.5 hr	7.6	57	<0.01	11	0.2	3.4	<0.02	<0.1	0.19	0.50	16	16	<0.1	0.18	0.3	0.06	13	<0.03	<0.1	<0.03	<0.02	0.01	2	2.5	0.52	0.91	1.6
T5-15	CE491-28	3000:1	0.5 hr	7.5	52	<0.01	11	0.3	1.6	<0.02	<0.1	0.17	0.66	17	6	0.1	0.08	0.6	<0.02	14	<0.03	<0.1	<0.03	<0.02	0.01	6	2.4	0.50	0.78	1.6
T5-16	CE491-29	3000:1	0.5 hr	7.7	46	<0.01	13	0.2	2.7	<0.02	<0.1	0.19	0.67	17	6	<0.1	0.16	<0.1	0.05	15	<0.03	<0.1	<0.03	<0.02	0.01	6	2.8	0.48	0.83	1.7
T5-17	CE491-29 Dup	3000:1	0.5 hr	7.6	51	<0.01	13	0.2	2.7	<0.02	<0.1	0.19	0.75	17	6	<0.1	0.12	0.7	<0.02	13	<0.03	<0.1	<0.03	<0.02	0.01	2	2.8	0.48	0.77	1.6
T5-18	CE491-31	3000:1	0.5 hr	7.8	34	<0.01	13	0.2	160.8	<0.02	<0.1	0.21	0.69	17	24	<0.1	0.06	0.6	0.02	24	<0.03	<0.1	<0.03	<0.02	0.03	13	3.0	0.69	0.81	1.7
T5-19	CE491-20	3000:1	18 hr	7.5	39	<0.01	28	0.4	1.8	<0.02	<0.1	0.15	1.05	18	37	<0.1	0.32	0.8	0.07	21	0.63	0.1	0.32	<0.02	0.04	16	3.3	0.66	1.09	1.9
T5-20	CE491-22	3000:1	18 hr	7.3	36	<0.01	20	0.2	4.7	<0.02	<0.1	0.19	0.68	14	35	<0.1	0.34	0.8	0.03	20	<0.03	0.1	<0.03	<0.02	0.02	10	3.5	0.66	0.99	1.9
T5-21	CE491-28	3000:1	18 hr	7.3	36	<0.01	20	0.2	2.7	<0.02	<0.1	0.16	0.78	18	22	<0.1	0.23	0.9	0.06	19	0.08	0.2	<0.03	<0.02	0.02	19	3.0	0.60	1.0	1.9
T5-22	CE491-29	3000:1	18 hr	7.4	37	<0.01	29	0.3	3.1	<0.02	<0.1	0.21	1.4	17	9.6	<0.1	0.26	0.4	0.05	17	<0.03	<0.1	<0.03	<0.02	0.02	10	3.3	0.56	0.95	1.9
T5-23	CE491-29 Dup	3000:1	18 hr	7.4	38	<0.01	28	0.3	3.4	<0.02	<0.1	0.22	1.2	16	9.8	<0.1	0.36	0.4	0.05	19	<0.03	0.1	<0.03	<0.02	0.01	7	3.5	0.61	1.0	2.0
T5-24	CE491-31	3000:1	18 hr	7.0	29	<0.01	7	0.1	5.3	<0.02	<0.1	0.20	0.82	15	0.26	<0.1	0.10	0.5	0.03	16	<0.03	<0.1	<0.03	<0.02	0.01	9	2.0	0.47	0.87	1.9
6B LS=500 t=30 min						<0.01	15	0.37	2.1	1.2	<0.1	0.27	0.78	19	5.9	0.1	0.33	1.2	0.05	11	<0.03	<0.1	<0.03	<0.02	0.08	3	1.8	3.5	0.96	1.8
6B LS=500 t=6 h						<0.01	14	0.11	2.6	<0.02	<0.1	0.19	0.44	18	9.8	0.2	0.39	0.4	<0.02	13	<0.03	<0.1	<0.03	<0.02	0.08	2	2.0	1.1	1.1	1.8
6E LS=500 t=30 min						<0.01	32	0.87	1.1	<0.02	<0.1	0.20	0.41	18	25	0.1	0.26	0.3	0.05	34	<0.03	<0.1	<0.03	<0.02	0.03	2	4.6	1.2	0.8	1.6
6E LS=500 t=6 h						<0.01	70	1.2	1.2	<0.02	<0.1	0.21	0.21	15	21	<0.1	0.38	0.1	<0.02	38	<0.03	0.3	<0.03	<0.02	0.05	<1	5.3	1.4	0.9	1.7
LOD (3σ)						0.01	1	0.01	0.03	0.02	0.1	0.03	0.04	0.2	0.03	0.1	0.04	0.1	0.02	0.4	0.03	0.1	0.03	0.02	0.01	1	0.01	0.04	0.01	*0.1*
Method Code	---	---	---	C-240	C-255	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-229	C-229	C-229	C-229

Spike recoveries

Sample Name	Sample Description	Liquid:Solid	Time (hr)	---	---	Ag	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mn	Mo	V	Ni	Se	Sr	Sn	Sb	Pb	Th	U	Zn	Ca	K	Mg	Na
						%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
T3-10	CE491-29	30: 1	3 hr			98	102	99	104	101	104	103	105	98	100	98	105	103	99	106	99	99	99	108	103	106	97	92	94	93
T3-48	CE491-31	300: 1	120 hr			99	112	104	110	107	104	101	104	102	105	97	103	103	103	99	103	98	99	109	105	101	108	102	102	106
CE491-62						99	96	102	104	99	103	104	104	94	98	98	103	104	95	107	97	99	99	104	103	101	96	98	94	98
T5-18	CE491-31	3000:1	0.5 hr			99	98	102	107	98	103	104	103	97	99	99	103	103	99	103	96	97	99	104	103	100	104	105	100	103
T5-20	CE491-22	3000: 1	18 hr			99	96	99	106	99	103	104	103	97	98	98	104	103	98	101	96	98	98	105	102	98	98	97	96	98

Sample Name	---	---	---	---	---	Ag	Al	As	Ba	Cd	Co	Cr	Cu	Fe	Mn	Mo	V	Ni	Se	Sr	Sn	Sb	Pb	Th	U	Zn	Ca	K	Mg	Na
	---	---	---	---	---	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/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	mg/L
TM24.4 avg (n=4)	---	---	---	---	---	---	32	5	16	4	7	6	7	15	8	6	8	5	4	126	4	---	6	---	5	---	---	---	---	---
Certified Value	---	---	---	---	---	---	32.9 ± 4.5	5.30 ± 0.53	15.0 ± 1.0	3.96 ± 0.34	6.27 ± 0.57	5.00 ± 0.59	6.31 ± 0.60	16.0 ± 2.3	8.24 ± 0.73	6.30 ± 0.56	7.00 ± 0.58	5.03 ± 0.53	3.56 ± 0.58	113 ± 8	3.72 ± 0.39	---	5.60 ± 0.52	---	4.24 ± 0.34	---	---	---	---	---
Recovery (%)	---	---	---	---	---	---	***98***	***103***	***107***	***100***	***112***	***110***	***115***	***95***	***99***	***99***	***110***	***107***	***103***	***111***	***100***	---	***101***	---	***111***	---	---	---	---	---
TMDA64.3 avg (n=4)	---	---	---	---	---	13	291	174	316	258	275	305	289	290	288	281	309	273	149	699	266	122	283	---	147	345	---	---	---	---
Certified Value	---	---	---	---	---	12.6 ± 1.3	291 ± 23	164 ± 15	287 ± 18	258 ± 21	250 ± 16	283 ± 17	261 ± 18	298 ± 21	292 ± 17	286 ± 21	279 ± 18	252 ± 18	154 ± 22	628 ± 34	281 ± 25	124 ± 11	280 ± 22	---	135 ± 11	320 ± 23	---	---	---	---
Recovery (%)						***101***	***100***	***106***	***110***	***100***	***110***	***108***	***111***	***97***	***99***	***98***	***111***	***108***	***97***	***111***	***95***	***98***	***101***	---	***109***	***108***	---	---	---	---

Appendix D2. Effect of L/S ratio on substance release from <75 µm composite rock materials (6B-6E results)

SUMMARY of Test 11: Investigation of Kelly's Plains L/S and kinetics effects of metal release and water quality

	Rock Spoil sample	L/S ratio	Mixing duration	Duration in water	pH	Na	K	Mg	Ca	SEC	Ag	Al	As	B	Ba	Be	Cd	Ce	Co	Cr	Cu	Fe	Li	Mn	Mo	Ni	P	Pb	S	Sn	Sr	Ti	Tl	V	Zn
Sample Labels				(h)		(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mS/cm	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
CE491_T11-1	6B	30:1	0.5 h	-	8.18	3.1	6.8	1.3	1.5	1330	<0.2	32	<1.1	<12	4.0	<0.03	<0.06	<0.8	<1.2	<0.3	0.3	5	1.7	2	1.4	<0.9	11.6	<1.8	672	<1.6	7	<0.04	<2.5	1.2	0.2
CE491_T11-2	6B	30:1	3 h	-	8.81	3.2	7.0	1.6	2.1	508	<0.2	43	1.8	<12	5.5	<0.03	<0.06	<0.8	<1.2	<0.3	<0.3	3	1.6	3	1.8	<0.9	11.5	<1.8	729	<1.6	9	0.07	<2.5	1.8	<0.05
CE491_T11-3	6B	30:1	18 h	-	9.09	3.4	7.3	2.2	3.1	572	<0.2	68	1.9	<12	8.0	0.03	<0.06	<0.8	<1.2	<0.3	<0.3	2	1.5	3	2.2	<0.9	11.9	<1.8	804	1.97	14	<0.04	<2.5	2.9	<0.05
CE491_T11-4	6B	30:1	120 h	-	8.83	3.7	7.9	3.1	4.5	246	<0.2	102	1.9	<12	9.6	<0.03	<0.06	<0.8	<1.2	<0.3	0.2	1	2.0	4	2.8	<0.9	13.6	<1.8	1060	<1.6	19	<0.04	<2.5	4.7	<0.05
CE491_T11-5	6B	300:1	0.5 h	-	7.53	1.8	1.5	1.1	1.9	207	<0.2	8	<1.1	<12	2.5	<0.03	<0.06	<0.8	<1.2	<0.3	0.6	12	0.5	8	<0.5	<0.9	<5.9	<1.8	212	<1.6	10	<0.04	<2.5	0.6	0.11
CE491_T11-6	6B	300:1	3 h	-	7.67	1.8	1.6	1.3	2.1	447	<0.2	15	1.7	<12	3.0	<0.03	<0.06	<0.8	<1.2	<0.3	0.4	11	0.6	12	<0.5	<0.9	<5.9	<1.8	227	1.88	11	0.05	<2.5	0.5	<0.05
CE491_T11-7	6B	300:1	18 h	-	8.05	1.8	1.6	1.5	2.7	160	<0.2	24	<1.1	<12	3.6	<0.03	<0.06	<0.8	<1.2	<0.3	0.3	9	0.7	18	<0.5	<0.9	<5.9	<1.8	236	<1.6	13	<0.04	<2.5	0.4	<0.05
CE491_T11-8	6B	300:1	120 h	-	8.15	1.8	1.7	1.9	3.4	536	<0.2	66	1.3	<12	4.2	<0.03	<0.06	<0.8	<1.2	<0.3	0.3	7	0.8	22	<0.5	<0.9	<5.9	<1.8	257	<1.6	15	<0.04	<2.5	0.7	<0.05
CE491_T11-9	6B duplicate	300:1	0.5 h	-	7.38	1.7	1.6	1.1	1.8	59	<0.2	10	<1.1	<12	2.5	<0.03	<0.06	<0.8	<1.2	<0.3	0.6	13	0.5	8	<0.5	<0.9	<5.9	<1.8	214	<1.6	10	0.06	<2.5	0.4	<0.05
CE491_T11-10	6B duplicate	300:1	3 h	-	7.59	1.8	1.5	1.3	2.2	74	<0.2	12	2.1	<12	3.0	<0.03	<0.06	<0.8	<1.2	<0.3	0.7	11	0.6	12	<0.5	<0.9	<5.9	<1.8	219	<1.6	11	0.05	<2.5	0.4	<0.05
CE491_T11-11	6B duplicate	300:1	18 h	-	7.93	1.8	1.6	1.5	2.7	141	<0.2	23	<1.1	<12	3.7	<0.03	<0.06	<0.8	<1.2	<0.3	0.5	9	0.7	18	<0.5	<0.9	<5.9	<1.8	237	1.7	13	0.07	<2.5	0.4	<0.05
CE491_T11-12	6B duplicate	300:1	120 h	-	8.04	1.8	1.7	1.9	3.4	318	<0.2	63	<1.1	<12	4.2	<0.03	<0.06	<0.8	<1.2	<0.3	0.5	7	0.8	23	<0.5	<0.9	<5.9	<1.8	250	<1.6	15	0.07	<2.5	0.7	<0.05
CE491_T11-13	6B	1000:1	0.5 h	-	7.15	1.6	0.8	0.9	1.8	69	<0.2	6	<1.1	<12	2.3	<0.03	<0.06	<0.8	<1.2	<0.3	0.6	14	0.2	6	<0.5	<0.9	<5.9	<1.8	176	<1.6	12	<0.04	<2.5	0.3	0.06
CE491_T11-14	6B	1000:1	3 h	-	7.40	1.6	0.9	1.0	2.0	118	<0.2	8	<1.1	<12	2.6	<0.03	<0.06	<0.8	<1.2	<0.3	0.4	14	0.3	9	<0.5	<0.9	6.55	<1.8	176	<1.6	13	<0.04	<2.5	0.3	0.08
CE491_T11-15	6B	1000:1	18 h	-	7.65	1.6	0.9	1.1	2.2	63	<0.2	12	1.4	<12	3.0	<0.03	<0.06	<0.8	<1.2	<0.3	0.3	12	0.4	16	<0.5	<0.9	<5.9	<1.8	182	<1.6	13	<0.04	<2.5	0.3	<0.05
CE491_T11-16	6B	1000:1	120 h	-	7.72	1.7	0.9	1.3	2.6	225	<0.2	27	<1.1	<12	3.4	<0.03	<0.06	<0.8	<1.2	<0.3	0.2	10	0.4	21	<0.5	<0.9	<5.9	<1.8	192	<1.6	14	0.07	<2.5	0.4	<0.05
CE491_T11-17	6B	3000:1	0.5 h	-	7.02	1.6	0.6	0.9	1.9	69	<0.2	10	<1.1	<12	2.7	<0.03	<0.06	<0.8	<1.2	<0.3	0.5	40	0.1	7	<0.5	1.04	<5.9	<1.8	156	<1.6	14	<0.04	<2.5	0.2	0.9
CE491_T11-18	6B	3000:1	3 h	-	7.19	1.6	0.6	0.9	1.9	122	<0.2	10	<1.1	<12	2.8	<0.03	<0.06	<0.8	<1.2	<0.3	0.6	22	0.1	9	<0.5	<0.9	<5.9	<1.8	175	1.95	14	<0.04	<2.5	0.2	0.36
CE491_T11-19	6B	3000:1	18 h	-	7.45	1.6	0.6	0.9	2.0	158	<0.2	10	<1.1	<12	3.1	<0.03	<0.06	<0.8	<1.2	<0.3	<0.3	15	0.2	13	<0.5	<0.9	<5.9	<1.8	169	1.91	14	<0.04	<2.5	0.2	0.09
CE491_T11-20	6B	3000:1	120 h	-	7.48	1.6	0.6	1.0	2.1	354	<0.2	16	1.3	<12	3.4	<0.03	<0.06	0.8	<1.2	<0.3	0.4	14	0.2	15	<0.5	<0.9	<5.9	<1.8	174	<1.6	14	0.05	<2.5	0.4	<0.05
CE491_T11-21	6E	30:1	0.5 h	-	9.40	2.4	10.6	1.5	7.0	156	<0.2	89	3.1	<12	2.8	<0.03	<0.06	<0.8	<1.2	<0.3	<0.3	<0.5	4.1	3	1.0	<0.9	<5.9	<1.8	3980	1.9	79	<0.04	<2.5	1.0	<0.05
CE491_T11-22	6E	30:1	3 h	-	9.41	2.5	10.8	1.5	7.3	181	<0.2	127	5.7	<12	2.8	<0.03	<0.06	<0.8	<1.2	<0.3	<0.3	<0.5	4.2	3	1.2	<0.9	<5.9	<1.8	4080	<1.6	82	<0.04	<2.5	1.5	<0.05
CE491_T11-23	6E	30:1	18 h	-	9.34	2.5	11.0	1.6	8.0	193	<0.2	171	9.9	<12	2.8	<0.03	<0.06	0.9	<1.2	<0.3	<0.3	<0.5	4.3	2	1.6	<0.9	8.85	<1.8	4250	<1.6	87	<0.04	<2.5	2.8	<0.05
CE491_T11-24	6E	30:1	120 h	-	8.64	2.7	12.5	2.2	13.2	303	<0.2	172	18.6	<12	3.9	<0.03	<0.06	<0.8	<1.2	<0.3	<0.3	<0.5	6.1	5	1.9	<0.9	6.07	<1.8	6800	<1.6	125	<0.04	<2.5	3.5	<0.05
CE491_T11-25	6E	300:1	0.5 h	-	9.22	1.6	2.0	0.9	5.7	122	<0.2	41	<1.1	<12	1.1	<0.03	<0.06	<0.8	<1.2	<0.3	<0.3	9	1.1	17	<0.5	<0.9	<5.9	<1.8	547	<1.6	40	<0.04	<2.5	0.3	<0.05
CE491_T11-26	6E	300:1	3 h	-	9.28	1.7	2.0	1.0	6.3	124	<0.2	68	1.6	<12	1.1	<0.03	<0.06	<0.8	<1.2	<0.3	<0.3	6	1.2	15	<0.5	<0.9	<5.9	<1.8	553	<1.6	43	<0.04	<2.5	0.4	<0.05
CE491_T11-27	6E	300:1	18 h	-	9.24	1.6	2.1	1.0	6.9	93	<0.2	147	<1.1	<12	1.1	<0.03	<0.06	<0.8	<1.2	<0.3	<0.3	4	1.4	11	<0.5	<0.9	<5.9	<1.8	574	<1.6	47	<0.04	<2.5	0.8	<0.05
CE491_T11-28	6E	300:1	120 h	-	8.87	1.7	2.3	1.0	8.6	239	<0.2	285	4.3	<12	1.2	<0.03	<0.06	<0.8	<1.2	<0.3	<0.3	2	1.7	10	<0.5	<0.9	<5.9	<1.8	807	<1.6	56	0.05	<2.5	1.3	<0.05
CE491_T11-29	6E duplicate	300:1	0.5 h	-	9.16	1.7	2.0	0.9	5.8	109	<0.2	40	3.1	<12	1.1	<0.03	<0.06	<0.8	<1.2	<0.3	<0.3	9	1.1	17	<0.5	<0.9	<5.9	<1.8	550	<1.6	41	<0.04	<2.5	0.3	0.06
CE491_T11-30	6E duplicate	300:1	3 h	-	9.28	1.7	2.0	1.0	6.4	134	<0.2	69	1.3	<12	1.1	<0.03	<0.06	<0.8	<1.2	<0.3	0.2	6	1.2	15	<0.5	<0.9	<5.9	<1.8	544	1.7	43	<0.04	<2.5	0.4	<0.05
CE491_T11-31	6E duplicate	300:1	18 h	-	9.27	1.7	2.1	1.0	6.9	101	<0.2	145	<1.1	<12	1.1	<0.03	<0.06	<0.8	<1.2	<0.3	<0.3	4	1.4	12	<0.5	<0.9	<5.9	<1.8	567	<1.6	46	0.06	<2.5	0.7	<0.05
CE491_T11-32	6E duplicate	300:1	120 h	-	8.89	1.7	2.2	1.1	8.6	100	<0.2	288	6.3	<12	1.2	<0.03	<0.06	<0.8	<1.2	<0.3	<0.3	2	1.7	11	<0.5	<0.9	<5.9	<1.8	810	<1.6	56	<0.04	<2.5	1.3	<0.05
CE491_T11-33	6E	1000:1	0.5 h	-	8.58	1.6	1.0	0.8	4.2	67	<0.2	19	<1.1	<12	1.0	<0.03	<0.06	<0.8	<1.2	<0.3	0.4	13	0.5	26	<0.5	<0.9	<5.9	<1.8	282	<1.6	30	0.06	<2.5	0.2	0.13
CE491_T11-34	6E	1000:1	3 h	-	8.94	1.7	1.0	0.9	5.1	91	<0.2	32	<1.1	<12	0.9	<0.03	<0.06	<0.8	<1.2	<0.3	0.3	11	0.6	30	<0.5	<0.9	<5.9	<1.8	273	<1.6	34	0.04	<2.5	0.3	<0.05
CE491_T11-35	6E	1000:1	18 h	-	9.01	1.6	1.0	0.9	6.1	69	<0.2	76	1.1	<12	0.9	<0.03	<0.06	<0.8	<1.2	<0.3	<0.3	8	0.7	31	<0.5	<0.9	<5.9	<1.8	292	<1.6	40	<0.04	<2.5	0.4	<0.05
CE491_T11-36	6E	1000:1	120 h	-	8.56	1.6	1.1	0.9	7.1	152	<0.2	175	<1.1	<12	1.0	<0.03	<0.06	<0.8	<1.2	<0.3	0.3	6	0.9	34	<0.5	<0.9	<5.9	<1.8	346	<1.6	45	0.05	<2.5	0.7	<0.05
CE491_T11-37	6E	3000:1	0.5 h	-	7.55	1.6	0.7	0.8	3.0	408	<0.2	9	<1.1	<12	1.1	<0.03	<0.06	<0.8	<1.2	<0.3	0.5	13	0.3	17	<0.5	<0.9	<5.9	<1.8	204	<1.6	22	<0.04	<2.5	0.2	0.19
CE491_T11-38	6E	3000:1	3 h	-	8.00	1.6	0.7	0.8	3.4	117	<0.2	13	<1.1	<12	1.1	<0.03	<0.06	<0.8	<1.2	<0.3	0.8	13	0.3	22	<0.5	<0.9	<5.9	<1.8	212	<1.6	24	0.06	<2.5	0.4	0.05
CE491_T11-39	6E	3000:1	18 h	-	7.90	1.6	0.7	0.8	3.9	269	<0.2	26	<1.1	<12	1.0	<0.03	<0.06	<0.8	<1.2	<0.3	0.4	11	0.4	29	<0.5	<0.9	<5.9	<1.8	203	<1.6	27	0.07	<2.5	0.2	<0.05
CE491_T11-40	6E	3000:1	120 h	-	7.83	1.6	0.7	0.9	4.0	160	<0.2	42	<1.1	<12	1.0	<0.03	<0.06	<0.8	<1.2	<0.3	0.5	9	0.4	30	<0.5	<0.9	<5.9	<1.8	237	<1.6	29	0.07	<2.5	0.3	0.08
CE491_T11-41	6B	300:1	0.5 h	18	7.89	1.8	1.7	1.2	2.1	83	<0.2	17	<1.1	<12	2.4	<0.03	<0.06	<0.8	<1.2	<0.3	<0.3	12	0.6	11	<0.5	<0.9	<5.9	<1.8	227	<1.6	10	<0.04	<2.5	0.6	<0.05
CE491_T11-42	6B	1000:1	0.5 h	18	7.62	1.6	0.9	1.0	2.1	55	<0.2	9	<1.1	<12	2.5	<0.03	<0.06	<0.8	<1.2	<0.3	0.5	15	0.3	10	<0.5	<0.9	<5.9	<1.8	175	<1.6	13	<0.04	<2.5	0.3	<0.05
CE491_T11-43	6E	300:1	0.5 h	18	9.31	1.7	2.3	1.0	5.8	219	<0.2	103	1.2	<12	1.0	<0.03	<0.06	<0.8	<1.2	<0.3	0.5	7	1.3	10	<0.5	<0.9	<5.9	<1.8	625	<1.6	42	<0.04	<2.5	0.5	<0.05
CE491_T11-44	6E	1000:1	0.5 h	18	8.89	1.6	1.0	0.9	4.8	108	<0.2	52	1.7	<12	0.9	<0.03	<0.06	0.8	<1.2	<0.3	0.3	13	0.6	22	<0.5	<0.9	<5.9	<1.8	281	<1.6	32	0.05	<2.5	0.5	<0.05

Appendix D2. Effect of L/S ratio on substance release from <75 µm composite rock materials (6B-6E results]

QUALITY CONTROL SUMMARY of Test 11: Investigation of Kelly's Plains L/S and kinetics effects of metal release and water quality

	Rock Spoil sample	L/S ratio	Mixing duration	Duration in water	Na	K	Mg	Ca	Ag	Al	As	B	Ba	Be	Cd	Ce	Co	Cr	Cu	Fe	Li	Mn	Mo	Ni	P	Pb	S	Sn	Sr	Ti	Tl	V	Zn
Sample Labels					(mg/L)	(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)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Mean blank					**-0.02**	**-0.03**	**0.02**	**0.00**	**0.4**	**-0.1**	**0.6**	**27.6**	**0.0**	**0.0**	**0.1**	**-0.6**	**0.1**	**0.0**	**0.1**	**-0.3**	**0.0**	**0.0**	**0.1**	**0.0**	**1.4**	**0.2**	**11.5**	**0.5**	**0.0**	**0.0**	**1.7**	**-0.2**	**0.1**
LOD (3 x S.d.)					**0.01**	**0.04**	**0.06**	**0.01**	**0.2**	**0.4**	**1.1**	**12.0**	**0.0**	**0.0**	**0.1**	**0.8**	**1.2**	**0.3**	**0.2**	**0.5**	**0.0**	**0.0**	**0.4**	**0.9**	**5.9**	**1.8**	**11.9**	**1.6**	**0.0**	**0.0**	**2.5**	**0.1**	**0.0**
TM24.4					9.0	1.0	5.2	25	9.2	39	5.7	3.4	17	2.3	4.3	-0.3	6.9	5.6	7.1	17	5.9	8.7	6.2	5.2	3.4	5.9		5.7	115	7.6	4.1	7.5	34
										32.9 ±	5.30 ±		15.0 ±		3.96 ±		6.27 ±	5.00 ±	6.31 ±	16.0 ±	4.95 ±	8.24±		5.03 ±		5.60 ±			113 ±			7.00 ±	
Certified TM24.4									8.92	4.5	0.53		1.0		0.34		0.57	0.59	0.60	2.3	0.42	0.73		0.53		0.52			8			0.58	
% recovery (TM24.4)									**103**	**117**	**108**		**110**		**109**		**111**	**112**	**112**	**108**	**119**	**105**		**103**		**105**			**102**			**107**	
TMDA64.3					9.4	1.1	5.3	24	12	299	165	255	306	166	272	-2	259	298	273	305	162	290	287	265	1	290		282	647	130	147	288	338
									12.6 ±	291 ±	164 ±		287 ±		258 ±		250 ±	283 ±	298 ±	298 ±	143 ±	292 ±		252 ±		280 ±			628 ±			279 ±	320 ±
Certified TM63.4									1.3	23	15		18		21		16	17	21	21	15	17		18		22			34			18	23
% recovery (TMDA63.4)									**96**	**103**	**101**		**107**		**105**		**103**	**105**	**92**	**102**	**113**	**99**		**105**		**104**			**103**			**103**	**106**
CE491_T11-1+spike					-	-	-	-	**99**	**97**	**100**	**97**	**98**	**100**	**99**	**98**	**99**	**98**	**101**	**97**	**102**	**99**	**99**	**98**	**99**	**98**	**93**	**99**	**98**	**99**	**97**	**99**	**100**
CE491_T11-10+spike					**99**	**99**	**99**	**99**	**100**	**99**	**101**	**104**	**100**	**100**	**100**	**100**	**101**	**100**	**101**	**100**	**103**	**100**	**100**	**99**	**100**	**100**	**94**	**101**	**101**	**100**	**99**	**101**	**101**
CE491_T11-20+spike					**97**	**97**	**97**	**97**	**100**	**99**	**101**	**105**	**100**	**101**	**100**	**100**	**102**	**100**	**100**	**100**	**103**	**101**	**101**	**99**	**100**	**100**	**97**	**101**	**100**	**100**	**100**	**101**	**101**
CE491_T11-30+spike					**97**	**97**	**97**	**97**	**99**	**99**	**101**	**107**	**99**	**101**	**100**	**99**	**100**	**100**	**100**	**99**	**104**	**100**	**101**	**99**	**100**	**100**	**97**	**100**	**99**	**100**	**100**	**101**	**100**
CE491_T11-40+spike					**99**	**99**	**99**	**99**	**101**	**99**	**101**	**107**	**100**	**102**	**100**	**100**	**101**	**100**	**102**	**99**	**103**	**102**	**101**	**99**	**101**	**99**	**99**	**101**	**100**	**100**	**99**	**100**	**100**

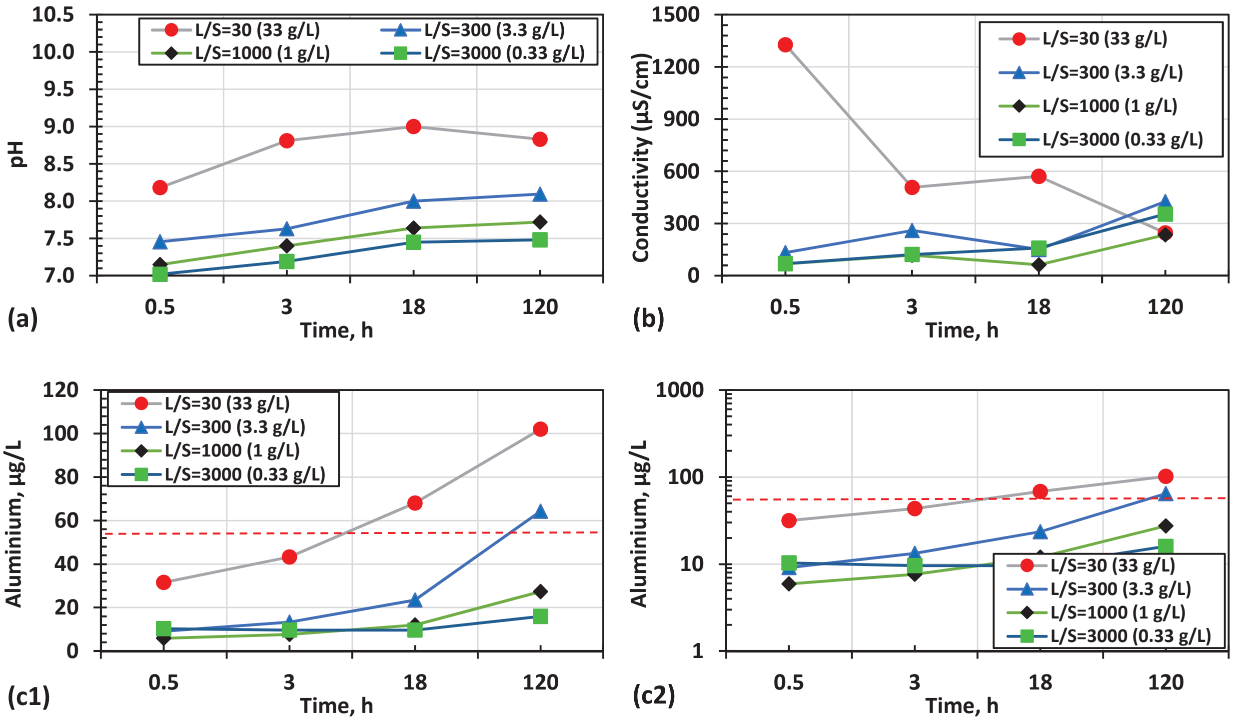

Figure D2.1 The pH, conductivity and dissolved Al concentration of composite 6B elutriate tests after times of 0.5, 3, 18 and 120 h for liquid to solid ratios (L/S) of 30, 300, 1000 and 3000 (c2 = log scale)

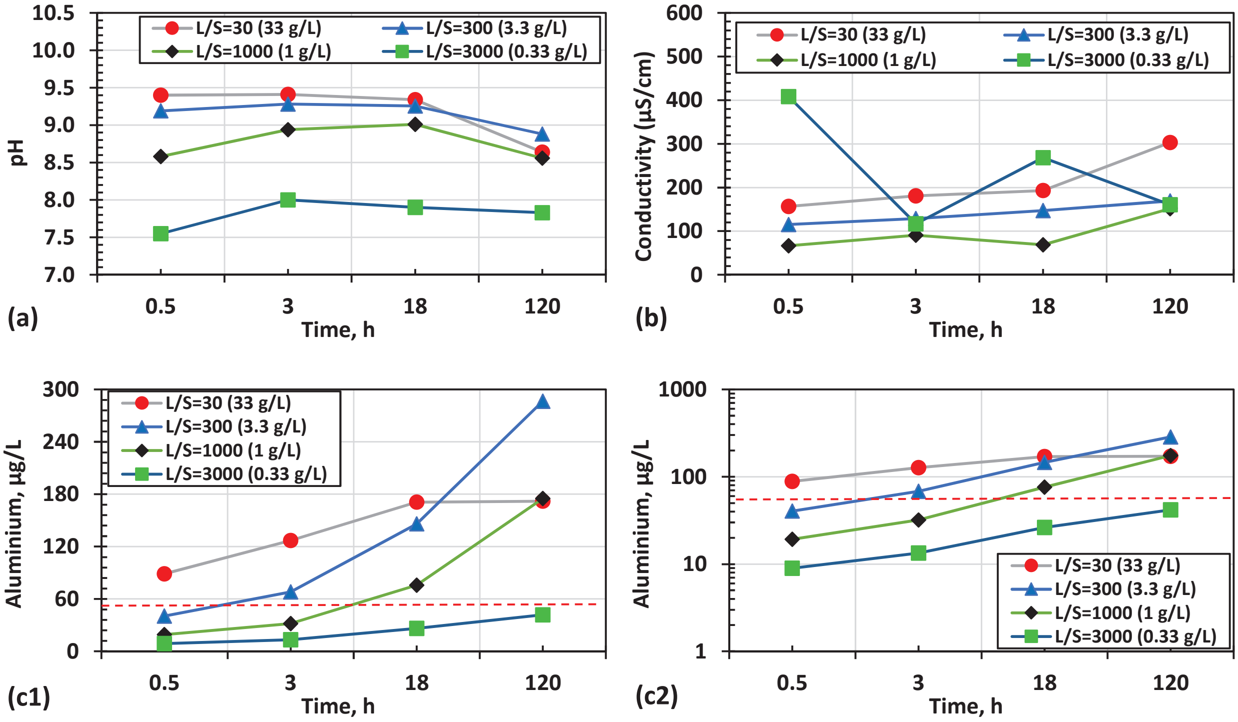

Figure D2.2 The pH, conductivity and dissolved Al concentration of composite 6E elutriate tests after times of 0.5, 3, 18 and 120 h for liquid to solid ratios (L/S) of 30, 300, 1000 and 3000 (c2 = log scale)

Figures for major cations from Memo 11 and 6B/6E tests

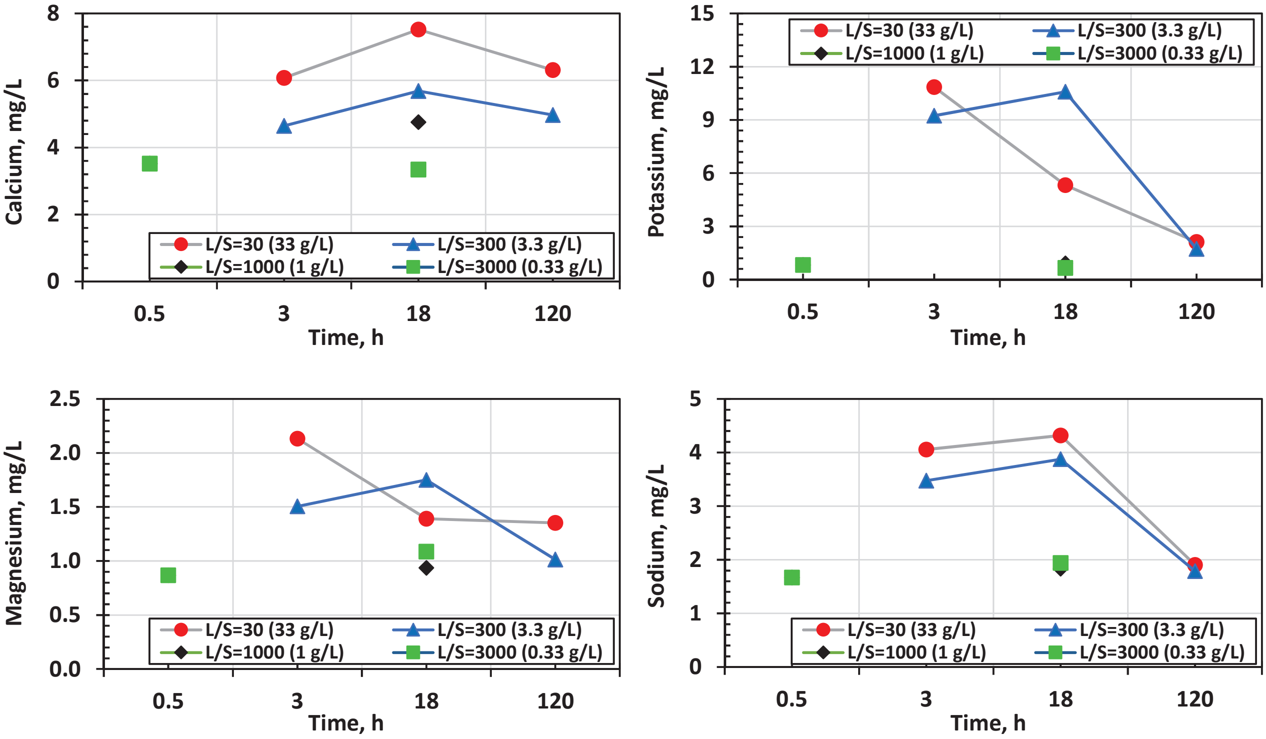

Figure D2.3 Dissolved major ions (Na, K, Mg, Ca) for composite 1B elutriate tests after times of 0.5, 3, 18 and 120 h for liquid to solid ratios (L/S) of 30, 300, 1000 and 3000

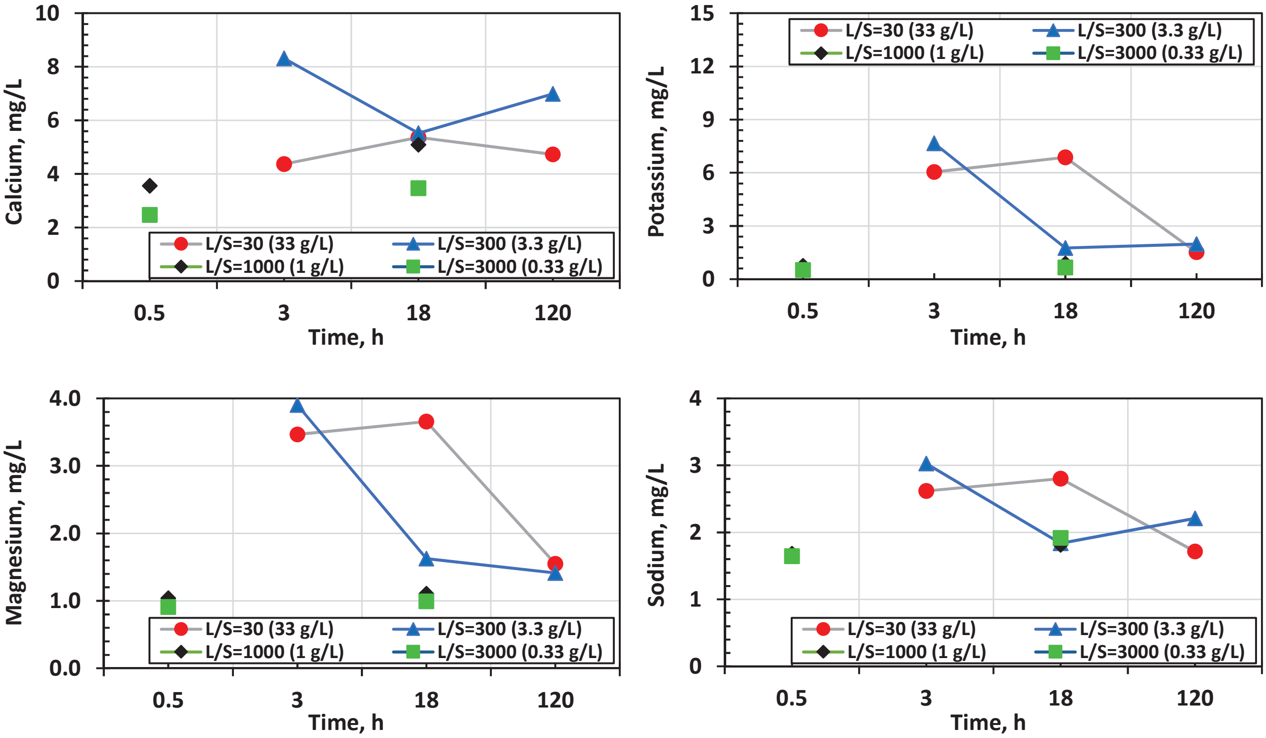

Figure D2.4 Dissolved major ions (Na, K, Mg, Ca) for composite 2B elutriate tests after times of 0.5, 3, 18 and 120 h for liquid to solid ratios (L/S) of 30, 300, 1000 and 3000

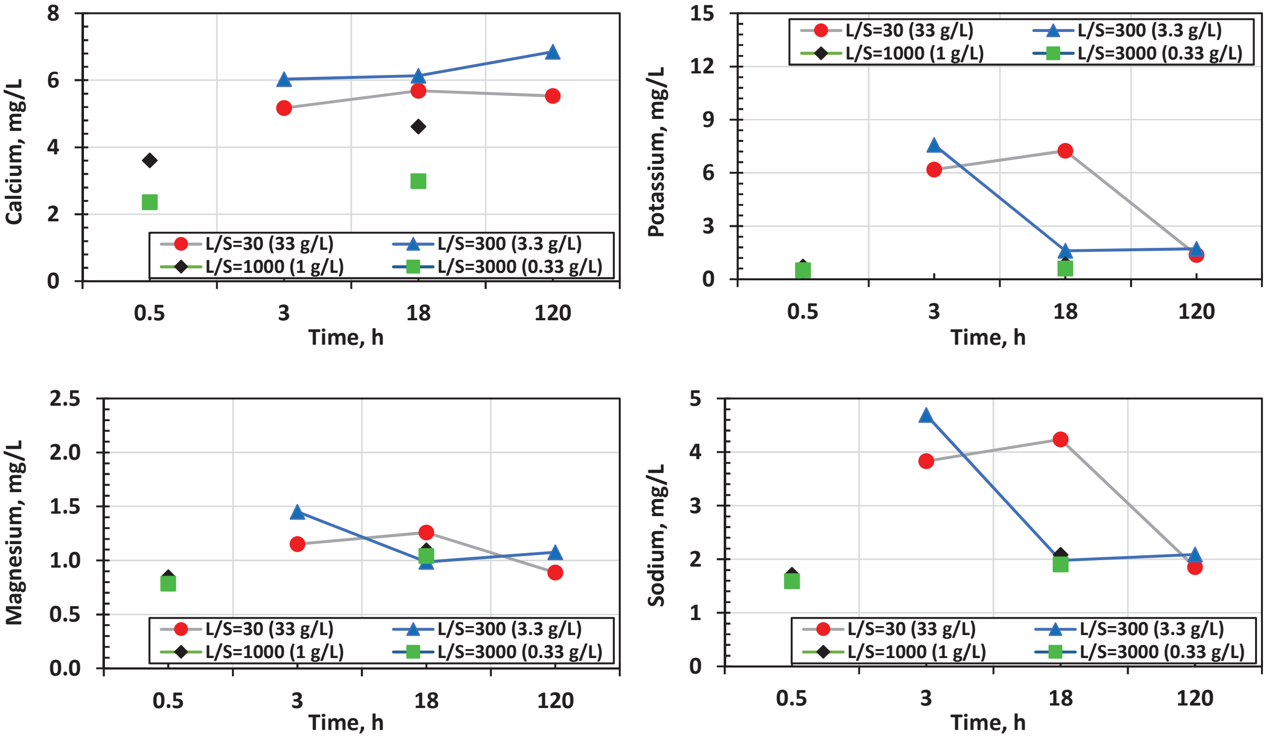

Figure D2.5 Dissolved major ions (Na, K, Mg, Ca) for of composite 5B elutriate tests after times of 0.5, 3, 18 and 120 h for liquid to solid ratios (L/S) of 30, 300, 1000 and 3000

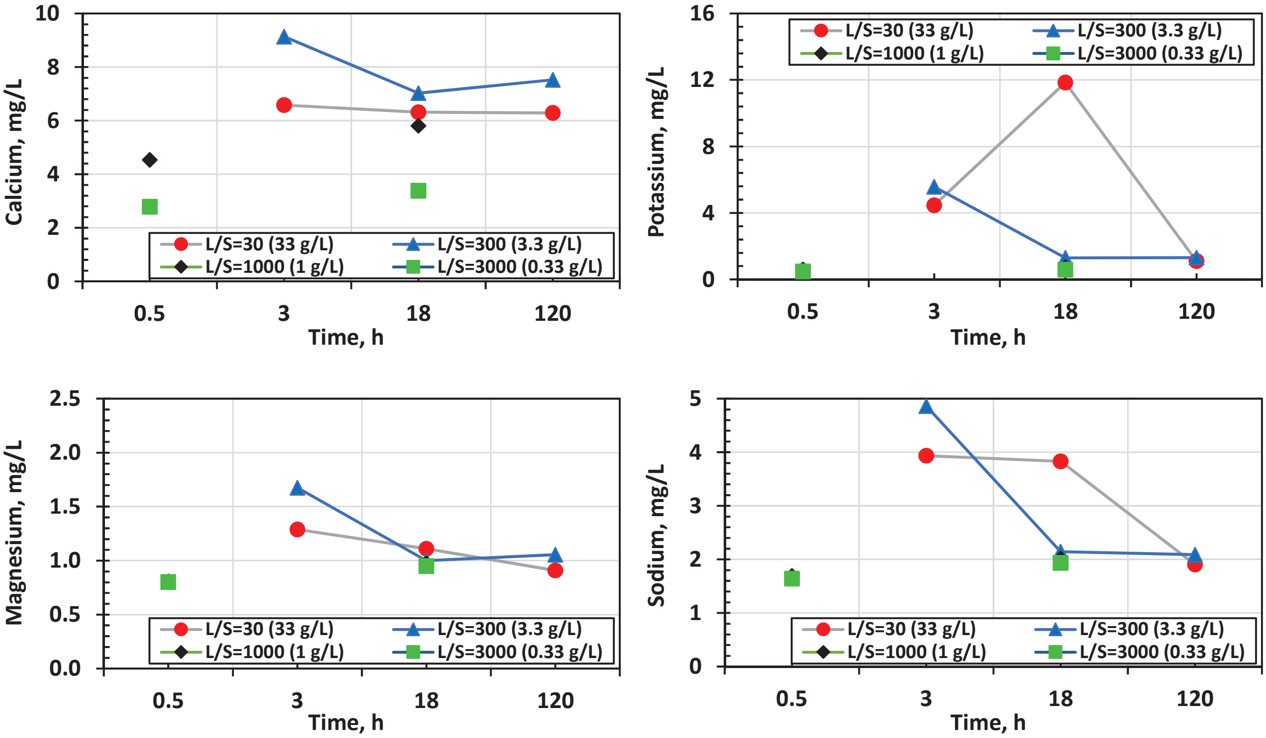

Figure D2.6 Dissolved major ions (Na, K, Mg, Ca) for composite 5E elutriate tests after times of 0.5, 3, 18 and 120 h for liquid to solid ratios (L/S) of 30, 300, 1000 and 3000

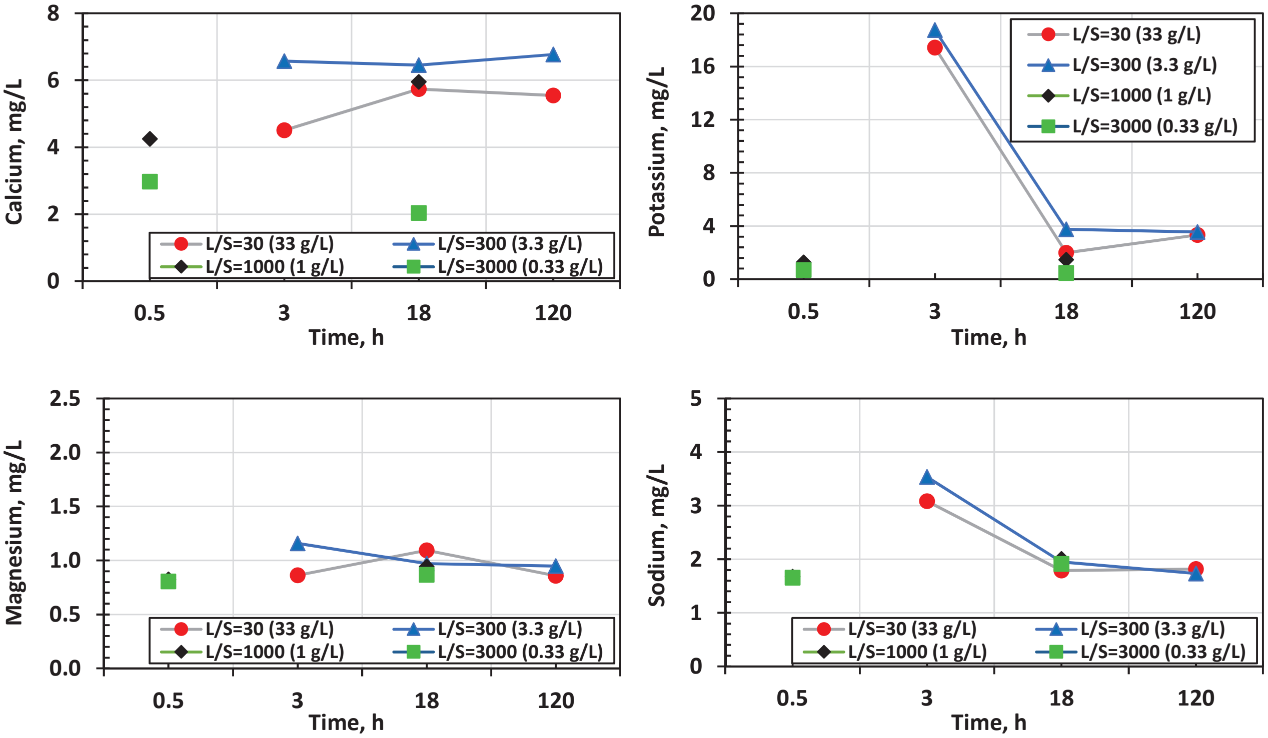

Figure D2.7 Dissolved major ions (Na, K, Mg, Ca) for composite 7E elutriate tests after times of 0.5, 3, 18 and 120 h for liquid to solid ratios (L/S) of 30, 300, 1000 and 3000

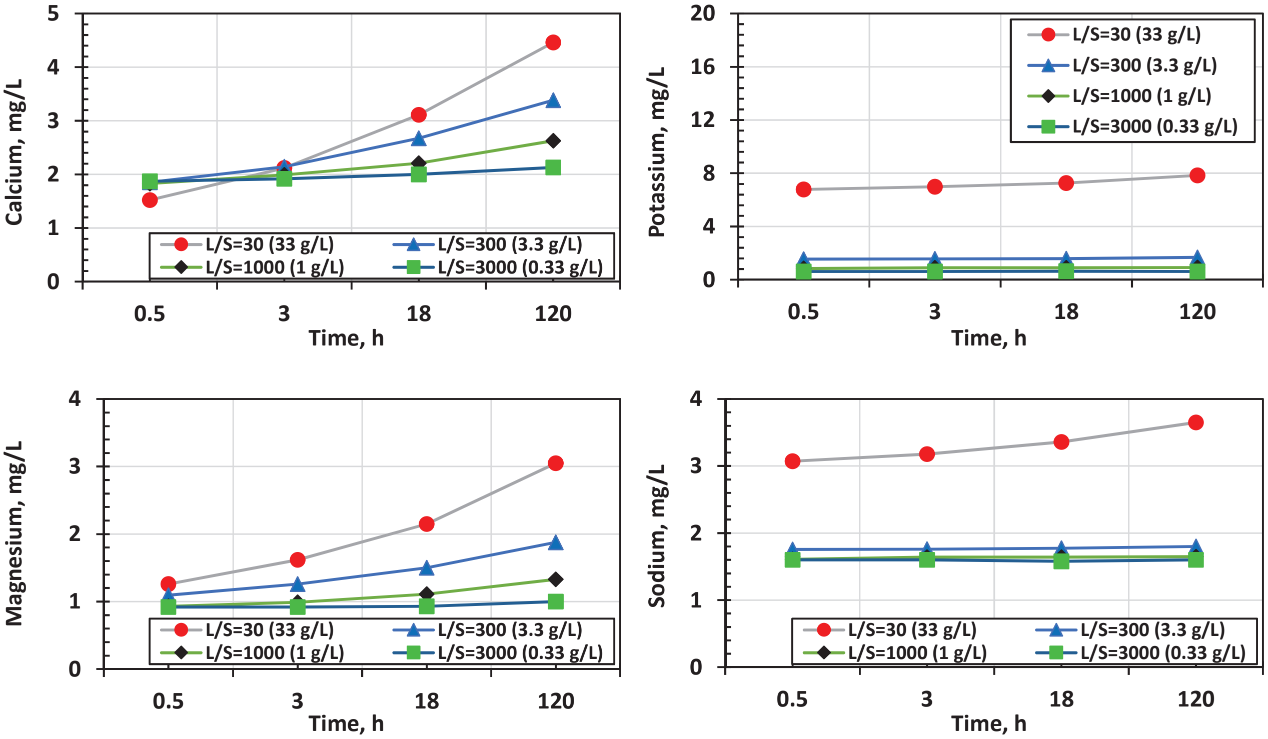

Figure D2.8 Dissolved major ions (Na, K, Mg, Ca) for composite 6B elutriate tests after times of 0.5, 3, 18 and 120 h for liquid to solid ratios (L/S) of 30, 300, 1000 and 3000

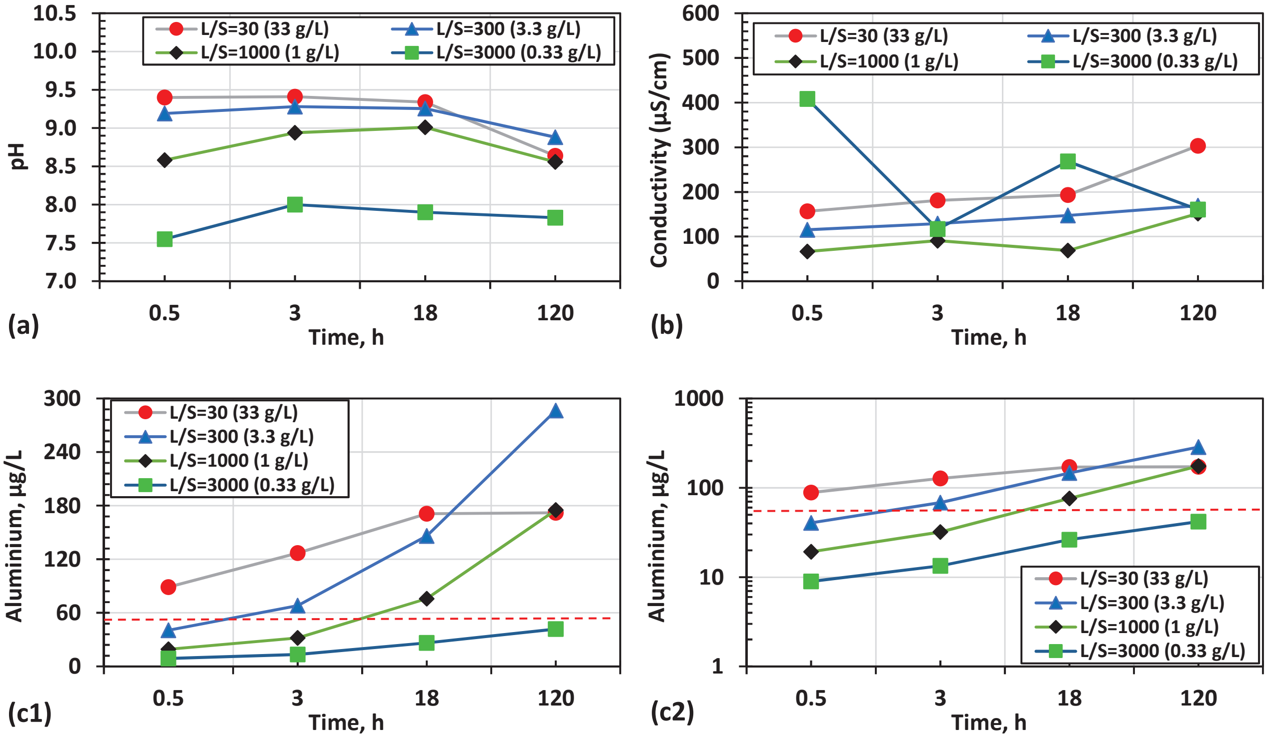

Figure D2.9 Dissolved major ions (Na, K, Mg, Ca) for composite 6E elutriate tests after times of 0.5, 3, 18 and 120 h for liquid to solid ratios (L/S) of 30, 300, 1000 and 3000 (c2 = log scale)

Appendix D3. Effect of mixing duration on substance release from <75 µm composite rock materials

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Note/Memo	CSIRO P4 Project Investigations
To:	Ali Watters (HKA)
From:	Brad Angel, Lucas Heights, NSW
Date:	18 October 2018
Copy:	Ryan Fraser, Stuart Simpson and Ellen Porter (SHL)
Our reference:	CSIRO P4 – Memo 5
Classification:	Internal use only
Subject:	Pollutant release from excavated rock composites – Effect of liquid to solid ratio and duration in reservoir water

Chemical formulas and acronyms

Al	Aluminium	dAl	Dissolved aluminium		
SEC	conductivity	DGV	Default guideline value	L/S	Liquid/solid ratio

Background - Introduction

The CSIRO was engaged by Haskoning Australia Pty Ltd (RHDHV) to undertake an investigation of the pollutant release from excavated rock disposal into Talbingo and Tantangara reservoirs.

The initial elutriate tests (Memo 4) investigating the release of pollutants from composite excavated rock samples (L/S = 10, 48 h) observed some significant changes in water quality with respect to pH, conductivity (SEC) the dissolved aluminium concentrations:

- pH increased from 7.0-7.1 to 8.9-9.8 range
- SEC increased from 29 µS/cm to 110-200 µS/cm range, and
- dissolved Al (<0.45 µm filterable) increased from <4 µg/L (ppb) to 200-800 µg/L range.

The conditions of those elutriate tests, L/S = 10, 48 h, were designed to assess a severe / worst case scenario for impacts to the receiving water in which large amounts of fine excavated rock materials may remain suspended in the waters in the main disposal area.

This technical memo describes results of elutriate tests performed on a single fine excavated rock composite material, 4E, in which the kinetics of the changes in pH, conductivity the dissolved aluminium concentrations were investigated over a range of Liquid/solid ratios (Figure 1):

- L/S = 100, 1000, 10000, and Reservoir water only (Talbingo)
    - [being 10 g/L, 1.0 g/L, 0.1 g/L and 0 g/L respectively]
- Measurements at times of 0.5, 2, 6 and 24 h
- Solids mixed in composite Talbingo control water for 30 s then allowed to stand for durations tested

Kinetics of pH, conductivity and dissolved aluminium

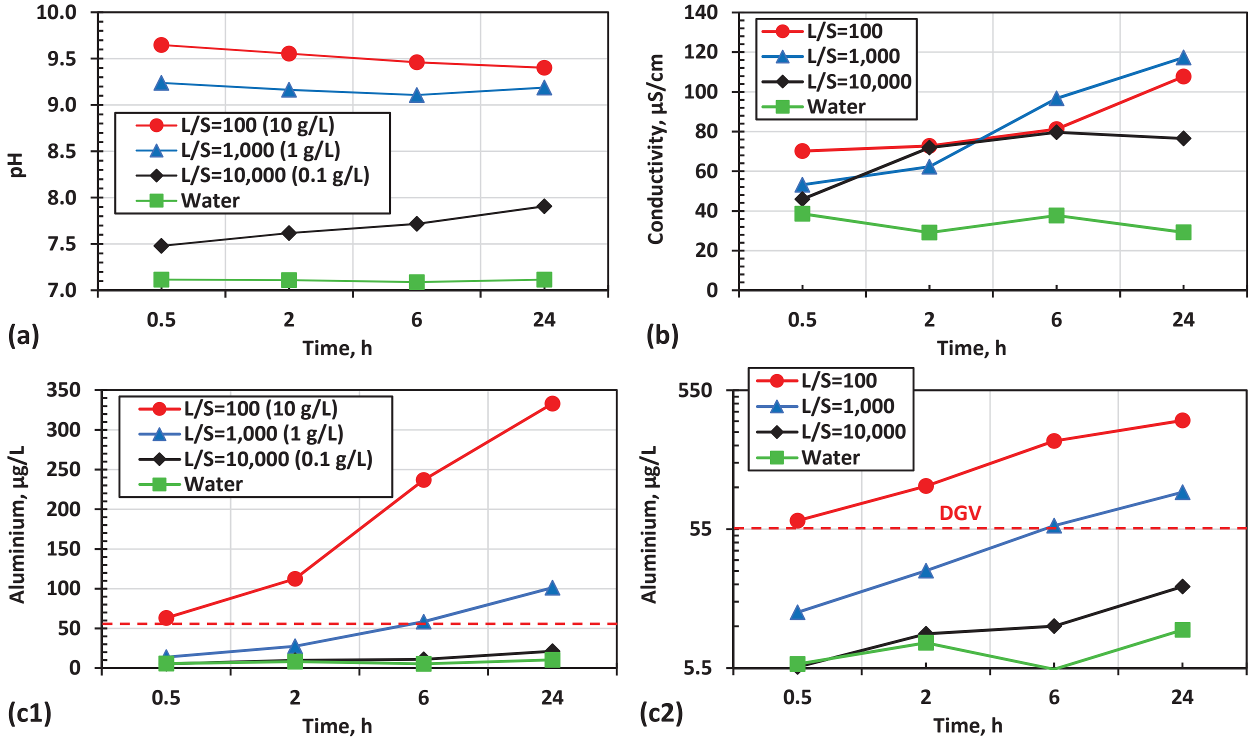

Figure 1. Water (Talbingo) (a) pH, (b) conductivity and (c1, c2) dissolved aluminium concentrations for elutriates of fine excavated rock composite material 4E. DVG represents the default guideline value (95% species protection for freshwater) of 55 µg Al/L, where the 99% species protection concentration is 27 µg/L.

Summary

The initial contact of the solids with the water resulted in a rapid increase in pH and conductivity.

Higher solids concentrations (lower L/S) resulted in greater initial pH, conductivity and dissolved aluminium concentrations.

Risks of adverse effect to aquatic organisms are predicted to occur due to:

- high pH (within 30 min) for Talbingo water containing ≥1 g 4E-fine_solids/L (L/S=1,000), pH >8.5 water likely occurring within 0.2-1 g/L 4E-fine_solids concentration range.
- high dissolved aluminium concentrations (dAl) after 6 h for Talbingo water containing 1 g 4E-fine_solids/L, or after 30 min for Talbingo water containing 10 g 4E-fine_solids/L (L/S=100)

The kinetics of the changes in pH, conductivity and the dissolved aluminium concentrations indicate increased dissolution of rock solids occur with time. For aluminium the increase with time is consistent with the high pH acting to increase dissolution through formation of the highly soluble aluminate ion, $Al(OH)_4^-$.

The rock composite 4E was selected owing to the high level of aluminium release observed in the initial elutriate test (Memo 4).

In tests now underway a greater range of rock composites are being investigated using a similar test design (1B, 1B, 5B, 5E, 7E), and across a wider range of L/S ratios (30, 3000, 1000, 3000). These tests are expected to provide a more representative assessment of potential changes in pH, conductivity and dissolved aluminium, along with other parameters.

Appendix D3. Effect of mixing duration on substance release from <75 µm composite rock materials

Memo 5, 4E data

Tests with rock composite 4E, measurements of water quality and substance release were made at times of 0.5, 2, 6 and 24 h for L/S = 100, 1000, and 10000 [being 10, 1 and 0.1 g/L, respectively].

				pH	Conductivity	Ag	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sn	Sr	Th	U	V	Zn
Sample ID	**Sample Description**	**Liquid:Solid**	**Time (h)**		µS/cm	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
T2-25	CE491-27 (4E) rep-1	100:1	0.5	9.7	81	0.06	91	0.83	1.1	6.8	<0.1	<0.1	0.21	0.5	16	2.2	0.9	4.7	0.22	1.8	0.6	0.24	0.04	0.05	<0.1	18	0.02	0.025	0.7	4
T2-26	CE491-27 (4E) rep-2			9.6	87	0.04	81	0.52	1.0	6.7	<0.1	<0.1	0.16	0.5	17	2.2	0.8	5.3	0.17	1.8	0.6	0.23	0.02	0.07	<0.1	16	<0.01	0.027	0.7	5
T2-27	CE491-27 (4E) rep-3			9.6	310	0.04	85	0.63	1.2	6.7	<0.1	<0.1	0.28	0.4	15	2.2	0.9	4.8	0.21	1.8	0.8	0.24	0.02	0.06	<0.1	17	<0.01	0.025	0.7	4
	CE491-27 (4E) avg			**9.6**	**159**	**0.05**	**86**	**0.66**	**1.1**	**6.7**	**<0.1**	**<0.1**	**0.22**	**0.4**	**16**	**2.2**	**0.9**	**4.9**	**0.20**	**1.8**	**0.7**	**0.24**	**0.03**	**0.06**	**<0.1**	**17**	**0.02**	**0.025**	**0.7**	**4**
T2-37	CE491-27 (4E) rep-1	100:1	2	9.6	94	0.05	136	0.98	1.1	6.8	<0.1	<0.1	0.36	0.5	16	2.3	0.9	3.4	0.21	2.0	0.8	0.23	0.06	0.05	<0.1	15	0.02	0.030	1.1	4
T2-38	CE491-27 (4E) rep-2			9.6	94	0.04	134	0.86	1.3	6.8	<0.1	<0.1	0.43	0.5	17	2.3	0.9	3.5	0.26	1.8	0.6	0.25	0.08	0.08	<0.1	17	0.02	0.027	1.0	5
T2-39	CE491-27 (4E) rep-3			9.5	393	0.04	131	0.84	1.1	7.0	<0.1	<0.1	0.30	0.4	16	2.4	0.9	3.5	0.21	1.8	0.8	0.23	0.06	0.05	<0.1	17	<0.01	0.035	1.1	5
	CE491-27 (4E) avg			**9.5**	**194**	**0.04**	**134**	**0.89**	**1.2**	**6.9**	**<0.1**	**<0.1**	**0.36**	**0.5**	**16**	**2.3**	**0.9**	**3.5**	**0.23**	**1.9**	**0.8**	**0.24**	**0.07**	**0.06**	**<0.1**	**16**	**0.02**	**0.030**	**1.1**	**5**
T2-49	CE491-27 (4E) rep-1	100:1	6	9.5	108	0.05	247	1.8	1.3	7.1	<0.1	<0.1	0.57	0.6	26	2.5	0.9	3.0	0.27	1.9	0.6	0.25	0.13	0.07	<0.1	17	<0.01	0.034	1.9	4
T2-50	CE491-27 (4E) rep-2			9.5	106	0.04	271	1.8	1.2	7.4	<0.1	<0.1	0.96	0.4	25	2.6	1.0	2.8	0.18	1.9	0.6	0.22	0.15	0.05	<0.1	20	<0.01	0.028	1.9	3
T2-51	CE491-27 (4E) rep-3			9.4	406	0.04	242	1.5	1.2	7.1	<0.1	<0.1	0.61	0.9	22	2.5	0.9	2.8	0.26	1.9	0.7	0.24	0.14	0.05	<0.1	17	<0.01	0.030	1.8	3
	CE491-27 (4E) avg			**9.4**	**206**	**0.04**	**253**	**1.7**	**1.2**	**7.2**	**<0.1**	**<0.1**	**0.72**	**0.6**	**24**	**2.5**	**0.9**	**2.8**	**0.24**	**1.9**	**0.6**	**0.23**	**0.14**	**0.06**	**<0.1**	**18**	**<0.01**	**0.031**	**1.9**	**3**
T2-61	CE491-27 (4E) rep-1	100:1	24	9.4	149	0.04	359	2.2	1.3	7.5	<0.1	<0.1	1.1	0.5	26	2.8	0.9	2.6	0.27	2.0	0.7	0.27	0.21	0.09	<0.1	17	<0.01	0.055	2.9	<1
T2-62	CE491-27 (4E) rep-2			9.4	123	0.04	352	3.5	1.2	8.0	<0.1	<0.1	0.93	0.4	22	2.8	1.0	3.3	0.21	2.2	1.1	0.29	0.19	0.10	<0.1	18	<0.01	0.059	2.6	2
T2-63	CE491-27 (4E) rep-3			9.3	440	0.03	345	2.9	1.1	7.6	<0.1	<0.1	0.94	0.4	28	2.7	1.0	2.7	0.28	2.0	1.0	0.27	0.19	0.08	<0.1	18	<0.01	0.055	2.5	<1
	CE491-27 (4E) avg			**9.4**	**237**	**0.04**	**352**	**2.9**	**1.2**	**7.7**	**<0.1**	**<0.1**	**1.0**	**0.5**	**25**	**2.8**	**1.0**	**2.9**	**0.25**	**2.1**	**0.9**	**0.28**	**0.20**	**0.09**	**<0.1**	**17**	**<0.01**	**0.056**	**2.7**	**2**
T2-28	CE491-27 (4E) rep-1	1000:1	0.5	9.2	57	0.04	35	0.29	1.8	5.1	<0.1	<0.1	0.29	0.8	20	~~5.9~~	0.8	28	<0.04	1.7	0.6	0.28	<0.02	<0.03	<0.1	19	<0.01	0.023	0.2	3
T2-29	CE491-27 (4E) rep-2			9.3	82	0.04	42	0.23	0.95	5.2	<0.1	<0.1	0.25	0.6	22	0.6	0.8	26	0.09	1.8	0.7	0.34	<0.02	0.04	<0.1	18	<0.01	0.025	0.2	4
T2-30	CE491-27 (4E) rep-3			9.3	62	0.04	32	0.18	0.91	5.0	<0.1	<0.1	0.47	0.7	21	0.6	0.8	26	0.05	1.6	0.5	0.27	<0.02	<0.03	<0.1	18	<0.01	0.019	0.2	4
	CE491-27 (4E) avg			**9.2**	**67**	**0.04**	**36**	**0.23**	**1.2**	**5.1**	**<0.1**	**<0.1**	**0.34**	**0.7**	**21**	**0.6**	**0.8**	**27**	**0.07**	**1.7**	**0.6**	**0.30**	**<0.02**	**<0.03**	**<0.1**	**18**	**<0.01**	**0.022**	**0.2**	**4**
T2-40	CE491-27 (4E) rep-1	1000:1	2	9.2	65	0.04	49	0.19	1.9	5.4	<0.1	<0.1	0.42	0.7	19	~~5.9~~	0.7	26	0.05	1.7	0.7	0.29	0.02	<0.03	<0.1	20	0.01	0.031	0.2	3
T2-41	CE491-27 (4E) rep-2			9.1	91	0.04	57	0.35	1.4	5.3	<0.1	<0.1	0.50	0.7	23	1.5	0.7	24	0.06	1.7	0.9	0.33	0.02	<0.03	<0.1	19	<0.01	0.026	0.3	7
T2-42	CE491-27 (4E) rep-3			9.2	96	0.03	45	0.28	0.99	5.2	<0.1	<0.1	0.47	0.6	20	0.7	0.7	25	0.07	1.6	0.6	0.27	<0.02	<0.03	<0.1	18	<0.01	0.031	0.2	3
	CE491-27 (4E) avg			**9.2**	**84**	**0.04**	**50**	**0.27**	**1.4**	**5.3**	**<0.1**	**<0.1**	**0.46**	**0.7**	**21**	**1.1**	**0.7**	**25**	**0.06**	**1.7**	**0.7**	**0.30**	**0.02**	**<0.03**	**<0.1**	**19**	**<0.01**	**0.029**	**0.2**	**4**
T2-52	CE491-27 (4E) rep-1	1000:1	6	9.0	74	0.04	74	0.43	1.8	5.7	<0.1	<0.1	0.71	0.8	21	~~5.9~~	0.8	25	0.08	1.8	0.9	0.27	0.02	<0.03	<0.1	20	<0.01	0.025	0.4	3
T2-53	CE491-27 (4E) rep-2			9.1	112	0.04	99	0.34	1.3	5.6	<0.1	<0.1	0.80	0.8	22	1.2	0.8	24	<0.04	1.7	0.9	0.30	0.04	<0.03	<0.1	21	<0.01	0.028	0.3	4
T2-54	CE491-27 (4E) rep-3			9.2	180	0.03	70	0.20	1.1	5.6	<0.1	<0.1	0.70	0.8	26	0.7	0.8	25	<0.04	1.6	0.5	0.91	<0.02	<0.03	<0.1	20	<0.01	0.029	0.4	4
	CE491-27 (4E) avg			**9.1**	**122**	**0.04**	**81**	**0.33**	**1.4**	**5.7**	**<0.1**	**<0.1**	**0.74**	**0.8**	**23**	**1.0**	**0.8**	**24**	**0.08**	**1.7**	**0.8**	**0.49**	**0.03**	**<0.03**	**<0.1**	**20**	**<0.01**	**0.027**	**0.4**	**4**
T2-64	CE491-27 (4E) rep-1	1000:1	24	9.2	101	0.06	123	0.55	1.9	7.1	<0.1	<0.1	1.1	0.7	20	~~6.3~~	0.8	29	0.09	1.6	1.0	0.34	0.07	0.04	<0.1	22	0.03	0.041	0.6	1
T2-65	CE491-27 (4E) rep-2			9.1	148	0.05	130	0.84	1.1	6.6	<0.1	<0.1	1.1	1.3	20	1.3	0.8	27	0.05	1.8	0.9	0.38	0.06	0.05	<0.1	20	0.03	0.037	0.6	6
T2-66	CE491-27 (4E) rep-3			9.3	189	0.04	119	0.87	1.2	6.7	<0.1	<0.1	1.3	0.8	27	0.9	0.8	27	0.05	1.6	2.3	0.37	0.06	<0.03	<0.1	21	0.02	0.038	0.6	5
	CE491-27 (4E) avg			**9.2**	**146**	**0.05**	**124**	**0.75**	**1.4**	**6.8**	**<0.1**	**<0.1**	**1.2**	**0.9**	**22**	**1.1**	**0.8**	**27**	**0.06**	**1.7**	**1.4**	**0.36**	**0.06**	**0.04**	**<0.1**	**21**	**0.0**	**0.038**	**0.6**	**4**
T2-31	CE491-27 (4E) rep-1	10,000:1	0.5	7.4	57	0.04	29	0.17	3.3	2.5	<0.1	<0.1	1.4	0.8	22	0.4	0.7	11	0.06	1.7	0.5	0.28	<0.02	<0.03	<0.1	16	<0.01	0.018	0.1	4
T2-32	CE491-27 (4E) rep-2			7.5	56	0.04	28	0.24	2.9	2.5	<0.1	<0.1	0.47	0.7	20	0.4	0.8	10	<0.04	1.5	0.6	0.28	<0.02	<0.03	<0.1	17	<0.01	0.018	0.2	4
T2-33	CE491-27 (4E) rep-3			7.5	44	0.04	27	0.35	2.6	2.5	<0.1	<0.1	0.35	0.7	20	0.4	0.8	11	0.04	1.8	1.1	0.23	<0.02	<0.03	<0.1	15	<0.01	0.018	0.1	4
	CE491-27 (4E) avg			**7.5**	**52**	**0.04**	**28**	**0.25**	**2.9**	**2.5**	**<0.1**	**<0.1**	**0.73**	**0.7**	**21**	**0.4**	**0.8**	**11**	**0.05**	**1.7**	**0.7**	**0.27**	**<0.02**	**<0.03**	**<0.1**	**16**	**<0.01**	**0.018**	**0.1**	**4**
T2-43	CE491-27 (4E) rep-1	10,000:1	2	7.7	61	0.04	38	0.31	2.9	2.7	<0.1	<0.1	0.36	0.8	19	0.4	0.7	13	<0.04	1.6	1.0	0.26	<0.02	<0.03	<0.1	17	<0.01	0.018	0.1	14
T2-44	CE491-27 (4E) rep-2			7.7	45	0.05	31	0.12	2.6	2.7	<0.1	<0.1	0.41	0.9	20	0.4	0.7	12	0.07	1.8	1.0	0.28	0.02	<0.03	<0.1	16	0.01	0.018	0.1	4
T2-45	CE491-27 (4E) rep-3			7.4	45	0.04	28	0.23	2.7	2.8	<0.1	<0.1	0.49	0.8	20	0.4	0.8	13	0.05	1.7	0.6	0.24	0.03	0.05	0.1	16	0.04	0.016	0.1	6
	CE491-27 (4E) avg			**7.6**	**51**	**0.04**	**32**	**0.22**	**2.7**	**2.7**	**<0.1**	**<0.1**	**0.42**	**0.8**	**20**	**0.4**	**0.7**	**13**	**0.06**	**1.7**	**0.9**	**0.26**	**0.03**	**0.05**	**<0.1**	**17**	**0.03**	**0.017**	**0.1**	**8**
T2-55	CE491-27 (4E) rep-1	10,000:1	6	7.8	52	0.04	31	0.15	2.3	2.9	<0.1	<0.1	0.79	0.6	20	0.4	0.8	15	0.05	1.5	0.5	0.22	<0.02	<0.03	<0.1	17	0.02	0.021	0.2	3
T2-56	CE491-27 (4E) rep-2			7.8	73	0.05	35	0.22	2.8	2.8	<0.1	<0.1	0.78	0.6	22	0.4	0.8	14	0.06	1.5	1.1	0.27	<0.02	<0.03	<0.1	16	0.03	0.019	0.2	4
T2-57	CE491-27 (4E) rep-3			7.6	65	0.04	34	0.22	2.5	3.0	<0.1	<0.1	0.74	0.6	23	0.4	0.8	16	<0.04	1.6	0.7	0.22	<0.02	<0.03	<0.1	18	0.02	0.019	0.1	4
	CE491-27 (4E) avg			**7.7**	**63**	**0.04**	**34**	**0.20**	**2.5**	**2.9**	**<0.1**	**<0.1**	**0.77**	**0.6**	**22**	**0.4**	**0.8**	**15**	**0.05**	**1.6**	**0.8**	**0.24**	**<0.02**	**<0.03**	**<0.1**	**17**	**0.02**	**0.019**	**0.2**	**4**
T2-67	CE491-27 (4E) rep-1	10,000:1	24	8.0	74	0.04	50	0.27	2.2	3.3	<0.1	<0.1	1.3	0.6	20	0.4	0.8	19	<0.04	1.8	2.0	0.29	0.02	<0.03	<0.1	17	0.01	0.025	0.2	2
T2-68	CE491-27 (4E) rep-2			7.9	43	0.05	42	0.26	2.2	3.2	<0.1	<0.1	1.3	0.6	23	0.4	0.8	16	0.13	1.6	0.8	0.30	<0.02	<0.03	<0.1	16	0.03	0.021	0.1	2
T2-69	CE491-27 (4E) rep-3			7.9	55	0.04	39	0.22	2.0	3.5	<0.1	<0.1	1.6	0.6	21	0.5	0.9	20	<0.04	1.6	1.2	0.31	<0.02	<0.03	<0.1	18	0.01	0.017	0.2	3
	CE491-27 (4E) avg			**7.9**	**58**	**0.05**	**44**	**0.25**	**2.2**	**3.4**	**<0.1**	**<0.1**	**1.4**	**0.6**	**21**	**0.5**	**0.8**	**18**	**0.13**	**1.7**	**1.3**	**0.30**	**<0.02**	**<0.03**	**<0.1**	**17**	**0.02**	**0.021**	**0.2**	**2**

Appendix D3. Effect of mixing duration on substance release from <75 µm composite rock materials

Memo 5, 4E data

Tests with rock composite 4E, measurements of water quality and substance release were made at times of 0.5, 2, 6 and 24 h for L/S = 100, 1000, and 10000 [being 10, 1 and 0.1 g/L, respectively].

				pH	Conductivity	Ag	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sn	Sr	Th	U	V	Zn
Sample ID	**Sample Description**	**Liquid:Solid**	**Time (h)**		**µS/cm**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**mg/L**	**µg/L**	**µg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
T2-34	Talbingo Composite rep-1	---	0.5	7.1	46	0.04	32	0.09	4.9	1.7	<0.1	<0.1	0.26	0.9	21	0.4	0.8	0.5	<0.04	1.8	0.6	0.27	<0.02	<0.03	<0.1	12	<0.01	0.014	0.15	19
T2-35	Talbingo Composite rep-2			7.1	97	0.04	27	0.24	4.3	1.7	<0.1	<0.1	0.37	0.8	20	0.4	0.7	<0.3	0.09	1.5	0.8	0.26	0.06	0.03	0.1	17	0.04	0.019	0.13	9
T2-36	Talbingo Composite rep-3			7.1	36	0.04	27	0.17	4.3	1.7	<0.1	<0.1	0.38	0.7	19	0.4	0.7	<0.3	0.04	1.8	0.6	0.24	0.04	<0.03	<0.1	15	0.02	0.022	0.16	4
	Talbingo Composite avg			**7.1**	**60**	**0.04**	**28**	**0.2**	**4.5**	**1.7**	**<0.1**	**<0.1**	**0.34**	**0.8**	**20**	**0.4**	**0.7**	**0.5**	**0.07**	**1.7**	**0.7**	**0.26**	**0.05**	**0.03**	**<0.1**	**15**	**0.03**	**0.018**	**0.15**	**11**
T2-46	Talbingo Composite rep-1	---	2	7.1	51	0.04	25	0.21	4.6	1.6	<0.1	<0.1	0.60	0.6	18	0.4	0.7	<0.3	<0.04	1.7	0.7	0.21	0.02	0.04	<0.1	16	0.02	0.017	0.13	4
T2-47	Talbingo Composite rep-2			7.1	140	0.04	33	0.18	4.9	1.6	<0.1	<0.1	0.57	0.9	19	0.4	0.8	0.3	0.04	1.7	0.7	0.30	<0.02	<0.03	<0.1	15	0.02	0.016	0.18	6
T2-48	Talbingo Composite rep-3			7.1	89	0.04	34	0.04	4.4	1.7	<0.1	<0.1	0.60	0.8	21	0.4	0.8	0.4	<0.04	1.8	0.7	0.26	0.02	<0.03	<0.1	16	0.02	0.019	0.13	6
	Talbingo Composite avg			**7.1**	**94**	**0.04**	**31**	**0.1**	**4.6**	**1.7**	**<0.1**	**<0.1**	**0.59**	**0.8**	**20**	**0.4**	**0.8**	**0.3**	**<0.04**	**1.7**	**0.7**	**0.26**	**0.02**	**0.04**	**<0.1**	**15**	**0.02**	**0.018**	**0.15**	**5**
T2-58	Talbingo Composite rep-1	---	6	7.1	57	0.04	27	0.21	4.0	1.7	<0.1	<0.1	0.99	0.6	19	0.4	0.8	<0.3	<0.04	1.9	0.5	0.22	<0.02	<0.03	<0.1	16	0.02	0.014	0.10	4
T2-59	Talbingo Composite rep-2			7.1	144	0.03	27	0.13	4.1	1.7	<0.1	<0.1	0.84	0.6	17	0.4	0.8	<0.3	<0.04	1.5	0.6	0.19	<0.02	<0.03	<0.1	14	<0.01	0.016	0.065	4
T2-60	Talbingo Composite rep-3			7.1	114	0.04	30	0.17	5.2	1.7	<0.1	<0.1	0.88	0.7	20	0.4	0.8	0.6	<0.04	1.5	0.6	0.20	<0.02	<0.03	<0.1	15	<0.01	0.015	0.10	5
	Talbingo Composite avg			**7.1**	**105**	**0.04**	**28**	**0.2**	**4.5**	**1.7**	**<0.1**	**<0.1**	**0.90**	**0.7**	**19**	**0.4**	**0.8**	**0.6**	**<0.04**	**1.6**	**0.6**	**0.20**	**<0.02**	**<0.03**	**<0.1**	**15**	**0.02**	**0.015**	**0.089**	**4**
T2-70	Talbingo Composite rep-1	---	24	7.1	60	0.04	39	0.25	4.1	1.7	<0.1	<0.1	1.5	0.7	25	0.4	0.8	1.6	<0.04	1.9	1.5	0.31	<0.02	0.05	<0.1	14	0.01	0.018	0.074	6
T2-71	Talbingo Composite rep-2			7.1	139	0.04	28	0.25	4.0	1.7	<0.1	<0.1	1.3	0.6	17	0.5	0.8	<0.3	<0.04	1.5	1.5	0.31	<0.02	<0.03	<0.1	14	0.01	0.017	0.039	2
T2-72	Talbingo Composite rep-3			7.1	115	0.04	32	0.35	4.8	1.8	<0.1	<0.1	1.5	0.7	18	0.4	0.8	<0.3	<0.04	1.7	0.9	0.30	<0.02	<0.03	<0.1	15	0.02	0.016	0.11	2
	Talbingo Composite avg			**7.1**	**105**	**0.04**	**33**	**0.3**	**4.3**	**1.7**	**<0.1**	**<0.1**	**1.5**	**0.7**	**20**	**0.5**	**0.8**	**1.6**	**<0.04**	**1.7**	**1.3**	**0.31**	**<0.02**	**<0.03**	**<0.1**	**14**	**0.01**	**0.017**	**0.075**	**3**
T2-79	MQ Blank rep-1	---	0.5	-	4	0.04	22	<0.03	0.20	<0.04	<0.1	<0.1	1.2	0.2	2.2	0.6	<0.1	<0.3	0.06	<0.2	0.7	0.20	0.03	<0.03	0.1	<0.5	0.02	0.008	0.009	6
T2-80	MQ Blank rep-2			-	13	0.05	24	0.04	0.25	<0.04	<0.1	<0.1	1.2	0.1	2.4	<0.1	<0.1	<0.3	<0.04	<0.2	0.8	0.19	<0.02	<0.03	<0.1	<0.5	0.03	0.007	0.017	3
T2-81	MQ Blank rep-3			-	24	0.04	22	<0.03	0.24	<0.04	<0.1	<0.1	1.3	<0.1	1.8	<0.1	<0.1	<0.3	<0.04	<0.2	0.6	0.18	<0.02	<0.03	<0.1	<0.5	0.01	0.005	0.009	4
	MQ Blank avg				**14**	**0.04**	**23**	**0.04**	**0.23**	**<0.04**	**<0.1**	**<0.1**	**1.2**	**0.16**	**2.1**	**0.6**	**<0.1**	**<0.3**	**0.06**	**<0.2**	**0.7**	**0.19**	**0.03**	**<0.03**	**<0.1**	**<0.5**	**0.02**	**0.01**	**0.012**	**5**
T2-82	MQ Blank rep-1	---	2	-	6	0.05	28	<0.03	0.30	<0.04	<0.1	<0.1	1.2	0.1	3.2	0.5	<0.1	<0.3	<0.04	<0.2	0.5	0.22	<0.02	<0.03	<0.1	<0.5	0.02	0.006	0.040	4
T2-83	MQ Blank rep-2			-	27	0.04	21	<0.03	0.96	<0.04	<0.1	<0.1	1.3	0.2	2.9	<0.1	<0.1	<0.3	<0.04	<0.2	0.5	0.21	<0.02	<0.03	<0.1	<0.5	<0.01	0.004	0.059	3
T2-84	MQ Blank rep-3			-	32	0.04	26	0.06	0.36	<0.04	<0.1	<0.1	1.3	<0.1	3.3	<0.1	<0.1	<0.3	<0.04	<0.2	1.4	0.23	<0.02	<0.03	<0.1	<0.5	<0.01	0.004	0.018	5
	MQ Blank avg				**22**	**0.04**	**25**	**0.06**	**0.54**	**<0.04**	**<0.1**	**<0.1**	**1.3**	**0.15**	**3.1**	**0.5**	**<0.1**	**<0.3**	**<0.04**	**<0.2**	**0.8**	**0.22**	**<0.02**	**<0.03**	**<0.1**	**<0.5**	**0.02**	**0.00**	**0.039**	**4**
T2-85	MQ Blank rep-1	---	6	-	6	0.04	25	<0.03	0.26	<0.04	<0.1	<0.1	1.3	0.2	3.6	0.5	<0.1	<0.3	<0.04	<0.2	0.8	0.22	<0.02	<0.03	<0.1	<0.5	0.01	0.003	0.064	3
T2-86	MQ Blank rep-2			-	37	0.03	22	<0.03	0.24	<0.04	<0.1	<0.1	1.4	0.1	2.2	<0.1	<0.1	<0.3	<0.04	<0.2	0.7	0.21	0.02	<0.03	<0.1	<0.5	<0.01	0.006	0.013	3
T2-87	MQ Blank rep-3			-	34	0.04	23	0.06	0.13	<0.04	<0.1	<0.1	1.3	<0.1	2.5	<0.1	<0.1	<0.3	<0.04	<0.2	0.6	0.21	<0.02	<0.03	<0.1	<0.5	0.01	0.005	0.018	3
	MQ Blank avg				**25**	**0.04**	**24**	**0.06**	**0.21**	**<0.04**	**<0.1**	**<0.1**	**1.3**	**0.15**	**2.8**	**0.5**	**<0.1**	**<0.3**	**<0.04**	**<0.2**	**0.7**	**0.21**	**<0.02**	**<0.03**	**<0.1**	**<0.5**	**0.01**	**0.00**	**0.03**	**3**
T2-88	MQ Blank rep-1	-	24	-	17	0.05	23	<0.03	0.23	<0.04	<0.1	<0.1	1.3	<0.1	2.5	0.6	<0.1	<0.3	<0.04	<0.2	0.6	0.27	<0.02	<0.03	<0.1	<0.5	0.01	0.006	0.026	1
T2-89	MQ Blank rep-2	-		-	40	0.05	21	<0.03	0.14	<0.04	<0.1	<0.1	1.7	<0.1	0.7	<0.1	<0.1	<0.3	<0.04	<0.2	0.9	0.26	<0.02	<0.03	<0.1	<0.5	<0.01	0.002	0.013	<1
	MQ Blank avg				**28**	**0.05**	**22**	**<0.03**	**0.19**	**<0.04**	**<0.1**	**<0.1**	**1.5**	**#####**	**1.6**	**0.6**	**<0.1**	**<0.3**	**<0.04**	**<0.2**	**0.8**	**0.27**	**<0.02**	**<0.03**	**<0.1**	**<0.5**	**0.01**	**0.004**	**0.020**	**1**
LOD (3σ)	---	---	---	---	---	0.01	3	0.03	0.04	0.04	0.1	0.1	0.02	0.1	0.2	0.1	0.1	0.3	0.04	0.2	0.1	0.05	0.02	0.03	0.1	0.5	0.01	0.001	0.004	1
Method Code	---	---	---	C-240	C-255	C-209	C-209	C-209	C-209	C-229	C-209	C-209	C-209	C-209	C-209	C-229	C-229	C-209	C-209	C-229	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209

Spike Recoveries

						Ag	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sn	Sr	Th	U	V	Zn
Sample ID	**Sample Description**	**Liquid:Solid**	**Time (h)**	**---**	**---**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
T2-34	Talbingo Composite rep-1	-	0.5	---	---	93	93	96	97	102	94	96	97	96	91	99	96	94	97	101	96	97	94	93	101	101	100	97	97	87
T2-41	CE491-27 (4E) rep-2	1000	2	---	---	93	92	94	96	108	93	94	96	96	92	103	102	93	97	100	96	96	94	91	101	98	98	95	96	91
T2-58	Talbingo Composite rep-1	-	6	---	---	87	98	89	92	101	97	92	90	92	98	99	99	98	91	94	93	90	88	95	101	90	92	89	91	90
T2-65	CE491-27 (4E) rep-2	1000	24	---	---	94	97	97	96	104	96	96	95	97	96	100	101	95	97	104	98	96	95	93	105	97	99	97	97	91
T2-80	MQ Blank rep-2	-	0.5	---	---	93	93	90	95	100	95	95	93	95	95	97	98	96	97	100	94	96	93	94	100	92	97	95	96	94
T2-84	MQ Blank rep-3	-	2	---	---	88	96	91	96	100	96	96	94	95	96	99	97	97	96	99	95	91	89	95	106	98	94	92	98	98

Certified Reference Material

	---	**---**	**---**	**---**	**---**	Ag	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sn	Sr	Th	U	V	Zn
Sample ID	**---**	**---**	**---**	**---**	**---**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**mg/L**	**µg/L**	**µg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
TM24.4 (n=5)	---	---	---	---	---	---	33	5	15	---	4	6	5	6	16	---	---	8	6	---	5	6	---	3	4	114	---	4	7	---
Certified Value	---	---	---	---	---	---	32.9 ± 4.5	5.30 ± 0.53	15.0 ± 1.0	---	3.96 ± 0.34	6.27 ± 0.57	5.00 ± 0.59	6.31 ± 0.60	16.0 ± 2.3	---	---	8.24 ± 0.73	6.30 ± 0.56	---	5.03 ± 0.53	5.60 ± 0.52	---	3.56 ± 0.58	3.72 ± 0.39	113 ± 8	---	4.24 ± 0.34	7.00 ± 0.58	---
Recovery (%)	---	---	---	---	---	---	100	94	100	---	96	102	99	102	98	---	---	98	98	---	100	100	---	92	112	100	---	99	100	---

Method Codes: C-209: ICP-MS C-229: ICP-AES C-240: Determination of pH C-255: Conductivity

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Note/Memo	CSIRO P4 Project Investigations
To:	Ali Watters (HKA)
From:	Brad Angel, Lucas Heights, NSW
Date:	2 November 2018
Copy:	Ryan Fraser, Stuart Simpson and Ellen Porter (SHL)
Our reference:	CSIRO P4 – Memo 7
Classification:	Internal use only
Subject:	Pollutant release from excavated rock composites – Alkalinity

Chemical formulas and acronyms

L/S	Liquid/solid ratio	SEC	Conductivity		

Background - Introduction

The CSIRO was engaged by Haskoning Australia Pty Ltd (RHDHV) to undertake an investigation of pollutant release from excavated rock disposal into Talbingo and Tantangara reservoirs.

The elutriate tests investigating the release of pollutants from composite excavated rock samples observed some significant changes in water quality with respect to water pH, with increases from 7.0-7.1 in Reservoir waters to 8.9-11 range in elutriates (L/S = 10 – 1,000).

This technical memo describes results of elutriate tests performed on eight fine (<75 µm) excavated rock composite materials (7 geological zones, including Kelly Plains 6B and 6E), for which the pH, conductivity, and alkalinity were measured after 30 min and 6 h. The tests were conducted at a liquid/solid ratio (L/S) of 500, and for one material (4E) tests were conducted for L/S = 500, 2000, 5000 and 10000 and compared with the alkalinity of the Talbingo Reservoir water.

Note, that these tests included for the first time the previously unavailable Kelly Plains materials – an additional ‘geological zone’ referred to as composite 6.

Water alkalinity

The pH, SEC and alkalinity after 0.5 h and 6 h settling of the Talbingo water and elutriate test performed on eight fine-rock composites at L/S=500 are shown in Table 1 and for the 4E fine-rock composite over a range of L/S in Table 2.

Similar to that reported in the initial result (Memo 1), the Talbingo water had neutral pH (7.0) and low conductivity (25-40 µS/cm). The alkalinity of the Talbingo water was 13-14 mg $CaCO_3$/L. For the L/S=500 elutriates the pH and conductivity were both higher after 0.5 h than after 6 h, and remained higher than the Talbingo water (Table 1). The 6 h result for 4E is an outlier with regards to this. For the L/S=500 elutriates the alkalinity was similar for measurements after 0.5 and 6 h, and was 50-100% higher than the original Talbingo water.

The increase in pH, SEC and alkalinity was much lower at higher L/S ratios (Table 2), where L/S 10,000 = (0.1 g fine-rock solids/L reservoir water) and L/S 500 = 2 g/L.

Summary

Overall the increases in alkalinity observed in the elutriate solutions were significant and will result in increased pH-buffering at the higher pH. However, the increases in alkalinity were generally modest and are unlikely to result in impacts to aquatic organisms.

Table 1. The pH, conductivity and alkalinity for elutriate test of the fine excavated rock composites.

Test water and fine-rock composite	L/S	Time h	pH	Conductivity (µS/cm)	Alkalinity (mg $CaCO_3$/L)
Talbingo water only	∞	0.5	7.0	39.9	14
Talbingo water only	∞	6	7.0	24.5	13
1E	500	0.5	8.4	76.9	23
1E	500	6	7.1	40.4	22
2E	500	0.5	9.1	78.8	25
2E	500	6	8.7	48.1	25
3E	500	0.5	9.2	52.1	25
3E	500	6	9.1	51.3	25
4E	500	0.5	9.2	55.6	27
4E	500	6	9.1	130	26
5E	500	0.5	9.2	54.6	25
5E	500	6	8.9	49.0	27
6E	500	0.5	8.8	58.6	21
6E	500	6	8.6	47.2	24
7E	500	0.5	9.1	58.0	24
7E	500	6	8.4	49.3	17
6B	500	0.5	7.4	62.0	15
6B	500	6	7.5	32.0	22

Table 2. Influence of L/S on pH, conductivity and alkalinity for elutriate test of the fine-rock composites 4E

Test water and fine-rock composite	L/S	Time h	pH	Conductivity (µS/cm)	Alkalinity as $CaCO_3$ mg/L
Talbingo water only	∞	0.5	7.0	39.9	14
Talbingo water only	∞	6	7.0	24.5	13
4E	10,000	0.5	7.3	42.2	16
4E	10,000	6	7.4	32.5	18
4E	5,000	0.5	8.0	45.1	18
4E	5,000	6	7.7	36.4	19
4E	2,000	0.5	8.9	46.9	22
4E	2,000	6	8.7	45.2	22
4E	500	0.5	9.2	55.6	27
4E	500	6	9.1	130	26

Figures for major cations from Memo 4 (4B)

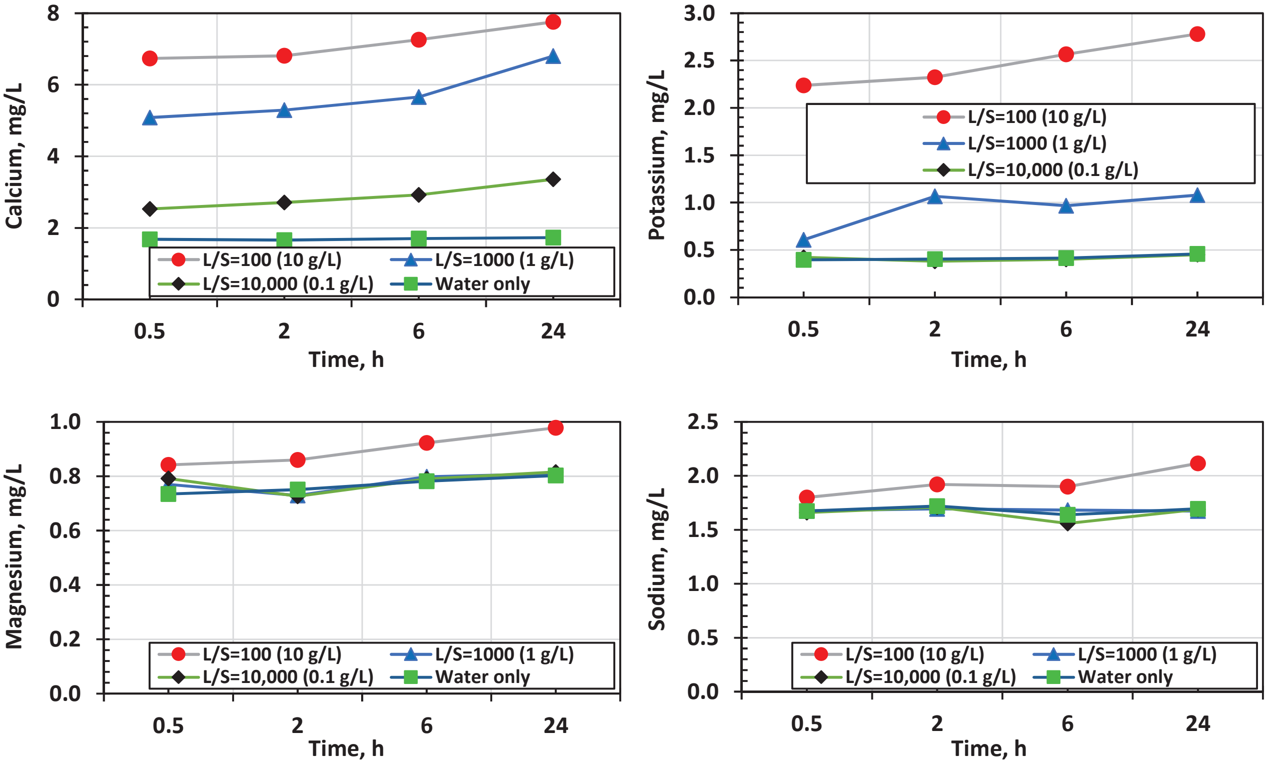

Figure D3.1. Major cation concentration of composite 4E elutriate tests after times of 0.5, 2, 6 and 24 h for liquid to solid ratios (L/S) of 100, 1000, and 10,000.

Appendix D4. Effect of rock material size on substance

Note/Memo	CSIRO P4 Project Investigations
To:	Ali Watters (HKA)
From:	Brad Angel, Lucas Heights, NSW
Date:	26 October 2018
Copy:	Ryan Fraser, Stuart Simpson and Ellen Porter (SHL)
Our reference:	CSIRO P4 – Memo 6
Classification:	Internal use only
Subject:	Pollutant release from excavated rock composites

Chemical formulas and acronyms

Ag	Silver	F^-	Fluoride	Sb	Antimony
Al	Aluminium	Fe	Iron	Se	Selenium
As	Arsenic	Mg	Magnesium	Sn	Tin
Ba	Barium	Mn	Manganese	SO_4^{2-}	Sulfate
Ca	Calcium	Mo	Molybdenum	Sr	Strontium
Cd	Cadmium	Na	Sodium	Th	Thorium
Cl^-	Chloride	Ni	Nickel	U	Uranium
Co	Cobalt	NO_3^-	Nitrate	V	Vanadium
Cr	Chromium	Pb	Lead	Zn	Zinc
Cu	Copper				
DOC	Dissolved organic carbon	DGV	Default guideline value	L/S	Liquid/solid ratio
SEC	Conductivity				

Background - Introduction

The CSIRO was engaged by Haskoning Australia Pty Ltd (RHDHV) to undertake an investigation of the pollutant release from excavated rock disposal into Talbingo and Tantangara reservoirs. This phase of the work involved investigating the release of pollutants from composite excavated rock samples in an initial elutriate test that had a liquid to solid (L/S) ratio of 10/1 and was run for 48 h. With respect to placement scenarios for the excavated rock, these tests were intended to assess a worst case scenario for impacts to the receiving water. It is envisaged that the design of the excavated rock placement will result in fast deposition of the majority of the excavated rock, and concentrations of fine materials within the waters will be managed to achieve considerably lower concentrations of suspended solids. The vast majority of the excavated rock, by mass, will be larger than sand size and should settle rapidly.

The materials with finer particle size are expected to represent the greatest environmental risk with respect to transport and release of pollutants. Materials with a larger particle size are expected to settle rapidly and release smaller amounts of pollutants to the reservoir waters.

This technical memo describes results of elutriate tests performed on four different excavated rock materials that had been mechanically crushed to provide materials with the size categories 10-25 mm; 2-10 mm, 0.21-2 mm and <0.21 mm (composite fine material). The kinetics of substance release was monitored at time periods of 1, 4 and 24 h after resuspension then settling in Talbingo reservoir water.

Preparation of rock materials in different size ranges

For each core material rock pieces larger than ~2 cm were passed through a jaw crusher plant. This process created a wide range of uneven shapes but were generally more flat than square. The crushed materials were sieved through plastic sieves to create the following size fractions: >10 mm; 2-10 mm, 0.21-2 mm and <0.21 mm (fine material). Owing to the varied shapes, the different size ranges included fractions that were able to pass through the sieve in a single direction but would not pass if perpendicular (e.g. long thin piece could pass). This was considered when selecting fractions for the tests, where the aim was to have pieces that were more 'square' than flat or thin.

The rock materials tested included 1E (Ravine), 4B (Gooandra Volcanics), 5B and 5E (Peppercorn/ Tantangara/Temperance Formations). For each test, the liquid to solid ratio (L/S, weight/weight) was 25, resulting in a greater number of pieces of rock for the tests with smaller L/S. For the 10-25 mm size range, a single piece of rock was selected, for the 2-10 mm size range 4-6 pieces were selected, with the finer size fractions prepared from homogenised samples. The tests were undertaken in volumes of 250 mL water for the two larger size fractions, 125 mL for the 0.21-2 mm fraction and 50 mL for the <0.21 mm size fraction. Each test was undertaken in triplicate, unless there was insufficient material, and this enabled variability across shapes to be incorporated. Talbingo reservoir water was used for all tests, comprising an equal volume composite from three buck waters. As fine dust was on the surface of large rock pieces, the three larger rock fraction underwent a 10-s leach (add, shake, then decant to waste) immediately before the test water was added.

For the elutriate tests, the materials (rock and water) were shaken briefly and then rolled for 30 min on a purpose built bottle roller (~50 rpm) to continually mix the water and solids of that period. The containers were then placed upright to allow the materials to settle until the time of the measurements. Subsamples were taken 1 h, 4 h, 24 h for measurement of pH, conductivity and dissolved analytes (filtered <0.45 µm). The containers were not shaken between time points.

The <0.21 mm fraction of the materials was analysed by laser diffraction to provide information on the particle size distribution and give an idea of the fine material that is likely to be the major source of pollutant release.

Results - Influence of rock material size (and time) on elutriate pH, conductivity and dissolved analytes

The pH, conductivity and dissolved analyte concentrations of the elutriates from the four size fractions of each excavated rock sample in Talbingo water were determined for elutriate tests lasting 1 h, 4 h, and 24 h at L/S = 25. Data has been generated from these tests for a range of other analytes, but results shown in this memo focus on dissolved aluminium owing to the concentrations exceeding the default guideline value (DVG) of 55 µg/L.

The pH, conductivity and dissolved aluminium for each elutriate time period as a function of the size of the rock materials are shown in Figures 1, 2, 3. The concentrations of dissolved major ions (Na, K, Mg, Ca) for each elutriate time period as a function of the size of the rock materials are shown in Figures 4, 5 and 6. The effect of the elutriate duration is clearer in Figure 7. The particle size distribution of the <0.21 mm size fraction is shown in Table 1 and Figure 8.

<u>Points to note:</u>

- pH range of 9.9 to 11.1 for the <25 mm rock materials was notably higher than the range from the initial elutriates (8.8 to 9.8) generated from the fine solids (<75 µm) at L/S=10 (Memo 4). The higher pH is expected to result in higher concentrations of the aluminate ion, $Al(OH)_4^-$.
- Conductivity range of 125 to 600 µS/cm, was notably higher than the range (110-200 µS/cm) from the initial elutriates generated from the fine solids (<75 µm) at L/S=10 (Memo 4). The pattern is consistent with Ca, followed by Na and K being the major contributors to the increased water conductivity (Figure 7).
- For both pH and conductivity, the high values were observed across the full range of rock material sizes, with conductivity increasing with time. Noting here that the rock materials that were crushed were a

range of different pieces and differences to the initial elutriates may reflect heterogeneity within the rocks material used in the studies.

- Dissolved aluminium exceeded the DVG of 55 µg/L by factor of 4 to 15 within 1 h for <0.21 mm size fraction, and below DGV for 0.21-2 mm size fraction initially then increasing to exceed the DGV for longer elutriate durations.
- pH kinetics: For the 0.21-2 mm size fraction, pH of 24 h elutriates was significantly lower than 1 h and 4 h elutriates.
- Conductivity kinetics: Major initial increases (1 h) then variable increases, potentially doubling conductivity over 4 h, with less change through to 24 h.
- Particle size distribution of <0.21 mm size fraction: The <0.21 mm samples had particle diameters that generally spanned the 0-0.21 mm range. Sample 4B (<0.21 mm) was the finest with 50% of the sample being <21.5 µm. The other samples comprised approximately 50% silt i.e. approximately 50% <63 µm.

Summary

Pollutant release is low, trends towards negligible, for rock materials >2 mm.

The finer <0.21 mm rock fraction is likely to have an impact on water quality that is an order of magnitude greater than that of rock fractions >2 mm in size.

The relationships between L/S, kinetics and water pH, conductivity and dissolved aluminium concentrations are becoming clearer.

Tests underway are investigating release from solids with TSS in 0.1 to 1 mg/L range, as this appears important for defining the transition to having dissolved aluminium concentrations above the DGV.

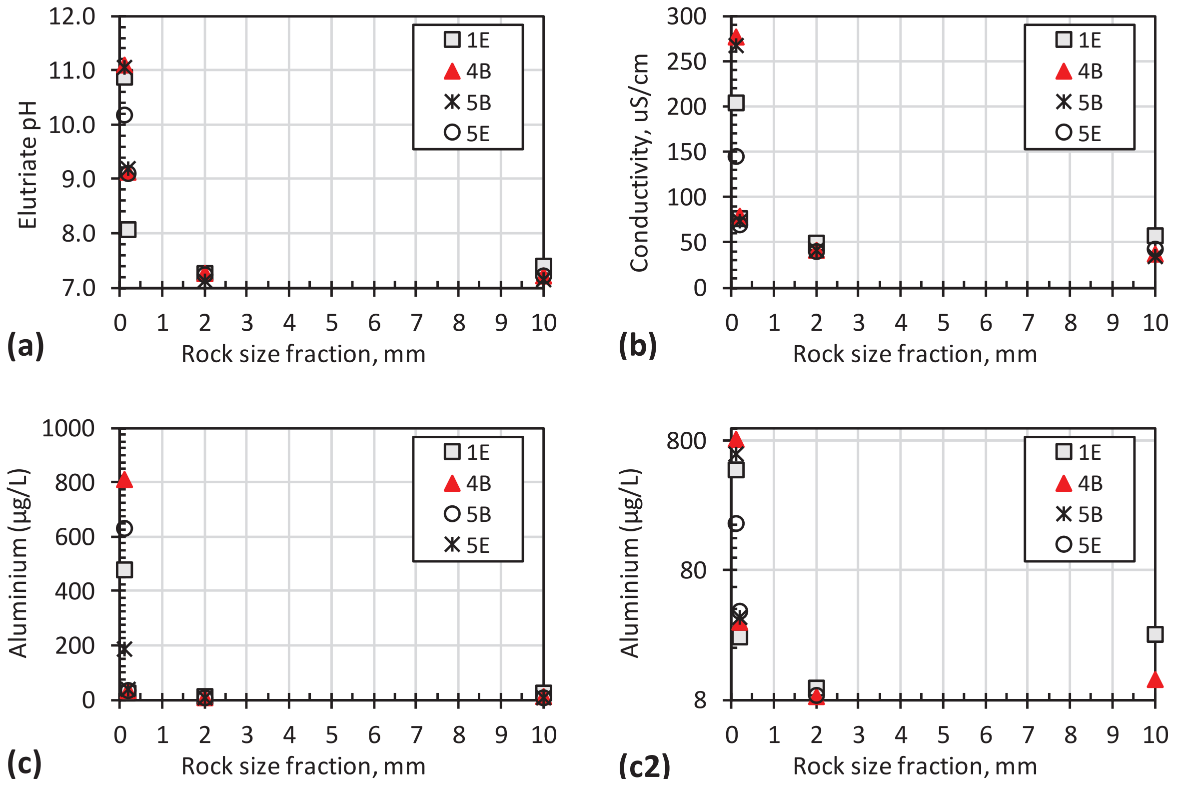

Figure 1. The pH, conductivity and dissolved aluminium after elutriate time of 1 h (c2 = log scale).

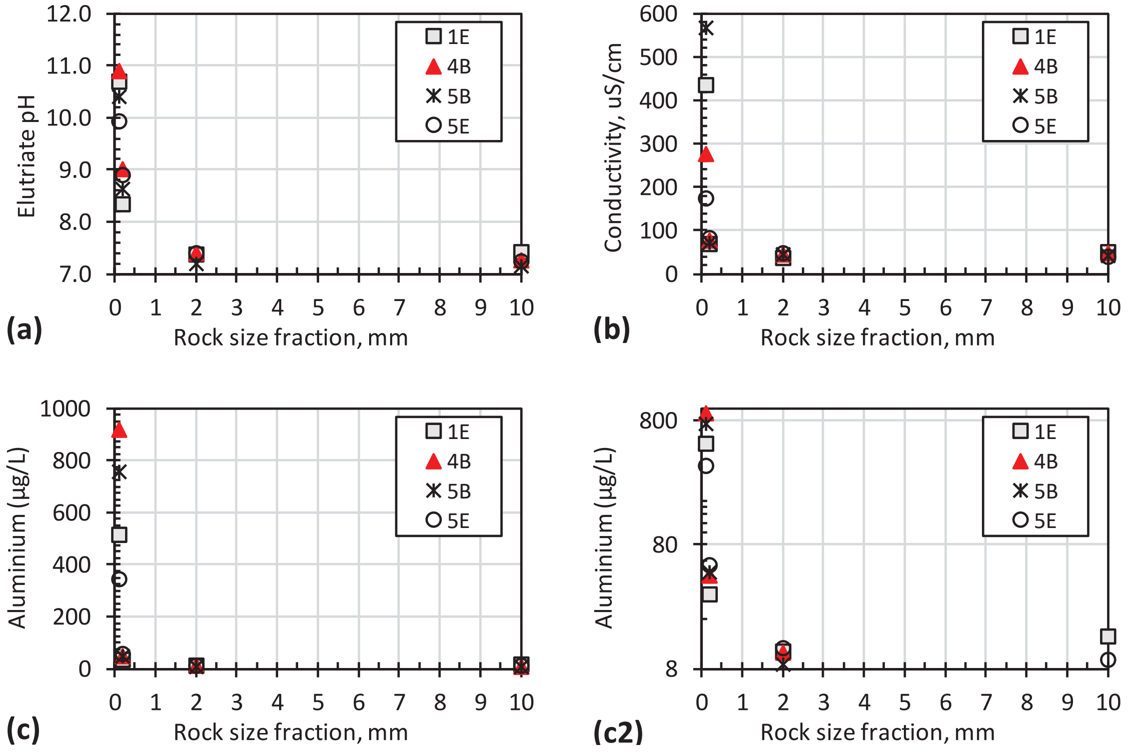

Figure 2. The pH, conductivity and dissolved aluminium after elutriate time of 4 h (c2 = log scale).

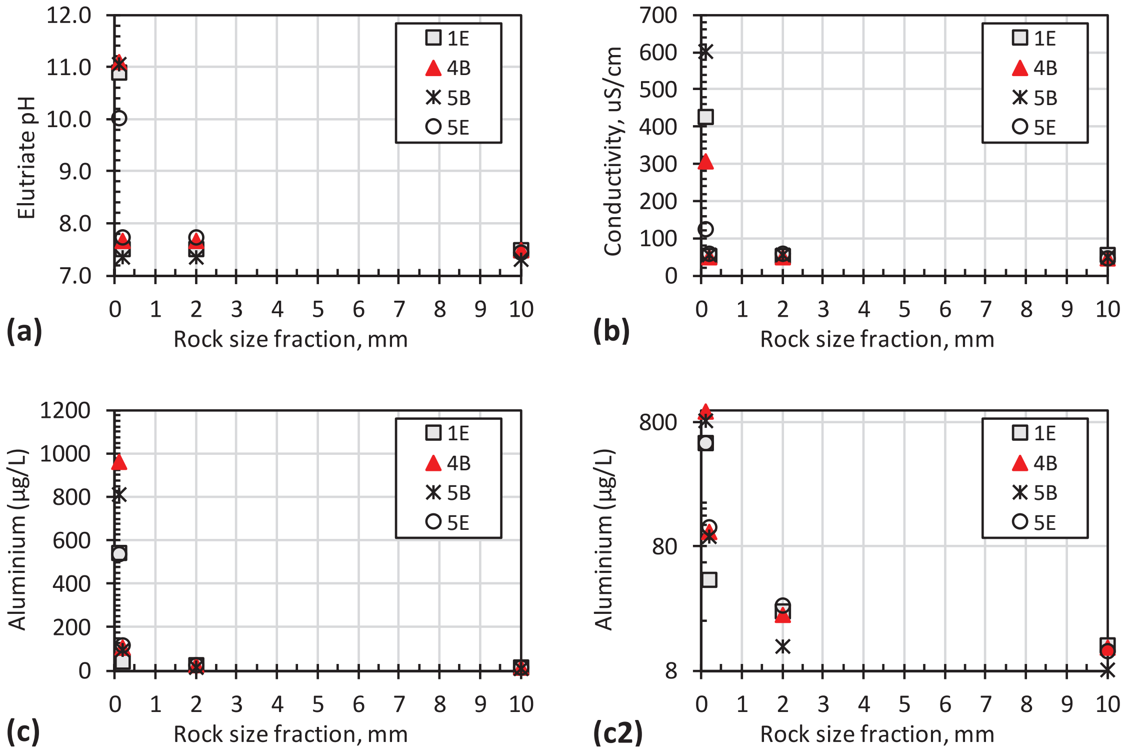

Figure 3. The pH, conductivity and dissolved aluminium after elutriate time of 24 h (c2 = log scale).

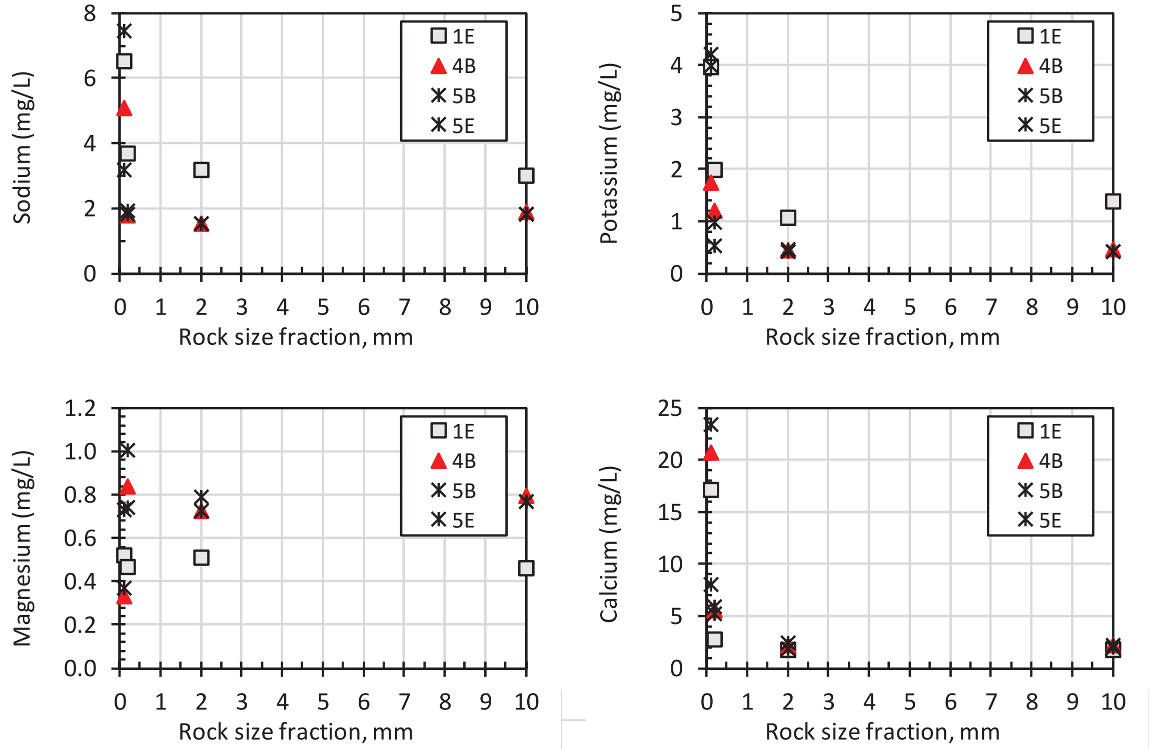

Figure 4. Dissolved major ions (Na, K, Mg, Ca) after elutriate time of 1 h.

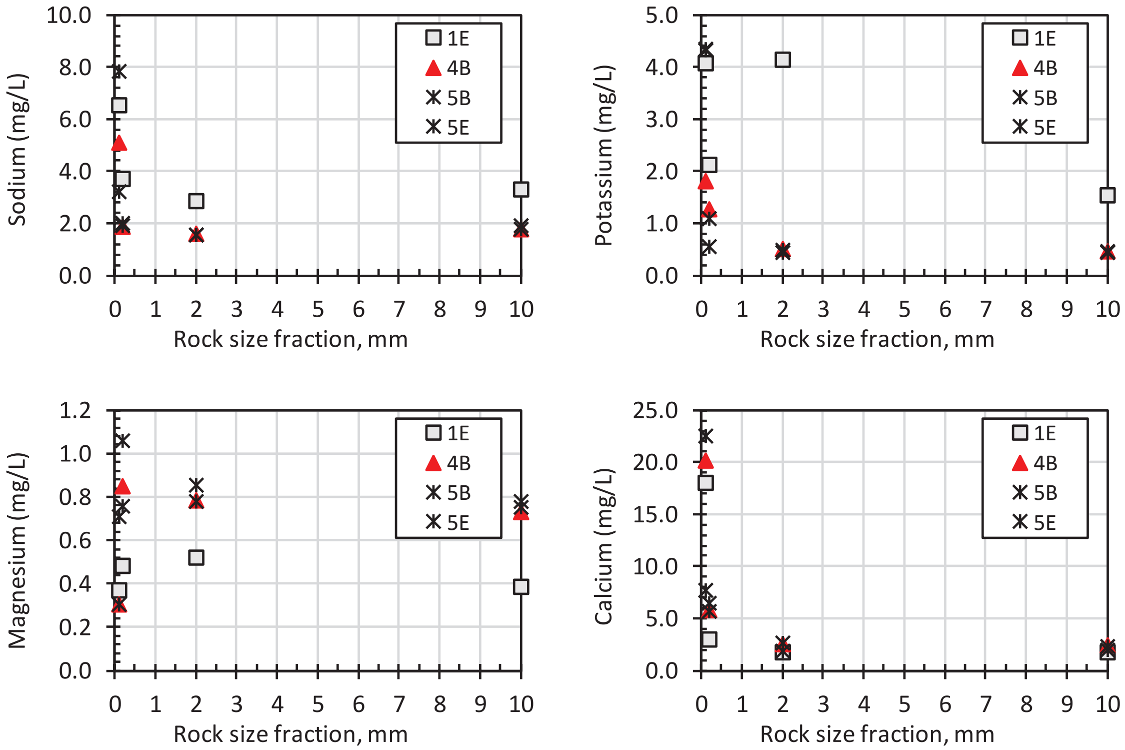

Figure 5. Dissolved major ions (Na, K, Mg, Ca) after elutriate time of 4 h.

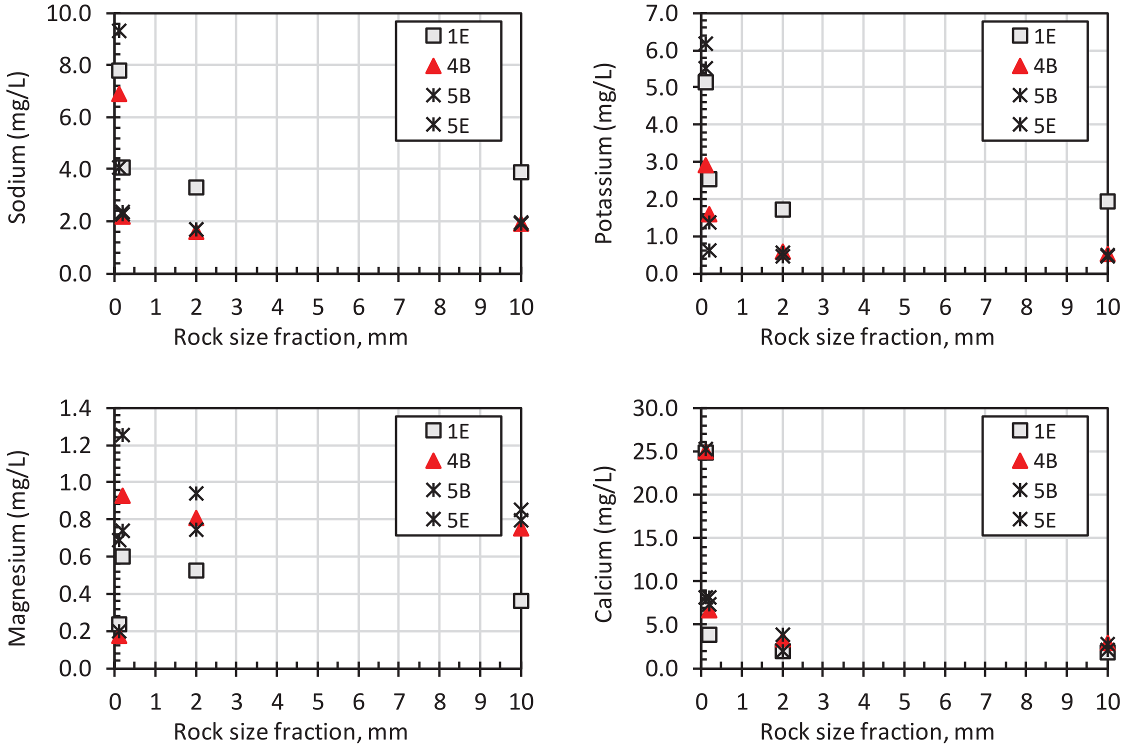

Figure 6. Dissolved major ions (Na, K, Mg, Ca) after elutriate time of 24 h.

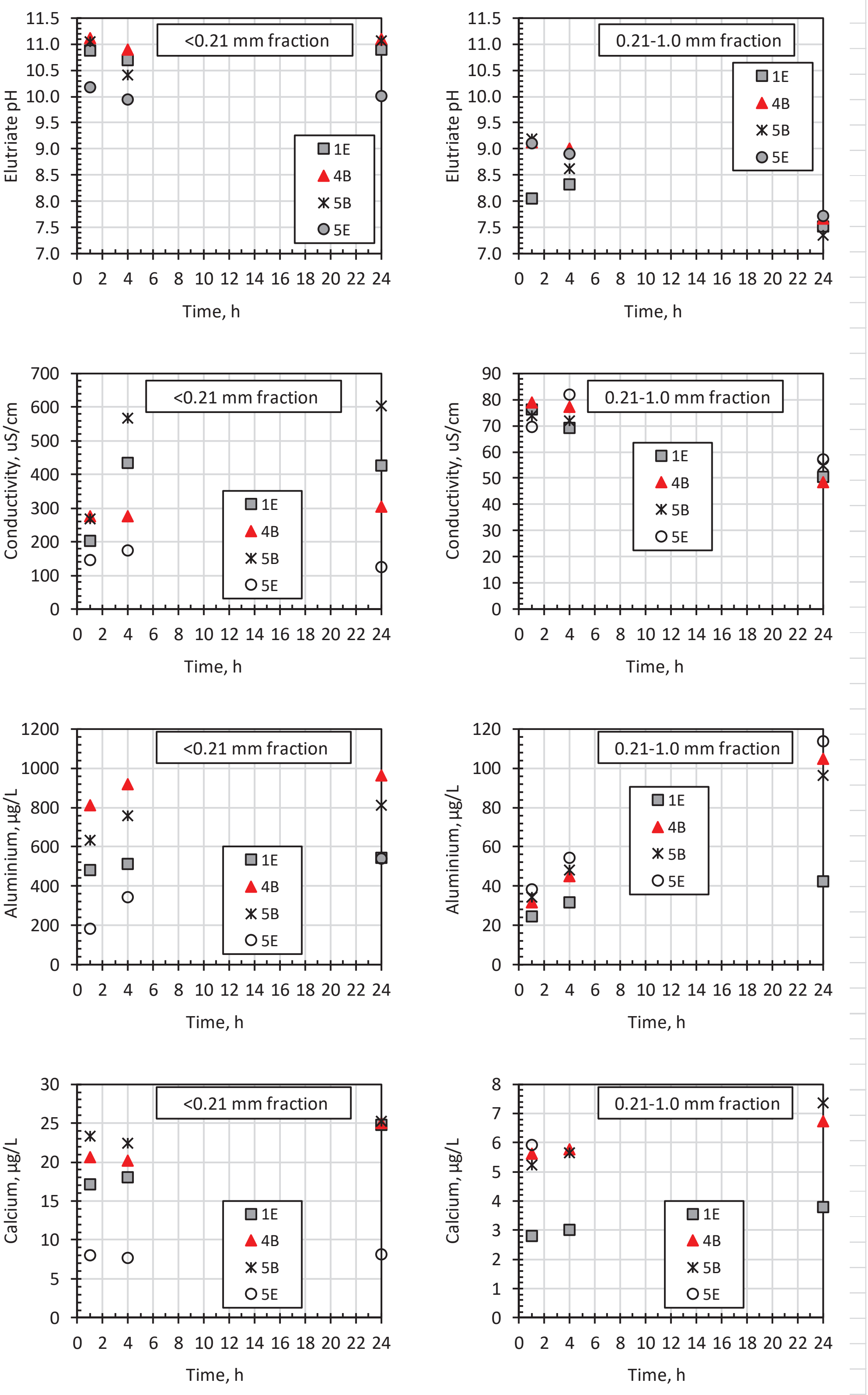

Figure 7. Effect of elutriate time on pH, conductivity and dissolved aluminium and calcium for the two smaller rock size fractions (<0.21 mm and 0.21-2 mm).

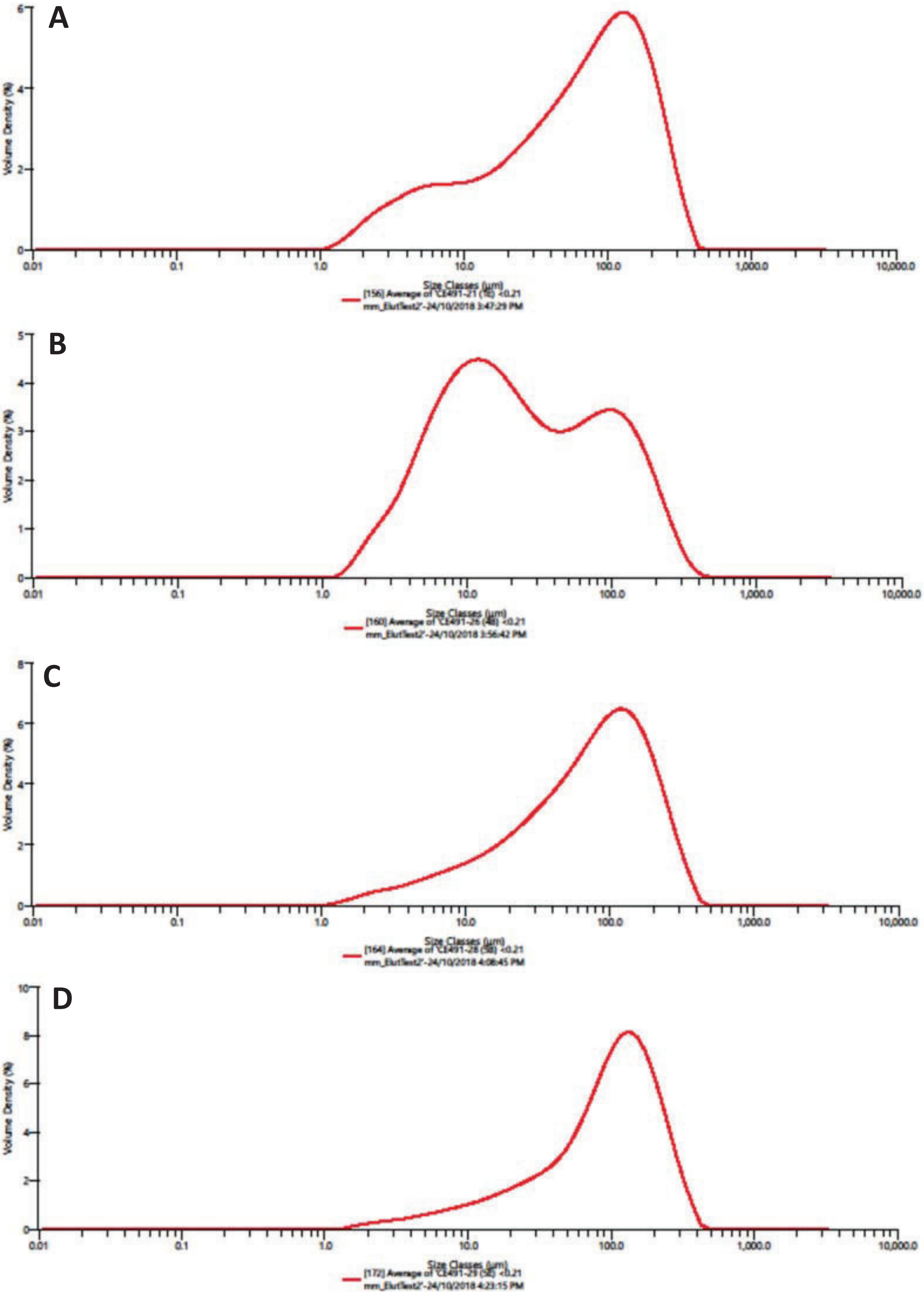

Figure 8. The particle size distribution of the <0.21 mm sieved fraction of samples 1E (A), 4B (B), 5B (C) and 5E (D).

Table 1. The particle size distribution of the <0.21 mm fraction used in grain size test

Sample Name	Dv (10) (µm)	Dv (50) (µm)	Dv (90) (µm)	Mean diameter (µm)
1E, <0.21 mm	5.93	66.3	206	88.3
4B, <0.21 mm	4.71	21.5	140	50.3
5B, <0.21 mm	10.7	75.6	210	95.3
5E, <0.21 mm	16	99.6	228	113

Note: Dv (x) refers to 10, 50 and 90th percentiles of particle diameters (on spherical volume basis)

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Note/Memo	CSIRO P4 Project Investigations
To:	Ali Watters (HKA)
From:	Brad Angel, Lucas Heights, NSW
Date:	5 November 2018
Copy:	Ryan Fraser, Stuart Simpson and Ellen Porter (SHL)
Our reference:	CSIRO P4 – Memo 8
Classification:	Internal use only
Subject:	Pollutant release from excavated rock composites – fine grain size effect

Chemical formulas and acronyms

Ag	Silver	F^-	Fluoride	Sb	Antimony
Al	Aluminium	Fe	Iron	Se	Selenium
As	Arsenic	Mg	Magnesium	Sn	Tin
Ba	Barium	Mn	Manganese	SO_4^{2-}	Sulfate
Ca	Calcium	Mo	Molybdenum	Sr	Strontium
Cd	Cadmium	Na	Sodium	Th	Thorium
Cl^-	Chloride	Ni	Nickel	U	Uranium
Co	Cobalt	NO_3^-	Nitrate	V	Vanadium
Cr	Chromium	Pb	Lead	Zn	Zinc
Cu	Copper				
DOC	Dissolved organic carbon	DGV	Default guideline value	L/S	Liquid/solid ratio
SEC	Conductivity				

Background - Introduction

The CSIRO was engaged by Haskoning Australia Pty Ltd (RHDHV) to undertake an investigation of the pollutant release from excavated rock disposal into Talbingo and Tantangara reservoirs. Previous elutriate testing that investigated the effect of excavated rock grain size; >10,000 µm, 2,000-10,000 µm, 210-2,000 µm and <210 µm (referred to as >10 mm; 2-10 mm, 0.21-2 mm and <0.21 mm in Memo 6) found the finer <210 µm rock fraction is likely to have an impact on water quality that is an order of magnitude greater than that of rock fractions >2000 µm in size. This testing was conducted at a liquid to solid ratio of 25 (i.e. 40 g/L). It is envisaged that the design of the excavated rock placement will result in fast deposition of the majority of the excavated rock, and concentrations of fine materials within the waters will be managed to achieve considerably lower concentrations of suspended solids. However, due to the much larger effect of the <210 µm rock fraction on water pH, conductivity and dissolved aluminium concentrations and the likelihood of fine material requiring special handling / treatment, an additional investigation of the effect of finer (sub 210 µm) excavated rock fractions on water quality was performed.

This technical memo describes results of elutriate tests performed on three different excavated rock materials that had been mechanically crushed and sieved to provide materials with the size categories 150-210, 63-150 and <63 µm (composite fine material). The tests were performed by resuspending sieved fractions of composites 1B, 4B and 5E in Talbingo water at a liquid to solid ratio of 1000.

Preparation of rock materials in different size ranges

For the elutriate tests, the 1B, 4B and 5E sieved materials (rock and water) were shaken briefly and then rolled for 30 min on a purpose built bottle roller (~50 rpm) to continually mix the water and solids of that period. The containers were then placed upright to allow the materials to settle until the time that measurements were performed; measurement of pH, conductivity and dissolved analytes (filtered <0.45 µm) 24 h after water initially added.

Results - Influence of rock material size (and time) on elutriate pH, conductivity and dissolved analytes

The pH, conductivity and dissolved analyte concentrations measured in the elutriate solutions generated from the three size fractions of each excavated rock sample in Talbingo water for elutriate tests lasting 24 h at L/S = 1000 are shown in Figure 1. The concentrations of dissolved major ions (Na, K, Mg, Ca) for each as a function of the size of the rock materials are shown in Figure 2. Data has been generated from these tests for a range of other analytes, but results shown in this memo focus on dissolved aluminium owing to the concentrations exceeding the default guideline value (DVG) of 55 µg/L.

The particle size distribution of the <210 µm size fraction (previously shown in memo 6) is shown in Figure 3 and Table 1 for the purpose of interpreting the importance of the findings for this test.

The pH, conductivity and dissolved aluminium all decreased as the size fraction increased. However, the pH, conductivity and dissolved aluminium exhibited linear decreases as the particle size increased rather than exponential, as observed for sizes between >10,000 µm to <210 µm (Memo 6).

Points to note:

- pH range of 7.84 to 9.68 was similar to most previous results when considering the liquid to solid ratio of 1000, and not as high as for some treatments in memo 6.
- Conductivity range of 38 to 99 µS/cm, was similar to most previous results when considering the liquid to solid ratio of 1000. The pattern is consistent with Ca, followed by Na being the major contributors to the increased water conductivity, with K and Mg contributing less (Figure 1).
- The dissolved aluminium exceeded the DVG of 55 µg/L by a factor of 4.2 to 1.1 for the <63 and 63-150 µm size fractions, and was below the DGV for the 150-210 µm size fraction (Figure 1).
- The dissolved calcium and potassium decreased as the size fraction increased, but the decreases were not as steep as for dissolved aluminium, while the dissolved magnesium and sodium were generally similar for the different size fractions (Figure 2).
- Particle size distribution of <210 µm size fraction: The <210 µm samples had particle diameters that generally spanned the 0-210 µm range. Sample 4B (<210 µm) was the finest with 50% of the sample being <21.5 µm. The other samples comprised approximately 50% silt, i.e. approximately 50% <63 µm.

Summary

The pH, conductivity and dissolved aluminium decreased as the particle size increased from <63 µm to 150-210 µm, however, the decrease was essentially linear rather than exponential, as observed for 210 µm to >10,000 µm fractions in memo 6.

For a liquid to solid ratio of 1000, the dissolved aluminium released from the <63 µm size fraction exceeded the DGV after 24 h. For the 63-150 µm, there was a much smaller exceedance of the DGV.

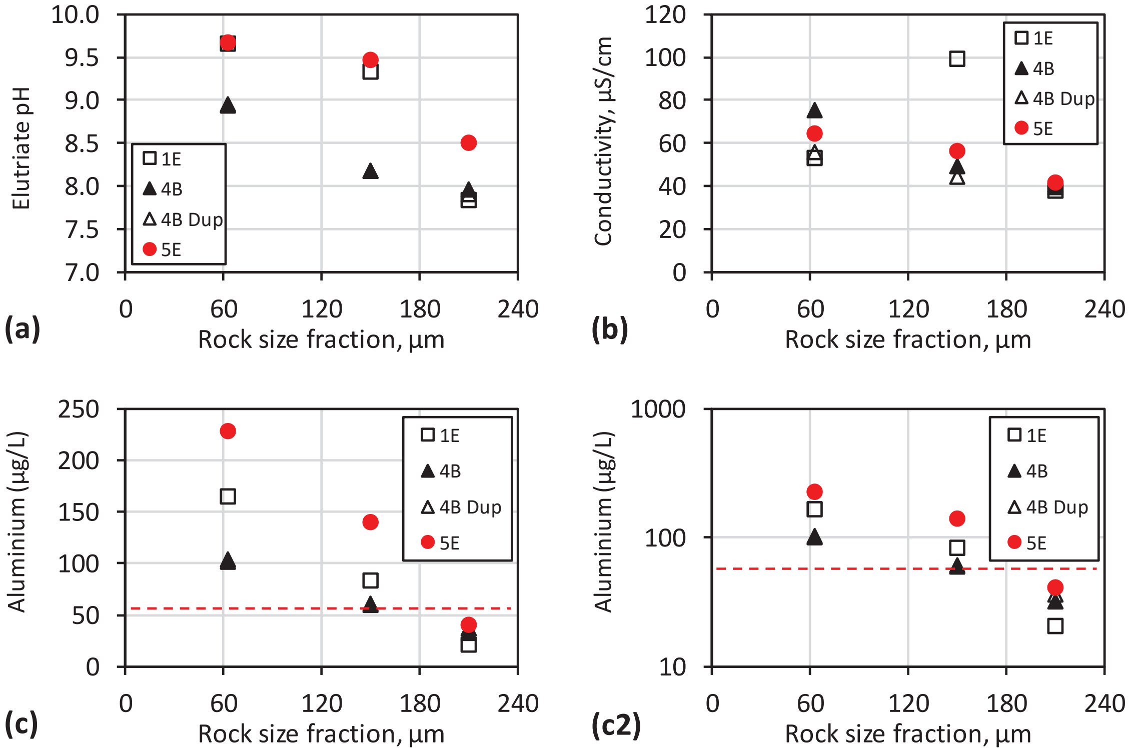


Figure 1. The pH (a), conductivity (b) and dissolved aluminium (c, c2) after an elutriate time of 24 h (c2 = log scale) for <63, 63-150 and 150-210 µm size fractions.

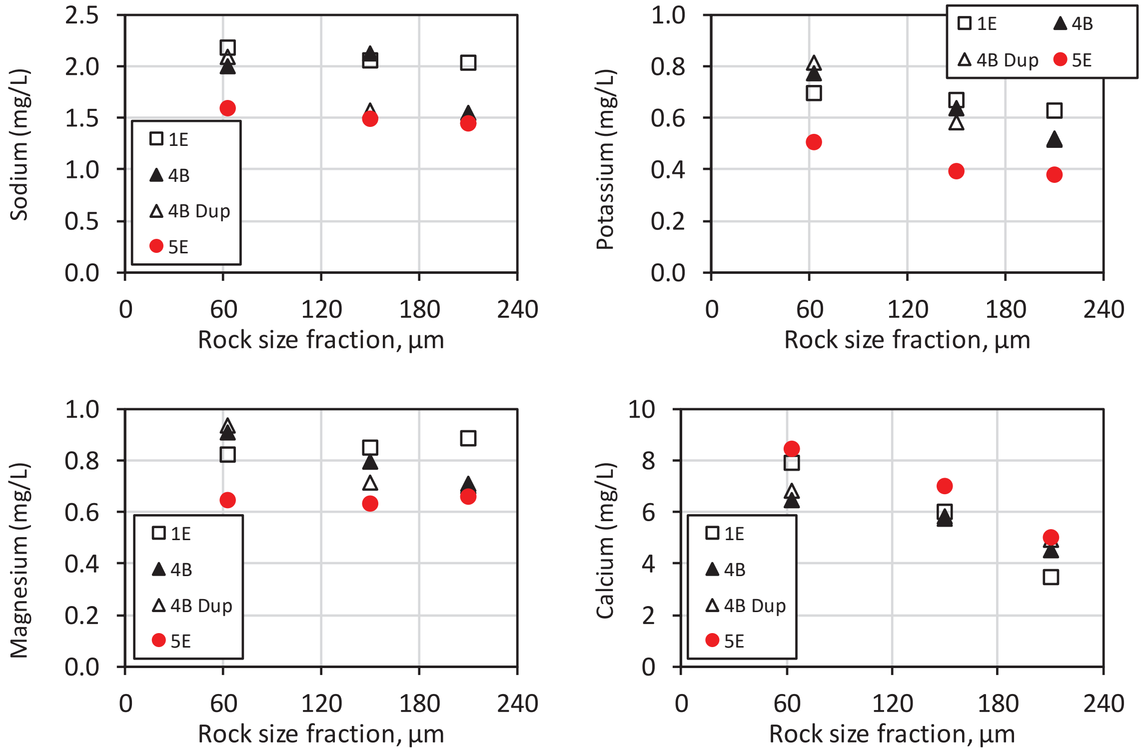


Figure 2. Dissolved major ions (Na, K, Mg, Ca) after an elutriate time of 24 h for <63, 63-150 and 150-210 µm size fractions.

Table 1. The particle size distribution of the <210 µm fraction used in grain size test

Sample Name	Dv (10) (µm)	Dv (50) (µm)	Dv (90) (µm)	Mean diameter (µm)
1E, <210 µm	5.93	66.3	206	88.3
4B, <210 µm	4.71	21.5	140	50.3
5B, <210 µm	10.7	75.6	210	95.3
5E, <210 µm	16	99.6	228	113

Note: Dv (x) refers to 10, 50 and 90th percentiles of particle diameters (on spherical volume basis)

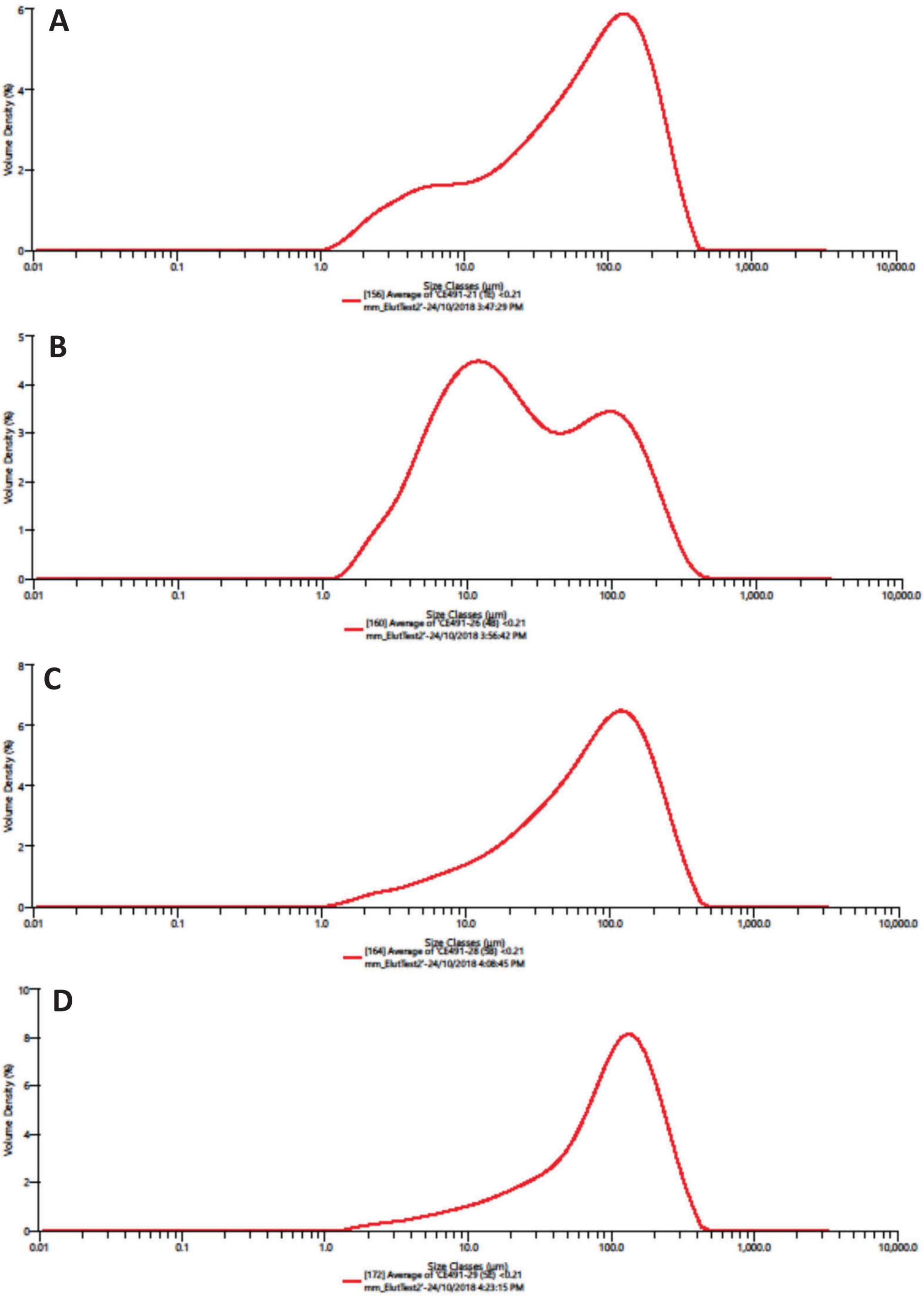


Figure 3. The particle size distribution of the <210 µm sieved fraction of samples 1E (A), 4B (B), 5B (C) and 5E (D).

Appendix D4. Effect of rock particle size in on substance release

Memo 6 (26 October 2018).

Notes
Composite Talbingo reservoir water used as leachate solution
Size categories 10-25 mm; 2-10 mm, 0.21-2 mm and <0.21 mm (composite fine material),
L/S of 25 (40 g/L) and measurement made at time periods of 1, 4 and 24 h after resuspension then settling in Talbingo reservoir water.

							Al	Ag	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sn	Sr	Th	U	V	Zn
Sample Name	**Sample ID**	**Sample Desc.**	**Particle Size**	**Time**	**pH**	**Conductivity (µS/cm)**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**mg/L**	**µg/L**	**µg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
T1-1	CE491-21 rep-1	1E rep-1	>10 mm	1 hr	7.3	73.1	26	<0.04	8.9	40	1.8	<0.1	0.2	<0.3	0.5	21	1.3	0.5	6.8	0.2	2.8	0.6	<1	0.1	<0.1	<0.3	115	0.1	0.14	0.3	4
T1-2	CE491-21 rep-2	1E rep-2			7.6	61.1	42	<0.04	47	50	1.3	<0.1	0.5	<0.3	0.5	24	2.2	0.2	6.6	0.8	4.1	0.9	<1	0.7	0.2	<0.3	109	0.2	0.44	1.5	<1
T1-3	CE491-21 rep-3	1E rep-3			7.3	37.5	8	<0.04	4.1	21	2.1	<0.1	0.3	<0.3	0.6	19	0.7	0.7	3.7	0.2	2.2	0.3	<1	0.2	<0.1	<0.3	39	<0.1	0.04	0.1	<1
	CE491-21 avg	**1E avg**			**7.4**	**57.3**	**25**	**<0.04**	**20**	**37**	**1.7**	**<0.1**	**0.3**	**<0.3**	**0.5**	**22**	**1.4**	**0.5**	**5.7**	**0.4**	**3.0**	**0.6**	**<1**	**0.3**	**<0.1**	**<0.3**	**87**	**0.2**	**0.21**	**0.6**	**4**
T1-13	CE491-21 rep-1	1E rep-1		4 hr	7.3	---	15	<0.04	14	41	1.8	<0.1	0.2	<0.3	0.4	21	1.4	0.4	7.3	0.3	3.0	0.8	<1	0.2	<0.1	<0.3	112	0.1	0.17	0.3	<1
T1-14	CE491-21 rep-2	1E rep-2			7.6	53.5	22	<0.04	54	51	1.3	<0.1	0.6	1.2	1.6	51	2.4	0.2	10	0.9	4.5	1.1	<1	1.0	0.1	<0.3	106	0.2	0.40	1.5	<1
T1-15	CE491-21 rep-3	1E rep-3			7.3	44.3	7	<0.04	7.7	22	2.1	<0.1	0.4	<0.3	0.4	18	0.8	0.6	4.4	0.3	2.4	0.6	<1	0.4	<0.1	<0.3	45	<0.1	0.06	0.2	<1
	CE491-21 avg	**1E avg**			**7.4**	**48.9**	**15**	**<0.04**	**25**	**38**	**1.7**	**<0.1**	**0.4**	**1.2**	**0.8**	**30**	**1.5**	**0.4**	**7.4**	**0.5**	**3.3**	**0.8**	**<1**	**0.5**	**<0.1**	**<0.3**	**88**	**0.2**	**0.21**	**0.7**	**<1**
T1-25	CE491-21 rep-1	1E rep-1		24 hr	7.4	60.9	14	<0.04	32	43	1.7	<0.1	0.2	0.5	0.3	19	1.8	0.4	8.5	0.4	3.6	0.7	<1	0.4	<0.1	<0.3	114	0.1	0.23	0.8	<1
T1-26	CE491-21 rep-2	1E rep-2			7.6	54.8	11	<0.04	117	57	1.6	<0.1	0.6	0.3	0.3	14	2.7	0.2	8.5	1.6	4.9	1.6	<1	2.3	0.2	<0.3	132	0.1	0.45	2.4	<1
T1-27	CE491-21 rep-3	1E rep-3			7.5	45.3	13	<0.04	19	27	2.2	<0.1	0.6	0.5	0.5	20	1.3	0.6	7.9	0.8	3.2	1.1	<1	1.1	<0.1	<0.3	72	<0.1	0.06	0.3	<1
	CE491-21 avg	**1E avg**			**7.5**	**53.7**	**13**	**<0.04**	**56**	**42**	**1.8**	**<0.1**	**0.5**	**0.5**	**0.4**	**18**	**1.9**	**0.4**	**8.3**	**0.9**	**3.9**	**1.1**	**<1**	**1.3**	**<0.1**	**<0.3**	**106**	**0.1**	**0.24**	**1.1**	**<1**
T1-37	CE491-21 rep-1	1E rep-1	2-10 mm	1 hr	7.3	---	10	<0.04	6.3	36	1.7	<0.1	0.3	<0.3	1.1	17	1.2	0.5	7.2	0.3	2.7	0.4	<1	0.1	<0.1	<0.3	87	<0.1	0.14	0.3	<1
T1-38	CE491-21 rep-2	1E rep-2			7.3	45.3	9	<0.04	7.7	49	1.7	<0.1	0.4	<0.3	0.8	17	1.1	0.5	8.0	0.3	2.6	0.6	<1	0.1	<0.1	<0.3	105	<0.1	0.12	0.3	4
T1-39	CE491-21 rep-3	1E rep-3			7.2	53.8	10	<0.04	6.5	34	1.8	<0.1	0.4	<0.3	0.6	18	1.0	0.6	7.1	0.2	4.4	0.5	<1	0.1	<0.1	<0.3	81	<0.1	0.09	0.3	1
	CE491-21 avg	**1E avg**			**7.3**	**49.5**	**10**	**<0.04**	**6.8**	**39**	**1.8**	**<0.1**	**0.4**	**<0.3**	**0.8**	**17**	**1.1**	**0.5**	**7.4**	**0.3**	**3.2**	**0.5**	**<1**	**0.1**	**<0.1**	**<0.3**	**91**	**<0.1**	**0.11**	**0.3**	**2**
T1-49	CE491-21 rep-1	1E rep-1		4 hr	7.4	33.4	13	<0.04	14	38	1.8	<0.1	0.3	<0.3	<0.2	18	7.4	0.5	8.2	0.3	2.9	0.7	<1	0.3	<0.1	<0.3	90	<0.1	0.18	0.5	5
T1-50	CE491-21 rep-2	1E rep-2			7.4	31.5	8	<0.04	16	54	1.8	<0.1	0.5	<0.3	<0.2	14	3.8	0.5	9.7	0.4	3.1	0.8	<1	0.3	0.1	<0.3	108	<0.1	0.14	0.4	<1
T1-51	CE491-21 rep-3	1E rep-3			7.3	42.7	12	<0.04	15	37	1.8	<0.1	0.6	<0.3	<0.2	18	1.2	0.5	8.7	0.3	2.6	0.7	<1	0.3	<0.1	<0.3	87	<0.1	0.14	0.4	1
	CE491-21 avg	**1E avg**			**7.4**	**35.9**	**11**	**<0.04**	**15**	**43**	**1.8**	**<0.1**	**0.4**	**<0.3**	**<0.2**	**17**	**4.1**	**0.5**	**8.9**	**0.4**	**2.9**	**0.8**	**<1**	**0.3**	**<0.1**	**<0.3**	**95**	**<0.1**	**0.15**	**0.5**	**3**
T1-61	CE491-21 rep-1	1E rep-1		24 hr	7.6	51.5	23	<0.04	41	43	1.9	<0.1	0.3	<0.3	<0.2	19	1.8	0.5	12	0.7	3.6	0.7	<1	1.1	<0.1	<0.3	103	<0.1	0.23	1.3	<1
T1-62	CE491-21 rep-2	1E rep-2			7.4	51.5	27	<0.04	40	61	1.9	<0.1	0.5	<0.3	<0.2	21	1.8	0.5	11	0.9	3.6	1.1	<1	0.9	0.1	<0.3	121	<0.1	0.20	1.1	3
T1-63	CE491-21 rep-3	1E rep-3			7.5	48.2	22	<0.04	33	44	2.0	<0.1	0.5	<0.3	<0.2	21	1.6	0.6	12	0.4	2.8	1.2	<1	0.8	0.1	<0.3	106	<0.1	0.17	0.9	3
	CE491-21 avg	**1E avg**			**7.5**	**50.4**	**24**	**<0.04**	**38**	**49**	**1.9**	**<0.1**	**0.5**	**<0.3**	**<0.2**	**20**	**1.7**	**0.5**	**12**	**0.7**	**3.3**	**1.0**	**<1**	**0.9**	**0.1**	**<0.3**	**110**	**<0.1**	**0.20**	**1.1**	**3**
T1-73	CE491-21 rep-1	1E rep-1	0.25 - 2 mm	1 hr	8.3	65.6	27	<0.04	18	52	2.8	<0.1	0.3	<0.3	<0.2	16	2.1	0.5	6.7	0.5	3.8	0.7	<1	0.3	<0.1	<0.3	156	<0.1	0.32	0.7	<1
T1-74	CE491-21 rep-2	1E rep-2			8.1	79.8	24	<0.04	15	56	2.8	<0.1	0.4	<0.3	<0.2	15	2.0	0.5	6.4	0.5	3.6	0.9	<1	0.2	<0.1	<0.3	160	<0.1	0.28	0.5	<1
T1-75	CE491-21 rep-3	1E rep-3			7.8	83.1	23	<0.04	15	54	2.7	<0.1	0.4	<0.3	<0.2	16	1.9	0.5	7.7	0.4	3.6	0.7	<1	0.2	<0.1	<0.3	142	<0.1	0.23	0.6	2
	CE491-21 avg	**1E avg**			**8.1**	**76.1**	**24**	**<0.04**	**16**	**54**	**2.8**	**<0.1**	**0.4**	**<0.3**	**<0.2**	**16**	**2.0**	**0.5**	**6.9**	**0.5**	**3.7**	**0.7**	**<1**	**0.2**	**<0.1**	**<0.3**	**153**	**<0.1**	**0.28**	**0.6**	**2**
T1-84**	CE491-21 rep-1	1E rep-1		4 hr	8.1	80.8	36	<0.04	23	61	3.2	<0.1	0.4	<0.3	<0.2	17	2.3	0.5	6.8	0.5	4.0	0.8	<1	0.4	<0.1	<0.3	170	<0.1	0.36	1.0	<1
T1-85	CE491-21 rep-2	1E rep-2			7.9	85.2	28	<0.04	21	62	3.0	<0.1	0.4	<0.3	<0.2	15	2.1	0.5	6.8	0.6	3.6	0.7	<1	0.3	<0.1	<0.3	163	<0.1	0.35	0.8	<1
T1-86	CE491-21 rep-3	1E rep-3			9.0	41.8	31	<0.04	21	59	2.8	<0.1	0.4	<0.3	0.3	17	2.0	0.5	8.0	0.6	3.5	0.8	<1	0.4	<0.1	<0.3	153	<0.1	0.34	0.6	<1
	CE491-21 avg	**1E avg**			**8.3**	**69.3**	**32**	**<0.04**	**22**	**61**	**3.0**	**<0.1**	**0.4**	**<0.3**	**0.3**	**16**	**2.1**	**0.5**	**7.2**	**0.6**	**3.7**	**0.7**	**<1**	**0.4**	**<0.1**	**<0.3**	**162**	**<0.1**	**0.35**	**0.8**	**<1**
T1-96	CE491-21 rep-1	1E rep-1		24 hr	7.6	51.5	48	<0.04	72	71	3.9	<0.1	0.4	0.7	0.4	17	2.6	0.6	7.3	1.3	4.1	1.2	<1	1.6	0.2	<0.3	226	<0.1	0.55	3.0	<1
T1-97	CE491-21 rep-2	1E rep-2			7.4	51.5	44	<0.04	63	78	3.8	<0.1	0.5	0.9	0.3	16	2.6	0.6	7.3	1.3	4.1	1.0	<1	1.5	0.2	<0.3	236	<0.1	0.62	2.8	4
T1-98	CE491-21 rep-3	1E rep-3			7.5	48.2	36	<0.04	67	74	3.6	<0.1	0.6	0.6	0.4	16	2.4	0.6	9.0	1.2	3.9	1.0	<1	1.6	0.2	<0.3	219	<0.1	0.48	2.5	<1
	CE491-21 avg	**1E avg**			**7.5**	**50.4**	**43**	**<0.04**	**67**	**74**	**3.8**	**<0.1**	**0.5**	**0.7**	**0.4**	**16**	**2.5**	**0.6**	**7.8**	**1.3**	**4.1**	**1.1**	**<1**	**1.5**	**0.2**	**<0.3**	**227**	**<0.1**	**0.55**	**2.8**	**4**
T1-108	CE491-21 rep-1	1E rep-1	<0.21 mm	1 hr	10.9	178	491	<0.04	39	48	17	<0.1	0.5	4.2	3.6	4	4.0	0.5	0.4	3.8	6.4	1.3	<1	0.8	0.2	<0.3	567	<0.1	0.21	5.4	6
T1-109	CE491-21 rep-2	1E rep-2			10.9	230	469	<0.04	39	47	17	<0.1	0.4	4.2	3.3	3	4.0	0.6	0.4	3.8	6.6	1.4	<1	0.8	0.2	<0.3	562	<0.1	0.22	5.6	<1
	CE491-21 avg	**1E avg**			**10.9**	**204**	**480**	**<0.04**	**39**	**48**	**17**	**<0.1**	**0.4**	**4.2**	**3.4**	**4**	**4.0**	**0.5**	**0.4**	**3.8**	**6.5**	**1.3**	**<1**	**0.8**	**0.2**	**<0.3**	**565**	**<0.1**	**0.21**	**5.5**	**6**
T1-120	CE491-21 rep-1	1E rep-1		4 hr	10.7	659	529	<0.04	47	54	19	<0.1	0.4	5.5	3.0	3	4.2	0.3	0.3	4.4	6.6	1.0	<1	1.1	0.3	<0.3	607	<0.1	0.19	6.8	<1
T1-121	CE491-21 rep-2	1E rep-2			10.7	210	500	<0.04	48	52	17	<0.1	0.4	4.5	3.1	3	4.0	0.4	0.3	3.9	6.4	0.9	<1	1.0	0.3	<0.3	586	<0.1	0.24	6.0	7
	CE491-21 avg	**1E avg**			**10.7**	**434**	**515**	**<0.04**	**48**	**53**	**18**	**<0.1**	**0.4**	**5.0**	**3.1**	**3**	**4.1**	**0.4**	**0.3**	**4.1**	**6.5**	**1.0**	**<1**	**1.0**	**0.3**	**<0.3**	**597**	**<0.1**	**0.21**	**6.4**	**7**
T1-132	CE491-21 rep-1	1E rep-1		24 hr	10.9	542	562	<0.04	60	64	25	<0.1	0.4	9.8	3.4	7	5.0	0.2	0.2	7.3	7.4	1.0	<1	1.9	0.4	<0.3	736	<0.1	0.10	11	<1
T1-133	CE491-21 rep-2	1E rep-2			10.9	311	522	<0.04	60	66	25	<0.1	0.4	11	3.4	2	5.2	0.3	<0.2	7.8	8.2	1.0	<1	2.1	0.4	<0.3	769	<0.1	0.12	11	<1
	CE491-21 avg	**1E avg**			**10.9**	**427**	**542**	**<0.04**	**60**	**65**	**25**	**<0.1**	**0.4**	**10**	**3.4**	**4**	**5.1**	**0.2**	**<0.2**	**7.5**	**7.8**	**1.0**	**<1**	**2.0**	**0.4**	**<0.3**	**753**	**<0.1**	**0.11**	**11**	**<1**

Appendix D4. Effect of rock particle size in on substance release

Memo 6 (26 October 2018).

T1-4	CE491-26 rep-1	4B rep-1	>10 mm	1 hr	7.2	36.2	22	<0.04	0.1	3.2	2.5	<0.1	<0.1	<0.3	0.6	18	0.4	0.8	4.3	<0.1	2.0	0.7	<1	<0.1	<0.1	<0.3	16	<0.1	<0.03	0.1	3
T1-5	CE491-26 rep-2	4B rep-2			7.2	35.8	6	<0.04	<0.1	3.6	2.1	<0.1	<0.1	<0.3	0.4	18	0.5	0.8	1.2	<0.1	1.9	<0.2	<1	<0.1	<0.1	<0.3	18	<0.1	<0.03	<0.1	<1
T1-6	CE491-26 rep-3	4B rep-3			7.2	37.4	6	<0.04	<0.1	3.7	2.1	<0.1	<0.1	<0.3	0.5	18	0.4	0.8	1.5	<0.1	1.8	<0.2	<1	<0.1	<0.1	<0.3	16	<0.1	<0.03	0.1	1
	CE491-26 avg	**4B avg**			**7.2**	**36.5**	**11**	**<0.04**	**<0.1**	**3.5**	**2.2**	**<0.1**	**<0.1**	**<0.3**	**0.5**	**18**	**0.5**	**0.8**	**2.3**	**<0.1**	**1.9**	**0.7**	**<1**	**<0.1**	**<0.1**	**<0.3**	**17**	**<0.1**	**<0.03**	**0.1**	**2**
T1-16	CE491-26 rep-1	4B rep-1		4 hr	7.3	51.5	9	<0.04	0.2	3.1	2.7	<0.1	<0.1	<0.3	0.6	17	0.4	0.7	5.9	<0.1	1.8	<0.2	<1	<0.1	<0.1	<0.3	17	<0.1	<0.03	0.2	2
T1-17	CE491-26 rep-2	4B rep-2			7.2	52.7	6	<0.04	0.2	3.6	2.2	<0.1	<0.1	<0.3	0.3	17	0.6	0.7	1.6	<0.1	1.6	0.3	<1	<0.1	<0.1	<0.3	20	<0.1	<0.03	0.1	<1
T1-18	CE491-26 rep-3	4B rep-3			7.2	39.0	6	<0.04	0.2	3.5	2.2	<0.1	<0.1	<0.3	0.3	16	0.4	0.7	2.1	<0.1	1.9	<0.2	<1	<0.1	<0.1	<0.3	15	<0.1	<0.03	0.1	<1
	CE491-26 avg	**4B avg**			**7.3**	**47.7**	**7**	**<0.04**	**0.2**	**3.4**	**2.4**	**<0.1**	**<0.1**	**<0.3**	**0.4**	**17**	**0.5**	**0.7**	**3.2**	**<0.1**	**1.8**	**0.3**	**<1**	**<0.1**	**<0.1**	**<0.3**	**17**	**<0.1**	**<0.03**	**0.1**	**2**
T1-28	CE491-26 rep-1	4B rep-1		24 hr	7.6	45.6	15	<0.04	<0.1	3.5	3.4	<0.1	<0.1	0.4	0.6	17	0.5	0.7	11	<0.1	1.9	0.3	<1	<0.1	<0.1	<0.3	20	<0.1	0.04	0.1	<1
T1-29	CE491-26 rep-2	4B rep-2			7.4	42.7	11	<0.04	0.3	3.7	2.6	<0.1	<0.1	0.5	0.5	18	0.5	0.8	4.1	<0.1	1.9	<0.2	<1	<0.1	<0.1	<0.3	23	<0.1	<0.03	0.1	1
T1-30	CE491-26 rep-3	4B rep-3			7.5	47.1	10	<0.04	0.1	4.6	2.7	<0.1	<0.1	0.6	0.4	17	0.5	0.8	4.9	<0.1	1.9	<0.2	<1	<0.1	<0.1	<0.3	18	<0.1	0.03	0.1	<1
	CE491-26 avg	**4B avg**			**7.5**	**45.1**	**12**	**<0.04**	**0.2**	**3.9**	**2.9**	**<0.1**	**<0.1**	**0.5**	**0.5**	**17**	**0.5**	**0.8**	**6.6**	**<0.1**	**1.9**	**0.3**	**<1**	**<0.1**	**<0.1**	**<0.3**	**20**	**<0.1**	**0.04**	**0.1**	**<1**
T1-40	CE491-26 rep-1	4B rep-1	2-10 mm	1 hr	7.3	43.5	8	<0.04	0.3	4.3	2.2	<0.1	<0.1	<0.3	0.7	18	0.4	0.8	4.5	<0.1	1.5	0.3	<1	<0.1	<0.1	<0.3	19	<0.1	<0.03	<0.1	2
T1-41	CE491-26 rep-2	4B rep-2			7.2	38.5	9	<0.04	0.2	3.8	2.2	<0.1	<0.1	<0.3	0.8	18	0.5	0.7	4.1	<0.1	1.5	0.2	<1	<0.1	<0.1	<0.3	18	<0.1	<0.03	<0.1	2
T1-42	CE491-26 rep-3	4B rep-3			7.2	43.7	206	<0.04	0.2	4.1	2.3	<0.1	<0.1	0.5	1.7	19	0.5	0.7	5.8	<0.1	1.6	0.2	<1	<0.1	<0.1	<0.3	20	<0.1	<0.03	<0.1	14
	CE491-26 avg	**4B avg**			**7.3**	**41.9**	**74**	**<0.04**	**0.3**	**4.1**	**2.2**	**<0.1**	**<0.1**	**0.5**	**1.0**	**18**	**0.4**	**0.7**	**4.8**	**<0.1**	**1.5**	**0.2**	**<1**	**<0.1**	**<0.1**	**<0.3**	**19**	**<0.1**	**<0.03**	**<0.1**	**6**
T1-52	CE491-26 rep-1	4B rep-1		4 hr	7.5	49.9	11	<0.04	0.5	4.7	2.4	<0.1	<0.1	<0.3	<0.2	17	0.5	0.8	5.5	<0.1	1.6	0.2	<1	<0.1	<0.1	<0.3	22	<0.1	<0.03	0.1	<1
T1-53	CE491-26 rep-2	4B rep-2			7.4	41.2	11	<0.04	0.6	4.3	2.5	<0.1	<0.1	<0.3	<0.2	18	0.5	0.8	5.5	<0.1	1.6	0.3	<1	<0.1	<0.1	<0.3	21	<0.1	<0.03	<0.1	<1
T1-54	CE491-26 rep-3	4B rep-3			7.4	41.9	11	<0.04	0.4	4.0	2.6	<0.1	<0.1	<0.3	<0.2	18	0.5	0.8	7.3	<0.1	1.6	0.5	<1	<0.1	<0.1	<0.3	20	<0.1	<0.03	0.2	3
	CE491-26 avg	**4B avg**			**7.4**	**44.3**	**11**	**<0.04**	**0.5**	**4.3**	**2.5**	**<0.1**	**<0.1**	**<0.3**	**<0.2**	**18**	**0.5**	**0.8**	**6.1**	**<0.1**	**1.6**	**0.3**	**<1**	**<0.1**	**<0.1**	**<0.3**	**21**	**<0.1**	**<0.03**	**0.1**	**3**
T1-64	CE491-26 rep-1	4B rep-1		24 hr	7.7	51.3	21	<0.04	1.1	8.3	3.1	<0.1	<0.1	<0.3	<0.2	20	0.5	0.8	8.6	<0.1	1.6	0.4	<1	<0.1	<0.1	<0.3	29	<0.1	<0.03	0.2	4
T1-65	CE491-26 rep-2	4B rep-2			7.7	44.9	21	<0.04	0.9	5.9	3.2	<0.1	<0.1	<0.3	<0.2	20	0.6	0.8	8.7	<0.1	1.6	0.5	<1	<0.1	<0.1	<0.3	27	<0.1	0.04	0.1	3
T1-66	CE491-26 rep-3	4B rep-3			7.7	48.9	25	<0.04	0.6	6.6	3.5	<0.1	<0.1	<0.3	<0.2	20	0.6	0.8	12	<0.1	1.6	0.7	<1	<0.1	<0.1	<0.3	27	<0.1	0.04	0.1	4
	CE491-26 avg	**4B avg**			**7.7**	**48.4**	**23**	**<0.04**	**0.9**	**6.9**	**3.3**	**<0.1**	**<0.1**	**<0.3**	**<0.2**	**20**	**0.6**	**0.8**	**9.7**	**<0.1**	**1.6**	**0.6**	**<1**	**<0.1**	**<0.1**	**<0.3**	**28**	**<0.1**	**0.04**	**0.2**	**4**
T1-76	CE491-26 rep-1	4B rep-1	0.25 - 2 mm	1 hr	9.1	64.3	31	<0.04	0.7	2.0	5.6	<0.1	<0.1	<0.3	<0.2	15	1.2	0.9	14	0.1	1.8	<0.2	<1	<0.1	<0.1	<0.3	28	<0.1	0.06	0.2	<1
T1-77	CE491-26 rep-2	4B rep-2			9.2	73.1	32	<0.04	0.8	1.9	5.6	<0.1	<0.1	<0.3	<0.2	15	1.2	0.8	13	<0.1	1.8	0.2	<1	<0.1	<0.1	<0.3	30	<0.1	0.06	0.3	<1
T1-78	CE491-26 rep-3	4B rep-3			9.1	99.2	33	<0.04	0.7	1.9	5.5	<0.1	<0.1	<0.3	<0.2	15	1.2	0.8	14	0.1	1.8	<0.2	<1	<0.1	<0.1	<0.3	30	<0.1	0.05	0.3	<1
	CE491-26 avg	**4B avg**			**9.1**	**78.9**	**32**	**<0.04**	**0.7**	**1.9**	**5.6**	**<0.1**	**<0.1**	**<0.3**	**<0.2**	**15**	**1.2**	**0.8**	**13**	**0.1**	**1.8**	**<0.2**	**<1**	**<0.1**	**<0.1**	**<0.3**	**29**	**<0.1**	**0.05**	**0.2**	**<1**
T1-87	CE491-26 rep-1	4B rep-1		4 hr	8.9	90.4	41	<0.04	0.6	2.2	5.7	<0.1	<0.1	<0.3	<0.2	15	1.2	0.8	14	<0.1	1.8	<0.2	<1	<0.1	<0.1	<0.3	32	<0.1	0.07	0.3	<1
T1-88	CE491-26 rep-2	4B rep-2			8.9	72.0	45	<0.04	0.9	2.1	5.8	<0.1	<0.1	<0.3	<0.2	14	1.3	0.8	12	<0.1	1.9	<0.2	<1	<0.1	<0.1	<0.3	30	<0.1	0.06	0.3	<1
T1-89	CE491-26 rep-3	4B rep-3			9.3	69.3	48	<0.04	0.6	2.4	5.8	<0.1	<0.1	<0.3	<0.2	15	1.3	0.9	12	<0.1	1.8	<0.2	<1	<0.1	<0.1	<0.3	31	<0.1	0.08	0.3	<1
	CE491-26 avg	**4B avg**			**9.0**	**77.2**	**45**	**<0.04**	**0.7**	**2.2**	**5.8**	**<0.1**	**<0.1**	**<0.3**	**<0.2**	**15**	**1.3**	**0.8**	**13**	**<0.1**	**1.8**	**<0.2**	**<1**	**<0.1**	**<0.1**	**<0.3**	**31**	**<0.1**	**0.07**	**0.3**	**<1**
T1-99	CE491-26 rep-1	4B rep-1		24 hr	7.7	51.3	97	<0.04	1.7	3.4	6.9	<0.1	<0.1	0.3	<0.2	13	1.5	0.9	12	0.2	2.1	<0.2	<1	<0.1	<0.1	<0.3	39	<0.1	0.16	0.9	1
T1-100	CE491-26 rep-2	4B rep-2			7.7	44.9	107	<0.04	2.7	2.7	6.4	<0.1	<0.1	0.4	<0.2	13	1.6	0.9	8.5	0.2	2.1	0.2	<1	<0.1	<0.1	<0.3	35	<0.1	0.15	0.8	<1
T1-101	CE491-26 rep-3	4B rep-3			7.7	48.9	110	<0.04	2.2	3.3	6.9	<0.1	<0.1	0.4	<0.2	12	1.6	0.9	11	0.3	2.3	<0.2	<1	0.1	<0.1	<0.3	36	<0.1	0.16	0.9	<1
	CE491-26 avg	**4B avg**			**7.7**	**48.4**	**105**	**<0.04**	**2.2**	**3.1**	**6.7**	**<0.1**	**<0.1**	**0.3**	**<0.2**	**13**	**1.6**	**0.9**	**10**	**0.3**	**2.2**	**0.2**	**<1**	**<0.1**	**<0.1**	**<0.3**	**37**	**<0.1**	**0.16**	**0.9**	**<1**
T1-111	CE491-26 rep-1	4B rep-1	<0.21 mm	1 hr	11.1	262	818	<0.04	0.7	7.9	20	<0.1	0.1	4.5	2.3	7	1.8	0.3	<0.2	4.2	5.1	0.9	<1	0.3	0.2	<0.3	63	<0.1	<0.03	4.9	5
T1-112	CE491-26 rep-2	4B rep-2			11.1	291	805	<0.04	0.9	7.5	21	<0.1	0.1	5.2	2.7	7	1.7	0.3	0.5	4.2	5.0	0.6	<1	0.3	0.2	<0.3	61	<0.1	<0.03	5.1	2
	CE491-26 avg	**4B avg**			**11.1**	**276**	**811**	**<0.04**	**0.8**	**7.7**	**21**	**<0.1**	**0.1**	**4.8**	**2.5**	**7**	**1.7**	**0.3**	**0.5**	**4.2**	**5.1**	**0.8**	**<1**	**0.3**	**0.2**	**<0.3**	**62**	**<0.1**	**<0.03**	**5.0**	**4**
T1-123	CE491-26 rep-1	4B rep-1		4 hr	10.9	276	935	<0.04	0.7	14	20	<0.1	0.2	5.3	2.4	7	1.8	0.3	<0.2	4.3	5.2	0.5	<1	0.4	0.3	<0.3	64	<0.1	<0.03	5.6	<1
T1-124	CE491-26 rep-2	4B rep-2			10.9	277	898	<0.04	0.9	13	20	<0.1	<0.1	5.1	2.4	7	1.8	0.3	<0.2	4.1	5.0	0.5	<1	0.3	0.3	<0.3	60	<0.1	<0.03	5.0	<1
	CE491-26 avg	**4B avg**			**10.9**	**277**	**917**	**<0.04**	**0.8**	**13**	**20**	**<0.1**	**0.2**	**5.2**	**2.4**	**7**	**1.8**	**0.3**	**<0.2**	**4.2**	**5.1**	**0.5**	**<1**	**0.4**	**0.3**	**<0.3**	**62**	**<0.1**	**<0.03**	**5.3**	**<1**
T1-135	CE491-26 rep-1	4B rep-1		24 hr	11.1	322	981	<0.04	1.0	24	26	<0.1	0.1	11	4.6	7	2.9	0.2	<0.2	7.9	7.1	0.5	<1	0.7	0.6	<0.3	91	<0.1	<0.03	10	<1
T1-136	CE491-26 rep-2	4B rep-2			11.1	289	944	<0.04	1.0	22	24	<0.1	<0.1	11	4.6	7	2.9	0.2	<0.2	8.0	6.7	0.4	<1	0.7	0.6	<0.3	83	<0.1	<0.03	9.9	1
	CE491-26 avg	**4B avg**			**11.1**	**305**	**963**	**<0.04**	**1.0**	**23**	**25**	**<0.1**	**<0.1**	**11**	**4.6**	**7**	**2.9**	**0.2**	**<0.2**	**8.0**	**6.9**	**0.4**	**<1**	**0.7**	**0.6**	**<0.3**	**87**	**<0.1**	**<0.03**	**10**	**<1**

Appendix D4. Effect of rock particle size in on substance release

Memo 6 (26 October 2018).

T1-7	CE491-28 rep-1	5B rep-1	>10 mm	1 hr	7.1	32.1	6	<0.04	0.3	7.8	2.0	0.1	<0.1	<0.3	0.3	18	0.4	0.8	0.4	<0.1	1.9	<0.2	<1	<0.1	<0.1	<0.3	14	<0.1	<0.03	0.1	<1
T1-8	CE491-28 rep-2	5B rep-2			7.2	35.9	5	<0.04	0.3	5.7	2.0	<0.1	<0.1	<0.3	0.4	17	0.4	0.8	0.3	<0.1	1.8	<0.2	<1	<0.1	<0.1	<0.3	16	<0.1	<0.03	<0.1	<1
T1-9	CE491-28 rep-3	5B rep-3			7.1	36.3	8	<0.04	<0.1	6.7	2.0	<0.1	<0.1	<0.3	1.0	19	0.4	0.8	0.5	<0.1	1.8	4.1	<1	<0.1	<0.1	<0.3	15	<0.1	<0.03	<0.1	13
	CE491-28 avg	**5B avg**			**7.1**	**34.8**	**7**	**<0.04**	**0.3**	**6.7**	**2.0**	**<0.1**	**<0.1**	**<0.3**	**0.6**	**18**	**0.4**	**0.8**	**0.4**	**<0.1**	**1.8**	**4.1**	**<1**	**<0.1**	**<0.1**	**<0.3**	**15**	**<0.1**	**<0.03**	**0.1**	**13**
T1-19	CE491-28 rep-1	5B rep-1		4 hr	7.1	45.8	6	<0.04	0.1	9.2	2.0	0.2	<0.1	0.3	0.3	17	0.5	0.7	0.6	<0.1	1.9	<0.2	<1	<0.1	<0.1	<0.3	13	<0.1	<0.03	<0.1	3
T1-20	CE491-28 rep-2	5B rep-2			7.2	37.4	6	<0.04	0.2	6.9	2.1	<0.1	<0.1	0.3	0.3	17	0.5	0.8	0.5	0.1	2.0	<0.2	<1	<0.1	<0.1	<0.3	15	<0.1	<0.03	<0.1	<1
T1-21	CE491-28 rep-3	5B rep-3			7.2	40.9	8	<0.04	0.1	6.8	2.0	<0.1	<0.1	0.4	0.5	17	0.5	0.8	0.6	0.2	1.9	0.5	<1	<0.1	<0.1	<0.3	14	<0.1	0.03	<0.1	14
	CE491-28 avg	**5B avg**			**7.2**	**41.4**	**7**	**<0.04**	**0.1**	**7.6**	**2.0**	**0.2**	**<0.1**	**0.3**	**0.4**	**17**	**0.5**	**0.8**	**0.5**	**0.1**	**1.9**	**0.5**	**<1**	**<0.1**	**<0.1**	**<0.3**	**14**	**<0.1**	**<0.03**	**<0.1**	**8**
T1-31	CE491-28 rep-1	5B rep-1		24 hr	7.3	45.3	11	<0.04	0.1	15	2.0	0.2	<0.1	0.5	0.4	18	0.5	0.8	0.9	0.1	1.9	<0.2	<1	<0.1	<0.1	<0.3	14	<0.1	<0.03	0.2	1
T1-32	CE491-28 rep-2	5B rep-2			7.3	58.9	8	<0.04	0.2	11	2.1	<0.1	<0.1	0.5	0.4	17	0.5	0.9	1.4	0.2	1.9	<0.2	<1	<0.1	<0.1	<0.3	13	<0.1	<0.03	0.1	<1
T1-33	CE491-28 rep-3	5B rep-3			7.3	41.4	6	<0.04	0.2	12	2.0	<0.1	<0.1	0.6	0.3	17	0.5	0.8	1.6	<0.1	2.1	<0.2	<1	<0.1	<0.1	<0.3	14	<0.1	<0.03	0.1	<1
	CE491-28 avg	**5B avg**			**7.3**	**48.5**	**8**	**<0.04**	**0.2**	**13**	**2.0**	**0.2**	**<0.1**	**0.5**	**0.4**	**17**	**0.5**	**0.9**	**1.3**	**0.2**	**2.0**	**<0.2**	**<1**	**<0.1**	**<0.1**	**<0.3**	**14**	**<0.1**	**<0.03**	**0.1**	**<1**
T1-43	CE491-28 rep-1	5B rep-1	2-10 mm	1 hr	7.1	---	7	<0.04	0.3	16	1.8	<0.1	<0.1	<0.3	0.6	18	0.4	0.8	1.7	0.5	1.5	<0.2	<1	<0.1	<0.1	<0.3	13	<0.1	<0.03	0.2	1
T1-44	CE491-28 rep-2	5B rep-2			7.1	41.9	7	<0.04	0.2	20	1.9	<0.1	<0.1	<0.3	0.7	19	0.5	0.8	1.7	0.3	1.5	0.2	<1	<0.1	<0.1	<0.3	13	<0.1	<0.03	<0.1	13
T1-45	CE491-28 rep-3	5B rep-3			7.1	40.6	8	<0.04	0.3	18	1.9	<0.1	<0.1	<0.3	0.6	20	0.4	0.8	1.6	0.3	1.6	<0.2	<1	<0.1	<0.1	<0.3	14	<0.1	<0.03	0.1	4
	CE491-28 avg	**5B avg**			**7.1**	**41.2**	**7**	**<0.04**	**0.3**	**18**	**1.9**	**<0.1**	**<0.1**	**<0.3**	**0.6**	**19**	**0.5**	**0.8**	**1.7**	**0.4**	**1.5**	**0.2**	**<1**	**<0.1**	**<0.1**	**<0.3**	**14**	**<0.1**	**<0.03**	**0.2**	**6**
T1-55	CE491-28 rep-1	5B rep-1		4 hr	7.2	46.1	8	<0.04	0.4	20	1.9	<0.1	<0.1	<0.3	<0.2	19	0.5	0.8	2.6	1.6	1.5	0.4	<1	<0.1	<0.1	<0.3	12	<0.1	0.03	0.1	2
T1-56	CE491-28 rep-2	5B rep-2			7.2	43.9	9	<0.04	0.4	24	1.9	<0.1	<0.1	<0.3	<0.2	21	0.5	0.9	2.7	0.8	1.6	<0.2	<1	<0.1	<0.1	<0.3	13	<0.1	<0.03	0.1	1
T1-57	CE491-28 rep-3	5B rep-3			7.2	46.6	9	<0.04	0.2	25	1.9	<0.1	<0.1	<0.3	<0.2	19	0.5	0.9	2.7	0.8	1.6	0.7	<1	<0.1	<0.1	<0.3	14	<0.1	<0.03	<0.1	4
	CE491-28 avg	**5B avg**			**7.2**	**45.5**	**9**	**<0.04**	**0.3**	**23**	**1.9**	**<0.1**	**<0.1**	**<0.3**	**<0.2**	**20**	**0.5**	**0.9**	**2.7**	**1.0**	**1.6**	**0.5**	**<1**	**<0.1**	**<0.1**	**<0.3**	**13**	**<0.1**	**<0.03**	**0.1**	**2**
T1-67	CE491-28 rep-1	5B rep-1		24 hr	7.4	43.5	12	<0.04	0.5	30	2.0	<0.1	<0.1	<0.3	<0.2	21	0.5	0.9	6.1	3.6	1.6	0.8	<1	<0.1	<0.1	<0.3	12	<0.1	0.04	0.1	4
T1-68	CE491-28 rep-2	5B rep-2			7.3	47.0	13	<0.04	0.7	36	2.0	<0.1	<0.1	<0.3	<0.2	21	0.6	0.9	4.2	2.2	1.8	0.2	<1	<0.1	<0.1	<0.3	13	<0.1	0.03	0.2	<1
T1-69	CE491-28 rep-3	5B rep-3			7.3	73.7	13	<0.04	0.5	36	2.0	<0.1	<0.1	<0.3	<0.2	21	0.5	0.9	5.0	2.7	1.7	0.2	<1	<0.1	<0.1	<0.3	12	<0.1	0.04	0.2	<1
	CE491-28 avg	**5B avg**			**7.3**	**54.7**	**13**	**<0.04**	**0.6**	**34**	**2.0**	**<0.1**	**<0.1**	**<0.3**	**<0.2**	**21**	**0.5**	**0.9**	**5.1**	**2.8**	**1.7**	**0.4**	**<1**	**<0.1**	**<0.1**	**<0.3**	**12**	**<0.1**	**0.04**	**0.2**	**4**
T1-79	CE491-28 rep-1	5B rep-1	0.25 - 2 mm	1 hr	9.3	87.3	39	<0.04	0.7	30	5.5	<0.1	<0.1	<0.3	<0.2	17	1.1	1.0	1.1	2.0	2.0	0.2	<1	<0.1	<0.1	<0.3	20	<0.1	0.06	0.5	<1
T1-80	CE491-28 rep-2	5B rep-2			9.1	67.0	30	<0.04	0.5	30	5.1	<0.1	<0.1	<0.3	<0.2	15	1.0	1.0	1.1	1.5	1.9	<0.2	<1	<0.1	<0.1	<0.3	19	<0.1	0.05	0.4	<1
T1-81	CE491-28 rep-3	5B rep-3			9.1	67.0	34	<0.04	0.4	29	5.1	<0.1	<0.1	<0.3	0.5	18	0.9	1.0	1.3	1.6	1.9	<0.2	<1	<0.1	<0.1	<0.3	18	<0.1	0.06	0.3	<1
	CE491-28 avg	**5B avg**			**9.2**	**73.8**	**34**	**<0.04**	**0.5**	**29**	**5.2**	**<0.1**	**<0.1**	**<0.3**	**0.5**	**17**	**1.0**	**1.0**	**1.2**	**1.7**	**1.9**	**<0.2**	**<1**	**<0.1**	**<0.1**	**<0.3**	**19**	**<0.1**	**0.06**	**0.4**	**<1**
T1-90	CE491-28 rep-1	5B rep-1		4 hr	9.1	71.7	54	<0.04	0.4	33	6.0	<0.1	<0.1	0.5	<0.2	17	1.2	1.1	1.0	3.1	2.1	0.8	<1	<0.1	<0.1	<0.3	20	<0.1	0.08	0.5	22
T1-91	CE491-28 rep-2	5B rep-2			7.1	76.1	44	<0.04	0.5	31	5.4	<0.1	<0.1	<0.3	<0.2	17	1.0	1.0	1.3	1.7	2.0	0.8	<1	<0.1	<0.1	<0.3	20	<0.1	0.07	0.5	5
T1-92	CE491-28 rep-3	5B rep-3			9.7	68.4	47	<0.04	0.4	33	5.6	<0.1	<0.1	<0.3	<0.2	17	1.1	1.1	1.2	2.5	2.0	0.6	<1	<0.1	<0.1	<0.3	20	<0.1	0.07	0.5	10
	CE491-28 avg	**5B avg**			**8.6**	**72.1**	**48**	**<0.04**	**0.4**	**32**	**5.7**	**<0.1**	**<0.1**	**<0.3**	**<0.2**	**17**	**1.1**	**1.1**	**1.2**	**2.4**	**2.0**	**0.7**	**<1**	**<0.1**	**<0.1**	**<0.3**	**20**	**<0.1**	**0.07**	**0.5**	**12**
T1-102	CE491-28 rep-1	5B rep-1		24 hr	7.4	43.5	104	<0.04	1.7	53	7.9	<0.1	<0.1	1.5	0.3	15	1.5	1.2	1.0	7.0	2.3	0.3	<1	0.3	0.1	<0.3	26	<0.1	0.15	1.8	<1
T1-103	CE491-28 rep-2	5B rep-2			7.3	47.0	93	<0.04	1.4	53	6.7	<0.1	<0.1	1.1	0.3	17	1.3	1.3	1.5	6.6	2.3	0.3	<1	0.2	<0.1	<0.3	21	<0.1	0.18	1.3	<1
T1-104	CE491-28 rep-3	5B rep-3			7.3	73.7	92	<0.04	2.0	52	7.4	<0.1	<0.1	1.4	0.4	15	1.4	1.3	1.2	6.9	2.2	0.4	<1	0.3	<0.1	<0.3	24	<0.1	0.19	1.5	<1
	CE491-28 avg	**5B avg**			**7.3**	**54.7**	**96**	**<0.04**	**1.7**	**53**	**7.4**	**<0.1**	**<0.1**	**1.3**	**0.4**	**16**	**1.4**	**1.3**	**1.2**	**6.8**	**2.3**	**0.3**	**<1**	**0.3**	**<0.1**	**<0.3**	**24**	**<0.1**	**0.17**	**1.5**	**<1**
T1-114	CE491-28 rep-1	5B rep-1	<0.21 mm	1 hr	11.1	315	638	<0.04	1.2	20	23	<0.1	<0.1	5.4	2.6	4	3.9	0.4	<0.2	8.3	7.3	0.7	<1	0.4	0.1	<0.3	65	<0.1	0.04	4.1	<1
T1-115	CE491-28 rep-2	5B rep-2			11.0	219	625	<0.04	1.5	20	24	<0.1	0.1	5.5	3.2	4	4.0	0.4	<0.2	7.9	7.6	0.7	<1	0.3	<0.1	<0.3	66	<0.1	0.03	4.7	<1
	CE491-28 avg	**5B avg**			**11.0**	**267**	**632**	**<0.04**	**1.3**	**20**	**23**	**<0.1**	**<0.1**	**5.5**	**2.9**	**4**	**4.0**	**0.4**	**<0.2**	**8.1**	**7.4**	**0.7**	**<1**	**0.3**	**0.1**	**<0.3**	**65**	**<0.1**	**0.03**	**4.4**	**<1**
T1-126	CE491-28 rep-1	5B rep-1		4 hr	10.9	304	761	<0.04	1.6	25	22	<0.1	0.1	6.4	2.6	8	4.3	0.3	<0.2	9.2	7.7	0.6	<1	0.4	0.1	<0.3	68	<0.1	<0.03	5.2	1
T1-127	CE491-28 rep-2	5B rep-2			10.0	830	754	<0.04	1.6	26	23	<0.1	<0.1	6.3	2.6	4	4.4	0.3	<0.2	9.4	7.9	0.6	<1	0.5	0.2	<0.3	68	<0.1	0.03	5.1	4
	CE491-28 avg	**5B avg**			**10.4**	**567**	**757**	**<0.04**	**1.6**	**26**	**22**	**<0.1**	**<0.1**	**6.3**	**2.6**	**6**	**4.3**	**0.3**	**<0.2**	**9.3**	**7.8**	**0.6**	**<1**	**0.4**	**0.2**	**<0.3**	**68**	**<0.1**	**<0.03**	**5.1**	**3**
T1-138	CE491-28 rep-1	5B rep-1		24 hr	11.1	382	813	<0.04	2.3	41	25	<0.1	0.1	13	3.8	5	6.2	0.2	<0.2	17	9.2	0.5	<1	0.8	0.2	<0.3	86	<0.1	<0.03	9.1	<1
T1-139	CE491-28 rep-2	5B rep-2			11.0	823	811	<0.04	2.3	36	26	<0.1	<0.1	13	4.2	5	6.1	0.2	<0.2	18	9.4	0.5	<1	0.8	0.2	<0.3	90	<0.1	<0.03	9.2	<1
	CE491-28 avg	**5B avg**			**11.1**	**603**	**812**	**<0.04**	**2.3**	**39**	**25**	**<0.1**	**<0.1**	**13**	**4.0**	**5**	**6.2**	**0.2**	**<0.2**	**17**	**9.3**	**0.5**	**<1**	**0.8**	**0.2**	**<0.3**	**88**	**<0.1**	**<0.03**	**9.2**	**<1**

Appendix D4. Effect of rock particle size in on substance release

Memo 6 (26 October 2018).

T1-10	CE491-29 rep-1	5E rep-1	>10 mm	1 hr	7.2	43.3	6	<0.04	0.2	3.9	2.3	<0.1	<0.1	<0.3	0.4	17	0.4	0.7	0.8	<0.1	1.8	<0.2	<1	<0.1	<0.1	<0.3	15	<0.1	<0.03	<0.1	<1
T1-11	CE491-29 rep-2	5E rep-2			7.2	48.5	10	<0.04	0.2	4.0	2.0	<0.1	<0.1	<0.3	0.4	17	0.4	0.8	0.3	0.1	1.8	<0.2	<1	<0.1	<0.1	<0.3	14	<0.1	<0.03	0.2	1
T1-12	CE491-29 rep-3	5E rep-3			7.2	37.3	5	<0.04	<0.1	4.0	2.2	<0.1	<0.1	<0.3	0.5	17	0.4	0.8	0.9	0.1	1.8	<0.2	<1	<0.1	<0.1	<0.3	14	<0.1	<0.03	0.1	<1
	CE491-29 avg	**5E avg**			**7.2**	**43.0**	**7**	**<0.04**	**0.2**	**3.9**	**2.2**	**<0.1**	**<0.1**	**<0.3**	**0.4**	**17**	**0.4**	**0.8**	**0.7**	**0.1**	**1.8**	**<0.2**	**<1**	**<0.1**	**<0.1**	**<0.3**	**15**	**<0.1**	**<0.03**	**0.1**	**<1**
T1-22	CE491-29 rep-1	5E rep-1		4 hr	7.3	39.1	11	<0.04	<0.1	3.4	2.4	<0.1	<0.1	0.3	0.3	17	0.4	0.7	1.1	<0.1	1.7	<0.2	<1	<0.1	<0.1	<0.3	15	<0.1	<0.03	<0.1	1
T1-23	CE491-29 rep-2	5E rep-2			7.2	35.9	7	<0.04	0.3	3.9	2.1	<0.1	<0.1	0.5	0.4	16	0.5	0.8	0.3	<0.1	1.8	0.4	<1	<0.1	<0.1	<0.3	16	<0.1	<0.03	0.2	1
T1-24	CE491-29 rep-3	5E rep-3			7.3	40.9	10	<0.04	0.2	3.9	2.4	<0.1	<0.1	0.3	0.4	18	0.4	0.7	1.2	<0.1	1.9	<0.2	<1	<0.1	<0.1	<0.3	15	<0.1	<0.03	0.1	2
	CE491-29 avg	**5E avg**			**7.2**	**38.6**	**9**	**<0.04**	**0.3**	**3.8**	**2.3**	**<0.1**	**<0.1**	**0.4**	**0.4**	**17**	**0.4**	**0.8**	**0.9**	**<0.1**	**1.8**	**<0.2**	**<1**	**<0.1**	**<0.1**	**<0.3**	**15**	**<0.1**	**<0.03**	**0.2**	**2**
T1-34	CE491-29 rep-1	5E rep-1		24 hr	7.5	51.7	13	<0.04	0.2	3.0	3.1	<0.1	<0.1	0.6	0.4	17	0.4	0.8	2.6	<0.1	1.9	<0.2	<1	<0.1	<0.1	<0.3	16	<0.1	<0.03	0.2	<1
T1-35	CE491-29 rep-2	5E rep-2			7.3	41.2	10	<0.04	0.3	3.3	2.2	<0.1	<0.1	0.6	0.4	17	0.4	0.8	0.6	<0.1	1.9	0.2	<1	<0.1	<0.1	<0.3	15	<0.1	<0.03	0.1	5
T1-36	CE491-29 rep-3	5E rep-3			7.5	44.1	12	<0.04	0.1	3.2	3.0	<0.1	<0.1	0.4	0.5	18	0.4	0.8	2.1	<0.1	1.9	<0.2	<1	<0.1	<0.1	<0.3	15	<0.1	<0.03	0.2	2
	CE491-29 avg	**5E avg**			**7.4**	**45.7**	**11**	**<0.04**	**0.2**	**3.2**	**2.8**	**<0.1**	**<0.1**	**0.5**	**0.4**	**17**	**0.4**	**0.8**	**1.8**	**<0.1**	**1.9**	**<0.2**	**<1**	**<0.1**	**<0.1**	**<0.3**	**16**	**<0.1**	**<0.03**	**0.1**	**4**
T1-46	CE491-29 rep-1	5E rep-1	2-10 mm	1 hr	7.3	40.0	10	<0.04	<0.1	3.5	2.5	<0.1	<0.1	<0.3	0.6	18	0.4	0.8	2.1	<0.1	1.5	<0.2	<1	<0.1	<0.1	<0.3	15	<0.1	<0.03	0.1	3
T1-47	CE491-29 rep-2	5E rep-2			7.2	39.6	8	<0.04	<0.1	3.3	2.4	<0.1	<0.1	0.4	0.6	18	0.4	0.7	2.1	<0.1	1.5	0.2	<1	<0.1	<0.1	<0.3	17	<0.1	<0.03	0.1	3
T1-48	CE491-29 rep-3	5E rep-3			7.2	40.0	7	<0.04	0.1	3.6	2.4	<0.1	<0.1	0.3	0.7	17	0.4	0.7	1.7	<0.1	1.6	0.3	<1	<0.1	<0.1	<0.3	15	<0.1	<0.03	0.1	2
	CE491-29 avg	**5E avg**			**7.2**	**39.8**	**9**	**<0.04**	**<0.1**	**3.5**	**2.4**	**<0.1**	**<0.1**	**0.3**	**0.6**	**18**	**0.4**	**0.7**	**2.0**	**<0.1**	**1.5**	**0.3**	**<1**	**<0.1**	**<0.1**	**<0.3**	**16**	**<0.1**	**<0.03**	**0.1**	**3**
T1-58	CE491-29 rep-1	5E rep-1		4 hr	7.4	46.8	12	<0.04	<0.1	3.3	2.7	<0.1	<0.1	<0.3	<0.2	18	0.5	0.8	2.5	<0.1	1.5	0.3	<1	<0.1	<0.1	<0.3	16	<0.1	<0.03	0.1	<1
T1-59	CE491-29 rep-2	5E rep-2			7.4	52.0	12	<0.04	<0.1	3.1	2.8	<0.1	<0.1	<0.3	<0.2	19	0.4	0.8	2.5	<0.1	1.6	0.5	<1	<0.1	<0.1	<0.3	17	<0.1	<0.03	0.2	4
T1-60	CE491-29 rep-3	5E rep-3			7.4	40.3	11	<0.04	0.1	3.4	2.6	<0.1	<0.1	<0.3	<0.2	19	0.4	0.8	2.0	<0.1	1.5	<0.2	<1	<0.1	<0.1	<0.3	15	<0.1	<0.03	<0.1	1
	CE491-29 avg	**5E avg**			**7.4**	**46.3**	**12**	**<0.04**	**<0.1**	**3.2**	**2.7**	**<0.1**	**<0.1**	**<0.3**	**<0.2**	**19**	**0.4**	**0.8**	**2.3**	**<0.1**	**1.5**	**0.4**	**<1**	**<0.1**	**<0.1**	**<0.3**	**16**	**<0.1**	**<0.03**	**0.2**	**3**
T1-70	CE491-29 rep-1	5E rep-1		24 hr	7.7	58.7	24	<0.04	0.1	2.8	3.8	0.1	<0.1	<0.3	<0.2	20	0.5	0.7	4.2	<0.1	1.6	0.3	<1	<0.1	<0.1	<0.3	17	<0.1	<0.03	0.3	<1
T1-71	CE491-29 rep-2	5E rep-2			7.7	53.1	27	<0.04	0.2	2.8	3.9	<0.1	<0.1	<0.3	<0.2	20	0.5	0.7	4.3	<0.1	1.7	0.2	<1	<0.1	<0.1	<0.3	17	<0.1	<0.03	0.4	1
T1-72	CE491-29 rep-3	5E rep-3			7.8	59.3	28	<0.04	0.2	2.8	4.1	<0.1	<0.1	<0.3	<0.2	21	0.4	0.8	4.5	<0.1	1.8	0.2	<1	<0.1	<0.1	<0.3	17	<0.1	<0.03	0.3	<1
	CE491-29 avg	**5E avg**			**7.7**	**57.0**	**26**	**<0.04**	**0.2**	**2.8**	**3.9**	**<0.1**	**<0.1**	**<0.3**	**<0.2**	**20**	**0.5**	**0.7**	**4.3**	**<0.1**	**1.7**	**0.2**	**<1**	**<0.1**	**<0.1**	**<0.3**	**17**	**<0.1**	**<0.03**	**0.3**	**<1**
T1-82	CE491-29 rep-1	5E rep-1	0.25 - 2 mm	1 hr	9.3	58.7	48	<0.04	0.2	3.9	6.1	<0.1	<0.1	<0.3	<0.2	18	0.6	0.7	1.4	0.2	1.8	<0.2	<1	<0.1	<0.1	<0.3	21	<0.1	<0.03	0.5	<1
T1-83	CE491-29 rep-2	5E rep-2			9.0	72.7	30	<0.04	0.3	3.5	5.8	<0.1	<0.1	<0.3	<0.2	18	0.5	0.8	3.1	0.1	1.7	0.2	<1	<0.1	<0.1	<0.3	21	<0.1	<0.03	0.2	<1
T1-84	CE491-29 rep-3	5E rep-3			9.1	77.6	38	<0.04	0.5	4.1	5.9	<0.1	<0.1	<0.3	<0.2	18	0.5	0.8	2.3	0.2	1.8	<0.2	<1	<0.1	<0.1	<0.3	21	<0.1	<0.03	0.3	<1
	CE491-29 avg	**5E avg**			**9.1**	**69.7**	**38**	**<0.04**	**0.3**	**3.8**	**5.9**	**<0.1**	**<0.1**	**<0.3**	**<0.2**	**18**	**0.5**	**0.7**	**2.3**	**0.2**	**1.8**	**<0.2**	**<1**	**<0.1**	**<0.1**	**<0.3**	**21**	**<0.1**	**<0.03**	**0.4**	**<1**
T1-93	CE491-29 rep-1	5E rep-1		4 hr	8.9	71.5	65	<0.04	0.2	5.3	6.7	<0.1	<0.1	<0.3	<0.2	18	0.5	0.7	1.5	0.3	2.0	0.6	<1	<0.1	<0.1	<0.3	25	<0.1	<0.03	0.6	3
T1-94	CE491-29 rep-2	5E rep-2			8.8	97.5	44	<0.04	0.2	4.7	6.2	<0.1	<0.1	<0.3	<0.2	18	0.5	0.8	2.9	0.2	1.8	0.6	<1	<0.1	<0.1	<0.3	22	<0.1	<0.03	0.5	5
T1-95	CE491-29 rep-3	5E rep-3			9.0	76.4	54	<0.04	0.3	4.9	6.5	<0.1	<0.1	<0.3	<0.2	18	0.5	0.8	2.4	0.2	2.0	0.6	<1	<0.1	<0.1	<0.3	22	<0.1	<0.03	0.5	4
	CE491-29 avg	**5E avg**			**8.9**	**81.8**	**54**	**<0.04**	**0.2**	**5.0**	**6.5**	**<0.1**	**<0.1**	**<0.3**	**<0.2**	**18**	**0.5**	**0.8**	**2.3**	**0.2**	**1.9**	**0.6**	**<1**	**<0.1**	**<0.1**	**<0.3**	**23**	**<0.1**	**<0.03**	**0.5**	**4**
T1-105	CE491-29 rep-1	5E rep-1		24 hr	7.7	58.7	133	<0.04	0.7	8.9	8.6	<0.1	<0.1	1.0	0.4	17	0.7	0.7	1.7	0.8	2.6	0.3	<1	0.2	0.2	<0.3	29	<0.1	0.03	2.3	<1
T1-106	CE491-29 rep-2	5E rep-2			7.7	53.1	101	<0.04	0.5	9.8	8.0	<0.1	<0.1	0.6	0.3	19	0.6	0.8	3.9	0.5	2.2	0.2	<1	0.1	0.1	<0.3	28	<0.1	<0.03	1.2	<1
T1-107	CE491-29 rep-3	5E rep-3			7.8	59.3	107	<0.04	0.6	6.8	7.9	<0.1	<0.1	0.9	0.2	18	0.6	0.7	2.9	0.6	2.2	0.4	<1	0.1	0.1	<0.3	27	<0.1	<0.03	1.6	<1
	CE491-29 avg	**5E avg**			**7.7**	**57.0**	**114**	**<0.04**	**0.6**	**8.5**	**8.2**	**<0.1**	**<0.1**	**0.8**	**0.3**	**18**	**0.6**	**0.7**	**2.8**	**0.6**	**2.4**	**0.3**	**<1**	**0.1**	**0.1**	**<0.3**	**28**	**<0.1**	**<0.03**	**1.7**	**<1**
T1-117	CE491-29 rep-1	5E rep-1	<0.21 mm	1 hr	10.2	142	190	<0.04	1.9	2.0	7.9	0.1	<0.1	1.8	1.7	6	4.2	0.7	0.3	1.1	3.1	0.4	<1	0.1	<0.1	<0.3	28	<0.1	0.05	1.9	3
T1-118	CE491-29 rep-2	5E rep-2			10.2	149	179	<0.04	2.4	1.9	8.1	<0.1	<0.1	1.8	1.6	9	4.2	0.7	0.3	1.1	3.2	0.2	<1	0.1	<0.1	<0.3	26	<0.1	0.06	2.0	2
	CE491-29 avg	**5E avg**			**10.2**	**145**	**185**	**<0.04**	**2.1**	**2.0**	**8.0**	**<0.1**	**<0.1**	**1.8**	**1.6**	**8**	**4.2**	**0.7**	**0.3**	**1.1**	**3.2**	**0.3**	**<1**	**0.1**	**<0.1**	**<0.3**	**27**	**<0.1**	**0.06**	**2.0**	**2**
T1-129	CE491-29 rep-1	5E rep-1		4 hr	9.9	184	346	<0.04	2.5	2.3	7.7	<0.1	<0.1	1.8	1.3	5	4.4	0.7	0.2	1.3	3.3	0.3	<1	0.1	<0.1	<0.3	26	<0.1	0.07	2.3	<1
T1-130	CE491-29 rep-2	5E rep-2			10.0	164	342	<0.04	2.4	2.2	7.6	<0.1	<0.1	1.7	1.2	5	4.3	0.7	0.2	1.2	3.1	0.3	<1	0.1	<0.1	<0.3	25	<0.1	0.07	2.2	7
	CE491-29 avg	**5E avg**			**9.9**	**174**	**344**	**<0.04**	**2.4**	**2.2**	**7.7**	**<0.1**	**<0.1**	**1.8**	**1.2**	**5**	**4.3**	**0.7**	**0.2**	**1.3**	**3.2**	**0.3**	**<1**	**0.1**	**<0.1**	**<0.3**	**26**	**<0.1**	**0.07**	**2.2**	**7**
T1-141	CE491-29 rep-1	5E rep-1		24 hr	10.0	115	542	<0.04	3.6	2.7	8.3	<0.1	<0.1	3.1	1.4	4	5.3	0.7	0.3	2.1	4.0	0.3	<1	0.4	<0.1	<0.3	29	<0.1	0.09	5.3	<1
T1-142	CE491-29 rep-2	5E rep-2			10.0	136	535	<0.04	4.9	3.5	8.0	<0.1	<0.1	3.7	1.5	5	5.7	0.7	<0.2	2.6	4.1	<0.2	<1	0.5	<0.1	<0.3	29	<0.1	0.09	6.4	<1
	CE491-29 avg	**5E avg**			**10.0**	**125**	**539**	**<0.04**	**4.2**	**3.1**	**8.1**	**<0.1**	**<0.1**	**3.4**	**1.5**	**5**	**5.5**	**0.7**	**0.3**	**2.3**	**4.1**	**0.3**	**<1**	**0.5**	**<0.1**	**<0.3**	**29**	**<0.1**	**0.09**	**5.9**	**<1**
LOD (3σ)	---	---	---	---	---	---	1	0.04	0.1	0.1	0.1	0.1	0.1	0.3	0.2	1	0.1	0.1	0.2	0.1	0.3	0.2	1	0.1	0.1	0.3	1	0.1	0.03	0.1	1
Method Code	---	---	---	---	C-240	C-255	C-209	C-209	C-209	C-209	C-229	C-209	C-209	C-209	C-209	C-209	C-229	C-229	C-209	C-209	C-229	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209

Appendix D4. Effect of rock particle size in on substance release
Memo 6 (26 October 2018).

Spike Recoveries

							Ag	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sn	Sr	Th	U	V	Zn
Sample Name	**Sample ID**	**Sample Desc.**	**Particle Size**	**Time**	**---**	**---**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
T1-10	CE491-29 rep-1	5E rep-1	>10 mm	1 hr	---	---	96	102	99	99	112	102	99	99	100	101	100	99	101	97	101	99	99	96	101	97	103	104	100	100	102
T1-20	CE491-28 rep-2	5B rep-2	>10 mm	4 hr	---	---	95	95	94	98	112	96	97	96	97	95	99	97	97	98	95	97	99	97	94	98	101	104	99	99	101
T1-30	CE491-26 rep-3	4B rep-3	>10 mm	24 hr	---	---	94	99	94	95	114	101	93	96	95	100	100	101	101	98	103	95	98	95	101	98	98	101	98	94	96
T1-40	CE491-26 rep-1	4B rep-1	2-10 mm	1 hr	---	---	93	91	95	99	108	92	98	96	97	92	103	102	92	95	104	99	96	94	91	94	99	99	96	96	95
T1-50	CE491-21 rep-2	1E rep-2	2-10 mm	4 hr	---	---	95	97	96	92	85	96	93	93	95	95	88	84	96	98	84	94	98	96	93	98	96	102	98	92	93
T1-60	CE491-29 rep-3	5E rep-3	2-10 mm	4 hr	---	---	96	95	96	97	101	96	97	95	97	96	98	99	96	97	104	97	99	97	93	100	99	103	97	94	94
T1-70	CE491-29 rep-1	5E rep-1	2-10 mm	24 hr	---	---	95	96	97	97	104	96	98	97	97	96	98	101	97	99	103	96	98	96	94	99	101	101	96	96	100
T1-80	CE491-28 rep-2	5B rep-2	0.25 - 2 mm	1 hr	---	---	95	99	97	98	102	99	97	97	98	100	97	98	99	99	102	96	98	96	96	99	99	99	96	95	95
T1-84	CE491-29 rep-3	5E rep-3	0.25 - 2 mm	1 hr	---	---	95	96	100	98	103	97	98	98	99	97	100	99	97	100	101	97	98	95	95	98	100	101	98	97	95
T1-90	CE491-28 rep-1	5B rep-1	0.25 - 2 mm	4 hr	---	---	94	94	95	99	97	95	97	96	99	96	100	96	96	98	101	96	98	95	93	98	101	101	97	98	87
T1-109	CE491-21 rep-2	1E rep-2	<0.21 mm	1 hr	---	---	103	103	92	96	115	94	95	95	94	94	103	100	94	96	105	93	107	105	90	107	94	110	109	95	92
T1-106	CE491-29 rep-2	5E rep-2	0.25 - 2 mm	24 hr	---	---	95	93	96	97	103	97	97	98	100	96	101	99	95	99	100	97	98	96	95	99	104	103	98	97	99
T1-124	CE491-26 rep-2	4B rep-2	<0.21 mm	4 hr	---	---	91	89	88	95	126	92	94	94	95	94	103	102	93	94	110	93	94	92	90	97	98	99	95	95	94

Certified Reference Materials

							Ag	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sn	Sr	Th	U	V	Zn
Sample Name	---	---	---	---	---	---	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**mg/L**	**µg/L**	**µg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
TM24.4 (n=3)	---	---	---	---	---	---	---	32.7	4.96	14.7	---	3.83	6.54	4.98	6.65	15.2	---	---	7.99	6.13	---	5.16	5.70	---	3.39	3.72	116	---	4.23	6.91	---
Certified Value	---	---	---	---	---	---	---	32.9 ± 4.5	5.30 ± 0.53	15.0 ± 1.0	---	3.96 ± 0.34	6.27 ± 0.57	5.00 ± 0.59	6.31 ± 0.60	16.0 ± 2.3	---	---	8.24 ± 0.73	6.30 ± 0.56	---	5.03 ± 0.53	5.60 ± 0.52	---	3.56 ± 0.58	3.72 ± 0.39	113 ± 8	---	4.24 ± 0.34	7.00 ± 0.58	---
Recovery (%)	---	---	---	---	---	---	---	99	94	98	---	97	104	100	105	95	---	---	97	97	---	103	102	---	95	100	103	---	100	99	---
TMDA64.3 (n=3)	---	---	---	---	---	---	11.9	291	156	281	---	247	247	274	257	281	---	---	276	279	---	245	276	121	142	267	633	---	131	273	324
Certified Value	---	---	---	---	---	---	12.6 ± 1.3	291 ± 23	164 ± 15	287 ± 18	---	258 ± 21	250 ± 16	283 ± 17	261 ± 18	298 ± 21	---	---	292 ± 17	286 ± 21	---	252 ± 18	280 ± 22	124 ± 11	154 ± 22	281 ± 25	628 ± 34	---	135 ± 11	279 ± 18	320 ± 23
Recovery (%)	---	---	---	---	---	---	94	100	95	98	---	96	99	97	99	94	---	---	95	97	---	97	99	98	92	95	101	---	97	98	101

Method Codes:

C-209: ICP-MS

C-229: ICP-AES

C-240: Determination of pH

C-255: Conductivity

Appendix D4. Effect of rock particle size in on substance release

Memo 8 (5 November 2018)

Notes

Composite Talbingo reservoir water used as leachate solution.

Size categories 150-210, 63-150 and <63 µm (composite fine material).

L/S of 1000 (1 g/L) and measurement made 24 h after resuspension then settling in Talbingo reservoir water.

				pH	Conductivity	Ag	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sn	Sr	Th	U	V	Zn
Sample ID	**Sample Description**	**Liquid:Solid**	**Time (hr)**		**µS/cm**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**mg/L**	**µg/L**	**µg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
CE491-45	CE491-21 (1E < 63 µm)	1000:1	24	9.7	53	<0.01	165	4.0	35	7.9	<0.04	<0.1	0.8	1	9	0.7	0.82	0.9	0.4	2.2	<1	<0.2	0.2	0.07	0.2	70	0.02	0.10	1.1	<1
CE491-46	CE491-21 (1E 63 - 150 µm)	1000:1	24	9.3	99	<0.01	84	4.2	34	6.0	<0.04	<0.1	0.4	1	13	0.7	0.85	2.3	0.4	2.1	<1	<0.2	<0.2	0.04	0.2	63	<0.01	0.096	0.8	<1
CE491-47	CE491-21 (1E 150-210 µm)	1000:1	24	7.8	38	<0.01	21	3.9	34	3.5	<0.04	0.2	0.2	<1	15	0.6	0.89	9.2	0.2	2.0	<1	<0.2	<0.2	0.03	<0.1	54	<0.01	0.056	0.4	2
CE491-48	CE491-26 (4B < 63 µm)	1000:1	24	9.1	76	<0.01	101	0.3	2.6	6.5	<0.04	<0.1	0.2	<1	8	0.8	0.91	13	0.1	2.0	<1	<0.2	<0.2	0.05	<0.1	23	<0.01	0.041	0.4	<1
CE491-49	CE491-26 (4B < 63 µm dup)	1000:1	24	9.0	56	<0.01	103	0.6	2.8	6.8	<0.04	<0.1	0.2	<1	9	0.8	0.93	13	0.2	2.1	<1	<0.2	<0.2	0.03	<0.1	26	<0.01	0.043	0.4	<1
CE491-50	CE491-26 (4B 63 - 150 µm)	1000:1	24	8.7	49	<0.01	55	0.3	1.8	5.8	<0.04	<0.1	<0.1	<1	10	0.6	0.80	23	<0.1	2.1	<1	<0.2	<0.2	<0.02	<0.1	20	<0.01	0.036	0.3	<1
CE491-51	CE491-26 (4B 63 - 150 µm Dup)	1000:1	24	8.7	45	<0.01	57	0.3	2.1	5.8	<0.04	<0.1	0.1	<1	10	0.6	0.71	23	<0.1	1.6	<1	<0.2	<0.2	0.03	<0.1	19	<0.01	0.030	0.2	<1
CE491-52	CE491-26 (4B 150-210 µm)	1000:1	24	7.1	39	<0.01	32	0.2	2.0	4.5	<0.04	<0.1	<0.1	<1	10	0.5	0.70	27	<0.1	1.5	<1	<0.2	<0.2	<0.02	<0.1	17	<0.01	0.019	0.2	<1
CE491-53	CE491-26 (4B 150-210 µm Dup)	1000:1	24	8.2	41	<0.01	37	0.2	1.8	4.9	<0.04	<0.1	<0.1	<1	10	0.5	0.71	27	<0.1	1.5	<1	<0.2	<0.2	<0.02	<0.1	18	<0.01	0.033	0.2	<1
CE491-54	CE491-29 (5E < 63 µm)	1000:1	24	9.7	65	<0.01	229	0.8	12	8.4	<0.04	<0.1	0.6	<1	4	0.5	0.65	0.4	0.5	1.6	<1	<0.2	<0.2	0.06	<0.1	27	<0.01	0.041	1.3	<1
CE491-55	CE491-29 (5E 63 - 150 µm)	1000:1	24	9.5	56	<0.01	140	0.5	6.7	7.0	<0.04	<0.1	0.3	<1	7	0.4	0.63	1.0	0.4	1.5	<1	<0.2	<0.2	0.05	<0.1	21	<0.01	0.034	0.7	<1
CE491-56	CE491-29 (5E 150-210 µm)	1000:1	24	8.5	42	<0.01	41	0.4	3.2	5.0	<0.04	<0.1	0.1	<1	10	0.4	0.66	5.4	0.1	1.4	<1	<0.2	<0.2	<0.02	<0.1	17	<0.01	0.017	0.3	1
T3-31						<0.01	76	1.0	1.1		<0.04	<0.1	<0.1	<1	8			7.7	<0.1		<1	<0.2	<0.2	0.03	0.2	24	0.04	0.056	1.0	<1
T3-37						<0.01	331	1.6	3.5		<0.04	<0.1	<0.1	<1	4			0.9	0.5		<1	<0.2	0.5	0.71	<0.1	23	<0.01	0.019	6.4	2
T4-5						<0.01	128	0.4	2.7		<0.04	<0.1	<0.1	<1	9			1.8	0.2		<1	<0.2	<0.2	0.11	0.1	17	<0.01	0.009	1.4	1
LOD (3σ)	---	---	---	---	---	0.01	3	0.1	0.1	0.02	0.04	0.1	0.1	1	2	0.1	0.03	0.1	0.1	0.1	1	0.2	0.2	0.02	0.1	0.1	0.01	0.002	0.1	1
Method Code	---	---	---	C-240	C-255	C-209	C-209	C-209	C-209	C-229	C-209	C-209	C-209	C-209	C-209	C-229	C-229	C-209	C-209	C-229	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209

Composite	**Size fraction**	**Liquid:Solid**	**Time (hr)**	**pH**	**Conductivity**	**Ag**	**Al**	**As**	**Ba**		**Cd**	**Co**	**Cr**	**Cu**	**Fe**			**Mn**	**Mo**		**Ni**	**Pb**	**Sb**	**Se**	**Sn**	**Sr**	**Th**	**U**	**V**	**Zn**
Duplicate test for 4B - 0.5 h shaking instead of 5 h					**(µS/cm)**	**µg/L**	**µg/L**	**µg/L**	**µg/L**		**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**			**µg/L**	**µg/L**		**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
4B	< 63 µm	1000:1	24	8.94	361	<0.01	145	0.32	2.3		<0.02	<0.1	0.21	0.86	10			14	0.2		0.6	<0.03	<0.1	0.06	0.27	19	0.02	0.05	0.49	<1
4B Dup	< 63 µm	1000:1	24	8.96	172	<0.01	139	0.73	2.4		<0.02	<0.1	0.17	0.80	10			15	0.2		0.2	<0.03	<0.1	<0.02	0.16	21	<0.02	0.05	0.48	<1
4B	63 - 150 µm	1000:1	24	8.18	57	<0.01	61	0.35	2.3		<0.02	<0.1	0.18	0.59	12			19	0.1		0.4	<0.03	<0.1	<0.02	0.09	17	<0.02	0.03	0.29	<1
4B Dup	63 - 150 µm	1000:1	24	8.17	61	<0.01	60	0.38	2.5		<0.02	<0.1	0.16	1.3	13			20	<0.1		0.3	<0.03	<0.1	<0.02	0.07	18	<0.02	0.04	0.34	<1
4B	150-210 µm	1000:1	24	7.97	75	<0.01	48	0.41	5.7		0.02	<0.1	0.16	0.65	13			25	0.1		0.2	<0.03	<0.1	<0.02	0.04	18	<0.02	0.03	0.26	<1
4B Dup	150-210 µm	1000:1	24	7.91	58	<0.01	42	0.58	2.3		<0.02	<0.1	0.21	0.63	19			22	<0.1		0.3	<0.03	<0.1	<0.02	<0.03	17	<0.02	0.03	0.18	<1

Spike Recoveries

						Ag	**Al**	**As**	**Ba**	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**Pb**	**Sb**	**Se**	**Sn**	**Sr**	**Th**	**U**	**V**	**Zn**
Sample ID	**Sample Description**	**Liquid:Solid**	**Time (hr)**	**---**	**---**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
CE491-50	CE491-26 (4B 63 - 150 µm)	1000:1	24	---	---	110	90	95	101	108	93	98	97	97	94	106	105	97	96	102	94	94	96	93	108	97	98	93	98	96

Certified Reference Material

	---	---	---	---	---	**Ag**	**Al**	**As**	**Ba**	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**Pb**	**Sb**	**Se**	**Sn**	**Sr**	**Th**	**U**	**V**	**Zn**
Sample ID	---	---	---	---	---	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**mg/L**	**µg/L**	**µg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
TM24.4 (n=2)	---	---	---	---	---	---	32	5	15	---	4	6	5	6	15	---	---	8	6	---	5	6	---	3	4	115	---	4	7	---
Certified Value	---	---	---	---	---	---	32.9 ± 4.5	5.30 ± 0.53	15.0 ± 1.0	---	3.96 ± 0.34	6.27 ± 0.57	5.00 ± 0.59	6.31 ± 0.60	16.0 ± 2.3	---	---	8.24 ± 0.73	6.30 ± 0.56	---	5.03 ± 0.53	5.60 ± 0.52	---	3.56 ± 0.58	3.72 ± 0.39	113 ± 8	---	4.24 ± 0.34	7.00 ± 0.58	---
Recovery (%)	---	---	---	---	---	---	98	97	99	---	98	100	102	99	92	---	---	100	97	---	92	99	---	95	98	102	---	98	99	---
TMDA64.3 (n=2)	---	---	---	---	---	14	289	160	288	---	255	251	282	262	287	---	---	285	291	---	247	281	125	149	297	638	---	132	282	320
Certified Value	---	---	---	---	---	12.6 ± 1.3	291 ± 23	164 ± 15	287 ± 18	---	258 ± 21	250 ± 16	283 ± 17	261 ± 18	298 ± 21	---	---	292 ± 17	286 ± 21	---	252 ± 18	280 ± 22	124 ± 11	154 ± 22	281 ± 25	628 ± 34	---	135 ± 11	279 ± 18	320 ± 23
Recovery (%)	---	---	---	---	---	108	99	97	100	---	99	100	100	100	96	---	---	97	102	---	98	100	101	97	106	102	---	98	101	100

Method Codes: C-209: ICP-MS C-229: ICP-AES C-240: Determination of pH C-255: Conductivity

Appendix D4.2. Additional data for L/S = 1000 data for new <210 µm composite.

Tests undertaken to provide additional data for L/S = 1000.

Notes **Composite Talbingo reservoir water used as leachate solution.**
Size categories <0.21 mm (composite fine material). (New rock crushed for this test, so not identical in PSD and some larger sized material the <75 µm composites)
L/S =1000, where solids and water were mixed for 30 min, then analyses made after 3 of 24 h.

Sample Labels	Rock Spoil sample	L/S ratio	Mixing duration	Duration in water	Ag	Al	As	B	Ba	Be	Ca	Cd	Ce	Co	Cr	Cu	Fe	K	Li	Mg	Mn	Mo	Na	Ni	P	Pb	S	Sn	Sr	Ti	Ti	V	Zn
					(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(mg/L)	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
CE491_T10-1	Talbingo water A				<0.19	4.53	<2.62	<17.31	4.32	<0.02	1.7	<0.06	<4.11	<1.39	<0.36	0.4	15.1	0.4	0.08	0.8	0.18	<0.61	1.6	<0.66	2.91	<0.91	159	<2.15	14.4	0.04	<0.02	<0.15	1.47
CE491_T10-2	Talbingo water B				<0.19	4.02	<2.62	<17.31	4.35	<0.02	1.7	<0.06	<4.11	<1.39	<0.36	0.41	15.7	0.4	0.09	0.8	0.19	<0.61	1.7	<0.66	<1.46	<0.91	158	<2.15	14.4	0.04	0.03	<0.15	1.41
CE491_T10-3	Talbingo water C				<0.19	4.12	<2.62	<17.31	4.31	<0.02	1.7	<0.06	<4.11	<1.39	<0.36	0.59	15.7	0.4	0.08	0.8	0.18	<0.61	1.7	<0.66	<1.46	<0.91	161	<2.15	14.2	<0.03	<0.02	0.17	1.42
CE491_T10-4	1E	1000/1	0.5 h	3 h	<0.19	20.8	<2.62	<17.31	11.2	<0.02	2.3	<0.06	<4.11	<1.39	<0.36	0.47	16.2	0.6	0.38	0.7	29.8	<0.61	1.6	<0.66	<1.46	<0.91	163	<2.15	40.3	0.06	<0.02	0.3	0.33
CE491_T10-5	4B	1000/1	0.5 h	3 h	<0.19	19.7	<2.62	<17.31	1.33	<0.02	3.7	<0.06	<4.11	<1.39	<0.36	0.74	15	0.5	0.12	0.7	24.6	<0.61	1.6	<0.66	2.94	<0.91	160	<2.15	16	0.05	<0.02	0.15	0.45
CE491_T10-6	4B dup	1000/1	0.5 h	3 h	<0.19	15.5	<2.62	<17.31	1.5	<0.02	3.3	<0.06	<4.11	<1.39	<0.36	1.07	14.7	0.5	0.11	0.7	20.7	<0.61	1.6	<0.66	<1.46	<0.91	164	<2.15	15.5	<0.03	0.02	<0.15	0.45
CE491_T10-7	5E	1000/1	0.5 h	3 h	<0.19	23	<2.62	<17.31	1.9	<0.02	4.2	0.06	<4.11	<1.39	<0.36	0.8	14.9	0.4	0.12	0.7	6.85	<0.61	1.6	<0.66	2.45	0.97	172	<2.15	15.5	0.13	<0.02	0.2	0.17
CE491_T10-8	1E	1000/1	0.5 h	24 h	<0.19	31.6	3.23	<17.31	11.4	<0.02	2.5	<0.06	<4.11	<1.39	<0.36	0.31	15.4	0.6	0.46	0.7	33.1	<0.61	1.6	<0.66	3.95	<0.91	165	<2.15	43.2	0.05	0.04	0.45	<0.14
CE491_T10-9	4B	1000/1	0.5 h	24 h	<0.19	55.7	<2.62	<17.31	1.42	<0.02	4.3	<0.06	<4.11	<1.39	0.48	1.03	15.2	0.5	0.19	0.7	22.3	<0.61	1.6	<0.66	3.73	<0.91	165	<2.15	16.9	0.05	<0.02	0.24	0.17
CE491_T10-10	4B dup	1000/1	0.5 h	24 h	<0.19	36.1	<2.62	<17.31	1.73	<0.02	4.3	<0.06	<4.11	<1.39	<0.36	0.84	17.9	0.5	0.13	0.8	26	<0.61	1.7	<0.66	<1.46	0.92	163	<2.15	18.4	0.11	<0.02	0.3	0.26
CE491_T10-11	5E	1000/1	0.5 h	24 h	<0.19	49	<2.62	<17.31	2.02	<0.02	4.5	<0.06	<4.11	<1.39	<0.36	0.65	17.3	0.4	0.15	0.7	5.61	<0.61	1.6	<0.66	3.51	<0.91	173	<2.15	16.3	0.12	0.08	0.3	<0.14

Quality Assurance and Quality Control

Sample Labels	Rock Spoil sample	L/S ratio	Mixing duration	Duration in water	Ag	Al	As	B	Ba	Be	Ca	Cd	Ce	Co	Cr	Cu	Fe	K	Li	Mg	Mn	Mo	Na	Ni	P	Pb	S	Sn	Sr	Ti	Ti	V	Zn
					(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(mg/L)	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Mean blank (x10 Dil)					**-0.34**	**-0.07**	**0.61**	**14.22**	**0.00**	**0.00**	**-0.1**	**-0.03**	**-1.71**	**0.87**	**-0.05**	**0.15**	**-0.24**	**0.0**	**-0.03**	**0.0**	**0.00**	**-0.11**	**-0.1**	**0.57**	**1.78**	**0.25**	**-2.31**	**0.96**	**-0.04**	**0.02**	**0.01**	**-0.03**	**0.01**
LOD (3 x S.d.) (x10 Dil)					**0.19**	**0.36**	**2.62**	**17.31**	**0.02**	**0.02**	**0.0**	**0.06**	**4.11**	**1.39**	**0.36**	**0.29**	**0.35**	**0.0**	**0.04**	**0.0**	**0.03**	**0.61**	**0.0**	**0.66**	**1.46**	**0.91**	**11.15**	**2.15**	**0.01**	**0.03**	**0.02**	**0.15**	**0.14**
TM24.4					9.2	33.5	6.9	1.2	15.8	2.1	21.9	4.2	0.0	6.5	5.6	6.4	15.6	1.1	5.6	5.5	8.1	5.8	9.4	4.8	0.2	5.5	5864.3	4.4	113.2	7.5	7.1	7.2	28.9
Certified TM24.4					8.92	32.9 ± 4.5	5.30 ± 0.53		15.0 ± 1.0			3.96 ± 0.34		6.27 ± 0.57	5.00 ± 0.59	6.31 ± 0.60	16.0 ± 2.3		4.95 ± 0.42		8.24± 0.73			5.03 ± 0.53		5.60 ± 0.52			113 ± 8			7.00 ± 0.58	
% recovery (TM24.4)					**103**	**102**	**129**		**105**			**106**		**103**	**111**	**101**	**98**		**113**		**98**			**96**		**98**			**100**			**103**	
TMDA64.3					12.0	293.2	162.7	255.0	296.0	159.2	21.4	264.9	0.5	252.7	288.1	260.8	293.4	1.1	158.3	5.5	278.0	279.5	9.6	258.1	1.6	285.6	5713.6	275.7	634.4	128.8	125.6	279.9	327.2
Certified TM63.4					12.6 ± 1.3	291 ± 23	164 ± 15		287 ± 18			258 ± 21		250 ± 16	283 ± 17	261 ± 18	298 ± 21		143 ± 15		292 ± 17			252 ± 18		280 ± 22			628 ± 34			279 ± 18	320 ± 23
% recovery (TMDA63.4)					**95**	**101**	**99**		**103**			**103**		**101**	**102**	**100**	**98**		**111**		**95**			**102**		**102**			**101**			**100**	**102**
CE491_x10 Dil_T10-1+spike					**97**	**97**	**99**	**98**	**98**	**102**	**101**	**98**	**98**	**99**	**99**	**98**	**99**	**101**	**98**	**101**	**99**	**98**	**101**	**98**	**98**	**97**	**102**	**98**	**99**	**99**	**98**	**99**	**98**
CE491_x10 Dil_T10-11+spike					**96**	**97**	**98**	**103**	**98**	**101**	**100**	**98**	**98**	**98**	**99**	**97**	**98**	**100**	**100**	**100**	**99**	**98**	**100**	**97**	**100**	**97**	**99**	**97**	**98**	**98**	**98**	**99**	**98**

Analysis

CSIRO

Measurement Details

Operator Name CSIRO Mastersizer
Sample Name Average of 'CE491-21 (1E) <0.21 mm_ElutTest2'
SOP File Name Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time 24/10/2018 3:47:29 PM
Measurement Date Time 24/10/2018 3:47:29 PM
Result Source Averaged

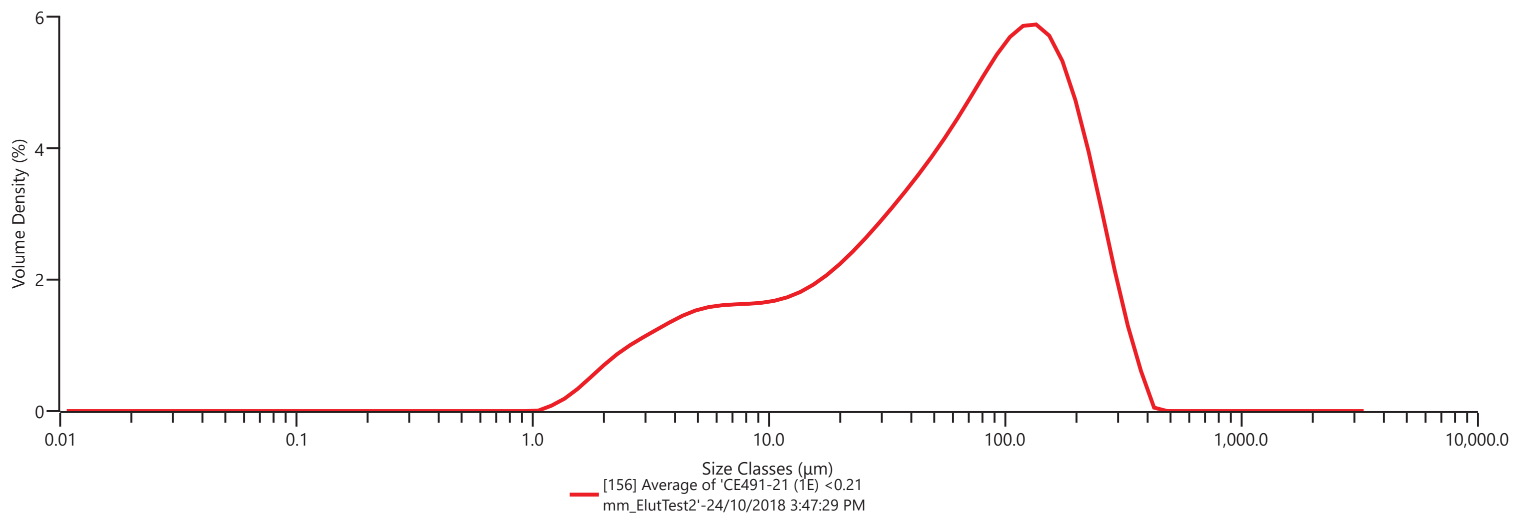
Analysis

Particle Name China Clay
Particle Refractive Index 1.555
Particle Absorption Index 0.010
Dispersant Name Water
Dispersant Refractive Index 1.330
Scattering Model Mie
Analysis Model General Purpose
Weighted Residual 0.35 %
Laser Obscuration 10.65 %

Result

Concentration 0.0221 %
Span 3.015
Uniformity 0.947
Specific Surface Area 340.4 m²/kg
D [3,2] 17.6 µm
D [4,3] 88.3 µm
Dv (10) 5.93 µm
Dv (50) 66.3 µm
Dv (90) 206 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	1.52	12.7	18.24	76.0	54.26	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	2.24	14.5	19.75	86.4	58.52	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	3.08	16.4	21.35	98.1	63.05	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	4.01	18.7	23.07	111	67.80	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	5.04	21.2	24.93	127	72.69	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	6.16	24.1	26.95	144	77.61	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.00	4.58	7.37	27.4	29.15	163	82.39	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.00	5.21	8.65	31.1	31.54	186	86.84	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.00	5.92	9.97	35.3	34.11	211	90.80	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.00	6.72	11.32	40.1	36.90	240	94.10	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.07	7.64	12.67	45.6	39.89	272	96.65	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.22	8.68	14.03	51.8	43.11	310	98.42	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.50	9.86	15.40	58.9	46.57	352	99.49	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	0.93	11.2	16.80	66.9	50.28	400	100.00	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name CSIRO Mastersizer
Sample Name Average of 'CE491-26 (4B) <0.21 mm_ElutTest2'
SOP File Name Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time 24/10/2018 3:56:42 PM
Measurement Date Time 24/10/2018 3:56:42 PM
Result Source Averaged

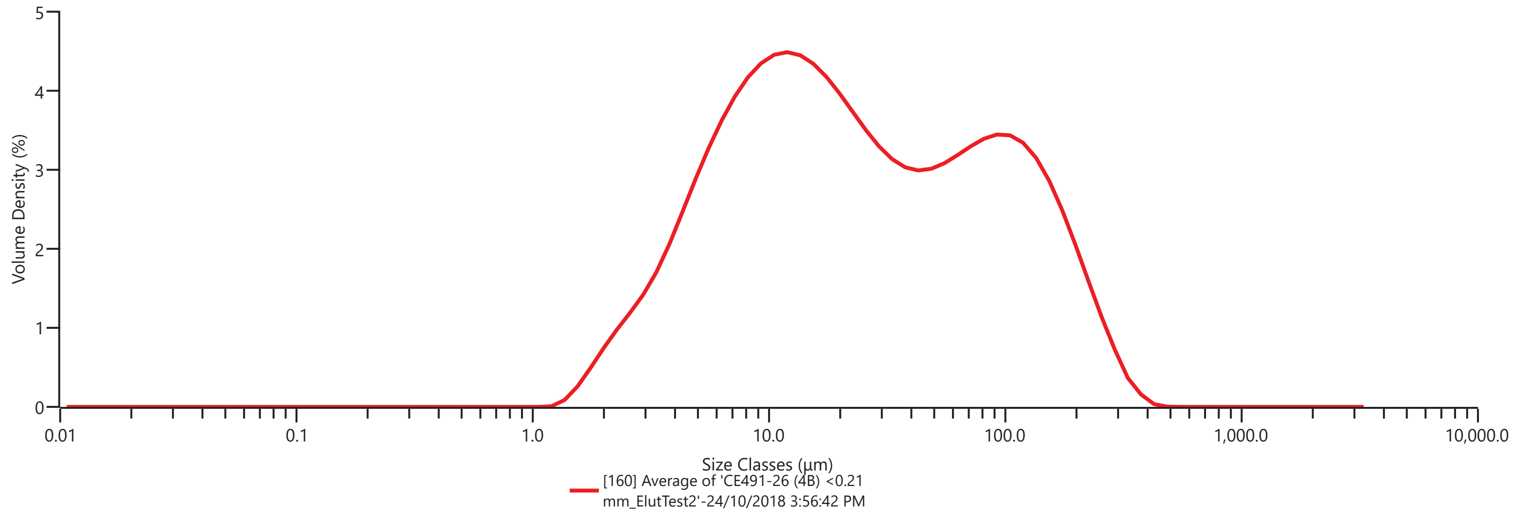
Analysis

Particle Name China Clay
Particle Refractive Index 1.555
Particle Absorption Index 0.010
Dispersant Name Water
Dispersant Refractive Index 1.330
Scattering Model Mie
Analysis Model General Purpose
Weighted Residual 0.49 %
Laser Obscuration 8.43 %

Result

Concentration 0.0120 %
Span 6.300
Uniformity 1.886
Specific Surface Area 505.9 m²/kg
D [3,2] 11.9 µm
D [4,3] 50.3 µm
Dv (10) 4.71 µm
Dv (50) 21.5 µm
Dv (90) 140 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	1.32	12.7	35.50	76.0	76.51	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	2.13	14.5	39.22	86.4	79.34	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	3.13	16.4	42.84	98.1	82.22	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	4.30	18.7	46.32	111	85.09	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	5.72	21.2	49.63	127	87.88	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	7.43	24.1	52.74	144	90.51	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.00	4.58	9.48	27.4	55.66	163	92.90	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.00	5.21	11.89	31.1	58.41	186	94.98	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.00	5.92	14.62	35.3	61.02	211	96.69	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.00	6.72	17.65	40.1	63.54	240	98.01	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.00	7.64	20.93	45.6	66.03	272	98.96	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.07	8.68	24.41	51.8	68.54	310	99.56	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.28	9.86	28.04	58.9	71.10	352	99.85	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	0.69	11.2	31.76	66.9	73.76	400	99.98	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name	CSIRO Mastersizer
Sample Name	Average of 'CE491-28 (5B) <0.21 mm_ElutTest2'
SOP File Name	Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time	24/10/2018 4:08:45 PM
Measurement Date Time	24/10/2018 4:08:45 PM
Result Source	Averaged

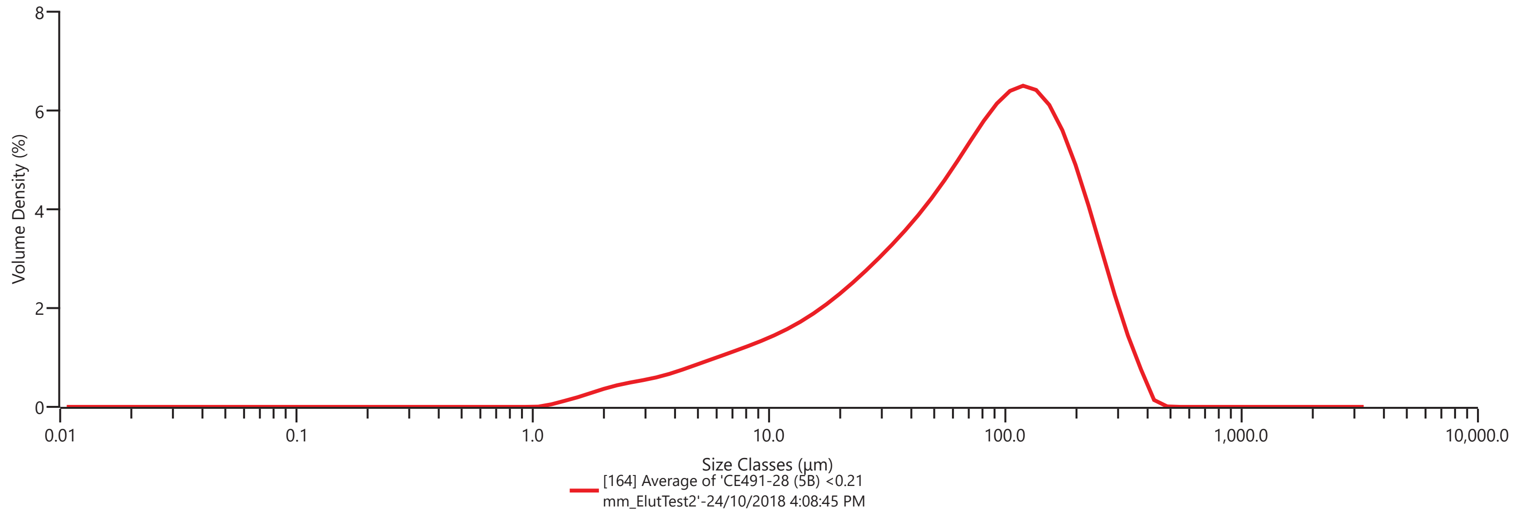
Analysis

Particle Name	China Clay
Particle Refractive Index	1.555
Particle Absorption Index	0.010
Dispersant Name	Water
Dispersant Refractive Index	1.330
Scattering Model	Mie
Analysis Model	General Purpose
Weighted Residual	0.37 %
Laser Obscuration	5.94 %

Result

Concentration	0.0176 %
Span	2.634
Uniformity	0.821
Specific Surface Area	239.3 m²/kg
D [3,2]	25.1 µm
D [4,3]	95.3 µm
Dv (10)	10.7 µm
Dv (50)	75.6 µm
Dv (90)	210 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	0.84	12.7	11.70	76.0	50.18	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	1.21	14.5	13.14	86.4	55.01	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	1.62	16.4	14.71	98.1	60.14	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	2.07	18.7	16.44	111	65.48	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	2.57	21.2	18.35	127	70.92	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	3.12	24.1	20.45	144	76.28	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.00	4.58	3.75	27.4	22.74	163	81.39	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.00	5.21	4.46	31.1	25.26	186	86.07	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.00	5.92	5.24	35.3	27.99	211	90.17	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.00	6.72	6.11	40.1	30.97	240	93.57	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.04	7.64	7.05	45.6	34.20	272	96.21	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.14	8.68	8.07	51.8	37.72	310	98.10	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.30	9.86	9.19	58.9	41.54	352	99.29	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	0.54	11.2	10.39	66.9	45.69	400	99.92	2390	100.00		

Analysis

CSIRO

Measurement Details

Operator Name CSIRO Mastersizer
Sample Name Average of 'CE491-29 (5E) <0.21 mm_ElutTest2'
SOP File Name Sediment Sonnication_SOP.msop

Measurement Details

Analysis Date Time 24/10/2018 4:23:15 PM
Measurement Date Time 24/10/2018 4:23:15 PM
Result Source Averaged

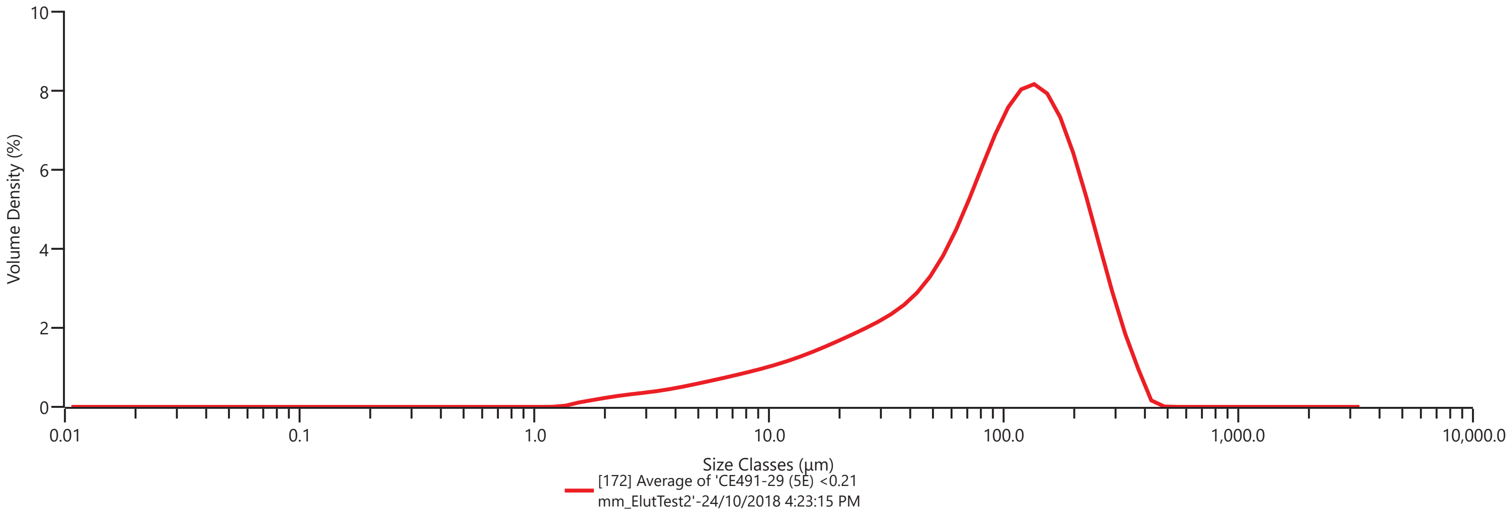
Analysis

Particle Name China Clay
Particle Refractive Index 1.555
Particle Absorption Index 0.010
Dispersant Name Water
Dispersant Refractive Index 1.330
Scattering Model Mie
Analysis Model General Purpose
Weighted Residual 0.49 %
Laser Obscuration 7.40 %

Result

Concentration 0.0307 %
Span 2.130
Uniformity 0.652
Specific Surface Area 175.6 m²/kg
D [3,2] 34.2 µm
D [4,3] 113 µm
Dv (10) 16.0 µm
Dv (50) 99.6 µm
Dv (90) 228 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.0597	0.00	0.357	0.00	2.13	0.45	12.7	8.04	76.0	38.44	454	100.00	2710	100.00
0.0114	0.00	0.0679	0.00	0.405	0.00	2.42	0.68	14.5	9.10	86.4	43.52	516	100.00	3080	100.00
0.0129	0.00	0.0771	0.00	0.460	0.00	2.75	0.95	16.4	10.26	98.1	49.27	586	100.00	3500	100.00
0.0147	0.00	0.0876	0.00	0.523	0.00	3.12	1.24	18.7	11.54	111	55.61	666	100.00		
0.0167	0.00	0.0995	0.00	0.594	0.00	3.55	1.57	21.2	12.94	127	62.33	756	100.00		
0.0189	0.00	0.113	0.00	0.675	0.00	4.03	1.95	24.1	14.46	144	69.16	859	100.00		
0.0215	0.00	0.128	0.00	0.767	0.00	4.58	2.37	27.4	16.12	163	75.80	976	100.00		
0.0244	0.00	0.146	0.00	0.872	0.00	5.21	2.86	31.1	17.91	186	81.93	1110	100.00		
0.0278	0.00	0.166	0.00	0.991	0.00	5.92	3.40	35.3	19.86	211	87.31	1260	100.00		
0.0315	0.00	0.188	0.00	1.13	0.00	6.72	4.00	40.1	22.01	240	91.75	1430	100.00		
0.0358	0.00	0.214	0.00	1.28	0.00	7.64	4.67	45.6	24.41	272	95.17	1630	100.00		
0.0407	0.00	0.243	0.00	1.45	0.02	8.68	5.40	51.8	27.15	310	97.59	1850	100.00		
0.0463	0.00	0.276	0.00	1.65	0.12	9.86	6.20	58.9	30.33	352	99.12	2100	100.00		
0.0526	0.00	0.314	0.00	1.88	0.26	11.2	7.08	66.9	34.07	400	99.92	2390	100.00		

Appendix D5. Comparison between leaching in Talbingo and Tantangara waters

Note/Memo	CSIRO P4 Project Investigations
To:	Ali Watters (HKA)
From:	Brad Angel, Lucas Heights, NSW
Date:	26 November 2018
Copy:	Ryan Fraser, Stuart Simpson and Ellen Porter (SHL)
Our reference:	CSIRO P4 – Memo 13
Classification:	Internal use only
Subject:	Elutriate test with Tantangara reservoir water investigating effect on water quality and pollutant release

Chemical formulas and acronyms

Al	Aluminium	DGV	Default guideline value	L/S	Liquid/solid ratio
SEC	Conductivity				

Background - Introduction

The CSIRO was engaged by Haskoning Australia Pty Ltd (RHDHV) to undertake an investigation of the effect on water quality of excavated rock disposal into the Talbingo and Tantangara reservoirs. Previous elutriate tests performed to date for this assessment have utilised Talbingo reservoir water, and have observed significant changes in water quality with respect to pH, conductivity (SEC) and the dissolved aluminium concentrations.

This technical memo describes results of elutriate tests performed in Tantangara reservoir water with five different excavated rock composite materials that had been milled to <75 µm. Comparison is made with results for matching tests performed using Talbingo reservoir water.

Test methodology

The 75-µm milled composites 1B, 2B, 5B, 5E and 7E characterised in Memo 3 were used in the elutriate tests in Tantangara reservoir water. The tests were performed at liquid to solid (L/S) ratios of 300 and 1000, which were equivalent to 3.3 and 1 g/L, respectively. The material was weighed into plastic vials to which Tantangara water at 21°C was added. The treatments were shaken (50 rpm) for 30 mins then allowed to stand at 21±2°C for the remaining duration so that they were in water for 3 and 18 h. The Tantangara reservoir elutriate treatments in this test were compared with Talbingo treatments from previous tests at the same L/S ratio and duration to assess if different reservoir waters cause differences in effects on water quality and pollutant release.

Results

A comparison of the pH, conductivity and dissolved aluminium for composites 1B, 2B, 5B, 5E and 7E in the Tantangara waters measured in this test with values in Talbingo water from previous tests are shown in Figures 1, 2, 3, 4 and 5, respectively. The pH varied between 7.27 and 9.35 in the elutriate tests with Tantangara reservoir water, compared to 7.36 in the Tantangara test control water and 8.15 to 9.29 in Talbingo reservoir treatments with the same L/S and durations. The main difference in pH between the different reservoir waters was observed for the 1000 L/S, with the Tantangara elutriate treatments having a lower pH than the corresponding Talbingo elutriate treatments after 18 h. No elutriate treatments with 3-h duration were undertaken at 1000 L/S in the Talbingo reservoir water so that comparison was not possible.

The conductivity varied between 34 and 282 µS/cm in the Tantangara reservoir elutriate treatments, compared to 36 µS/cm in the Tantangara test control water and 52 and 87 µS/cm for the corresponding Talbingo reservoir elutriate treatments. The conductivity was in a similar range in each corresponding Tantangara and Talbingo reservoir elutriate treatment except for higher values measured in the Tantangara 300-L/S_3-h and 1000-L/S_18-h treatments with excavated rock composites 1B and 7E, respectively.

For the dissolved aluminium, the Talbingo elutriate treatments had higher concentrations than the Tantangara treatments for the 1000-L/S_18-h tests, whereas, the Tantangara elutriate treatments had higher concentrations than the Talbingo treatments for the 300 L/S_3- and 300-L/S_-h tests. However, the concentration of dissolved aluminium was in the same general range in the different reservoir treatments; 23.5-216 µg/L and 61.2-146 µg/L in the Tantangara and Talbingo reservoir water treatments, respectively. The Tantangara test control water had a dissolved aluminium concentration of 25.3 µg/L.

For the Tantangara reservoir water treatments, the concentration of dissolved aluminium was below the DGV of 55 µg/L for the 1000-L/S treatments at 3-h and 18-h, and exceeded the DGV for the 300 L/S treatments at 3 and 18 h.

The lower pH of the Tantangara 18-h_1000-L/S treatments than the corresponding Talbingo treatments indicates the Tantangara reservoir water had a greater ability to buffer pH increases than the Talbingo reservoir water. In turn, the lower dissolved aluminium released from the Tantangara 18-h_1000-L/S treatments than the corresponding Talbingo treatments is likely influenced by the lower pH resulting in slower mineral dissolution and release of aluminium as the aluminate ion, which is favoured at higher pH's.

The higher concentrations of dissolved aluminium in the 300-L/S Tantangara reservoir treatments may be the result of greater aluminium colloid formation in this water, as this reservoir water has higher concentrations of dissolved organic carbon (DOC) and dissolved (<0.45 µm) iron than the Talbingo reservoir water (Memo 1), which are often associated with colloids.

Summary

The elutriate water pH was similar in the Tantangara and Talbingo reservoir water treatments for the 300-L/S tests, but lower in the Tantangara reservoir treatments for the 1000-L/S_18-h tests, probably due to this water having a greater ability to buffer pH increases.

The conductivities were generally in a similar range for the two reservoir waters except for a few Tantangara reservoir treatments having higher values.

The concentration of dissolved aluminium was in the range 23.5-216 µg/L in the Tantangara reservoir elutriate treatments, which was in a similar range to corresponding Talbingo reservoir treatments conducted in previous tests. Small differences were observed for corresponding treatments, with the Talbingo elutriate treatments having higher concentrations than the Tantangara treatments for the 1000-L/S_18-h tests, and the Tantangara elutriate treatments having higher concentrations than the Talbingo treatments for the 300-L/S_3-h and 300-L/S_18-h tests.

The concentration of dissolved aluminium in the 1000-L/S Tantangara reservoir water treatments was below the DGV of 55 µg/L for the 1000-L/S treatments, and exceeded the DGV for the 300-L/S treatments.

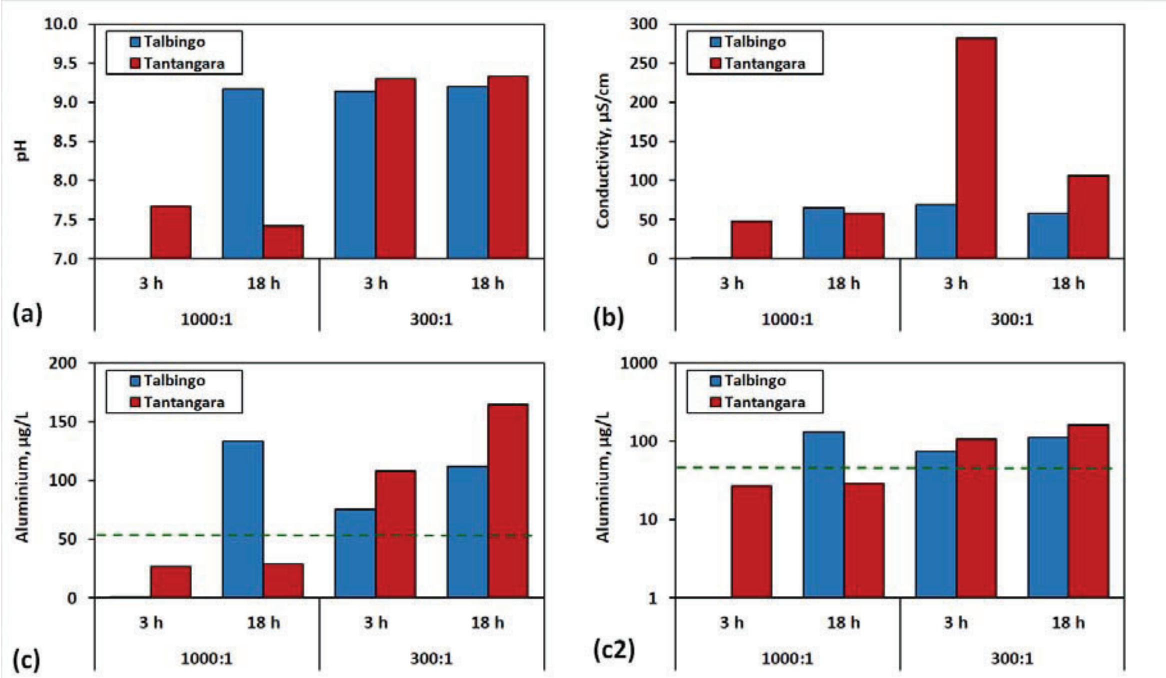


Figure 1. Comparison between the pH, conductivity and dissolved aluminium concentration measured in Talbingo and Tantangara reservoir waters following elutriate tests with excavated rock composite 1B (c2 = log scale). The dotted green line is the DGV for 95% species protection in freshwater of 55 µg/L.

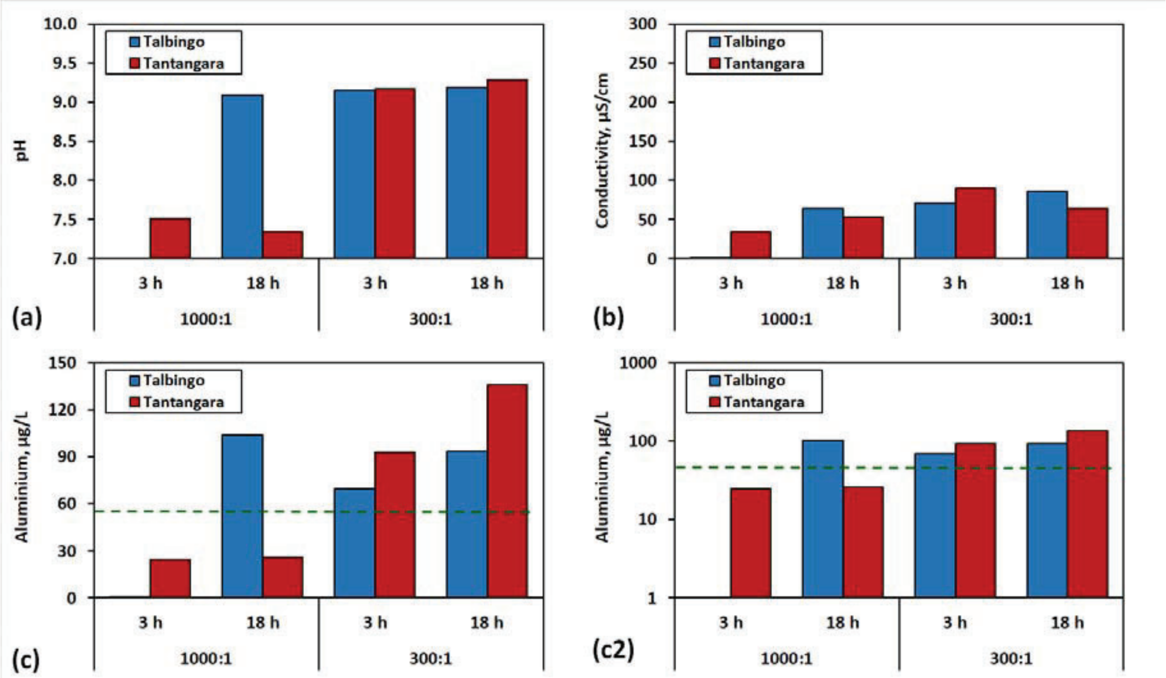


Figure 2. Comparison between the pH, conductivity and dissolved aluminium concentration measured in Talbingo and Tantangara reservoir waters following elutriate tests with excavated rock composite 2B (c2 = log scale). The dotted green line is the DGV for 95% species protection in freshwater of 55 µg/L.

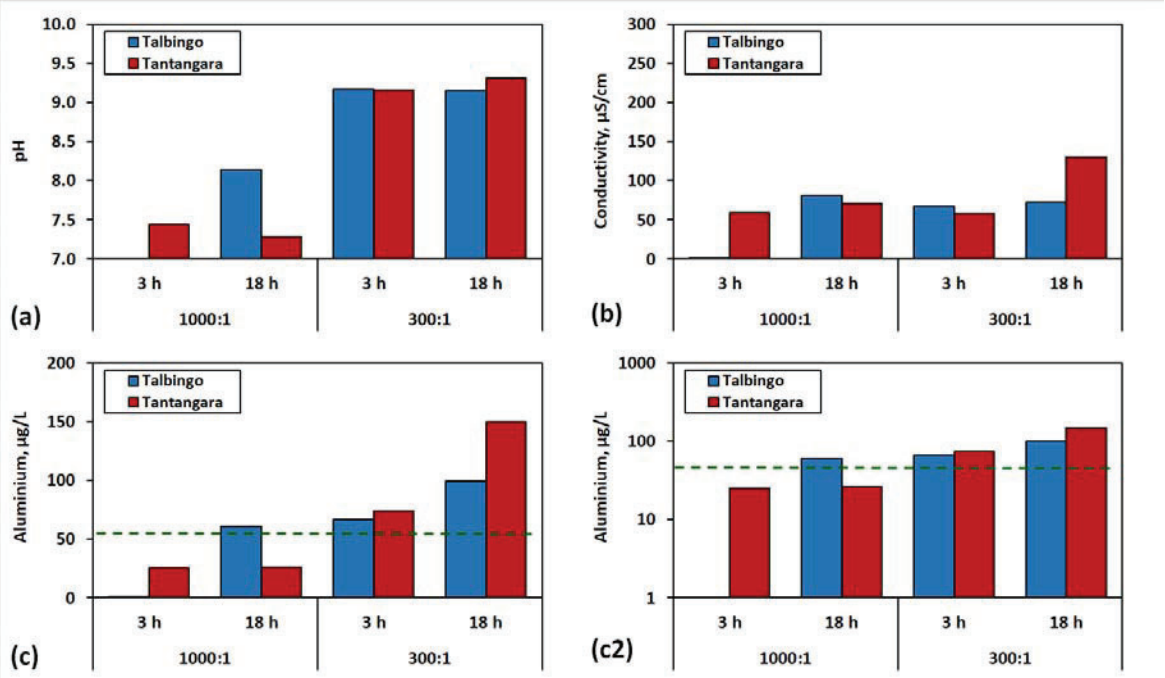


Figure 3. Comparison between the pH, conductivity and dissolved aluminium concentration measured in Talbingo and Tantangara reservoir waters following elutriate tests with excavated rock composite 5B (c2 = log scale). The dotted green line is the DGV for 95% species protection in freshwater of 55 µg/L.

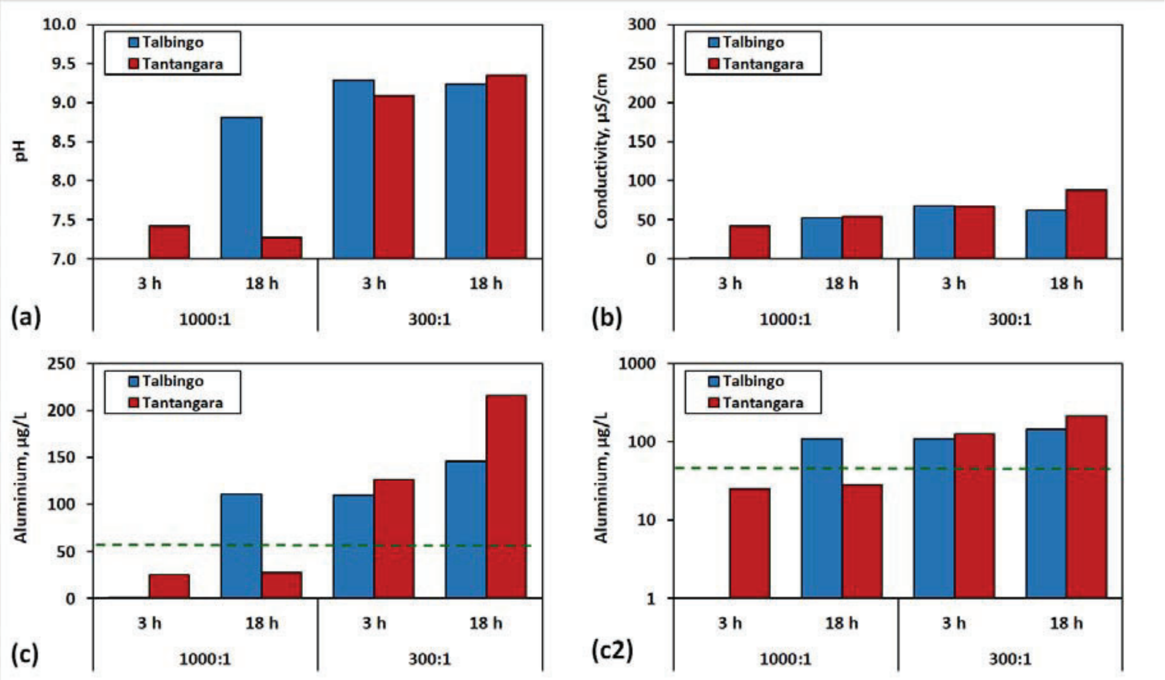


Figure 4. Comparison between the pH, conductivity and dissolved aluminium concentration measured in Talbingo and Tantangara reservoir waters following elutriate tests with excavated rock composite 5E (c2 = log scale). The dotted green line is the DGV for 95% species protection in freshwater of 55 µg/L.

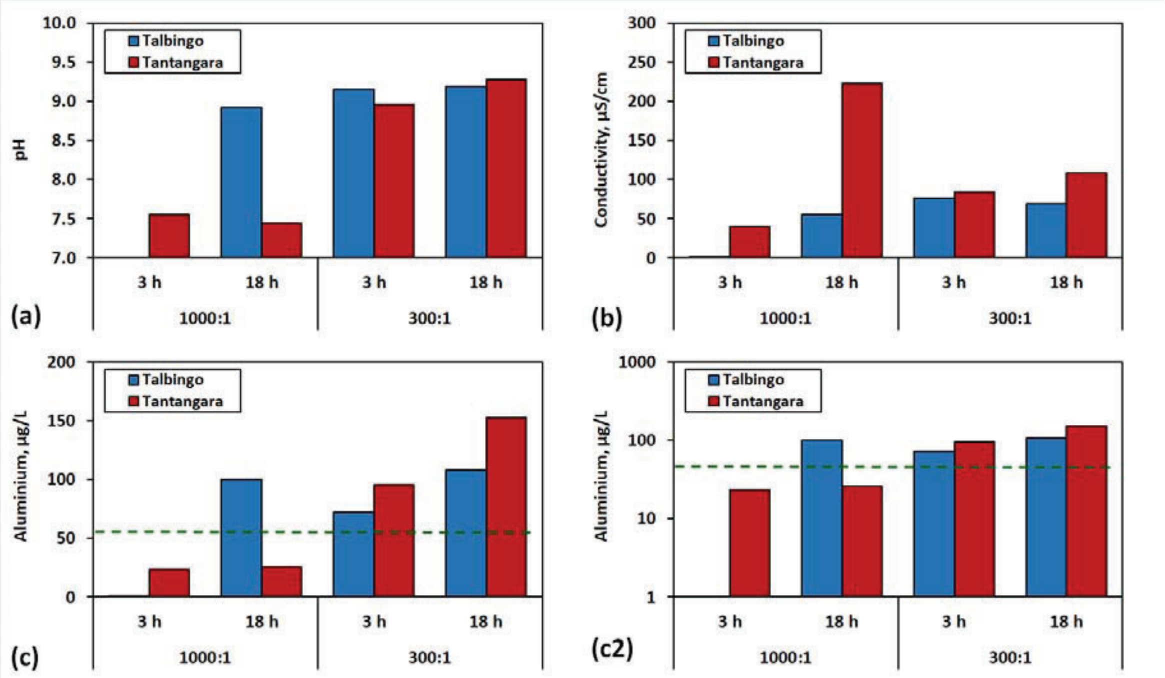


Figure 5. Comparison between the pH, conductivity and dissolved aluminium concentration measured in Talbingo and Tantangara reservoir waters following elutriate tests with excavated rock composite 7E (c2 = log scale). The dotted green line is the DGV for 95% species protection in freshwater of 55 µg/L.

Appendix D5 Comparison between leaching in Talbingo and Tantangara waters

Memo 13 (26 November 2018)

Notes **Composite Tantangara reservoir water used as leachate solution**
<75 µm composite rock materials
L/S of 300 and 1000 (3.3 and 1 g/L) with measurements made at 3 and 18 h.

Sample Labels	Rock Spoil sample	L/S ratio	Duration in water	Water	Ag	Al	As	B	Ba	Be	Ca	Cd	Ce	Co	Cr	Cu	Fe	K	Li	Mg	Mn	Mo	Na	Ni	P	Pb	S	Sn	Sr	Ti	Tl	V	Zn
					(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(mg/L)	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
CE491_T9-1	Tantangara water A			Tantangara	<0.12	23.6	<4.2	<17	6.0	0.04	1.6	<0.19	<0.8	<0.9	<0.26	<0.64	284	0.5	0.1	1.0	2.2	<0.47	1.60	<0.55	4	<1.1	148	<2.8	15	0.29	<3.5	<0.4	1.04
CE491_T9-2	Tantangara water B			Tantangara	<0.12	25.3	<4.2	<17	6.1	<0.02	1.6	<0.19	<0.8	1.0	<0.26	<0.64	298	0.6	0.1	0.9	2.4	<0.47	1.6	<0.55	6	<1.1	148	<2.8	15	0.33	<3.5	<0.4	1.02
CE491_T9-3	Tantangara water C			Tantangara	<0.12	27	<4.2	<17	6.1	<0.02	1.6	<0.19	<0.8	<0.9	<0.26	<0.64	308	0.8	0.1	1.0	2.5	<0.47	1.6	0.82	4	<1.1	158	<2.8	15	0.32	<3.5	<0.4	1.05
CE491_T9-4	1B	300/1	3 h	Tantangara	<0.12	108	<4.2	<17	1.1	0.09	4.7	<0.19	1.02	<0.9	<0.26	<0.64	222	2.0	1.0	1.2	10	<0.47	2.3	<0.55	7	<1.1	150	<2.8	23	0.29	<3.5	1.18	0.17
CE491_T9-5	2B	300/1	3 h	Tantangara	<0.12	93.2	<4.2	<17	4.1	0.04	4.6	<0.19	<0.8	<0.9	<0.26	<0.64	181	1.8	1.0	1.8	7.0	<0.47	2.5	<0.55	15	<1.1	191	<2.8	15	0.21	<3.5	1.15	0.77
CE491_T9-6	5B	300/1	3 h	Tantangara	<0.12	74.2	<4.2	<17	1.5	0.05	5.0	<0.19	<0.8	<0.9	<0.26	<0.64	229	1.6	0.2	1.1	6.9	<0.47	1.9	<0.55	9	<1.1	163	<2.8	16	0.35	<3.5	<0.4	0.23
CE491_T9-8	5E	300/1	3 h	Tantangara	<0.12	127	<4.2	<17	2.5	0.08	5.8	<0.19	<0.8	<0.9	<0.26	<0.64	209	1.2	0.2	1.1	5.9	<0.47	2.5	<0.55	12	<1.1	280	<2.8	17	0.49	<3.5	0.96	0.23
CE491_T9-9	7E	300/1	3 h	Tantangara	<0.12	95.4	<4.2	<17	407.0	0.09	4.9	<0.19	0.93	<0.9	<0.26	0.76	136	3.4	1.2	1.0	14	<0.47	1.8	<0.55	5	<1.1	567	<2.8	50	0.1	<3.5	0.46	<0.12
CE491_T9-10	1B	300/1	18 h	Tantangara	<0.12	165	<4.2	<17	1.2	0.06	5.1	<0.19	1.000	<0.9	<0.26	<0.64	229	2.0	1.1	1.2	10	<0.47	1.9	<0.55	6	1.25	147	<2.8	25	0.37	<3.5	1.23	0.21
CE491_T9-11	2B	300/1	18 h	Tantangara	<0.12	136	<4.2	<17	4.2	0.06	4.8	<0.19	<0.8	<0.9	<0.26	<0.64	194	1.8	1.1	1.7	6.9	<0.47	1.8	<0.55	14	<1.1	152	<2.8	15	0.26	<3.5	1.25	0.13
CE491_T9-12	5B	300/1	18 h	Tantangara	<0.12	150	<4.2	<17	1.8	0.09	5.4	<0.19	<0.8	<0.9	<0.26	<0.64	264	1.6	0.2	1.1	7.8	<0.47	1.9	<0.55	10	<1.1	164	<2.8	17	0.52	<3.5	0.64	0.24
CE491_T9-14	5E	300/1	18 h	Tantangara	<0.12	216	<4.2	<17	2.7	0.04	5.9	<0.19	<0.8	<0.9	<0.26	1.09	242	1.3	0.3	1.1	6.5	<0.47	1.9	<0.55	9	<1.1	307	<2.8	17	0.71	<3.5	1.26	0.39
CE491_T9-15	7E	300/1	18 h	Tantangara	<0.12	153	<4.2	<17	422.0	0.13	5.2	<0.19	<0.8	<0.9	<0.26	0.86	138	3.5	1.4	1.0	12	<0.47	1.8	<0.55	6	<1.1	573	<2.8	52	0.16	<3.5	0.82	0.22
CE491_T9-16	1B	1000/1	3 h	Tantangara	<0.12	27.3	<4.2	<17	2.1	0.04	2.2	<0.19	<0.8	<0.9	<0.26	<0.64	249	0.7	0.2	1.1	16	<0.47	1.7	<0.55	7	<1.1	145	<2.8	16	0.24	<3.5	<0.4	0.22
CE491_T9-17	2B	1000/1	3 h	Tantangara	<0.12	24.7	<4.2	<17	4.5	0.07	2.0	<0.19	<0.8	<0.9	<0.26	<0.64	261	0.6	0.1	1.0	12	<0.47	1.7	<0.55	7	<1.1	152	<2.8	15	0.25	<3.5	<0.4	0.31
CE491_T9-18	5B	1000/1	3 h	Tantangara	<0.12	25.4	<4.2	<17	3.3	0.08	1.9	<0.19	<0.8	<0.9	<0.26	<0.64	272	0.6	0.1	1.0	6.1	<0.47	1.7	<0.55	7	<1.1	151	<2.8	15	0.30	<3.5	<0.4	0.68
CE491_T9-20	5E	1000/1	3 h	Tantangara	<0.12	25.3	<4.2	<17	4.5	<0.02	1.9	<0.19	<0.8	1.18	<0.26	<0.64	253	0.6	0.1	1.0	4.3	<0.47	1.6	<0.55	4	<1.1	154	<2.8	15	0.28	<3.5	<0.4	0.46
CE491_T9-21	7E	1000/1	3 h	Tantangara	<0.12	23.5	<4.2	<17	130.0	0.17	2.2	<0.19	<0.8	<0.9	<0.26	<0.64	245	0.7	0.2	1.0	16	<0.47	1.7	<0.55	4	<1.1	192	<2.8	19	0.25	<3.5	<0.4	0.48
CE491_T9-22	1B	1000/1	18 h	Tantangara	<0.12	29.3	<4.2	<17	2.8	0.09	2.1	<0.19	<0.8	<0.9	<0.26	<0.64	265	0.7	0.2	1.0	15	<0.47	1.7	<0.55	8	<1.1	155	<2.8	16	0.24	<3.5	<0.4	0.3
CE491_T9-23	2B	1000/1	18 h	Tantangara	<0.12	26.2	<4.2	<17	4.9	0.04	2.1	<0.19	<0.8	<0.9	<0.26	<0.64	258	0.6	0.2	1.0	13	<0.47	1.7	<0.55	7	<1.1	152	<2.8	15	0.24	<3.5	<0.4	0.29
CE491_T9-24	5B	1000/1	18 h	Tantangara	<0.12	26.4	<4.2	<17	3.6	0.06	2.0	<0.19	<0.8	<0.9	<0.26	<0.64	262	0.6	0.1	1.0	9.3	<0.47	1.7	<0.55	5	<1.1	152	<2.8	15	0.30	<3.5	<0.4	0.48
CE491_T9-26	5E	1000/1	18 h	Tantangara	<0.12	28.2	<4.2	<17	4.7	0.04	2.0	<0.19	<0.8	<0.9	<0.26	<0.64	250	0.6	0.1	1.0	4.5	<0.47	1.7	<0.55	4	<1.1	156	<2.8	15	0.28	<3.5	<0.4	0.36
CE491_T9-27	7E	1000/1	18 h	Tantangara	<0.12	25.9	<4.2	<17	165.0	0.1	2.3	<0.19	<0.8	0.92	<0.26	<0.64	246	0.7	0.2	1.0	17	<0.47	1.6	<0.55	4	<1.1	202	<2.8	20	0.26	<3.5	<0.4	0.39
CE491_T9-28	1B	1000/1	18 h	Talbingo	0.22	11	<4.2	<17	1.8	<0.02	2.4	<0.19	<0.8	<0.9	<0.26	<0.64	18	0.5	0.2	0.9	16	<0.47	1.6	<0.55	<3.3	<1.1	170	<2.8	16	<0.09	<3.5	<0.4	0.3
CE491_T9-29	2B	1000/1	18 h	Talbingo	<0.12	8.61	<4.2	<17	3.7	<0.02	2.3	<0.19	<0.8	<0.9	<0.26	<0.64	16	0.5	0.1	0.8	14	<0.47	1.6	<0.55	<3.3	<1.1	170	<2.8	15	<0.09	<3.5	<0.4	0.16
CE491_T9-30	5B	1000/1	18 h	Talbingo	<0.12	7.87	<4.2	<17	2.7	<0.02	2.0	<0.19	<0.8	<0.9	<0.26	<0.64	18	0.5	0.1	0.8	6.8	<0.47	1.5	<0.55	<3.3	<1.1	161	<2.8	15	<0.09	<3.5	<0.4	0.74
CE491_T9-31	5E	1000/1	18 h	Talbingo	<0.12	10.7	<4.2	<17	3.3	<0.02	2.2	<0.19	<0.8	<0.9	0.32	0.67	16	0.5	0.1	0.8	3.4	<0.47	1.5	<0.55	<3.3	<1.1	162	<2.8	15	<0.09	<3.5	<0.4	0.41
CE491_T9-32	7E	1000/1	18 h	Talbingo	<0.12	8.93	<4.2	<17	170.0	<0.02	2.5	<0.19	<0.8	<0.9	<0.26	0.8	16	0.6	0.2	0.8	16	<0.47	1.5	<0.55	<3.3	<1.1	214	<2.8	20	<0.09	<3.5	<0.4	0.32

Appendix D5 Comparison between leaching in Talbingo and Tantangara waters

Memo 13 (26 November 2018)

Sample Labels	Rock Spoil sample	L/S ratio	Duration in water	Water	Ag	Al	As	B	Ba	Be	Ca	Cd	Ce	Co	Cr	Cu	Fe	K	Li	Mg	Mn	Mo	Na	Ni	P	Pb	S	Sn	Sr	Ti	Tl	V	Zn
					(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(mg/L)	(µg/L)	(µg/L)	(mg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Mean blank					**-0.34**	**0**	**1.8**	**30**	**-0.01**	**0**	**-0.02**	**-0.07**	**-0.02**	**-0.37**	**-0.12**	**-0.05**	**0.27**	**0.00**	**0**	**0.00**	**0.01**	**0.24**	**-0.02**	**-0.35**	**0.08**	**0.37**	**-5.85**	**2**	**0**	**-0.02**	**1.7**	**0.19**	**-0.03**
LOD (3 x S.d.)					**0.12**	**0.12**	**4.2**	**17**	**0.02**	**0.02**	**0.01**	**0.19**	**0.8**	**0.91**	**0.26**	**0.64**	**0.3**	**0.02**	**0.01**	**0.02**	**0.03**	**0.47**	**0.01**	**0.55**	**3.3**	**1**	**6.8**	**2.8**	**0.01**	**0.09**	**3.4**	**0.43**	**0.12**
TM24.4					9	32	6	0	15	2	20	4	0	7	5	6	16	1	5	5	8	7	9	5	1	7	5710	2	110	7	3	7	28
						32.9 ±	5.30 ±		15.0 ±			3.96 ±		6.27 ±	5.00 ±	6.31 ±	16.0 ±		4.95 ±		8.24±			5.03 ±		5.60 ±						7.00 ±	
Certified TM24.4					8.92	4.5	0.53		1.0			0.34		0.57	0.59	0.60	2.3		0.42		0.73			0.53		0.52			113 ± 8			0.58	
% recovery (TM24.4)					**98**	**97**	**105**		**102**			**102**		**106**	**102**	**103**	**99**		**102**		**98**			**94**		**117**			**98**			**100**	
TMDA64.3					12	284	158	253	288	162	20	261	-1	250	286	258	290	1	141	5	286	274	9	252	3	278	5546	266	627	126	141	278	321
					12.6 ±	291 ±	164 ±		287 ±			258 ±		250 ±	283 ±	261 ±	298 ±		143 ±		292 ±			252 ±		280 ±			628 ±			279 ±	320 ±
Certified TM63.4					1.3	23	15		18			21		16	17	18	21		15		17			18		22			34			18	23
% recovery (TMDA63.4)					**93**	**98**	**96**		**100**			**101**		**100**	**101**	**99**	**97**		**99**		**98**			**100**		**99**			**100**			**100**	**100**
CE491_T9-10+spike					**99**	**98**	**100**	**104**	**100**	**101**	**97**	**101**	**100**	**100**	**100**	**99**	**93**	**99**	**101**	**98**	**100**	**101**	**98**	**101**	**102**	**100**	**98**	**100**	**99**	**101**	**100**	**101**	**100**
CE491_T9-20+spike					**99**	**99**	**100**	**107**	**99**	**100**	**101**	**100**	**100**	**100**	**99**	**99**	**92**	**101**	**100**	**99**	**97**	**100**	**99**	**100**	**101**	**100**	**95**	**100**	**98**	**100**	**100**	**100**	**100**
CE491_T9-30+spike					**98**	**99**	**100**	**108**	**99**	**102**	**101**	**100**	**99**	**100**	**99**	**99**	**100**	**100**	**100**	**100**	**99**	**100**	**101**	**100**	**103**	**99**	**94**	**100**	**99**	**100**	**99**	**99**	**100**

Appendix D6. Effect of water temperature on substance

Note/Memo	CSIRO P4 Project Investigations
To:	Ali Watters (HKA)
From:	Brad Angel, Lucas Heights, NSW
Date:	7 November 2018
Copy:	Ryan Fraser, Stuart Simpson and Ellen Porter (SHL)
Our reference:	CSIRO P4 – Memo 9
Classification:	Internal use only
Subject:	Effect of temperature on pollutant release from excavated rock composites

Chemical formulas and acronyms

Ag	Silver	F^-	Fluoride	Sb	Antimony
Al	Aluminium	Fe	Iron	Se	Selenium
As	Arsenic	Mg	Magnesium	Sn	Tin
Ba	Barium	Mn	Manganese	SO_4^{2-}	Sulfate
Ca	Calcium	Mo	Molybdenum	Sr	Strontium
Cd	Cadmium	Na	Sodium	Th	Thorium
Cl^-	Chloride	Ni	Nickel	U	Uranium
Co	Cobalt	NO_3^-	Nitrate	V	Vanadium
Cr	Chromium	Pb	Lead	Zn	Zinc
Cu	Copper				
DOC	Dissolved organic carbon	DGV	Default guideline value	L/S	Liquid/solid ratio
SEC	Conductivity				

Background - Introduction

The CSIRO was engaged by Haskoning Australia Pty Ltd (RHDHV) to undertake an investigation of the effect on water quality of excavated rock disposal into the Talbingo and Tantangara reservoirs. Previous elutriate tests performed to date to assess the release of pollutants into reservoir waters have been conducted at a temperature of 21°C. The temperature of the reservoirs varies between approximately 6 and 21°C, with significant changes over depth and season. Lower temperatures may substantially slow the kinetics of reactions that effect the release of pollutants from excavated rock material into the reservoirs

This technical memo describes results of elutriate tests performed on five different excavated rock composite materials that had been milled to <75 µm. The kinetics of substance release was monitored at time periods of 6, 18 and 48 h after resuspension then settling in Talbingo reservoir water at 6°C. The results were compared to data generated from the same liquid to solid ratio and duration in water at 21°C (full details of results from the 21°C tests will be reported in a future memo).

Test methodology

The 75 µm milled composites 1B, 2B, 5B, 5E and 7E characterised in memo 3 were used in the elutriate tests investigating the effect of temperature. The tests were performed at liquid to solid ratios of 300 and 1000, which were equivalent to 3.3 and 1 g/L, respectively. The material was weighed into plastic vials to which Talbingo water at 6°C was added. The treatments were shaken (50 rpm) for 30 mins then allowed to stand at 6±1°C for the remaining duration so that they were in water for 6, 18 and 48 h. The 21±2°C treatments to which they were compared were sampled after 0.5 and 18 h, with the 3.3 g/L (300/1 L/S) also being sampled after 3 and 120 h. Therefore, the 18-h time point was directly comparable and trends over time were also compared to investigate the effect of temperature on water quality.

Results - Influence of rock material size (and time) on elutriate pH, conductivity and dissolved analytes

The pH, conductivity and dissolved aluminium for composites 1B, 2B, 5B, 5E and 7E are shown in Figures 1, 2, 3, 4 and 5, respectively. For the 6°C treatments, the pH varied between 7.84 and 9.34 and the conductivity varied between 40 and 88 µS/cm. The pH and conductivity generally decreased marginally between the 6 and 48-h measurements.

For the 6°C treatments, only the 3.3 g/L (300 L/S) had dissolved aluminium that exceeded the DGV of 55 µg/L (dotted red line in graphs), which occurred for the 48 h sampling time for all but composite 5E, for which the DGV was exceeded for all durations tested. The dissolved aluminium increased continuously over the 48 h test period for all 6°C treatments and would presumably continue to increase for some time if the test was run longer (i.e. the concentration did not plateau after 48 h).

For the dissolved major cation concentrations, the excavated rock material affected the calcium most followed by magnesium, with the concentrations increasing rapidly, followed by either a slow increase or being steady over the 48 h duration for the 6°C treatments (data not shown). The dissolved magnesium and sodium were only marginally higher in composite treatments than reservoir control water.

A comparison between the 6 and 21°C values for pH and dissolved aluminium is shown for different treatments in Figures 1 to 5 for each composite material and for all treatments at 18 h in Figure 6. Conductivity was similar for both temperatures. It can be seen that the pH and dissolved aluminium are mostly higher at 21°C than at 6°C.

The concentrations of major cations were generally similar for the 1 g/L (1000 L/S) at both temperatures, whereas for the 3.3 g/L (300 L/S), marginally higher concentrations were generally measured for the 21°C than the 6°C (data not shown).

Summary

The release of aluminium occurred significantly more slowly in the 6°C treatments than the 21°C treatments. As such, after 18 h, the concentration of dissolved aluminium (and pH) were generally substantially lower for the lower temperature treatment. The dissolved aluminium continued to increase over the 48-h period of the 6°C test and did not plateau. After 48-h, the dissolved aluminium exceeded the DGV of 55 µg/L for all 6°C treatments at 3.3 g/L (300 L/S), but did not exceed the DGV for any 1 g/L (1000 L/S) treatments.

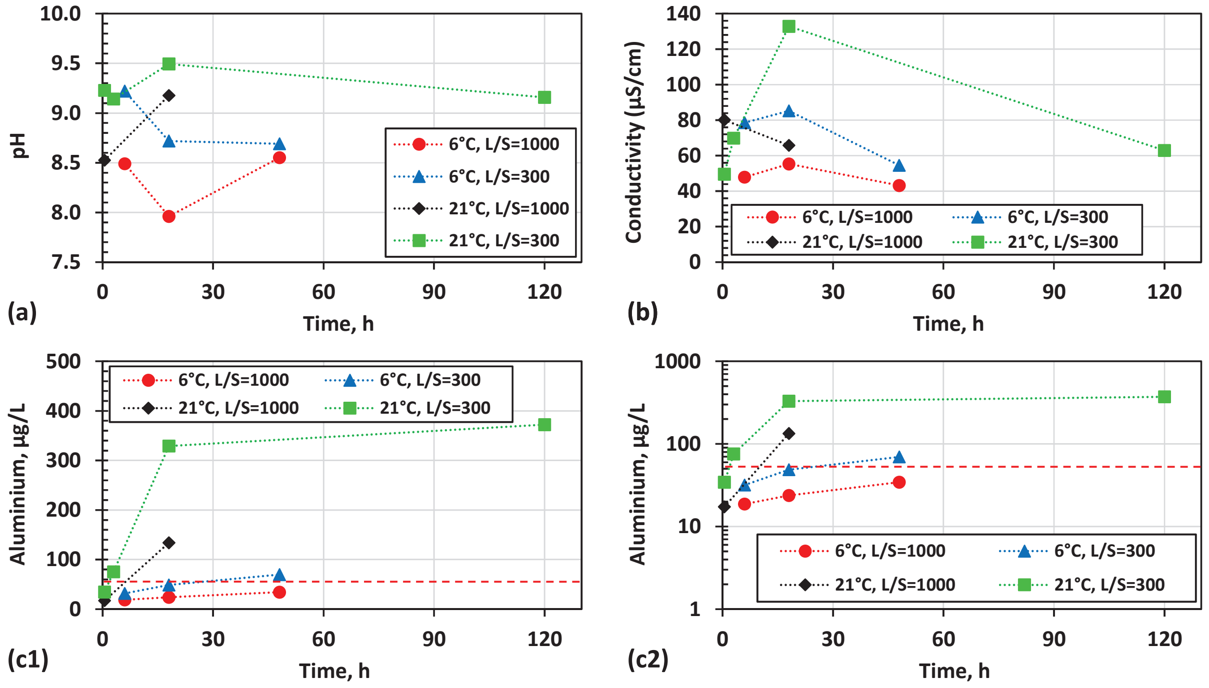


Figure 1. The pH, conductivity and dissolved aluminium over time for composite 1B (c2 = log scale). The dotted red line is the DGV for 95% species protection in freshwater of 55 µg/L.

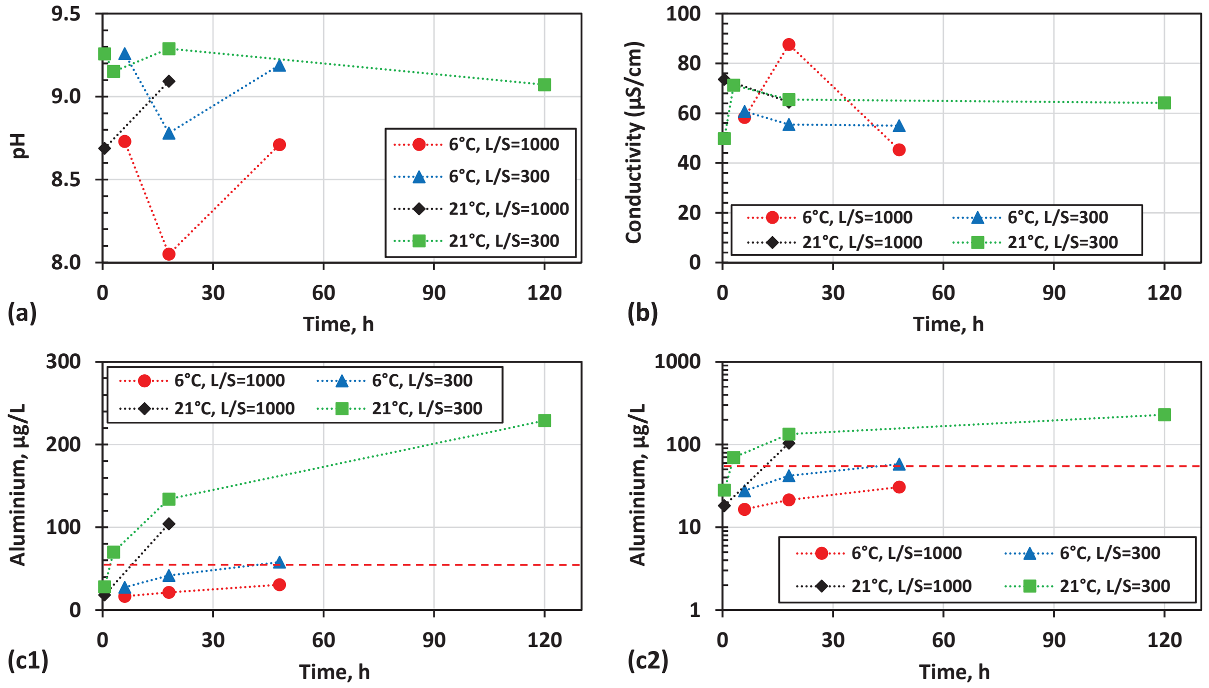


Figure 2. The pH, conductivity and dissolved aluminium over time for composite 2B (c2 = log scale). The dotted red line is the DGV for 95% species protection in freshwater of 55 µg/L.

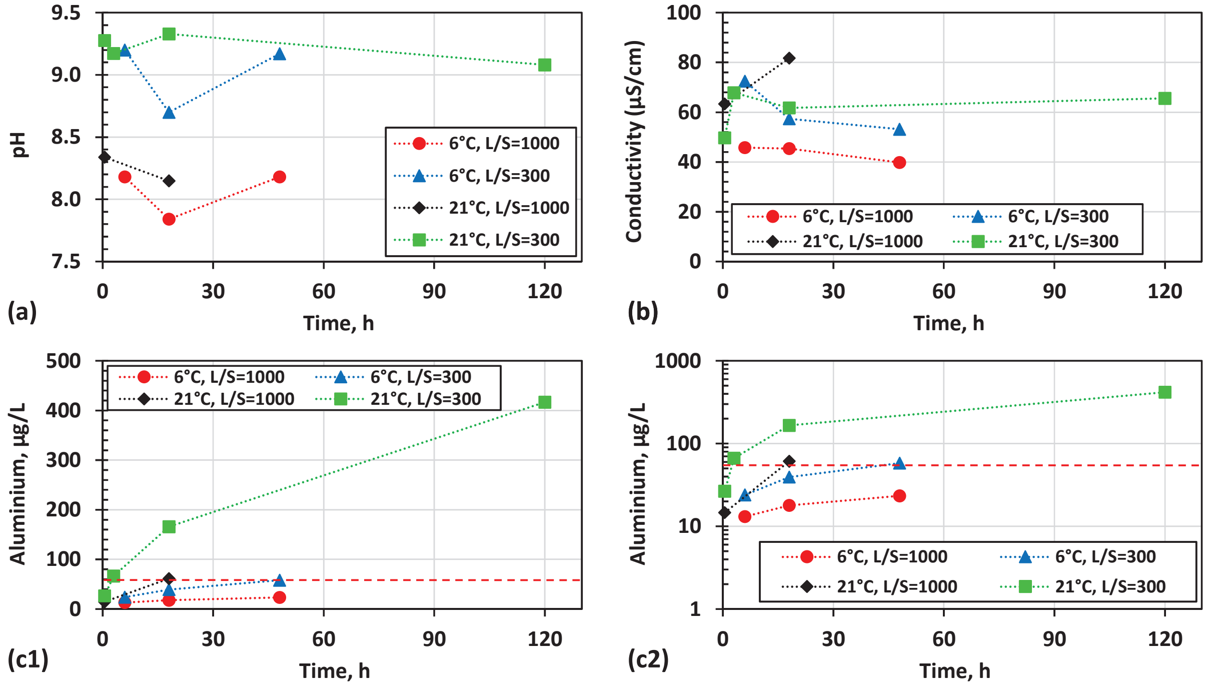


Figure 3. The pH, conductivity and dissolved aluminium over time for composite 5B (c2 = log scale). The dotted red line is the DGV for 95% species protection in freshwater of 55 µg/L.

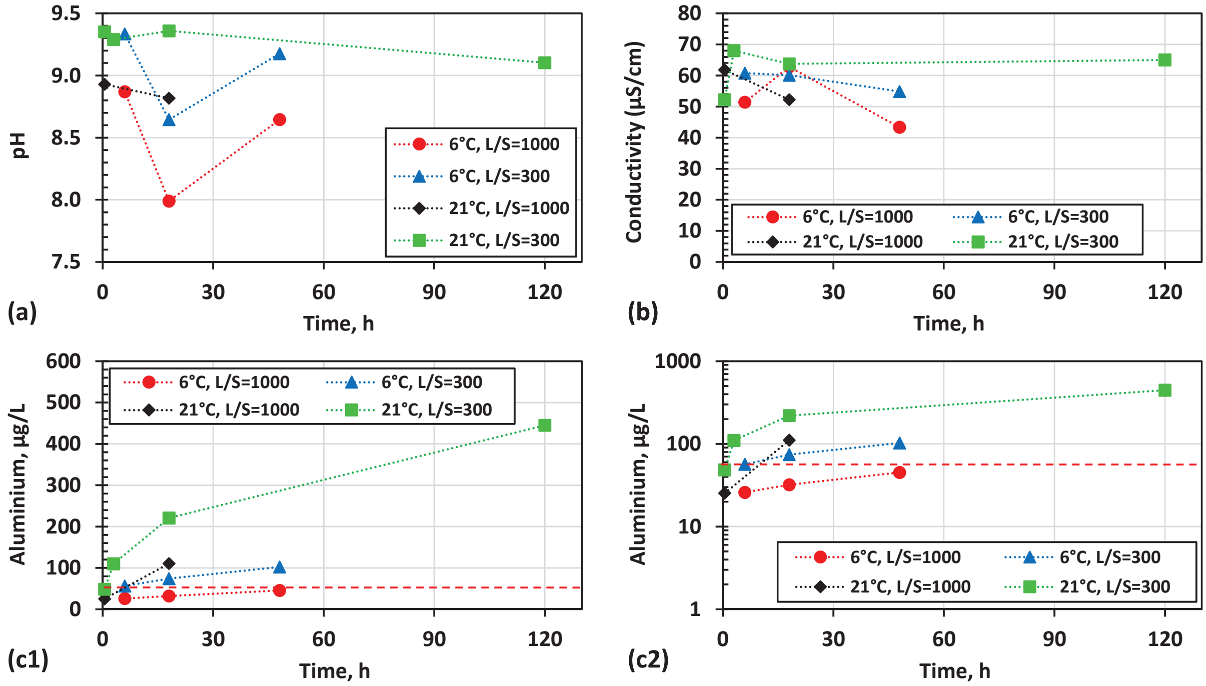


Figure 4. The pH, conductivity and dissolved aluminium over time for composite 5E (c2 = log scale). The dotted red line is the DGV for 95% species protection in freshwater of 55 µg/L.

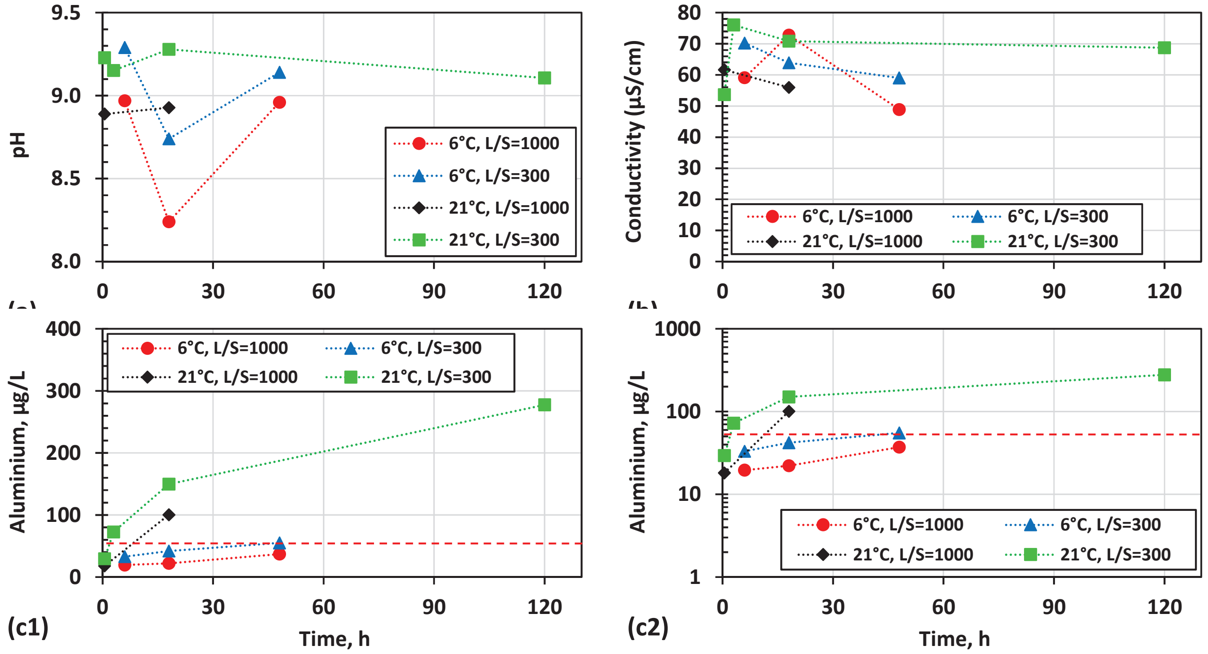


Figure 5. The pH, conductivity and dissolved aluminium over time for composite 5E (c2 = log scale). The dotted red line is the DGV for 95% species protection in freshwater of 55 µg/L.

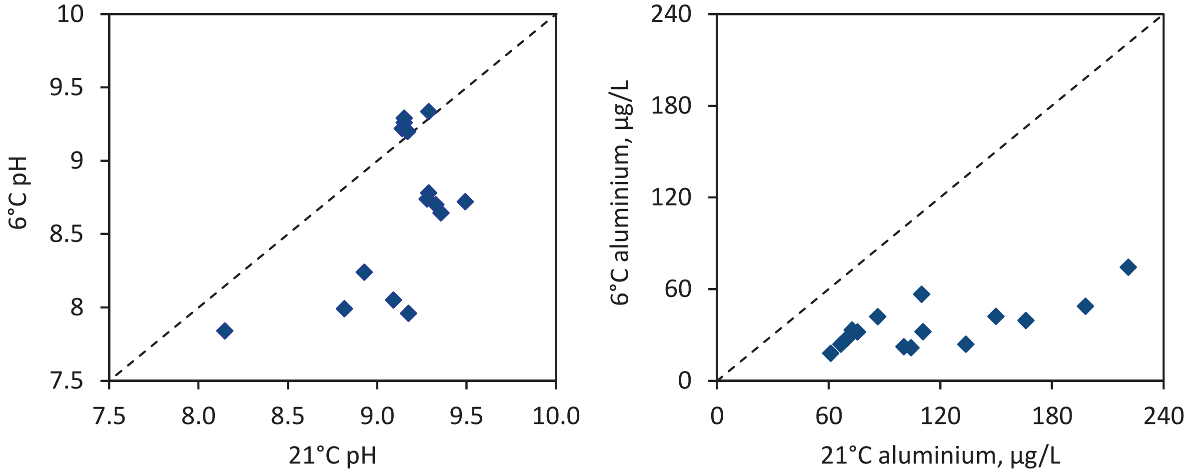


Figure 6. Comparison between temperatures of 6 and 21°C on the pH and dissolved aluminium for 1B, 2B, 5B, 5E and 7E composites after 18 h in Talbingo reservoir water. The dotted unity line indicates a 1:1 relationship.

Appendix D6 Effect of water temperature on substance release

Memo 9 (7 November 2018)

Notes
Composite Talbingo reservoir water used as leachate solution
<75 µm composite rock materials
Substance release at 6 ºC monitored at 6, 18 and 48 h. L/S = 300 and 1000.

Sample Labels	Spoil composite	L/S ratio	Duration (h)	pH	Conductivity (mS/cm)	Ag (µg/L)	Al (µg/L)	As (µg/L)	B (µg/L)	Ba (µg/L)	Be (µg/L)	Ca (mg/L)	Cd (µg/L)	Ce (µg/L)	Co (µg/L)	Cr (µg/L)	Cu (µg/L)	Fe (µg/L)	K (mg/L)	Li (µg/L)	Mg (mg/L)	Mn (µg/L)	Mo (µg/L)	Na (mg/L)	Ni (µg/L)	P (µg/L)	Pb (µg/L)	S (µg/L)	Sn (µg/L)	Sr (µg/L)	Ti (µg/L)	V (µg/L)	Zn (µg/L)
CE491_T6-1	1B	300/1	6	9.22	78.6	<0.2	31.9	<1.7	<0.3	0.8	<0.2	5.1	<0.08	<1.4	<1.7	<0.14	<1.2	11	1.9	0.3	1.0	13	<0.3	1.7	<0.4	<6.1	<3	160	<0.4	24	<0.1	0.6	<0.07
CE491_T6-2	2B	300/1	6	9.26	60.7	<0.2	27.6	<1.7	<0.3	3.5	<0.2	4.8	<0.08	<1.4	<1.7	0.23	<1.2	12	1.7	0.5	1.5	12	<0.3	1.6	<0.4	7.3	<3	168	0.5	17	<0.1	<0.4	<0.07
CE491_T6-3	5B	300/1	6	9.2	72.5	<0.2	23.9	<1.7	<0.3	1.2	<0.2	5.2	<0.08	<1.4	<1.7	<0.14	<1.2	14	1.4	0.4	0.9	6	0.4	1.7	<0.4	<6.1	<3	169	<0.4	18	0.1	<0.4	<0.07
CE491_T6-4	5E	300/1	6	9.34	66.1	<0.2	54.6	<1.7	<0.3	2.1	<0.2	6.0	<0.08	<1.4	<1.7	<0.14	<1.2	20	1.1	0.5	0.9	5	0.3	1.7	<0.4	<6.1	<3	288	<0.4	18	0.6	<0.4	<0.07
CE491_T6-5	5E duplicate	300/1	6	9.33	55.4	<0.2	58.4	<1.7	<0.3	2.1	<0.2	6.0	<0.08	<1.4	<1.7	<0.14	1.3	19	1.2	0.4	0.9	5	<0.3	1.7	<0.4	11.6	<3	290	<0.4	18	0.6	<0.4	0.16
CE491_T6-6	7E	300/1	6	9.29	70.2	<0.2	33.1	<1.7	<0.3	323	<0.2	5.1	<0.08	<1.4	<1.7	<0.14	<1.2	10	3.2	0.4	0.9	17	0.3	1.7	<0.4	<6.1	<3	486	<0.4	48	<0.1	<0.4	<0.07
CE491_T6-7	1B	300/1	18	8.72	85.3	<0.2	48.7	<1.7	<0.3	1.0	<0.2	5.4	<0.08	<1.4	<1.7	0.18	<1.2	12	1.9	0.3	1.1	8	<0.3	1.7	<0.4	<6.1	<3	169	<0.4	27	<0.1	0.6	<0.07
CE491_T6-8	2B	300/1	18	8.78	55.5	<0.2	42	<1.7	<0.3	3.7	<0.2	4.9	<0.08	<1.4	<1.7	<0.14	<1.2	11	1.6	0.5	1.6	7	1.8	1.6	<0.4	11.6	<3	165	<0.4	17	<0.1	0.5	<0.07
CE491_T6-9	5B	300/1	18	8.7	57.3	<0.2	39.5	<1.7	<0.3	1.4	<0.2	5.6	<0.08	<1.4	<1.7	<0.14	<1.2	15	1.4	0.6	0.9	5	0.5	1.7	<0.4	<6.1	<3	175	0.4	19	0.2	<0.4	<0.07
CE491_T6-10	5E	300/1	18	8.64	59.5	<0.2	75.6	<1.7	<0.3	2.1	<0.2	6.3	<0.08	<1.4	<1.7	<0.14	1.2	23	1.1	0.7	0.9	5	<0.3	1.7	<0.4	10	<3	287	<0.4	18	0.8	0.5	<0.07
CE491_T6-11	5E duplicate	300/1	18	8.65	60.7	<0.2	73.1	<1.7	<0.3	2.1	<0.2	6.3	<0.08	<1.4	<1.7	0.19	<1.2	21	1.1	0.5	1.0	5	<0.3	1.7	<0.4	8.6	<3	287	<0.4	18	0.7	0.4	<0.07
CE491_T6-12	7E	300/1	18	8.74	63.9	<0.2	42.1	<1.7	<0.3	313	<0.2	5.6	<0.08	<1.4	<1.7	<0.14	<1.2	9	3.3	0.4	0.9	15	<0.3	1.7	<0.4	<6.1	<3	514	<0.4	49	<0.1	<0.4	<0.07
CE491_T6-13	1B	300/1	48	8.69	54.5	<0.2	69.8	2.9	<0.3	1.0	<0.2	5.7	<0.08	<1.4	<1.7	<0.14	<1.2	10	1.9	0.5	1.1	7	<0.3	1.7	<0.4	<6.1	<3	168	<0.4	27	<0.1	0.9	<0.07
CE491_T6-14	2B	300/1	48	9.19	55.0	<0.2	58	<1.7	<0.3	3.7	<0.2	5.2	<0.08	<1.4	<1.7	<0.14	<1.2	9	1.7	0.3	1.7	5	1.6	1.6	<0.4	12.3	5.6	165	<0.4	17	<0.1	0.8	<0.07
CE491_T6-15	5B	300/1	48	9.17	53.1	<0.2	58.3	<1.7	<0.3	1.4	<0.2	5.8	<0.08	<1.4	<1.7	<0.14	<1.2	13	1.4	0.6	0.9	5	0.6	1.9	<0.4	11.6	<3	180	<0.4	19	0.2	0.5	<0.07
CE491_T6-16	5E	300/1	48	9.14	54.6	<0.2	103	<1.7	<0.3	2.1	<0.2	6.4	<0.08	<1.4	<1.7	<0.14	1.3	23	1.2	0.3	0.9	4	<0.3	1.7	<0.4	13.6	<3	312	<0.4	19	0.9	0.5	<0.07
CE491_T6-17	5E duplicate	300/1	48	9.21	55.1	<0.2	102	<1.7	<0.3	2.1	<0.2	6.5	<0.08	<1.4	<1.7	<0.14	<1.2	23	1.1	0.6	1.0	4	0.3	1.7	0.49	10	<3	302	0.7	19	0.9	0.7	<0.07
CE491_T6-18	7E	300/1	48	9.14	59.0	<0.2	55.1	<1.7	<0.3	359	<0.2	5.8	<0.08	<1.4	<1.7	0.23	<1.2	8	3.2	0.3	0.9	16	<0.3	1.7	<0.4	<6.1	<3	533	1.0	53	<0.1	0.5	<0.07
CE491_T6-19	1B	1000/1	6	8.49	47.9	<0.2	18.7	<1.7	<0.3	0.8	<0.2	4.0	<0.08	<1.4	<1.7	0.18	<1.2	16	0.9	0.5	0.9	22	<0.3	1.6	<0.4	<6.1	<3	163	<0.4	21	<0.1	<0.4	<0.07
CE491_T6-20	2B	1000/1	6	8.73	58.3	<0.2	16.5	<1.7	<0.3	3.0	<0.2	4.2	<0.08	<1.4	<1.7	<0.14	<1.2	15	0.8	0.5	1.1	24	<0.3	1.5	<0.4	<6.1	<3	162	<0.4	17	<0.1	<0.4	<0.07
CE491_T6-21	5B	1000/1	6	8.18	45.8	0.3	13.1	<1.7	<0.3	1.2	<0.2	3.9	<0.08	<1.4	<1.7	0.19	<1.2	18	0.8	0.3	0.9	11	0.3	1.5	<0.4	7	<3	178	<0.4	18	0.1	<0.4	<0.07
CE491_T6-22	5E	1000/1	6	8.93	57.2	<0.2	26	<1.7	<0.3	1.9	<0.2	4.8	<0.08	<1.4	<1.7	0.14	1.5	19	0.6	0.4	0.8	9	<0.3	1.6	<0.4	<6.1	<3	198	0.8	18	0.3	<0.4	<0.07
CE491_T6-23	5E duplicate	1000/1	6	8.81	45.6	<0.2	25.7	<1.7	<0.3	1.9	<0.2	4.8	<0.08	<1.4	<1.7	<0.14	<1.2	19	0.6	0.6	0.8	9	<0.3	1.5	0.45	<6.1	<3	194	0.5	18	0.3	<0.4	<0.07
CE491_T6-24	7E	1000/1	6	8.97	59.1	<0.2	19.6	<1.7	<0.3	268	<0.2	4.8	<0.08	<1.4	<1.7	<0.14	<1.2	15	1.4	0.5	0.8	39	<0.3	1.5	<0.4	<6.1	<3	306	0.5	38	<0.1	<0.4	<0.07
CE491_T6-25	1B	1000/1	18	7.96	55.3	<0.2	23.8	<1.7	<0.3	0.8	<0.2	4.3	<0.08	<1.4	<1.7	<0.14	<1.2	15	0.9	0.4	0.9	23	<0.3	1.5	<0.4	<6.1	<3	160	0.5	22	<0.1	<0.4	<0.07
CE491_T6-26	2B	1000/1	18	8.05	87.6	<0.2	21.5	<1.7	<0.3	3.2	<0.2	4.5	<0.08	<1.4	<1.7	<0.14	<1.2	15	0.9	0.6	1.1	23	<0.3	1.5	<0.4	<6.1	<3	154	<0.4	18	<0.1	<0.4	<0.07
CE491_T6-27	5B	1000/1	18	7.84	45.4	<0.2	17.9	<1.7	<0.3	1.2	<0.2	4.1	<0.08	<1.4	<1.7	<0.14	<1.2	17	0.8	0.3	0.9	13	<0.3	1.5	<0.4	<6.1	<3	162	<0.4	18	<0.1	<0.4	<0.07
CE491_T6-28	5E	1000/1	18	7.98	57.0	<0.2	32.2	<1.7	<0.3	1.9	<0.2	5.0	<0.08	<1.4	<1.7	<0.14	1.6	18	0.6	0.4	0.8	9	<0.3	1.5	<0.4	<6.1	<3	198	<0.4	18	0.3	<0.4	<0.07
CE491_T6-29	5E duplicate	1000/1	18	8	68.5	<0.2	31.9	<1.7	<0.3	1.9	<0.2	4.9	<0.08	<1.4	<1.7	<0.14	<1.2	19	0.7	0.7	0.8	9	<0.3	1.6	<0.4	<6.1	<3	183	<0.4	18	0.3	<0.4	<0.07
CE491_T6-30	7E	1000/1	18	8.24	72.8	<0.2	22.2	<1.7	<0.3	294	<0.2	5.4	<0.08	<1.4	<1.7	<0.14	<1.2	14	1.4	0.4	0.8	47	<0.3	1.5	<0.4	<6.1	<3	313	<0.4	41	<0.1	<0.4	<0.07
CE491_T6-31	1B	1000/1	48	8.55	43.1	<0.2	34.4	<1.7	<0.3	0.8	<0.2	4.6	<0.08	<1.4	<1.7	<0.14	<1.2	14	0.9	0.4	1.0	22	<0.3	1.5	<0.4	<6.1	<3	164	<0.4	23	<0.1	0.4	<0.07
CE491_T6-32	2B	1000/1	48	8.71	45.3	<0.2	30.7	<1.7	<0.3	3.2	<0.2	4.8	<0.08	<1.4	<1.7	<0.14	<1.2	14	0.9	0.4	1.1	20	<0.3	1.5	<0.4	<6.1	<3	157	<0.4	19	<0.1	0.4	<0.07
CE491_T6-33	5B	1000/1	48	8.18	39.8	<0.2	23.4	<1.7	<0.3	1.3	<0.2	4.2	<0.08	<1.4	<1.7	<0.14	<1.2	17	0.8	0.4	0.9	16	<0.3	1.5	<0.4	<6.1	<3	160	<0.4	19	<0.1	<0.4	<0.07
CE491_T6-34	5E	1000/1	48	8.54	43.4	<0.2	45	<1.7	<0.3	1.8	<0.2	4.9	<0.08	<1.4	<1.7	<0.14	1.3	20	0.6	0.6	0.8	9	<0.3	1.5	<0.4	<6.1	<3	201	<0.4	18	0.4	<0.4	<0.07
CE491_T6-35	5E duplicate	1000/1	48	8.75	43.2	<0.2	45.6	<1.7	<0.3	1.8	<0.2	5.3	<0.08	<1.4	<1.7	0.19	<1.2	18	0.7	0.4	0.8	9	<0.3	1.5	<0.4	9.6	<3	193	<0.4	19	0.3	<0.4	<0.07
CE491_T6-36	7E	1000/1	48	8.96	48.9	<0.2	37.1	<1.7	<0.3	309	<0.2	5.4	<0.08	<1.4	<1.7	<0.14	<1.2	13	1.4	0.5	0.8	36	<0.3	1.5	<0.4	<6.1	<3	329	<0.4	42	<0.1	<0.4	<0.07
CE491_T6-37	Talbingo water rep 1			7.3	46	<0.2	5.82	<1.7	<0.3	4.3	<0.2	2.0	<0.08	<1.4	<1.7	<0.14	<1.2	17	0.5	0.2	0.8	0.2	<0.3	1.4	<0.4	<6.1	<3	156	<0.4	17	<0.1	<0.4	2.11
CE491_T6-38	Talbingo water rep 2			7.31	38	<0.2	4.4	<1.7	<0.3	4.3	<0.2	2.0	<0.08	<1.4	<1.7	<0.14	<1.2	17	0.4	<0.2	0.8	0.2	<0.3	1.5	<0.4	<6.1	<3	158	<0.4	16	<0.1	<0.4	1.56
CE491_T6-39	Talbingo water rep 3			7.32	35	<0.2	4.52	<1.7	<0.3	4.3	<0.2	2.0	<0.08	<1.4	<1.7	0.21	1.4	18	0.5	<0.2	0.8	0.2	<0.3	1.5	<0.4	<6.1	<3	157	<0.4	17	<0.1	<0.4	1.54

Memo 9 (7 November 2018)

Sample Labels	Spoil composite	L/S ratio	Duration (h)	Ag (µg/L)	Al (µg/L)	As (µg/L)	B (µg/L)	Ba (µg/L)	Be (µg/L)	Ca (mg/L)	Cd (µg/L)	Ce (µg/L)	Co (µg/L)	Cr (µg/L)	Cu (µg/L)	Fe (µg/L)	K (mg/L)	Li (µg/L)	Mg (mg/L)	Mn (µg/L)	Mo (µg/L)	Na (mg/L)	Ni (µg/L)	P (µg/L)	Pb (µg/L)	S (µg/L)	Sn (µg/L)	Sr (µg/L)	Ti (µg/L)	V (µg/L)	Zn (µg/L)
Mean blank				**0.0**	**-0.8**	**-0.3**	**0.6**	**-0.1**	**-0.1**	**0.6**	**-0.1**	**0.2**	**0.9**	**-0.3**	**-0.9**	**0.1**	**0.0**	**-0.1**	**0.0**	**-0.2**	**-0.2**	**0.0**	**-0.1**	**-0.5**	**-0.9**	**-2.5**	**-0.1**	**-0.2**	**0.0**	**-0.1**	**-3.0**
LOD (3 x S.d.)				**0.21**	**0.24**	**1.7**	**0.27**	**0.02**	**0.15**	**0.4**	**0.08**	**1.4**	**1.7**	**0.14**	**1.2**	**0.56**	**0.1**	**0.21**	**0.0**	**0.05**	**0.25**	**0.0**	**0.41**	**6.1**	**3**	**9.8**	**0.36**	**0.01**	**0.1**	**0.37**	**0.07**
TM-24.4				10	35	5	9	15	2		4	-1	6	5	7	16	1	0	5	8	6	8	5	-1	6	5893	4	120	8	7	29
					32.9 ±	5.30 ±		15.0 ±			3.96 ±		6.27 ±	5.00 ±	6.31 ±	16.0 ±		4.95 ±		8.24±			5.03 ±		5.60 ±					7.00 ±	
Certified TM24.4				8.92	4.5	0.53		1.0			0.34		0.57	0.59	0.60	2.3		0.42		0.73			0.53		0.52			113 ± 8		0.58	
% recovery (TM24.4)				**111**	**106**	**91**		**102**			**107**		**97**	**108**	**106**	**102**		**5**		**101**			**107**		**106**			**106**		**104**	
TMDA-64.3				13	306	164	271	287	170		267	-1	268	292	272	301	1	121	5	295	289	9	265	2	293	5848	284	628	130	287	333
				12.6 ±	291 ±	164 ±		287 ±			258 ±		250 ±	283 ±	261 ±	298 ±		143 ±		292 ±			252 ±		280 ±			628 ±		279 ±	320 ±
Certified TM63.4				1.3	23	15		18			21		16	17	18	21		15		17			18		22			34		18	23
% recovery (TMDA63.4)				**103**	**105**	**100**		**100**			**104**		**107**	**103**	**104**	**101**		**85**		**101**			**105**		**105**			**100**		**103**	**104**
CE491_T6-1 + spike				**100**	**97**	**100**	**100**	**98**	**98**		**99**	**99**	**102**	**99**	**99**	**99**		**96**		**98**	**99**		**99**	**104**	**99**	**99**	**99**	**98**	**99**	**100**	**99**
CE491_T6-11 + spike				**99**	**96**	**100**	**100**	**98**	**99**		**99**	**99**	**101**	**99**	**99**	**99**		**95**		**99**	**100**		**99**	**102**	**99**	**96**	**99**	**98**	**98**	**99**	**99**
CE491_T6-21 + spike				**99**	**98**	**100**	**100**	**98**	**97**		**98**	**99**	**98**	**99**	**99**	**99**		**96**		**98**	**99**		**99**	**101**	**99**	**97**	**99**	**98**	**99**	**99**	**98**
CE491_T6-31 + spike				**99**	**99**	**100**	**101**	**99**	**98**		**99**	**99**	**99**	**99**	**100**	**99**		**96**		**99**	**100**		**99**	**100**	**99**	**98**	**100**	**98**	**99**	**99**	**99**
X 10 T6-10 + Spike										**83**							**99**		**100**			**98**									
X 10 T6-20 + Spike										**88**							**101**		**97**			**98**									
X 10 T6-30 + Spike										**84**							**99**		**99**			**98**									

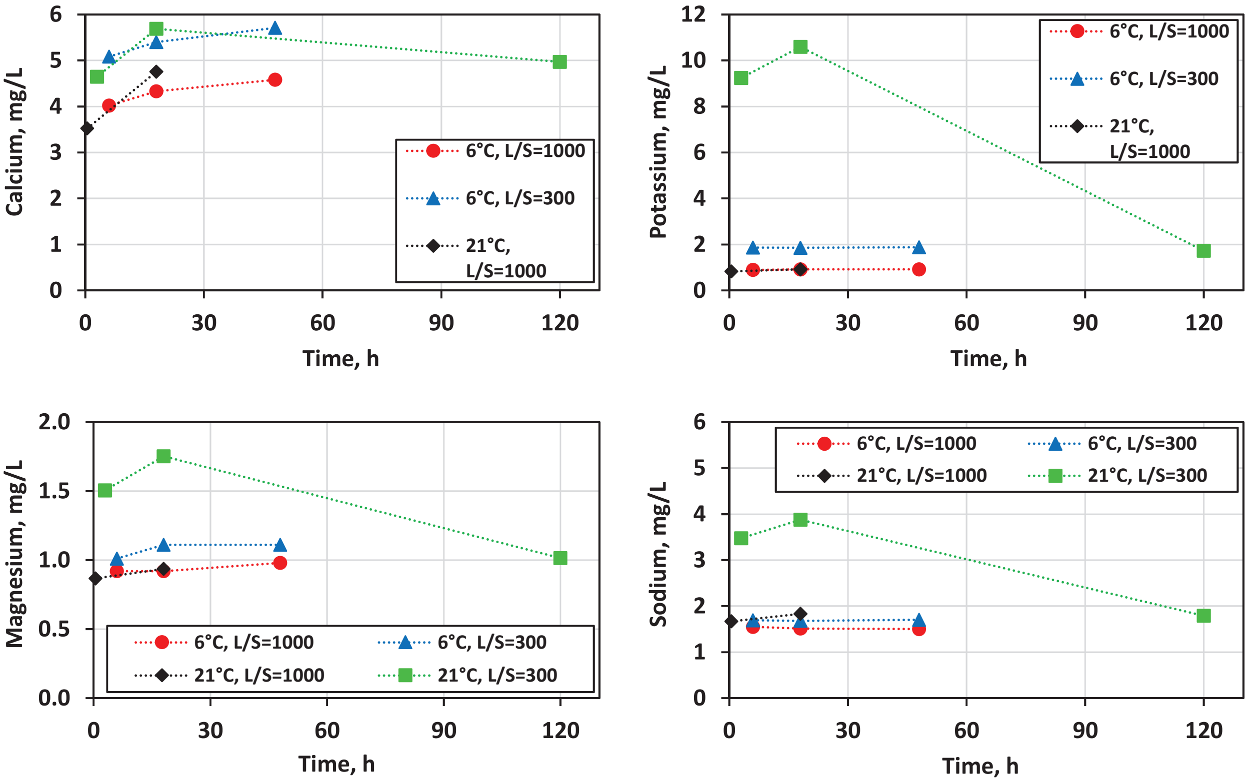


Figure D6.1. Major cation concentration of composite 1B elutriate tests undertaken at 6ºC and 21ºC

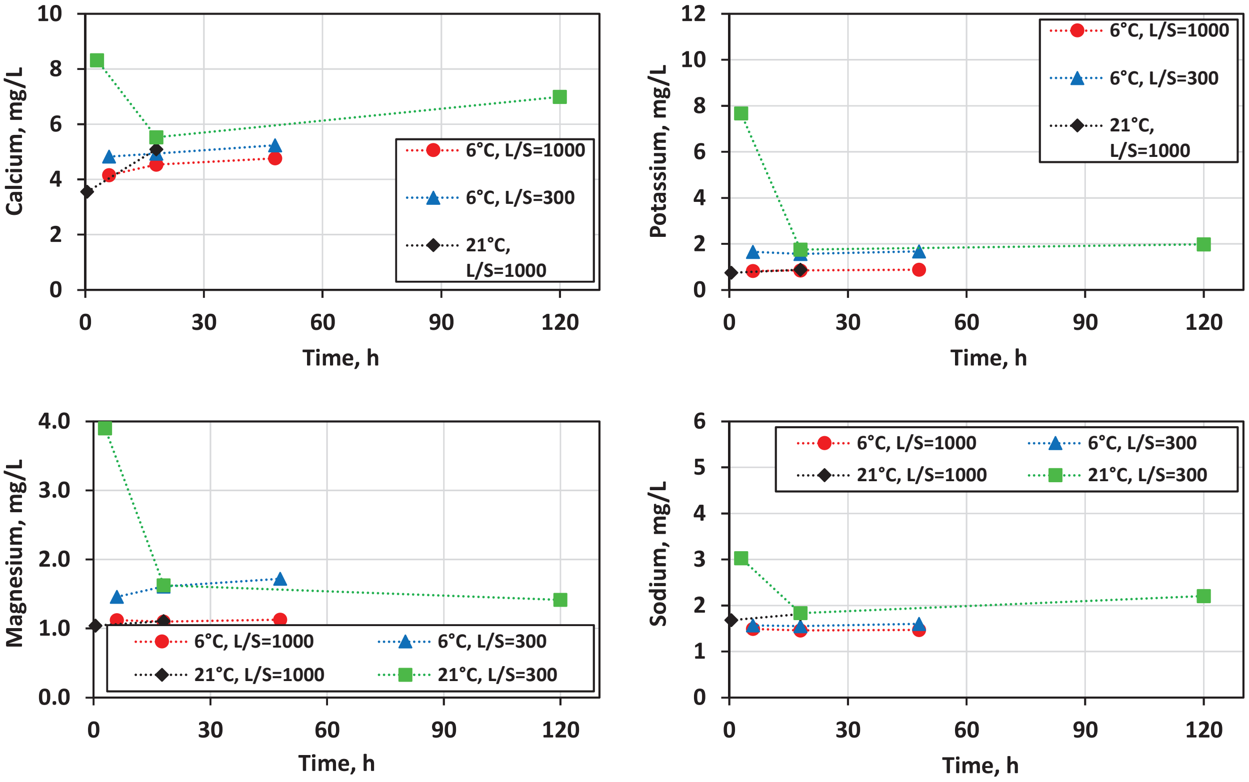


Figure D6.2. Major cation concentration of composite 2B elutriate tests undertaken at 6ºC and 21ºC

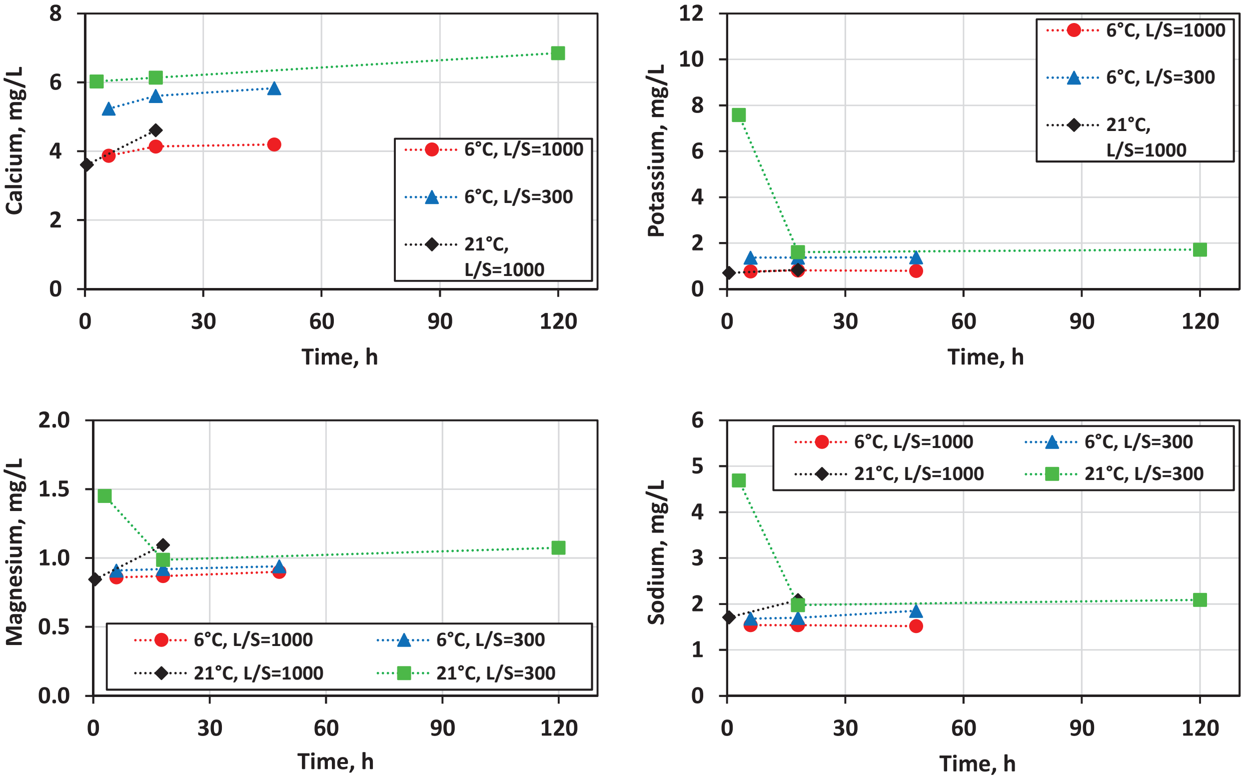


Figure D6.3. Major cation concentration of composite 5B elutriate tests undertaken at 6ºC and 21ºC

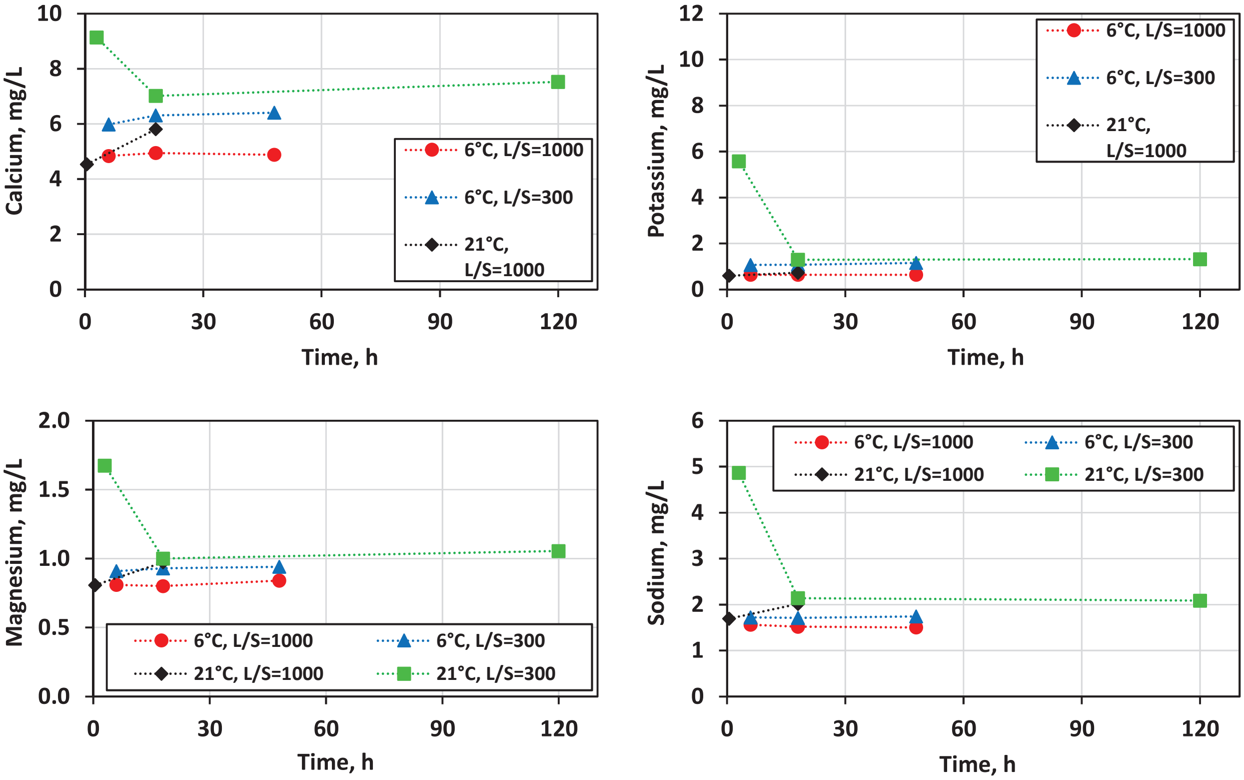


Figure D6.4. Major cation concentration of composite 5E elutriate tests undertaken at 6ºC and 21ºC

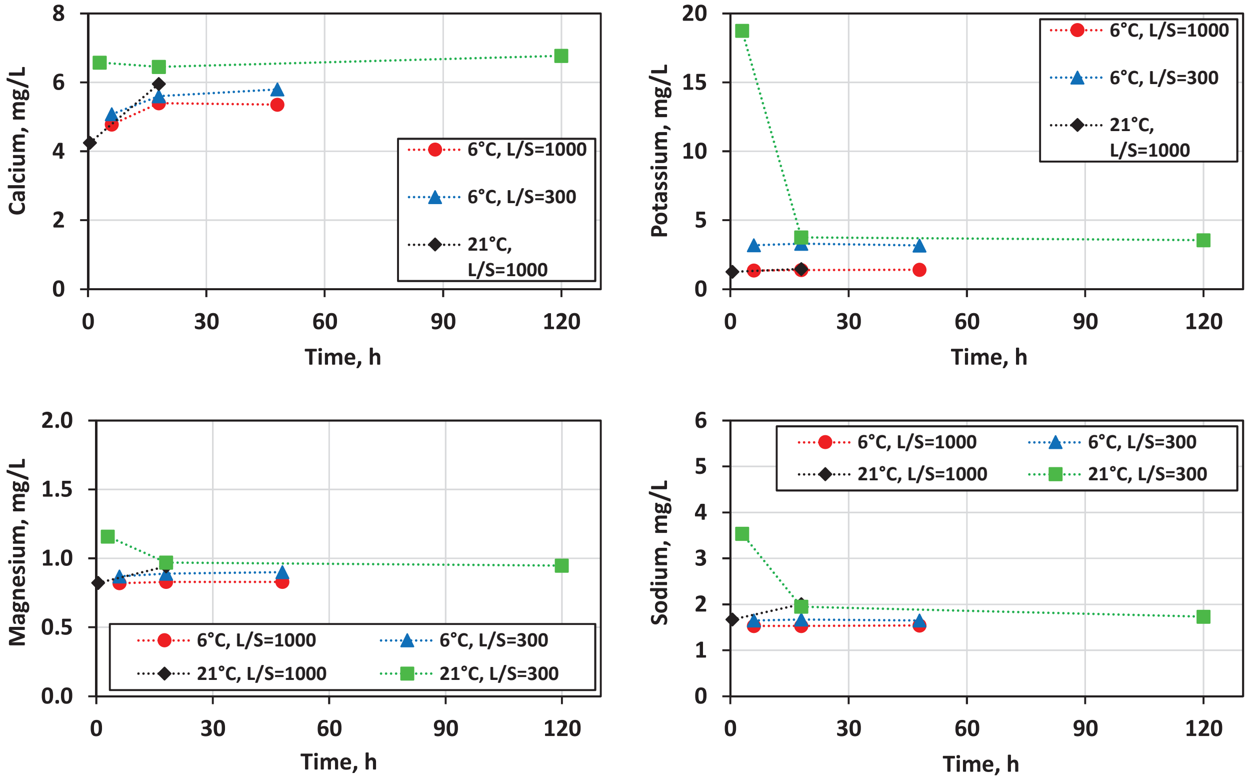


Figure D6.5. Major cation concentration of composite 7E elutriate tests undertaken at 6ºC and 21ºC

Appendix D7. Effect of repeat leaching on substance release

Note/Memo	CSIRO P4 Project Investigations
To:	Ali Watters (HKA)
From:	Brad Angel, Lucas Heights, NSW
Date:	23 November 2018
Copy:	Ryan Fraser, Stuart Simpson and Ellen Porter (SHL)
Our reference:	CSIRO P4 – Memo 12
Classification:	Internal use only
Subject:	Pollutant release from excavated rock composites: effect of successive leaches and temperature on water quality and pollutant release

Chemical formulas and acronyms

Al	Aluminium	DGV	Default guideline value	L/S	Liquid/solid ratio
SEC	Conductivity				

Background - Introduction

The CSIRO was engaged by Haskoning Australia Pty Ltd (RHDHV) to undertake an investigation of the pollutant release from excavated rock disposal into Talbingo and Tantangara reservoirs. Previous elutriate tests (e.g. Memos 4, 5, 6) investigating the release of pollutants from composite excavated rock samples have observed significant changes in water quality with respect to pH, conductivity (SEC) and the dissolved aluminium concentrations. The temperature of elutriate solutions was also shown to have a strong effect on water quality and aluminium concentrations (Memo 9).

This technical memo describes results of two series of successive elutriate tests (3 leaches each) performed to investigate the effect of excavated rock composites 1B, 2B, 5B, 5E and 7E in Talbingo reservoir water on pH, conductivity (SEC), and the dissolved aluminium concentration. The first successive leach test series investigated the effect of two mixing durations for two liquid to solid (L/S) ratios at 21°C. The second successive leach test series investigated the effect of temperature (6°C and 21°C) for the two L/S ratios. The tests were performed using the following conditions:

- Successive leach test series 1
    - L/S = 30 and 300 i.e. 33 and 3.3 g/L, respectively
    - Mixing durations for each successive leach of either 0.5 or 18 h
    - Talbingo reservoir water at 21±2°C
- Successive leach test series 2
    - L/S = 30 and 300 i.e. 33 and 3.3 g/L, respectively
    - Mixing durations for each successive leach of 18 h
    - Talbingo reservoir water at 6±1°C and 21±2°C

Test methodology

The 75 µm milled composites 1B, 2B, 5B, 5E and 7E characterised in memo 3 were used in the successive leach tests. The desired mass of each sample was weighed into 50 mL acid washed polyethylene tubes, to which 50 mL of composite Talbingo (TAL-PL1A, TAL-PL2A and TAL-PL2B) reservoir water was added. The water was adjusted to 6°C and 21°C before addition. For successive leach test series 1, the treatments were shaken (50 rpm) at 21°C for either 0.5 or 18 h for each cycle. For successive leach test series 2, the treatments were shaken for 0.5 h, then stood in temperature controlled rooms (6±1°C and 21±2°C) for another 17.5 h so that they were in contact with the water for 18 h for each leach cycle. This allowed an additional comparison of the effect of mixing vs standing for the 18 h, 21±2°C treatments in tests series 1 and 2.

After each leach cycle, the tubes were centrifuged (2000 g, 5 mins) followed by subsampling for measurement of pH, SEC, and dissolved (0.45 µm) metals analyses. The remaining supernatant was decanted and 50 mL fresh composite Talbingo reservoir water of the desired temperature added. The tube and its' contents were weighed before adding fresh reservoir water to check on the residual water carried over from one leach to the next; this was 2-4% by volume and considered negligible. The process was repeated so that each treatment received three leaches in total.

Results

Test series *1 (0.5 h or 18 h mixing, 21°C):*

The pH, conductivity and dissolved aluminium concentrations measured in successive leach test series 1 (21°C treatments) with excavated rock composites 1B, 2B, 5B, 5E and 7E are shown in Figures 1, 2, 3, 4 and 5, respectively.

For all excavated rock samples at each L/S ratio and mixing duration, the pH of the leach 1, 2 and 3 solutions were in the range 9.23-9.67, 8.83-9.57, and 7.89-9.51, respectively. The pH was generally higher for a lower L/S ratio and longer mixing duration and decreased in each successive leach.

For all excavated rock samples at each L/S ratio and mixing duration, the conductivity of the leach 1, 2 and 3 solutions were in the range 50-133, 40-89, and 33-117 µS/cm, respectively. The conductivity was more variable than pH, but was generally marginally higher for the lower L/S, and for the 300 L/S ratio, was higher for the longer mixing duration. Apart from a few treatments, the conductivity generally decreased in each successive leach.

For all excavated rock samples at each L/S ratio and mixing duration, the concentration of dissolved aluminium in the leach 1, 2 and 3 solutions were in the range 26.6-329, 26.7-416, and 26.5-512 µg/L, respectively. The concentration of dissolved aluminium was generally similar or increased over successive leaches, despite the water pH successively decreasing. The exception was the 300 L/S, 18 h mixing duration treatments, where the aluminium concentration of leach 2 was similar or higher than leach 1, but often decreased for leach 3. Figures 1-5 also show that mixing duration (i.e. leach contact time) was more important than the L/S ratio, as the 0.5 h treatments for each L/S ratio also had lower concentrations of dissolved aluminium than the 18 h treatments.

The dissolved aluminium exceeded the default guideline value (DVG) of 55 µg/L for three leaches of each material for the 18 h mixing duration. The DGV was never exceeded for the 300 L/S, 0.5 h treatments, with the dissolved aluminium remaining at a similar concentration for each successive leach, i.e. the short 0.5 h mixing duration at this L/S was not adequate to either release enough aluminium to exceed the DGV or exhaust the pool of aluminium in the samples, so the concentration remained steady. The concentration of dissolved aluminium released in the 30 L/S, 0.5 h treatments always increased over successive leaches, with the initial leach often being below the DGV and the later leaches being above the DGV.

Test series 2 *(0.5 h mixing, 17.5 h standing, 6°C or 21°C):*

The pH, conductivity and dissolved aluminium concentrations measured in successive leach test series 2 (6°C and 21°C treatments) with excavated rock composites 1B, 2B, 5B, 5E and 7E are shown in Figures 6, 7, 8, 9 and 10, respectively.

The pH was higher for a lower L/S ratio, but temperature generally had little effect on pH. The pH was generally similar or marginally lower over successive leaches for the 30 L/S ratio, while for the 300 L/S ratio the pH was generally similar between the first two leaches then decreased for the third leach.

There were no discernible trends for the conductivity in successive leach test series 2, i.e. temperature had no clear effect on conductivity. The conductivity was in the range 35-402 µS/cm.

For all excavated rock samples at each L/S ratio at 6°C, the concentration of dissolved aluminium in the leach 1, 2 and 3 solutions were in the range 23.1-109, 27.9-129, and 16.8-137 µg/L, respectively, and at 21°C, the concentration of dissolved aluminium in the leach 1, 2 and 3 solutions were in the range 93.6-299, 125-403, and 65.0-384 µg/L, respectively. Less aluminium was released in the lower temperature treatments for each L/S ratio, and more aluminium was released by treatments with a lower L/S ratio. For the 21°C treatments the dissolved aluminium was generally steady or decreased over the successive leaches, whereas, for the 6°C treatments the dissolved aluminium was steady or increased over the successive leaches. The dissolved aluminium exceeded the default guideline value (DVG) of 55 µg/L for all of the leaches of the 21°C treatments and most leaches of 6°C, 30 L/S treatments, while the DGV was not exceeded by any of the 6°C, 300 L/S treatments.

A comparison of the 21°C treatments that were in contact with the reservoir water for 18 h, 0.5 h mixing (successive leach test series 2) and 18 h mixing (successive leach test series 1) indicated that longer physical mixing often caused an increase in the release of dissolved aluminium (Figure 11); most evident for the 2nd and 3rd leaches. This is likely to be the cause of the difference in trends over successive leaches between the tests for the 21°C treatments i.e. generally steady or increased in test series 1 and generally steady or decreased in test series 2.

Discussion

The lack of an effect of temperature on the conductivity and pH indicates the increase in pH occurs due to a rapid release of ions that increase the alkalinity, and this release likely occurs via ion exchange reactions. This is supported by measurements of rapid pH increase in previous tests of kinetics (Memos 6 and 11).

The results of the successive leach tests showing sustained release of aluminium over successive leaches is evidence of a dissolution process controlling the release of aluminium. This process continues while the excavated rock particles are in contact with the reservoir water and contain aluminium in forms that can be released. This process occurs more slowly at a lower temperature, so the pool of available aluminium is drawn down more slowly resulting in a greater pool available in successive leaches for the lower temperature treatments. In other words, the aluminium available for dissolution is depleted more slowly at a lower temperature.

The increased release for successive leaches and longer mixing times may be influenced by water taking time to fully encompass / contact all of the surfaces of rock particles (i.e. porosity), or particles disaggregating over time, particularly for longer mixing durations, leading to more surfaces being available for dissolution reactions to occur.

Summary

Successive leaches of excavated rock samples with Talbingo reservoir water did not rapidly exhaust the aluminium available for release into solution. To the contrary, many treatments had similar or increased aluminium concentrations in the 2nd and 3rd successive leaches. The lower temperature substantially decreased the concentration of aluminium released into reservoir waters. These results suggest a dissolution process is responsible for the release of aluminium, which is dependent on the duration of contact with water and the temperature. Longer durations of physical mixing also generally increased the release of dissolved aluminium.

The DGV for aluminium, 55 µg/L, was exceeded by most treatments in the successive leach tests.

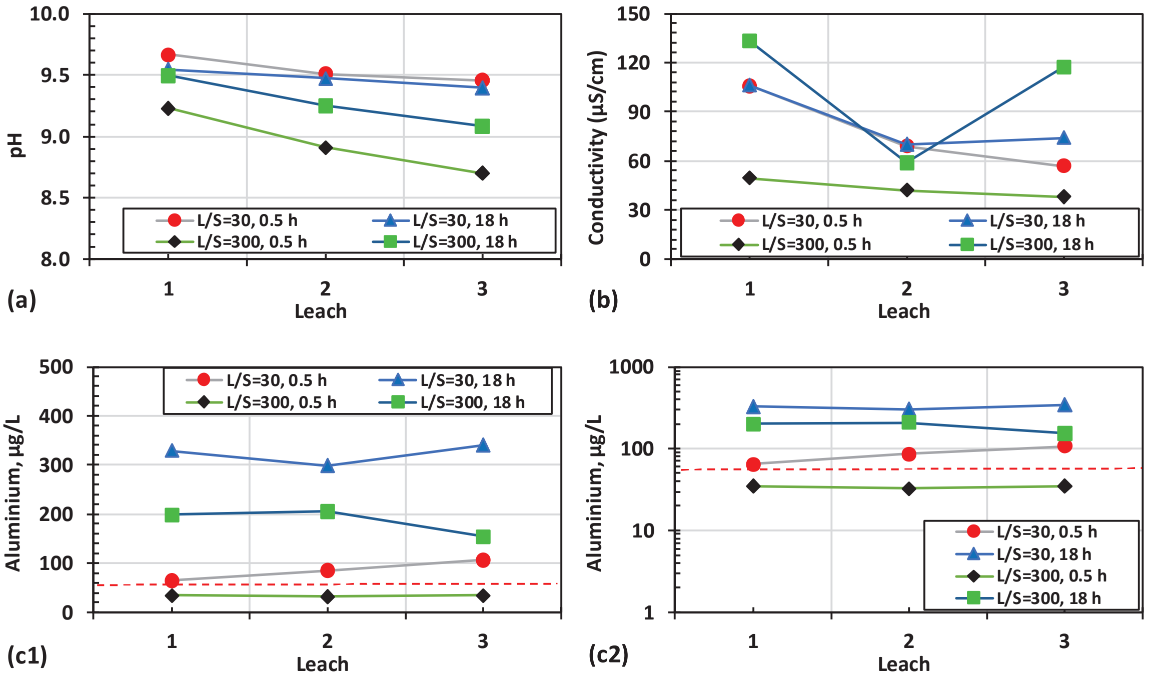


Figure 1. The pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 21±2°C for excavated rock sample 1B (successive leach test 1), where the effect of mixing duration and L/S ratio was investigated (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the red dotted line.

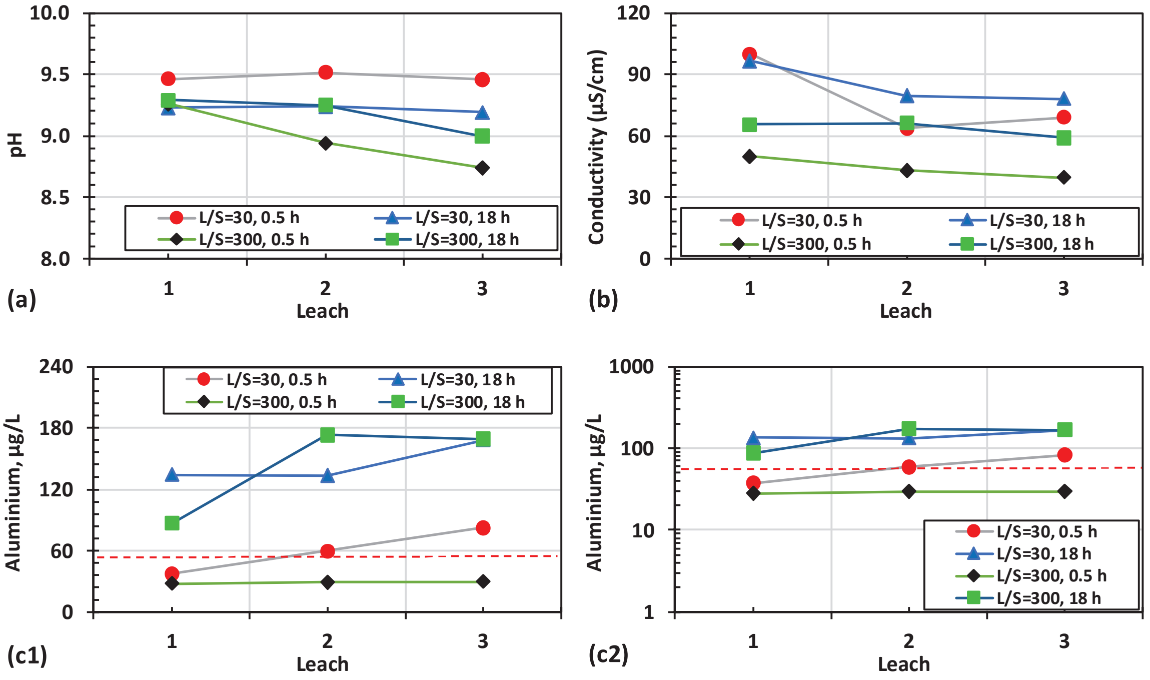


Figure 2. The pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 21±2°C for excavated rock sample 2B (successive leach test 1), where the effect of mixing duration and L/S ratio was investigated (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the red dotted line.

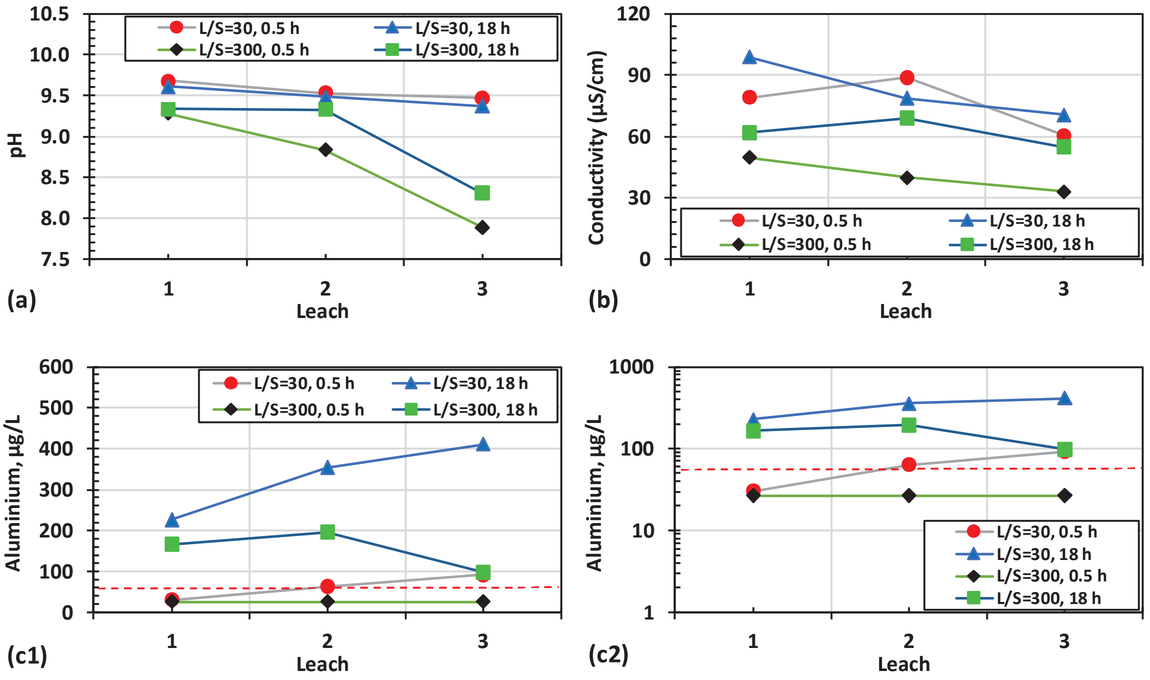


Figure 3. The pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 21±2°C for excavated rock sample 5B (successive leach test 1), where the effect of mixing duration and L/S ratio was investigated (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the red dotted line.

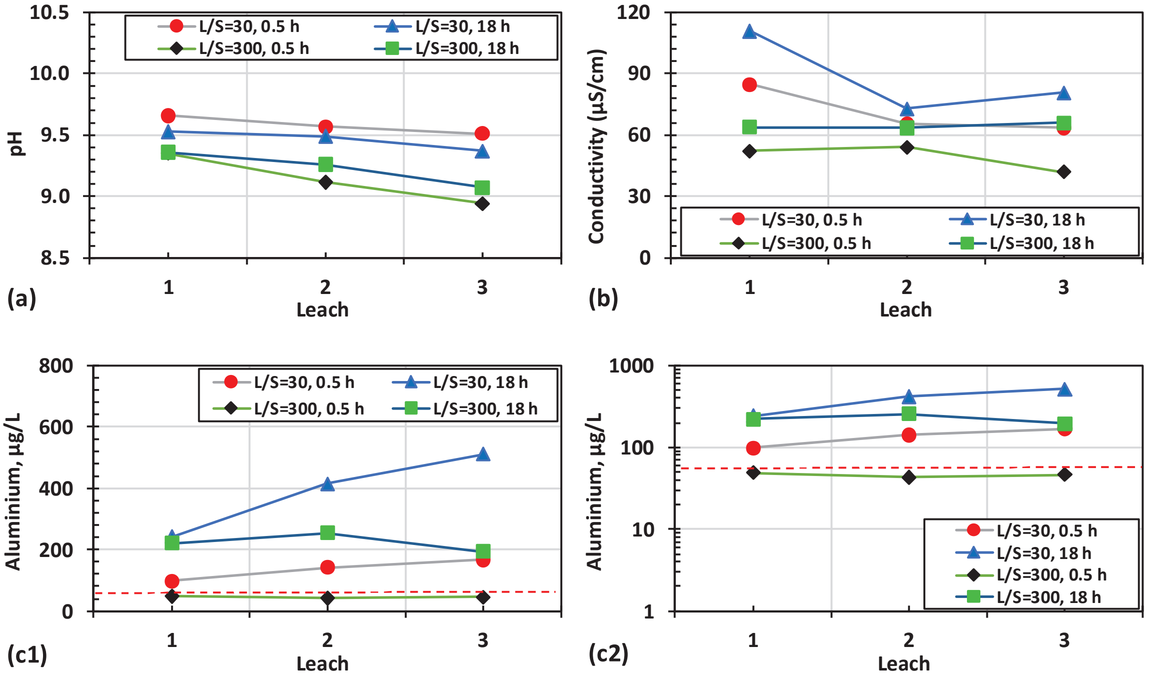


Figure 4. The pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 21±2°C for excavated rock sample 5E (successive leach test 1), where the effect of mixing duration and L/S ratio was investigated (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the red dotted line.

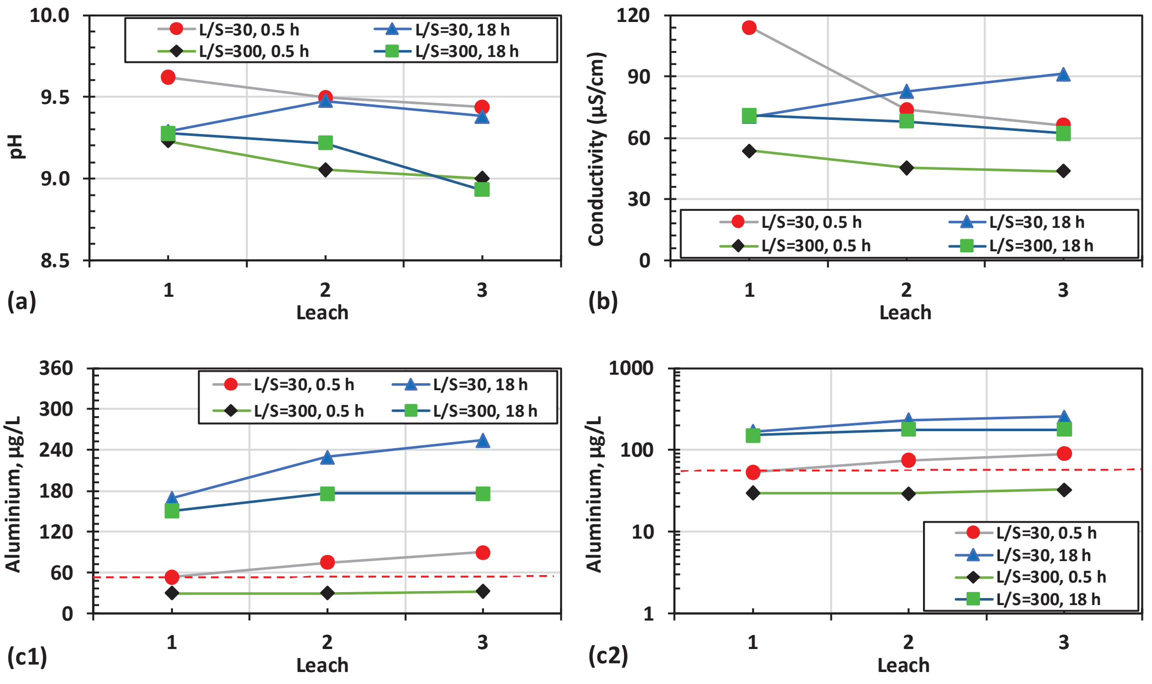


Figure 5. The pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 21±2°C for excavated rock sample 7E (successive leach test 1), where the effect of mixing duration and L/S ratio was investigated (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the red dotted line.

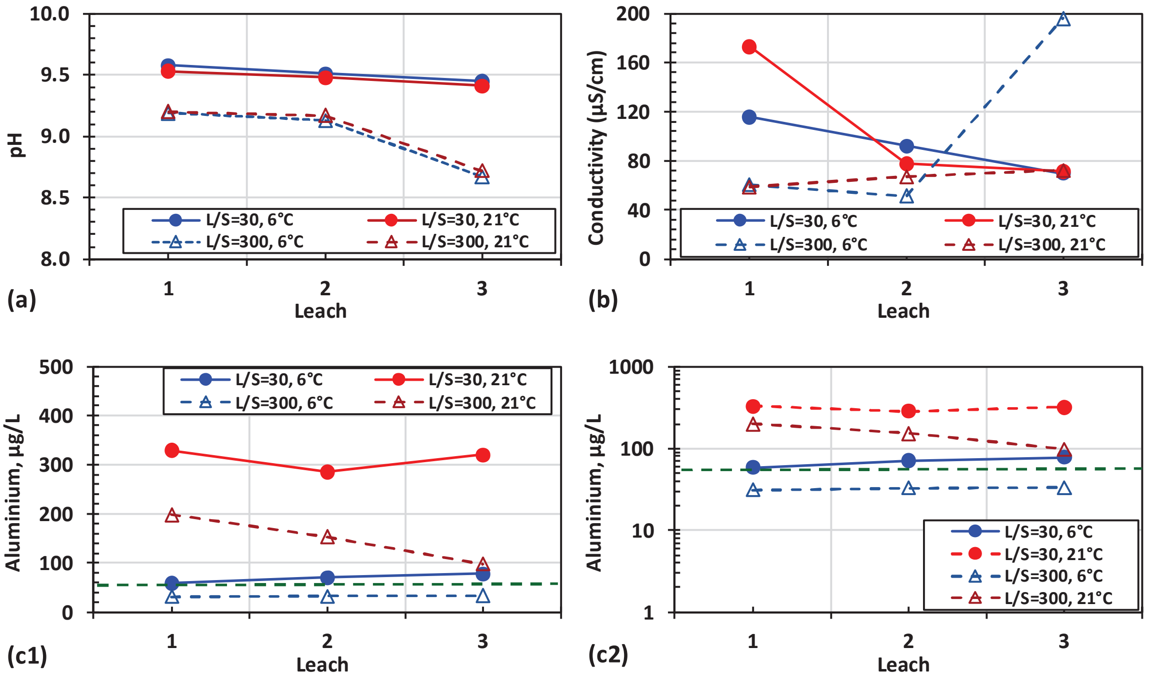


Figure 6. The effect of temperature on the pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 6±1°C and 21±2°C for excavated rock sample 1B (successive leach test 2), (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the green dotted line.

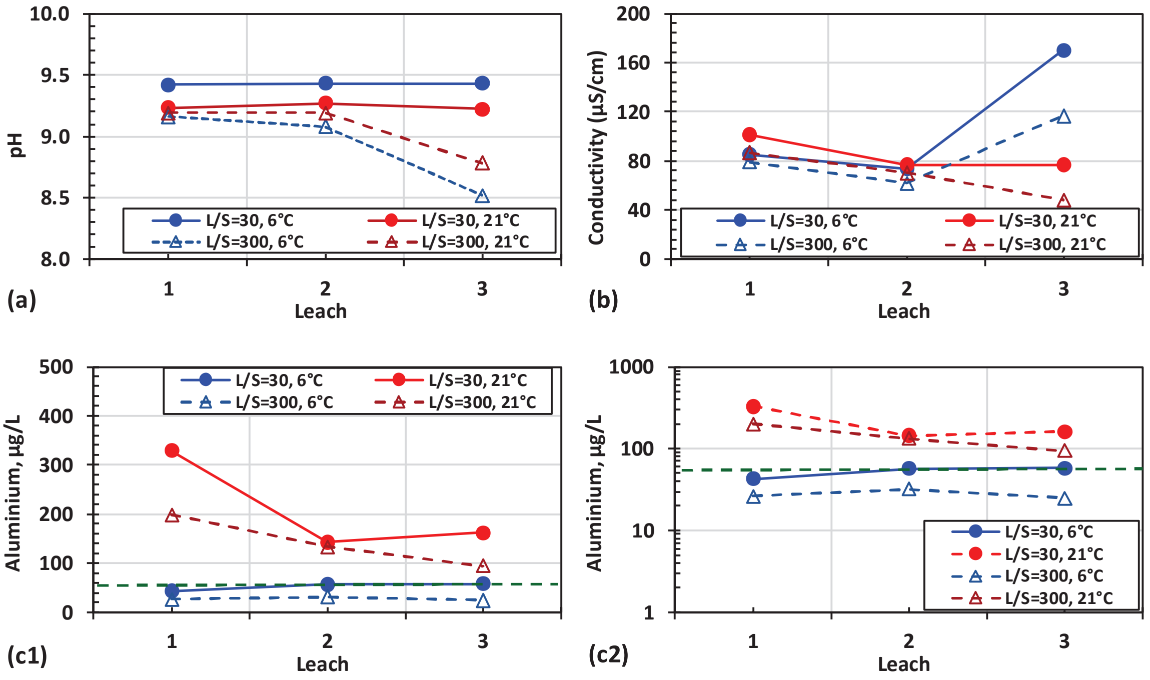


Figure 7. The effect of temperature on the pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 6±1°C and 21±2°C for excavated rock sample 2B (successive leach test 2), (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the green dotted line.

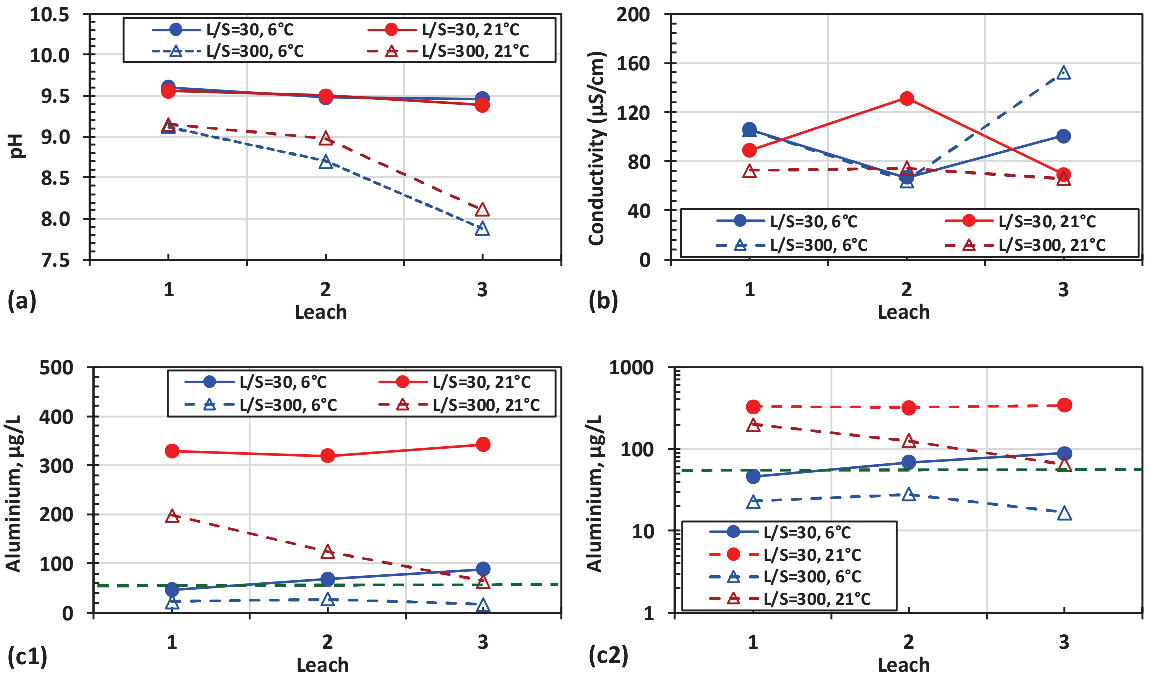


Figure 8. The effect of temperature on the pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 6±1°C and 21±2°C for excavated rock sample 5B (successive leach test 2), (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the green dotted line.

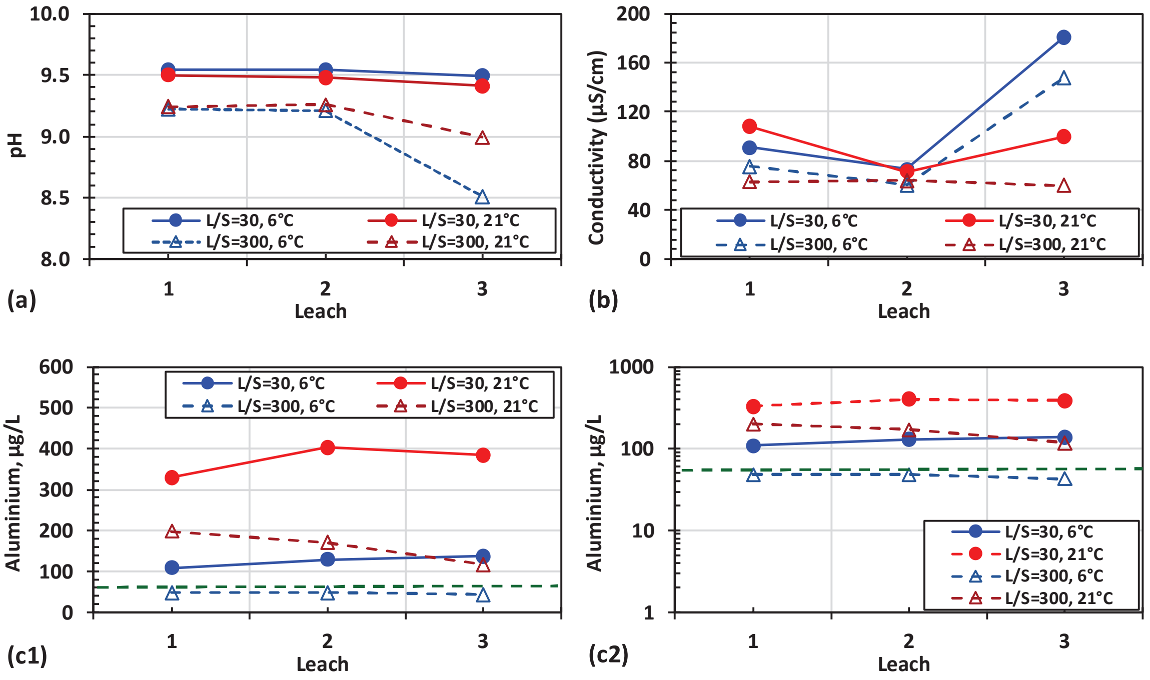


Figure 9. The effect of temperature on the pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 6±1°C and 21±2°C for excavated rock sample 5E (successive leach test 2), (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the green dotted line.

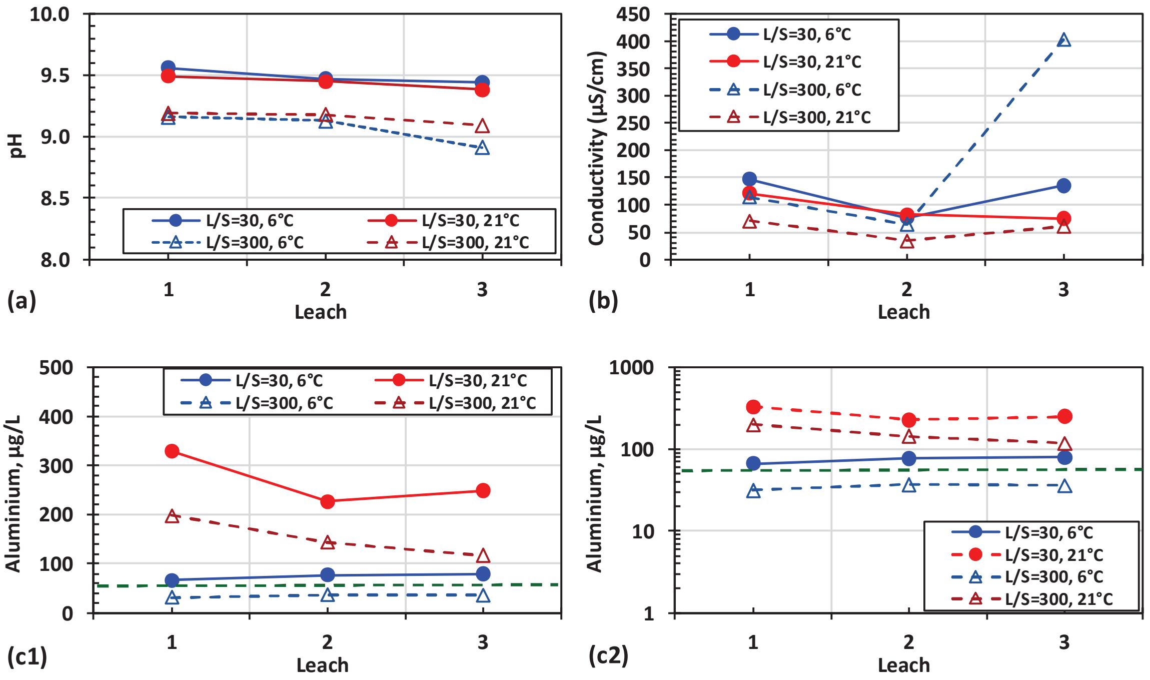


Figure 10. The effect of temperature on the pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 6±1°C and 21±2°C for excavated rock sample 7E (successive leach test 2), (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the green dotted line.

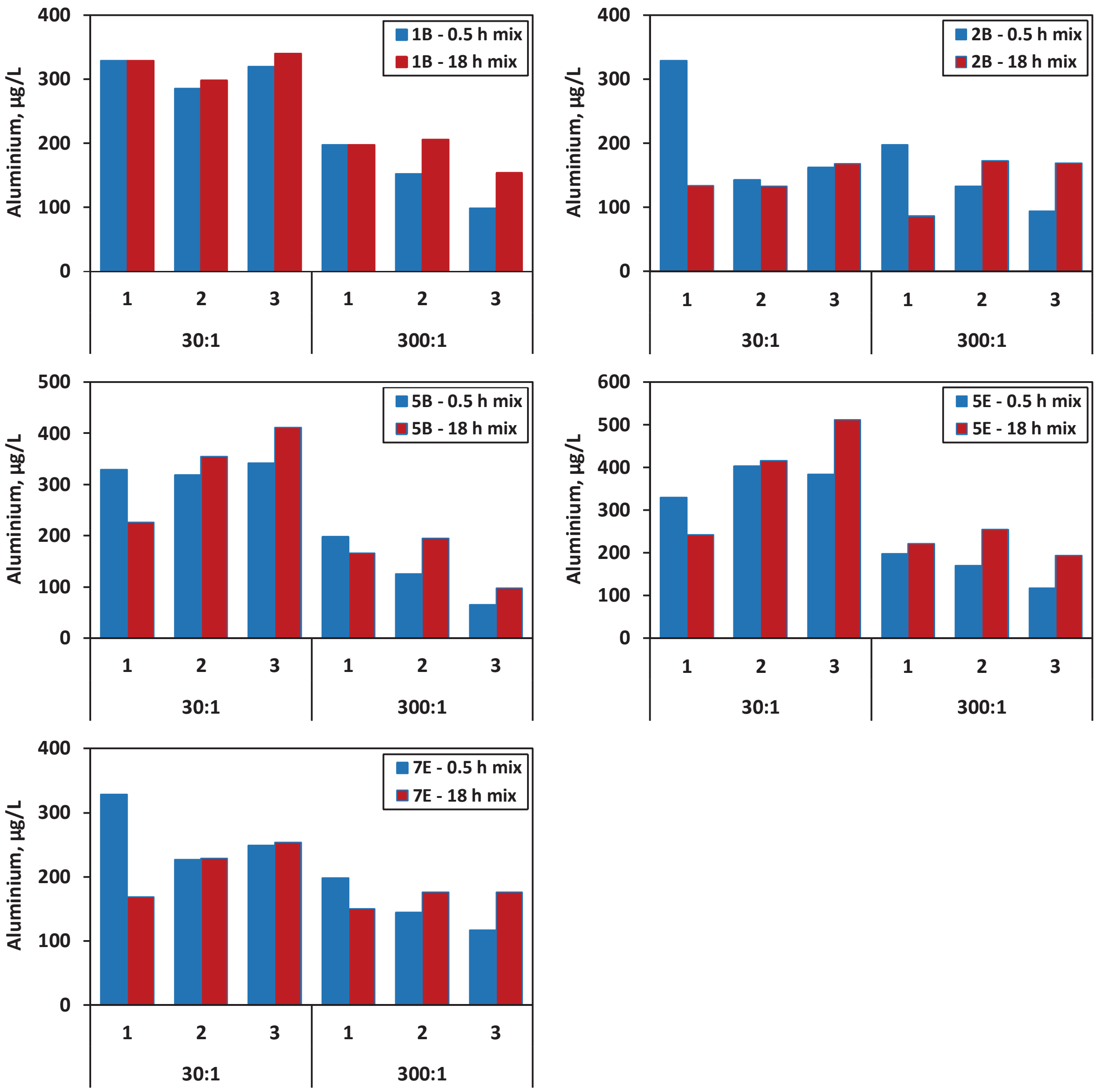


Figure 11. Comparison between the dissolved aluminium released from excavated rock material at L/S ratios of 30 and 300 in Talbingo reservoir water after 18 h contact with water between successive leach test 1 (18 h mixing, red bars) and leach test 2 (0.5 h mixing, 17.5 h standing, blue bars) at 21°C to assess the effect of mixing vs standing for each successive leach (1, 2 and 3).

Appendix D7 Effect of repeat leaching on substance release

Memo 12 (23 November 2018).

Notes **Composite Talbingo reservoir water used as leachate solution**
<75 µm composite rock materials
Successive elutriate tests (3 leaches each) with two mixing durations (0.5 or 18 h) at L/S of 30 and 300 at 21°C.

Spoil composite	L/S ratio	Duration (h)	Leach	pH	Conductivity (µs/cm)	Ag (µg/L)	Al (µg/L)	As (µg/L)	Ba (µg/L)	Cd (µg/L)	Co (µg/L)	Cr (µg/L)	Cu (µg/L)	Fe (µg/L)	Mn (µg/L)	Mo (µg/L)	Ni (µg/L)	Pb (µg/L)	Sb (µg/L)	Se (µg/L)	Sn (µg/L)	Sr (µg/L)	Th (µg/L)	Tl (µg/L)	U (µg/L)	V (µg/L)	Zn (µg/L)	Ca (mg/L)	K (mg/L)	Mg (mg/L)	Na (mg/L)
1B	30:1	0.5	1	9.66	106	<0.03	64.3	1.2	1.6	<0.05	<0.088	<0.2	<0.2	2	2	0.2	<0.2	<0.3	0.1	0.1	<0.4	36	<0.048		<0.003	2.6	<0.6				
1B	30:1	0.5	2	9.51	69	<0.02	85.2	1.4	1.5	<0.04	<0.06	<0.2	<0.2	5	3	0.1	0.3	<0.4	0.1	0.0	<0.2	29	<0.008	<0.07	0.02	2.4	6.0				
1B	30:1	0.5	3	9.45	57	<0.02	107	1.3	0.7	<0.04	<0.06	<0.2	<0.2	4	3	<0.07	0.1	<0.4	0.1	0.1	<0.2	24	<0.008	<0.07	0.03	1.7	<1.1				
1B	30:1	18	1	9.55	106	<0.02	329	7.1	2.0	<0.04	<0.06	<0.2	<0.2	1	1	0.4	<0.08	<0.4	0.9	0.2	<0.2	37	0.022	<0.07	0.03	8.1	<1.1	7.5	5.3	1.4	4.3
1B	30:1	18	2	9.47	70	<0.02	298	5.4	1.6	<0.04	<0.06	<0.2	<0.2	2	2	<0.07	0.1	<0.4	0.4	0.1	<0.2	31	<0.008	<0.07	0.16	5.3	<1.1				
1B	30:1	18	3	9.40	74	<0.02	340	6.0	0.9	<0.04	0.073	<0.2	1.51	7	3	0.1	3.2	0.9	0.4	0.1	<0.2	31	0.11	<0.07	0.27	3.2	12.7				
1B	300:1	0.5	1	9.23	50	<0.03	34.5	0.3	0.9	<0.05	<0.088	<0.2	<0.2	15	11	<0.07	0.3	<0.3	<0.09	<0.05	<0.4	24	<0.048		0.05	0.5	8.5				
1B	300:1	0.5	2	8.91	42	<0.02	32.2	0.4	0.8	<0.04	<0.06	<0.2	<0.2	16	18	<0.07	0.1	<0.4	<0.04	<0.04	<0.2	19	<0.008	<0.07	0.04	0.4	<1.1				
1B	300:1	0.5	3	8.70	38	<0.02	34.6	0.3	0.8	<0.04	<0.06	<0.2	<0.2	18	23	<0.07	0.1	<0.4	<0.04	<0.04	<0.2	18	<0.008	<0.07	0.02	0.3	<1.1				
1B	300:1	18	1	9.49	133	<0.02	198	1.4	3.2	<0.04	<0.06	<0.2	<0.2	4	1	0.6	0.1	<0.4	0.4	0.6	<0.2	19	<0.008	<0.07	0.01	6.6	<1.1	5.7	11	1.8	3.9
1B	300:1	18	2	9.25	59	<0.02	206	1.0	0.5	<0.04	<0.06	<0.2	<0.2	12	9	<0.07	0.4	<0.4	<0.04	<0.04	<0.2	20	<0.008	<0.07	0.06	0.8	1.4				
1B	300:1	18	3	9.08	117	<0.02	154	0.6	3.4	<0.04	<0.06	<0.2	<0.2	11	7	<0.07	0.3	<0.4	0.1	<0.04	<0.2	20	<0.008	<0.07	0.04	0.7	<1.1				
2B	30:1	0.5	1	9.46	100	<0.03	37.6	0.5	6.4	<0.05	<0.088	0.3	<0.2	3	2	0.7	<0.2	<0.3	0.1	0.1	<0.4	12	<0.048		<0.003	2.2	<0.6				
2B	30:1	0.5	2	9.51	64	<0.02	59.6	0.5	3.4	<0.04	<0.06	<0.2	<0.2	5	2	0.1	0.2	<0.4	0.1	0.0	<0.2	12	<0.008	<0.07	0.08	2.4	1.9				
2B	30:1	0.5	3	9.46	69	<0.02	82.4	0.4	2.7	<0.04	<0.06	<0.2	<0.2	7	2	<0.07	0.1	<0.4	0.1	<0.04	<0.2	12	<0.008	<0.07	0.08	2.3	<1.1				
2B	30:1	18	1	9.23	96	<0.02	134	2.2	6.5	<0.04	<0.06	0.43	<0.2	1	1	1.1	0.1	<0.4	1.1	0.1	<0.2	18	<0.008	<0.07	0.07	6.1	<1.1	5.4	6.9	3.7	2.8
2B	30:1	18	2	9.24	79	<0.02	133	3.5	4.9	<0.04	<0.06	<0.2	0.29	1	1	0.2	0.7	<0.4	0.5	0.1	<0.2	15	<0.008	<0.07	0.17	6.7	<1.1				
2B	30:1	18	3	9.19	78	<0.02	168	3.5	4.5	<0.04	<0.06	<0.2	<0.2	4	1	0.1	0.2	<0.4	0.4	0.1	<0.2	16	0.028	<0.07	0.22	5.1	<1.1				
2B	300:1	0.5	1	9.26	50	<0.03	28.1	0.3	3.5	<0.05	<0.088	<0.2	<0.2	17	10	0.1	<0.2	<0.3	<0.09	<0.05	<0.4	14	<0.048		<0.003	0.6	<0.6				
2B	300:1	0.5	2	8.94	43	<0.02	29.4	0.3	2.7	<0.04	<0.06	<0.2	<0.2	18	16	<0.07	0.1	<0.4	<0.04	<0.04	<0.2	15	<0.008	<0.07	0.01	0.5	<1.1				
2B	300:1	0.5	3	8.74	40	<0.02	29.5	<0.25	2.4	<0.04	<0.06	<0.2	<0.2	19	23	<0.07	0.1	<0.4	<0.04	<0.04	<0.2	14	<0.008	<0.07	<0.007	0.4	<1.1				
2B	300:1	18	1	9.29	65	<0.02	86.5	0.9	3.6	<0.04	<0.06	<0.2	<0.2	8	2	0.1	0.3	<0.4	0.1	0.1	<0.2	15	<0.008	<0.07	0.06	2.0	<1.1	5.5	1.8	1.6	1.8
2B	300:1	18	2	9.25	66	<0.02	173	0.7	3.3	<0.04	<0.06	<0.2	<0.2	10	3	<0.07	0.2	<0.4	<0.04	<0.04	<0.2	17	<0.008	<0.07	0.04	1.1	2.7				
2B	300:1	18	3	9.00	59	<0.02	169	0.5	0.9	<0.04	<0.06	<0.2	<0.2	12	19	<0.07	0.3	<0.4	0.1	0.1	<0.2	21	<0.008	<0.07	0.04	0.5	<1.1				
5B	30:1	0.5	1	9.67	79	<0.03	30.4	0.4	1.9	<0.05	<0.088	<0.2	<0.2	3	1	3.3	<0.2	<0.3	<0.09	<0.05	<0.4	16	<0.048		<0.003	1.0	<0.6				
5B	30:1	0.5	2	9.53	89	<0.02	63.4	0.5	1.6	<0.04	<0.06	<0.2	<0.2	10	2	0.6	0.1	<0.4	<0.04	<0.04	<0.2	14	<0.008	<0.07	0.06	0.8	4.6				
5B	30:1	0.5	3	9.47	60	<0.02	91.6	0.4	1.4	<0.04	<0.06	<0.2	0.88	11	2	0.4	<0.08	<0.4	<0.04	0.1	<0.2	15	<0.008	<0.07	0.11	0.7	1.1				
5B	30:1	18	1	9.61	99	<0.02	226	3.8	2.8	<0.04	<0.06	<0.2	6.48	2	1	4.9	<0.08	<0.4	0.2	<0.04	<0.2	18	<0.008	<0.07	0.12	4.1	2.0	5.7	7.3	1.3	4.2
5B	30:1	18	2	9.48	78	<0.02	354	3.8	1.4	<0.04	<0.06	<0.2	<0.2	6	1	0.4	0.1	<0.4	0.0	0.1	<0.2	17	<0.008	<0.07	0.28	2.3	<1.1				
5B	30:1	18	3	9.37	70	<0.02	411	2.4	2.1	<0.04	<0.06	<0.2	<0.2	17	2	0.1	0.3	<0.4	0.1	0.1	<0.2	17	0.028	<0.07	0.28	1.4	<1.1				
5B	300:1	0.5	1	9.28	50	<0.03	26.6	0.2	1.2	<0.05	<0.088	<0.2	<0.2	19	5	0.4	0.2	<0.3	<0.09	<0.05	<0.4	16	<0.048		0.03	0.3	<0.6				
5B	300:1	0.5	2	8.83	40	<0.02	26.7	<0.25	1.0	<0.04	<0.06	<0.2	<0.2	22	9	<0.07	0.3	<0.4	<0.04	0.0	<0.2	17	<0.008	<0.07	0.02	0.2	42.0				
5B	300:1	0.5	3	7.89	33	<0.02	26.5	<0.25	1.0	<0.04	<0.06	<0.2	<0.2	21	18	0.1	0.2	<0.4	<0.04	0.1	<0.2	15	0.02	<0.07	0.02	0.2	<1.1				
5B	300:1	18	1	9.33	62	<0.02	166	0.5	1.6	<0.04	<0.06	<0.2	<0.2	13	4	0.5	0.2	<0.4	<0.04	<0.04	<0.2	18	<0.008	<0.07	0.08	0.7	<1.1	6.1	1.6	1.0	2.0
5B	300:1	18	2	9.33	69	<0.02	195	0.6	1.7	<0.04	<0.06	<0.2	<0.2	18	6	<0.07	0.2	<0.4	<0.04	<0.04	<0.2	18	<0.008	<0.07	0.04	0.6	<1.1				
5B	300:1	18	3	8.31	55	<0.02	98.2	<0.25	1.2	<0.04	<0.06	<0.2	<0.2	16	31	<0.07	0.3	<0.4	<0.04	<0.04	<0.2	15	<0.008	<0.07	0.03	0.1	<1.1				
5E	30:1	0.5	1	9.66	85	<0.03	97.3	0.4	3.4	<0.05	<0.088	<0.2	<0.2	5	1	0.2	<0.2	<0.3	<0.09	0.3	<0.4	19	<0.048	#DIV/0!	<0.003	1.2	0.9				
5E	30:1	0.5	2	9.57	65	<0.02	141	0.3	2.8	<0.04	<0.06	<0.2	<0.2	14	2	0.1	<0.08	<0.4	<0.04	0.1	0.13	17	<0.008	<0.07	0.01	1.6	1.3				
5E	30:1	0.5	3	9.51	64	<0.02	168	0.5	2.2	<0.04	<0.06	<0.2	<0.2	19	2	<0.07	0.1	<0.4	0.1	0.1	<0.2	15	<0.008	<0.07	0.01	1.6	2.4				
5E	30:1	18	1	9.53	111	<0.02	242	5.4	137	<0.04	<0.06	<0.2	<0.2	3	1	0.4	0.2	<0.4	1.0	0.3	<0.2	42	<0.008	<0.07	0.16	6.4	2.8	6.3	11.8	1.1	3.8
5E	30:1	18	2	9.49	73	<0.02	416	2.4	2.2	<0.04	<0.06	<0.2	<0.2	14	1	<0.07	0.1	<0.4	0.1	0.3	<0.2	18	<0.008	<0.07	0.05	4.4	<1.1				
5E	30:1	18	3	9.37	81	<0.02	512	1.9	2.1	<0.04	<0.06	<0.2	0.92	69	3	<0.07	0.3	<0.4	0.2	0.3	<0.2	17	<0.008	<0.07	0.13	3.0	<1.1				
5E	300:1	0.5	1	9.35	52	<0.03	48.6	<0.12	2.2	<0.05	<0.088	<0.2	<0.2	25	5	<0.07	<0.2	<0.3	<0.09	<0.05	<0.4	18	<0.048		<0.003	0.5	1.0				
5E	300:1	0.5	2	9.12	54	<0.02	43	<0.25	1.8	<0.04	<0.06	<0.2	<0.2	30	9	<0.07	0.1	<0.4	<0.04	<0.04	<0.2	16	<0.008	<0.07	0.01	0.3	<1.1				
5E	300:1	0.5	3	8.94	42	<0.02	46	<0.25	1.7	<0.04	<0.06	<0.2	<0.2	27	10	<0.07	0.2	<0.4	<0.04	<0.04	<0.2	14	<0.008	<0.07	0.01	0.3	<1.1				
5E	300:1	18	1	9.36	64	<0.02	221	0.3	2.3	<0.04	<0.06	<0.2	<0.2	19	2	<0.07	0.2	<0.4	<0.04	0.2	<0.2	18	0.008	<0.07	0.02	1.4	2.6	7.0	1.3	1.0	2.1
5E	300:1	18	2	9.26	64	<0.02	255	0.3	2.0	<0.04	<0.06	<0.2	0.43	20	4	<0.07	0.1	<0.4	<0.04	0.0	<0.2	17	<0.008	<0.07	0.03	0.8	1.2				
5E	300:1	18	3	9.07	66	<0.02	194	0.3	1.9	<0.04	<0.06	0.25	0.63	23	6	<0.07	0.2	<0.4	<0.04	<0.04	<0.2	17	<0.008	<0.07	0.02	0.5	<1.1				

Spoil composite	L/S ratio	Duration (h)	Leach	pH	Conductivity (µs/cm)	Ag (µg/L)	Al (µg/L)	As (µg/L)	Ba (µg/L)	Cd (µg/L)	Co (µg/L)	Cr (µg/L)	Cu (µg/L)	Fe (µg/L)	Mn (µg/L)	Mo (µg/L)	Ni (µg/L)	Pb (µg/L)	Sb (µg/L)	Se (µg/L)	Sn (µg/L)	Sr (µg/L)	Th (µg/L)	Tl (µg/L)	U (µg/L)	V (µg/L)	Zn (µg/L)	Ca (mg/L)	K (mg/L)	Mg (mg/L)	Na (mg/L)
7E	30:1	0.5	1	9.62	114	<0.03	53.6	1.8	245	<0.05	<0.088	<0.2	<0.2	3	2	0.3	<0.2	<0.3	0.3	0.1	<0.4	50	<0.048		0.13	2.3	<0.6				
7E	30:1	0.5	2	9.49	74	<0.02	74.5	1.6	332	<0.04	<0.06	<0.2	<0.2	4	4	0.1	0.1	<0.4	0.2	0.0	<0.2	64	<0.008	<0.07	0.23	1.5	<1.1				
7E	30:1	0.5	3	9.44	66	<0.02	89.5	1.6	370	<0.04	<0.06	<0.2	<0.2	4	6	0.1	0.1	<0.4	0.2	<0.04	<0.2	65	<0.008	<0.07	0.24	1.0	1.1				
7E	30:1	18	1	9.49	70	<0.02	169	1.1	err	<0.04	<0.06	<0.2	<0.2	9	5	<0.07	0.4	<0.4	0.1	<0.04	<0.2	25	<0.008	<0.07	0.06	1.7	<1.1	5.7	2.0	1.1	1.8
7E	30:1	18	2	9.48	83	<0.02	229	6.2	367	<0.04	<0.06	<0.2	<0.2	1	1	0.1	0.1	<0.4	0.7	<0.04	<0.2	77	<0.008	<0.07	0.40	2.9	<1.1				
7E	30:1	18	3	9.38	91	<0.02	254	3.9	446	<0.04	<0.06	<0.2	<0.2	3	2	<0.07	0.3	<0.4	0.4	0.1	<0.2	82	<0.008	<0.07	0.39	1.8	<1.1				
7E	300:1	0.5	1	9.23	54	<0.03	29.5	0.3	308	<0.05	<0.088	<0.2	<0.2	13	18	<0.07	<0.2	<0.3	<0.09	<0.05	<0.4	47	<0.048		0.09	0.4	<0.6				
7E	300:1	0.5	2	9.06	45	<0.02	29.3	0.4	263	<0.04	<0.06	<0.2	<0.2	14	32	<0.07	0.1	<0.4	<0.04	<0.04	<0.2	33	<0.008	<0.07	0.04	0.2	<1.1				
7E	300:1	0.5	3	9.00	44	<0.02	32.2	0.3	259	<0.04	<0.06	<0.2	<0.2	15	43	<0.07	0.1	<0.4	<0.04	<0.04	<0.2	30	<0.008	<0.07	0.03	0.1	<1.1				
7E	300:1	18	1	9.28	71	<0.02	150	1.1	438	<0.04	<0.06	<0.2	<0.2	6	8	<0.07	0.2	<0.4	0.1	<0.04	<0.2	55	<0.008	<0.07	0.16	1.0	<1.1	6.5	3.8	1.0	1.9
7E	300:1	18	2	9.22	68	<0.02	176	0.8	408	<0.04	<0.06	<0.2	<0.2	9	15	<0.07	0.2	<0.4	0.1	<0.04	<0.2	40	<0.008	<0.07	0.07	0.5	<1.1				
7E	300:1	18	3	8.93	62	<0.02	176	0.7	389	<0.04	<0.06	<0.2	<0.2	11	25	<0.07	0.3	<0.4	<0.04	<0.04	<0.2	38	<0.008	<0.07	0.05	0.3	<1.1				

Appendix D7 Effect of repeat leaching on substance release

Memo 12 (23 November 2018).

Sample code	Sample name	L/S ratio	Duration (h)	Leach	Ag (µg/L)	Al (µg/L)	As (µg/L)	Ba (µg/L)	Cd (µg/L)	Co (µg/L)	Cr (µg/L)	Cu (µg/L)	Fe (µg/L)	Mn (µg/L)	Mo (µg/L)	Ni (µg/L)	Pb (µg/L)	Sb (µg/L)	Se (µg/L)	Sn (µg/L)	Sr (µg/L)	Th (µg/L)	Tl (µg/L)	U (µg/L)	V (µg/L)	Zn (µg/L)
LOD (3σ)					**0.017**	**0.267**	**0.249**	**0.076**	**0.032**	**0.056**	**0.172**	**0.235**	**0.257**	**0.059**	**0.073**	**0.080**	**0.440**	**0.040**	**0.036**	**0.209**	**0.175**	**0.008**	**0.070**	**0.007**	**0.036**	**1.106**
Avg TM24.4					8.9	34.1	5.1	15.0	3.8	6.4	4.9	6.3	15.7	8.1	6.4	4.9	5.4	3.3	3.3	3.6	113.0	0.1	4.2	4.2	7.0	23.4
TM-24.4 Certified						32.9 ± 4.5	5.30 ± 0.53	15.0 ± 1.0	3.96 ± 0.34	6.27 ± 0.57	5.00 ± 0.59	6.31 ± 0.60	16.0 ± 2.3	8.24 ± 0.73	6.30 ± 0.56	5.03 ± 0.53	5.60 ± 0.52		3.56 ± 0.58	3.72 ± 0.39	113 ± 8		4.20 ± 0.34	4.24 ± 0.34	7.00 ± 0.58	
% Recovery						***104***	***96***	***100***	***97***	***102***	***99***	***100***	***98***	***99***	***101***	***98***	***97***		***92***	***97***	***100***		***99***	***98***	***100***	
x10 T4-10 Spk Rec (%)					**96**	**94**	**98**	**97**	**97**	**97**	**96**	**97**	**93**	**97**	**98**	**95**	**98**	**97**	**101**	**96**	**101**	**106**	**99**	**99**	**95**	**97**
x10 T4-40 Spk Rec (%)					**92**	**90**	**93**	**92**	**94**	**93**	**93**	**93**	**90**	**94**	**94**	**92**	**95**	**93**	**95**	**97**	**98**	**109**	**96**	**101**	**92**	**89**
x10 T3-40 Spk Rec (%)					**92**	**90**	**93**	**92**	**93**	**95**	**94**	**95**	**90**	**94**	**94**	**94**	**93**	**92**	**95**	**96**	**98**	**107**	**94**	**98**	**94**	**93**
x10 T4-48 Spk Rec (%)					**96**	**92**	**102**	**100**	**97**	**99**	**98**	**100**	**97**	**98**	**98**	**97**	**98**	**97**	**96**	**97**	**100**	**103**	**100**	**98**	**97**	**99**
x10 T4-40 Spk Rec (%)					**92**	**90**	**93**	**92**	**94**	**93**	**93**	**93**	**90**	**94**	**94**	**92**	**95**	**93**	**95**	**97**	**98**	**109**	**96**	**101**	**92**	**89**

Appendix D7 Effect of repeat leaching on substance release

Memo 12 (23 November 2018).

Notes	**Composite Talbingo reservoir water used as leachate solution**
	<75 µm composite rock materials
	Successive leach test series for 18 h at L/S of 30 and 300 at 6°C and 21°C.

Sample Labels	Sample	L/S ratio	Temperature (°C)	Leach	pH	Conductivity (µS/cm)	Ag (µg/L)	Al (µg/L)	As (µg/L)	B (µg/L)	Ba (µg/L)	Be (µg/L)	Ca (mg/L)	Cd (µg/L)	Ce (µg/L)	Co (µg/L)	Cr (µg/L)	Cu (µg/L)	Fe (µg/L)	K (mg/L)	Li (µg/L)	Mg (mg/L)	Mn (µg/L)	Mo (µg/L)	Na (mg/L)	Ni (µg/L)	P (µg/L)	Pb (µg/L)	S (µg/L)	Sn (µg/L)	Sr (µg/L)	Ti (µg/L)	Tl (µg/L)	V (µg/L)	Zn (µg/L)
CE491_T8-61	Talbingo water A				7.19	30	<0.5	3.93	<7	<19	4.4	0.03	1.7	<0.07	<0.5	<1	<0.5	0.8	15.5	0.4	0.1	0.8	0.3	<0.8	1.7	<1.3	2.1	<1.7	154	<1.7	15	0.02	<2.4	0.3	1.2
CE491_T8-62	Talbingo water B				7.20	30	<0.5	4.07	<7	<19	4.5	<0.02	1.7	<0.07	<0.5	<1	<0.5	0.9	15.8	0.4	0.1	0.8	0.3	<0.8	1.5	<1.3	2.1	<1.7	159	<1.7	15	<0.02	<2.4	<0.3	1.3
CE491_T8-63	Talbingo water C				7.21	35	<0.5	3.9	<7	<19	4.5	0.02	1.7	<0.07	<0.5	<1	<0.5	0.6	16.3	0.4	0.1	0.8	0.3	<0.8	1.5	<1.3	<1.36	<1.7	158	<1.7	15	0.02	<2.4	<0.3	1.3
CE491_T8-1	1B	30:1	21	Leach 1	9.53	173	<0.5	197	<7	<19	2.1	<0.02	4.9	<0.07	0.7	<1	<0.5	<0.5	0.9	9.4	3.6	1.5	1.2	<0.8	3.4	<1.3	7.5	<1.7	203	<1.7	37	<0.02	<2.4	5.5	<0.12
CE491_T8-2	2B	30:1	21	Leach 1	9.23	101	<0.5	109	<7	<19	7.5	0.05	4.8	<0.07	<0.5	<1	<0.5	<0.5	1.0	5.8	3.9	3.7	1.1	3.4	2.5	<1.3	34.9	<1.7	231	<1.7	16	<0.02	<2.4	4.9	0.1
CE491_T8-3	5B	30:1	21	Leach 1	9.56	89	<0.5	200	<7	<19	2.6	<0.02	5.5	<0.07	<0.5	<1	<0.5	<0.5	3.1	6.8	0.5	1.2	1.0	4.5	3.9	<1.3	21.3	<1.7	298	<1.7	18	0.09	<2.4	2.9	<0.12
CE491_T8-4	5E	30:1	21	Leach 1	9.50	108	<0.5	299	<7	<19	4.3	<0.02	7.2	<0.07	<0.5	<1	<0.5	<0.5	9.7	4.8	0.6	1.3	1.0	<0.8	4.0	<1.3	17.3	<1.7	1550	<1.7	21	0.69	<2.4	3.6	<0.12
CE491_T8-5	7E	30:1	21	Leach 1	9.49	121	<0.5	173	<7	<19	281	0.03	4.7	<0.07	<0.5	<1	<0.5	<0.5	0.8	17.7	5.7	0.9	1.1	<0.8	3.0	<1.3	5.4	<1.7	2220	<1.7	64	<0.02	<2.4	5.0	<0.12
CE491_T8-6	1B	30:1	6	Leach 1	9.58	116	<0.5	58.9	<7	<19	1.8	<0.02	4.6	<0.07	<0.5	<1	<0.5	<0.5	0.7	8.4	2.3	1.6	1.8	<0.8	3.2	<1.3	5.2	<1.7	193	<1.7	35	0.03	<2.4	3.1	<0.12
CE491_T8-7	2B	30:1	6	Leach 1	9.42	85	<0.5	42.9	<7	<19	6.2	0.02	4.2	<0.07	<0.5	<1	<0.5	0.5	0.4	5.1	2.5	3.5	1.5	1.9	2.4	<1.3	24.1	<1.7	221	<1.7	15	<0.02	<2.4	2.8	<0.12
CE491_T8-8	5B	30:1	6	Leach 1	9.60	106	<0.5	46.4	<7	<19	2.1	<0.02	5.4	<0.07	0.79	<1	<0.5	<0.5	2.1	5.9	0.4	1.2	1.3	4.1	3.6	<1.3	17.0	<1.7	274	<1.7	17	0.07	<2.4	1.2	<0.12
CE491_T8-9	5E	30:1	6	Leach 1	9.54	91	<0.5	109	<7	<19	4.1	0.02	7.1	<0.07	<0.5	<1	<0.5	<0.5	6.2	4.2	0.4	1.4	1.3	<0.8	3.7	<1.3	10.3	<1.7	1400	<1.7	21	0.47	<2.4	2.0	<0.12
CE491_T8-10	7E	30:1	6	Leach 1	9.56	146	<0.5	66.6	<7	<19	240	<0.02	4.3	<0.07	<0.5	<1	<0.5	<0.5	0.7	15.7	4.3	0.9	1.6	<0.8	2.9	<1.3	6.2	<1.7	1700	<1.7	53	<0.02	<2.4	3.0	<0.12
CE491_T8-11	1B	300:1	21	Leach 1	9.20	59	<0.5	112	<7	<19	1.1	<0.02	5.4	<0.07	0.68	<1	<0.5	0.6	9.2	1.9	1.2	1.1	8.0	<0.8	1.7	<1.3	5.5	<1.7	161	<1.7	25	0.06	<2.4	1.2	<0.12
CE491_T8-12	2B	300:1	21	Leach 1	9.19	87	<0.5	93.6	<7	<19	4.1	<0.02	5.1	<0.07	<0.5	<1	<0.5	<0.5	9.2	1.6	1.1	1.5	5.7	<0.8	1.6	<1.3	11.2	<1.7	169	<1.7	16	0.05	<2.4	1.3	<0.12
CE491_T8-13	5B	300:1	21	Leach 1	9.15	72	<0.5	99.8	<7	<19	1.6	0.03	5.7	<0.07	<0.5	<1	<0.5	0.5	12.4	1.4	0.3	0.9	5.2	<0.8	1.7	<1.3	10.4	<1.7	175	<1.7	18	0.11	<2.4	0.6	<0.12
CE491_T8-14	5E	300:1	21	Leach 1	9.24	63	<0.5	146	<7	<19	2.4	<0.02	6.4	<0.07	<0.5	<1	<0.5	1.3	15.7	1.1	0.3	0.9	3.7	<0.8	1.8	<1.3	11.6	<1.7	328	<1.7	17	0.45	<2.4	1.1	<0.12
CE491_T8-15	7E	300:1	21	Leach 1	9.19	70	<0.5	108	<7	<19	498	<0.02	5.6	<0.07	0.73	<1	<0.5	0.8	8.0	3.2	1.4	0.9	11.7	<0.8	1.7	<1.3	3.8	<1.7	622	<1.7	54	0.05	<2.4	0.9	<0.12
CE491_T8-16	1B	300:1	6	Leach 1	9.19	61	<0.5	31.2	<7	<19	1.0	0.02	5.3	<0.07	<0.5	<1	<0.5	0.6	9.4	1.7	0.7	1.0	10.5	<0.8	1.7	<1.3	3.8	<1.7	167	<1.7	24	0.02	<2.4	0.8	<0.12
CE491_T8-17	2B	300:1	6	Leach 1	9.16	79	<0.5	26.2	<7	<19	3.7	<0.02	4.7	<0.07	<0.5	<1	<0.5	0.7	9.6	1.4	0.7	1.6	11.4	<0.8	1.6	<1.3	6.5	<1.7	168	<1.7	15	<0.02	<2.4	0.8	<0.12
CE491_T8-18	5B	300:1	6	Leach 1	9.12	106	<0.5	23.1	<7	<19	1.3	0.02	5.7	<0.07	<0.5	<1	<0.5	0.5	12.0	1.2	0.2	0.9	6.4	<0.8	1.7	<1.3	7.4	<1.7	176	<1.7	18	0.08	<2.4	<0.3	<0.12
CE491_T8-19	5E	300:1	6	Leach 1	9.22	76	<0.5	48.2	<7	<19	2.3	<0.02	6.2	<0.07	0.55	<1	<0.5	0.5	13.2	1.0	0.3	0.9	5.3	<0.8	1.7	<1.3	9.1	<1.7	292	<1.7	17	0.27	<2.4	0.5	<0.12
CE491_T8-20	7E	300:1	6	Leach 1	9.16	114	<0.5	31.5	<7	<19	353	<0.02	5.4	<0.07	<0.5	<1	<0.5	0.7	8.7	3.0	1.0	0.9	18.6	<0.8	1.7	<1.3	3.4	<1.7	486	<1.7	46	<0.02	<2.4	0.6	<0.12
CE491_T8-21	1B	30:1	21	Leach 2	9.48	78	<0.5	286	<7	<19	1.2	<0.02	5.6	<0.07	0.69	<1	<0.5	<0.5	1.5	3.7	2.6	1.4	1.9	<0.8	1.8	<1.3	5.9	<1.7	176	2.64	31	<0.02	<2.4	5.3	<0.12
CE491_T8-22	2B	30:1	21	Leach 2	9.27	77	<0.5	143	<7	<19	5.0	<0.02	5.1	<0.07	<0.5	<1	<0.5	<0.5	0.8	3.3	2.5	2.5	0.9	0.9	1.7	<1.3	39.3	<1.7	194	<1.7	14	<0.02	<2.4	5.7	<0.12
CE491_T8-23	5B	30:1	21	Leach 2	9.50	131	<0.5	319	<7	<19	1.8	<0.02	6.1	<0.07	<0.5	<1	<0.5	0.5	7.1	2.7	0.5	1.1	1.8	<0.8	1.9	<1.3	19.0	<1.7	209	<1.7	17	0.22	<2.4	2.0	<0.12
CE491_T8-24	5E	30:1	21	Leach 2	9.48	71	<0.5	403	<7	<19	2.5	<0.02	7.1	<0.07	<0.5	<1	<0.5	1.0	20.7	1.9	0.5	1.1	1.5	<0.8	1.9	<1.3	20.0	<1.7	523	<1.7	17	1.07	<2.4	4.2	<0.12
CE491_T8-25	7E	30:1	21	Leach 2	9.45	82	<0.5	227	<7	<19	388	<0.02	5.9	<0.07	1.02	<1	<0.5	0.8	1.5	7.0	3.4	1.0	2.0	<0.8	1.7	<1.3	5.2	<1.7	1330	<1.7	80	0.03	<2.4	2.9	<0.12
CE491_T8-26	1B	30:1	6	Leach 2	9.51	92	<0.5	70.4	<7	<19	1.1	<0.02	5.4	<0.07	<0.5	<1	<0.5	<0.5	1.6	3.3	1.8	1.5	2.8	<0.8	1.7	<1.3	7.4	<1.7	165	<1.7	29	<0.02	<2.4	2.8	<0.12
CE491_T8-27	2B	30:1	6	Leach 2	9.43	74	<0.5	56.8	<7	<19	4.1	<0.02	4.3	<0.07	1.02	<1	<0.5	<0.5	1.3	2.9	1.7	2.5	1.6	1.06	1.6	<1.3	26.4	<1.7	163	<1.7	13	<0.02	<2.4	3.1	<0.12
CE491_T8-28	5B	30:1	6	Leach 2	9.48	67	<0.5	68.4	<7	<19	1.4	<0.02	6.1	<0.07	0.75	<1	<0.5	<0.5	4.5	2.3	0.3	1.1	2.2	<0.8	1.8	<1.3	16.8	<1.7	177	<1.7	16	0.06	<2.4	1.0	<0.12
CE491_T8-29	5E	30:1	6	Leach 2	9.54	73	<0.5	129	<7	<19	2.3	<0.02	6.9	<0.07	<0.5	<1	<0.5	0.7	7.9	1.7	0.4	1.1	1.6	<0.8	1.8	<1.3	15.2	<1.7	285	1.67	17	0.39	<2.4	2.0	<0.12
CE491_T8-30	7E	30:1	6	Leach 2	9.47	76	<0.5	77.1	<7	<19	295	0.03	5.5	<0.07	<0.5	<1	<0.5	0.6	1.8	6.7	2.5	1.0	3.3	<0.8	1.7	<1.3	5.7	<1.7	1010	<1.7	66	<0.02	<2.4	1.7	<0.12
CE491_T8-31	1B	300:1	21	Leach 2	9.17	67	<0.5	153	<7	<19	0.8	<0.02	5.1	<0.07	1.07	<1	<0.5	0.7	13.4	0.7	0.7	0.9	11.6	<0.8	1.5	<1.3	3.1	<1.7	167	<1.7	20	0.09	<2.4	0.9	<0.12
CE491_T8-32	2B	300:1	21	Leach 2	9.19	70	<0.5	133	<7	<19	3.1	<0.02	5.3	<0.07	<0.5	<1	<0.5	<0.5	11.3	0.7	0.6	1.0	5.6	<0.8	1.5	<1.3	8.0	<1.7	162	<1.7	17	0.02	<2.4	1.1	<0.12
CE491_T8-33	5B	300:1	21	Leach 2	8.98	75	<0.5	125	<7	<19	1.3	0.04	4.7	<0.07	0.71	<1	<0.5	<0.5	17.0	0.6	0.2	0.9	8.1	<0.8	1.5	<1.3	4.5	<1.7	172	<1.7	17	0.12	<2.4	<0.3	<0.12
CE491_T8-34	5E	300:1	21	Leach 2	9.26	64	<0.5	170	<7	<19	1.8	<0.02	5.9	<0.07	<0.5	<1	<0.5	1.3	24.5	0.6	0.2	0.8	5.3	<0.8	1.6	<1.3	6.9	<1.7	195	<1.7	17	0.69	<2.4	0.7	<0.12
CE491_T8-35	7E	300:1	21	Leach 2	9.18	35	<0.5	144	<7	<19	446	<0.02	5.6	<0.07	<0.5	<1	<0.5	0.8	9.2	1.0	0.6	0.8	17.9	<0.8	1.6	<1.3	4.3	<1.7	373	<1.7	44	0.04	<2.4	0.5	<0.12
CE491_T8-36	1B	300:1	6	Leach 2	9.13	51	<0.5	32.8	<7	<19	0.7	<0.02	5.3	<0.07	<0.5	<1	<0.5	0.8	12.5	0.6	0.4	0.9	18.0	<0.8	1.5	<1.3	2.4	<1.7	160	<1.7	20	0.05	<2.4	0.5	<0.12
CE491_T8-37	2B	300:1	6	Leach 2	9.08	62	<0.5	31.8	<7	<19	2.9	<0.02	4.9	<0.07	<0.5	<1	<0.5	0.7	14.0	0.7	0.4	1.0	14.8	<0.8	1.5	<1.3	7.5	<1.7	158	<1.7	16	0.06	<2.4	0.7	<0.12
CE491_T8-38	5B	300:1	6	Leach 2	8.70	64	<0.5	27.9	<7	<19	1.1	<0.02	4.5	<0.07	<0.5	<1	<0.5	<0.5	16.8	0.6	0.2	0.8	11.3	<0.8	1.6	<1.3	5.6	<1.7	166	<1.7	17	0.13	<2.4	<0.3	<0.12
CE491_T8-39	5E	300:1	6	Leach 2	9.21	60	<0.5	47.8	<7	<19	1.8	<0.02	5.6	<0.07	<0.5	<1	<0.5	1.0	22.7	0.5	0.2	0.8	8.6	<0.8	1.5	<1.3	6.4	<1.7	169	<1.7	17	0.59	<2.4	0.4	<0.12
CE491_T8-40	7E	300:1	6	Leach 2	9.13	64	<0.5	37	<7	<19	321	<0.02	5.4	<0.07	<0.5	<1	<0.5	<0.5	11.2	0.9	0.5	0.8	33.0	<0.8	1.5	<1.3	3.5	<1.7	311	<1.7	38	0.03	<2.4	0.3	<0.12
CE491_T8-41	1B	30:1	21	Leach 3	9.41	72	<0.5	320	<7	<19	1.0	<0.02	5.9	<0.07	<0.5	<1	<0.5	<0.5	3.6	2.1	2.0	1.4	2.6	<0.8	1.5	<1.3	5.5	<1.7	159	<1.7	27	0.02	<2.4	3.3	<0.12
CE491_T8-42	2B	30:1	21	Leach 3	9.22	77	<0.5	162	<7	<19	4.4	<0.02	5.6	<0.07	1.25	<1	<0.5	<0.5	1.6	2.2	1.9	2.0	1.0	<0.8	1.6	<1.3	28.9	<1.7	226	<1.7	14	0.04	<2.4	4.7	<0.12
CE491_T8-43	5B	30:1	21	Leach 3	9.39	70	<0.5	342	<7	<19	1.5	<0.02	6.3	<0.07	<0.5	<1	<0.5	<0.5	7.9	1.6	0.4	1.0	2.3	<0.8	1.6	<1.3	10.4	<1.7	224	<1.7	16	0.13	<2.4	1.3	<0.12
CE491_T8-44	5E	30:1	21	Leach 3	9.41	99	<0.5	384	<7	<19	2.0	<0.02	5.3	<0.07	<0.5	<1	<0.5	1.1	7.1	0.9	0.5	0.7	1.6	<0.8	1.2	<1.3	14.1	<1.7	402	<1.7	17	0.21	<2.4	2.9	<0.12
CE491_T8-45	7E	30:1	21	Leach 3	9.38	74	<0.5	249	<7	<19	443	<0.02	6.2	<0.07	<0.5	<1	<0.5	0.5	1.7	3.6	2.4	0.9	2.9	<0.8	1.5	<1.3	5.1	<1.7	924	<1.7	81	<0.02	<2.4	1.7	<0.12

Appendix D7 Effect of repeat leaching on substance release

Memo 12 (23 November 2018).

Sample Labels	Sample	L/S ratio	Temperature (°C)	Leach	pH	Conductivity (µS/cm)	Ag (µg/L)	Al (µg/L)	As (µg/L)	B (µg/L)	Ba (µg/L)	Be (µg/L)	Ca (mg/L)	Cd (µg/L)	Ce (µg/L)	Co (µg/L)	Cr (µg/L)	Cu (µg/L)	Fe (µg/L)	K (mg/L)	Li (µg/L)	Mg (mg/L)	Mn (µg/L)	Mo (µg/L)	Na (mg/L)	Ni (µg/L)	P (µg/L)	Pb (µg/L)	S (µg/L)	Sn (µg/L)	Sr (µg/L)	Ti (µg/L)	Tl (µg/L)	V (µg/L)	Zn (µg/L)
CE491_T8-46	1B	30:1	6	Leach 3	9.45	70	<0.5	78	<7	<19	0.9	<0.02	5.8	<0.07	<0.5	<1	<0.5	<0.5	3.1	2.0	1.5	1.3	3.3	<0.8	1.5	<1.3	5.1	<1.7	166	<1.7	27	<0.02	<2.4	2.3	<0.12
CE491_T8-47	2B	30:1	6	Leach 3	9.43	170	<0.5	57.7	<7	<19	3.8	<0.02	4.7	<0.07	0.69	<1	<0.5	0.6	3.0	2.1	1.4	2.2	1.9	<0.8	1.5	<1.3	23.4	<1.7	162	<1.7	13	<0.02	<2.4	2.4	<0.12
CE491_T8-48	5B	30:1	6	Leach 3	9.46	101	<0.5	88.6	<7	<19	1.3	<0.02	6.3	<0.07	<0.5	<1	<0.5	<0.5	7.0	1.5	0.3	1.0	2.7	<0.8	1.6	<1.3	13.4	<1.7	166	<1.7	16	0.1	<2.4	0.8	<0.12
CE491_T8-49	5E	30:1	6	Leach 3	9.49	180	<0.5	137	<7	<19	1.9	<0.02	7.0	<0.07	<0.5	<1	<0.5	0.9	5.7	1.2	0.4	1.0	1.8	<0.8	1.6	<1.3	17.9	<1.7	221	<1.7	16	0.2	2.8	2.0	<0.12
CE491_T8-50	7E	30:1	6	Leach 3	9.44	135	<0.5	79.1	<7	<19	327	0.04	6.0	<0.07	<0.5	<1	<0.5	0.7	2.2	3.7	1.9	1.0	4.7	<0.8	1.6	<1.3	6.7	<1.7	766	<1.7	69	<0.02	<2.4	1.2	<0.12
CE491_T8-51	1B	300:1	21	Leach 3	8.72	72	<0.5	98.3	<7	<19	0.7	<0.02	3.6	<0.07	<0.5	<1	<0.5	0.6	15.1	0.5	0.5	0.9	21.0	<0.8	1.5	<1.3	<1.36	<1.7	163	<1.7	17	0.1	<2.4	0.6	<0.12
CE491_T8-52	2B	300:1	21	Leach 3	8.78	48	<0.5	94.6	<7	<19	2.6	0.02	4.1	<0.07	<0.5	<1	<0.5	0.5	13.2	0.6	0.4	0.8	10.3	<0.8	1.5	<1.3	3.9	<1.7	164	<1.7	16	0.0	<2.4	0.6	<0.12
CE491_T8-53	5B	300:1	21	Leach 3	8.11	66	<0.5	65	<7	<19	1.2	<0.02	2.8	<0.07	<0.5	<1	<0.5	0.8	19.0	0.5	0.2	0.9	27.2	<0.8	1.5	<1.3	2.4	<1.7	166	<1.7	15	0.1	<2.4	<0.3	<0.12
CE491_T8-54	5E	300:1	21	Leach 3	8.99	60	<0.5	117	<7	<19	1.7	<0.02	4.8	<0.07	<0.5	<1	<0.5	1.2	22.5	0.4	0.2	0.8	7.2	<0.8	1.5	<1.3	4.7	<1.7	173	<1.7	16	0.5	<2.4	0.6	<0.12
CE491_T8-55	7E	300:1	21	Leach 3	9.09	61	<0.5	117	<7	<19	369	<0.02	5.2	<0.07	<0.5	<1	<0.5	0.7	10.9	0.6	0.3	0.8	28.8	<0.8	1.5	<1.3	<1.36	<1.7	251	<1.7	34	0.0	<2.4	0.3	<0.12
CE491_T8-56	1B	300:1	6	Leach 3	8.67	196	<0.5	33.3	<7	<19	0.7	<0.02	4.2	<0.07	<0.5	<1	<0.5	<0.5	14.0	0.5	0.4	0.9	26.9	<0.8	1.5	<1.3	1.6	<1.7	167	<1.7	18	0.1	<2.4	0.4	<0.12
CE491_T8-57	2B	300:1	6	Leach 3	8.52	117	<0.5	24.9	<7	<19	2.7	<0.02	4.1	<0.07	<0.5	<1	<0.5	0.6	14.0	0.5	0.4	0.8	23.0	<0.8	1.5	<1.3	6.2	<1.7	154	<1.7	16	0.1	<2.4	0.4	<0.12
CE491_T8-58	5B	300:1	6	Leach 3	7.88	152	<0.5	16.8	<7	<19	1.1	<0.02	2.8	<0.07	<0.5	<1	<0.5	0.5	16.3	0.6	0.2	1.0	31.6	<0.8	1.5	<1.3	3.8	<1.7	159	<1.7	15	0.1	<2.4	<0.3	<0.12
CE491_T8-59	5E	300:1	6	Leach 3	8.51	148	<0.5	42.9	<7	<19	1.6	<0.02	4.4	<0.07	0.59	<1	<0.5	0.9	20.4	0.5	0.1	0.8	10.4	<0.8	1.5	<1.3	5.4	<1.7	168	<1.7	16	0.4	<2.4	<0.3	<0.12
CE491_T8-60	7E	300:1	6	Leach 3	8.91	402	<0.5	35.8	<7	<19	283	<0.02	5.2	<0.07	0.68	<1	<0.5	0.8	11.6	0.6	0.4	0.8	44.7	<0.8	1.5	<1.3	2.7	<1.7	255	<1.7	33	0.0	<2.4	0.4	<0.12

Sample Labels	Rock Spoil sample	L/S ratio	Temperature (°C)	Leach	Ag (µg/L)	Al (µg/L)	As (µg/L)	B (µg/L)	Ba (µg/L)	Be (µg/L)	Ca (mg/L)	Cd (µg/L)	Ce (µg/L)	Co (µg/L)	Cr (µg/L)	Cu (µg/L)	Fe (µg/L)	K (mg/L)	Li (µg/L)	Mg (mg/L)	Mn (µg/L)	Mo (µg/L)	Na (mg/L)	Ni (µg/L)	P (µg/L)	Pb (µg/L)	S (µg/L)	Sn (µg/L)	Sr (µg/L)	Ti (µg/L)	Tl (µg/L)	V (µg/L)	Zn (µg/L)
Mean blank					0.00	-0.28	0.07	28	-0.03	0.00	0.01	0.04	-0.46	-0.75	-0.07	-0.14	0.18	-0.03	-0.03	0.01	0.00	-0.06	-0.02	-0.01	1.30	0.31	1.2	0.73	-0.03	0.01	-1.4	-0.02	-0.74
LOD (3 x S.d.)					0.54	0.21	7.35	19	0.01	0.02	0.03	0.07	0.53	1.22	0.49	0.46	0.34	0.04	0.06	0.01	0.07	0.78	0.01	1.3	1.4	1.7	8.5	1.7	0.02	0.02	2.4	0.27	0.12
TM24.4					9	33	5	-2	16	2		4	0	6	5	7	16	10	5	53	8	6	90	5	3	6		4	113	7	4	7	29
Certified TM24.4					8.92	32.9 ± 4.5	5.30 ± 0.53		15.0 ± 1.0			3.96 ± 0.34		6.27 ± 0.57	5.00 ± 0.59	6.31 ± 0.60	16.0 ± 2.3		4.95 ± 0.42		8.24± 0.73			5.03 ± 0.53		5.60 ± 0.52			113 ± 8			7.00 ± 0.58	
% recovery (TM24.4)					100	100	91		104			102		100	103	104	99		105		99			90		116			100			101	
TMDA64.3					12	291	160	251	292	160		262	0	257	287	262	294	11	147	52	288	278	94	257	2	281		271	630	127	140	279	325
Certified TM63.4					12.6 ± 1.3	291 ± 23	164 ± 15		287 ± 18			258 ± 21		250 ± 16	283 ± 17	261 ± 18	298 ± 21		143 ± 15		292 ± 17			252 ± 18		280 ± 22			628 ± 34			279 ± 18	320 ± 23
% recovery (TMDA63.4)					93	100	98		102			102		103	102	100	99		103		98			102		100			100			100	102
CE491_T8-10 + spike					98	96	99	103	95	98	94	97	97	96	97	100	96	75	97	97	95	98	94	95	99	96	84	98	96	99	96	98	98
CE491_T8-20 + spike					98	97	100	105	96	100	98	99	98	97	98	99	98	98	99	99	96	99	97	97	101	97	95	99	98	100	97	99	99
CE491_T8-30 + spike					99	105	99	107	96	101	97	99	98	99	98	100	98	86	99	99	99	99	98	98	100	98	85	99	98	100	98	99	100
CE491_T8-40 + spike					100	97	100	108	96	99	98	99	99	100	99	101	99	100	99	100	100	100	99	99	101	99	97	99	98	100	99	99	100
CE491_T8-50 + spike					98	97	100	108	96	99	96	99	99	98	99	100	99	100	99	99	100	100	98	97	101	98	90	100	98	100	98	100	100
CE491_T8-60 + spike					101	98	101	109	99	99	96	100	100	98	100	102	100	100	101	101	99	100	99	97	101	99	98	100	100	100	100	100	100

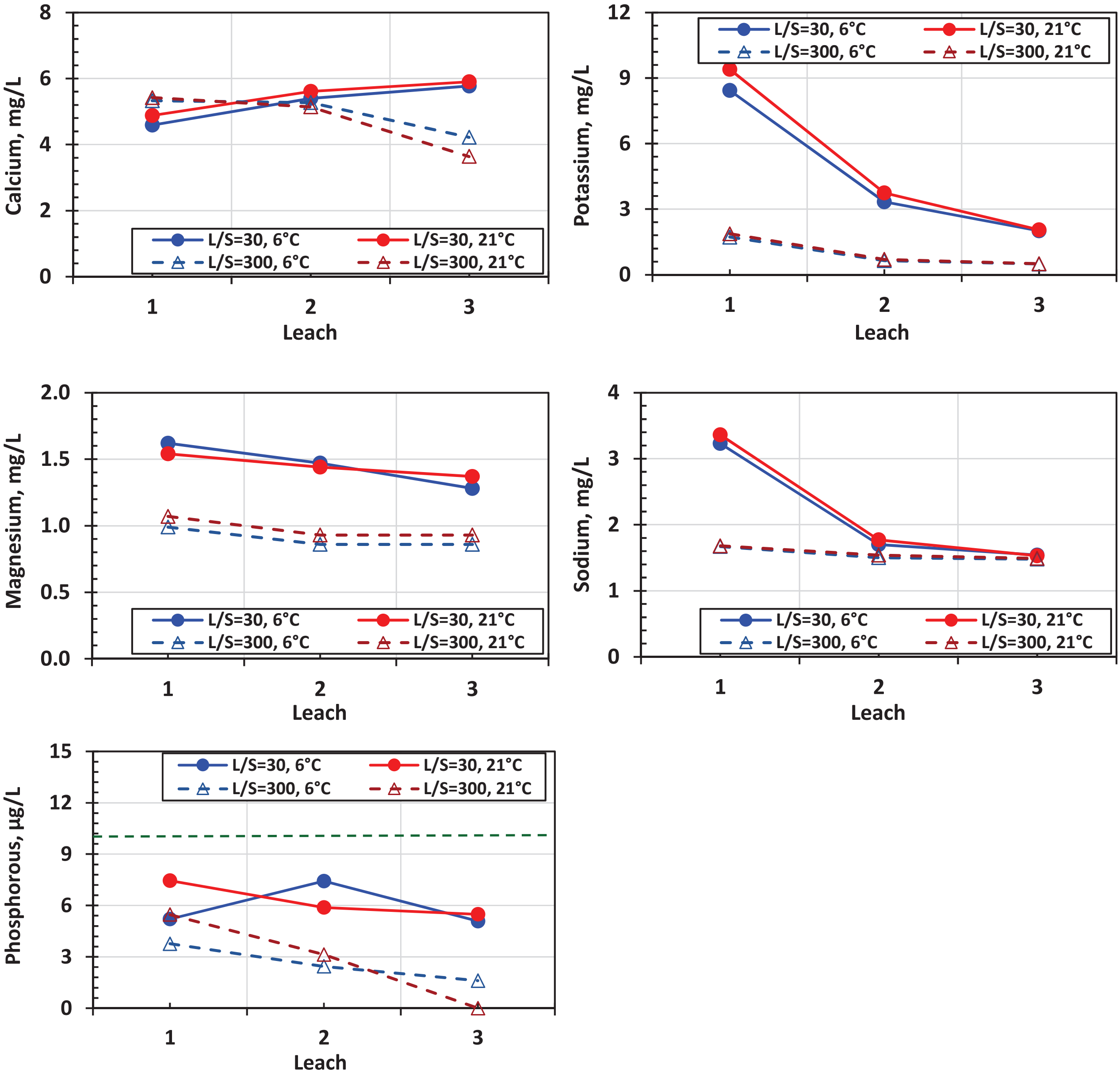


Figure D7.1. Major cation and total-P concentrations for successive elutriates at 6ºC and 21 ºC of composite 1B at L/S of 30 and 300.

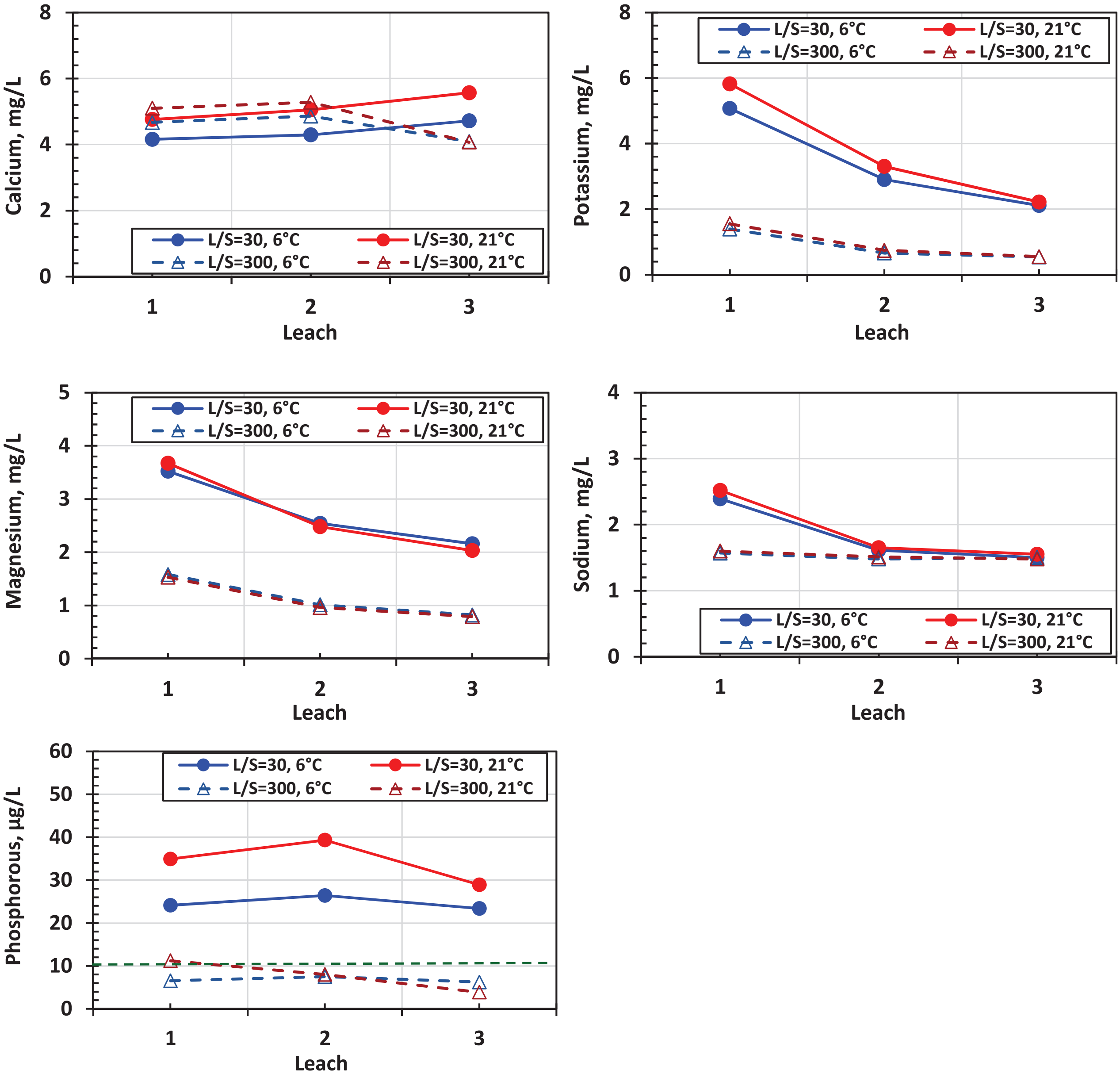


Figure D7.2 Major cation and total-P concentrations for successive elutriates at 6ºC and 21 ºC of composite 2B at L/S of 30 and 300.

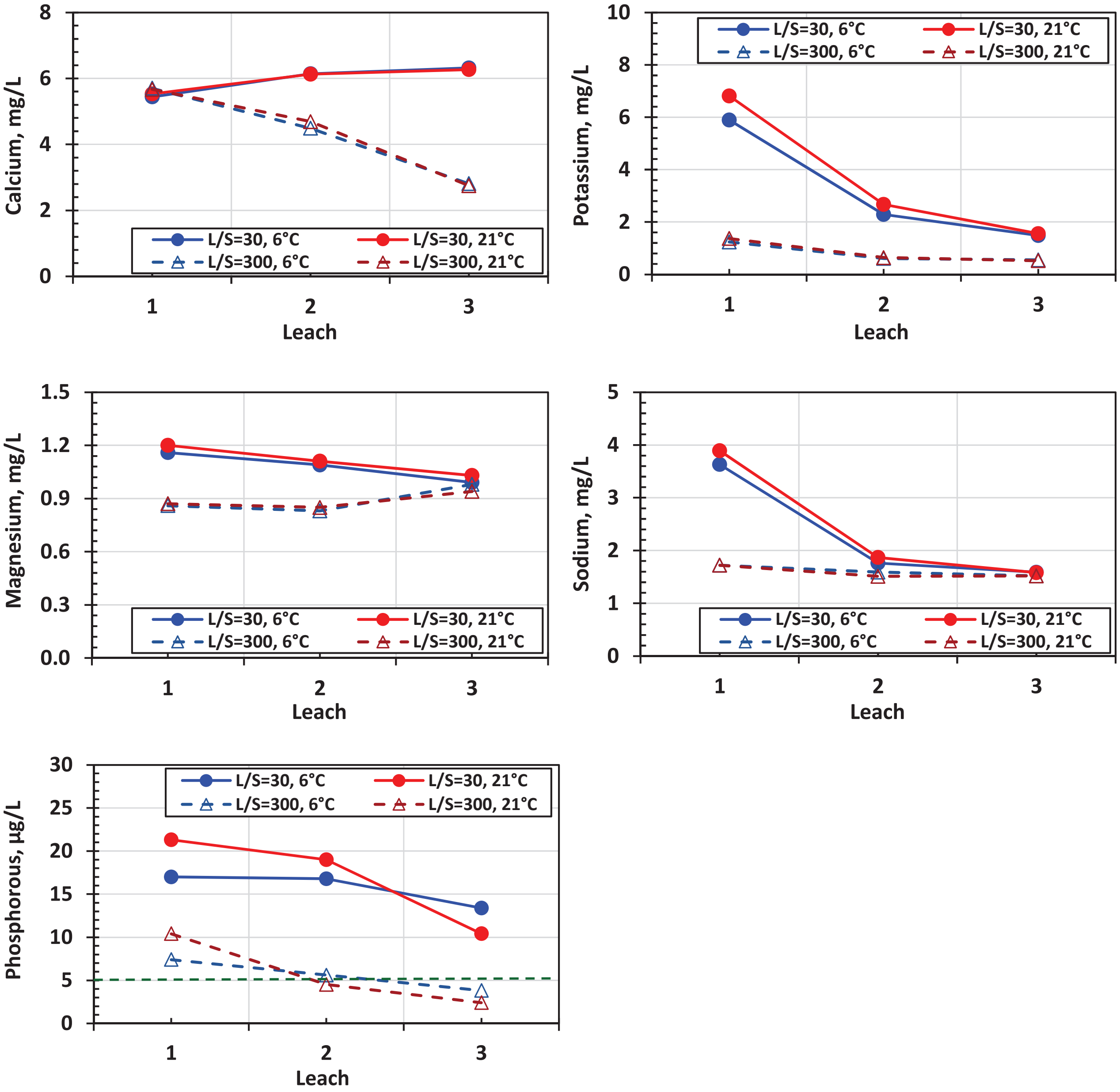


Figure D7.3. Major cation and total-P concentrations for successive elutriates at 6ºC and 21 ºC of composite 5B at L/S of 30 and 300.

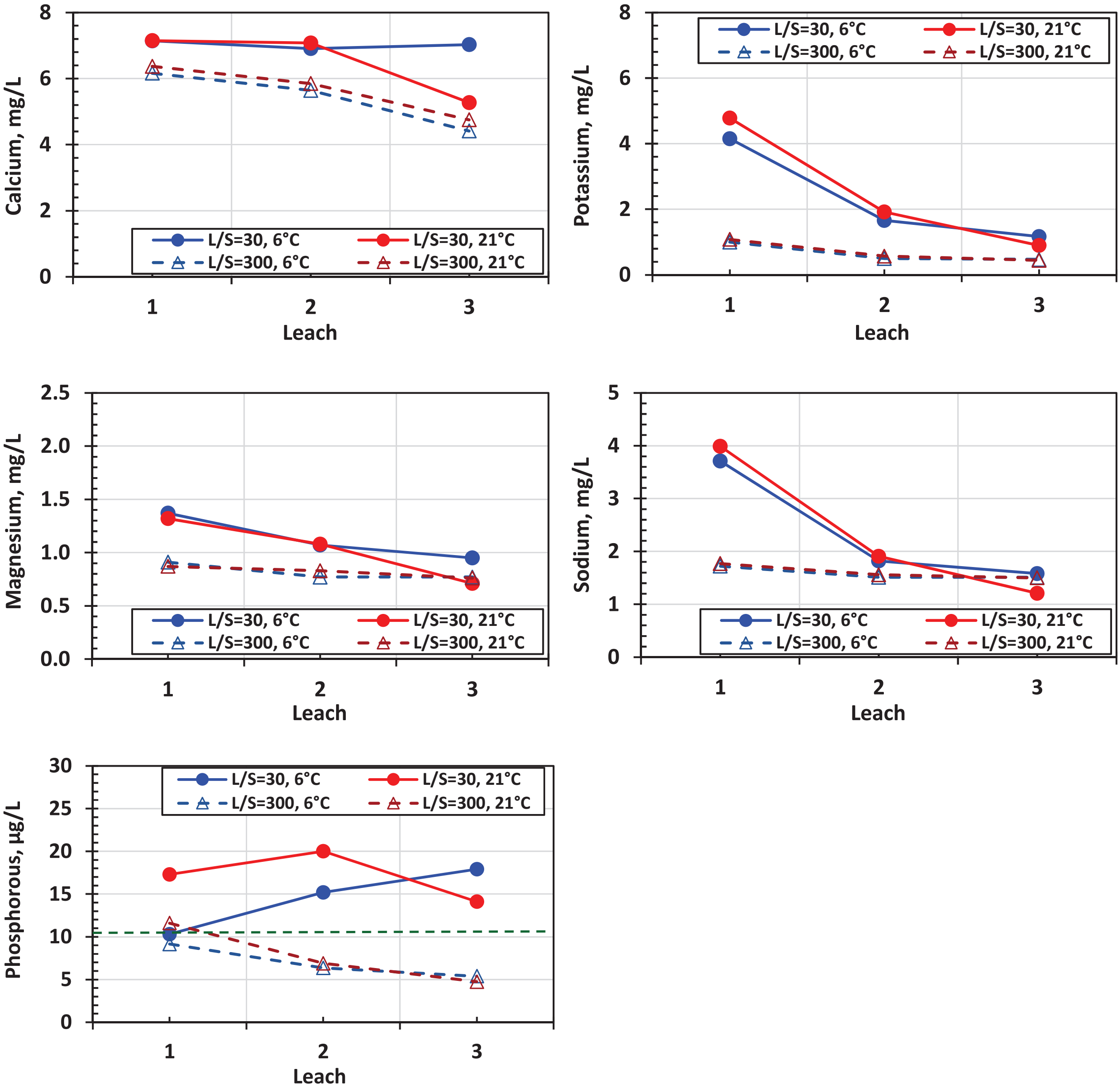


Figure D7.4. Major cation and total-P concentrations for successive elutriates at 6ºC and 21 ºC of composite 5E at L/S of 30 and 300.

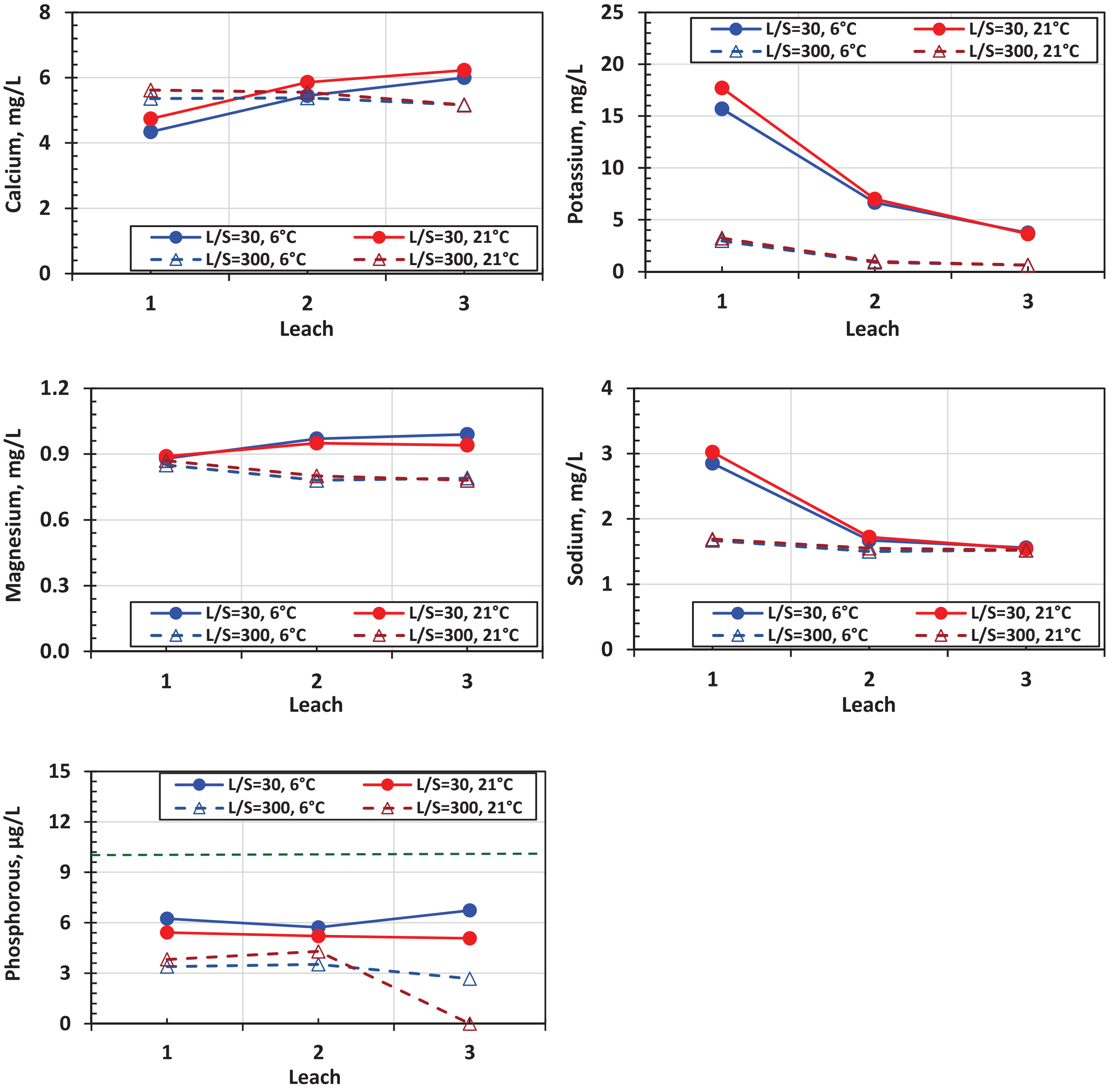


Figure D7.5. Major cation and total-P concentrations for successive elutriates at 6ºC and 21 ºC of composite 7E at L/S of 30 and 300.

Appendix D8. Colloidal forms of Al with <0.45 µm filtered water

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Note/Memo	CSIRO P4 Project Investigations
To:	Ali Watters (HKA)
From:	Brad Angel, Lucas Heights, NSW
Date:	23 November 2018
Copy:	Ryan Fraser, Stuart Simpson and Ellen Porter (SHL)
Our reference:	CSIRO P4 – Memo 12
Classification:	Internal use only
Subject:	Pollutant release from excavated rock composites: effect of successive leaches and temperature on water quality and pollutant release

Chemical formulas and acronyms

Al	Aluminium	DGV	Default guideline value	L/S	Liquid/solid ratio
SEC	Conductivity				

Background - Introduction

The CSIRO was engaged by Haskoning Australia Pty Ltd (RHDHV) to undertake an investigation of the pollutant release from excavated rock disposal into Talbingo and Tantangara reservoirs. Previous elutriate tests (e.g. Memos 4, 5, 6) investigating the release of pollutants from composite excavated rock samples have observed significant changes in water quality with respect to pH, conductivity (SEC) and the dissolved aluminium concentrations. The temperature of elutriate solutions was also shown to have a strong effect on water quality and aluminium concentrations (Memo 9).

This technical memo describes results of two series of successive elutriate tests (3 leaches each) performed to investigate the effect of excavated rock composites 1B, 2B, 5B, 5E and 7E in Talbingo reservoir water on pH, conductivity (SEC), and the dissolved aluminium concentration. The first successive leach test series investigated the effect of two mixing durations for two liquid to solid (L/S) ratios at 21°C. The second successive leach test series investigated the effect of temperature (6°C and 21°C) for the two L/S ratios. The tests were performed using the following conditions:

- Successive leach test series 1
    - L/S = 30 and 300 i.e. 33 and 3.3 g/L, respectively
    - Mixing durations for each successive leach of either 0.5 or 18 h
    - Talbingo reservoir water at 21±2°C
- Successive leach test series 2
    - L/S = 30 and 300 i.e. 33 and 3.3 g/L, respectively
    - Mixing durations for each successive leach of 18 h
    - Talbingo reservoir water at 6±1°C and 21±2°C

Test methodology

The 75 µm milled composites 1B, 2B, 5B, 5E and 7E characterised in memo 3 were used in the successive leach tests. The desired mass of each sample was weighed into 50 mL acid washed polyethylene tubes, to which 50 mL of composite Talbingo (TAL-PL1A, TAL-PL2A and TAL-PL2B) reservoir water was added. The water was adjusted to 6°C and 21°C before addition. For successive leach test series 1, the treatments were shaken (50 rpm) at 21°C for either 0.5 or 18 h for each cycle. For successive leach test series 2, the treatments were shaken for 0.5 h, then stood in temperature controlled rooms (6±1°C and 21±2°C) for another 17.5 h so that they were in contact with the water for 18 h for each leach cycle. This allowed an additional comparison of the effect of mixing vs standing for the 18 h, 21±2°C treatments in tests series 1 and 2.

After each leach cycle, the tubes were centrifuged (2000 g, 5 mins) followed by subsampling for measurement of pH, SEC, and dissolved (0.45 µm) metals analyses. The remaining supernatant was decanted and 50 mL fresh composite Talbingo reservoir water of the desired temperature added. The tube and its’ contents were weighed before adding fresh reservoir water to check on the residual water carried over from one leach to the next; this was 2-4% by volume and considered negligible. The process was repeated so that each treatment received three leaches in total.

Results

Test series *1 (0.5 h or 18 h mixing, 21°C):*

The pH, conductivity and dissolved aluminium concentrations measured in successive leach test series 1 (21°C treatments) with excavated rock composites 1B, 2B, 5B, 5E and 7E are shown in Figures 1, 2, 3, 4 and 5, respectively.

For all excavated rock samples at each L/S ratio and mixing duration, the pH of the leach 1, 2 and 3 solutions were in the range 9.23-9.67, 8.83-9.57, and 7.89-9.51, respectively. The pH was generally higher for a lower L/S ratio and longer mixing duration and decreased in each successive leach.

For all excavated rock samples at each L/S ratio and mixing duration, the conductivity of the leach 1, 2 and 3 solutions were in the range 50-133, 40-89, and 33-117 µS/cm, respectively. The conductivity was more variable than pH, but was generally marginally higher for the lower L/S, and for the 300 L/S ratio, was higher for the longer mixing duration. Apart from a few treatments, the conductivity generally decreased in each successive leach.

For all excavated rock samples at each L/S ratio and mixing duration, the concentration of dissolved aluminium in the leach 1, 2 and 3 solutions were in the range 26.6-329, 26.7-416, and 26.5-512 µg/L, respectively. The concentration of dissolved aluminium was generally similar or increased over successive leaches, despite the water pH successively decreasing. The exception was the 300 L/S, 18 h mixing duration treatments, where the aluminium concentration of leach 2 was similar or higher than leach 1, but often decreased for leach 3. Figures 1-5 also show that mixing duration (i.e. leach contact time) was more important than the L/S ratio, as the 0.5 h treatments for each L/S ratio also had lower concentrations of dissolved aluminium than the 18 h treatments.

The dissolved aluminium exceeded the default guideline value (DVG) of 55 µg/L for three leaches of each material for the 18 h mixing duration. The DGV was never exceeded for the 300 L/S, 0.5 h treatments, with the dissolved aluminium remaining at a similar concentration for each successive leach, i.e. the short 0.5 h mixing duration at this L/S was not adequate to either release enough aluminium to exceed the DGV or exhaust the pool of aluminium in the samples, so the concentration remained steady. The concentration of dissolved aluminium released in the 30 L/S, 0.5 h treatments always increased over successive leaches, with the initial leach often being below the DGV and the later leaches being above the DGV.

Test series 2 (0.5 h mixing, 17.5 h standing, 6°C or 21°C):

The pH, conductivity and dissolved aluminium concentrations measured in successive leach test series 2 (6°C and 21°C treatments) with excavated rock composites 1B, 2B, 5B, 5E and 7E are shown in Figures 6, 7, 8, 9 and 10, respectively.

The pH was higher for a lower L/S ratio, but temperature generally had little effect on pH. The pH was generally similar or marginally lower over successive leaches for the 30 L/S ratio, while for the 300 L/S ratio the pH was generally similar between the first two leaches then decreased for the third leach.

There were no discernible trends for the conductivity in successive leach test series 2, i.e. temperature had no clear effect on conductivity. The conductivity was in the range 35-402 µS/cm.

For all excavated rock samples at each L/S ratio at 6°C, the concentration of dissolved aluminium in the leach 1, 2 and 3 solutions were in the range 23.1-109, 27.9-129, and 16.8-137 µg/L, respectively, and at 21°C, the concentration of dissolved aluminium in the leach 1, 2 and 3 solutions were in the range 93.6-299, 125-403, and 65.0-384 µg/L, respectively. Less aluminium was released in the lower temperature treatments for each L/S ratio, and more aluminium was released by treatments with a lower L/S ratio. For the 21°C treatments the dissolved aluminium was generally steady or decreased over the successive leaches, whereas, for the 6°C treatments the dissolved aluminium was steady or increased over the successive leaches. The dissolved aluminium exceeded the default guideline value (DVG) of 55 µg/L for all of the leaches of the 21°C treatments and most leaches of 6°C, 30 L/S treatments, while the DGV was not exceeded by any of the 6°C, 300 L/S treatments.

A comparison of the 21°C treatments that were in contact with the reservoir water for 18 h, 0.5 h mixing (successive leach test series 2) and 18 h mixing (successive leach test series 1) indicated that longer physical mixing often caused an increase in the release of dissolved aluminium (Figure 11); most evident for the 2nd and 3rd leaches. This is likely to be the cause of the difference in trends over successive leaches between the tests for the 21°C treatments i.e. generally steady or increased in test series 1 and generally steady or decreased in test series 2.

Discussion

The lack of an effect of temperature on the conductivity and pH indicates the increase in pH occurs due to a rapid release of ions that increase the alkalinity, and this release likely occurs via ion exchange reactions. This is supported by measurements of rapid pH increase in previous tests of kinetics (Memos 6 and 11).

The results of the successive leach tests showing sustained release of aluminium over successive leaches is evidence of a dissolution process controlling the release of aluminium. This process continues while the excavated rock particles are in contact with the reservoir water and contain aluminium in forms that can be released. This process occurs more slowly at a lower temperature, so the pool of available aluminium is drawn down more slowly resulting in a greater pool available in successive leaches for the lower temperature treatments. In other words, the aluminium available for dissolution is depleted more slowly at a lower temperature.

The increased release for successive leaches and longer mixing times may be influenced by water taking time to fully encompass / contact all of the surfaces of rock particles (i.e. porosity), or particles disaggregating over time, particularly for longer mixing durations, leading to more surfaces being available for dissolution reactions to occur.

Summary

Successive leaches of excavated rock samples with Talbingo reservoir water did not rapidly exhaust the aluminium available for release into solution. To the contrary, many treatments had similar or increased aluminium concentrations in the 2nd and 3rd successive leaches. The lower temperature substantially decreased the concentration of aluminium released into reservoir waters. These results suggest a dissolution process is responsible for the release of aluminium, which is dependent on the duration of contact with water and the temperature. Longer durations of physical mixing also generally increased the release of dissolved aluminium.

The DGV for aluminium, 55 µg/L, was exceeded by most treatments in the successive leach tests.

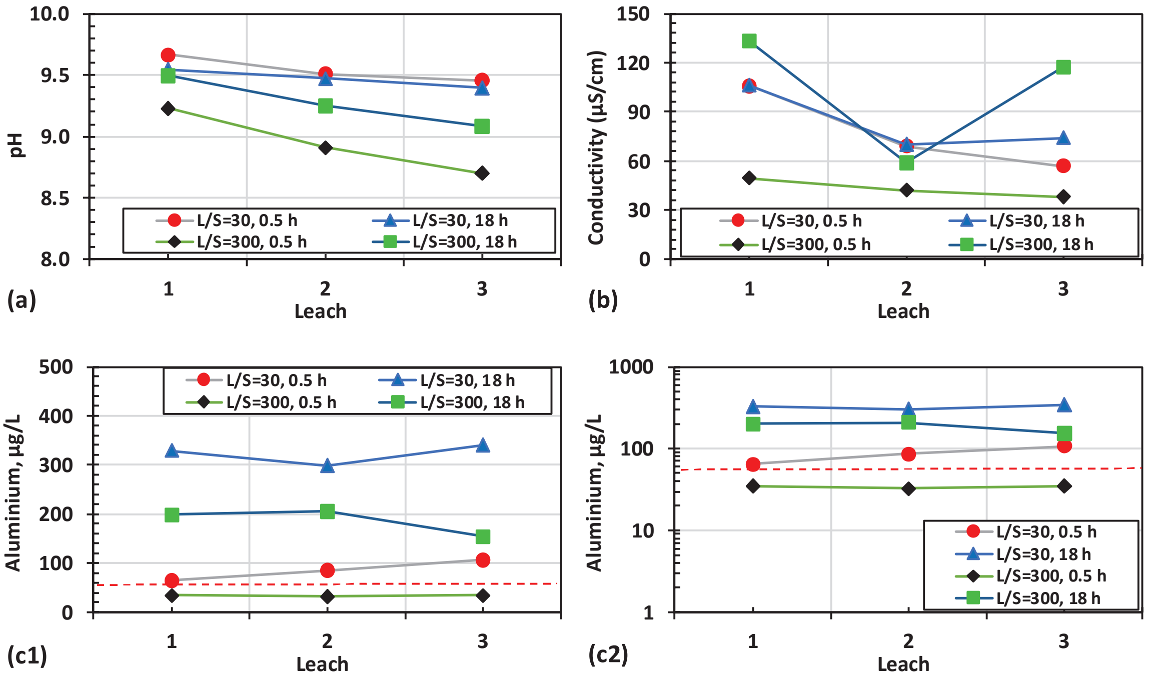

Figure 1. The pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 21±2°C for excavated rock sample 1B (successive leach test 1), where the effect of mixing duration and L/S ratio was investigated (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the red dotted line.

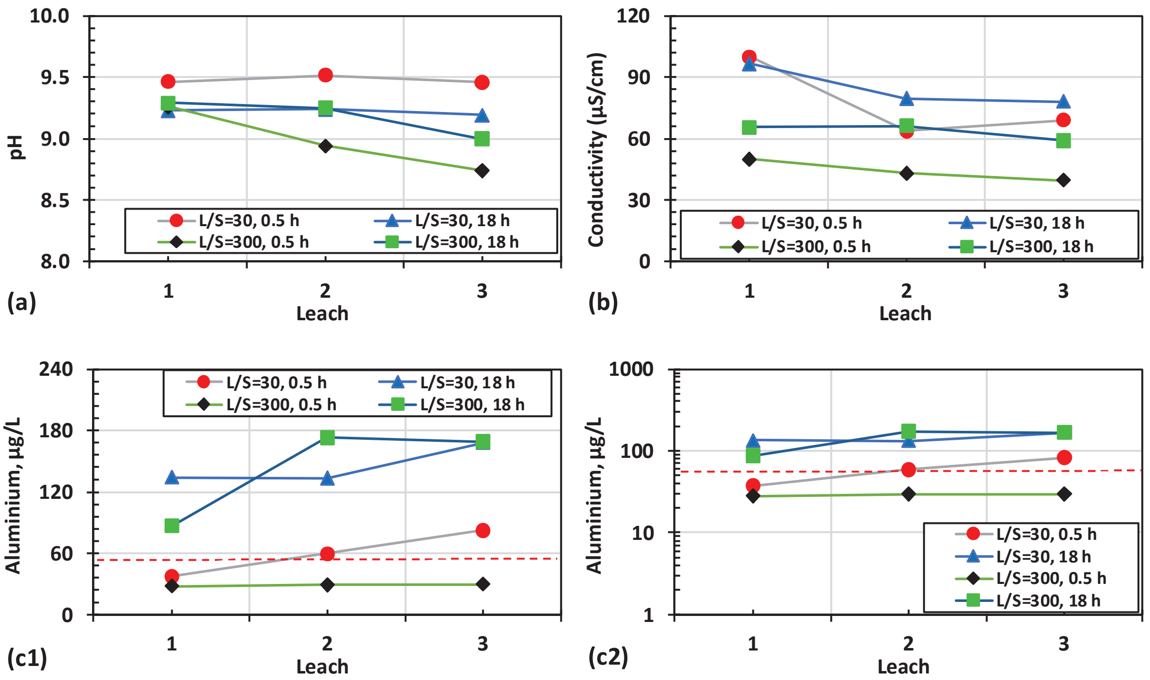

Figure 2. The pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 21±2°C for excavated rock sample 2B (successive leach test 1), where the effect of mixing duration and L/S ratio was investigated (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the red dotted line.

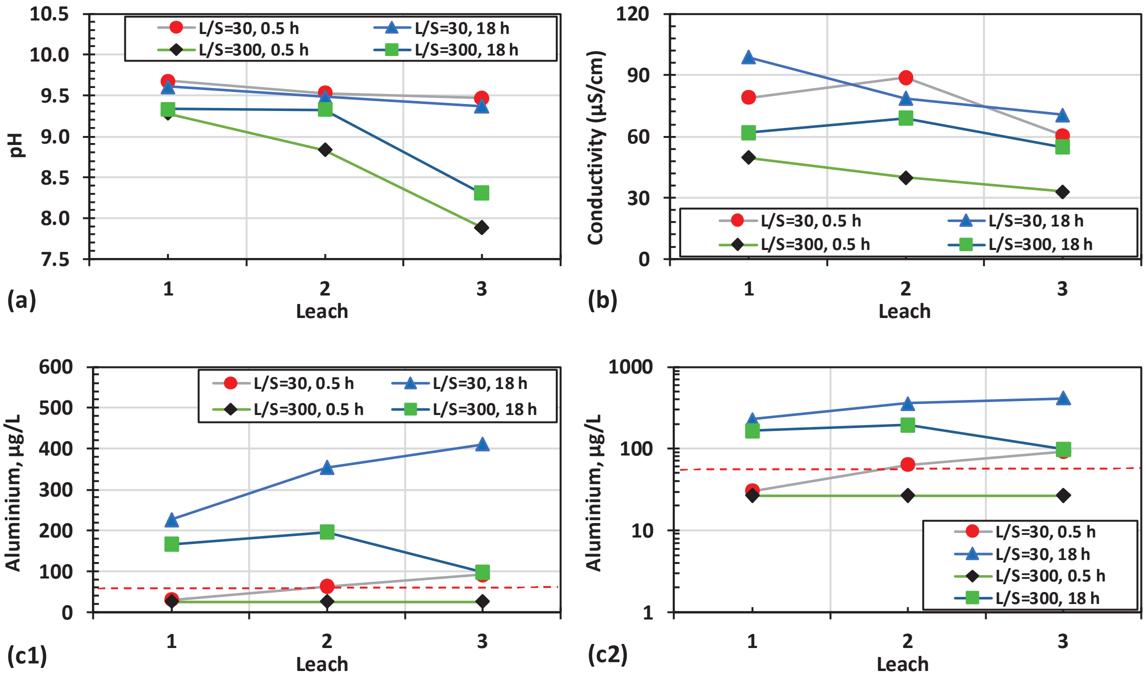

Figure 3. The pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 21±2°C for excavated rock sample 5B (successive leach test 1), where the effect of mixing duration and L/S ratio was investigated (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the red dotted line.

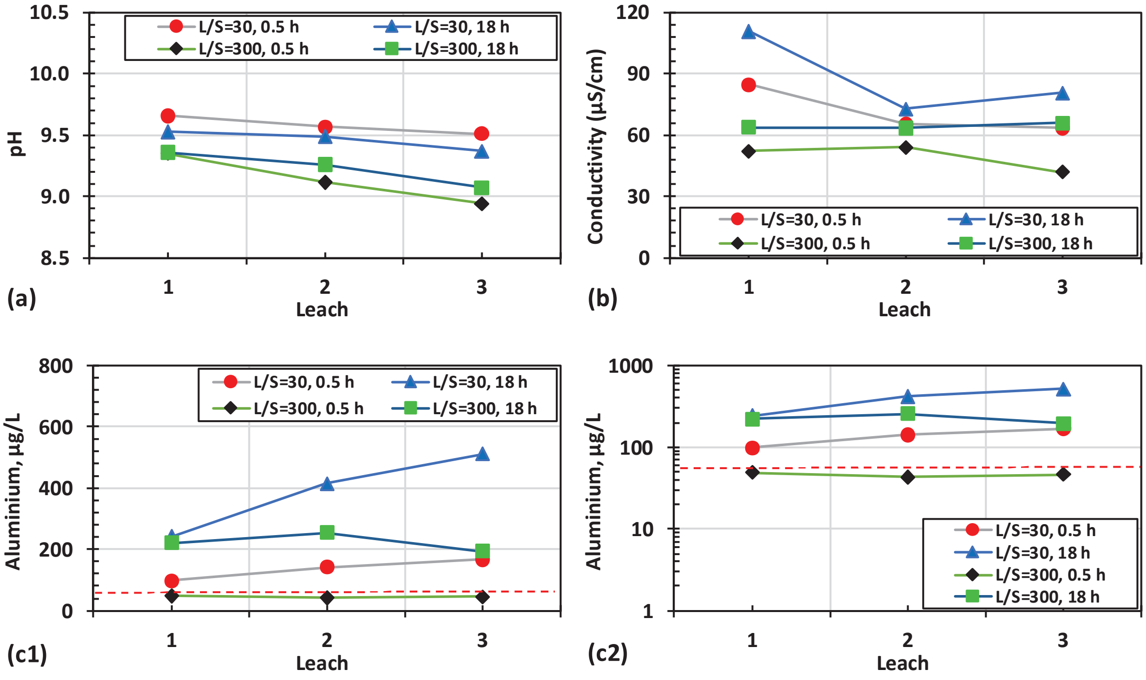

Figure 4. The pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 21±2°C for excavated rock sample 5E (successive leach test 1), where the effect of mixing duration and L/S ratio was investigated (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the red dotted line.

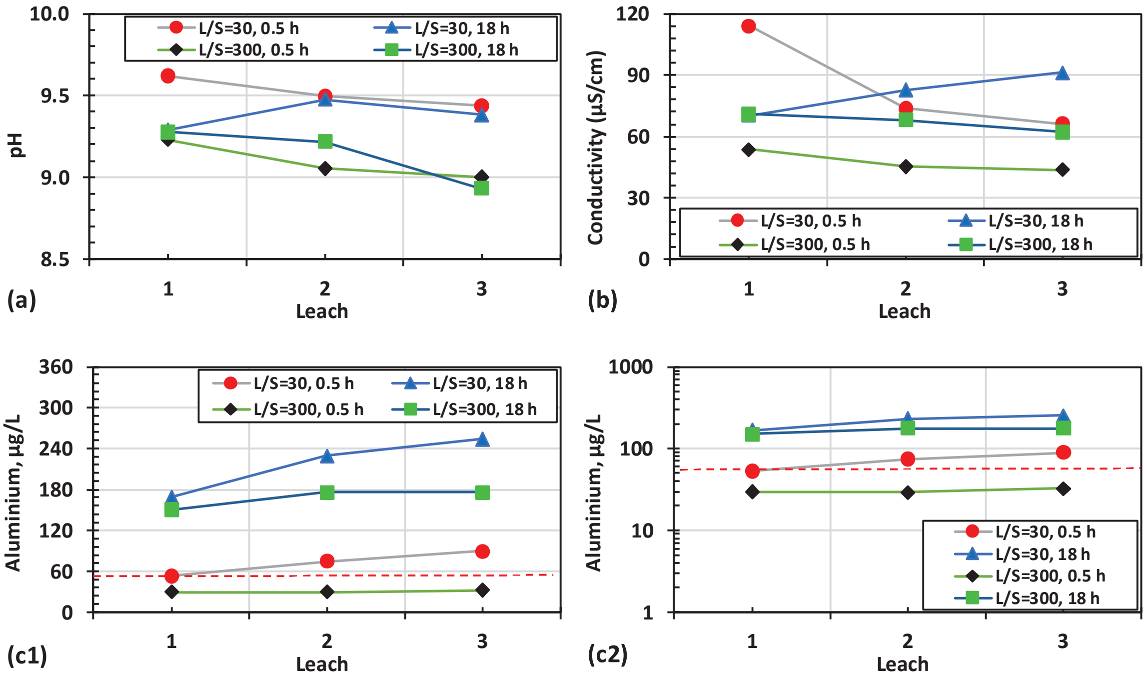

Figure 5. The pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 21±2°C for excavated rock sample 7E (successive leach test 1), where the effect of mixing duration and L/S ratio was investigated (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the red dotted line.

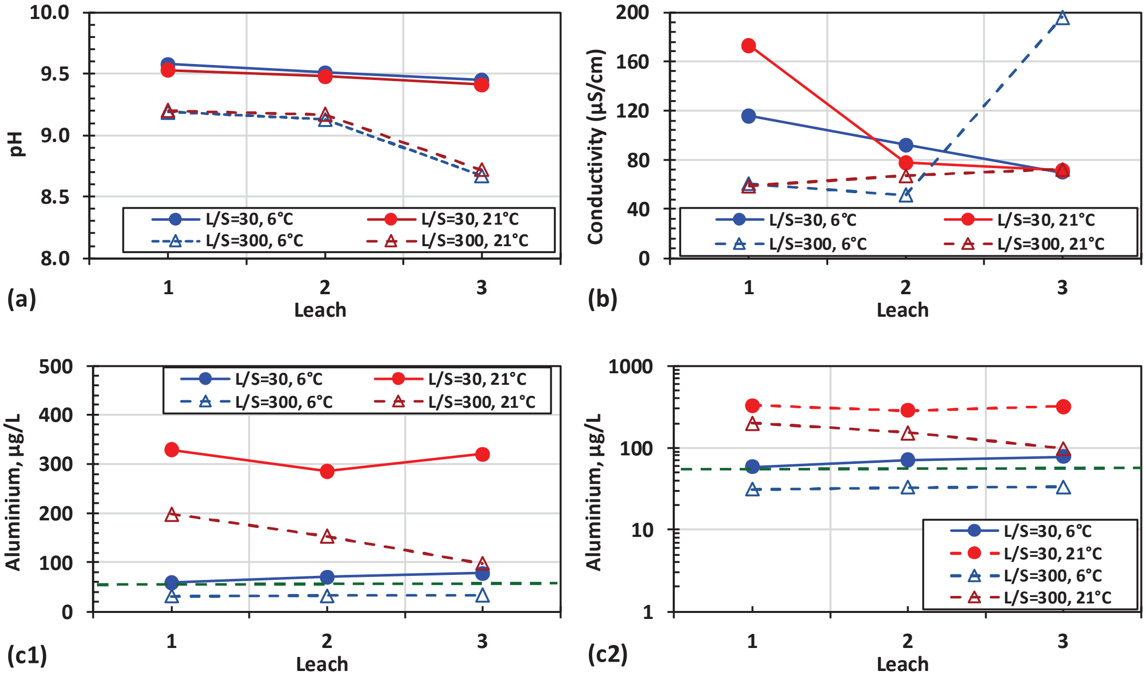

Figure 6. The effect of temperature on the pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 6±1°C and 21±2°C for excavated rock sample 1B (successive leach test 2), (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the green dotted line.

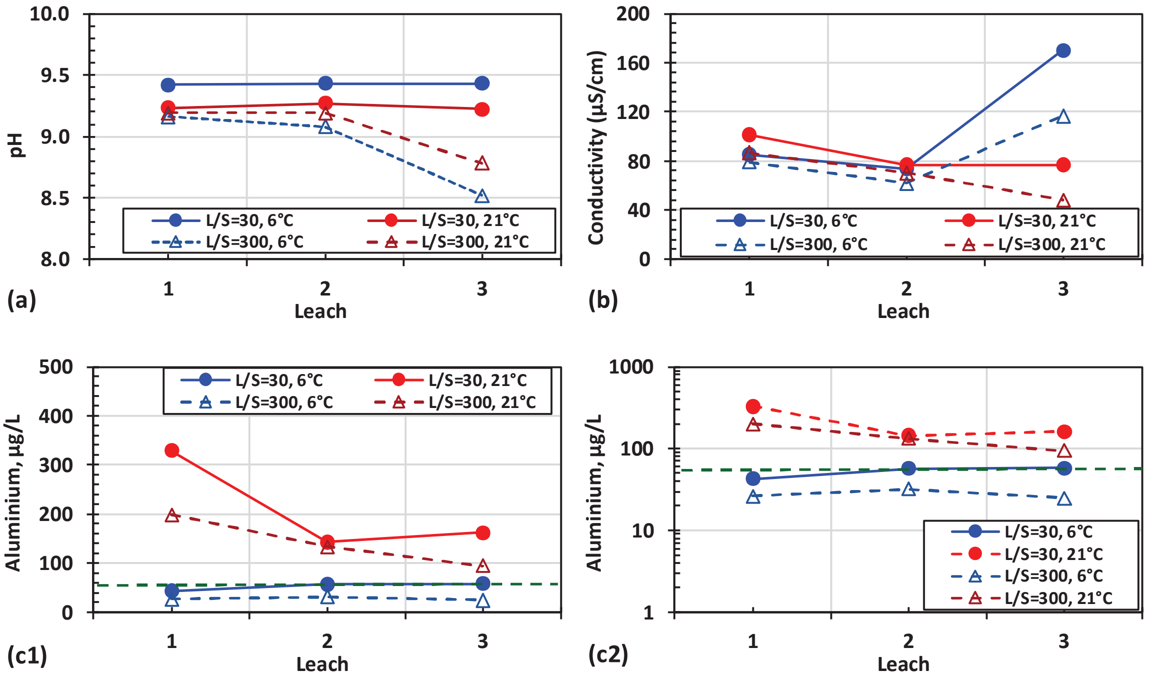

Figure 7. The effect of temperature on the pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 6±1°C and 21±2°C for excavated rock sample 2B (successive leach test 2), (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the green dotted line.

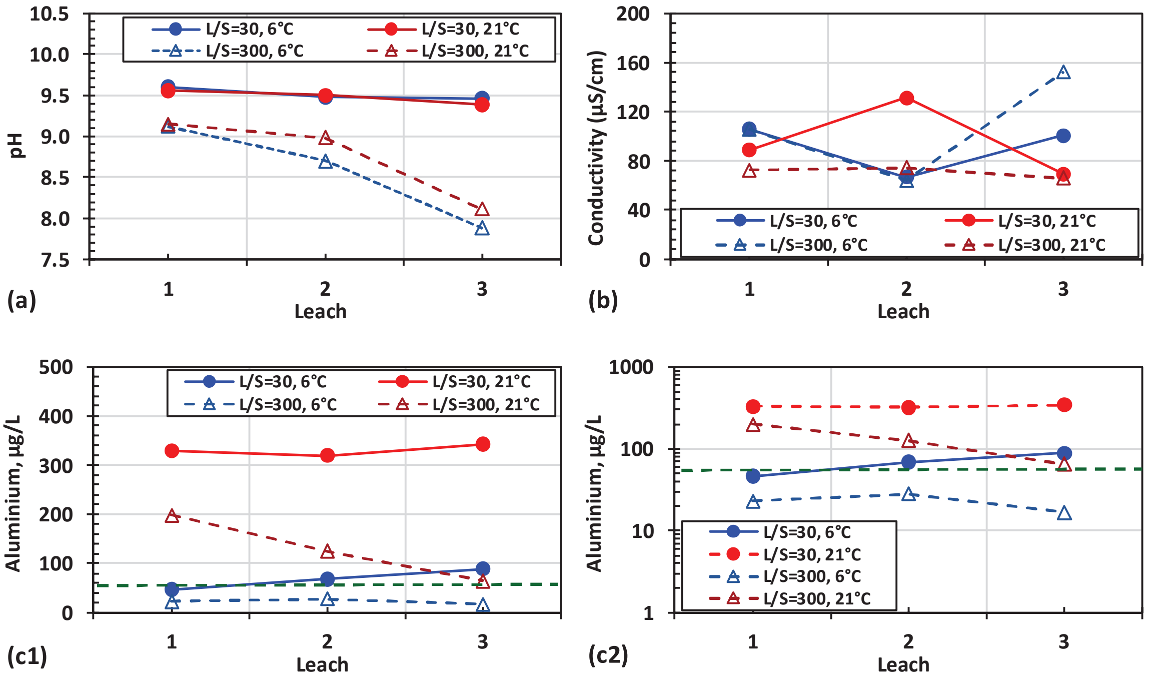

Figure 8. The effect of temperature on the pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 6±1°C and 21±2°C for excavated rock sample 5B (successive leach test 2), (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the green dotted line.

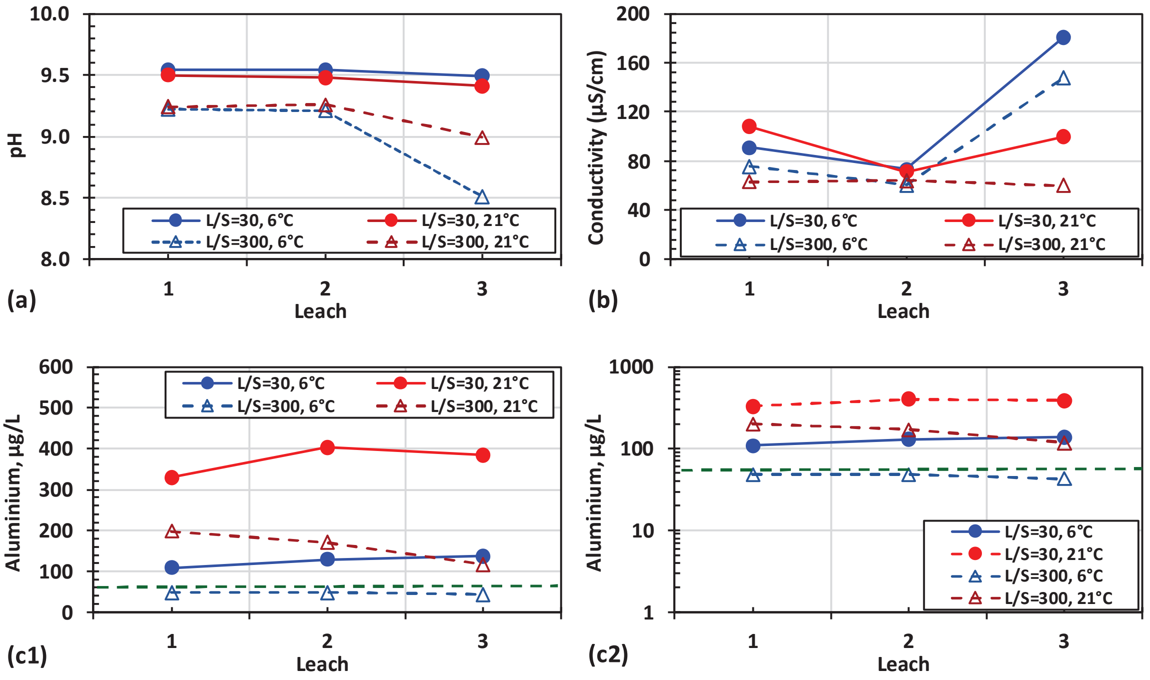

Figure 9. The effect of temperature on the pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 6±1°C and 21±2°C for excavated rock sample 5E (successive leach test 2), (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the green dotted line.

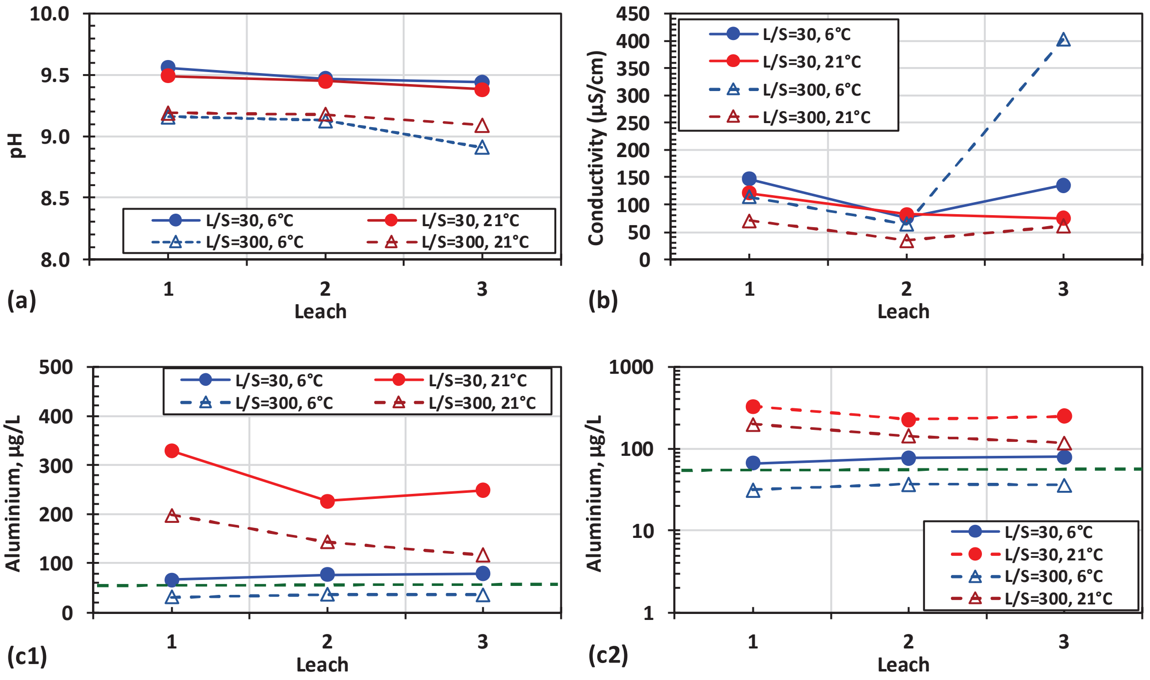

Figure 10. The effect of temperature on the pH, conductivity and dissolved aluminium concentration after three successive leach cycles at 6±1°C and 21±2°C for excavated rock sample 7E (successive leach test 2), (c2 = log scale). The 95% species protection default guideline value for dissolved aluminium is shown by the green dotted line.

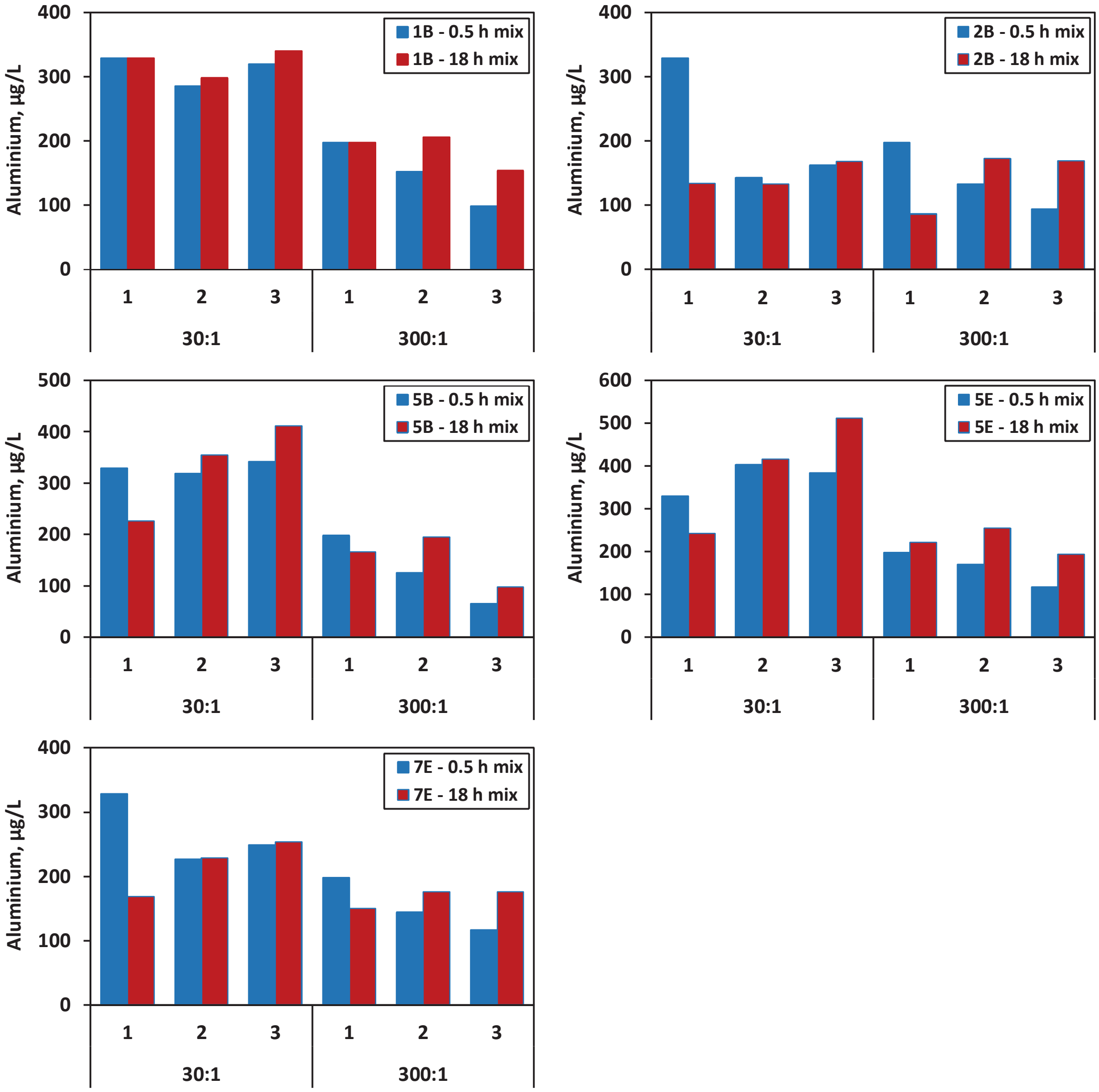

Figure 11. Comparison between the dissolved aluminium released from excavated rock material at L/S ratios of 30 and 300 in Talbingo reservoir water after 18 h contact with water between successive leach test 1 (18 h mixing, red bars) and leach test 2 (0.5 h mixing, 17.5 h standing, blue bars) at 21°C to assess the effect of mixing vs standing for each successive leach (1, 2 and 3).

Appendix D8 Significance of colloidal forms of aluminium with <0.45 µm filtered water

No Memo

Notes **Composites or either Talbingo or Tantangara reservoir waters used as leachate solution**
<75 µm composite rock materials
L/S = 300 in Talbingo and Tantangara waters, filtered after 18 and 120 h: 0.45 µm (dissolved and colloidal substances) and 0.003 µm (dissolved substances) (Appendix D8).

Sample Labels	Sample	L/S ratio	Water	Duration	Size fraction	pH	Conductivity	Na	K	Mg	Ca	Ag	Al	As	B	Ba	Be	Cd	Ce	Co	Cr	Cu	Fe	Li	Mn	Mo	Ni	P	Pb	S	Sn	Sr	Ti	Tl	V	Zn
				(h)	(µm)		(mS/cm)	(mg/L)	(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)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
					Filtration																															
CE491_Talbingo (<0.45 um)								1.5	0.4	0.6	1.2	<0.5	3.79	<2.8	<17	2.3	<0.05	<0.2	<0.9	<0.7	<0.3	0.5	14.4	0.1	0.2	<0.5	<2.5	<5.9	<0.9	143	<2.4	9.4	<0.05	<3.6	<0.6	0.6
CE491_Talbingo (<0.003 um) A						6.99		1.5	0.3	0.5	1.0	<0.5	0.52	<2.8	<17	1.9	<0.05	<0.2	<0.9	<0.7	0.5	<0.4	<0.5	0.1	0.1	<0.5	<2.5	7.1	<0.9	108	<2.4	8.3	<0.05	<3.6	<0.6	0.5
CE491_Talbingo (<0.003 um) B						7.12		1.6	0.4	0.6	1.1	<0.5	0.72	<2.8	<17	2.1	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	<0.5	0.1	0.1	<0.5	<2.5	8.4	<0.9	118	<2.4	8.8	<0.05	<3.6	<0.6	0.7
CE491_Talbingo (<0.003 um) C						7.15	108	1.6	0.4	0.6	1.1	<0.5	0.74	<2.8	<17	2.1	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	<0.5	0.1	0.1	<0.5	<2.5	<5.9	<0.9	127	<2.4	8.8	<0.05	<3.6	<0.6	0.6
CE491_Tantangara (<0.45 um)								1.6	0.5	0.7	1.1	<0.5	33.4	<2.8	<17	3.3	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	325	0.1	2.5	<0.5	<2.5	<5.9	<0.9	125	<2.4	9.6	0.41	<3.6	<0.6	0.7
CE491_Tantangara (<0.003 um) A						7.18	196	1.6	0.5	0.7	1.0	<0.5	<0.5	<2.8	<17	2.6	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	<0.5	0.1	0.2	<0.5	<2.5	7.1	<0.9	112	<2.4	8.6	<0.05	<3.6	<0.6	0.3
CE491_Tantangara (<0.003 um) B						7.22	119	1.6	0.5	0.7	1.0	<0.5	<0.5	<2.8	<17	2.6	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	<0.5	0.1	0.2	<0.5	<2.5	<5.9	<0.9	116	<2.4	8.7	<0.05	<3.6	<0.6	0.3
CE491_Tantangara (<0.003 um) C						7.22	112	1.6	0.5	0.7	1.0	<0.5	<0.5	<2.8	<17	2.6	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	<0.5	0.1	0.2	<0.5	<2.5	6.6	<0.9	109	<2.4	8.7	<0.05	<3.6	<0.6	0.3
100 ug/L Al (0.45 um)									19.8	2.9	1.3	<0.5	25	<2.8	<17	0.1	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	<0.5	<0.1	151	1.1	<2.5	121	<0.9		<2.4	0.4	<0.05	<3.6	<0.6	1.4
100 ug/L Al (0.003 um) A									14.8	1.9	0.8	<0.5	25.6	<2.8	<17	0.1	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	<0.5	<0.1	99	<0.5	<2.5	99.1	<0.9		<2.4	0.3	<0.05	<3.6	<0.6	0.9
100 ug/L Al (0.003 um) B									17.5	2.5	1.1	<0.5	26.8	<2.8	<17	0.1	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	0.7	<0.1	130	<0.5	<2.5	112	<0.9		<2.4	0.3	<0.05	<3.6	<0.6	1.4
100 ug/L Al (0.003 um) C									16.7	2.4	1.1	<0.5	23.2	<2.8	<17	0.1	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	<0.5	<0.1	123	<0.5	<2.5	115	<0.9		<2.4	0.3	<0.05	<3.6	<0.6	1.1
CE491_T12-1	1B	300/1	Talbingo	18	<0.45	9.17	957	1.9	1.8	1.1	5.8	<0.5	161	2.9	<17	1.1	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	6.5	1.3	5.1	<0.5	<2.5	<5.9	<0.9	214	<2.4	25	<0.05	<3.6	1.7	<0.1
CE491_T12-2	1B	300/1	Talbingo	18	<0.003			1.8	1.7	1.1	5.7	<0.5	155	<2.8	<17	1.0	<0.05	<0.2	<0.9	<0.7	0.4	<0.4	0.6	1.3	4.4	<0.5	<2.5	7.1	<0.9	199	<2.4	25	<0.05	<3.6	1.7	<0.1
CE491_T12-3	1B	300/1	Talbingo	120	<0.45	9.04	467	1.9	1.9	1.4	6.4	<0.5	328	5.4	<17	1.1	<0.05	<0.2	<0.9	<0.7	<0.3	0.5	4.1	1.8	5.3	<0.5	<2.5	<5.9	<0.9	217	<2.4	28	<0.05	<3.6	2.7	<0.1
CE491_T12-4	1B	300/1	Talbingo	120	<0.003			1.9	1.9	1.3	6.2	<0.5	317	<2.8	<17	1.1	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	<0.5	1.8	5.0	<0.5	<2.5	<5.9	<0.9	218	<2.4	28	0.05	<3.6	2.7	0.3
CE491_T12-5	2B	300/1	Talbingo	18	<0.45	9.17	109	1.7	1.5	1.6	5.5	<0.5	117	<2.8	<17	3.7	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	4.6	1.2	2.4	<0.5	<2.5	13.4	<0.9	199	<2.4	16	<0.05	<3.6	1.7	<0.1
CE491_T12-6	2B	300/1	Talbingo	18	<0.003			1.7	1.4	1.5	5.3	<0.5	112	3.3	<17	3.6	<0.05	<0.2	<0.9	<0.7	0.5	<0.4	<0.5	1.2	2.2	<0.5	<2.5	11.6	<0.9	195	<2.4	15	<0.05	<3.6	1.8	0.2
CE491_T12-7	2B	300/1	Talbingo	120	<0.45	8.95	349	1.8	1.7	1.5	7.1	<0.5	192	<2.8	<17	4.8	<0.05	<0.2	<0.9	<0.7	0.4	<0.4	3.6	1.5	1.9	<0.5	<2.5	16.8	<0.9	242	<2.4	20	<0.05	<3.6	3.2	<0.1
CE491_T12-8	2B	300/1	Talbingo	120	<0.003			1.8	1.6	1.5	6.9	<0.5	185	3.4	<17	4.6	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	0.5	1.5	1.6	<0.5	<2.5	15.2	<0.9	232	<2.4	20	<0.05	<3.6	2.9	0.3
CE491_T12-9	5B	300/1	Talbingo	18	<0.45	9.24	119	1.9	1.4	0.9	6.0	<0.5	144	<2.8	<17	1.5	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	8.1	0.3	3.9	0.6	<2.5	7.3	<0.9	222	<2.4	18	0.06	<3.6	0.7	<0.1
CE491_T12-10	5B	300/1	Talbingo	18	<0.003			1.9	1.3	0.9	5.8	<0.5	138	<2.8	<17	1.4	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	<0.5	0.3	3.8	<0.5	<2.5	7.6	<0.9	197	<2.4	17	<0.05	<3.6	0.7	<0.1
CE491_T12-11	5B	300/1	Talbingo	120	<0.45	9.07	1450	2.0	1.5	1.1	6.6	<0.5	359	3.1	<17	1.9	<0.05	<0.2	<0.9	<0.7	<0.3	0.7	9.6	0.4	4.8	0.6	<2.5	8.8	<0.9	250	<2.4	20	0.23	<3.6	1.4	<0.1
CE491_T12-12	5B	300/1	Talbingo	120	<0.003			2.0	1.5	1.1	6.5	<0.5	343	<2.8	<17	1.8	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	0.9	0.4	4.5	<0.5	<2.5	10.8	<0.9	243	<2.4	20	<0.05	<3.6	1.3	1
CE491_T12-13	5E	300/1	Talbingo	18	<0.45	9.22	127	1.9	1.0	0.9	6.7	<0.5	190	<2.8	<17	2.1	<0.05	<0.2	<0.9	<0.7	<0.3	0.6	9.2	0.3	2.7	<0.5	<2.5	12.1	<0.9	344	<2.4	17	0.19	<3.6	1.2	<0.1
CE491_T12-14	5E	300/1	Talbingo	18	<0.003			1.9	1.0	0.9	6.5	<0.5	183	<2.8	<17	2.0	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	0.8	0.3	2.6	<0.5	<2.5	13.2	<0.9	324	<2.4	17	0.06	<3.6	1.2	<0.1
CE491_T12-15	5E	300/1	Talbingo	120	<0.45	9.09	885	2.0	1.2	1.0	7.4	<0.5	382	<2.8	<17	2.2	<0.05	<0.2	<0.9	<0.7	<0.3	1.0	22.4	0.4	3.3	<0.5	<2.5	11.2	<0.9	547	<2.4	19	0.69	<3.6	2.5	<0.1
CE491_T12-16	5E	300/1	Talbingo	120	<0.003			2.0	1.1	1.0	7.2	<0.5	355	3.6	<17	2.1	<0.05	<0.2	<0.9	<0.7	<0.3	0.7	0.5	0.4	2.6	<0.5	<2.5	10.8	<0.9	516	<2.4	18	<0.05	<3.6	2.3	0.2
CE491_T12-17	7E	300/1	Talbingo	18	<0.45	9.23	191	1.8	3.1	0.9	5.9	<0.5	134	<2.8	<17	470	<0.05	<0.2	<0.9	<0.7	<0.3	0.5	4.2	1.5	8.9	<0.5	<2.5	<5.9	<0.9	668	<2.4	56	<0.05	<3.6	1.1	<0.1
CE491_T12-18	7E	300/1	Talbingo	18	<0.003			1.8	2.9	0.9	5.7	<0.5	133	3.7	<17	450	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	<0.5	1.5	8.3	<0.5	<2.5	<5.9	<0.9	592	<2.4	54	<0.05	<3.6	0.9	<0.1
CE491_T12-19	7E	300/1	Talbingo	120	<0.45	8.89	354	1.8	3.2	1.0	7.3	<0.5	212	6.7	<17	487	<0.05	<0.2	<0.9	<0.7	<0.3	0.7	1.9	2	8.7	<0.5	<2.5	<5.9	<0.9	731	<2.4	65	<0.05	<3.6	1.6	<0.1
CE491_T12-20	7E	300/1	Talbingo	120	<0.003			1.9	3.2	1.0	7.2	<0.5	206	<2.8	<17	489	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	0.7	2	8.3	<0.5	<2.5	<5.9	<0.9	703	<2.4	66	<0.05	<3.6	1.7	0.2
CE491_T12-21	1B	300/1	Tantangara	18	<0.45	9.21	536	1.9	1.9	1.3	5.5	<0.5	234	<2.8	<17	1.2	0.06	<0.2	<0.9	<0.7	<0.3	<0.4	185	1.3	8.9	<0.5	<2.5	6.3	<0.9	175	<2.4	25	0.33	<3.6	1.4	0.2
CE491_T12-22	1B	300/1	Tantangara	18	<0.003			1.9	1.9	1.3	5.4	<0.5	222	<2.8	<17	1.0	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	<0.5	1.3	5.1	<0.5	<2.5	8.4	<0.9	166	<2.4	25	<0.05	<3.6	1.1	<0.1
CE491_T12-23	1B	300/1	Tantangara	120	<0.45	9.07	606	2.0	2.1	1.6	6.3	<0.5	479	<2.8	<17	1.2	<0.05	<0.2	<0.9	<0.7	<0.3	0.8	49.5	1.8	5.9	<0.5	<2.5	<5.9	<0.9	182	<2.4	28	0.18	<3.6	2.7	<0.1
CE491_T12-24	1B	300/1	Tantangara	120	<0.003			2.0	2.1	1.5	6.1	<0.5	467	<2.8	<17	1.2	<0.05	<0.2	<0.9	<0.7	<0.3	0.5	0.5	1.8	4.7	<0.5	<2.5	6.6	<0.9	183	<2.4	28	<0.05	<3.6	2.5	<0.1
CE491_T12-25	2B	300/1	Tantangara	18	<0.45	9.17	98	1.8	1.6	1.7	5.3	<0.5	167	<2.8	<17	4.1	0.05	<0.2	<0.9	<0.7	<0.3	<0.4	143	1.2	4.4	<0.5	<2.5	16.8	<0.9	178	<2.4	16	0.19	<3.6	1.6	<0.1
CE491_T12-26	2B	300/1	Tantangara	18	<0.003			1.8	1.6	1.7	5.2	<0.5	158	<2.8	<17	3.8	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	3.2	1.2	2.1	<0.5	<2.5	15.1	<0.9	160	<2.4	15	<0.05	<3.6	1.6	0.2
CE491_T12-27	2B	300/1	Tantangara	120	<0.45	8.96	394	1.9	1.9	1.6	7.0	<0.5	244	<2.8	<17	4.8	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	8.7	1.6	1.6	<0.5	<2.5	14.1	<0.9	212	<2.4	21	<0.05	<3.6	2.6	<0.1
CE491_T12-28	2B	300/1	Tantangara	120	<0.003			1.8	1.7	1.5	6.7	<0.5	232	4.6	<17	4.8	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	<0.5	1.5	1.3	<0.5	<2.5	13.1	<0.9	186	<2.4	20	<0.05	<3.6	2.5	<0.1
CE491_T12-29	5B	300/1	Tantangara	18	<0.45	9.23	257	2.0	1.5	1.1	5.7	<0.5	213	<2.8	<17	1.8	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	228	0.3	7.0	0.6	<2.5	7.5	1.0	189	<2.4	18	0.47	<3.6	0.7	0.2
CE491_T12-30	5B	300/1	Tantangara	18	<0.003			2.0	1.4	1.1	5.5	<0.5	199	<2.8	<17	1.5	<0.05	<0.2	<0.9	<0.7	0.4	<0.4	0.6	0.3	3.4	<0.5	<2.5	6.8	<0.9	166	<2.4	17	0.06	<3.6	0.6	<0.1
CE491_T12-31	5B	300/1	Tantangara	120	<0.45	9.04	363	2.1	1.7	1.3	6.4	<0.5	488	<2.8	<17	2.1	0.14	<0.2	<0.9	<0.7	<0.3	0.5	114	0.4	6.2	<0.5	<2.5	9.6	<0.9	216	<2.4	20	0.39	<3.6	1.3	<0.1
CE491_T12-32	5B	300/1	Tantangara	120	<0.003			2.1	1.6	1.3	6.2	<0.5	465	<2.8	<17	1.9	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	<0.5	0.4	3.9	0.6	<2.5	8.1	<0.9	187	<2.4	20	<0.05	<3.6	1.2	<0.1
CE491_T12-33	5E	300/1	Tantangara	18	<0.45	9.28	989	2.0	1.2	1.1	6.4	<0.5	294	<2.8	<17	2.5	0.09	<0.2	<0.9	<0.7	<0.3	1.6	193	0.3	5.4	<0.5	<2.5	14.1	<0.9	325	<2.4	17	0.54	<3.6	1.6	0.3
CE491_T12-34	5E	300/1	Tantangara	18	<0.003			2.0	1.2	1.1	6.2	<0.5	285	<2.8	<17	2.2	<0.05	<0.2	<0.9	<0.7	<0.3	0.8	0.8	0.3	2.5	<0.5	<2.5	10	<0.9	305	<2.4	17	<0.05	<3.6	1.3	<0.1
CE491_T12-35	5E	300/1	Tantangara	120	<0.45	9.03	315	2.1	1.3	1.3	7.2	<0.5	580	<2.8	<17	2.3	<0.05	<0.2	<0.9	<0.7	<0.3	2.1	24.7	0.5	3.1	<0.5	<2.5	7	<0.9	574	<2.4	19	0.15	<3.6	2.6	<0.1
CE491_T12-36	5E	300/1	Tantangara	120	<0.003			2.1	1.3	1.3	7.0	<0.5	557	<2.8	<17	2.2	<0.05	<0.2	<0.9	<0.7	<0.3	1.3	0.6	0.4	2.6	<0.5	<2.5	11.5	<0.9	511	<2.4	19	<0.05	<3.6	2.4	<0.1
CE491_T12-37	7E	300/1	Tantangara	18	<0.45	9.22	87	1.9	3.2	1.1	5.7	<0.5	195	<2.8	<17	442	0.13	<0.2	<0.9	<0.7	<0.3	0.7	113	1.5	10.6	<0.5	<2.5	<5.9	1.1	628	<2.4	56	0.16	<3.6	0.8	0.6
CE491_T12-38	7E	300/1	Tantangara	18	<0.003			1.9	3.0	1.0	5.5	<0.5	187	<2.8	<17	429	<0.05	<0.2	<0.9	<0.7	<0.3	<0.4	0.6	1.5	7.3	<0.5	<2.5	<5.9	<0.9	571	<2.4	53	<0.05	<3.6	0.8	<0.1
CE491_T12-39	7E	300/1	Tantangara	120	<0.45	8.98	233	1.9	3.4	1.1	6.6	<0.5	347	3.4	<17	446	<0.05	<0.2	<0.9	<0.7	<0.3	1.4	50	2	7.3	<0.5	<2.5	<5.9	<0.9	695	<2.4	63	0.14	<3.6	1.8	<0.1
CE491_T12-40	7E	300/1	Tantangara	120	<0.003			1.9	3.3	1.1	6.4	<0.5	332	3	<17	445	<0.05	<0.2	<0.9	<0.7	<0.3	0.9	<0.5	2	5.7	<0.5	<2.5	<5.9	<0.9	643	<2.4	61	<0.05	<3.6	1.4	0.2

Appendix D8 Significance of colloidal forms of aluminium with <0.45 µm filtered water

No Memo

Sample Labels	Sample	L/S ratio	Water	Duration	Size fraction	pH	Conductivity	Na	K	Mg	Ca	Ag	Al	As	B	Ba	Be	Cd	Ce	Co	Cr	Cu	Fe	Li	Mn	Mo	Ni	P	Pb	S	Sn	Sr	Ti	Tl	V	Zn
				(h)	(µm)		(mS/cm)	(mg/L)	(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)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
					Filtration																															
Mean blank								**-0.02**	**-0.01**	**-0.003**	**-0.03**	**0.1**	**0.1**	**-3.3**	**26.1**	**0.0**	**0.0**	**0.0**	**0.9**	**-0.4**	**-0.2**	**0.2**	**-0.2**	**-0.1**	**0.0**	**0.1**	**-0.4**	**-0.7**	**-1.3**	**3.7**	**-1.3**	**0.0**	**0.0**	**-0.7**	**0.1**	**-1.2**
LOD (3 x S.d.)								**0.001**	**0.001**	**0.003**	**0.001**	**0.5**	**0.5**	**2.8**	**16.8**	**0.0**	**0.0**	**0.2**	**0.9**	**0.7**	**0.3**	**0.4**	**0.5**	**0.1**	**0.0**	**0.5**	**2.5**	**5.9**	**0.9**	**15.8**	**2.4**	**0.0**	**0.0**	**3.6**	**0.6**	**0.1**
TM24.4								**9.2**	**1.1**	**5.3**	**20.1**	8.6	32.4	6.0	0.7	15.3	2.3	4.1	-0.8	6.7	5.4	6.2	16.7	5.1	8.2	6.6	4.3	1.8	6.1	5707	3.2	111	7.4	6.2	7.3	28.8
Certified TM24.4												8.92	32.9 ± 4.5	5.30 ± 0.53		15.0 ± 1.0		3.96 ± 0.34		6.27 ± 0.57	5.00 ± 0.59	6.31 ± 0.60	16.0 ± 2.3	4.95 ± 0.42	8.24± 0.73		5.03 ± 0.53		5.60 ± 0.52			113 ± 8			7.00 ± 0.58	
% recovery (TM24.4)												**96**	**99**	**113**		**102**		**103**		**107**	**107**	**98**	**104**	**103**	**99**		**86**		**109**			**98**			**104**	
TMDA64.3								**9.37**	**1.14**	**5.27**	**19.5**	12.1	285	161	250	286	161	260	-1	247	286	257	293	145	288	277	254	0	281	5615	273	618	128	141	277	321
Certified TM63.4												12.6 ± 1.3	291 ± 23	164 ± 15		287 ± 18		258 ± 21		250 ± 16	283 ± 17	298 ± 21	298 ± 21	143 ± 15	292 ± 17		252 ± 18		280 ± 22			628 ± 34			279 ± 18	320 ± 23
% recovery (TMDA63.4)												**96**	**98**	**98**		**100**		**101**		**99**	**101**	**86**	**98**	**102**	**99**		**101**		**100**			**98**			**99**	**100**
CE491_T12-1+spike								**86**	**109**	**83**		**98**	**95**	**99**	**102**	**98**	**99**	**98**	**99**	**99**	**99**	**99**	**98**	**99**	**97**	**100**	**97**	**100**	**97**	**87**	**97**	**98**	**99**	**97**	**99**	**98**
CE491_T12-11+spike								**100**	**122**	**87**		**98**	**96**	**101**	**106**	**100**	**100**	**100**	**100**	**101**	**100**	**100**	**100**	**101**	**100**	**100**	**99**	**101**	**99**	**88**	**100**	**100**	**100**	**99**	**101**	**101**
CE491_T12-21+spike								**93**	**119**	**88**		**98**	**96**	**100**	**106**	**99**	**99**	**99**	**100**	**98**	**99**	**99**	**99**	**100**	**100**	**100**	**99**	**100**	**98**	**91**	**99**	**99**	**100**	**97**	**100**	**100**
CE491_T12-31+spike								**103**	**120**	**82**		**98**	**95**	**102**	**108**	**99**	**101**	**100**	**99**	**98**	**99**	**99**	**99**	**100**	**98**	**100**	**99**	**101**	**98**	**93**	**99**	**99**	**100**	**99**	**101**	**101**
CE491_T12-40+spike								**95**	**116**	**85**		**97**	**96**	**101**	**109**	**95**	**99**	**99**	**99**	**99**	**100**	**100**	**99**	**100**	**98**	**101**	**99**	**101**	**98**	**88**	**99**	**98**	**100**	**97**	**100**	**99**

Appendix D9. Longer term substance release

Appendix D9. Longer term substance release

No Memo

Notes

Composite Talbingo reservoir water used as leachate solution.

Size categories 150-210, 63-150 and <63 µm (composite fine material).

L/S of 300 (3.3 g/L) and 1000 (1 g/L), 6 and 21 ºC, shaken for 30 min in Talbingo reservoir water and measurements made after 0.75, 5, 14, 28, 42 and 56 days.

Sample Labels	Sample	L/S ratio	Temperature	Duration	pH	Conductivity	Na	K	Mg	Ca	Ag	Al	As	B	Ba	Be	Cd	Ce	Co	Cr	Cu	Fe	Li	Mn	Mo	Ni	Pb	Sn	Sr	Ti	Tl	V	Zn	P	S
			(°C)	(d)		(mS/cm)	(mg/L)	(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)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
CE491_T7-49	Talbingo A				7.08	28	1.5	0.4	0.8	1.9	<0.5	3.5	<1.5	<16	4.3	<0.02	<0.1	<2.5	0.7	<0.6	<1.0	17	<0.1	0.2	<0.2	<1.2	<1.8	<2.9	14	<0.03	<3.2	0.1	1.6	<2.5	169
CE491_T7-50	Talbingo B				7.07	24	1.5	0.4	0.8	1.9	<0.5	3.3	<1.5	<16	4.3	<0.02	<0.1	<2.5	<0.6	<0.6	<1.0	17	0.1	0.2	<0.2	<1.2	<1.8	<2.9	15	0.04	<3.2	0.2	1.6	<2.5	167
CE491_T7-51	Talbingo C				7.09	27	1.5	0.4	0.8	1.9	<0.5	3.6	2.2	<16	4.3	<0.02	<0.1	<2.5	0.9	<0.6	<1.0	17	0	0.2	<0.2	<1.2	<1.8	<2.9	14	<0.03	<3.2	0.2	1.6	<2.5	169
CE491_T7-1	1B	300/1	21	0.75	9.36	79	1.7	1.8	1.1	5.7	<0.5	86	2.7	<16	0.9	<0.02	<0.1	<2.5	<0.6	<0.6	<1.0	10	1	6	<0.2	<1.2	<1.8	<2.9	24	0.05	<3.2	1.3	<0.2	6.3	165
CE491_T7-2	1B	300/1	21	5	8.86	71	1.7	2.0	1.2	6.2	<0.5	216	1.7	<16	1.0	<0.02	<0.1	<2.5	<0.6	<0.6	<1.0	9	2	6	0.2	<1.2	<1.8	<2.9	26	0.04	<3.2	2.3	<0.2	2.8	182
CE491_T7-3	1B	300/1	21	14	8.42	223	1.8	2.2	1.7	10.8	<0.5	252	3.4	<16	1.6	<0.02	<0.1	<2.5	<0.6	<0.6	<1.0	5	2	22	<0.2	<1.2	<1.8	<2.9	37	<0.03	<3.2	3.2	<0.2	<2.5	188
CE491_T7-4	1B	300/1	21	28	7.78	344	1.8	2.2	2.0	12.9	<0.5	194	3.6	<16	1.9	<0.02	<0.1	<2.5	<0.6	<0.6	<1.0	3	3	37	<0.2	<1.2	<1.8	<2.9	42	0.05	<3.2	3.0	<0.2	4.8	189
CE491_T7-5	1B	300/1	21	42	8.04	250	1.9	2.4	2.3	13.9	<0.8	132	4.7	<18	2.2	<0.02	<0.2	<1	<1.51	<0.6	0.5	1	3	54	<0.3	<1.9	<1.6	<1.7	48	<0.03	<2.4	3.0	<0.04	3.01	202
CE491_T7-6	1B	300/1	21	56	8.13	564	1.9	2.5	2.6	15.0	<0.8	112	3.8	<18	2.4	<0.02	<0.2	<1	<1.51	<0.6	0.4	1	3	62	<0.3	<1.9	<1.6	<1.7	52	0.05	<2.4	3.4	<0.04	<2.51	208
CE491_T7-7	1B	300/1	6	0.75	9.4	138	1.7	1.7	1.1	5.6	<0.5	28	<1.5	<16	0.8	<0.02	<0.1	<2.5	0.8	<0.6	<1.0	10	1	9	0.3	<1.2	<1.8	<2.9	23	<0.03	<3.2	0.8	<0.2	<2.5	163
CE491_T7-8	1B	300/1	6	5	9.1	181	1.7	1.7	1.1	5.9	<0.5	50	<1.5	<16	0.9	<0.02	<0.1	<2.5	0.7	<0.6	<1.0	8	1	7	0.2	<1.2	<1.8	<2.9	25	0.06	<3.2	1.3	0.4	3.7	167
CE491_T7-9	1B	300/1	6	14	8.7	251	1.7	1.9	1.4	8.1	<0.5	75	2.6	<16	1.1	<0.02	<0.1	<2.5	<0.6	<0.6	<1.0	6	1	15	<0.2	<1.2	<1.8	<2.9	31	0.39	<3.2	1.7	<0.2	<2.5	175
CE491_T7-10	1B	300/1	6	28	8.03	472	1.8	1.9	1.5	9.5	<0.5	76	<1.5	<16	1.3	<0.02	<0.1	<2.5	<0.6	<0.6	<1.0	6	2	22	<0.2	<1.2	<1.8	<2.9	34	0.39	<3.2	1.6	<0.2	<2.5	175
CE491_T7-11	1B	300/1	6	42	8.05	217	1.8	2.1	1.8	12.4	<0.8	55	3.7	<18	2.0	<0.02	<0.2	<1	<1.51	<0.6	0.4	3	2	61	<0.3	<1.9	<1.6	<1.7	45	0.33	<2.4	1.5	<0.04	<2.51	176
CE491_T7-12	1B	300/1	6	56	8.08	486	1.9	2.3	2.2	14.7	<0.8	39	2.2	<18	2.4	<0.02	<0.2	<1	<1.51	<0.6	0.3	1	2	98	<0.3	<1.9	<1.6	2.32	53	0.22	<2.4	1.5	<0.04	2.95	174
CE491_T7-13	5E	300/1	21	0.75	9.46	60	1.8	1.1	0.9	6.9	<0.5	115	<1.5	<16	2.1	<0.02	<0.1	<2.5	<0.6	<0.6	<1.0	17	0	3	<0.2	<1.2	<1.8	<2.9	16	0.25	<3.2	0.9	<0.2	8.7	306
CE491_T7-14	5E	300/1	21	5	8.71	81	1.9	1.2	1.0	7.5	<0.5	259	<1.5	<16	2.3	<0.02	<0.1	<2.5	<0.6	<0.6	1.3	17	0	4	<0.2	<1.2	<1.8	<2.9	18	0.27	<3.2	1.8	<0.2	9	455
CE491_T7-15	5E	300/1	21	14	8.38	123	2.0	1.3	1.2	13.8	<0.5	274	2.8	<16	3.3	<0.02	<0.1	<2.5	<0.6	<0.6	1.1	11	1	13	<0.2	<1.2	<1.8	<2.9	25	0.2	<3.2	2.1	<0.2	9.6	821
CE491_T7-16	5E	300/1	21	28	8.06	312	2.0	1.4	1.2	16.3	<0.5	212	<1.5	<16	3.7	<0.02	<0.1	<2.5	<0.6	<0.6	1.9	6	1	20	<0.2	<1.2	<1.8	<2.9	27	0.25	<3.2	2.1	<0.2	5.4	1000
CE491_T7-17	5E	300/1	21	42	8.1	197	2.1	1.5	1.3	16.2	<0.8	150	4.1	<18	4.1	<0.02	<0.2	<1	<1.51	<0.6	2.4	8	1	26	<0.3	<1.9	<1.6	<1.7	30	0.05	<2.4	2.0	0.1	4.75	1270
CE491_T7-18	5E	300/1	21	56	8.14	355	2.2	1.5	1.4	16.8	<0.8	135	1.6	<18	4.2	<0.02	<0.2	<1	<1.51	<0.6	2.6	10	1	28	<0.3	<1.9	<1.6	<1.7	31	0.07	<2.4	2.1	0.14	6.1	1660
CE491_T7-19	5E	300/1	6	0.75	9.46	112	1.8	1.0	0.9	6.7	<0.5	40	<1.5	<16	2.0	<0.02	<0.1	<2.5	<0.6	<0.6	<1.0	15	0	5	<0.2	<1.2	<1.8	<2.9	17	0.07	<3.2	0.6	<0.2	6.3	297
CE491_T7-20	5E	300/1	6	5	8.93	145	1.7	1.0	0.9	7.0	<0.5	68	<1.5	<16	1.9	<0.02	<0.1	3.1	<0.6	<0.6	<1.0	13	0	4	<0.2	<1.2	<1.8	<2.9	17	0.05	<3.2	0.9	<0.2	9.4	308
CE491_T7-21	5E	300/1	6	14	8.37	469	1.8	1.1	1.0	10.7	<0.5	87	<1.5	<16	2.7	<0.02	<0.1	<2.5	<0.6	<0.6	1.4	9	0	12	<0.2	<1.2	<1.8	<2.9	21	<0.03	<3.2	1.1	<0.2	9.6	399
CE491_T7-22	5E	300/1	6	28	8.04	320	1.9	1.4	1.1	13.2	<0.5	81	<1.5	<16	3.2	<0.02	<0.1	<2.5	<0.6	<0.6	1.8	6	0	18	<0.2	<1.2	<1.8	<2.9	24	0.03	<3.2	1.3	0.2	9.2	460
CE491_T7-23	5E	300/1	6	42	8.06	221	2.0	1.3	1.1	15.9	<0.8	56	<1.4	<18	4.4	<0.02	<0.2	<1	<1.51	<0.6	1.7	6	1	37	<0.3	<1.9	<1.6	<1.7	29	0.06	<2.4	1.0	0.09	7.2	543
CE491_T7-24	5E	300/1	6	56	8.08	317	2.1	1.4	1.2	17.7	<0.8	46	<1.4	<18	4.8	<0.02	<0.2	<1	<1.51	<0.6	1.6	4	1	47	<0.3	<1.9	<1.6	<1.7	31	0.08	<2.4	1.1	0.17	<2.51	705
CE491_T7-25	1B	1000/1	21	0.75	8.83	49	1.6	0.9	0.9	4.6	<0.5	43	<1.5	<16	0.8	<0.02	<0.1	<2.5	<0.6	<0.6	1.1	15	1	17	<0.2	<1.2	<1.8	<2.9	19	0.29	<3.2	0.6	<0.2	<2.5	165
CE491_T7-26	1B	1000/1	21	5	8.22	95	1.6	0.9	1.1	5.5	<0.5	142	3.7	<16	1.0	<0.02	<0.1	<2.5	<0.6	<0.6	<1.0	14	1	19	0.2	<1.2	<1.8	<2.9	22	0.3	<3.2	1.2	<0.2	<2.5	154
CE491_T7-27	1B	1000/1	21	14	8.06	80	1.6	1.0	1.6	6.7	<0.5	96	<1.5	<16	1.2	<0.02	<0.1	<2.5	<0.6	<0.6	<1.0	10	1	56	<0.2	<1.2	<1.8	<2.9	26	0.24	<3.2	1.2	<0.2	<2.5	168
CE491_T7-28	1B	1000/1	21	28	7.93	201	1.6	1.0	1.7	7.1	<0.5	75	<1.5	<16	1.3	<0.02	<0.1	<2.5	<0.6	<0.6	<1.0	8	1	65	<0.2	<1.2	<1.8	<2.9	27	0.45	<3.2	1.3	<0.2	<2.5	169
CE491_T7-29	1B	1000/1	21	42	7.94	133	1.7	1.1	1.9	6.5	<0.8	65	1.7	<18	1.5	<0.02	<0.2	<1	<1.51	<0.6	0.3	5	1	67	<0.3	<1.9	<1.6	<1.7	28	0.28	<2.4	1.2	<0.04	<2.51	160
CE491_T7-30	1B	1000/1	21	56	7.94	293	1.7	1.1	2.0	6.8	<0.8	59	<1.4	<18	1.5	<0.02	<0.2	<1	<1.51	<0.6	<0.28	2	1	61	<0.3	<1.9	<1.6	2.02	29	0.26	<2.4	1.2	<0.04	<2.51	161
CE491_T7-31	1B	1000/1	6	0.75	8.55	216	1.6	0.8	0.9	4.4	<0.5	15	<1.5	<16	0.7	<0.02	<0.1	<2.5	<0.6	<0.6	<1.0	14	0	20	<0.2	<1.2	<1.8	<2.9	19	0.19	<3.2	0.4	<0.2	<2.5	160
CE491_T7-32	1B	1000/1	6	5	8.21	122	1.6	0.9	1.0	5.3	<0.5	34	<1.5	<16	0.8	<0.02	<0.1	<2.5	0.8	<0.6	<1.0	13	1	21	<0.2	<1.2	<1.8	<2.9	21	0.3	<3.2	0.7	<0.2	<2.5	164
CE491_T7-33	1B	1000/1	6	14	7.86	210	1.6	0.9	1.3	6.4	<0.5	27	<1.5	<16	1.2	<0	<0.1	<2.5	<0.6	<0.6	<1.0	10	1	58	<0.2	<1.2	<1.8	<2.9	25	<0.03	<3.2	0.6	<0.2	<2.5	159
CE491_T7-34	1B	1000/1	6	28	7.81	158	1.6	0.9	1.4	6.8	<0.5	22	<1.5	<16	1.3	<0	<0.1	<2.5	<0.6	<0.6	<1.0	10	1	71	<0.2	<1.2	<1.8	<2.9	26	<0.03	<3.2	0.6	0.4	<2.5	175
CE491_T7-35	1B	1000/1	6	42	7.85	164	1.6	1.0	1.6	6.7	<0.8	22	<1.4	<18	1.5	<0.05	<0.2	<1	<1.51	<0.6	0.7	9	1	90	<0.3	<1.9	<1.6	<1.7	28	<0.03	<2.4	0.7	0.08	<2.51	162
CE491_T7-36	1B	1000/1	6	56	7.81	431	1.6	1.0	1.8	7.0	<0.8	20	<1.4	<18	1.5	<0.05	<0.2	<1	<1.51	0.67	0.6	6	1	103	<0.3	<1.9	<1.6	<1.7	29	<0.03	<2.4	0.6	0.08	<2.51	161
CE491_T7-37	5E	1000/1	21	0.75	9.11	87	1.6	0.6	0.8	5.5	<0.5	57	<1.5	<16	1.9	<0	<0.1	<2.5	<0.6	<0.6	<1.0	21	0	7	<0.2	<1.2	<1.8	<2.9	16	<0.03	<3.2	0.5	<0.2	3.8	196
CE491_T7-38	5E	1000/1	21	5	8.76	122	1.6	0.7	0.9	6.3	<0.5	188	<1.5	<16	2.0	<0	<0.1	<2.5	<0.6	<0.6	1.1	21	0	7	<0.2	<1.2	<1.8	<2.9	17	<0.03	<3.2	0.8	<0.2	3.1	254
CE491_T7-39	5E	1000/1	21	14	7.85	179	1.6	0.7	1.0	6.7	<0.5	94	<1.5	<16	2.4	<0	<0.1	<2.5	<0.6	<0.6	<1.0	16	0	16	<0.2	<1.2	<1.8	<2.9	18	<0.03	<3.2	0.8	<0.2	3.3	331
CE491_T7-40	5E	1000/1	21	28	7.76	170	1.6	0.7	1.0	6.8	<0.5	76	<1.5	<16	2.5	<0	<0.1	<2.5	0.7	<0.6	1.7	17	0	19	<0.2	<1.2	<1.8	<2.9	18	<0.03	<3.2	1.0	<0.2	3.9	408
CE491_T7-41	5E	1000/1	21	42	7.82	122	1.7	0.7	1.1	6.4	<0.8	74	<1.4	<18	2.6	<0.05	<0.2	<1	<1.51	<0.6	1.9	17	0	21	<0.3	<1.9	<1.6	<1.7	19	<0.03	<2.4	1.1	0.13	<2.51	493
CE491_T7-42	5E	1000/1	21	56	7.8	276	1.7	0.8	1.1	6.5	<0.8	73	<1.4	<18	2.6	<0.05	<0.2	<1	<1.51	<0.6	2.3	17	0	23	<0.3	<1.9	<1.6	<1.7	20	0.73	<2.4	1.2	0.2	3.26	621
CE491_T7-43	5E	1000/1	6	0.75	8.91	199	1.6	0.6	0.8	5.3	<0.5	24	<1.5	<16	1.8	<0	<0.1	<2.5	<0.6	<0.6	<1.0	20	0	8	<0.2	<1.2	<1.8	<2.9	16	0.3	<3.2	0.3	<0.2	3.4	201
CE491_T7-44	5E	1000/1	6	5	8.5	175	1.6	0.6	0.8	6.0	<0.5	48	<1.5	<16	1.8	<0	<0.1	<2.5	<0.6	<0.6	<1.0	18	0	8	<0.2	<1.2	<1.8	<2.9	16	0.3	<3.2	0.7	<0.2	2.6	211
CE491_T7-45	5E	1000/1	6	14	8.09	427	1.6	0.7	0.9	6.7	<0.5	66	1.6	<16	2.1	<0	<0.1	<2.5	0.7	<0.6	1.4	15	0	13	<0.2	<1.2	<1.8	<2.9	17	0.2	<3.2	0.5	<0.2	<2.5	230
CE491_T7-46	5E	1000/1	6	28	7.74	87	1.6	0.7	0.9	6.8	<0.5	45	<1.5	<16	2.3	<0	<0.1	<2.5	<0.6	<0.6	1.7	15	0	16	0.3	<1.2	<1.8	<2.9	18	0.3	<3.2	0.5	0.2	<2.5	246
CE491_T7-47	5E	1000/1	6	42	7.73	282	1.6	0.7	1.0	6.5	<0.8	29	<1.4	<18	2.7	<0.05	<0.2	<1	<1.51	<0.6	1.7	18	0	21	<0.3	<1.9	<1.6	<1.7	19	0.4	<2.4	0.6	0.14	<2.51	276
CE491_T7-48	5E	1000/1	6	56	7.68	346	1.6	0.7	1.0	6.5	<0.8	26	<1.4	<18	2.8	<0.05	<0.2	<1	<1.51	<0.6	2.2	16	0	21	<0.3	<1.9	<1.6	<1.7	19	0.44	<2.4	0.7	0.25	3.16	305

Appendix D9. Longer term substance release

Sample Labels	Na	K	Mg	Ca	Ag	Al	As	B	Ba	Be	Cd	Ce	Co	Cr	Cu	Fe	Li	Mn	Mo	Ni	Pb	Sn	Sr	Ti	Tl	V	Zn	P	S
	(mg/L)	(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)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)	(µg/L)
Mean blank	**0.0**	**0.0**	**0.0**	**-0.1**	**0.0**	**-0.6**	**0.2**	**24.0**	**-0.1**	**-0.01**	**0.0**	**-0.3**	**0.4**	**-0.2**	**-0.1**	**0.1**	**-0.1**	**-0.1**	**0.0**	**-0.4**	**0.8**	**-0.2**	**-0.1**	**-0.01**	**0.4**	**-0.2**	**-3.9**	**0.4**	**-12.1**
LOD (3 x S.d.)	**0.013**	**0.001**	**0.003**	**0.000**	**0.5**	**0.4**	**1.5**	**16.1**	**0.0**	**0.02**	**0.1**	**2.5**	**0.6**	**0.6**	**1.0**	**0.2**	**0.1**	**0.0**	**0.2**	**1.2**	**1.8**	**2.9**	**0.0**	**0.03**	**3.2**	**0.1**	**0.2**	**2.5**	**15.8**
Mean blank	**-0.012**	**0.000**	**-0.001**	**0.000**	**0.2**	**0.1**	**0.1**	**18.6**	**0.0**	**-0.02**	**0.1**	**-0.4**	**0.0**	**-0.1**	**-0.2**	**0.1**	**0.0**	**0.0**	**-0.3**	**0.4**	**-0.5**	**-0.4**	**0.0**	**0.03**	**-0.7**	**0.0**	**0.1**	**1.3**	**0.1**
LOD (3 x S.d.)	**0.011**	**0.002**	**0.005**	**0.001**	**0.8**	**0.4**	**1.4**	**18.1**	**0.0**	**0.05**	**0.2**	**1.2**	**1.5**	**0.6**	**0.3**	**0.3**	**0.1**	**0.0**	**0.3**	**1.9**	**1.6**	**1.7**	**0.0**	**0.07**	**2.4**	**0.1**	**0.0**	**2.5**	**13.5**
TM24.4	8.97	1.14	5.38	22.8	9.3	33.8	2.5	0.7	15.6	2.2	4.1	0.3	7.2	5.0	6.6	16.3	5.8	8.3	6.5	4.3	5.9	4.2	113	7.5	6.0	7.3	29.6	-0.1	5835
Certified TM24.4					8.92	32.9 ± 4.5	5.30 ± 0.53		15.0 ± 1.0		3.96 ± 0.34		6.27 ± 0.57	5.00 ± 0.59	6.31 ± 0.60	16.0 ± 2.3	4.95 ± 0.42	8.24± 0.73		5.03 ± 0.53	5.60 ± 0.52		113 ± 8			7.00 ± 0.58			
% recovery (TM24.4)					**104**	**103**	**82**		**104**		**104**		**114**	**101**	**105**	**102**	**117**	**100**		**85**	**106**		**100**			**104**			
TM24.4	8.9	1.1	5.4	21.2	8.7	33.4	4.3	-3.4	15.8	2.2	4.3	0.3	6.8	5.6	6.6	15.8	5.8	8.1	7.8	5.0	6.1	2.4	114.7	7.5	2.8	7.3	30.2	3.0	5721
Certified TM24.4					8.92	32.9 ± 4.5	5.30 ± 0.53		15.0 ± 1.0		3.96 ± 0.34		6.27 ± 0.57	5.00 ± 0.59	6.31 ± 0.60	16.0 ± 2.3	4.95 ± 0.42	8.24± 0.73		5.03 ± 0.53	5.60 ± 0.52		113 ± 8			7.00 ± 0.58			
% recovery (TM24.4)					**98**	**101**	**82**		**106**		**107**		**109**	**112**	**105**	**98**	**117**	**99**		**100**	**110**		**101**			**105**			
TMDA64.3	9.20	1.16	5.33	22.2	12	288	158	249	290	161	262	-0.4	248	289	260	293	156	285	275	256	281	271	622	128	141	276	324	0.9	5698
Certified TM63.4					12.6 ± 1.3	291 ± 23	164 ± 15		287 ± 18		258 ± 21		250 ± 16	283 ± 17	298 ± 21	298 ± 21	143 ± 15	292 ± 17		252 ± 18	280 ± 22		628 ± 34			279 ± 18	320 ± 23		
% recovery (TMDA63.4)					**96**	**99**	**96**		**101**		**101**		**99**	**102**	**87**	**98**	**109**	**98**		**102**	**100**		**99**			**99**	**101**		
TMDA64.3	9.4	1.2	5.3	20.6	12.1	292	158	246	296	159	267	-0.3	245	291	261	294	161	283	277	264	282	271	632	129	142	283	328	1.0	5568
Certified TM63.4					12.6 ± 1.3	291 ± 23	164 ± 15		287 ± 18		258 ± 21		250 ± 16	283 ± 17	261 ± 18	298 ± 21	143 ± 15	292 ± 17		252 ± 18	280 ± 22		628 ± 34			279 ± 18	320 ± 23		
% recovery (TMDA63.4)					**96**	**100**	**96**		**103**		**104**		**98**	**103**	**100**	**99**	**113**	**97**		**105**	**101**		**101**			**101**	**102**		
CE491_T7-9+spike	**108**	**114**	**83**		**99**	**98**	**99**	**104**	**99**	**101**	**100**	**99**	**100**	**100**	**99**	**100**	**102**	**98**	**100**	**99**	**99**	**101**	**99**	**100**	**100**	**100**	**101**	**101**	**97**
CE491_T7-25+spike	**109**	**116**	**89**		**98**	**98**	**100**	**106**	**100**	**100**	**99**	**100**	**98**	**100**	**99**	**99**	**101**	**99**	**100**	**99**	**99**	**100**	**98**	**99**	**99**	**99**	**99**	**101**	**99**
CE491_T7-39+spike	**113**	**113**	**90**		**98**	**98**	**100**	**108**	**99**	**100**	**99**	**99**	**99**	**100**	**99**	**99**	**101**	**100**	**100**	**99**	**99**	**100**	**99**	**99**	**99**	**100**	**100**	**101**	**100**
CE491_T7-46+spike	**105**	**113**	**87**		**98**	**98**	**99**	**108**	**99**	**100**	**99**	**100**	**98**	**99**	**99**	**98**	**102**	**97**	**99**	**99**	**99**	**99**	**99**	**98**	**98**	**99**	**100**	**101**	**97**
CE491_T7-5 + spike	**105**	**114**	**80**		**100**	**97**	**101**	**101**	**99**	**101**	**99**	**98**	**99**	**99**	**100**	**99**	**103**	**98**	**100**	**99**	**98**	**99**	**99**	**100**	**99**	**100**	**100**	**101**	**101**
CE491_T7-41 + spike	**113**	**115**	**86**		**101**	**113**	**101**	**108**	**100**	**104**	**100**	**100**	**101**	**100**	**101**	**100**	**104**	**100**	**102**	**100**	**99**	**101**	**101**	**100**	**101**	**100**	**100**	**101**	**89**

Appendix D10. Effect of resuspended sediment in attenuation of substances released from rock materials

Note/Memo	CSIRO P4 Project Investigations
To:	Ali Watters (HKA)
From:	Brad Angel, Lucas Heights, NSW
Date:	8 November 2018
Copy:	Ryan Fraser, Stuart Simpson and Ellen Porter (SHL)
Our reference:	CSIRO P4 – Memo 10
Classification:	Internal use only
Subject:	Pollutant release from excavated rock composites – Attenuation Test 1

Chemical formulas and acronyms

Al	Aluminium	dAl	Dissolved aluminium		
SEC	Conductivity	L/S	Liquid/solid ratio		
		DGV	Default guideline value		

Background - Introduction

The CSIRO was engaged by Haskoning Australia Pty Ltd (RHDHV) to undertake an investigation of the pollutant release from excavated rock disposal into Talbingo and Tantangara reservoirs.

The initial elutriate tests (Memo 4) investigating the release of pollutants from composite excavated rock samples (L/S = 10, 48 h) observed some significant changes in water quality with respect to pH, conductivity (SEC) and the dissolved aluminium concentrations:

- pH increased from 7.0-7.1 to 8.9-9.8 range
- SEC increased from 29 µS/cm to 110-200 µS/cm range, and
- Dissolved Al (<0.45 µm filterable) increased from <4 µg/L (ppb) to 200-800 µg/L range.

The conditions of those elutriate tests, L/S = 10, 48 h, were designed to assess a severe / worst case scenario for impacts to the receiving water in which large amounts of fine excavated rock materials may remain suspended in the waters in the main disposal area.

Following release of substances from the fine-rock materials, a series of attenuation processes may occur, such as adsorption of dissolved aluminium onto particulate matter. A series of tests are underway to determine the magnitude and rate of attenuation that occurs in the presence of resuspended and deposited sediments.

This technical memo describes results of the initial attenuation test performed using elutriate waters from six fine-rock composites (liquid to solid ratio (L/S) of 500) created during the ‘Alkalinity’ tests 4 days earlier (Memo 7). Attenuation of pollutants in these elutriate solutions was investigated using a single sediment (PL2) material resuspended at L/S=500 and L/S=50, where L=elutriate and S=sediment. The sediment-elutriate was shaken to mix for 10 sec, and then left to settle for 24 h, after which, the pH, SEC and dissolved metals were measured. This is referred to as a sediment resuspension-attenuation test.

Changes in elutriate water composition with time

While it was not the intent of this test to investigate this, some interesting observations were made.

The pH and conductivity of the elutriate waters that were used in the tests (2nd row for each material in Table 1) differed from that of the original elutriate water (1st row for each material) that had been prepared four days earlier and allowed to sit overlying the small amount of fine-rock composition it was prepared from (i.e. 2 g fine-rock/1 L Talbingo water). Except for 1E, generally the pH was approximately one unit lower – potentially due to equilibration with air (increased carbon dioxide dissolving into the waters). All of the elutriate waters used had a higher conductivity than the original elutriate water– consistent with some further dissolution of salts from the solids that remained wet during the 4 day period before the attenuation test was performed.

Attenuation

The effect of 2 and 20 g/L of PL2 sediment compared to no added sediment on the pH, conductivity and dissolved aluminium in the elutriate solutions is shown in Figure 1. The pH and conductivity of the elutriate waters decreased with increasing amounts of resuspended sediment, as measured 24 h after the sediment resuspension occurring. The dissolved aluminium concentrations in the 2 g/L added sediment treatments were substantially lower than the elutriate treatments with no added sediment, indicating the sediment attenuated the aluminium. However, for the 20 g/L added sediment treatments, variable results were observed; the addition of 20 g/L PL2 sediment resulted in lower concentrations of dissolved aluminium for elutriates 3E and 4E, similar concentrations for elutriate 2E, and higher concentrations for elutriates 1E, 5E and 7E. These results indicate that competing processes occur upon the addition of sediment to the elutriate solutions; the dissolved aluminium may decrease via adsorption onto particulate matter, but the sediment may also act as a source of aluminium and increase its' concentration, possibly in colloidal form.

Points to note:

- The pH ranges for the L/S = 500 and 50 sediment resuspension-attenuation tests were 7.1-7.6 and 6.5-6.6, respectively compared to the pH range for the initial waters of 7.8-8.0, and that of the Talbingo Reservoir water of pH 7.0.
- The conductivity ranges for the L/S = 500 and 50 sediment resuspension-attenuation tests were 56-96 µS/cm and 33-55 µS/cm respectively compared to the conductivity range for the initial waters of 98-188 µS/cm, and that of the Talbingo Reservoir water of 25-40 µS/cm.
- The dissolved aluminium ranges for the L/S = 500 and 50 sediment resuspension-attenuation tests were 18-28 µg/L and 73-186 µg/L, respectively compared to the range for the initial waters of 76-176 µg/L, and that of the Talbingo Reservoir water of ca. 5 µg/L.
- The dissolved aluminium in the porewater of the PL2 sediment was 600 µg/L (reported in memo 2 and shown in Table 2 below). Based on the mass of sediment and volumes of test solutions, the maximum contribution of porewater aluminium from the addition of 20 g/L PL2 would be less than 10 µg/L. Therefore, significant aluminium is contributed by the particulate phase of the PL2 sediment. Additional information on the sediment contribution of aluminium and its' increase over time will be reported for other attenuation tests that have been performed in a future memo.

Summary

The interaction of the elutriate water with the reservoir sediment resulted in pH and conductivity decreasing to levels similar to the original reservoir water. The dissolved aluminium concentrations decreased in the presence of 2 g/L of PL2 sediment, but were variable in the presence of 20 g/L PL2 sediment; lower for 3E and 4E, similar 2E, and higher for 1E, 5E and 7E. The results indicate sediments may decrease dissolved aluminium via adsorption, but also contribute aluminium when resuspended.

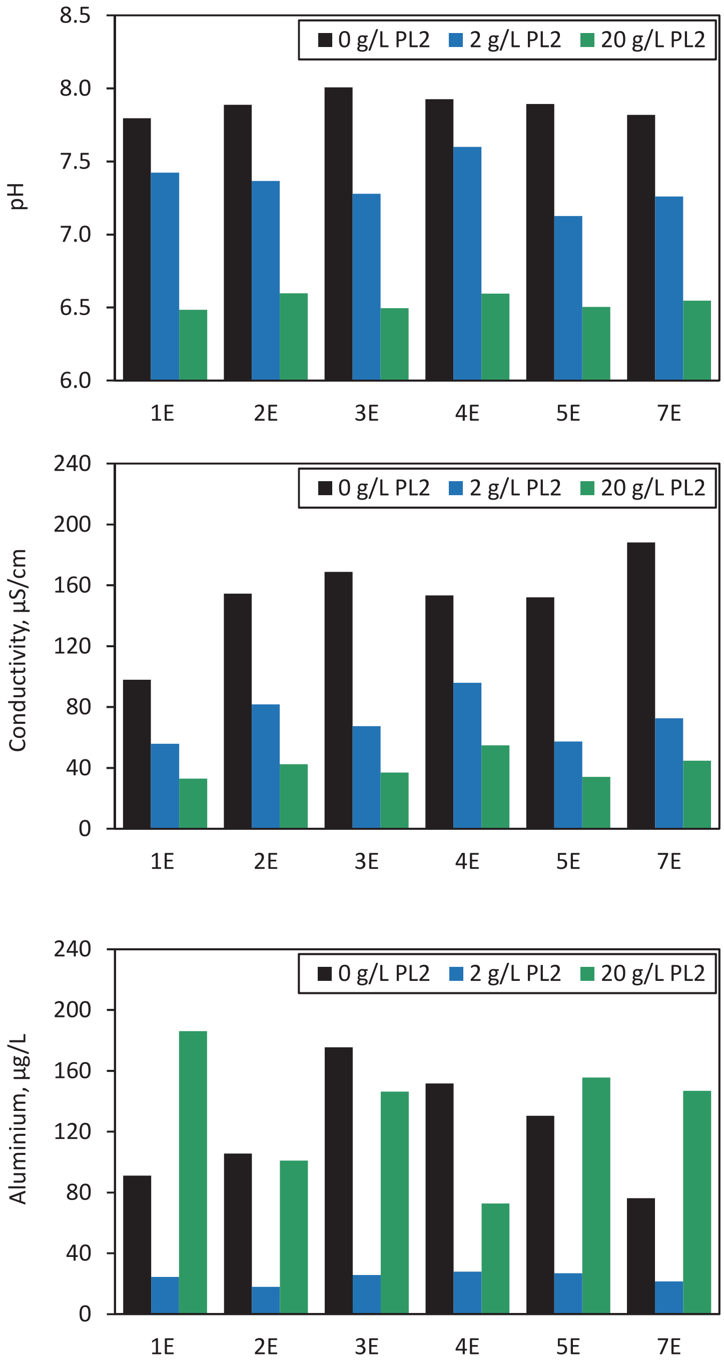

Figure 1. The pH, conductivity and dissolved aluminium after 0, 2 and 20 g/L of PL2 sediment was mixed for 10 s with 4-d old composite (1E, 2E, 3E, 4E, 5E and 7E) elutriates then allowed to stand for 24 h before measurement.

Table 1. The pH, conductivity and dissolved aluminium for sediment-resuspension attenuation Test 1.

Sample	L/S, where L= elutriate, S=sediment	Time h	pH	Conductivity µS/cm	dAL µg/L
1E original elutriate	Prepared 4 days earlier		7.8	60	NM
1E elutriate used	∞	24 h	7.8	98	**91**
1E	500 [2 g sediment/L elutriate]	24 h	7.4	56	24
1E	50 [20 g sediment/L elutriate]	24 h	6.5	33	**186**
2E original elutriate	Prepared 4 days earlier		8.8	45	NM
2E elutriate used	∞	24 h	7.9	155	**106**
2E	500	24 h	7.4	82	18
2E	50	24 h	6.6	43	**101**
3E original elutriate	Prepared 4 days earlier		9.1	51	NM
3E elutriate used	∞	24 h	8.0	170	**176**
3E	500	24 h	7.3	67	26
3E	50	24 h	6.5	37	**146**
4E original elutriate	Prepared 4 days earlier		9.1	90	NM
4E elutriate used	∞	24 h	7.9	150	**152**
4E	500	24 h	7.6	96	28
4E	50	24 h	6.6	55	**73**
5E original elutriate	Prepared 4 days earlier		9.0	52	NM
5E elutriate used	∞	24 h	7.9	150	**130**
5E	500	24 h	7.1	57	27
5E	50	24 h	6.5	34	**156**
7E original elutriate	Prepared 4 days earlier		8.8	54	NM
7E elutriate used	∞	24 h	7.8	190	**76**
7E	500	24 h	7.3	73	22
7E	50	24 h	6.5	45	**147**
DGV			-	-	55

Elutriate used differs from original elutriate in that is was prepared 4 days earlier. NM = not measured.

Table 2. The pH, conductivity, redox potential and dissolved aluminium measured in sediment porewaters reported in memo 2.

Sediment ID	pH	Conductivity (µS/cm)	Redox, Eh (mV)	Al (µg/L)
CA1	7.30	23.5	-175	10
CA2	7.60	26.5	-180	8
CA3	7.45	19.0	-170	**67**
PL1	7.05	20.0	-140	**278**
PL2	7.30	15.7	-125	**600**
PL3	7.40	18.9	-160	32
RA1	7.25	22.7	-160	**144**
RA2	7.30	24.0	-185	51
RA3	7.50	21.6	-190	6
TN1	6.70	33.0	-105	**180**
TN2	7.10	36.0	-140	**179**
TN3	7.00	36.7	-155	**59**
Minimum	6.70	15.7	-190	**5.5**
Maximum	7.60	36.7	-105	**600**
DGV	-	-	-	55

Appendix D10.1 Effect of resuspended sediment in attenuation of substances released from rock materials

Memo 10 (8 November 2018).

Notes

Composite Talbingo reservoir water used as leachate solution

<75 µm composite rock materials used to create elutraite water at L/S of 500 (6 days before use)

Sediment (PL2) resuspended at L/S=500 or 50, where the liquid was an elutriate created from leaching rock composite and the sediment = S (2 and 20 g/L of PL2, respectively) and attenuation measured after 24 h.

L/S of 50 and 500 [L-E/Sed=500 and L-E/Sed=50 (L-E=elutriate and Sed=sediment 2 and 20 g/L of PL2, respectively]

Rock composite-Treatment			Attenuation duration (h)	pH	Conductivity	Ag	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sn	Sr	Th	U	V	Zn
	Sediment	L-E/Sed			(µS/cm)	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
1E-1	PL2	No sediment	24	7.8	98	<0.01	91	5.2	6.8	6.8	<0.1	<0.1	0.2	0.5	12	1.4	1.3	58	0.1	1.9	0.7	0.41	0.67	<0.1	<0.04	40	<0.01	0.05	0.90	2
2E-1	PL2	No sediment	24	7.9	155	<0.01	106	1.2	3.2	9.0	<0.1	<0.1	0.2	0.2	12	1.9	1.0	42	0.1	1.7	0.5	0.04	0.78	<0.1	<0.04	38	<0.01	0.17	0.86	<1
3E-1	PL2	No sediment	24	8.0	169	<0.01	176	0.4	0.5	9.8	<0.1	<0.1	0.3	0.8	16	1.1	1.1	11	<0.1	1.9	0.5	<0.04	0.02	<0.1	<0.04	16	<0.01	0.01	0.80	<1
4E-1	PL2	No sediment	24	7.9	153	<0.01	152	2.0	1.5	11	<0.1	<0.1	0.2	0.4	23	1.2	1.0	34	0.2	1.8	0.3	<0.04	0.13	<0.1	<0.04	28	<0.01	0.08	1.1	<1
5E-1	PL2	No sediment	24	7.9	152	<0.01	130	0.7	3.1	8.8	<0.1	<0.1	0.2	0.8	22	1.0	0.98	11	<0.1	1.9	<0.1	<0.04	0.08	0.1	<0.04	20	<0.01	0.05	0.98	<1
7E-1	PL2	No sediment	24	7.8	188	<0.01	76	2.1	505	8.0	<0.1	<0.1	0.2	0.7	11	2.5	0.99	40	0.1	1.8	0.3	0.05	0.35	<0.1	0.21	63	0.02	0.21	0.90	<1
1E-2	PL2	500 (2 g/L)	24	7.4	56	<0.01	24	1.0	18	5.1	<0.1	0.2	0.2	0.3	34	1.5	1.3	1300	0.1	1.9	0.6	0.17	0.47	<0.1	0.18	30	0.01	0.02	0.71	<1
2E-2	PL2	500 (2 g/L)	24	7.4	82	<0.01	18	0.7	16	10	<0.1	0.1	0.2	0.4	20	1.8	1.0	1400	0.3	1.8	0.4	<0.04	0.55	<0.1	0.08	43	<0.01	0.07	0.86	<1
3E-2	PL2	500 (2 g/L)	24	7.3	67	<0.01	26	0.7	11	7.7	<0.1	<0.1	0.2	0.3	38	1.0	1.0	1400	0.2	2.0	0.3	<0.04	0.06	<0.1	<0.04	21	<0.01	0.02	0.67	<1
4E-2	PL2	500 (2 g/L)	24	7.6	96	<0.01	28	0.7	15	13	<0.1	<0.1	0.2	0.3	31	1.1	0.95	1500	0.2	1.8	1.1	<0.04	0.12	<0.1	<0.04	40	<0.01	0.22	0.80	<1
5E-2	PL2	500 (2 g/L)	24	7.1	57	<0.01	27	0.6	18	5.8	<0.1	0.2	0.3	0.7	41	1.0	0.85	1500	0.2	2.0	5.2	0.05	0.11	<0.1	<0.04	25	<0.01	0.01	0.94	2
7E-2	PL2	500 (2 g/L)	24	7.3	73	<0.01	22	0.6	334	7.9	<0.1	0.2	0.2	0.5	29	2.3	0.92	1400	0.2	1.8	3.2	<0.04	0.24	<0.1	<0.04	52	<0.01	0.03	0.91	<1
1E-3	PL2	50 (20 g/L)	24	6.5	33	<0.01	186	0.9	14	1.7	<0.1	0.4	0.4	0.6	153	1.1	0.42	1500	0.2	1.8	0.7	0.09	0.26	<0.1	<0.04	10	0.04	0.02	0.67	<1
2E-3	PL2	50 (20 g/L)	24	6.6	42	<0.01	101	1.0	18	2.7	<0.1	0.5	0.3	0.5	97	1.4	0.50	2000	<0.1	1.8	0.6	0.06	0.30	<0.1	<0.04	15	0.03	0.02	0.51	<1
3E-3	PL2	50 (20 g/L)	24	6.5	37	<0.01	146	0.9	16	2.1	<0.1	0.4	0.3	0.6	134	0.9	0.43	1800	0.2	1.9	1.5	0.06	0.07	<0.1	<0.04	10	0.05	0.02	0.69	3
4E-3	PL2	50 (20 g/L)	24	6.6	55	<0.01	73	0.6	25	4.4	<0.1	0.6	0.4	0.5	74	1.1	0.64	2700	0.2	1.9	0.8	0.04	0.17	<0.1	0.21	22	0.04	0.03	0.67	<1
5E-3	PL2	50 (20 g/L)	24	6.5	34	<0.01	156	1.0	13	1.6	<0.1	0.4	0.5	0.7	155	0.9	0.35	1500	0.2	1.8	0.6	0.09	0.11	0.1	0.14	9.4	0.05	0.04	0.83	<1
7E-3	PL2	50 (20 g/L)	24	6.5	45	<0.01	147	0.7	53	2.0	<0.1	0.7	0.3	0.7	139	1.5	0.41	1800	0.2	1.8	0.9	0.10	0.17	0.2	0.07	15	0.04	0.04	0.58	<1
LOD (3σ)						0.01	1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.04	0.1	0.1	0.1	0.1	0.04	0.01	0.1	0.04	0.3	0.01	0.01	0.02	1
Method Code:						C-209	C-209	C-209	C-209	C-229	C-209	C-209	C-209	C-209	C-209	C-229	C-229	C-209	C-209	C-229	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209

Method Codes:	C-209: ICP-MS	C-229: ICP-AES

Appendix D10.2 Attenuation test 2. Effect of different resuspended sediments in attenuation of substances released from rock materials

Memo 10 (8 November 2018).

Notes **Composite Talbingo reservoir water used to prepare elutriate solution from mixture of rock composites 1B, 2B, 5B, 5E and 7E (same mass proportions) at L/S of 100**
Sediments resuspended at L/S of 40,000 (25 mg/L), 200,000 (5 mg/L), and 1,000,000 (1 mg/L), where L= the elutriate water and S= sediment).
Measurement ade after 1 and 24 h

Sample Name	Natural sediment	TSS concentration [a]	Attenuation duration	pH	Conductivity	Dissolved O_2	Ag	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sn	Sr	Th	U	V	Zn
		(mg/L)	(h)		(µS/cm)	(mg/L)	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
AT2-1	Dissolved bulk elutriate rep 1	-	-	9.52	120.1	9.06	<0.01	154	1.6	190	5.9	<0.1	<0.1	<0.1	0.6	6.8	3.7	1.4	4.6	0.5	2.3	0.1	0.05	0.35	0.1	0.21	48	0.03	0.11	2.4	4
AT2-2	Dissolved bulk elutriate rep 2	-	-	9.51	98.6	9.01	0.02	150	2.3	187	5.8	<0.1	<0.1	<0.1	0.5	4.3	3.8	1.4	3.8	0.5	2.3	0.2	0.05	0.35	<0.1	0.11	51	<0.01	0.13	2.3	<1
AT2-3	Talbingo reservoir control A	-	-	7.13	59	10.32	<0.01	6.3	0.1	5.0	2.1	<0.1	<0.1	<0.1	0.6	18	0.6	0.88	0.5	<0.1	2.0	0.3	0.04	0.05	<0.1	0.11	18	<0.01	0.02	0.04	2
AT2-4	Talbingo reservoir control B	-	-	7.13	52	10.68	<0.01	6.8	0.1	5.1	2.1	<0.1	<0.1	<0.1	0.9	19	0.6	0.88	0.2	<0.1	2.0	0.3	0.07	0.01	<0.1	0.09	17	0.01	0.02	0.09	3
AT2-5	Talbingo reservoir control C	-	-	7.11	41	10.83	<0.01	4.9	0.1	4.9	2.1	<0.1	<0.1	<0.1	0.7	18	0.5	0.87	0.4	<0.1	2.0	0.2	<0.04	0.02	<0.1	<0.04	17	<0.01	0.02	0.10	2
AT2-6	CA3 (CE491-11)	1	1	8.59	75	9.41	<0.01	154	1.6	186	5.8	<0.1	<0.1	<0.1	0.5	7.9	3.7	1.4	6.1	0.4	2.3	0.2	0.05	0.29	<0.1	<0.04	52	<0.01	0.10	2.3	<1
AT2-7	CA3 (CE491-11)	5	1	8.52	90	9	<0.01	151	2.1	184	5.7	<0.1	<0.1	0.1	0.4	6.4	3.5	1.4	13	0.4	2.3	0.1	<0.04	0.30	<0.1	<0.04	47	<0.01	0.10	2.4	5
AT2-8	CA3 (CE491-11)	25	1	8.36	85	9.02	<0.01	151	1.3	168	5.6	<0.1	<0.1	<0.1	0.5	7.0	3.4	1.3	55	0.3	2.3	0.1	0.05	0.27	<0.1	<0.04	46	<0.01	0.12	2.5	1
AT2-9	PL2 (CE491-17)	1	1	8.49	98	9.05	<0.01	153	1.7	190	5.8	<0.1	<0.1	0.1	0.5	6.4	3.5	1.4	5.2	0.4	2.3	0.2	0.05	0.27	<0.1	<0.04	47	<0.01	0.11	2.2	<1
AT2-10	PL2 (CE491-17)	5	1	8.43	82	9.16	<0.01	154	1.6	184	5.7	<0.1	<0.1	<0.1	0.4	6.8	3.4	1.5	12	0.4	2.2	0.2	0.06	0.31	<0.1	<0.04	46	<0.01	0.11	2.3	<1
AT2-11	PL2 (CE491-17)	5 dup	1	8.42	95	9.09	<0.01	152	1.6	187	5.7	<0.1	<0.1	0.1	0.4	5.9	3.4	1.4	9.4	0.4	2.2	0.1	<0.04	0.39	0.1	0.22	47	0.05	0.12	2.2	<1
AT2-12	PL2 (CE491-17)	25	1	8.21	86	9.04	<0.01	143	1.3	174	5.4	<0.1	<0.1	0.1	0.3	6.7	3.2	1.4	37	0.4	2.2	<0.1	<0.04	0.37	0.1	0.14	48	0.03	0.13	2.2	<1
AT2-13	RA1 (CE491-12)	1	1	8.24	98	9.08	<0.01	149	1.5	180	5.5	<0.1	<0.1	<0.1	0.3	6.1	3.2	1.4	5.8	0.4	2.2	<0.1	<0.04	0.30	<0.1	0.06	48	0.03	0.11	2.0	<1
AT2-14	RA1 (CE491-12)	5	1	9.03	119	9.09	<0.01	149	2.0	188	5.4	<0.1	<0.1	<0.1	0.4	5.9	3.1	1.4	12	0.3	2.2	0.1	<0.04	0.33	<0.1	<0.04	48	0.02	0.12	2.3	<1
AT2-15	RA1 (CE491-12)	25	1	8.02	76	9.01	<0.01	138	1.3	171	5.2	<0.1	<0.1	<0.1	0.4	6.6	3.1	1.3	42	0.3	2.1	<0.1	<0.04	0.29	<0.1	<0.04	46	0.01	0.13	2.2	<1
AT2-19	CA3 (CE491-11)	1	24	8.74	78	9.09	<0.01	160	1.7	188	5.3	<0.1	<0.1	0.1	0.4	5.0	3.1	1.4	4.6	0.4	2.1	<0.1	<0.04	0.32	<0.1	<0.04	50	<0.01	0.12	2.4	<1
AT2-20	CA3 (CE491-11)	5	24	8.69	74	9.05	<0.01	154	1.7	180	5.5	<0.1	<0.1	0.2	0.4	3.1	3.2	1.4	13	0.4	2.2	<0.1	<0.04	0.28	<0.1	<0.04	50	<0.01	0.12	2.5	<1
AT2-21	CA3 (CE491-11)	25	24	8.58	84	9.01	<0.01	150	1.2	165	5.4	0.1	<0.1	0.1	0.2	5.7	3.1	1.4	46	0.5	2.1	<0.1	<0.04	0.30	<0.1	<0.04	48	<0.01	0.14	2.5	<1
AT2-22	PL2 (CE491-17)	1	24	8.68	85	8.96	<0.01	157	1.3	185	5.7	<0.1	<0.1	0.2	0.3	3.5	3.3	1.4	4.3	0.4	2.2	<0.1	<0.04	0.26	<0.1	<0.04	50	<0.01	0.12	2.3	<1
AT2-23	PL2 (CE491-17)	5	24	8.65	69	8.9	<0.01	155	1.9	207	5.6	<0.1	<0.1	0.1	0.4	4.4	3.2	1.4	10	0.4	2.2	<0.1	<0.04	0.27	<0.1	<0.04	57	<0.01	0.12	2.6	<1
AT2-24	PL2 (CE491-17)	25	24	8.5	68	9.06	0.01	149	1.7	167	5.6	<0.1	<0.1	0.2	0.3	4.6	3.3	1.3	33	0.4	2.2	0.1	<0.04	0.37	0.1	0.23	49	0.02	0.14	2.4	<1
AT2-25	RA1 (CE491-12)	1	24	8.62	80	9.1	<0.01	155	1.7	182	5.7	<0.1	<0.1	0.3	0.3	2.3	3.4	1.4	5.2	0.4	2.2	<0.1	<0.04	0.32	<0.1	0.14	47	0.01	0.12	2.1	<1
AT2-26	RA1 (CE491-12)	5	24	8.57	90	9.1	<0.01	151	1.7	177	5.7	<0.1	<0.1	0.1	0.3	3.5	3.3	1.4	10	0.4	2.2	<0.1	<0.04	0.34	0.1	0.07	48	<0.01	0.13	2.1	<1
AT2-27	RA1 (CE491-12)	25	24	8.39	68	9.02	<0.01	146	1.5	166	5.6	<0.1	<0.1	0.2	0.2	6.3	3.2	1.4	33	0.5	2.2	<0.1	<0.04	0.29	<0.1	<0.04	48	<0.01	0.13	2.3	<1
AT2-28	RA1 (CE491-12)	25 dup	24	8.32	69	8.96	<0.01	143	1.5	162	5.6	<0.1	<0.1	0.2	0.3	6.1	3.2	1.4	33	0.5	2.2	<0.1	<0.04	0.30	<0.1	0.05	44	<0.01	0.13	2.1	2
Method Code:							C-209	C-209	C-209	C-209	C-229	C-209	C-209	C-209	C-209	C-209	C-229	C-229	C-209	C-209	C-229	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209
LOD (3σ)							0.01	1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.04	0.1	0.1	0.1	0.1	0.04	0.01	0.1	0.04	0.3	0.01	0.01	0.02	1

Spike Recoveries

	Ag	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sn	Sr	Th	U	V	Zn
Sample Name	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
AT2-10	102	96	102	106	95	99	100	102	102	96	94	100	102	105	99	102	96	99	95	99	102	96	90	103	103
AT2-20	100	99	97	102	111	100	101	102	102	97	112	105	99	100	108	101	100	100	98	99	99	102	100	102	101
5E-3	99	94	99	97	102	98	97	98	98	86	105	99	111	98	103	98	99	98	96	97	99	100	98	99	98

[a] TSS concentration based on basis of sediment dry weight

Certified Reference Materials

	Ag	Al	As	Ba	Ca	Cd	Co	Cr	Cu	Fe	K	Mg	Mn	Mo	Na	Ni	Pb	Sb	Se	Sn	Sr	Th	U	V	Zn
Sample Name	µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	µg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
TM24.4 avg (n=4)	---	31.7	5.0	15.3	---	3.9	6.4	5.2	6.5	15.2	---	---	7.9	6.3	---	5.2	5.7	---	3.3	3.4	110.6	---	4.2	7.2	---
Certified Value	---	32.9 ± 4.5	5.30 ± 0.53	15.0 ± 1.0	---	3.96 ± 0.34	6.27 ± 0.57	5.00 ± 0.59	6.31 ± 0.60	16.0 ± 2.3	---	---	8.24 ± 0.73	6.30 ± 0.56	---	5.03 ± 0.53	5.60 ± 0.52	---	3.56 ± 0.58	3.72 ± 0.39	113 ± 8	---	4.24 ± 0.34	7.00 ± 0.58	---
Recovery (%)	---	96	94	102	---	99	102	105	103	95	---	---	95	100	---	104	102	---	94	93	98	---	99	102	---
TMDA64.3 avg (n=4)	12.5	286	157	286	---	253	250	281	263	285	---	---	290	284	---	250	278	124	145	270	627	---	130	282	314
Certified Value	12.6 ± 1.3	291 ± 23	164 ± 15	287 ± 18	---	258 ± 21	250 ± 16	283 ± 17	261 ± 18	298 ± 21	---	---	292 ± 17	286 ± 21	---	252 ± 18	280 ± 22	124 ± 11	154 ± 22	281 ± 25	628 ± 34	---	135 ± 11	279 ± 18	320 ± 23
Recovery (%)	99	98	96	100	---	98	100	99	101	96	---	---	99	99	---	99	99	100	94	96	100	---	97	101	98

Appendix D10.3 Attenuatio Test 3. Effect of resuspended sediment in attenuation of substances released from rock materials

Memo 10 (8 November 2018).

Notes **Composite Talbingo reservoir water used as leachate solution**
<75 µm composite rock materials
Sediment (PL2) resuspended at L/S=500 or 50, where the liquid was an elutriate created from leaching rock composite and the sediment = S (2 and 20 g/L of PL2, respectively) and attenuation measured after 24 h

Sample ID	Sediment	Treatment	Treatment	Time	pH	Conductivity (µS/cm)	Ag µg/L	Al µg/L	As µg/L	Ba µg/L	Ca mg/L	Cd µg/L	Co µg/L	Cr µg/L	Cu µg/L	Fe µg/L	K mg/L	Mg mg/L	Mn µg/L	Mo µg/L	Na mg/L	Ni µg/L	Pb µg/L	Sb µg/L	Se µg/L	Sn µg/L	Sr µg/L	Th µg/L	U µg/L	V µg/L	Zn µg/L
AT3-1	**Bulk elutriate (<0.45 µm) metals rep 1**				**9.52**	**120.1**	**<0.01**	**110**	**1.6**	**200**	**5.9**	**<0.2**	**<0.1**	**0.09**	**0.7**	**3.7**	**3.4**	**1.4**	**4.1**	**0.47**	**2.2**	**0.3**	**<0.04**	**0.36**	**<0.1**	**0.23**	**50**	**0.01**	**0.12**	**2.3**	**<1**
AT3-2	**Bulk elutriate (<0.45 µm) metals rep 2**				**9.51**	**98.6**	**<0.01**	**113**	**1.5**	**200**	**5.7**	**<0.2**	**<0.1**	**<0.02**	**0.6**	**7.0**	**3.2**	**1.4**	**4.9**	**0.48**	**2.2**	**0.3**	**<0.04**	**0.30**	**<0.1**	**0.12**	**48**	**0.01**	**0.13**	**2.2**	**<1**
AT3-5	CA3_P4	Rep 1	Control	6	6.7	24	<0.01	17	<0.3	7.8	1.3	<0.2	0.2	0.10	0.6	38	0.42	0.60	460	0.03	1.5	0.4	<0.04	<0.03	<0.1	0.04	11	<0.01	<0.01	0.32	2
AT3-6	CA3_P4	Rep 2	Control	6	6.8	25	<0.01	14	<0.3	7.3	1.4	<0.2	0.2	0.06	0.7	29	0.45	0.62	400	<0.02	1.6	0.4	<0.04	<0.03	<0.1	0.10	13	<0.01	0.02	0.23	1
AT3-9	CA3_P4	Rep 1	Control	24	6.5	74	<0.01	20	<0.3	10	1.0	<0.2	0.6	0.14	0.8	41	0.49	0.46	1300	0.05	1.5	0.8	<0.04	<0.03	<0.1	<0.02	8	<0.01	<0.01	0.33	<1
AT3-10					6.6	126	<0.01	20	0.3	9.2	1.3	<0.2	0.3	0.07	0.6	33	0.47	0.55	670	<0.02	1.5	0.5	<0.04	<0.03	<0.1	<0.02	11	<0.01	<0.01	0.29	2
AT3-3	CA3_P4	Rep 3	Treatment	1	7.8	80	<0.01	85	1.5	170	5.5	<0.2	<0.1	0.06	0.6	16	3.2	1.4	370	0.43	2.2	0.3	<0.04	0.28	<0.1	0.10	47	0.01	0.11	2.0	2
AT3-4	CA3_P4	Rep 4	Treatment	1	7.7	76	<0.01	79	1.5	170	5.6	<0.2	<0.1	<0.02	0.5	4.7	3.2	1.4	310	0.37	2.2	0.4	<0.04	0.27	<0.1	0.05	46	<0.01	0.10	2.2	<1
AT3-7	CA3_P4	Rep 3	Treatment	6	7.2	62	<0.01	44	0.8	150	5.0	<0.2	0.2	0.09	0.6	19	2.8	1.3	630	0.43	2.2	0.5	<0.04	0.20	<0.1	<0.02	42	<0.01	0.07	1.8	<1
AT3-8	CA3_P4	Rep 4	Treatment	6	6.7	51	<0.01	31	1.2	140	5.0	<0.2	0.3	0.04	0.6	119	2.8	1.2	750	0.27	2.2	0.5	<0.04	0.25	<0.1	<0.02	41	<0.01	0.06	1.8	2
AT3-11	CA3_P4	Rep 5	Treatment	24	6.9	90	0.02	24	1.4	150	4.7	<0.2	0.2	0.12	0.5	20	2.6	1.2	850	0.44	2.2	0.5	<0.04	0.31	<0.1	0.23	42	0.03	0.05	1.7	1
AT3-12	CA3_P4	Rep 6	Treatment	24	7.0	92	<0.01	11	0.9	130	4.6	<0.2	0.2	0.12	0.5	8.9	2.6	1.2	980	0.36	2.2	0.6	<0.04	0.27	<0.1	0.15	40	0.01	0.04	1.2	1
AT3-13	CA3_P4	Rep 7	Treatment	96	6.4	77	<0.01	19	0.3	84	2.9	<0.2	0.6	0.10	0.6	17	1.7	0.76	2000	0.29	2.1	0.9	<0.04	0.18	<0.1	0.12	26	0.03	0.03	0.86	<1
AT3-14	CA3_P4	Rep 8	Treatment	96	6.4	91	<0.01	22	0.5	81	2.9	<0.2	0.4	0.08	0.6	19	1.7	0.76	2000	0.27	2.1	0.8	<0.04	0.20	<0.1	0.04	25	0.01	0.03	1.1	<1
AT3-17	PL2_P4	Rep 1	Control	6	6.7	23	<0.01	16	<0.3	6.2	1.3	<0.2	<0.1	0.21	0.6	25	0.50	0.61	180	0.02	1.6	0.5	<0.04	<0.03	<0.1	<0.02	13	<0.01	0.02	0.12	2
AT3-18	PL2_P4	Rep 2	Control	6	6.8	23	<0.01	16	<0.3	6.0	1.2	<0.2	0.2	0.13	0.6	27	0.39	0.59	300	0.03	1.5	0.4	<0.04	<0.03	<0.1	<0.02	11	<0.01	0.01	0.47	2
AT3-21	PL2_P4	Rep 1	Control	24	6.5	62	<0.01	26	<0.3	6.6	1.2	<0.2	0.2	0.37	0.7	32	0.47	0.50	290	0.10	1.5	0.7	<0.04	0.05	<0.1	0.28	10	0.02	0.03	0.38	2
AT3-22	PL2_P4	Rep 2	Control	24	6.5	42	<0.01	24	0.3	7.0	1.2	<0.2	0.1	0.30	0.6	33	0.44	0.54	330	0.07	1.5	0.6	0.06	<0.03	<0.1	0.17	10	0.02	0.02	0.60	1
AT3-15	PL2_P4	Rep 3	Treatment	1	7.5	74	<0.01	35	0.7	110	4.9	<0.2	0.3	0.15	0.4	15	3.2	1.3	540	0.24	2.3	0.4	<0.04	0.25	<0.1	0.05	41	<0.01	0.05	1.4	1
AT3-16	PL2_P4	Rep 4	Treatment	1	7.5	72	<0.01	35	0.8	120	5.1	<0.2	0.1	0.15	0.3	13	3.1	1.3	400	0.34	2.3	0.4	<0.04	0.25	<0.1	0.03	45	<0.01	0.07	1.5	1
AT3-19	PL2_P4	Rep 3	Treatment	6	7.1	61	<0.01	27	0.5	110	4.8	<0.2	0.2	0.16	0.6	17	2.8	1.2	530	0.39	2.3	0.4	<0.04	0.26	<0.1	<0.02	40	<0.01	0.04	1.2	4
AT3-20	PL2_P4	Rep 4	Treatment	6	7.1	61	<0.01	22	0.7	120	4.8	<0.2	0.2	0.19	0.5	13	2.8	1.2	510	0.39	2.3	0.5	<0.04	0.22	<0.1	<0.02	40	<0.01	0.03	1.5	<1
AT3-23	PL2_P4	Rep 5	Treatment	24	6.8	71	0.01	25	0.7	120	4.5	<0.2	0.1	0.23	0.6	20	2.6	1.2	510	0.45	2.2	0.6	<0.04	0.23	<0.1	0.11	38	<0.01	0.04	1.4	4
AT3-24	PL2_P4	Rep 6	Treatment	24	6.8	76	0.02	26	0.7	130	4.6	<0.2	0.1	0.32	0.6	25	2.6	1.2	440	0.35	2.3	0.6	0.04	0.23	<0.1	0.05	37	0.02	0.03	1.3	<1
AT3-25	PL2_P4	Rep 7	Treatment	96	6.3	61	<0.01	21	0.4	63	2.3	<0.2	0.2	0.32	0.5	16	1.6	0.67	760	0.09	2.1	0.7	<0.04	0.15	<0.1	0.05	20	0.01	0.05	0.72	1
AT3-26	PL2_P4	Rep 8	Treatment	96	6.2	72	<0.01	12	0.5	56	2.3	<0.2	0.2	0.49	0.5	7.8	1.6	0.65	790	0.14	2.1	0.8	<0.04	0.16	<0.1	0.04	21	<0.01	0.02	0.58	1
AT3-29	RA1_P4	Rep 1	Control	6	6.6	22	<0.01	28	0.6	13	1.2	<0.2	0.2	0.32	0.7	44	0.45	0.51	360	<0.02	1.7	0.5	<0.04	<0.03	<0.1	<0.02	10	<0.01	0.02	0.73	1
AT3-30	RA1_P4	Rep 2	Control	6	6.7	22	<0.01	23	<0.3	8.7	1.3	<0.2	0.2	0.24	0.6	30	0.47	0.57	310	0.05	1.7	0.5	<0.04	<0.03	<0.1	<0.02	10	<0.01	0.01	0.50	1
AT3-33	RA1_P4	Rep 1	Control	24	6.4	58	<0.01	42	0.5	9.8	1.0	<0.2	0.2	0.39	0.9	59	0.50	0.45	410	0.09	1.6	0.5	<0.04	<0.03	<0.1	0.10	9	0.02	0.02	0.64	1
AT3-34	RA1_P4	Rep 2	Control	24	6.4	27	<0.01	42	0.5	9.8	1.1	<0.2	0.2	0.37	0.8	45	0.48	0.45	370	0.06	1.6	0.6	<0.04	<0.03	<0.1	0.04	9	0.01	0.03	0.66	1
AT3-27	RA1_P4	Rep 3	Treatment	1	7.4	70	<0.01	37	0.8	120	5.1	<0.2	0.2	0.25	0.4	20	3.2	1.3	440	0.34	2.4	0.5	<0.04	0.27	<0.1	<0.02	40	<0.01	0.06	1.4	2
AT3-28	RA1_P4	Rep 4	Treatment	1	7.5	76	<0.01	59	1.0	140	5.4	<0.2	0.1	0.29	0.5	18	3.4	1.3	330	0.25	2.4	0.5	<0.04	0.25	<0.1	<0.02	45	<0.01	0.07	1.5	1
AT3-31	RA1_P4	Rep 3	Treatment	6	7.0	55	<0.01	24	0.6	110	4.5	<0.2	0.2	0.31	0.5	23	2.7	1.1	530	0.40	2.4	0.6	<0.04	0.30	<0.1	0.27	37	0.03	0.05	1.3	2
AT3-32	RA1_P4	Rep 4	Treatment	6	7.2	59	<0.01	30	0.7	130	5.0	<0.2	0.1	0.24	0.5	18	2.9	1.2	420	0.42	2.4	0.5	<0.04	0.27	<0.1	0.13	40	0.02	0.05	1.2	1
AT3-35	RA1_P4	Rep 5	Treatment	24	6.8	62	<0.01	23	0.8	110	4.2	<0.2	0.2	0.33	2.8	20	2.6	1.1	590	0.36	2.3	0.5	<0.04	0.22	<0.1	0.06	34	<0.01	0.02	1.1	1
AT3-36	RA1_P4	Rep 6	Treatment	24	6.9	67	<0.01	24	0.5	120	4.3	<0.2	0.1	0.28	0.6	20	2.5	1.1	510	0.31	2.3	0.5	<0.04	0.20	<0.1	<0.02	35	<0.01	0.02	1.3	1
AT3-37	RA1_P4	Rep 7	Treatment	96	6.3	52	<0.01	31	0.4	72	2.4	<0.2	0.3	0.31	0.6	29	1.7	0.65	830	0.16	2.2	0.7	<0.04	0.15	<0.1	0.03	18	<0.01	0.02	0.75	2
AT3-38	RA1_P4	Rep 8	Treatment	96	6.4	55	<0.01	13	0.7	87	2.9	<0.2	0.2	0.34	0.8	13	1.8	0.80	730	0.27	2.3	0.7	<0.04	0.19	<0.1	<0.02	25	<0.01	0.02	0.82	2
LOD (3σ)							0.01	0.3	0.3	0.04	0.1	0.2	0.1	0.02	0.3	0.1	0.02	0.02	0.4	0.02	0.1	0.2	0.04	0.03	0.1	0.02	1	0.01	0.01	0.04	1
Method Code:							C-209	C-209	C-209	C-209	C-229	C-209	C-209	C-209	C-209	C-209	C-229	C-229	C-209	C-209	C-229	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209	C-209

Appendix D10 Effect of resuspended sediment in attenuation of substances released from rock material

Memo 10 (8 November 2018).

Notes	**Composite Talbingo reservoir water used as leachate solution**
	<75 µm composite rock materials
	Sediment (PL2) resuspended at L/S=500 or 50, where the liquid was an elutriate created from leaching rock composite and the sediment = S (2 and 20 g/L of PL2, respectively) and attenuation measured after 24 h

						Conductivity	**Ag**	**Al**	**As**	**Ba**	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**Pb**	**Sb**	**Se**	**Sn**	**Sr**	**Th**	**U**	**V**	**Zn**
Sample ID	**Sediment**	**Treatment**	**Treatment**	**Time**	**pH**	**(µS/cm)**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**mg/L**	**µg/L**	**µg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**

Spike Recoveries

							Ag	**Al**	**As**	**Ba**	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**Pb**	**Sb**	**Se**	**Sn**	**Sr**	**Th**	**U**	**V**	**Zn**
Sample ID							**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**	**%**
AT3-10	CA3_P4	Rep 2	Control	24			99	94	98	102	103	98	100	100	101	94	100	100	107	99	107	98	99	99	95	98	100	101	98	99	98
AT3-20	PL2_P4	Rep 4	Treatment	6			100	96	98	107	107	97	100	100	99	94	104	101	97	98	108	100	98	99	96	98	99	101	99	100	97
AT3-30	RA1_P4	Rep 2	Control	6			98	95	100	99	104	98	99	100	102	95	103	100	107	97	107	99	98	98	96	97	102	101	99	99	101

Certified Reference Materials

Sample ID							**Ag**	**Al**	**As**	**Ba**	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**K**	**Mg**	**Mn**	**Mo**	**Na**	**Ni**	**Pb**	**Sb**	**Se**	**Sn**	**Sr**	**Th**	**U**	**V**	**Zn**
							µg/L	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**mg/L**	**mg/L**	**µg/L**	**µg/L**	**mg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**	**µg/L**
TM24.4 avg (n=4)							---	---	5.1	16.6	---	3.9	6.2	5.2	---	---	---	---	8.2	6.1	---	6.7	6.0	---	3.4	3.8	110	---	4.2	7.0	---
Certified Value							---	---	5.30 ± 0.53	15.0 ± 1.0	---	3.96 ± 0.34	6.27 ± 0.57	5.00 ± 0.59	---	---	---	---	8.24 ± 0.73	6.30 ± 0.56	---	5.03 ± 0.53	5.60 ± 0.52	---	3.56 ± 0.58	3.72 ± 0.39	113 ± 8	---	4.24 ± 0.34	7.00 ± 0.58	---
Recovery (%)							---	---	96	111	---	98	100	105	---	---	---	---	99	97	---	134	107	---	97	103	97	---	99	99	---
TMDA64.3 avg (n=4)							12.4	309	158	312	---	252	249	279	263	315	---	---	286	281	---	250	277	122	145	266	624	---	131	278	337
Certified Value							12.6 ± 1.3	291 ± 23	164 ± 15	287 ± 18	---	258 ± 21	250 ± 16	283 ± 17	261 ± 18	298 ± 21	---	---	292 ± 17	286 ± 21	---	252 ± 18	280 ± 22	124 ± 11	154 ± 22	281 ± 25	628 ± 34	---	135 ± 11	279 ± 18	320 ± 23
Recovery (%)							98	106	96	109	---	98	100	99	101	106	---	---	98	98	---	99	99	98	94	95	99	---	97	100	105

Method Codes:	C-209: ICP-MS	C-229: ICP-AES

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Annexure D Ecotoxicology Assessment of Excavated Rock

Ecotoxicological Assessment of Excavated Rock Leachates in Water and Excavated Rock-Sediment Mixtures

Snowy 2.0, CSIRO Assignment P5

Anu Kumar, Merrin Adams, Adrienne Gregg, Bhanu Nidumolu, Andrea Ramirez Sepulveda and Angel Rea

27th June 2019

Prepared for Haskoning Australia (HKA) on behalf of Snowy Hydro Limited (SHL)

Report number: EP191174

[Commercial-in-confidence]

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Total 143 pages in the Final Report and three appendices prepared as supplementary information (Appendix B, Appendix I and Appendix J).

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Foreword and Assignment Summary

CSIRO was requested by Snowy Hydro Limited (SHL) in November 2017 to provide scientific expertise and capability in relation to identifying and assessing the environmental risks associated with the placement of excavated rocks from the development and operations of the proposed Snowy 2.0 Project. EMM Consulting (EMM) is preparing the Environmental Impact Statement (EIS) on behalf of SHL, and CSIRO's role was to develop and undertake a series of assignments to provide information to inform handling of excavated rock materials from the proposed works. In December 2017, CSIRO worked with EMM to develop conceptual models to provide information for the environmental risk assessment (ERA). As a result, CSIRO agreed to undertake an initial series of five assignments.

In March 2018, Haskoning Australia (HKA) was engaged to provide additional capability, specifically to lead the project entitled: "Engineering Option for Placement of Excavated Rocks". The draft work assignments that CSIRO had previously provided to SHL and EMM (in late January 2018) were subsequently updated to ensure that they would fulfil the needs of the EIS requirements and HKA's "Engineering Option for placement of Excavated Rocks" project. These updated assignments have been executed and are providing relevant input into the ERA.

This report details the results of Assignment P5. *Ecotoxicological Assessment of Excavated Rock Leachates in Water and Excavated Rock-Sediment Mixtures*

Disclaimer

This Assignment Subcontract and all documents and information provided by CSIRO to HKA under this Assignment Subcontract are prepared: (i) as inputs for further scientific services to be performed for HKA by CSIRO under separate Assignment Subcontracts to be agreed; and (ii) to assist HKA in its development of an Excavated Rock Placement and Management Plan as part of the EIS process for the proposed Snowy 2.0 Pumped Hydro Electric Scheme ("Purpose"), and for no other purpose. This Assignment Subcontract does not involve the provision of advice or recommendations in relation to specific risks or mitigations associated with Excavated Rock placement and management or design and construction of the Snowy 2.0 project. In the course of performing this Assignment Subcontract, CSIRO may rely on stated assumptions and/or information provided by HKA or third parties which are not within the control of CSIRO, and this Assignment does not involve CSIRO verifying such assumptions or information except to the extent expressly stated herein. If CSIRO provides any forecasts or projections, CSIRO does not represent that they will be realised as forecast or projected and actual outcomes may vary materially from forecast or projected outcomes. Documents and information provided to HKA under this Assignment Subcontract are to be read as a whole, and if reproduced must be reproduced in full and no part should be read or relied upon out of context. CSIRO does not accept responsibility for, or liability arising from, any error in, or omission in connection with stated assumptions or third party-supplied information, or reliance on documents or information provided under this Assignment by HKA other than for the Purpose, or by any other person.

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Abbreviations/Acronyms

Abbreviation / Acronym	Description
µg	microgram
AEM	Dilute-acid extractable metal (or other element)
CRM	Certified reference material
d	day
DGV	Default guideline value
DO	Dissolved oxygen
DOC	Dissolved organic carbon
EC	Electrical conductivity
Eh	Redox potential
EIS	Environmental impact statement
GV	Guideline Value, replaces term ‘trigger value’ (TV) in water quality guidelines (ANZG, 2018)
h	hour
kg	kilogram
L	litre
L/S	Liquid/solid ratio
LoE	Line of evidence
M	mol per litre
mg	milligram
Milli-Q	High purity deionised water
mL	millilitre
mm	millimetre
PC95(50)	concentration that is protective of 95% of species (with 50% confidence)
PC99(50)	concentration that is protective of 99% of species (with 50% confidence)
PSU	Practical salinity units
QA/QC	Quality assurance/quality control
SD	standard deviation
SE	standard error
SEM	Scanning electron microscope
SQGV	Sediment quality guideline value
TOC	Total organic carbon
TRM	Total recoverable metal (or other element)
TSS	Total suspended solids
WOE	Weight of evidence
WQGV	Water quality guideline value (ANZECC/ARMCANZ, 2000)

Chemical symbols and Acronyms

Ag	Silver	F^-	Fluoride	Sb	Antinomy
Al	Aluminium	Fe	Iron	Se	Selenium
As	Arsenic	Mg	Magnesium	Sn	Tin
Ba	Barium	Mn	Manganese	SO_4^{2-}	Sulphate
Ca	Calcium	Mo	Molybdenum	Sr	Strontium
Cd	Cadmium	Na	Sodium	Th	Thorium
Cl^-	Chloride	Ni	Nickel	U	Uranium
Co	Cobalt	NO_3^-	Nitrate	V	Vanadium
Cr	Chromium	Pb	Lead	Zn	Zinc
Cu	Copper				
dAl	Dissolved Aluminium (<0.45 µm filtered)				

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Executive Summary

Snowy Hydro Limited (SHL) is exploring options for the placement of “excavated rock” within two reservoirs (Talbingo and Tantangara) as part of a proposed expansion of their operations known as Snowy 2.0 Pumped Hydro Electric Scheme (Snowy 2.0). The excavated rock placement should not compromise, within reasonable parameters, the ecological, chemical, physiochemical, or physical state of the environment in the reservoirs.

CSIRO was engaged by Haskoning Australia (HKA) on behalf of SHL to provide four studies involving tests and data analysis to help inform an Environmental Impact Statement (EIS) for Snowy 2.0. These studies are:

- Assignment Pl: Comprehensive Geochemistry Examination;
- Assignment P2: Environmental Risk Categorisation of Rock Materials;
- Assignment P4: Environmental Categorisation of Excavated Rock Interactions with and Potential Impacts on Reservoir Waters and Sediments; and
- Assignment P5: Ecotoxicological Assessment of Excavated Rock Leachates in Water and Excavated Rock-Sediment Mixtures.

This report relates to the ecotoxicological assessment of excavated rock addition to reservoir waters and sediments, and is an output of Assignment P5.

Assignment P5 - Ecotoxicological Assessment of Excavated Rock Leachates in Water and Excavated Rock-Sediment Mixtures provides information on the potential toxicity of leachates of excavated rock and excavated rock-sediment mixtures. These potential toxicities were used to assess the potential impacts of the excavated rock materials on water and sediment quality within the two reservoirs. Fourteen excavated rock materials were selected to represent the possible range of materials that may be placed in the reservoirs; they comprised ‘Baseline’ and ‘Enriched’ rock composites for seven of nine geological units likely to be intercepted during construction of the 27 km of tunnel (refer to the Assignment P2 report for detailed descriptions). The waters and sediments used in the testing were collected from locations where excavated rock placement may potentially occur. The toxicity to microalgae and three invertebrate species under various interactions of the rock materials and reservoir waters/sediments was evaluated, so as to generate results relevant to a range of scenarios and environmental conditions.

The water samples from the Talbingo and Tantangara Reservoirs exhibited no acute toxicity to water fleas, midge larvae and blackworms. In relation to water quality guidelines (ANZG, 2018), the concentrations of contaminants of potential concern (COPCs) in waters were less than the corresponding guideline values (GVs), i.e. they represented no impediment to preserving the ecological status. Few of the metals present in rock materials were present at concentrations in excess of the sediment quality GVs.

During the period that excavated rock placement within the reservoirs occurs, significant amounts of fine rock material may remain present in the waters, and the finest fractions may take many weeks or months to settle after placement activities cease. The properties of substances released from submerged rock materials was assessed using a series of tests that involved mixing and leaching rock with reservoir water. Leachates from excavated rock and water with ratios from 1 to 10 were used. Toxicity tests (chronic and acute) with representatives of four groups of aquatic life (a microalga, a water flea, a midge and blackworm) were carried out on leachates of excavated rock material prepared with water from Talbingo or Tantangara Reservoirs. Leachates of excavated rock had high levels of suspended solids (turbidity) that did not completely settle out of solution after 24 h. Therefore, the toxicity of leachates was assessed with water fleas, midges and blackworms on raw and/or after 12-day settling and/or filtered leachates. Microalgae were only tested with filtered leachates.

Toxicity tests (chronic) with midges and blackworms were carried out on excavated rock material under varying scenarios of mixing and layering. Benthic sediment scenarios ranged from predominantly excavated rock becoming the substrate, to excavated rock mixing with sediments to form a smaller fraction of the substrate, and also thin layers of excavated rock that may spread and deposit at locations away from the main placement area. Measurements of dominant stressors (e.g. dissolved metals, pH, electrical conductivity (EC) and suspended solids) in toxicity tests provided information to link the ecotoxicology effects to stressors.

The waters within the reservoirs (in which excavated rock placement may occur) are generally quite clear (low suspended solids), have low EC, and have low buffering capacity (low alkalinity). Based on an integrated ranking system as given below in Table E1, the raw leachates from enriched excavated rock materials from Ravine, Byron and Shaw zones exhibited high toxicity. The toxicity tests using raw leachates are the ‘worst case’ scenarios unlikely to be encountered during placement activities. Settling of some leachates at 4°C for 12 days reduced turbidity but fine colloidal particles were still found to be suspended in the leachate. 12-day settled leachates from the Kellys (Enriched) and Byron (Baseline) zones exhibited moderate toxicity. Turbidity in the range of 50-200 NTU due to suspension of particulate material from excavated rock can also harm fish and other aquatic life during chronic long-term exposures by reducing food supplies, degrading spawning beds, and affecting gill function.

Macroinvertebrates including midge and blackworms are present in the Talbingo and Tantangara Reservoirs and were used as test organisms in this study to assess impacts associated with sedimentation of excavated material. Sediments mixed with excavated rock or top of reservoir sediments generally showed no toxicity to low toxicity during 7-day exposures to midge larvae and 28-day exposure to blackworms. Exposures to neat Enriched excavated rock material from all zones as a worst-case scenario exhibited moderate toxicity to high toxicity. As an integrated toxicity assessment, Shaw (Enriched and Baseline), Volcanics (Enriched) and Peppercorn (Baseline) excavated material exhibited low to moderate level toxicity to blackworms and midge larvae when exposed as mixtures of sediment and excavated rock material mixtures.

Increase in turbidity and metals and metalloids such Al that might be introduced to the water body as a consequence of suspended sediments from the excavated rock and/or due to sedimentation. These multistressors could result in low level of toxicological, physiological or physical impacts on fish and macroinvertebrates. Suggestions for collection of further biological assessment data for Talbingo and Tantangara reservoirs, including ecotoxicological effects and an ongoing in-situ monitoring program based on sufficient baseline data are provided.

Table E1. Integrated toxicological assessment as toxic units (TU) and colour coding based on the acute and chronic tests conducted in this study. 100% raw leachate and neat excavated rock material exposures are the worst-case scenarios and are not expected during the excavated rock placement within the reservoirs. Higher the toxic unit (TU) greater the toxicity (e.g. TU 2.0-2.2 represent high toxicity and TU 0.0 – 0.3 represent no toxicity).

		Leachates			Sediments		
Scenarios		Raw	Settled	Filtered	Top	Mixed	Rock
Ravine	B	1.3	0.3	0.7	0.7	0.0	0.0
	E	2.0	0.3	0.3	0.0	0.0	2.0
Byron	B	1.3	1.0	0.7	0.0	0.0	0.0
	E	2.0	0.3	0.7	0.0	0.0	2.3
Shaw	B	1.3	0.0	0.3	1.7	1.0	2.0
	E	2.0	0.3	1.0	0.7	0.0	1.0
Volcanics	B	1.3	0.7	0.7	0.0	0.0	2.0
	E	1.7	0.7	1.3	1.0	1.7	1.0
Peppercorn	B	1.3	0.3	0.3	1.7	0.7	2.0
	E	1.3	0.0	0.3	0.3	0.7	2.0
Kellys	E	NA	NA	0.0	NA	NA	NA
	B	1.0	1.0	1.0	0.0	0.0	0.0
Felsic	B	1.3	0.7	0.3	0.0	0.0	2.0
	E	1.0	0.3	0.7	0.7	0.0	1.0

1 Introduction

1.1 Background

Snowy Hydro Limited (SHL) is embarking on the development of the landmark Snowy 2.0 Pumped Hydro Electric Scheme (Snowy 2.0). As part of Snowy 2.0, options are being sought for the management and ultimate placement of excavated rock as part of an Environmental Impact Statement (EIS) and practical engineering options for its management. There are several challenges associated with this expansion and an extensive environmental assessment is necessary. To accomplish Snowy 2.0, a 27 km tunnel will be excavated between the Talbingo and Tantangara Reservoirs. This process will remove approximately 9 million m^3 of excavated rock (bulked) that will need to be disposed of primarily within these two reservoirs. Land-based placement of significant quantities of excavated rock not possible within the National Park, nor is it practicable to remove it from the project area.

Haskoning Australia (HKA) have been appointed lead consultant to manage and deliver an Engineering Option Assessment for Excavated Rock Placement for Snowy 2.0. CSIRO has been requested to provide scientific insight into the environmental impacts associated with the excavated rock placement options.

As the subsurface geology was largely unknown, a geological study complemented by a geochemical and mineralogical characterisation was required to determine the composition of the materials to be extracted in the construction phase. Before its placement within the reservoirs, the excavated rock will be temporarily stockpiled on land and then relocated, along with other materials, into the reservoirs. It is required that the excavated rock be deemed physically and chemically stable now and into the future so the ecological, chemical, physiochemical, and physical state of the environment is not compromised. Further, the placement of the excavated rock (to the extent possible) must:

- not compromise existing reservoir operations during the expansion construction;
- not compromise existing environmental flows;
- ensure extreme and “1 in 100” year weather events do not impact the long-term stability of the excavated rock placed within either Talbingo or Tantangara Reservoirs;
- remain stable under maximum generation loads of approximately 350 cumecs (maximum pumping loads will be less) during expanded hydro operations (intake and outflow); and
- not adversely impact threatened species (both terrestrial and aquatic) located in, around and downstream of the reservoirs.

Finally, ensuring all the above, a social licence to operate must be maintained.

1.2 CSIRO work assignments

A series of work assignments were undertaken by CSIRO to inform the EIS:

- Assignment P1: Comprehensive Geochemistry Examination, i.e. mineralogy and geochemistry characterisation of excavated rock.
- Assignment P2: Environmental Risk Categorisation of Rock Materials, i.e. identifying the reactivity of the rock and its risk category;
- Assignment P4: Environmental Categorisation of Excavated Rock Interactions and Potential Impacts on Reservoir Waters and Sediments, i.e. categorising excavated rock impacts on reservoir water and sediments
- Assignment P5: Ecotoxicological Assessment of Excavated Rock Leachates in Water and Excavated Rock-Sediment Mixtures, i.e. assessing the ecotoxicological impact of placement of the excavated rocks within the reservoirs

This report relates to Assignment P5 and is provided to HKA to inform their work programs, considering both the needs of the EIS and the longer-term ecological risk assessment (ERA). Information from baseline studies (primarily from consultancy firm EMM) and from Assignments P1 and P2 (CSIRO) was used to select a subset of materials (excavated rock, waters and sediments) and conditions for use in Assignments P4 and P5.

1.3 Context of Assignment P5: Ecotoxicology

The context for the assessment is informed by the conceptual site model (CSM, Appendix A) and identification of pathways among pressures, stressors, and likely biological receptors and their responses. Although the likely placement method has since evolved, at the time of developing this assessment, the placement of excavated rock material was assumed to be in deep waters within the reservoirs, possibly via placement methods that result in rock material dropping through the water column with the intent of depositing them within a specific range of placement depths. In the CSM, the placement of excavated rock material was assumed to be in deep waters within the reservoirs, possibly via placement methods that result in rock material dropping through the water column with the intent of depositing them within a specific range of placement depths. The CSM incorporates the services for protection, which, for Snowy 2.0, will include the power assets, ecosystem, and recreational services. The CSM enables management aims, community values, management goals, and required levels of protection to be defined.

For Snowy 2.0, the assessment issue may be broadly categorised as a ‘proposed development in a greenfields (undisturbed) location’ or a more general ‘development approval’ (partly or moderately disturbed). For a greenfields location in advance of future development, the assessment issue relates to the gathering of baseline (pre-disturbance) data and information that enables prediction of potential impacts. Typically, following development of the CSM of existing and future pressures, the assessment should seek to provide an adequate baseline characterisation for defining the water quality and ecological health and potential organism sensitivities (and assessing other baseline pressures). In the case of the EIS, EMM has indicated that it is gathering baseline information on water quality (spatial and temporal) and ecosystem status (i.e. what species and functions require protecting). Establishing the pre-development background conditions is necessary to determine the potential additive effects from additional stressors that might be introduced to the water body as a consequence of the proposed development.

The services for protection being considered in Assignment P4 (stressors) and Assignment P5 (ecosystem receptors) are broadly described as 'water quality', of which sediment quality is a component. The waters within the reservoirs (in which excavated rock placement may occur) are generally quite clear (low suspended solids), have low EC and have low buffering capacity (low alkalinity). In relation to Snowy 2.0 and Assignment P4, the stressors of potential concern (SOPCs) include physical and physico-chemical characteristics, such as suspended solids/sediment and benthic flocs of fine crushed material along with chemical contaminant stressors (e.g. traditional COPCs for which water and sediment quality guideline values exist) and the interactions of these multiple stressors. Multiple stressors may contribute complex and variable effects within ecosystems, and for many individual stressors, no guidelines exist. Furthermore, the interactions of different stressors and how these interactions influence aquatic organisms, is poorly understood.

The quality of the lines of evidence (LoE) is an important consideration for the assessment (EIS/ERA), and this is strongly influenced by the type of assessment. For Snowy 2.0 (development approval/greenfield site), use of chemistry and physical stressor data alone (Assignment P4) may frequently be considered as a low quality LoE. LoE assessments require integration with ecosystem receptors (biological effects). For Snowy 2.0, it is unlikely that any baseline ecosystem information exists to determine the potential sensitivity of the local ecosystem. Ecosystem receptors, or biological effects, include the assessment of toxicity to organisms, biodiversity (ecology and/or ecosystem function), bioaccumulation of substances by organisms and biomarkers (indicator of exposure to stressors).

Establishing the baseline for the biodiversity (ecology) LoE is important for: (i) identifying the key receptors (sensitive species and functions - biodiversity indicators) which can highlight the key potential sensitivities of the reservoir ecosystem, and (ii) selecting locations to represent the reference/control and potential impact sites (for which risks of adverse effects are to be assessed). This information will assist in identifying those classes/types of organisms and habitats that should be considered in more detail during assessment components that seek to predict potential adverse effects from the proposed development (i.e. potential stressors identified in P4). Thus, the ecology LoE for the Snowy 2.0 EIS/ERA assist but cannot enable a suitable prediction of impacts unless species' sensitivity to the stressors has been pre-established based on ecotoxicological approaches. The thresholds/tolerance limits of each stressor such as turbidity for key species present in the receiving environment (the two reservoirs) needs to be determined. Assignment P5 provides stressor sensitivities through direct assessment of potential effects using toxicity tests on representative and sensitive species (and endpoints) under conditions (stressor extremes and multiple stressors) predicted to potentially exist from Assignment P4.

Based on the present CSM, assessment of the potential for elevated bioaccumulation by local organisms seems unlikely to aid the weight of evidence (WoE) assessment. Biomarkers are limited in their interpretability because, without a direct known adverse outcome pathway connecting the biomarker response to a population-based ecological outcome, biomarkers tend to indicate exposure to stressors, not necessarily biological effects.

Together, information from Assignments P1, P2, P4 and P5, supported by the baseline information is expected to provide the multiple LoEs to enable a WoE assessment to be undertaken (in accordance with current National Water Quality Management Strategy (NWQMS) assessment guidance, ANZG (2018): http://www.waterquality.gov.au/anz-guidelines).

1.4 Assignment P5: Ecotoxicology assessment of excavated rock leachates in water and excavated rock-sediment mixtures

Assignment P5 addresses the potential impacts of the excavated rock materials on water and sediment quality within the reservoirs to predict the risks of effects of potential management options for disposing the excavated rock material. It provides an ecosystem response (effect) using the ecotoxicology LoE and links with the stressor exposure LoE provided by P4. Like P4, this project uses excavated rock material, and leachates of excavated rock, considered representative of the proposed range of excavated rock placement operations. The reservoir waters and sediments used in this study were collected from locations where excavated rock placement sites/locations may eventually be chosen.

The ecotoxicity of reservoir waters and sediment before and after addition of excavated rock material provides information on the potential for the excavated rock to cause toxicity to organisms that inhabit the water column and sediments at the proposed placement sites. The project uses standardised bioassays with sensitive species to assess the acute and chronic effects that occur due to leachates of excavated rocks within waters (effects on water-column species) and excavated rock-sediment mixtures (effects on benthic species).

1.4.1 Potential impact pathways associated with placement of excavated material

Fine suspended sediments in water column may results in:

1. Reduced light penetration inhibiting growth of aquatic plants and algae with profound ‘bottom-up’ ecological impacts;
2. Damage to zooplankton such as waterfleas by clogging their filter feeding apparatus and digestive organs;
3. Reduced food quality of organic suspended matter for filter-feeders by ‘dilution’ with fine mineral sediment;
4. Toxicity mainly due to leaching of dissolved metals and other potential contaminants; and
5. Damage to respiratory structures such as irritation and clogging of the gills of fish.

Sediment particles are capable of adversely affecting benthic macroinvertebrates such as midge larvae and blackworms and could exhibit behavioural, physiological, or toxicological responses. The potential impact pathways can include:

1. Direct smothering of organisms inhabiting the stream bed;
2. Clogging of feeding apparatus in filter-feeding taxa causing stress or mortality;
3. Reducing the effectiveness of oxygen exchange organs such as gills through clogging;
4. Altering habitat, for example by filling the interstices of the substrate;

5. Bioavailability of sediment bound contaminants resulting in adverse effects;
6. Behavioural responses, such as increased invertebrate drift as an avoidance response to increased SPM levels;
7. Influencing both the decomposition and availability of detrital material, with consequent impacts on the availability of food for many macroinvertebrates;

In the present study, midge and blackworm were exposed to combination of excavated rock and reservoir sediments to assess impact pathways 1-5 as listed above.

1.4.2 Ecotoxicological assessment of excavated rock material

In the present study, the acute and chronic toxicity of contaminants (inorganics including metals) and physico-chemical stressors such as pH, EC, DO and turbidity released from excavated rock materials was assessed. A suite of standardised ecotoxicological bioassays under two different experimental set-ups were conducted with the following objectives:

1. Assess toxicity to aquatic organisms due to fine **suspended sediments** from excavated rock material interacting with the reservoir water and;
2. Assess toxicity to benthic organisms due to fine **deposited sediments** from excavated rock material interacting with the reservoir sediments.

Chronic toxicity tests have durations of weeks to months, and were used to provide an appropriate level of confidence for predicting the risks of toxicity. An exception was the chronic toxicity test with microalgae – which tested for population growth rate inhibition over three days. Acute toxicity tests (with test durations of up to two days) were also incorporated into the study to screen the water/leachate samples for toxicity prior to initiating long-term chronic toxicity tests. Toxicity tests with an aquatic microalga and a water flea, benthic midge and blackworms were selected for use in this project because they either represent sensitive species or are known to be present in the reservoirs. The test endpoints (e.g. growth rate, reproduction) measured during toxicity testing have well-established quality assurance (QA) and quality control (QC) criteria.

Excavated rock leachate testing

In the present study, the leachates from excavated rock and reservoir water with ratios of 1 to 10 were used for ecotoxicological assessment. The 1:10 mass/mass, sample to water ratio, is double the projected volume of rock spoil (5%) to be deposited in Lakes Talbingo and Tantangara. This assessment intentionally represents worse-case scenarios. The effect of various concentrations of suspended solids in the leachates was also assessed to indicate how the risk might change over time following a placement event (e.g. following settling of solids after a period of time, and filtration. Leachate toxicity tests were carried out with one microalga and three macroinvertebrates (waterfleas, midge and blackworms).

Water/leachate toxicity tests included:

- Chronic single-celled microalgal population growth rate inhibition with the freshwater temperate species *Raphidocelis subcapitata* (previously known as *Pseudokirchneriella subcapitata* and as *Selenastrum capricornutum*) over 72 h.
- Acute (48-h immobilisation) and chronic (7-d reproduction) toxicity tests with the cladoceran water flea *Ceriodaphnia dubia*.

- Acute toxicity tests with the midge *Chironomus tepperi* measuring immobilisation/survival after 48 h.
- Acute toxicity tests with the blackworm *Lumbriculus variegatus* measuring immobilisation after 48 h.

The macroinvertebrate tests were conducted using the following three scenarios to determine if any toxicity associated with excavated material was due to contaminants (such as metals/ions) and/or the presence of suspended sediments:

(i) Raw scenario: 24 h settled leachates were tested to determine a combination of the contaminants and turbidity impacts. This represented the 'worst case' scenarios unlikely to be encountered during placement activities;

(ii) 12-day settled scenario: to determine impacts due to contaminants and reduced turbidity after 12-day settling of leachates; and

(iii) Filtered scenario: leachates were filtered through 0.45 µm filter to minimise suspended sediments in the leachates and to examine toxicity associated with dissolved metals.

Excavated rock-sediment mixtures testing

Under the different benthic sediment scenarios, the substrate composition varied from predominantly excavated rock, to excavated rock mixed with sediments and also thin layers of excavated rock that may spread and deposit at locations away from the main placement area.

Sediment/excavated rock toxicity tests were carried out with two benthic species (midge and blackworms) and covered three excavated-rock and sediment mixture scenarios:

(i) Top scenario: thin layers of excavated rock material covering natural sediments (spreading and being deposited at locations away from the main placement area);

(ii) Mixed scenario: excavated rock mixing with sediments to form a smaller fraction of the substrate; and

(iii) Rock scenario: excavated rock becoming the dominant substrate in an area. This represented the 'worst case' scenarios unlikely to be encountered during placement activities.

Toxicity tests included:

- Chronic toxicity tests with the midge *C. tepperi* measuring survival and growth (length) over 7 days.
- Chronic toxicity tests with the blackworm *L. variegatus* measuring reproduction and biomass over 28 days. Endobenthic aquatic oligochaetes such as *L. variegatus* burrow in the sediment, and ingest sediment particles below the sediment surface. This ensures exposure to the test substance via all possible uptake routes (e.g. contact with and ingestion of contaminated sediment particles; via pore water; via overlying water.

Measurements of the dominant stressors (e.g. dissolved metals, pH, EC and suspended solids) in toxicity tests provided information to link the ecotoxicology effects to those stressors. In Assignment P5, the ecotoxicological assessment was based on specific scenarios testing under laboratory conditions. Following this project, modelling and refinement of the proposed excavated rock placement methods will be undertaken to determine how likely the tested experimental scenarios will be to conditions experienced within the reservoirs.

A total of 14 excavated rock materials assessed in this project represented seven of nine geological zones that will likely be encountered during tunnel construction, each with a classification of Baseline and Enriched materials. The samples were informed from Assignments P2 (Douglas et al., 2018) and were the same as those used in Assignment P4 (Simpson et al., 2019). Douglas and co-workers used a classification based on a comparison to the Post-Archean Australian Shale, an average upper crustal composition, to assist in the selection of Baseline and Enriched Groups for each of the seven geological zones. The most common attribute of the Enriched Group being elevated S and trace element (metal and metalloids) concentrations over the Baseline Group. Further details are given in Section 2.1.

This project can be used to categorise the potential environmental risk to organisms that inhabit the waters and surface sediments of the reservoirs following addition of excavated rock material. It will contribute towards better management and mitigation strategies (e.g. excavated rock placement, containment, and remediation) to reduce environmental impacts of the placement of excavated rock material.

2 Methodology

2.1 Waters, sediments and excavated rock materials

2.1.1 Samples

The excavated rock samples used in the study were selected based on results from Assignment P2 (Douglas et al., 2018). A total of fourteen composite samples were used to represent Baseline and Enriched materials from seven geological zones (Table 1).

Table 1. Geographical units for the excavated rock materials

Zone	Geographical Unit	Description	Abbreviation used
i	Ravine Group	geology of western portion of the tunnel transect and surge shaft (13 km with (ii))	Ravine (R)
ii	Byron/Boraig Group	geology of western portion of the tunnel transect and surge shaft (13 km with (i))	Byron (B)
iii	Shaw Hill Gabbro	in the tunnel transect and constitutes (~1 km)	Shaw Gabbro (S)
iv	Gooandra Volcanics	in the tunnel transect (~5 km)	Volcanics (V)
v	Peppercorn/Tantaranga/Temperance Formations	in the tunnel transect (~ 9 km); based on the available information these could not be readily differentiated, but has a mostly similar geology and form a contiguous sequence along the tunnel transect so have been aggregated	Peppercorn (P)
vi	Kellys Plain Volcanics	in the intake area at the Tantaranga Reservoir (~2 km of the tunnel); Note that this material was only made available from late in the study	Kellys Plain (K)
vii	Felsic/Granite/Gneiss/Ignimbrite	compilation of granitic/extrusive equivalents present at various places along the tunnel transect	Felsic (F)

For each of these geological units, composite material was prepared from between four and nine individual excavated rock sources, which are described more fully in the Assignment P4 report (Simpson et al., 2019 and Appendix B). The composites for each geological unit were prepared by weighing equal amounts of each individual excavated rock materials (<75 µm) available for that geological unit and homogenising them thoroughly.

The samples of reservoir waters (Table 2) and sediments (Table 3) used in the study were provided by HKA and were from locations near proposed placement areas for the excavated rock. Seven water samples were collected (~15 L each) in 20-L plastic carboys. Twelve sediment samples (~4 kg each) were collected from three sites in Tantangara Reservoir and nine sites in Talbingo Reservoir, and transported to CSIRO in Eskys with ice and were stored at 4°C until further testing. For one sub-sample of reservoir water received at CSIRO Lucas Heights (TAL_PL1B) there appeared to have been a leak because it contained only approximately 4 L. Chemical analysis confirmed that this sample had an elevated dissolved copper concentration and hence this reservoir water sub-sample was not used in this study.

Excavated rock material for each baseline and enriched geographical unit, along with water and sediment samples received by CSIRO Adelaide, were used in the water flea, midge and blackworm toxicity tests. The microalgal toxicity tests were carried out with excavated rock material and reservoir water samples received by CSIRO Lucas Heights, and the same as those used in Assignment P4.

Table 2. Reservoir water samples used for ecotoxicological testing

Reservoir*	CSIRO Laboratory Received	Sample I.D.	Date received	Time received
Tantangara	Lucas Heights	TAN-TN2A	3/07/2018	11:30
		TAN-TN3A	3/07/2018	11:00
		TAN-TN1A	3/07/2018	12:05
	Adelaide	TN1-B	12/07/2018	14:30
		TN2-B	12/07/2018	14:30
		TN3-B	12/07/2018	14:30
Talbingo	Lucas Heights	TAL-PL2A	4/07/2018	13:50
		TAL-PL1A	4/07/2018	14:00
		TAL-PL1B (leaked / contaminated)	4/07/2018	14:00
		TAL-PL2B	4/07/2018	13:50
	Adelaide	TAL-PL1C	12/07/2018	14:30
		TAL-PL2C	12/07/2018	14:30
		TAL-PL1D	12/07/2018	14:30
		TAL-PL2D	12/07/2018	14:30

* Refer to Assignment P4 (Simpson et al., 2019, Appendix B) for sampling notes and locations.

Table 3. Reservoir sediment samples used for ecotoxicological testing

Reservoir*	CSIRO Laboratory Received	Sample I.D.	Date	Time
Tantangara	Lucas Heights	TN2_P4	3/07/2018	11.15
		TN1_P4	3/07/2018	11.45
		TN3_P4	3/07/2018	10.40
	Adelaide**	TN1_P5	7/3/2018	1150
		TN2_P5	7/3/2018	1120
		TN3-P5	7/3/2018	1050
Talbingo	Lucas Heights	RA1_P4	4/07/2018	10.20
		RA2_P4	4/07/2018	10:45
		RA3_P4	4/07/2018	11:20
		PL1_P4	4/07/2018	14:20
		PL2_P4	4/07/2018	13:15
		PL3_P4	4/07/2018	12:35
		CA1_P4	5/07/2018	11:20
		CA2_P4	5/07/2018	10:15
		CA3_P4	5/07/2018	9:45
	Adelaide**	PL1_P5	7/4/2018	1430
		PL2_P5	7/4/2018	1325
		PL3_P5	7/4/2018	1245
		CA1_P5	7/5/2018	1130
		CA2_P5	7/5/2018	1025
		CA3_P5	7/5/2018	945
		RA1_P5	7/4/2018	1020
		RA2_P5	7/4/2018	1050
		RA3_P5	7/4/2018	1130

* Refer to Assignment P4 (Simpson et al., 2019, Appendix B) for sampling notes and locations. **dates and time refer to the days and time the sediment samples were collected by Cardno.

2.1.2 Preparation of leachates of excavated rock

Toxicity tests with microalgae, water fleas, midges and blackworms were carried out on leachates of composite excavated rock material (milled to <75 µm, Appendix B) with a liquid:solid ratio of 10 (L:S = 10, equivalent to 100 g/L).

For microalgal toxicity tests, 20 g of each sample of excavated rock and 200 mL of Talbingo Reservoir water were added to a 250-mL high-density polyethylene bottle. Reservoir water control treatment was prepared by combining equal volumes of three sub-samples of water from Talbingo Reservoir (TAL-PL1A, TAL-PL2A and TAL-PL2B). The bottles were capped (double bagged in zip-locked bags) and mixed end-on-end for 18 h at 32 rpm. A procedural method blank (MB) consisted of reservoir water control treatment that was prepared in parallel with the leachates (i.e. rotated for 18 h and filtered). After 18 h, leachates were collected and filtered through an acid-washed 47-mm diameter, 0.45 µm filter (cellulose acetate membrane, Sartorius) using an acid-washed polycarbonate filter unit (Sartorius). [Filtration was required to remove the solids and microalgae present in the samples, precluding them from interfering with the subsequent measurement of the test species.] Leachates were tested within 3 h of filtration.

Leachate preparation for toxicity tests with water fleas (acute and chronic tests), midges (acute tests) and blackworms (acute tests) were prepared by adding 4 g excavated rock and 40 mL of reservoir water to a 50-mL plastic tube with a screw cap. The particular reservoir water used to prepare leachates was based on the likely placement site (Appendix B). Talbingo Reservoir water was used to prepare leachates of Ravine, Byron, Shaw Gabbro, Volcanics and Felsic excavated rock, and Tantangara Reservoir water for Peppercorn and Kellys Plain, respectively. Approximately 70 tubes were prepared for each excavated rock sample, comprising in total approximately 2.5 L of leachate for toxicity testing. The tubes were mixed overnight (18 h) using a mechanical shaker and then placed upright in a fridge (~4°C) for 24 h to allow some settling of suspended solids at the bottom of the tubes.

Three types of leachate: ‘raw’, 12-d ‘settling’ and ‘filtered’ were prepared and used in the acute toxicity test with water fleas, midges and blackworms. The supernatant (liquid fraction above the settled suspended solids) of each leachate sample was collected in glass jars. This fraction was termed the ‘raw’ leachate and contained a relatively large amount of suspended solids that did not settle out of solution within the 24-h settling time. Raw leachates were kept in 1 L glass jars for 12 days to allow additional settling of suspended solids prior to testing, producing ‘settling’ leachates. In addition, a third treatment consisted of filtering (0.45 µm polyvinylidene fluoride membrane) raw leachate to obtain a ‘filtered’ leachate sample that was devoid of the majority of the suspended solids.

2.1.3 Preparation of excavated rock-sediment mixtures for toxicity testing

The toxicity of 13 excavated rock materials (excluding Kellys Plain Baseline) was assessed using benthic organisms (midges and blackworms). Similar to the reservoir water analyses, three scenarios were prepared and tested, each using excavated rock material sieved to 425 µm and reservoir sediments. Reservoir sediments with no excavated rock material were used as controls and tested concurrently with every geological zone testing and reservoir water was used as overlying water for each testing regime.

Scenarios for blackworm toxicity tests included:

1. Excavated rock becoming the dominant substrate in an area. This was prepared by adding 75 g of neat excavated rock material to each test vial.

2. Excavated rock mixed with sediments to form a smaller fraction of the substrate. This was prepared by adding 75 g reservoir sediment to 20 g excavated rock material to each vial and mixing thoroughly prior to testing.

3. Thin layers of excavated rock material covering natural sediments. This scenario represents the spreading and deposition of excavated rock at locations away from the main placement area. This was prepared by adding 75 g reservoir sediment to each test vial followed by 20 g of excavated rock material on to the surface of the reservoir sediment.

Scenarios for midge toxicity tests included:

1. Excavated rock becoming the dominant substrate in an area. This was prepared by adding 140 g of neat excavated rock material to each test chamber.

2. Excavated rock mixed with sediments to form a smaller fraction of the substrate. This was prepared by adding 140 g reservoir sediment to 20 g excavated rock material to each test chamber and mixing thoroughly prior to testing.

3. Thin layers of excavated rock material covering natural sediments. This scenario represents the spreading and deposition of excavated rock at locations away from the main placement area. This was prepared by adding 140 g reservoir sediment to each test chamber followed by 20 g of excavated rock material on to the surface of the reservoir sediment.

2.1.4 Physico-chemical and chemical analysis

Water pH, EC, dissolved oxygen (DO) and temperature measurements were made using either Thermo Orion (VersaStar Pro-series) or Hanna (HI9819X-series) meters and probes that were calibrated as per the manufacturer's instructions. Turbidity was measured using a TN-100 Turbidimeter (Eutech Instruments).

Excavated rock, leachates, reservoir waters and sediments were measured for total and/or dissolved (0.45 µm filtered) metals. If not already filtered to 0.45 µm during sample preparation (section 2.2.1), samples for dissolved metals analysis were filtered through acid-washed 0.45-µm syringe filters (Sartorius, Australia) with the first ~3 mL of sample pre-conditioning the filter and discarded to waste, before collecting the filtrate in an acid-washed polycarbonate vial. All samples were acidified with concentrated nitric acid (Tracepur, Merck) to 0.2 % (v/v) prior to analysis.

Concentrations of metals and major ions were determined by inductively coupled plasma atomic emission spectrometry (ICP-AES) (CSIRO Method C-229), inductively coupled plasma mass spectrometry (ICP-MS) (CSIRO Method C-209) or aqua regia digestion for total recoverable metals (TRM, CSIRO Method C-223) and dilute-acid extractable metal (AEM, CSIRO Method C-241).

Analysis of samples from the microalgal toxicity tests were carried out at CSIRO Lucas Heights. Analysis of samples from the water flea, midge and blackworm toxicity tests were carried out at CSIRO Adelaide. Metal and metalloids analysed included: aluminium (Al), arsenic (As), boron (B), barium (Ba), calcium (Ca), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), molybdenum (Mo), sodium (Na), nickel (Ni), lead (Pb), antimony (Sb), selenium (Se), silicon (Si), tin (Sn), strontium (Sr), thorium (Th), uranium (U), vanadium (V), zinc (Zn), mercury (Hg), sulphur (S) and phosphorus (P).

The composition of the 'raw' leachate samples were also analysed by scanning electron microscopy (SEM) (for imagery and to provide energy dispersive X-ray) and X-ray power diffraction (XRD) spectrometry (carried out at CSIRO Adelaide; refer to Appendix I and J, respectively, for methods).

The total recoverable metals (and other elements) in the sediments and rock samples (<75 µm) were extracted based on the methods validated and described in Assignment P4 (Simpson et al., 2019). Sediments and excavated rock samples were extracted within pre-cleaned Teflon digestion vessels using aqua regia digestions in a microwave-assisted reaction system (MARS). The Teflon vessels were extensively cleaned as per CSIRO Method C-223. The sediments were freeze-dried (Christ Alpha 1-2 LDplus) and ground to a powder using a mortar and pestle before digestion.

The sediments and rock samples were weighed into the pre-cleaned MARS Teflon vessels to which 9 mL of concentrated nitric acid (Merck Tracepur) and 3 mL of concentrated hydrochloric acid (Merck Tracepur) were added. The digestion vessels were heated at high pressure in a MARS digestion system for 90 minutes (CSIRO Method C-223). Once cool, digests were diluted to a final volume of 40 mL with deionised water. The digest solutions were subsequently diluted 10-fold using deionised water and analysed using a combination of ICPAES (Varian730 ES) and ICPMS (Agilent 8800 CE) with matrix-matched calibration standards.

Dilute-acid-extractable metals (AEM) were determined for each solid using an extraction in 1 M HCl (84 mL of 36% HCl/L) for 60 min, followed by filtration (<0.45 µm). The extraction treatments were shaken each 20 min over the 60 min extraction duration. The 1 M HCl sample extracts were subsequently diluted 10-fold using deionised water and analysed using a combination of ICPAES (Varian730 ES) and ICPMS (Agilent 8800 CE), with matrix-matched calibration standards.

2.2 Ecotoxicity testing - overview

Toxicity tests (chronic and acute) with microalgae, water fleas, midges and blackworms were carried out on leachates of excavated rock material prepared with water from Talbingo or Tantangara Reservoirs. Toxicity tests (chronic) with midges and blackworms were carried out on excavated rock material under varying scenarios of mixing and layering (Table 4).

Leachates of excavated rock had high levels of suspended solids (turbidity), which had not completely settled out of solution after 24 h. Therefore, the toxicity of leachates was assessed with water fleas, midge and blackworms on raw and/or after settling (12 d) and/or 0.45 µm filtered leachates based on the decision tree in Figure 1.

Table 4. Summary of toxicity tests and material tested

Species	Endpoint (acute or chronic)	Exposure (d)	Material tested
Water (leachate) tests			
Microalga, *Raphidocelis subcapitata*	Population growth rate inhibition (chronic)	3	(i) Reservoir water (0.45 µm filtered) (ii) Leachates of excavated rock representing 7 geological units (each with a Baseline and Enriched composite) prepared with reservoir water (and filtered to 0.45 µm prior to toxicity testing)
Water flea (cladoceran), *Ceriodaphnia dubia*	(i) Survival (acute)	2	(i) Reservoir water (ii) Leachates of excavated rock representing 7 geological units (each with a Baseline and Enriched composite) prepared with reservoir water representing three treatments a) Raw leachate as a worst-case scenario a) 12-day settled leachate b) Filtered leachate
Water flea (cladoceran), *Ceriodaphnia dubia*	Reproduction (chronic)	8	(i) Reservoir water (ii) Leachates of excavated rock representing 6 geological units (each with a 0.45 µm filtered Enriched composite) prepared with reservoir water
Midge *Chironomus tepperi*	Immobilisation (acute)	2	(i) Reservoir water (ii) Leachates of excavated rock representing 7 geological units (each with a Baseline and Enriched composite) prepared with reservoir water representing three treatments based on decision tree given in Figure 1
Blackworm, *Lumbriculus variegatus*	Immobilisation (acute)	2	As above
Sediment (excavated rock) tests			
Midge larvae, *Chironomus tepperi*	(i) Survival (chronic) (ii) Growth (length) (chronic)	7	(i) Reservoir sediment (ii) Reservoir water as overlying water (ii) Excavated rock representing 7 geological units (each with a Baseline and Enriched composite) b) mixed with reservoir sediment c) as a surface layer on top of reservoir sediment d) 100% Enriched excavated rock as a worst-case scenario
Blackworm, *Lumbriculus variegatus*	(i) Reproduction (chronic) (ii) Biomass (chronic)	28	As above

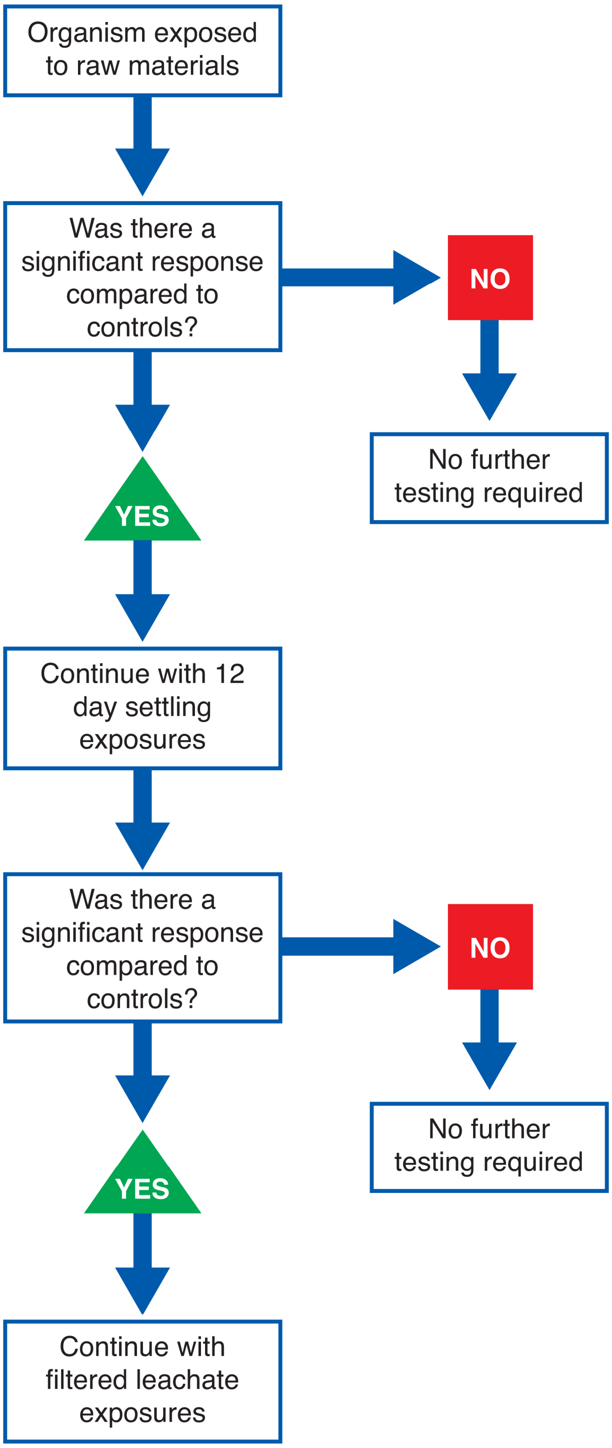

Figure 1. Decision tree for toxicity testing of raw, settling and filtered (0.45 µm) leachates with water fleas, midges and blackworms.

2.3 Toxicity testing of leachates of excavated rock material

2.3.1 Microalgal toxicity testing

Chronic toxicity to the temperate freshwater microalga *Raphidocelis subcapitata* (strain CS-327 CSIRO National Algal Culture Collection) was tested in this project, based on Test Guideline 201 (2002), Organisation for Economic Co-operation and Development (OECD). Toxicity was measured as an inhibition in population growth rate over 72 h. Toxicity tests with *R. subcapitata* are summarised in Table 5 and described in Stauber et al. (2005).

Toxicity tests were carried out on filtered (0.45 µm) reservoir waters to remove the natural phytoplankton present in the samples, as it interferes with the measurement of microalgal cell densities (and hence microalgal growth rates) of the inoculated test species (refer to Appendix C, Test report 1). Leachate water was also tested after filtration (0.45 µm) to remove particulates from the leachate that can potentially interfere with the determination of algal cell densities. Reservoir waters and leachates (14 samples) were screened for toxicity by testing undiluted water (100%). Leachates of Gooandra Baseline and Gooandra Enriched were tested further by diluting each leachate with filtered reservoir water (1 in 2) to achieve six leachate concentrations of 6.3%, 13%, 25%, 50%, 75% and 100%.

Cultured algal cells in their exponential growth phase (5-6 d) were washed by centrifugation to remove culture media and cell exudates (potential sources of metal ligands) before being added to each minivial glass test vessel (1-2×10^3 cells/mL) along with essential nutrients (USEPA nutrients, without EDTA, Stauber et al., 2005). Control treatments consisting of reservoir water, leachate MB and USEPA media were also prepared. All treatments were prepared at least in triplicate as a minimum. All treatments were incubated at 24°C under a 24-h light cycle. Cell densities in each vial were then determined daily for three days using a FACSCalibur flow cytometer (BD Bioscience) and the microalgal cell division rates were calculated (Stauber et al., 2005). For quality control purposes, a reference toxicant (copper) was also tested to ensure that the microalgae were responding to a known toxicant in a reproducible way. Additional toxicity test conditions are summarised in Table 5.

The pH and EC of each treatment was measured at the beginning of the test and pH was measured at the end of the test. Temperature was monitored throughout the test. Selected chemical analyses included dissolved metals at the beginning of the test (Section 2.3.3).

Significant differences ($p \leq 0.05$) in the microalgal growth rates measured between different treatments were tested using the Homoscedatic t-test following tests for normality (Shapiro-Wilk's test) and variance (F-test). Where a concentration-response relationship was observed (e.g. for the reference toxicant), the toxicity was expressed as the concentration of sample that causes a 10% or 50% inhibition in algal growth rate relative to the control (IC10 and IC50 values, respectively) derived through linear interpolation. The lower the IC10 or IC50, the more toxic the sample. The lowest observable effect (LOEC) and no observable effect (NOEC) concentrations were calculated using the Dunnett's Test. All statistical tests were carried out using ToxCalc Version 5.0.23 (Tidepool Software).

Table 5. Summary of the test protocol for growth inhibition tests with the temperate microalga *Raphidocelis subcapitata*

Parameter	Test condition
Test type	Static, non-renewal
Temperature	24 ± 2°C
Light quality	Cool white fluorescent daylight lighting
Light intensity	65 µmol photons/m^2/s
Photoperiod	24 h light
Test chamber size	20 mL
Test solution volume	6 mL
Renewal of test solutions	None
Age of test organisms	5-6 days
Initial cell density in test chambers	1-2 x 10^3 cells/mL
No. of replicate chambers/concentration	3 (minimum)
Shaking rate	Twice daily by hand
Dilution water	USEPA media
Sample (leachate) concentrations	Screening tests: 1 (undiluted, 100%) Concentration-response curve: 6 (minimum)
Dilution factor	Screening tests: not applicable Concentration-response curve: 1 in 2 (minimum)
Test duration	72 h
Endpoint	Cell division rate (growth rate)
Test acceptability	• Cell division rate in control within Cusum chart limits (2.2–2.6 doublings per day) • Variability in the controls <20% • Reference toxicant, copper, IC50 within Cusum chart limits (9–21 µg/L)

2.3.2 Cladoceran immobilisation (acute) and reproduction (chronic) tests

Toxicity tests with *Ceriodaphnia dubia* employed the endpoints of immobilisation and reproduction for the acute and chronic tests, respectively. Cultures of *C. dubia* were sourced from CSIRO Lucas Heights and maintained at CSIRO Adelaide throughout the project.

Cladoceran 48-h acute immobilisation test

The acute toxicity test measures immobilisation of *C. dubia* over 48 h and follows the OECD guideline 202 (OECD, 2004) with minor modifications (Table 6). For each leachate sample, 25 mL was dispensed into 50 mL beakers, with control treatments of 25 mL moderately hard water (MHW; US EPA, 2002) and reservoir water. All treatments were prepared with four replicates. Five *C. dubia* neonates (aged <24 h) were added to each test vessel and the vessels incubated at 25 ± 1˚C under a 16:8 h light: dark cycle. After 48 h, the number of surviving (mobile) and non-surviving (immobile) neonates were observed and counted under a stereomicroscope. Surviving cladocerans were identified by signs of movement. Test solutions were not renewed during the 48 h exposure. A control consisting of MHW containing a reference toxicant of copper, was tested for quality assurance purposes.

Table 6. Summary of the cladoceran acute (48-h immobilisation) and chronic (8-d reproduction) test

Parameter	Acute test condition	Chronic test condition
Test type	Static, non-renewal	Semi-static
Test duration	48 h	8 d
Temperature	25 ± 1˚C	25 ± 1˚C
Light quality	Cool white fluorescent tube lighting	Cool white fluorescent tube lighting
Light intensity	800 ± 160 Lux	800 ± 160 Lux
Photoperiod	16 h light : 8 h dark	16 h light : 8 h dark
Test chamber size	50 mL vial	50 mL
Test solution volume	25 mL	25 mL
Renewal of test solution	None	48 h
Age of test organisms	≤24 h (neonate)	≤24 h (neonate)
No. of organisms per replicate	5	1
No. of replicates per treatment	4	10
No. of organisms per treatment	20	10
Feeding regime	None	*R. subcapitata* and *Dunaliella salina* daily
Dilution water/control treatments	reservoir water	Moderately hard water (MHW) and reservoir water
Sample (leachate) concentrations	Screening tests: 1 (undiluted, 100%)	1 (undiluted, 100%)
Dilution factor	Screening tests: not applicable Concentration-response curve: 1 in 2 (minimum)	Not applicable
Endpoint	Immobilisation	Total number of neonates (over three broods for the control treatment)
Test acceptability criteria	≥90% survival in controls Reference toxicant, copper, EC50 within Cusum chart control limits	≥80% survival in controls Reference toxicant, copper, 48-h acute EC50 within Cusum chart control limits

Cladoceran 8-d chronic reproduction test

Reproduction of *C. dubia* was assessed over 8 days with a method based on the OECD Test Guideline 211 (1984 and 2012) for *Daphnia magna* (Table 6). Tests were carried out in 50 mL beakers each containing 25 mL of test solution. Control treatments were also prepared with MHW and reservoir water, with each treatment consisting of ten replicates. One neonate (<24-h old) was added to each beaker and incubated at 25 ± 1˚C with a photoperiod of 16:8 h light: dark cycle. *C. dubia* were fed a microalgal mixture of *R. subcapitata* and *Dunaliella salina* on a daily basis. During the 8-d toxicity test, test solutions were renewed every 48 h using the originally prepared leachate. After 8 days, the number of surviving *C. dubia* and the total number of young generated over three broods were counted. The pH, DO, EC and temperature were measured at the beginning and end of the bioassay and when test solutions were renewed.

2.3.3 Midge survival (acute) tests

The acute toxicity test measures immobilisation of *C. tepperi* over 48 h. For each leachate, 25 mL was dispensed into 50 mL beakers, with control treatments of 25 mL MHW (US EPA, 2002) and reservoir water. All treatments were prepared with four replicates. Five 2nd instar larvae were added to each test vessel and the vessels incubated at 25 ± 1˚C under a 16:8 h light: dark cycle.

After 48 h, the number of surviving (mobile based on gentle prodding) and non-surviving (immobile) larvae were counted under a stereo microscope. Test solutions were not renewed during the 48 h exposure (Table 7). A control consisting of MHW containing a reference toxicant of copper, was tested for quality assurance purposes.

Table 7. Summary of the acute (48-h survival) midge test

Parameter	Acute test condition (waters)
Test type	Static, non-renewal
Test duration	48 h
Temperature	21 ± 1˚C
Light quality	Cool-white fluorescent tube lighting
Light intensity	800 ± 160 Lux
Photoperiod	16 h light : 8 h dark
Test chamber size	50 mL vial
Test solution volume	25 mL
Age of test organisms	Similar sizes
No. of organisms per replicate	5
No. of replicates per treatment	4
No. of organisms per treatment	20
Feeding regime	None
Dilution water	Reservoir water
Test concentrations	4 + 1 Control (if 100% sample shows toxicity)
Control treatments	Moderately hard water (MHW) and Reservoir water
Endpoint	Survival (Immobilisation)
Test acceptability criterion	≥90% survival in the controls Reference toxicant, copper, EC50 within Cusum chart limits

2.3.4 Blackworm survival (acute) tests

The acute toxicity test measures immobilisation of *L. variegatus* over 48 adult blackworms of similar physiological development (synchronised) were exposed to leachates of excavated rock material prepared in reservoir water. Test vessels with reservoir water were used as the control treatments. For each leachate, 25 mL was dispensed into 50 mL beakers, with control treatments of 25 mL MHW (US EPA, 2002) and reservoir water. All treatments were prepared with four replicates. After 48 h, the number of surviving (mobile based on gentle prodding) and non-surviving (immobile) adult blackworms were counted under a stereomicroscope. Test solutions were not renewed during the 48 h exposure (Table 8). A control consisting of MHW containing a reference toxicant of copper, was tested for quality assurance purposes.

Table 8. Summary of the acute (48-h survival) blackworm test

Parameter	Acute test condition (waters)
Test type	Static, non-renewal
Test duration	48 h
Temperature	21 ± 1˚C
Light quality	Cool white fluorescent tube lighting
Light intensity	800 ± 160 Lux
Photoperiod	16 h light : 8 h dark
Test chamber size	50 mL vial
Test solution volume	25 mL
Age of test organisms	Similar sizes (physiological synchronised)
No. of organisms per replicate	5
No. of replicates per treatment	4
No. of organisms per treatment	20
Feeding regime	None
Dilution water	Reservoir water
Test concentrations	4 + 1 Control (if 100% sample shows toxicity)
Control treatments	Moderately hard water (MHW) and Reservoir water
Endpoint	Survival (immobilisation)
Test acceptability criterion	≥90% survival in controls Reference toxicant, copper, EC50 within Cusum chart control limits

2.4 Toxicity testing of excavated rock-sediment mixtures

2.4.1 Midge survival and growth (chronic) tests

The chronic toxicity of excavated rock mixtures with sediment were assessed using *C. tepperi* larvae. The survival and growth of midge larvae was measured after 7 days based on methods described by Simpson and Kumar (2016) and summarised in Table 9.

For the sediment and excavated rock midge bioassay, ten 5-day old midge larvae were added to beakers containing 140 g (wet weight) of 425 µm sieved sediment and 250 mL of reservoir water (4 replicates per site, Figure 2). The beakers were incubated for 7 days at 21 ± 1˚C (16:8 h light: dark). After 7 days, and prior to pupation, larvae from each replicate were removed, pooled and their wet weights recorded. Individual midge larvae lengths were measured using image analysing software. Survival of the midge larvae was also determined.

The pH, EC, DO and temperature of the overlying water was measured at the beginning and end of the test, and on Day 3 and 5 when overlying water of the test chambers were renewed.

Table 9. Summary of the chronic (7-d survival and growth) midge test

Parameter	Chronic test condition (sediments)
Test type	Semi-static with aeration
Test duration	7 d
Temperature	21 ± 1˚C
Light quality	Cool-white fluorescent tube lighting
Light intensity	800 ± 160 Lux
Photoperiod	16 h light : 8 h dark
Test chamber size	400 mL beaker
Test solution volume (overlying water)	250 mL
Sediment and excavated rock	Three treatments (1) 140 g (wet weight) of 425 µm sieved sediment and 20 g excavated rock material on top of sediments (2) 140 g (wet weight) of 425 µm sieved sediment and 20 g excavated rock material mixed with sediments (3) 160 g (wet weight) of 425 µm excavated rock material
Age of test organisms	2nd instar larvae (5 day old larvae after collecting egg sacs)
No. of organisms per replicate	10
No. of replicates per treatment	4
No. of organisms per treatment	40
Feeding regime	1.5 mL food added on alternate days (3 times during the test)
Dilution water	Reservoir water
Control treatments	Reservoir sediment
Endpoint	Survival and growth
Test acceptability criterion	≥80% survival in controls. The oxygen concentration in the overlying water should not be <80% of air saturation value at test temperature at the end of the test. Copper reference test for 48 hours –water only exposures

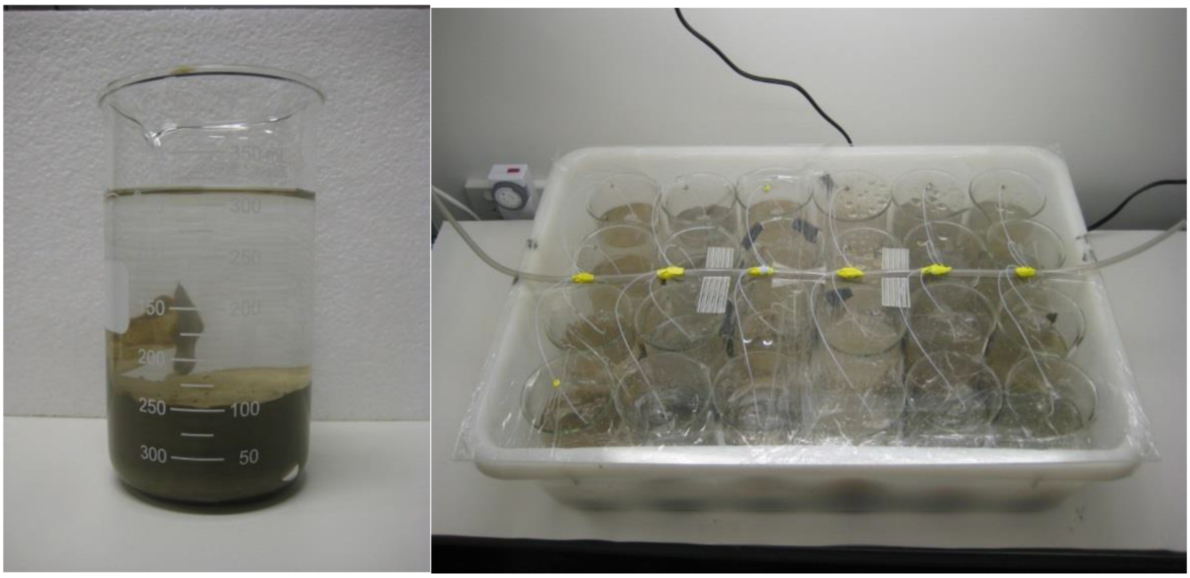

Figure 2. Midge whole sediment toxicity test set up

2.4.2 Blackworm reproduction and biomass (chronic) tests

This test determines effects on the reproduction and the biomass of the blackworm *L. variegatus* and follows the OECD guideline 225 (OECD, 2007). The chronic measured biological parameters are the total number of surviving worms and the biomass (dry weight) at the end of the exposure. Acute toxicity of leachates of excavated rock material was also assessed as a screening tool prior to initiating long-term chronic toxicity tests by measuring survival of *L. variegatus* over 48 h (Section 2.3.4). A summary of the chronic toxicity tests is described in Table 10.

Blackworms were exposed to the reservoir sediment- excavated material for 28 days.

Table 10. Summary of the chronic (28-d survival and growth) blackworm test

Parameter	Chronic test condition (sediments)
Test type	Static with aeration (overlying water topped up on Day 14 of test)
Test duration	28 d
Temperature	20 ± 2°C
Light quality	Cool white fluorescent tube lighting
Light intensity	800 ± 160 Lux
Photoperiod	16 h light : 8 h dark
Test chamber size	400 mL beaker
Test solution volume	250 mL (overlying water to be topped-up on Day 14)
Sediment and excavated rock	Three treatments (1) 75 g (wet weight) of 425µm sieved sediment and 20 g excavated rock on top of sediments and (2) 75 g sediments and 20 g excavated rock mixed well and (3) last treatment of neat excavated rock material of 75 grams.
Age of test organisms	Smallest BW used in the test should not be less than half the size of the largest BW used in the test.
No. of organisms per replicate	10
No. of replicates per treatment	4
No. of organisms per treatment	40
Feeding regime	Food added to the sediment prior to testing. Add 100 mg spirulina crushed tablet and 100 mg sera-micron powder to sediment or excavated rock materials. No additional feeding required during 28 days test.
Dilution water	Reservoir water
Control treatments	Reservoir sediment
Endpoint	Survival and growth
Test acceptability criterion	The average number of living worms per replicate in the controls should have increased by a factor of at least 1.8 at the end of exposure compared to the number of worms per replicate at the start of exposure. The oxygen concentration in the overlying water should not be <30% of air saturation Value at test temperature at the end of the test.

Adult worms of similar physiological development (synchronised) were exposed to a combination of treatments of excavated-rock mixtures with sediment collected from the proposed placement sites. Talbingo Reservoir water was used as overlying water for Ravine, Byron, Shaw Gabbro, Volcanics and Felsic excavated rock-sediment testing scenarios. And Tantangara Reservoir water was used as overlying water for Peppercorn and Kellys Plain excavated rock-sediment testing scenarios. Test vessels with reservoir water and sediment, without the addition of the excavated rock material were used as the control treatments. Blackworms were exposed to the sediment-water treatments for 28 days. To ensure that there was sufficient organic matter to allow the worms to grow over 28 days, the organic content of the control sediment was supplemented by mixing in 0.75 g of flaked tropical fish food.

The pH, EC, DO and temperature of the surface waters were measured at the beginning and end of the test, and every day in which surface waters were renewed.

3 Results

3.1 Introduction

Each of the acute and chronic toxicity tests with waters/leachates and excavated-rock sediment mixtures met their respective QA/QC criteria (refer to Appendices C–H).

Detailed toxicity test results for chronic microalgal tests, acute and chronic cladoceran tests, acute midge tests and acute blackworm tests with excavated rock leachates are presented in Appendices C, D, E and F respectively. Detailed test reports for chronic midge tests and chronic blackworm tests are detailed in Appendices G and H respectively.

3.2 Toxicity of leachates of excavated rock to microalgae

3.2.1 Reservoir water (baseline, pre-placement)

The conductivities of waters from Tantangara Reservoir and Talbingo Reservoir were low (26.0–26.3 and 24.3–24.9 µS/cm respectively) and the pH was near neutral (7.21–7.25 and 7.18–7.29 respectively) (Appendix C, Test Report 3). For Tantangara, concentrations of dissolved aluminium exceeded the GV for 99% species protection (Simpson et al., 2019).

Toxicity tests with microalgae are generally carried out in waters with higher EC and the low EC of the reservoir water may have affected the growth rate of microalgae. Initial toxicity testing with *C. vulgaris* indicated that while this microalgae achieved good growth rates at low conductivities (16 µS/cm) in synthetic soft water, microalgal growth was lower in Tantangara Reservoir (59–69% inhibition) than in Talbingo Reservoir (15–24% inhibition) waters suggesting that some other unknown characteristic(s) of the reservoir water supressed *C. vulgaris* growth rates (refer to Appendix C, Test Report 2). Therefore, without further investigation, *C. vulgaris* was considered an unsuitable test species for this project and an alternative temperate freshwater species was selected: *R. subcapitata*. The toxicity test with *R. subcapitata* is an internationally standardised toxicity test protocol and has been used worldwide for the assessment of chemicals and waters for more than 30 years.

Toxicity test protocols for *R. subcapitata* require the addition of a range of nutrients (USEPA nutrients, Stauber et al., 2005) to each test solution. While this ensures an acceptable microalgal growth rate is achieved, it also alters the water quality parameters of the solutions being tested. For example, following additional of USEPA nutrients, the Tantangara Reservoir and Talbingo Reservoir waters increased in EC to 117–119 and 113–118 µS/cm respectively and pH of 7.53–7.61 and 7.50–7.59 respectively (similar to the EC and pH of the standard control treatment (USEPA media, 93 µS/cm and pH of 7.37, Appendix C, Test Report 3).

Where water characteristics have altered, care should be taken when interpreting the toxicity data. Overall, following addition of the USEPA nutrients to lake waters the pH increased by 0.3 units, conductivity increased by 93 µS/cm and the hardness increased by a factor of 2 (from 11 to 22 mg CaCO3/L, calculated from Mg and Ca concentrations) and still considered soft water (<30 mg CaCO3/L (ANZG, 2019). Interpretation of these results with supporting information (chemical measurements and toxicity to other species) strengthens the overall toxicity assessment of lake water and leachates of excavated rock.

Water from Tantangara Reservoir (three locations) and Talbingo Reservoir (three locations) did not inhibit microalga *R. subcapitata* population growth rate (i.e. they were not toxic) with growth rates of 2.24–2.32 and 2.29–2.38 doublings/day, respectively, and similar to the standard control treatment (USEPA media, 2.28 doublings/day). This may be an artefact of the addition of USEPA nutrients to each test solution which resulted in the EC and pH of the reservoir waters to be similar to the standard control treatment (additional details are provided in Appendix C, Test Report 3).

3.2.2 Leachates of excavated rock

The effect of suspended solids on microalgal growth is difficult to assess because they interfere with microalgal cell density measurements (and hence microalgal growth rate), and the solids can shade microalgae from light that is essential for photosynthesis and cell division. Hence, leachates tested in this study were filtered to 0.45 µm prior to testing, but some leachate samples were visibly cloudy indicating that suspended solids/colloids (<0.45 µm) were also likely to be present in the leachate samples that were tested. Reduction in microalgal growth rates due to a potential of blocking of light in the toxicity tests on the elutriates in this study was not expected. For example, Volcanics Enriched sample was the cloudiest, but was not the most toxic elutriate to the microalgae.

Concentrations of dissolved metals and major ions in leachates used in the microalgal toxicity tests were measured before and after the addition of microalgal nutrients (+ N, i.e. the leachate sample tested for toxicity) (Table 11 and Table 12). The most toxic leachate (Gooandra Enriched, 47% inhibition in algal growth rate) did not have the highest concentrations of dissolved metals (aluminium, arsenic, zinc) but it did have the highest concentration of copper (7 µg/L; Table 11 and Table 12).The dissolved aluminium concentrations exceeded the 95% GV for all leachates tested (88 to >2000 µg/L) and highest concentrations were observed for Felsic Enriched (1847 and >2000 µg/L). Felsic Enriched also had the highest concentrations of dissolved arsenic and zinc, exceeding the respective 95% GVs. Other notable 95% GV exceedances include arsenic for Ravine Enriched and Kellys Plain Enriched samples.

The addition of USEPA nutrients to the leachates (immediately prior to toxicity testing) did not alter (in general) the concentration of dissolved aluminium (86 to 109% of the original leachate); the exception was for Kellys Plain Enriched, whose dissolved aluminium concentrations decreased by 55% after addition of the microlagal nutrients (590 to 265 µg/L) and Felsic Enriched (>2000 to 1847 µg/L). For Felsic Enriched, zinc, copper and iron concentrations also decreased by 47%, 62% and 60% respectively. For Kellys Plain Enriched, arsenic and iron concentrations also decreased (by 59% and 66% respectively).

The addition of the microalgal nutrients to the leachates can increase concentrations of dissolved metals and major ions (e.g. iron, manganese, sodium, calcium and magnesium) or, decrease concentrations of dissolved metals by complexation (potentially making them less bioavailable). Microalgal test solutions with simpler nutrient addition (e.g. nitrate and phosphate only) is likely to minimise these changes to the original composition and speciation of the leachates being tested.

Leachates of excavated rock material prepared with Tantangara Reservoir water (S/L ratio of 10, 18 h mixing, 0.45 µm filtration) did not inhibit *R. subcapitata* growth rate (that is, they were not toxic) for Baseline samples of Ravine, Byron, Gooandra, Kellys Plain and Felsic, and Enriched samples of Kellys Plain (Figure 3). However, Baseline samples of Shaw Gabbro and Peppercorn, and Enriched samples of Ravine, Byron, Shaw Gabbro, Peppercorn and Felsic significantly inhibited microalgal growth by ≥18%. The Enriched Gooandra sample inhibited microlagal growth to the greatest extent (47% inhibition, compared to the control).

Serial dilution of Gooandra Baseline and Enriched samples (the latter being the most toxic leachate sample) indicated that a dilution of 1 in 2 (i.e. 50% leachate) was sufficient to remove the toxicity of the leachate to *R. subcapitata* (Figure 4).

There were no clear trends between the dissolved metal concentrations in the leachates and the toxicity observed. The leachate with the highest concentrations of metals (Al, As and Zn), Felsic Enriched, was the third most toxic leachate sample (total of 14 leachates) and of similar toxicity to other leachates.

Table 11. Concentrations of dissolved (0.45 µm) major ions, pH and EC in leachates of excavated rock material (18 h mixing)*

Sample Name	pH	EC (µS/cm)	Ca	K	Mg	Na				
Ravine, Baseline	9.27	133	4800	19000	2100	7100				
Ravine, Baseline + N					8.94	216	6100	19000	5100	18000
Ravine, Enriched					9.16	139	5400	19000	2300	7100
Ravine, Enriched + N					8.81	222	6600	19000	5200	18000
Byron, Baseline					8.74	132	6300	11000	5900	4800
Byron, Baseline + N					8.45	219	7500	12000	8800	16000
Byron, Enriched					9.07	146	6100	25000	1400	4400
Byron, Enriched + N					8.72	232	7200	26000	4200	16000
Shaw Gabbro, Baseline					9.31	109	4800	9800	1700	8600
Shaw Gabbro, Baseline + N					8.95	197	6100	10000	4600	21000
Shaw Gabbro, Enriched					9.39	107	4600	7900	2300	8700
Shaw Gabbro, Enriched + N					8.99	188	5800	8300	5300	20000
Volcanics, Baseline					8.87	93	5500	10000	860	6000
Volcanics, Baseline + N					8.76	180	7300	12000	4100	19000
Volcanics, Enriched					8.98	115	6500	14000	1300	6300
Volcanics, Enriched + N					8.83	203	8100	15000	4400	18000
Peppercorn, Baseline					9.38	118	4700	14000	1400	8600
Peppercorn, Baseline + N					8.96	202	6000	15000	4300	20000
Peppercorn, Enriched					9.16	125	7200	10000	1700	8800
Peppercorn, Enriched + N					8.71	208	8300	10000	4600	20000
Kellys Plain, Baseline					8.41	114	3000	11000	2300	6500
Kellys Plain, Baseline + N					8.46	199	4100	11000	4900	16000
Kellys Plain, Enriched					8.43	179	19000	>25,000	4500	8100
Kellys Plain, Enriched + N					8.48	263	11000	16000	4900	14000
Felsic, Baseline					9.40	125	4300	18000	680	8700
Felsic, Baseline + N					8.98	209	5400	19000	3500	21000
Felsic, Enriched					7.99	181	6500	>25,000	3000	6500
Felsic, Enriched + N					8.06	262	6400	>25,000	5000	18000
Volcanics, Baseline 6% + N					7.84	118	3300	1500	3700	12000
Volcanics, Baseline 75% + N					8.63	163	5700	8600	3700	16000
Volcanics, Baseline + N					8.76	180	7300	12000	4100	19000
Volcanics, Enriched 6% + N					7.91	118	3300	1700	3600	12000
Volcanics, Enriched 75% + N					8.57	179	6600	11000	4000	16000
Volcanics, Enriched + N					8.83	203	8100	15000	4400	18000
DGV or 95% GV[a]					–	–	–	–	–	–

* Analytes reported are based on the major analytes detected in Assignment P4 (Simpson et al., 2019)

[a] http://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/

DGV = default guideline value, representing the 95% species protection guideline values (95% GV) for freshwater.

Table 12. Concentrations of dissolved (0.45 µm) metals (µg/L) in leachates of excavated rock material (18 h mixing)*

Sample Name	Al	As	Cu	Fe	Mn	Ni	P	Zn
Ravine, Baseline	**340**	**11**	0.9	250	5.4	<5.9	11	0.6
Ravine, Baseline + N	**350**	**11**	<0.7	290	120	<5.9	150	**2.4**
Ravine, Enriched	**280**	**16**	<0.7	93	5.2	<5.9	7.7	1.0
Ravine, Enriched + N	**280**	**15**	<0.7	120	120	<5.9	150	**2.8**
Byron, Baseline	**89**	<8.3	<0.7	33	2.5	<5.9	36	<0.2
Byron, Baseline + N	**88**	<8.3	<0.7	62	120	<5.9	180	1.6
Byron, Enriched	**270**	**11**	<0.7	130	2.7	<5.9	14	0.3
Byron, Enriched + N	**270**	**9.7**	<0.7	160	120	<5.9	150	1.6
Shaw Gabbro, Baseline	**510**	<8.3	<0.7	46	1.7	<5.9	2.2	0.5
Shaw Gabbro, Baseline + N	**480**	<8.3	<0.7	77	110	<5.9	140	2.0
Shaw Gabbro, Enriched	**300**	<8.3	**1.5**	10	0.7	<5.9	8.0	<0.2
Shaw Gabbro, Enriched + N	**290**	<8.3	0.7	41	110	<5.9	130	1.7
Volcanics, Baseline	**270**	**11**	0.9	<0.8	1.2	<5.9	<1.0	<0.2
Volcanics, Baseline + N	**230**	<83	<7	<8	130	<59	140	<2
Volcanics, Enriched	**480**	**8.5**	<0.7	1.7	1.4	<5.9	2.5	<0.2
Volcanics, Enriched + N	**440**	<83	**7.0**	<8	120	<59	80	<2
Peppercorn, Baseline	**260**	**11**	<0.7	110	2.8	<5.9	37	<0.2
Peppercorn, Baseline + N	**260**	**8.6**	**1.0**	140	120	<5.9	180	1.8
Peppercorn, Enriched	**360**	<8.3	<0.7	91	2.8	<5.9	21	<0.2
Peppercorn, Enriched + N	**340**	<8.3	0.7	110	110	<5.9	160	1.6
Kellys Plain, Baseline	**180**	<5.2	<1.1	95	4	NR	22	0.9
Kellys Plain, Baseline + N	**190**	**5.7**	<1.1	160	110	NR	170	**2.5**
Kellys Plain, Enriched	**590**	**27**	<1.1	370	10	NR	23	1.7
Kellys Plain, Enriched + N	**270**	**11**	<1.1	130	110	NR	150	2.1
Felsic, Baseline	**270**	<8.3	<0.7	69	4.7	<5.9	7.8	0.2
Felsic, Baseline + N	**280**	<8.3	<0.7	99	110	<5.9	150	1.9
Felsic, Enriched	**>2,000**	**19**	**2.7**	2300	34	<5.9	27	**360**
Felsic, Enriched + N	**1800**	**20**	**1.0**	940	130	<5.9	160	**190**
Volcanics, Baseline 6% + N	20	<8.3	<0.7	25	110	<5.9	140	**7.5**
Volcanics, Baseline 75% + N	**180**	<83	<7	<8	100	<59	120	2.1
Volcanics, Baseline + N	**230**	<83	<7	<8	130	<59	140	<2
Volcanics, Enriched 6% + N	**32**	<8.3	0.7	22	110	<5.9	140	**2.6**
Volcanics, Enriched 75% + N	**290**	<83	<7	8.5	110	<59	91	<2
Volcanics, Enriched + N	**440**	<83	**7.0**	<8	120	<59	80	<2
DGV or 95% GV[a]	**55**	**13**	**1.4**	**–**	**–**	**11**	**–**	**8.0**
99% GV[b]	**27**	**0.8**	**1.0**	**–**	**–**	**8**	**–**	**2.4**

* Analytes reported are based on the major analytes detected in Assignment P4 (Simpson et al., 2019)

[a] http://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/

DVG = default guideline value, representing the 95% species protection guideline values (95% GV) for freshwater.

[b] 99% species protection guideline values (99% GV) for freshwater. Values for Arsenic are for As(V)

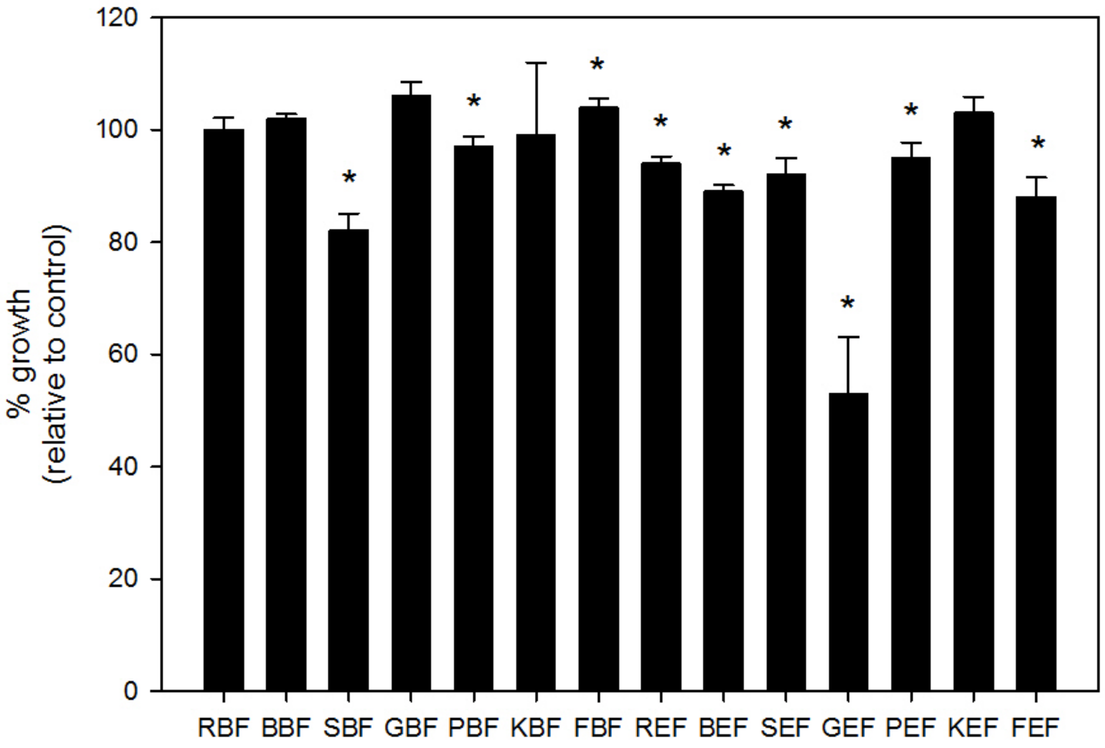

Figure 3. Toxicity of leachates of excavated rock material (prepared in Talbingo Reservoir water) to the microalga *Raphidocelis subcapitata*. Microalgal population growth (72 h) is expressed as % of control treatment (algal growth rate in the Method Blank control (Talbingo Reservoir water). The lower the column, the more toxic the sample. The x-axis labels consist of three letters; first letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Gooandra Volcanics (G), Peppercorn (P), Kellys Plain (K) and Felsic (F); second letter represents Baseline (B) or Enriched (E) excavated rock. All leachates were filtered (0.45 µm). Error bars represent 1 standard deviation. * indicates treatment is significantly different to the control treatment ($p \leq 0.05$). FBF is significantly greater than the control (i.e. stimulation in response)

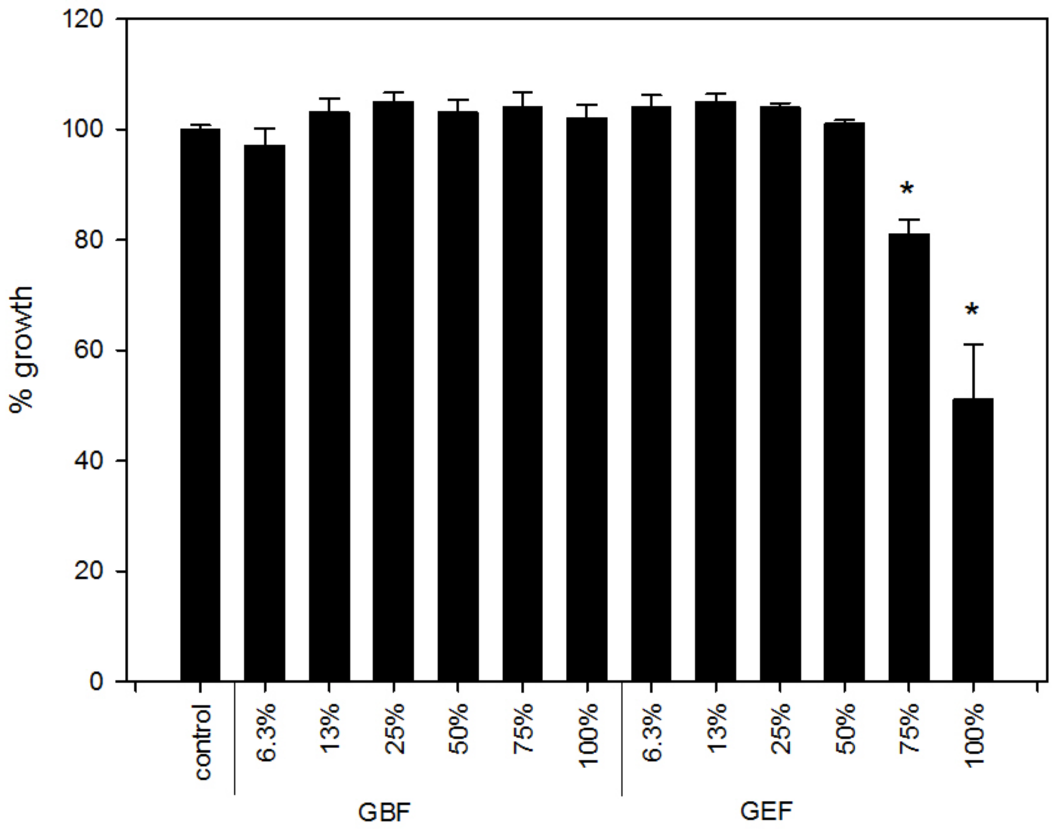

Figure 4. Toxicity of Gooandra Baseline (GBF) and Gooandra Enriched (GEF) leachates of excavated rock material (prepared in Talbingo Reservoir water) to the microalga *Raphidocelis subcapitata* (72 h population growth rate). Leachates were serially diluted 1 in 2 with control water (USEPA media). Microalgal growth is expressed as % of control treatment (algal growth rate in the USEPA media). The lower the column, the more toxic the sample. * indicates treatment is significant different to the control treatment ($p \leq 0.05$)

The most toxic leachate (Gooandra Enriched, 47% inhibition in algal growth rate) did not have the highest concentrations of dissolved metals (aluminium, arsenic, zinc) but it did have the highest concentration of copper (7 µg/L). It is unclear if the toxicity was due to truly dissolved metals and/or, suspended solids/precipitated metals of <0.45 µm.

3.3 Characterisation of reservoir water used for baseline toxicity assessment using macroinvertebrates

The pH, EC, DO and turbidity measured in the Talbingo and Tantangara Reservoir waters are shown in Table 13. The pH, EC, DO and turbidity were similar in both reservoirs and ranged from 7.58 to 8.0, 30 to 33 µS/cm, 104-108% DO, and 0.5 to 2.55 NTU, respectively. The concentrations of metal and metalloid elements are shown in Table 14. The concentrations of dissolved Ag, Be, Cd, Li, Mo, Sb, Se, Sn, Sr and Tl were similar in both reservoirs. The concentrations of dissolved Al, As, Ba, Co, Cr, Fe, Mn, Ni, Pb, Th and V were higher in the Tantangara Reservoir than the Talbingo Reservoir waters.

The dissolved metal concentrations were compared to the corresponding GVs for water quality (ANZG, 2018), representing the 95 and 99% of species protection concentrations, when values were available (Table 14). Tantangara Reservoir and Talbingo Reservoir waters exceeded the 99% guideline value (99% GV) for dissolved Al and Fe.

3.4 Characterisation of leachates used for determining toxicity using macroinvertebrates

The vast majority of the excavated rock, by mass, is expected to be larger than sand size and should settle rapidly, whereas the finest fractions (clay to low-silt size range) of the excavated rock materials may remain suspended in the waters in the main disposal area for a considerable period of time and not settle for many weeks or months after the placement activities cease. Consequently the bottom waters may contain a high concentration of suspended fine excavated rock material for the duration of the placement activities and potentially for weeks beyond the date placement is deemed complete.

Characterisation of leachate samples is given in Table 15, Table 16 and Table 17. Al, Fe, Cr, Cu, As, Pb were above the GVs in raw and 12-day settled leachates. Raw leachates had the highest concentration of metals and there was >50% reduction in metal concentrations in the 12-day settled corresponding leachates. Filtered leachates had the lowest concentrations of metals and only aluminium and chromium were still reported to be higher than the GVs. However, Al was also exceeding the 99% GV value (27 µg/L) in the Tantangara Reservoir water samples.

Table 13. The pH, EC, dissolved oxygen, turbidity, major cations, sulphur and phosphorus in background water samples from Talbingo and Tantangara Reservoirs

Sample	pH	DO % Saturation	EC µs/cm	Turbidity NTU	Ca mg/L	K mg/L	Mg mg/L	Na mg/L	S mg/L	P mg/L
TN1-B	7.84	104.5	31.0	0.51	1.4	0.6	0.9	1.6	<0.2	0.2
TN2-B	7.87	105.5	31.4	1.06	1.4	0.6	0.9	1.7	<0.2	0.1
TN3-B	8.00	108.5	32.1	0.79	1.4	0.6	0.9	1.7	<0.2	0.2
TAL-PL1C	7.71	107.1	30.4	1.81	1.6	0.4	0.7	1.6	<0.2	0.2
TAL-PL2C	7.76	104.3	30.1	2.55	1.6	0.4	0.7	1.6	<0.2	0.2
TAL-PL1D	7.58	106.2	33.0	1.83	1.6	0.4	0.7	1.5	<0.2	0.2
TAL-PL2D	7.67	104.6	30.3	0.77	1.6	0.4	0.7	1.5	<0.2	0.2
Min	7.58	104.3	30.1	0.51	1.4	0.4	0.7	1.5	<0.2	0.1
Max	8.0	108.5	33.0	2.55	1.6	0.6	0.9	1.7	<0.2	0.2
95% GV[a]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**0.39**	**8.51**
99% GV[a]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**0.01**	**-**

http://www.waterquality.gov.au/anz-guidelines/guideline-values/default/water-quality-toxicants/

[a] GV guideline value represents the 95% (95% GV) and 99% (99% GV) species protection guideline values for freshwater. Values highlighted in red and blue is where default guideline value is exceeded.

Table 14. The concentrations of metals and metalloids in background water samples from Talbingo and Tantangara Reservoirs

Sample	Al µg/L	As µg/L	B mg/L	Ba µg/L	Cd µg/L	Co µg/L	Cr µg/L	Cu µg/L	Fe µg/L	Hg µg/L	Mn µg/L	Mo µg/L
TN1-B	45	<0.5	<0.05	4.1	<0.1	<0.1	<1	<0.5	304	<0.5	3	<0.1
TN2-B	50	<0.5	<0.05	4.0	<0.1	<0.1	<1	<0.5	306	<0.5	3	<0.1
TN3-B	50	<0.5	<0.05	2.9	<0.1	<0.1	<1	<0.5	309	<0.5	2	<0.1
TAL-PL1C	7	<0.5	<0.05	2.8	<0.1	<0.1	<1	<0.5	13	<0.5	<1	<0.1
TAL-PL2C	7	<0.5	<0.05	3.0	<0.1	<0.1	<1	<0.5	14	<0.5	<1	<0.1
TAL-PL1D	2	<0.5	<0.05	1.2	<0.1	<0.1	<1	<0.5	8	<0.5	<1	<0.1
TAL-PL2D	4	<0.5	<0.05	1.2	<0.1	<0.1	<1	<0.5	8	<0.5	<1	<0.1
Min	2	<0.5	<0.05	1.2	<0.1	<0.1	<1	<0.5	8	<0.5	<1	<0.1
Max	50	<0.5	<0.05	4.1	<0.1	<0.1	<1	<0.5	309	<0.5	3	<0.1
95% GV[a]	**55**	**13**	**0.37**	**-**	**0.2**	**-**	**0.4**	**1.4**	**700**	**-**	**1900**	**-**
99% GV[a]	**27**	**0.8**	**0.09**	**-**	**0.06**	**-**	**0.01**	**1**	**400**	**-**	**1200**	**-**
Sample	**Ni µg/L**	**Pb µg/L**	**Sb µg/L**	**Se µg/L**	**Si mg/L**	**Sn µg/L**	**Sr µg/L**	**Th µg/L**	**U µg/L**	**V µg/L**	**Zn µg/L**	
TN1-B	<0.5	<0.1	<0.5	0.5	0.4	<0.5	11.2	<0.1	<0.05	0.2	0.8	
TN2-B	<0.5	<0.1	<0.5	0.6	0.4	<0.5	10.9	<0.1	<0.05	0.2	<0.5	
TN3-B	<0.5	<0.1	<0.5	0.8	0.5	<0.5	9.7	<0.1	<0.05	0.2	<0.5	
TAL-PL1C	<0.5	<0.1	<0.5	2.0	0.6	<0.5	12.2	<0.1	<0.05	<0.1	<0.5	
TAL-PL2C	<0.5	<0.1	<0.5	2.0	0.7	<0.5	11.3	<0.1	<0.05	<0.1	<0.5	
TAL-PL1D	<0.5	<0.1	<0.5	2.0	0.3	<0.5	6.3	<0.1	<0.05	<0.1	<0.5	
TAL-PL2D	<0.5	<0.1	<0.5	2.0	0.5	<0.5	7.6	<0.1	<0.05	<0.1	<0.5	
Min	<0.5	<0.1	<0.5	0.55	0.30	<0.5	6.30	<0.1	<0.05	<0.1	<0.5	
Max	<0.5	<0.1	<0.5	2.01	0.70	<0.5	12.20	<0.1	<0.05	0.2	0.8	
95% GV[a]	**11**	**3.4**	**-**	**11**	**-**	**-**	**-**	**-**	**-**	**-**	**8**	
99% GV[a]	**8**	**1**	**-**	**5**	**-**	**-**	**-**	**-**	**-**	**-**	**2.4**	

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[a] GV guideline value represents the 95% (95% GV) and 99% (99% GV) species protection guideline values for freshwater. Values highlighted in red and blue is where default guideline value is exceeded. Values for arsenic are for As(V), chromium are for Cr(VI), and tin are for inorganic tin

Table 15. The pH, EC, dissolved oxygen, turbidity, major cations, sulphur and phosphorus in leachates of excavated rock from seven geological zones

Sample			pH	DO % Saturation	EC µs/cm	Turbidity NTU	Ca mg/L	K mg/L	Mg mg/L	Na mg/L	S mg/L	P mg/L
Ravine	**Baseline**	**Raw**	7.91	81.3	121.4	4390	5.9	12	22	6	<1	<1
		Settling	7.59	93.9	119.3	150	4.4	8.9	11	5.1	<1	<1
		Filtered	7.55	90.7	103.6	1.49	4.2	6.7	2.1	7.3	**0.3**	<0.2
	Enriched	**Raw**	7.86	88.4	160.0	8370	5	16	26	<5	<5	<5
		Settling	7.79	93.1	143.7	99.7	5.4	7.3	8.2	4.9	**1.1**	<1
		Filtered	7.86	92.6	146.5	2.62	4.1	11	3.3	4.9	**1.3**	<0.2
Byron	**Baseline**	**Raw**	7.83	83.3	192.1	7810	9.9	85	19	5	<1	<1
		Settling	7.23	93.6	149.8	570	6.4	45	8.1	4.3	**0.4**	<1
		Filtered	7.50	89.2	148.9	4.23	2.6	24	0.7	5.5	**0.9**	<0.2
	Enriched	**Raw**	7.93	84.7	250.0	6890	7	42	10	<5	<5	<5
		Settling	7.68	95.3	196.1	53.1	9.0	17	2.8	4.2	**3.0**	<1
		Filtered	7.93	93.6	198.0	2.14	4.3	27	1.3	3.8	**2.9**	<0.2
Shaw Gabbro	**Baseline**	**Raw**	7.98	84.4	154.6	1750	5.1	5	4.6	8	<1	<1
		Settling	7.67	93.7	135.4	7.02	5.2	5.2	1.9	6.7	<1	<1
		Filtered	7.64	90.8	110.3	0.46	3.2	8.2	2.0	10	**0.2**	<0.2
	Enriched	**Raw**	7.82	87.7	147.7	824	8	9	6	<5	<5	<5
		Settling	7.82	93.4	111.1	30.7	6.6	3.4	1.9	3.9	<1	<1
		Filtered	7.86	93.0	114.4	6.38	4.0	7.3	1.0	4.5	**0.3**	<0.2
Volcanics	**Baseline**	**Raw**	8.04	80.6	160.8	2930	7.0	15	6.1	8	<1	<1
		Settling	7.73	93.7	133.9	61.4	4.9	9.3	1.5	5.6	<1	<1
		Filtered	7.67	90.0	114.3	4.92	5.2	13	0.9	7.7	**0.3**	<0.2
	Enriched	**Raw**	7.83	91.1	123.4	436.8	8	<5	<3	<5	<5	<5
		Settling	7.80	93.8	122.4	2.06	7.8	2.4	0.9	3.1	**1.1**	<1
		Filtered	7.82	92.8	132.7	3.37	7.8	8.4	1.3	5.0	**3.3**	<0.2
Peppercorn	**Baseline**	**Raw**	7.97	80.6	131.6	3340	8.7	16	11	7	<1	<1
		Settling	7.50	94.1	111.7	155	5.9	9.0	4.1	5.4	<1	<1
		Filtered	7.53	90.1	93.7	3.14	5.5	6.3	1.5	6.6	**0.4**	<0.2
	Enriched	**Raw**	7.81	88.1	168.1	436.8	9	16	9	<5	<5	<5
		Settling	7.71	93.6	138.5	103	8.8	7.5	4.0	5.5	**2.8**	<1
		Filtered	7.83	92.7	143.8	3.42	5.3	8.3	1.8	5.3	**3.9**	<0.2
Kelly's Plain	**Enriched**	**Raw**	7.89	88.7	144.6	6660	5	31	17	<5	<5	<5
		Settling	7.74	93.8	126.3	196	4.4	11	8.1	4.6	**2.1**	<1
		Filtered	7.84	93.2	139.9	1.75	2.6	7.4	3.9	4.4	**3.1**	<0.2
Felsic	**Baseline**	**Raw**	7.96	81.4	152.2	6290	8.7	20	11	7	<1	<1
		Settling	7.43	94.3	125.2	153	6.0	10	3.0	6.3	<1	<1
		Filtered	7.53	90.2	105.8	1.71	5.4	8.4	1.1	8.1	**0.2**	<0.2
	Enriched	**Raw**	8.05	87.6	203.8	6920	11	115	32	<5	<5	<5
		Settling	7.74	95.4	159.4	531	9.9	48	12	4.9	**1.1**	<1
		Filtered	7.90	93.0	165.8	6.69	3.3	18	1.1	5.1	**1.4**	<0.2
		Min	7.23	80.6	93.7	0.46	2.6	2.4	0.7	3.1	0.2	<0.2
		Max	8.05	95.4	250.0	8370	10.5	115.1	32.4	10.3	3.9	<5
		95% GV[a]	-	-	-	-	-	-	-	-	**0.39**	**8.51**
		99% GV[a]	-	-	-	-	-	-	-	-	**0.01**	-

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Table 16. The concentrations of metals and metalloids in leachates of excavated rock from seven geological zones (part A)

Sample ID			Al µg/L	As µg/L	B mg/L	Ba µg/L	Cd µg/L	Co µg/L	Cr µg/L	Cu µg/L	Fe µg/L	Hg µg/L	Mn µg/L	Mo µg/L
Ravine	**Baseline**	**Raw**	**39011**	**19**	<0.2	220	<0.5	17.4	**112**	**39**	**29236**	<3	625	<2
		Settling	**17794**	**11**	<0.2	119	<0.5	6.9	**77**	**8**	**14437**	<3	208	<2
		Filtered	**181**	**5.7**	<0.05	2.0	<0.1	0.08	**0.6**	0.4	79	<0.5	1.4	<0.4
	Enriched	**Raw**	**35794**	<10	<1	286	<3	16	**148**	<5	**30402**	<10	759	<10
		Settling	**9561**	<2	<0.2	111	<0.5	3.5	**58**	**8**	**8292**	<3	205	<2
		Filtered	**131**	**2.9**	<0.05	17.9	<0.1	<0.05	<0.4	<0.2	59	<0.5	3.8	1.1
Byron	**Baseline**	**Raw**	**186110**	**20**	<0.2	1061	<0.5	10.7	**74**	**10**	**14764**	<3	358	9
		Settling	**84476**	**15**	<0.2	482	<0.5	3.6	**51**	**3**	**13616**	<3	113	3
		Filtered	**400**	**12.2**	<0.05	5.3	<0.1	<0.05	**2.1**	<0.2	60	<0.5	0.9	3.2
	Enriched	**Raw**	**59828**	**11**	<1	437	<3	9	**88**	<5	**17998**	<10	135	32
		Settling	**7683**	**6**	<0.2	56	<0.5	1.3	**35**	**8**	**2075**	<3	23	5
		Filtered	**52**	**7.6**	<0.05	2.6	<0.1	<0.05	<0.4	<0.2	3	<0.5	0.6	9.0
Shaw Gabbro	**Baseline**	**Raw**	**2491**	<2	<0.2	3	<0.5	4.1	**33**	**4**	**2191**	<3	49	<2
		Settling	**483**	<2	<0.2	3	<0.5	1.0	**38**	**3**	**310**	<3	10	<2
		Filtered	**214**	0.7	<0.05	<0.4	<0.1	0.05	**8.0**	0.3	4	<0.5	<0.4	<0.4
	Enriched	**Raw**	**19904**	<10	<1	172	<3	9	**54**	**9**	**8516**	<10	245	<10
		Settling	**5093**	**2**	<0.2	41	<0.5	1.7	**36**	**5**	**2150**	<3	64	<2
		Filtered	**144**	**2.4**	<0.05	5.3	<0.1	<0.05	**0.5**	0.6	34	<0.5	1.8	<0.4
Volcanics	**Baseline**	**Raw**	**27611**	**18**	<0.2	269	<0.5	4.9	**29**	**8**	**9555**	<3	169	<2
		Settling	**5849**	**18**	<0.2	61	<0.5	1.3	**36**	**3**	**1812**	<3	29	2
		Filtered	**465**	**16.8**	<0.05	2.0	<0.1	0.05	**0.5**	0.4	25	<0.5	1.6	<0.4
	Enriched	**Raw**	**2273**	**15**	<1	25	<3	6	**31**	**71**	**876**	<10	16	<10
		Settling	**235**	**12**	<0.2	7	<0.5	0.7	**30**	**4**	57	<3	12	<2
		Filtered	**108**	**15.0**	<0.05	1.1	<0.1	<0.05	<0.4	0.3	16	<0.5	1.5	1.1
Peppercorn	**Baseline**	**Raw**	**37918**	**7**	<0.2	381	<0.5	7.1	**67**	**5**	**16079**	<3	292	4
		Settling	**17509**	**6**	<0.2	188	<0.5	2.9	**59**	**6**	**6491**	<3	92	4
		Filtered	**241**	**4.9**	<0.05	3.9	<0.1	0.07	**0.6**	0.3	60	<0.5	1.4	3.0
	Enriched	**Raw**	**37547**	<10	<1	890	<3	9	**70**	**31**	**15624**	<10	237	<10
		Settling	**13769**	**3**	<0.2	435	<0.5	2.3	**44**	**14**	**6106**	<3	92	<2
		Filtered	**545**	**2.6**	<0.05	83.9	<0.1	0.10	**0.7**	**1.2**	275	<0.5	5.8	1.7
Kelly's Plain	**Enriched**	**Raw**	**91102**	<10	<1	270	<3	13	**123**	**6**	**22727**	<10	251	17
		Settling	**35343**	**2**	<0.2	107	3.1	3.2	**58**	10	**8715**	<3	76	14
		Filtered	**369**	**1.7**	<0.05	8.0	<0.1	<0.05	**0.5**	<0.2	93	<0.5	3.3	12.1
Felsic	**Baseline**	**Raw**	**47513**	**3**	<0.2	314	<0.5	7.6	**72**	**6**	**18782**	<3	187	<2
		Settling	**14523**	**2**	<0.2	107	<0.5	2.1	**44**	**5**	**5629**	<3	65	<2
		Filtered	**218**	**2.1**	<0.05	3.3	<0.1	0.06	<0.4	0.2	37	<0.5	1.1	0.7
	Enriched	**Raw**	**204275**	**22**	<1	2063	<3	15	**167**	**17**	**46306**	<10	243	<10
		Settling	**97202**	**20**	<0.2	960	<0.5	5.0	**89**	**11**	**19816**	<3	121	2
		Filtered	**709**	**19.4**	<0.05	25.0	<0.1	0.06	**0.6**	**1.9**	122	<0.5	1.2	2.3
		Min	52	1	<0.05	1	3	<0.05	1	0	3	<0.5	1	1
		Max	204275	22	<1	2063	3	17	167	71	46306	<10	759	32
		95% GV[a]	**55**	**13**	**0.37**	**-**	**0.2**	**-**	**0.4**	**1.4**	**700**	**-**	**1900**	**-**
		99% GV[a]	**27**	**0.8**	**0.09**	**-**	**0.06**	**-**	**0.01**	**1**	**400**	**-**	**1200**	**-**

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Table 17. The concentrations of metals and metalloids in leachates of excavated rock from seven geological zones (part B)

Sample ID			Ni µg/L	Pb µg/L	Sb µg/L	Se µg/L	Si mg/L	Sn µg/L	Sr µg/L	Th µg/L	U µg/L	V µg/L	Zn µg/L
Ravine	**Baseline**	**Raw**	**93**	**16**	<3	4	45	5	84	10.9	2.2	93	**86**
		Settling	**45**	**4**	2	4	24	3.7	73	4.0	0.9	43	**28**
		Filtered	0.3	<0.4	1.0	0.5	2.7	1.0	33.8	<0.1	<0.1	3.6	<0.5
	Enriched	**Raw**	**111**	**137**	<10	<10	40	15	71	<3	<3	113	**115**
		Settling	**26**	**43**	8	4	13	3.0	95	0.6	<0.5	26	**37**
		Filtered	0.3	<0.4	8.4	<0.5	1.8	<0.1	31.9	<0.1	<0.1	3.5	<0.5
Byron	**Baseline**	**Raw**	**32**	**12**	7	**33**	27	26	55	32.1	7.2	152	**47**
		Settling	**11**	**4**	7	3	51	11.0	34	8.5	3.3	67	**15**
		Filtered	0.2	<0.4	6.5	0.7	3.7	0.9	9.0	<0.1	0.2	5.7	<0.5
	Enriched	**Raw**	**17**	**12**	33	<10	54	38	49	12	<3	107	**20**
		Settling	3	<2	14	4	9.9	3.9	78	0.6	1.4	13	**8**
		Filtered	<0.2	<0.4	15.4	1.1	1.7	<0.1	18.9	<0.1	<0.1	5.7	<0.5
Shaw Gabbro	**Baseline**	**Raw**	5	<2	<3	<3	5	4	5	<0.5	<0.5	15	**6**
		Settling	1	<2	<2	4	2.3	1.3	5	<0.5	<0.5	11	**4**
		Filtered	<0.2	<0.4	<0.5	<0.5	2.1	0.8	2.5	<0.1	<0.1	8.1	<0.5
	Enriched	**Raw**	**14**	<10	<10	<10	23	13	32	14	<3	41	**22**
		Settling	3	2	<2	3	8.6	2.9	28	3.6	0.9	13	**8**
		Filtered	<0.2	<0.4	<0.5	<0.5	2.1	<0.1	6.7	<0.1	0.2	5.4	<0.5
Volcanics	**Baseline**	**Raw**	7	**14**	<3	4	30	4	47	11.9	1.7	35	**23**
		Settling	2	**3**	<2	4	8.2	2.5	22	2.2	0.8	11	**6**
		Filtered	<0.2	<0.4	0.7	<0.5	2.3	<0.4	9.5	<0.1	0.1	4.4	<0.5
	Enriched	**Raw**	**108**	<10	<10	<10	<5	11	15	<3	<3	16	**428**
		Settling	1	<2	2	<3	1.1	1.6	21	<0.5	<0.5	9	<3
		Filtered	<0.2	<0.4	2.5	<0.5	1.2	<0.1	14.1	<0.1	0.2	6.5	<0.5
Peppercorn	**Baseline**	**Raw**	**17**	4	<3	5	47	7	60	12.4	3.0	74	**27**
		Settling	7	<2	<2	<3	24	3.7	41	3.9	1.6	34	**13**
		Filtered	<0.2	<0.4	<0.5	<0.5	3.3	0.7	17.6	<0.1	0.2	3.9	<0.5
	Enriched	**Raw**	**26**	<10	<10	<10	34	16	32	4	<3	69	**49**
		Settling	**10**	**4**	<2	5	18	3.6	44	1.2	0.6	23	**16**
		Filtered	0.7	<0.4	1.4	<0.5	2.2	0.2	16.3	<0.1	0.1	3.9	<0.5
Kelly's Plain	**Enriched**	**Raw**	**18**	**35**	<10	<10	56	26	23	15	6	207	**53**
		Settling	7	**7**	<2	5	39	7.5	18	3.5	2.1	61	**19**
		Filtered	0.2	<0.4	0.6	<0.5	3.5	0.6	4.2	<0.1	0.1	3.0	1.0
Felsic	**Baseline**	**Raw**	**13**	5	4	3	54	7	113	8.6	1.7	109	**21**
		Settling	4	<2	3	4	21	3.0	82	2.4	0.9	37	**8**
		Filtered	<0.2	<0.4	1.8	0.5	2.6	0.4	42.2	<0.1	<0.1	8.7	<0.5
	Enriched	**Raw**	22	**15**	12	<10	33	74	101	21	6	410	**66**
		Settling	**8**	**8**	6	4	45	22.6	123	5.5	3.8	157	**26**
		Filtered	<0.2	<0.4	5.9	<0.5	3.8	0.6	19.4	<0.1	0.4	10.4	**6.2**
		Min	<0.2	<0.4	0.6	<0.5	1.1	<0.1	2.5	<0.1	<0.1	3.0	<0.5
		Max	111	137	33	33	56	74	123	32	7	410	428
		95% GV[a]	**11**	**3.4**	**-**	**11**	**-**	**-**	**-**	**-**	**-**	**-**	**8**
		99% GV[a]	**8**	**1**	**-**	**5**	**-**	**-**	**-**	**-**	**-**	**-**	**2.4**

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3.5 Toxicity of leachates of excavated rock to macroinvertebrates

3.5.1 Leachate toxicity to the water flea (*Ceriodaphnia dubia*)

Acute toxicity

Results on acute toxicity of raw (Scenario 1), 12-day settled (Scenario 2), and filtered (Scenario 3) leachates of excavated rock to water fleas over 48 h exposure are given below:

- Reservoir water samples (Tantangara Reservoir from three locations; Talbingo Reservoir from three locations, and pooled reservoir water samples) and QA control treatments exhibited >95% survival of water fleas over 48-h exposures, and thus did not exhibit any adverse effects (Appendix D, Table D3 and Table D4).
- Toxicity tests with water fleas are generally carried out in waters with higher EC and the low EC of the reservoir water may affect the survival of waterfleas during 48-h acute exposures. Acute toxicity testing using dilutions of moderately hard water (MHW) at EC between 30-300 µS/cm did not demonstrate significant mortality in the exposed water flea (*C. dubia,* Appendix D, Table D5).
- Water fleas exhibited 100% mortality during 48-h exposures to all 1:10 raw leachates of Baseline and Enriched excavated rock samples, except the Baseline Volcanics sample (70% mortality (Figure 5);
- Raw leachates (Scenario 1) demonstrated very high turbidity. Values were 427-774 NTU in 1:10 Enriched leachates from Peppercorn, Volcanics and Shaw Gabbo zones. Higher turbidities (666-837 NTU) were present in 1:100 leachates for Byron, Felsic, Kelly Plains and Ravine zones.
- 12-day settled leachates (Scenario 2) from Byron, Volcanics and Felsics exhibited toxicity to water fleas with turbidity of 570, 61 and 153, respectively (Table 15). All Enriched 12-day settled leachates did not exhibit toxicity to waterfleas and the measured turbidity in these samples varied between 2-200 NTU.
- All filtered leachate samples (1:10) of Baseline and Enriched excavated rock samples (Scenario 3) showed >90% survival in water fleas (Figure 5) and the turbidity all filtered leachates varied between 0.5-6 NTU (Table 15).
- Acute toxicity to water fleas was completely removed after filtration of raw leachates. This confirms that the high content of the suspended sediments in the raw leachates was the major contributor to the high mortality observed in water fleas during 48 h exposures.
- There were no clear trends between the dissolved metal concentrations in the leachates and the toxicity observed.

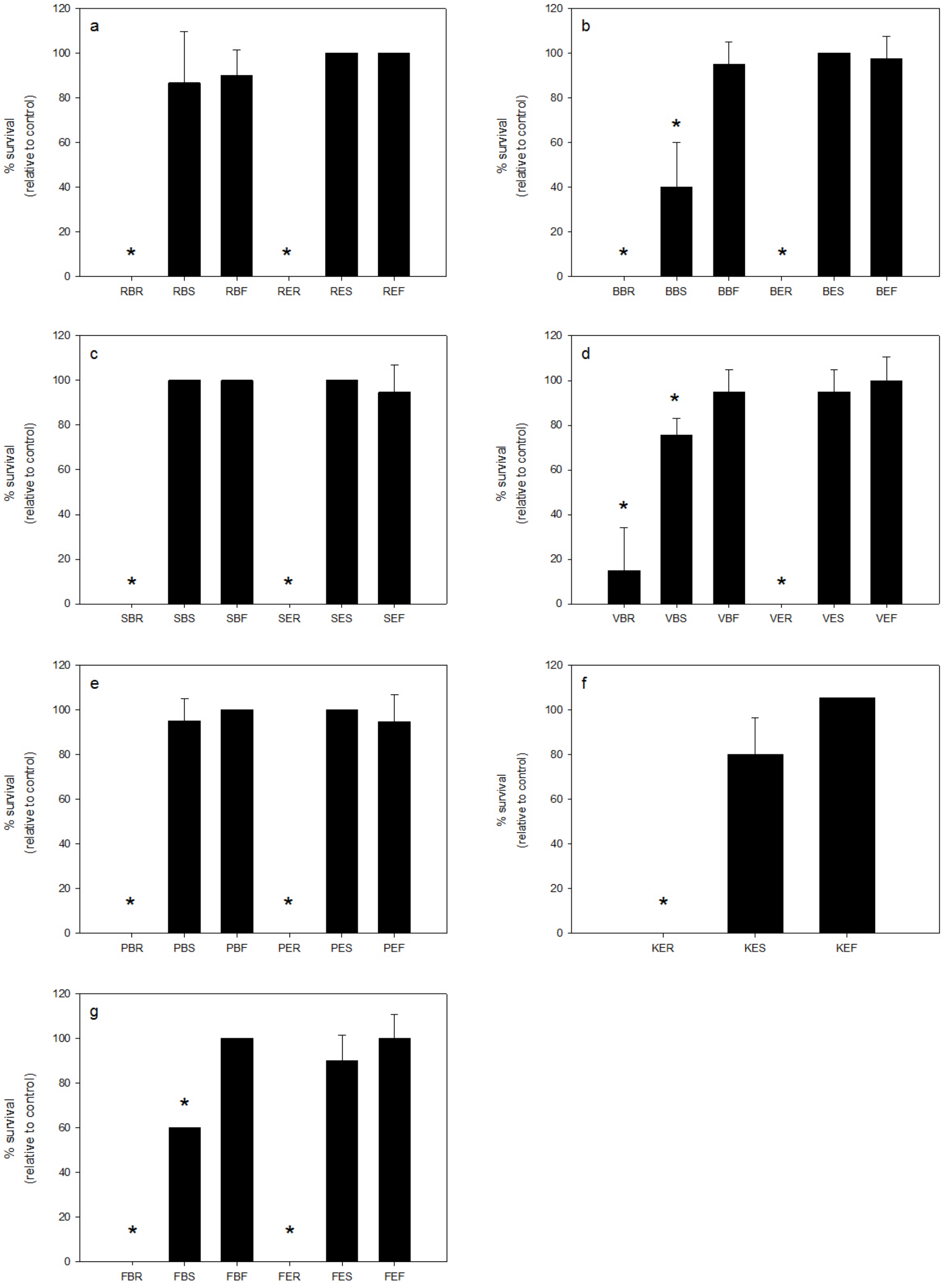


Figure 5. Acute toxicity of leachates of excavated rock to water fleas *Ceriodaphnia dubia* (48-h immobilisation/survival). Data expressed as percent survival. Geological units are (a) Ravine, (b) Byron, (c) Shaw Gabbro, (d) Volcanics, (e) Peppercorn, (f) Kellys Plain and (g) Felsic. The x-axis labels consist of three letters; first letter represents the geological zone R, B, S, V, P, K and F respectively; second letter represents Baseline (B) or Enriched (E) excavated rock; third letter represents raw (R), after 24 h settling (S) and filtered (F) fraction of leachate. Error bars represent 1 standard deviation. * indicates treatment is significant different to the control treatment ($p \leq 0.05$).

Acute toxicity of Byron baseline leachates to water fleas

A preliminary toxicity assessment of the dilutions of raw leachate (after 24 h settling) from a Byron Baseline sample was conducted. The toxicity was expressed as the dilution series of the leachate (1:10) and also expressed as turbidity. A 12.5% dilution of the leachate, corresponding to 1640 NTU, exhibited toxicity to water fleas with only 50% survival during 48-h exposures (Figure 6 and Figure 7). The undiluted raw leachate (100%) and its 50 % dilution (representing 6400 and 20,608 NTU turbidity, respectively) resulted in 100% mortality of waterfleas during 48 h exposures (Figures 6 and 7).

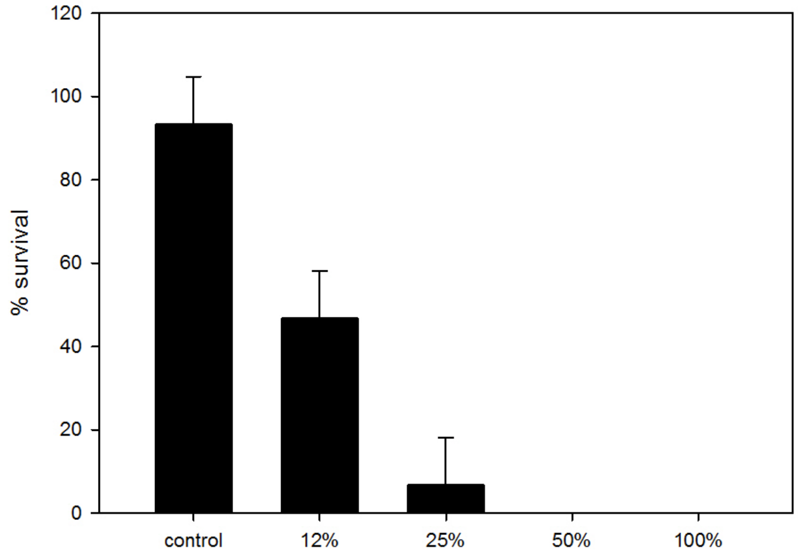


Figure 6. Acute toxicity (48 h) response of the raw leachate for Byron Baseline excavated rock, controls represent reservoir water (n=20/treatment). 50 and 100% treatments resulted in 100% mortality of exposed waterfleas.

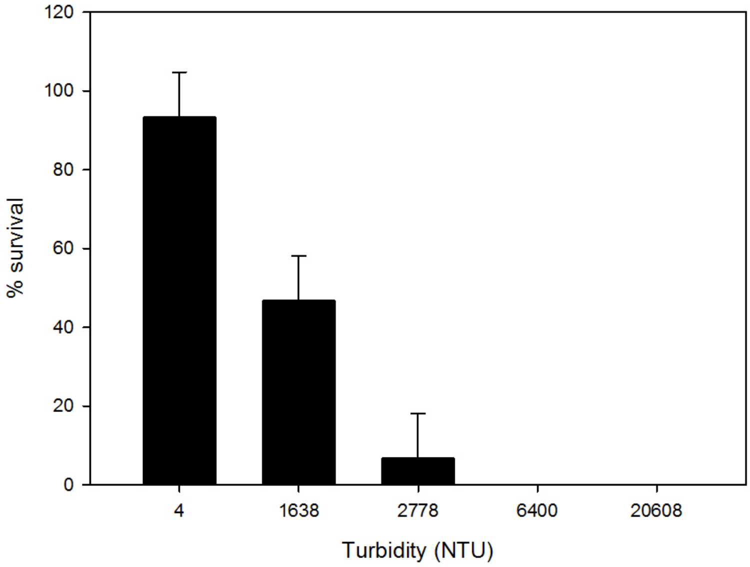


Figure 7. Acute toxicity (48 h) response of the Byron Baseline excavated rock leachate dilutions expressed as turbidity units. 3.8 NTU represents turbidity of reservoir water. 6400 and 20608 NTU resulted in 100% mortality of exposed waterfleas.

Chronic toxicity to water fleas

Chronic toxicity assessment to water fleas was conducted using 0.45 µm filtered Enriched samples only. The tests conducted were based on survival and reproduction endpoints. The undiluted filtered leachate (100%) from Kelly's Plain Enriched excavated rock sample exhibited a significant effect on reproduction success of water fleas, with the number of neonates produced in three broods over 8 days (Mean 9.6 ± 4.7; n=10) suppressed in comparison to the control treatment (Mean: 16.3 ± 2.1, n=10; Figure 8; Appendix D). In addition, 20% water flea mortality was exhibited in Volcanics undiluted filtered leachate and 10% in both Kelly's Plain and Ravine undiluted filtered samples but these effects were non-significant. The undiluted filtered leachates representing Ravine, Byron, Shaw Gabbro, Volcanics, Peppercorn and Felsic zones did not exhibit any chronic toxicity to waterfleas during 8-day exposure.

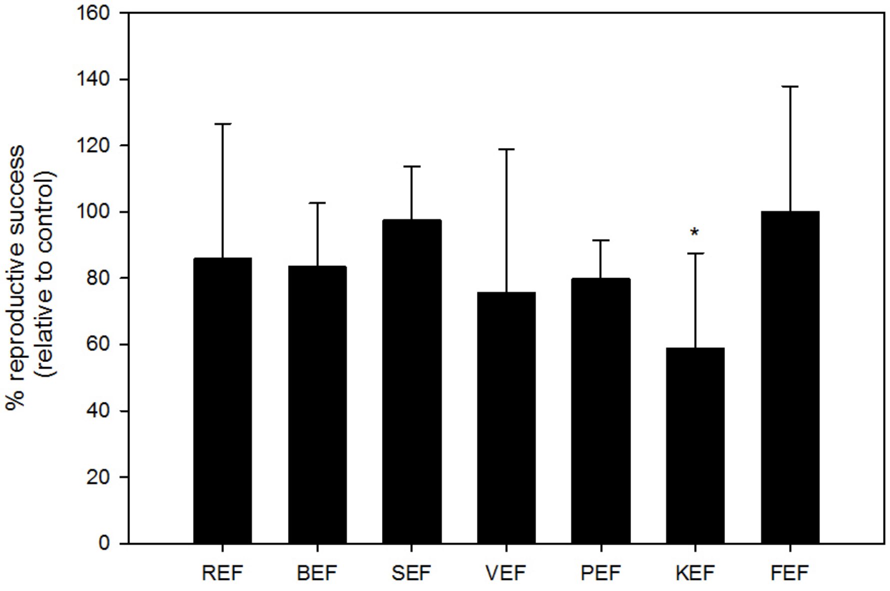


Figure 8.. Chronic toxicity of leachates of excavated rock material to the water flea *Ceriodaphnia dubia* (8-d reproduction). Data expressed as relative to reservoir water control (as a percentage of the reservoir water control). Geological units are (a), (b) Byron, (c) Shaw Gabbro, (d) Volcanics, (e) Peppercorn, (f) Kellys Plain and (g) Felsic. The x-axis labels consist of three letters; first letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F); second letter represents Enriched (E) excavated rock material; third letter represents the filtered (F) fraction of leachate tested. Error bars represent 1 standard deviation, n=10 per treatment. * indicates treatment is significant different to the control treatment (p≤0.05).

3.5.2 Leachate toxicity to midge larvae

- Water from Tantangara Reservoir (three locations) and Talbingo Reservoir (three locations) did not exhibit acute toxicity to midge larvae over 48 h exposures (Appendix E, Table E3).
- Toxicity tests with midge are generally carried out in waters with higher EC (~ 270-320 µS/cm) and the low EC of the reservoir water may have affected the survival of midge larvae during 48-h acute exposures. Acute toxicity testing using dilutions of MHW at EC between 30-300 µS/cm and sodium chloride (125-2000mg/L) did not demonstrate significant mortality in the exposed midge larvae (*C. tepperi,* Appendix E, Table E4 and Table E5*).*This confirmed the use of reservoir water as controls for leachate testing.
- Baseline raw leachates (1:10) did not indicate toxicity to midge larvae during 48-h acute exposures (Figure 9) with turbidity measured in the range of (Table ---)
- Midge larvae exhibited significant toxicity to raw Enriched leachates from Byron, Ravine, Shaw and Volcanics during 48-h exposures (Figure 9) with turbidity of 4390, 7810, 1750 and 436 NTU, respectively (Table 15).
- Further midge testing using Enriched 12-day settled leachates showed toxicity only in Kelly's Plain Enriched sample with turbidity of 196 NTU.
- There were no clear trends between the turbidity and dissolved metal concentrations in the leachates and the toxicity observed in the midge larvae.

3.5.3 Leachate toxicity to blackworms

- Water from Tantangara Reservoir (three locations) and Talbingo Reservoir (three locations) did not exhibit toxicity to blackworms (Appendix F, Table F3).
- Toxicity tests with blackworms are generally carried out in waters with higher EC and the low EC of the reservoir water may have affected the survival of blackworms during 48-h acute exposures. Acute toxicity testing using dilutions of moderately hard water (MHW) at EC between 30-300 µS/cm did not demonstrate significant mortality in the exposed midge larvae (*L. variegatus,* Appendix F, Table F4*).*
- Blackworms exhibited no acute toxicity (with 100% survival) when exposed to Baseline and Enriched raw leachates (1:10) under Scenario 1. (Figure 10).
- No further toxicity testing was conducted with 12-day settled and filtered leachates representing Scenarios 2 and 3.

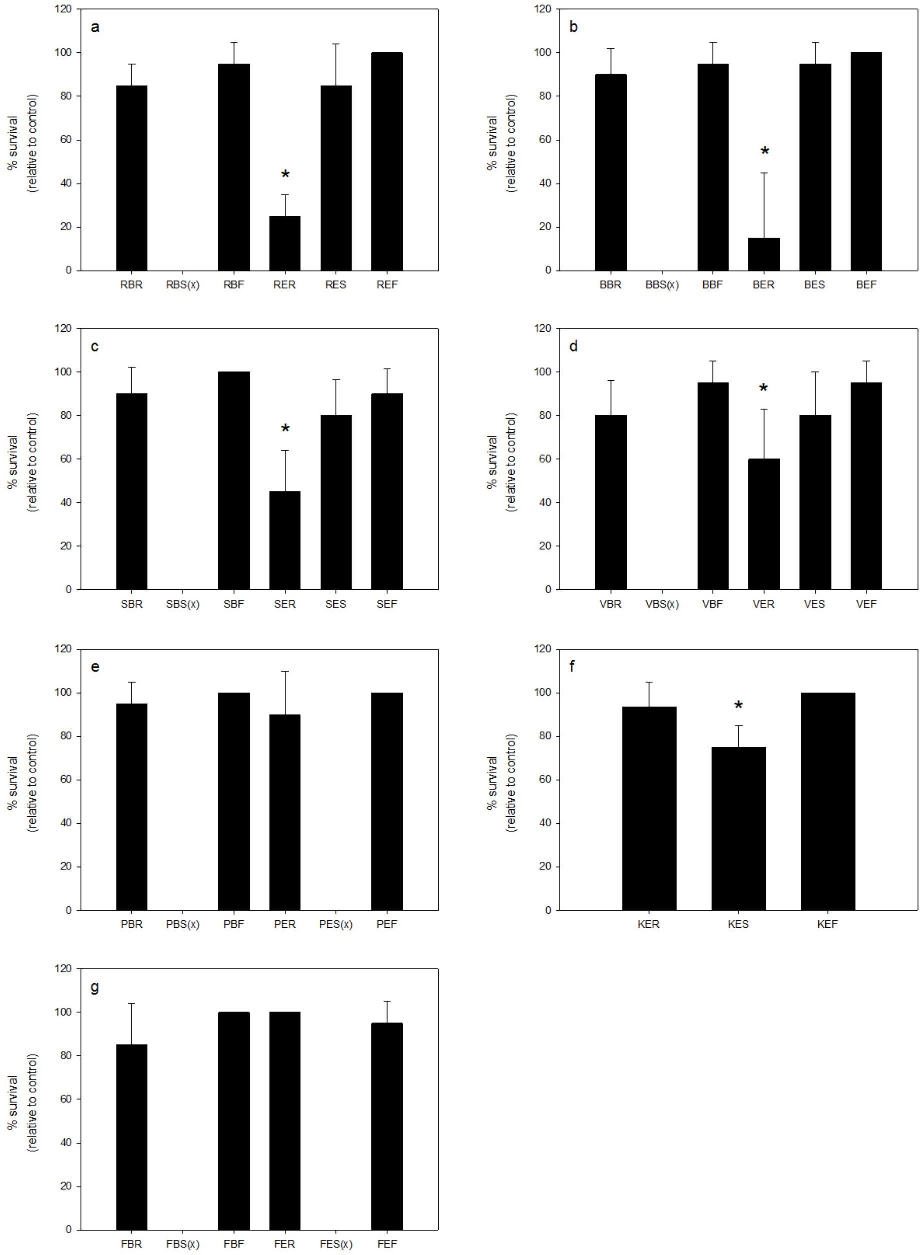


Figure 9. Acute toxicity of leachates of excavated rock to the midge *Chironomus tepperi* (48-h survival). Data expressed as percent survival. Geological units are (a) Ravine, (b) Byron, (c) Shaw Gabbro, (d) Volcanics, (e) Peppercorn, (f) Kellys Plain and (g) Felsic. The x-axis labels consist of three letters; first letter represents the geological zone R, B, S, V, P, K and F respectively; second letter represents Baseline (B) or Enriched (E) excavated rock; third letter represents raw (R), after 24 h settling (S) and filtered (F) fraction of leachates. Error bars represent 1 standard deviation. * indicates treatment is significant different to the control treatment ($p \leq 0.05$).

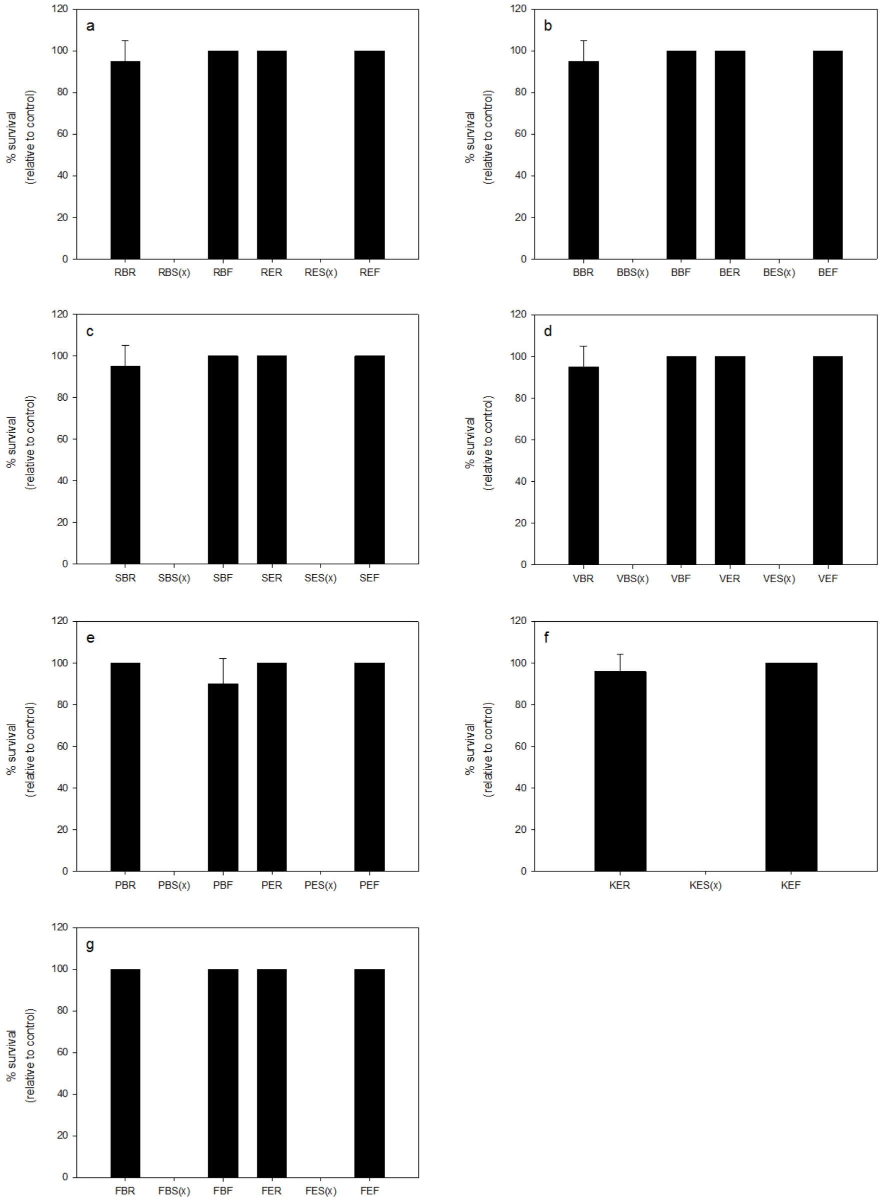


Figure 10. Acute toxicity of leachates of excavated rock to blackworm *Lumbriculus variegatus* (48-h survival). Data expressed as percent survival. Geological units are (a) Ravine, (b) Byron, (c) Shaw Gabbro, (d) Volcanics, (e) Peppercorn, (f) Kellys Plain and (g) Felsic. The x-axis labels consist of three letters; first letter represents the geological zone R, B, S, V, P, K and F respectively; second letter represents Baseline (B) or Enriched (E) excavated rock; third letter represents raw (R) and filtered (F) fraction of leachate. Error bars represent 1 standard deviation. * indicates treatment is significant different to the control treatment ($p \leq 0.05$).

3.6 Characterisation of reservoir sediments used for determining toxicity to macroinvertebrates

The total nitrogen, phosphorus, inorganic and organic carbon in the benthic reservoir sediments are shown in Table 18. Spatial variation of sediment quality was evident. For Talbingo Reservoir, the Ravine Bay sites had lower concentrations of many parameters than the Cascade Bay and Plain Creek Bay sites. The Tantangara Reservoir sediments had similar or higher concentrations of each parameter than those in Talbingo Reservoir, with concentrations of varying approximately two-fold between the different sites in the two reservoirs. There were generally higher concentrations of Sb, Ca, Cr, Cu, Fe, K, Mg, Mn, Ni, Na, Sr, Sn, Ti, and U in the Talbingo sediments and a higher concentration of sulphur in the Tantangara sediments (Table 18).

These concentrations reflect the background surface sediment concentrations with the concentrations of nickel exceeding the corresponding sediment quality guideline value (SQGV) (Simpson et al., 2013; ANZG, 2018), which some consider an overly conservative value (Vangheluwe et al., 2013; Simpson and Batley, 2016).

A significant portion of the total element concentration (extracted using concentrated acids) may release inert (not easily released) fractions of metals of very low bioavailability. For most metals, the ‘maximum bioavailable concentration’ can be determined by dilute-acid-extractable metal (AEM) analyses, as commonly achieved by extracting the solid in 1-M hydrochloric acid for 1 h (Simpson and Batley, 2016). AEM data can also be useful for interpreting the partitioning of elements between the dissolved and particulate phases, and the availability of reactive binding phases.

There was generally little variation in the dilute-acid-extractable concentrations of metal, metalloid, and other major ions between the different sites in Talbingo Reservoir (Table 19). No concentrations of dilute-acid-extractable metals, metalloids and major cations exceeded their respective SQGVs.

Table 18. Concentrations of carbon, nitrogen, total recoverable metals, metalloids and other elements in reservoir sediments

Sample	C (Total)	N (Total)	Ca	K	Mg	Na	S	P	Al	As	B	Cd
Reservoir sediments	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
PL1	5.7	0.50	1500	4200	4700	120	440	1100	42000	9	5	<4
PL2	5.6	0.41	1700	4700	4900	130	450	1100	46000	9	6	<4
RPL1	3.9	0.29	1300	4200	4500	90	260	620	31000	6	5	<4
RPL2	3.8	0.27	1300	4500	4600	90	270	630	33000	6	7	<4
TN1	5.8	0.48	600	4500	2900	110	650	1200	47000	6	6	<4
TN2	5.8	0.53	600	4500	3000	110	660	1200	47000	6	5	<4
RA1	4.1	0.34	1300	4900	5500	110	350	930	41000	11	7	<4
RA2	4.0	0.34	1300	5300	5600	120	350	920	43000	10	8	<4
PL-TN &RA1	4.9	0.42	1200	4900	4600	120	460	1000	44000	9	7	<4
PL-TN &RA2	5.0	0.43	1000	3900	4000	110	450	1000	38000	9	4	<4
Min	3.8	0	600	3900	2900	90	260	620	31000	6	4	<4
Max	5.8	1	1700	5300	5600	130	660	1200	47000	11	8	<4
SQGV[a]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**20**	**NA**	**1.5**

Sample	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Sb	Se	Zn
Reservoir sediments	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
PL1	27	66	46	47000	1900	<4	56	15	<8	<4	85
PL2	28	70	47	50000	1900	<4	57	16	<8	<4	89
RPL1	14	44	31	28000	900	<4	38	17	<8	<4	80
RPL2	14	46	32	28000	910	<4	38	18	<8	<4	81
TN1	19	39	27	37000	660	<4	21	20	<8	<4	99
TN2	20	39	28	38000	670	<4	22	21	<8	<4	100
RA1	21	57	46	40000	2400	<4	51	20	<8	<4	95
RA2	21	58	46	41000	2400	<4	52	21	<8	<4	96
PL-TN &RA1	22	55	42	42000	1800	<4	45	19	<8	<4	95
PL-TN &RA2	21	51	40	39000	1700	<4	42	19	<8	<4	90
Min	14	39	27	28000	660	<4	21	15	<8	<4	80
Max	28	70	47	50000	2400	<4	57	21	<8	<4	100
SQGV[a]	**NA**	**80**	**65**	**NA**	**NA**	**NA**	**21**	**50**	**NA**	**NA**	**200**

Table 19. Concentrations of dilute acid-extractable metals, metalloids and other elements in reservoir sediments

Sample Reservoir sediments	Ca mg/kg	K mg/kg	Mg mg/kg	Na mg/kg	S mg/kg	P mg/kg	Al mg/kg	As mg/kg	B mg/kg	Cd mg/kg	
PL1	1200	290	390	46	70	670	4300	4	<3	<3	
PL2	1100	300	400	36	65	660	4300	4	<3	<3	
RPL1	1200	300	250	21	43	320	2600	<3	<3	<3	
RPL2	1200	300	250	23	44	330	2600	<3	<3	<3	
TN1	600	190	170	23	110	760	4100	<3	<3	<3	
TN2	610	190	180	26	110	770	4200	<3	<3	<3	
RA1	1400	220	250	25	37	560	3500	4	<3	<3	
RA2	1400	220	240	22	36	550	3500	5	<3	<3	
PL-TN &RA1	1100	220	270	25	61	640	3900	4	<3	<3	
PL-TN &RA2	1100	230	280	30	65	660	4000	4	<3	<3	
Min	600	190	170	21	36	320	2600	<3	<3	<3	
Max	1400	300	400	46	110	770	4300	5	<3	<3	
SQGV[a]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**20**	**NA**	**1.5**	
Sample Reservoir sediments	**Co mg/kg**	**Cr mg/kg**	**Cu mg/kg**	**Fe mg/kg**	**Mn mg/kg**	**Mo mg/kg**	**Ni mg/kg**	**Pb mg/kg**	**Sb mg/kg**	**Se mg/kg**	**Zn mg/kg**
PL1	15	6	24	23000	1800	29	8	13	<6	<3	33
PL2	15	6	24	23000	1800	<3	8	13	<6	<3	64
RPL1	6	<3	17	7700	770	<3	4	15	<6	<3	50
RPL2	6	<3	17	8100	770	<3	4	15	<6	<3	46
TN1	14	5	15	21000	610	<3	4	14	<6	<3	68
TN2	14	5	15	21000	620	<3	4	14	<6	<3	69
RA1	11	5	26	17000	2300	<3	7	18	<6	<3	48
RA2	11	5	26	16000	2300	<3	7	18	<6	<3	47
PL-TN &RA1	13	5	23	19000	1800	<3	6	16	<6	<3	52
PL-TN &RA2	13	5	23	20000	1700	<3	7	15	<6	<3	52
Min	6	5	15	7700	610	<3	4	13	<6	<3	33
Max	15	6	26	23000	2300	29	8	18	<6	<3	69
SQGV[a]	**NA**	**80**	**65**	**NA**	**NA**	**NA**	**21**	**50**	**NA**	**NA**	**200**

[a] SQGV: The sediment quality guideline values (Simpson et al., 2013). Values highlighted in red is where default guideline value exceeded. NA-not available. For cadmium, the detection limit was higher than the sediment quality guideline value. However the concentrations were expected to be below the sediment quality guideline value based on cadmium concentrations reported in Simpson et al. (2019) (excavated rock material ≤1 mg/kg and reservoir water sediments ≤0.27 mg/kg)

3.7 Characterisation of excavated rocks used for sediment toxicity assessment

The total recoverable metal, metalloid, and major cation concentrations measured in the milled rock composites are shown in Table 20. The concentrations of all metals were below the corresponding SQGVs.

The AEM concentrations (see Section 3.6) of metals, metalloids and major cations measured in the milled rock composites are shown in Table 21. The concentrations of each parameter were all below their respective SQGVs.

Table 20. Concentrations of total recoverable metals, metalloids and other elements excavated rock material

Sample	C (Total)	N (Total)	Ca	K	Mg	Na	S	P	Al	As	B	Cd
Excavated rock	%	%	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/Kg
Ravine Baseline	0.38	0.04	6600	4400	18000	160	90	520	26000	8	9	<4
Ravine Enriched	0.28	0.04	5500	5500	20000	130	790	610	32000	7	10	<4
Byron Baseline	0.25	0.12	5600	9200	4400	200	130	340	24000	<4	12	<4
Byron Enriched	0.35	0.03	8600	8400	6900	170	3900	520	25000	11	13	<4
Shaw Gabbro Baseline	0.60	0.03	37000	2500	22000	430	<16	340	38000	<4	<4	<4
Shaw Gabbro Enriched	0.16	0.02	14000	1400	10000	240	<16	380	21000	<4	<4	<4
Volcanics Baseline	0.36	0.04	12000	5300	7000	560	<16	460	23000	<4	<4	<4
Volcanics Enriched	0.46	0.02	15000	2800	6800	210	5800	1100	20000	63	<4	<4
Peppercorn Baseline	0.21	0.00	6400	3000	6000	190	150	500	14000	<4	<4	<4
Peppercorn Enriched	0.21	0.01	13000	4100	10000	350	3400	750	27000	7	5	<4
Kelly's Plain Enriched	0.21	0.01	1500	3700	8100	190	650	360	17000	5	<4	<4
Felsics Baseline	0.86	0.04	26000	5000	11000	160	<16	430	22000	<4	6	<4
Felsics Enriched	0.17	0.03	9600	10000	6600	130	610	470	27000	6	12	<4
Min	0.2	0.00	1500	1400	4400	130	<16	340	14000	<4	<4	<4
Max	0.9	0.12	37000	10000	22000	560	5800	1100	38000	63	13	<4
SQGV[a]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**20**	**NA**	**1.5**

Sample	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Sb	Se	Zn
Excavated rock	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Ravine Baseline	19	83	32	45000	750	<4	96	7	<8	<4	90
Ravine Enriched	19	110	33	52000	1100	<4	116	410	<8	<4	550
Byron Baseline	4	20	7	20000	290	<4	14	<4	<8	<4	21
Byron Enriched	9	48	14	34000	380	<4	28	5	<8	<4	28
Shaw Gabbro Baseline	24	160	59	42000	660	<4	40	<4	<8	<4	42
Shaw Gabbro Enriched	12	44	23	27000	520	<4	19	6	<8	<4	47
Volcanics Baseline	8	14	15	22000	490	<4	9	17	<8	<4	39
Volcanics Enriched	17	6	110	47000	430	<4	10	7	<8	<4	79
Peppercorn Baseline	6	20	5	19000	340	<4	13	<4	<8	<4	19
Peppercorn Enriched	15	43	270	49000	700	<4	25	6	<8	<4	76
Kelly's Plain Enriched	8	26	13	29000	310	<4	14	9	<8	<4	56
Felsics Baseline	9	52	7	34000	740	<4	18	<4	<8	<4	31
Felsics Enriched	6	21	82	21000	250	<4	10	8	<8	<4	27
Min	4	6	5	19000	250	<4	9	<4	<8	<4	19
Max	24	160	270	52000	1100	<4	116	410	<8	<4	550
SQGV[a]	**NA**	**80**	**65**	**NA**	**NA**	**NA**	**21**	**50**	**NA**	**NA**	**200**

[a] SQGV: The sediment quality guideline values (Simpson et al., 2013). Values highlighted in red is where default guideline value exceeded. .N A-not available. For cadmium, the detection limit was higher than the sediment quality guideline value. However the concentrations were expected to be below the sediment quality guideline value based on cadmium concentrations reported in Simpson et al. (2019) (excavated rock material ≤1 mg/kg and reservoir water sediments ≤0.27 mg/kg)

Table 21. Concentrations of dilute acid-extractable metals, metalloids and other elements in excavated rock material

Sample Excavated rock	Ca mg/kg	K mg/kg	Mg mg/kg	Na mg/kg	S mg/kg	P mg/kg	Al mg/kg	As mg/kg	B mg/kg	Cd mg/kg
Ravine Baseline	5700	470	2300	83	<12	500	1100	<3	<3	<3
Ravine Enriched	7100	410	1900	47	130	580	1200	<3	<3	<3
Byron Baseline	6900	1300	780	81	<12	360	1900	<3	<3	<3
Byron Enriched	8700	1400	1200	79	22	570	2000	<3	<3	<3
Shaw Gabbro Baseline	18000	2000	3400	180	<12	380	3400	<3	<3	<3
Shaw Gabbro Enriched	6200	250	530	94	<12	450	900	<3	<3	<3
Volcanics Baseline	11000	790	610	140	<12	510	1700	<3	<3	<3
Volcanics Enriched	18000	350	640	76	33	1200	1300	<3	<3	<3
Peppercorn Baseline	6000	320	890	81	<12	530	670	<3	<3	<3
Peppercorn Enriched	7800	500	1100	110	380	790	1600	<3	<3	<3
Kelly's Plain Enriched	2000	370	1000	66	17	390	720	<3	<3	<3
Felsics Baseline	23000	500	920	92	<12	440	870	<3	<3	<3
Felsics Enriched	10000	1100	510	61	<12	480	1100	<3	<3	<3
Min	2000	250	510	47	<12	360	670	<3	<3	<3
Max	23000	2000	3400	180	380	1200	3400	<3	<3	<3
SQGV[a]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**20**	**NA**	**1.5**

Sample Excavated rock	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe mg/kg	Mn mg/kg	Mo mg/kg	Ni mg/kg	Pb mg/kg	Sb mg/kg	Se mg/kg	Zn mg/kg
Ravine Baseline	<3	3	<3	5100	370	<3	5	6	<6	<3	15
Ravine Enriched	<3	4	<3	3700	350	<3	5	190	<6	<3	45
Byron Baseline	<3	<3	<3	4700	190	<3	3	<3	<6	<3	7
Byron Enriched	<3	4	<3	6300	270	<3	3	4	<6	<3	7
Shaw Gabbro Baseline	4	22	23	5400	200	<3	8	<3	<6	<3	11
Shaw Gabbro Enriched	<3	<3	6	1900	69	<3	<3	<3	<6	<3	6
Volcanics Baseline	<3	<3	6	2200	240	<3	<3	12	<6	<3	6
Volcanics Enriched	<3	<3	4	3300	150	<3	<3	5	<6	<3	11
Peppercorn Baseline	<3	<3	<3	2300	120	<3	<3	<3	<6	<3	4
Peppercorn Enriched	<3	6	10	4400	100	<3	<3	7	<6	<3	14
Kelly's Plain Enriched	<3	<3	<3	6600	120	<3	<3	7	<6	<3	16
Felsics Baseline	<3	<3	<3	3100	610	<3	<3	<3	<6	<3	4
Felsics Enriched	<3	<3	3	2300	190	<3	<3	5	<6	<3	4
Min	<3	<3	<3	1900	69	<3	<3	<3	<6	<3	4
Max	4	22	23	6600	610	<3	8	190	<6	<3	45
SQGV[a]	**NA**	**80**	**65**	**NA**	**NA**	**NA**	**21**	**50**	**NA**	**NA**	**200**

[a] SQGV: The sediment quality guideline values (Simpson et al., 2013). Values highlighted in red is where default guideline value exceeded. . NA-not available. For cadmium, the detection limit was higher than the sediment quality guideline value. However the concentrations were expected to be below the sediment quality guideline value based on cadmium concentrations reported in Simpson et al. (2019) (excavated rock material ≤1 mg/kg and reservoir water sediments ≤0.27 mg/kg)

3.8 Toxicity of excavated rock and excavated rock-sediment mixtures

3.8.1 Toxicity to midge larvae

Excavated rocks from each geological zone were tested using three scenarios and a control treatment of reservoir sediment was also included with each batch of tests:

(1) 140 g (wet weight) of 425-µm sieved sediment with 20 g Excavated rock on top of sediments - both Enriched and Baseline from each zone.
(2) 140 g sediments and 20 g Excavated rock mixed well - both Enriched and Baseline from each zone.
(3) 160 g excavated rock material only (Enriched Excavated rock from each zone).

Key results are given below:

- Reservoir sediments (as listed in Table 3) were used as control treatments with each batch of sediment and excavated testing scenarios. Exposure of midge larvae to these control reservoir sediments over 7 days resulted in greater than 90% survival. All experimental data was expressed as % of control response (Figures 11 and 12).
- In general, excavated rock material (both Enriched and Baseline) on top of sediments (Scenario 1) and mixed with sediments (Scenario 2) did not exhibit significant toxicity, with all treatments exhibiting >80% survival.
- Midge larvae showed reduced survival (30-65%) when exposed to Shaw Gabbro, Volcanics and Felsics Enriched excavated rock under Scenario 3. However, midge larvae survival was not affected over 7 days exposure to Enriched Ravine, Byron, Peppercorn and Kellys rock material under Scenario 3 (Figure 11 and Figure 12).
- Growth of midge larvae was not significantly affected in all scenarios of excavated rock and reservoir sediments except for Byron Enriched under Scenario 3 (Figure 11 and Figure 12).
- In the chronic toxicity tests, nickel concentrations (ranging from 28-64 mg/kg) were above the sediments guideline values (SGVs) in all combinations of sediment and excavated rock materials (Table 22). Nickel in the reservoir sediments were below the SGVs as reported in Table 21.

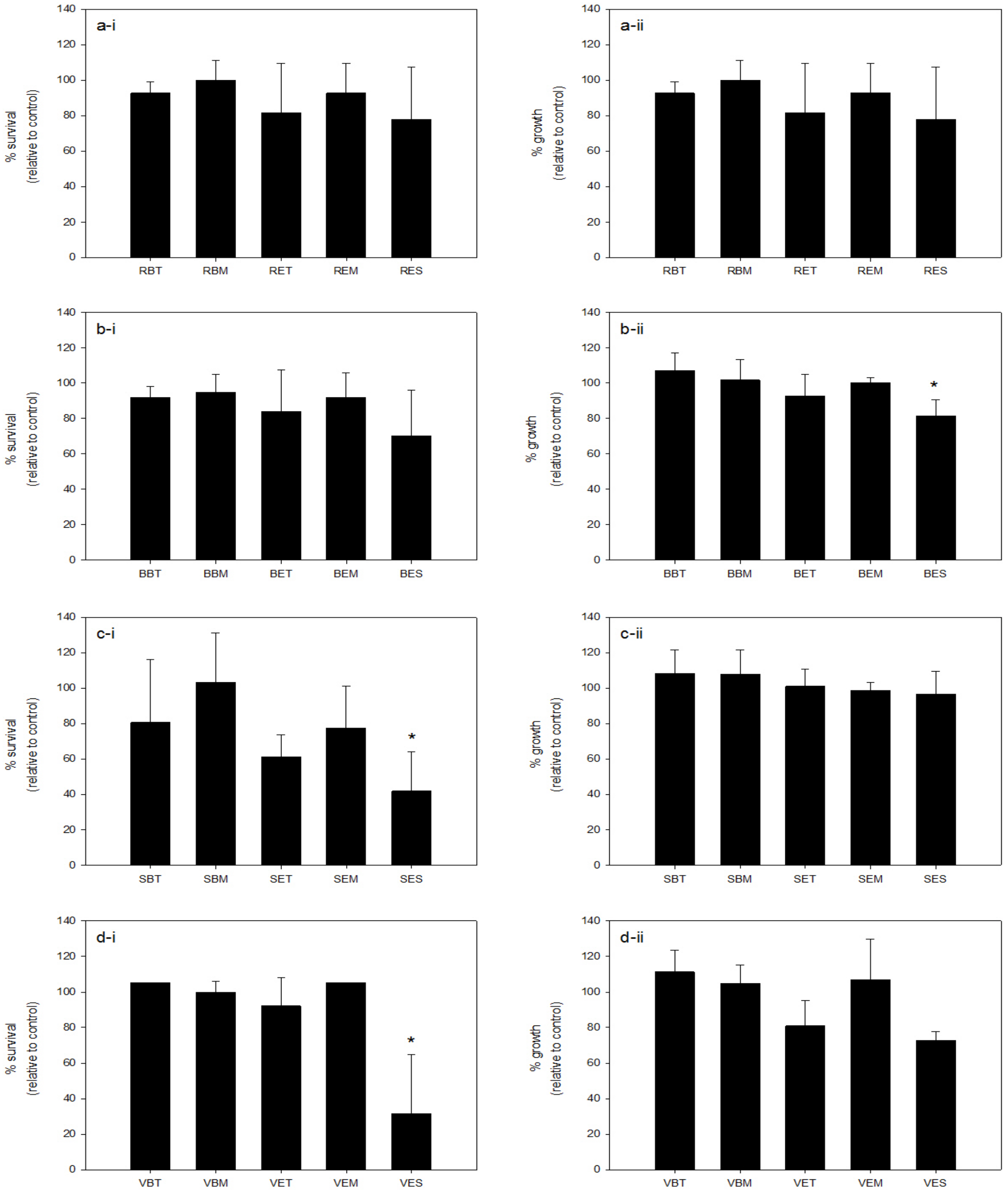


Figure 11. Chronic toxicity of excavated rock and sediment mixtures to the midge *Chironomus tepperi* (7-d survival and growth) Part 1. Data expressed as percent survival. Geological units are (a) Ravine, (b) Byron, (c) Shaw Gabbro, (d) Volcanics with test endpoint of (i) survival and (ii) growth (as length). The x-axis labels consist of three letters; first letter represents the geological zone R, B, S and V respectively; second letter represents Baseline (B) or Enriched (E) excavated rock; third letter represents excavated rock as a surface layer on sediment (T), excavated rock mixed with sediment (M) and excavated rock (S) scenario. Error bars represent 1 standard deviation. * indicates treatment is significantly different to the control treatment ($p \leq 0.05$).

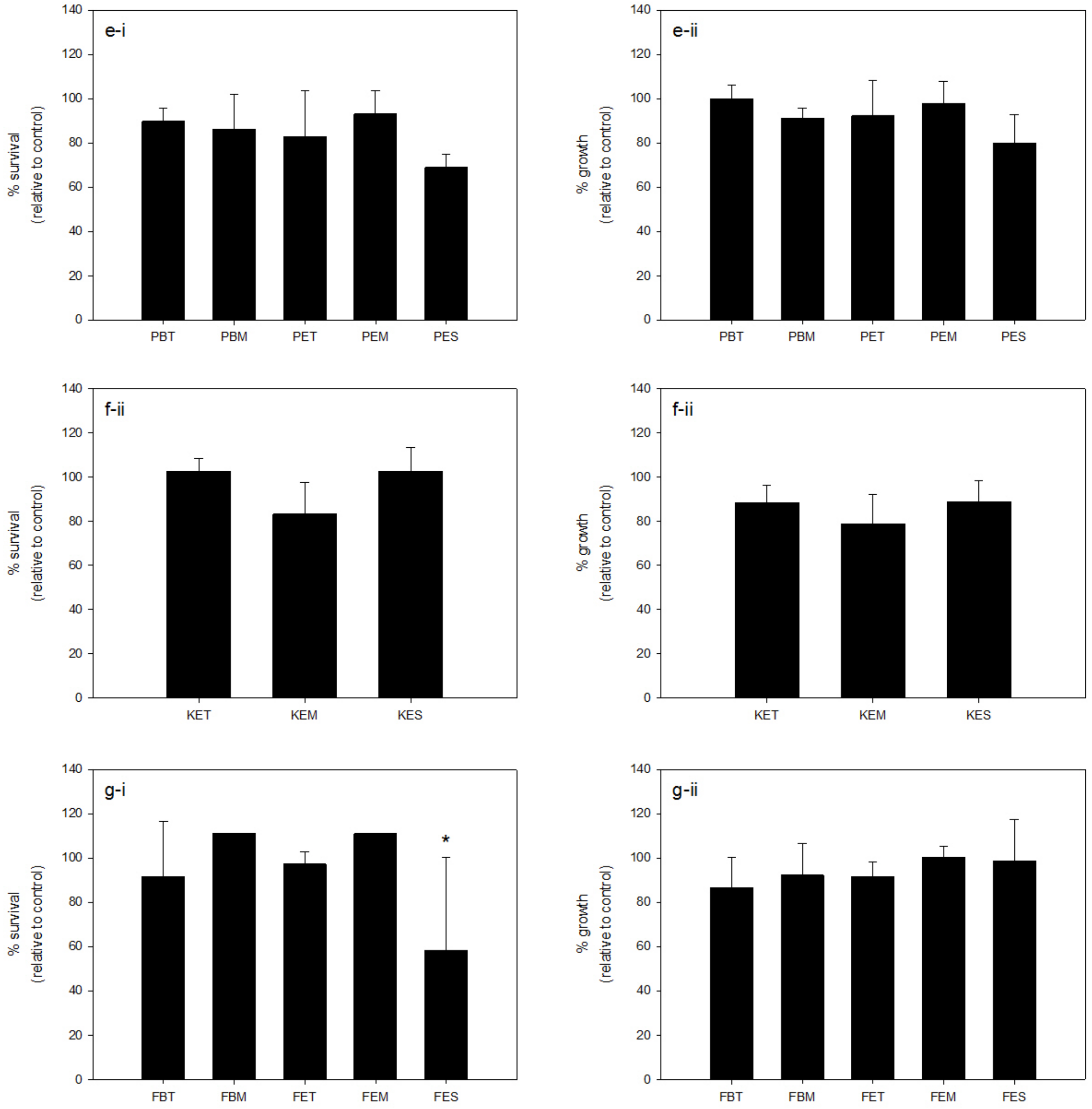


Figure 12. Chronic toxicity of excavated rock and sediment mixtures to the midge *Chironomus tepperi* (7-d survival and growth) Part 2. Data expressed as percent survival. Geological units are (e) Peppercorn, (f) Kellys Plain and (g) Felsic with test endpoint of (i) survival and (ii) growth (as length). The x-axis labels consist of three letters; first letter represents the geological zone P, K, and F respectively; second letter represents Baseline (B) or Enriched (E) excavated rock; third letter represents excavated rock as a surface layer on sediment (T), excavated rock mixed with sediment (M) and excavated rock (S) scenario. Error bars represent 1 standard deviation. * indicates treatment is significant different to the control treatment ($p \leq 0.05$).

Table 22. Concentrations of total recoverable metals, metalloids and other elements excavated rock material in the midge chronic toxicity tests

Sample Midge test	C (Total) %	N (Total) %	Ca mg/kg	K mg/kg	Mg mg/kg	Na mg/kg	S mg/kg	P mg/kg	Al mg/kg	As mg/kg	B mg/kg	Cd mg/kg
Ravine Baseline	3.1	0.16	2800	2800	10000	120	310	830	30000	9	<4	<4
Ravine Enriched	3.2	0.17	3500	2900	7900	90	540	820	30000	8	<4	<4
Byron Baseline	3.1	0.26	2800	3300	4500	120	330	760	26000	6	4	<4
Byron Enriched	3.1	0.16	3400	3700	5000	120	1600	810	26000	9	<4	<4
Shaw Gabbro Baseline	3.2	0.26	16000	5500	13000	290	270	790	47000	6	7	<4
Shaw Gabbro Enriched	3.0	0.26	5700	5300	7700	220	270	790	41000	6	7	<4
Volcanics Baseline	3.0	0.15	4800	3200	6700	210	280	790	29000	8	<4	<4
Volcanics Enriched	3.3	0.16	7500	2300	7100	120	2200	920	29000	16	<4	<4
Peppercorn Baseline	2.9	0.24	2800	2300	4500	120	330	800	24000	6	<4	<4
Peppercorn Enriched	3.1	0.26	4000	2500	5800	190	1600	900	28000	8	<4	<4
Kelly's Plain Enriched	3.0	0.14	1200	2500	5400	130	500	770	25000	7	<4	<4
Felsics Baseline	3.2	0.15	8100	2900	6500	110	280	770	27000	6	<4	<4
Felsics Enriched	3.1	0.16	3600	9000	5400	160	520	820	42000	7	11	<4
Min	2.9	0.14	1200	2300	4500	90	270	760	24000	6	<4	<4
Max	3.3	0.26	16000	9000	13000	290	2200	920	47000	16	11	<4
SQGV[a]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**20**	**NA**	**1.5**

Sample Midge test	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe mg/kg	Mn mg/kg	Mo mg/kg	Ni mg/kg	Pb mg/kg	Sb mg/kg	Se mg/kg	Zn mg/kg
Ravine Baseline	21	59	38	40000	1400	<4	64	14	<8	<4	92
Ravine Enriched	19	51	39	40000	1300	<4	52	57	<8	<4	150
Byron Baseline	15	35	27	32000	1200	<4	31	12	<8	<4	63
Byron Enriched	16	43	29	35000	1200	<4	34	12	<8	<4	63
Shaw Gabbro Baseline	24	100	48	40000	1300	<4	42	10	<8	<4	68
Shaw Gabbro Enriched	18	54	34	34000	1200	<4	33	13	<8	<4	71
Volcanics Baseline	17	36	30	34000	1300	<4	30	15	<8	<4	74
Volcanics Enriched	22	31	48	43000	1300	<4	28	12	<8	<4	78
Peppercorn Baseline	15	35	25	31000	1200	<4	30	11	<8	<4	60
Peppercorn Enriched	18	40	130	40000	1300	<4	33	15	<8	<4	82
Kelly's Plain Enriched	16	39	31	35000	1200	<4	30	13	<8	<4	77
Felsics Baseline	16	46	27	34000	1300	<4	31	11	<8	<4	61
Felsics Enriched	15	44	61	32000	1100	<4	30	14	<8	<4	66
Min	15	31	25	31000	1100	<4	28	10	<8	<4	60
Max	24	100	130	43000	1400	<4	64	57	<8	<4	150
SQGV[a]	**NA**	**80**	**65**	**NA**	**NA**	**NA**	**21**	**50**	**NA**	**NA**	**200**

[a] SQGV: The sediment quality guideline values (Simpson et al., 2013). Values highlighted in red is where default guideline value exceeded. For Cd the detection limit was higher than the sediment quality guideline value. However the concentrations were expected to be below the sediment quality guideline value based on cadmium concentrations reported in Simpson et al. (2019) (excavated rock material ≤1 mg/kg and reservoir water sediments ≤0.27 mg/kg)

Table 23. Concentrations of dilute acid-extractable metals, metalloids and other elements in excavated rock material in the midge chronic toxicity tests

Sample Midge test	Ca mg/kg	K mg/kg	Mg mg/kg	Na mg/kg	S mg/kg	P mg/kg	Al mg/kg	As mg/kg	B mg/kg	Cd mg/kg
Ravine Baseline	2900	310	1100	46	41	590	2800	3	<3	<3
Ravine Enriched	4200	300	570	29	43	580	2800	<3	<3	<3
Byron Baseline	3500	640	440	43	39	540	3000	<3	<3	<3
Byron Enriched	4300	700	630	46	57	620	3200	<3	<3	<3
Shaw Gabbro Baseline	8000	960	1700	85	25	550	3900	<3	<3	<3
Shaw Gabbro Enriched	2900	230	350	52	40	570	2700	<3	<3	<3
Volcanics Baseline	5000	490	530	70	35	600	3200	3	<3	<3
Volcanics Enriched	8800	250	400	40	33	770	2900	3	<3	<3
Peppercorn Baseline	3100	250	510	47	39	590	2500	<3	<3	<3
Peppercorn Enriched	3400	330	530	57	71	700	3000	<3	<3	<3
Kelly's Plain Enriched	1400	300	530	47	46	550	2600	<3	<3	<3
Felsics Baseline	10000	330	500	49	28	550	2700	<3	<3	<3
Felsics Enriched	4500	580	360	39	40	590	2900	<3	<3	<3
Min	1400	230	350	29	25	540	2500	<3	<3	<3
Max	10000	960	1700	85	71	770	3900	<3	<3	<3
SQGV[a]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**20**	**NA**	**1.5**

Sample Midge test	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe mg/kg	Mn mg/kg	Mo mg/kg	Ni mg/kg	Pb mg/kg	Sb mg/kg	Se mg/kg	Zn mg/kg
Ravine Baseline	9	4	14	13000	1100	<3	6	11	<6	<3	38
Ravine Enriched	8	4	13	13000	1100	<3	5	45	<6	<3	38
Byron Baseline	8	4	14	14000	1100	<3	5	10	<6	<3	36
Byron Enriched	9	5	15	14000	1100	<3	5	11	<6	<3	36
Shaw Gabbro Baseline	10	12	22	14000	1000	<3	7	9	<6	<3	25
Shaw Gabbro Enriched	8	4	16	12000	1000	<3	4	10	<6	<3	23
Volcanics Baseline	8	4	14	12000	1100	<3	5	12	<6	<3	37
Volcanics Enriched	8	4	14	13000	1100	<3	4	11	<6	<3	36
Peppercorn Baseline	8	3	13	12000	970	<3	4	9	<6	<3	34
Peppercorn Enriched	8	6	17	13000	1000	<3	5	12	<6	<3	38
Kelly's Plain Enriched	8	4	13	13000	1000	<3	4	12	<6	<3	37
Felsics Baseline	8	4	13	12000	1200	<3	4	10	<6	<3	21
Felsics Enriched	8	4	15	13000	1100	<3	4	11	<6	<3	23
Min	8	3	13	12000	970	<3	4	9	<6	<3	21
Max	10	12	22	14000	1200	<3	7	45	<6	<3	38
SQGV[a]	**NA**	**80**	**65**	**NA**	**NA**	**NA**	**21**	**50**	**NA**	**NA**	**200**

[a] SQGV: The sediment quality guideline values (Simpson et al., 2013). Values highlighted in red is where default guideline value exceeded. For Cd the detection limit was higher than the sediment quality guideline value. However the concentrations were expected to be below the sediment quality guideline value based on cadmium concentrations reported in Simpson et al. (2019) (excavated rock material ≤1 mg/kg and reservoir water sediments ≤0.27 mg/kg)

3.8.2 Toxicity to blackworms

Excavated rocks from each geological zone were tested using three scenarios as given below and a control treatment was also included with each geological zone excavated rock and sediment mixture tests.

(1) 75 g (wet weight) of 425-µm sieved sediment with 20 g Excavated rock on top of sediments - both Enriched and Baseline from each zone.

(2) 75 g sediments and 20 g Excavated rock mixed well - both Enriched and Baseline from each zone.

(3) 75 g excavated rock material only (Enriched Excavated rock from each zone).

Key results were:

- There was no significant difference in the reproductive success of blackworms in comparison to controls under Scenario 1 or 2 exposures (Figure 13; Figure 14).
- Exposure Scenarios 1 and 2 of Enriched Shaw Gabbo and Baseline Peppercorn resulted in significant reduction of the reproductive success in blackworms than in comparison to the reservoir sediment control treatments.
- Exposure to 100% Enriched excavated rock (Scenario 3) for 28 days caused 100% mortality of blackworms resulting in reproduction failure and zero biomass (Figure 13; Figure 14).
- The biomass of blackworms was significantly reduced in half of the combinations of excavated rock and reservoir sediments (indicated by * in Figure 13 and Figure 14) with Peppercorn Baseline and Enriched, Shaw Gabbro and Kellys Plain Enriched samples exhibiting significant effects in Scenarios 1 and 2.
- Biomass in blackworms was also affected when exposed to Byron and Volcanics Baseline excavated rock material as Scenario1 and Ravine Baselines rock material when exposed as Scenario 2.
- In the blackworm chronic toxicity tests, Ni concentration (ranging from 26-91 mg/kg) was above the SQGV in all combinations of sediment and excavated rock materials (Table 24).
- As acid-extractable metal concentrations, lead was above the SQGV in Ravine Enriched excavated rock material in the chronic tests (Table 25).

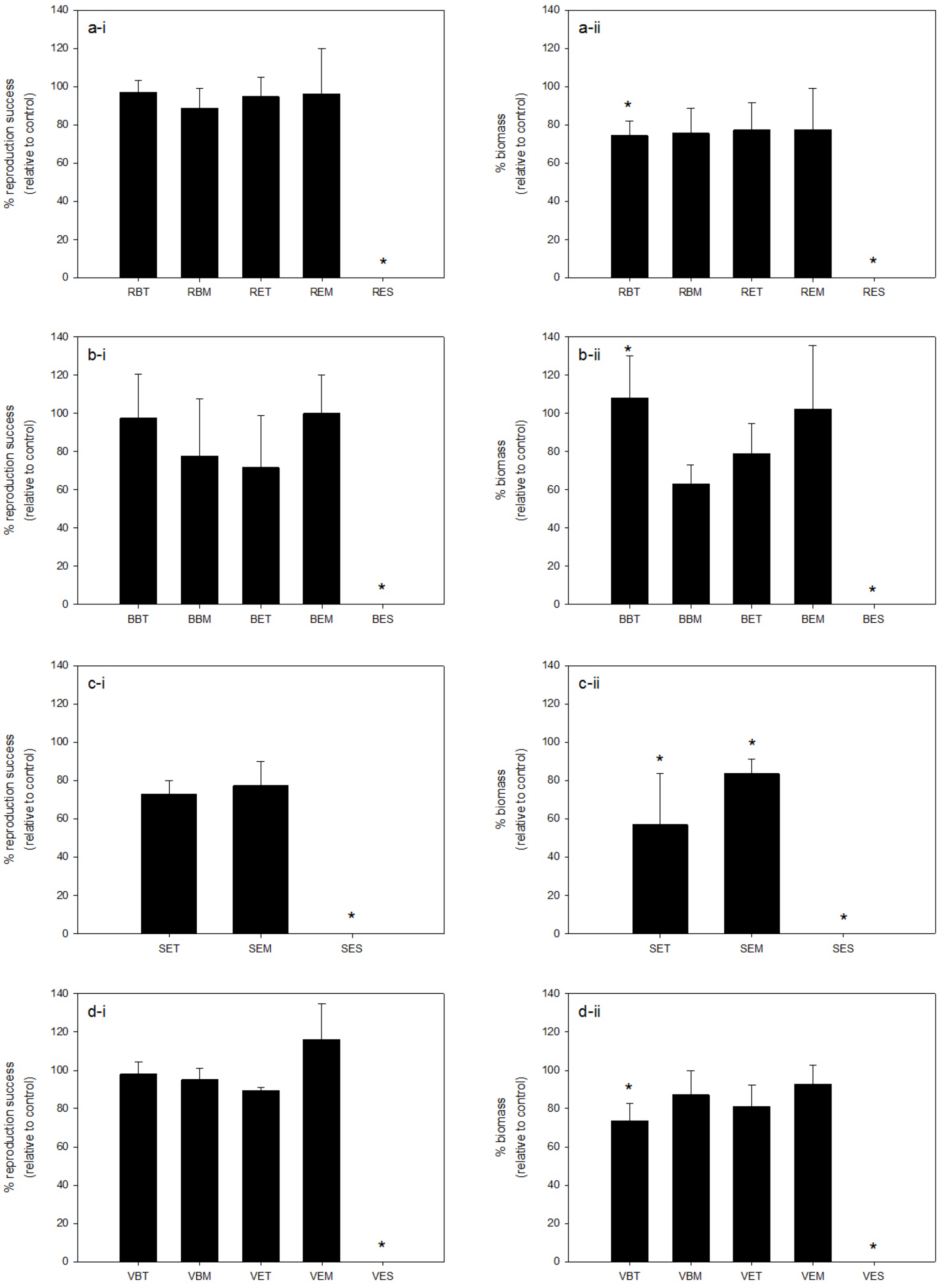


Figure 13. Chronic toxicity of excavated rock and sediment mixtures to the blackworm *Lumbriculus variegatus* (28-d reproduction and biomass) Geological units are (a) Ravine, (b) Byron, (c) Shaw Gabbro, (d) with test endpoint of (i) average number of juveniles and (ii) Biomass. The x-axis labels consist of three letters; first letter represents the geological zone R, B, S and V respectively; second letter represents Baseline (B) or Enriched (E) excavated rock; third letter represents excavated rock as a surface layer on sediment (T), excavated rock mixed with sediment (M) and excavated rock (S) scenario. Error bars represent 1 standard deviation. * indicates treatment is significant different to the control treatment ($p \leq 0.05$).

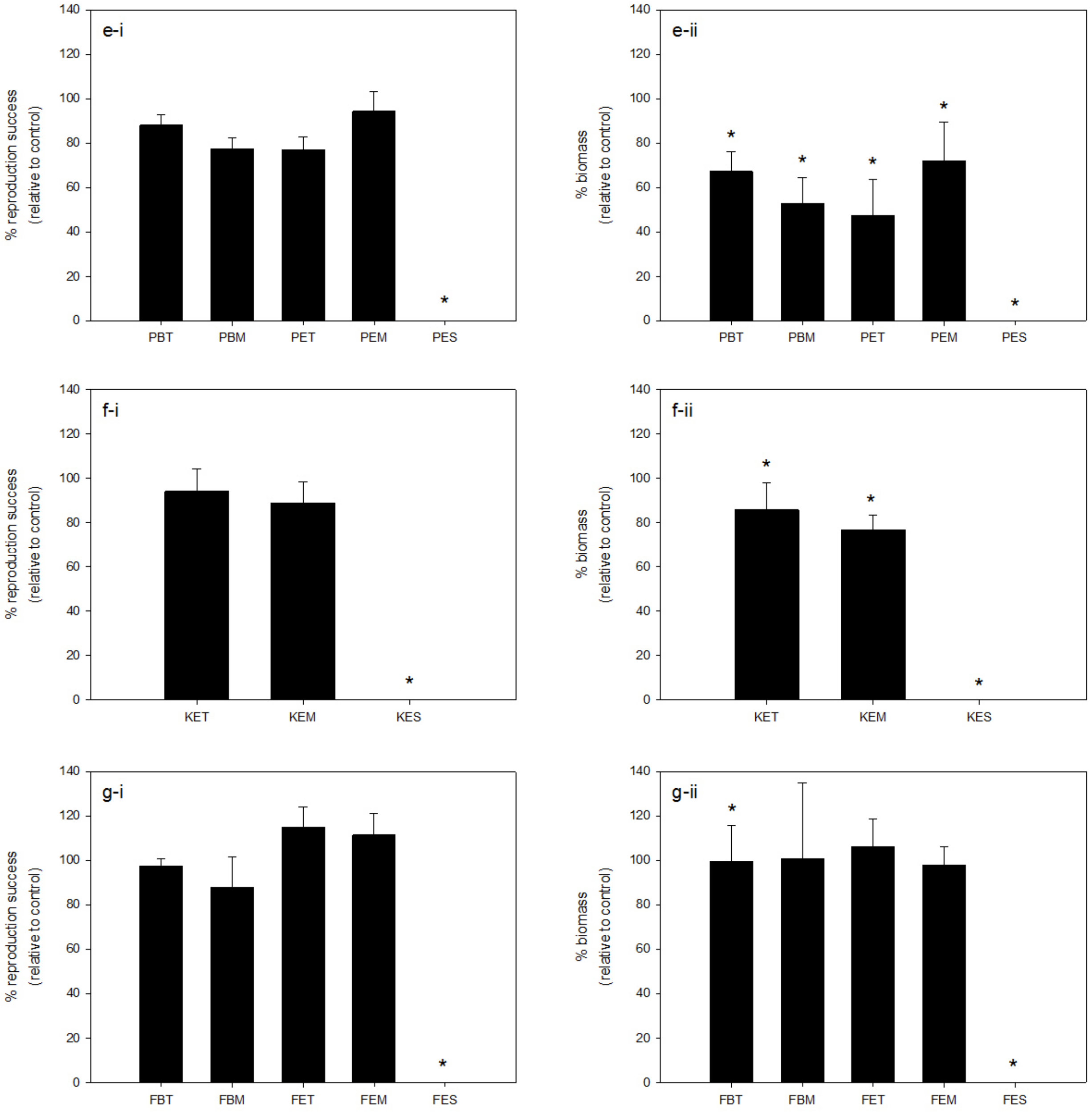


Figure 14. Chronic toxicity of excavated rock and sediment mixtures to the blackworm *Lumbriculus variegatus* (28-d reproduction and biomass) Data expressed as percent survival. Geological units are (e) Peppercorn, (f) Kellys Plain and (g) Felsic with test endpoint of (i) Average number of juveniles and (ii) Biomass. The x-axis labels consist of three letters; first letter represents the geological zone P, K, and F respectively; second letter represents Baseline (B) or Enriched (E) excavated rock; third letter represents excavated rock as a surface layer on sediment (T), excavated rock mixed with sediment (M) and excavated rock (S) scenario. Error bars represent 1 standard deviation. * indicates treatment is significant different to the control treatment ($p \leq 0.05$).

Table 24. Concentrations of total recoverable metals, metalloids and other elements excavated rock material in the blackworm chronic toxicity tests

Sample Blackworm test	C(Total) %	N(Total) %	Ca mg/kg	K mg/kg	Mg mg/kg	Na mg/kg	S mg/kg	P mg/kg	Al mg/kg	As mg/kg	B mg/kg	Cd mg/kg
Ravine Baseline	2.8	0.25	3000	3800	12000	140	280	770	33000	8	6	<4
Ravine Enriched	2.6	0.24	2800	4100	15000	120	490	820	37000	8	6	<4
Byron Baseline	2.6	0.24	3100	5500	4500	150	300	680	31000	6	8	<4
Byron Enriched	2.6	0.24	3500	6100	5500	150	2450	770	32000	10	7	<4
Shaw Gabbro Baseline	2.9	0.23	14000	3400	12000	250	230	690	35000	5	<4	<4
Shaw Gabbro Enriched	2.7	0.23	4900	2700	7200	190	250	720	29000	6	<4	<4
Volcanics Baseline	2.7	0.24	6200	3900	7500	240	250	770	32000	8	4	<4
Volcanics Enriched	2.9	0.23	11000	2900	9600	130	1990	880	33000	10	<4	<4
Peppercorn Baseline	2.6	0.23	3400	3200	5400	150	300	780	27000	6	4	<4
Peppercorn Enriched	2.6	0.23	5700	3700	6600	240	1900	880	33000	8	5	<4
Kelly's Plain Enriched	2.6	0.22	1300	3400	5800	140	530	690	28000	7	4	<4
Felsics Baseline	2.8	0.19	11000	4300	7300	140	240	700	31000	5	5	<4
Felsics Enriched	2.8	0.24	4200	5500	5000	120	520	730	30000	7	7	<4
Min	2.6	0.19	1300	2700	4500	120	230	680	27000	5	<4	<4
Max	2.9	0.25	14000	6100	15000	250	2450	880	37000	10	8	<4
SQGV[a]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**20**	**NA**	**1.5**

Sample Blackworm test	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe mg/kg	Mn mg/kg	Mo mg/kg	Ni mg/kg	Pb mg/kg	Sb mg/kg	Se mg/kg	Zn mg/kg
Ravine Baseline	20	63	37	39000	1200	<4	67	13	<8	<4	87
Ravine Enriched	21	84	41	46000	1500	<4	91	150	<8	<4	390
Byron Baseline	13	35	24	30000	1000	<4	29	10	<8	<4	55
Byron Enriched	16	46	30	35000	1000	<4	34	13	<8	<4	57
Shaw Gabbro Baseline	23	97	47	36000	1100	<4	40	9	<8	<4	64
Shaw Gabbro Enriched	18	47	33	32000	1200	<4	32	12	<8	<4	70
Volcanics Baseline	17	36	31	35000	1200	<4	29	15	<8	<4	72
Volcanics Enriched	21	30	39	48000	1300	<4	26	9	<8	<4	74
Peppercorn Baseline	14	35	23	30000	1000	<4	29	10	<8	<4	55
Peppercorn Enriched	18	44	160	42000	1200	<4	36	13	<8	<4	85
Kelly's Plain Enriched	15	39	30	35000	1000	<4	29	13	<8	<4	75
Felsics Baseline	15	50	24	34000	1200	<4	29	10	<8	<4	58
Felsics Enriched	14	34	64	29000	1000	<4	26	13	<8	<4	58
Min	13	30	23	29000	1000	<4	26	9	<8	<4	55
Max	23	97	160	48000	1500	<4	91	150	<8	<4	390
SQGV[a]	**NA**	**80**	**65**	**NA**	**NA**	**NA**	**21**	**50**	**NA**	**NA**	**200**

[a] SQGV: The sediment quality guideline values (Simpson et al., 2013). Values highlighted in red is where default guideline value exceeded. For cadmium, the detection limit was higher than the sediment quality guideline value. However the concentrations were expected to be below the sediment quality guideline value based on cadmium concentrations reported in Simpson et al. (2019) (excavated rock material ≤1 mg/kg and reservoir water sediments ≤0.27 mg/kg)

Table 25. Concentrations of dilute-acid-extractable metals, metalloids and other elements in excavated rock material in the blackworm chronic toxicity tests

Sample Blackworm test	Ca mg/kg	K mg/kg	Mg mg/kg	Na mg/kg	S mg/kg	P mg/kg	Al mg/kg	As mg/kg	B mg/kg	Cd mg/kg
Ravine Baseline	3500	330	1300	54	33	580	2600	3	<3	<3
Ravine Enriched	3300	320	1100	43	37	660	2600	<3	<3	<3
Byron Baseline	4000	750	480	52	34	520	2900	<3	<3	<3
Byron Enriched	4400	830	650	47	53	600	3000	<3	<3	<3
Shaw Gabbro Baseline	9400	1000	1900	92	19	520	3700	<3	<3	<3
Shaw Gabbro Enriched	3300	260	380	65	35	570	2600	<3	<3	<3
Volcanics Baseline	5500	510	510	76	29	600	3100	<3	<3	<3
Volcanics Enriched	12000	240	460	46	16	760	2700	<3	<3	<3
Peppercorn Baseline	3400	250	570	49	33	580	2200	<3	<3	<3
Peppercorn Enriched	3800	340	550	62	70	690	2700	<3	<3	<3
Kelly's Plain Enriched	1400	290	530	47	44	510	2200	<3	<3	<3
Felsics Baseline	13000	350	560	58	8	530	2400	<3	<3	<3
Felsics Enriched	5300	650	370	40	32	580	2500	<3	<3	<3
Min	1400	240	370	40	8	510	2200	<3	<3	<3
Max	13000	1000	1900	92	70	760	3700	<3	<3	<3
SQGV[a]	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**20**	**NA**	**1.5**

Sample Blackworm test	Co mg/kg	Cr mg/kg	Cu mg/kg	Fe mg/kg	Mn mg/kg	Mo mg/kg	Ni mg/kg	Pb mg/kg	Sb mg/kg	Se mg/kg	Zn mg/kg
Ravine Baseline	8	4	13	12000	1000	<3	6	11	<6	<3	39
Ravine Enriched	7	5	12	12000	1000	<3	6	**120**	<6	<3	43
Byron Baseline	7	4	13	12000	920	<3	5	9	<6	<3	37
Byron Enriched	7	5	13	13000	930	<3	5	10	<6	<3	36
Shaw Gabbro Baseline	9	13	22	13000	920	<3	7	8	<6	<3	35
Shaw Gabbro Enriched	7	4	15	12000	910	<3	4	9	<6	<3	35
Volcanics Baseline	7	4	13	12000	990	<3	4	12	<6	<3	35
Volcanics Enriched	7	3	13	11000	970	<3	4	9	<6	<3	33
Peppercorn Baseline	7	3	11	10000	850	<3	4	8	<6	<3	32
Peppercorn Enriched	7	5	16	11000	860	<3	4	11	<6	<3	35
Kelly's Plain Enriched	7	3	11	12000	860	<3	4	11	<6	<3	35
Felsics Baseline	6	4	12	11000	1100	<3	4	9	<6	<3	31
Felsics Enriched	7	3	13	11000	900	<3	4	10	<6	<3	32
Min	6	3	11	10000	850	<3	4	8	<6	<3	31
Max	9	13	22	13000	1100	<3	7	120	<6	<3	43
SQGV[a]	**NA**	**80**	**65**	**NA**	**NA**	**NA**	**21**	**50**	**NA**	**NA**	**200**

[a] SQGV: The sediment quality guideline values (Simpson et al., 2013). Values highlighted in red is where default guideline value exceeded. For cadmium, the detection limit was higher than the sediment quality guideline value. However the concentrations were expected to be below the sediment quality guideline value based on cadmium concentrations reported in Simpson et al. (2019) (excavated rock material ≤1 mg/kg and reservoir water sediments ≤0.27 mg/kg)

4 Fine suspended and deposited sediment associated adverse effects

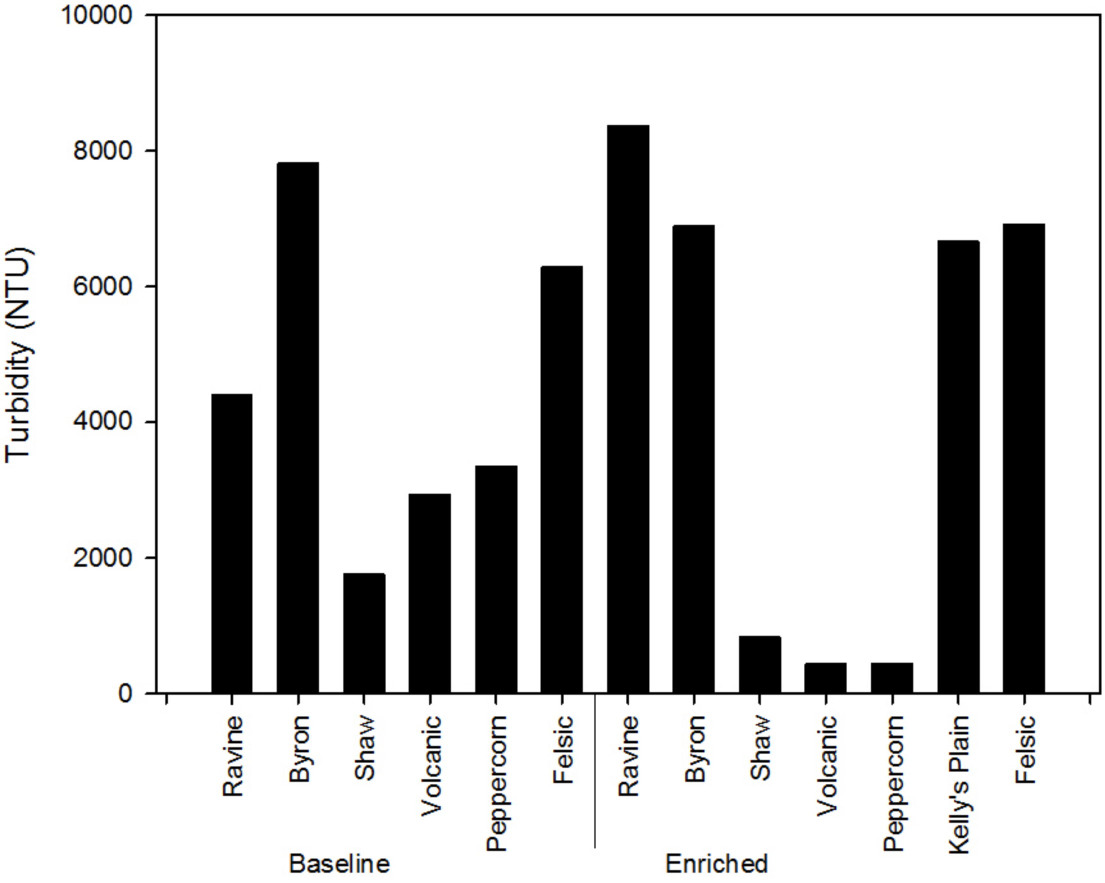
Turbidity is a measure of suspended particulate matter (SPM) concentrations and is a non-toxic direct-effect stressor (ANZG, 2018). The SPM may have a deleterious influence on aquatic ecosystems while in suspension and then a further effect when it settles out of suspension as sediment. Measurements of suspended sediments are typically reported in either turbidity levels (Nephelometric Turbidity Units or NTU) or suspended sediment concentrations (mg/L) and is a direct measure of the mass of sediments suspended in a water sample. Turbidity can also be influenced by suspended particles other than inorganic sediment (e.g. organic matter, algal cells). Thus it is possible to have high turbidity without high suspended sediments concentrations (Bilotta & Brazier 2008). Furthermore, turbidity is also influenced by the physical and optical properties of the suspended particles (e.g. particle size, shape, mineral composition) and the amount of dissolved colour (e.g. humic substances), which can vary widely between waterways and within a waterway over time (Davies-Colley & Smith 2001; Bilotta & Brazier 2008).

The default turbidity GVs for ecosystem protection for slightly disturbed ecosystems in south-eastern Australia are 2-25 NTU for upland rivers and 1-20 NTU for lakes and reservoirs (ANZG, 2018). Filtered excavated rock leachates from all geological and the reservoir water were well below this range (0.5-6.5 NTU).

In the present study, turbidity of the raw leachates (after 24 h settling period, Scenario 1) of excavated rock material was above 400 NTU for all geological zones. Ravine Enriched zone leachate showed the highest turbidity of 8100 NTU and 12-day settling reduced this high turbidity significantly to 100 NTU, whereas the 12-day settled leachates from Byron Baseline and Felsic Enriched zones remained around 520 NTU (Figure 15).

Both the scientific literature and international water quality guidelines relating to SS are dominated by the implicit assumption that the concentration-response model applies to SS effects on aquatic biota (i.e. increase in SS = increase in effect on aquatic biota) (Newcombe and MacDonald 1991). Indeed, numerous authors have reported that the magnitude of the effects of SS on aquatic organisms generally increases with their concentration. However, other factors such as the duration of exposure, particle-size distribution and chemical composition of the SS, and the presence of other contaminants on the solids, also appear to have an important control over the effect of SS on aquatic biota. These additional factors complicate the relationship between the magnitude of effect of SS and the concentration, making it difficult to predict the effect of SS on an organism merely by considering just the concentration.

The geochemical composition of the suspended load in a waterbody is an important factor in determining its effect on aquatic organisms. The geochemical composition will influence both the physical characteristics of the solids (including the shape, angularity and particle-size of the SS) and the chemical characteristics of the solids, including the likelihood of any chemical alterations in the receiving waters (e.g. pH, salinity, dissolved oxygen, phosphorus concentration, and toxicity).



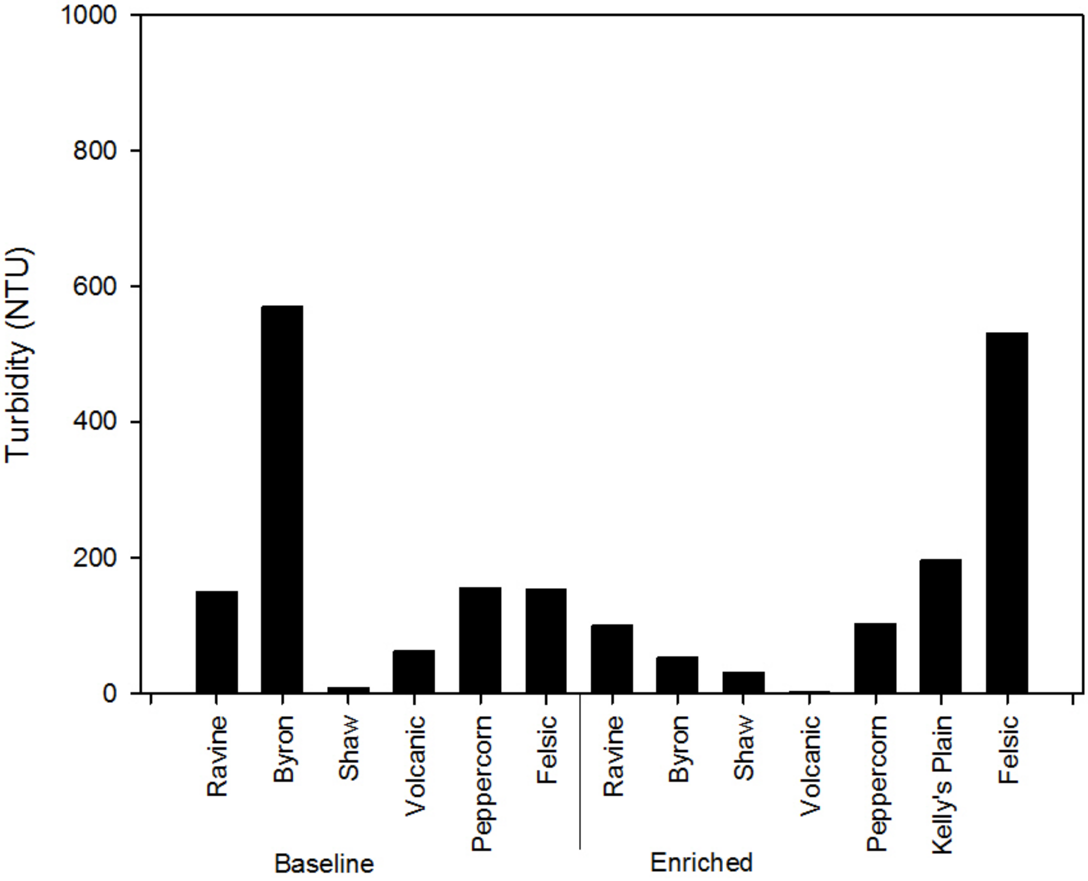


Figure 15. Turbidity (NTU) of raw and 12-day settled leachates of Baseline and Enriched excavated rocks

The detailed literature review "Adverse effects of fine sediments on aquatic organisms" has been submitted to SHL as a separate task. Some of the key points are discussed below.

Sub-aqueous excavated rock placement could degrade crucial life cycle processes among microflora (diatoms, green algae, cyanobacteria, and fungi), protozoa, microcrustacea and macroinvertebrates due to increased sedimentation at the placement locations. Often, these ecosystem elements drive the cascades of change that indirectly limit the productivity, food web relationships, health and survivorship of fish and crayfish. Increased or excessive suspended sediments can reduce productivity by (1) inhibiting photosynthesis, due to decreased light penetration; (2) physically smothering benthic communities; (3) removing periphyton by scouring; and (4) affecting community composition (Singleton, 1985). Notwithstanding these general patterns, temporary resuspension (e.g. dredging and logging) of sediments and nutrients in the water column can temporarily augment algal productivity (Bilby and Bisson, 1992).

Sediment particles are capable of adversely affecting benthic macroinvertebrates in several ways. These include:

1) direct smothering of benthic organisms (Hogg and Norris, 1991);
2) clogging of feeding apparatus in filter-feeding taxa causing stress or mortality (Newcombe and MacDonald, 1991: Metzeling et al., 1995);
3) reducing the effectiveness of oxygen exchange organs such as gills through clogging;
4) behavioural responses, such as increased invertebrate drift as an avoidance response to increased SPM levels (Doeg and Milledge, 1991; Richardson, 1985);and
5) influencing both the decomposition and availability of detrital material, with consequent impacts on the availability of food for many macroinvertebrates (Metzeling et al., 1995).

Potential impact pathway 4 listed above is not relevant to a reservoir environment and impact pathway 6 listed above was not investigated in the present study.

Excessive amounts of suspended sediment can harm fisheries ecosystems in any of six ways (Newcombe, 2003) by:

1. acting directly on free-swimming fish;
2. preventing the successful development of fish eggs and larvae;
3. modifying the natural movements and migrations of fish;
4. reducing the abundance of food available to the fish;
5. altering habitat; and
6. reducing catch per unit effort.

In the present study, toxicity of excavated rock material to fish was not carried out and all investigation were based on microalga and the invertebrate species.

There have been numerous studies on the effects of SPM on fish, with most focused on the effects on northern hemisphere salmonoid species in riverine environments (Lloyd, 1987). Impact types for fish range from direct mortality, to stress, (resulting in increased incidence of disease and reduced growth rates), to behavioural responses such as avoidance and altered feeding patterns, and adverse effects on reproduction. SPM has been shown to directly affect fish by clogging or coating gills, which can lead to death if concentrations are high enough. Indirectly, turbid water may impair feeding behaviour, particularly for species that use visual cues for foraging (Wenger et al., 2017). Alternatively, diets may be altered by changes in populations of prey species (Garmen and Moring, 1993). Reproduction may also be affected, with SPM likely to cause impaired respiration and development, or in severe cases smothering, of eggs (Lloyd 1987).

While the above effects are particularly well known for salmonid species, the relevance of these overseas data to fish populations in Australian and New Zealand ecosystems is not well understood (Stowar, 1997). For example, Ryan (1991) has noted that the biological effects of SPM will depend upon many factors, including the nature of the SPM, the dissolved oxygen concentration, water temperature, natural SPM levels, and the species of fish in question, and this makes it difficult to extrapolate overseas data to aquatic Australian ecosystems. It is also important to note that mobile species will have the ability to move away and avoid the disturbance area.

There have been few Australian or New Zealand studies on the effects of SPM on fish populations (Campbell and Doeg, 1989). New Zealand studies have shown that turbidity levels over 25 NTU resulted in reduced feeding rates and avoidance behaviour in banded kokopu (*Galaxias fasciatus*) (Boubee et al., 1997; Rowe and Dean, 1998; Richardson et al., 2001). Richardson (1985) found that logging activities in NSW resulted in reduced abundance of the common jollytail (*Galaxias maculatus*). In these studies, it is difficult to disassociate the individual effects of SPM, sedimentation and habitat alteration. A laboratory study reportedly showed increased mortalities of river blackfish (*Gadopsis marmoratus*) and common galaxias (*Galaxias maculatus*) when exposed to increased levels of SPM, but unfortunately no data were presented (Koehn and O'Connor, unpublished data reported by Metzeling et al. (1995)).

Recent literature suggests silt-clay particles are most likely responsible for suffocating salmonid eggs. Decreased embryo survival was related to a change in fine sediment (<0.074mm) from less than 0.5% to 1.5% (Louhi et al.,2011). Fine sediment infilling may not be well correlated to % cover; instead suspended sediment (analogous to the deposited re-suspendable fraction in the silt-clay range) is likely to be the most appropriate attribute (Collins et al., 2011). Very fine sediment is likely to be more damaging than sand-sized material.

Wenger et al. (2017) note that, in line with the precautionary principle, management plans for sediment should consider both direct and indirect impacts to fish, as there can also be significant indirect effects of habitat loss, which can compound the direct effects of lethal and sub lethal toxicity, leading to further impacts.

However, indirect effects on fish through loss of prey, changes to biochemical processes and habitat loss may also occur. As the primary energy source, disruptions to the dynamics of light can fundamentally influence biogeochemistry. A reduction in light penetration will result in a net decrease in photochemical processes including the breakdown of contaminants by photolysis. This may reduce the capacity for waters to naturally degrade contaminants (Dunlop et al. 2005). Further, cloudier water traps more heat energy than the equivalent volume of clear water; the consequent increase in temperature decreases the absolute solubility of oxygen, and may contribute to depletion of this essential gas in ecosystems. The risk of increased temperature related low DO in the reservoirs of the size of Talbingo and Tantnagara could be low.

Carefully controlled experiments, subjecting organisms to different conditions, are rare. The variability and uncertainty in response of aquatic biota to concentrations of SS is such that although the effect of SPM is related to the concentration of SS in the water column, it also depends on the type/species of organism, the stage that the organism is at within its life cycle, the duration and seasonal timing of exposure to the SS. Suggestions for further work to refine the understanding of likely impacts on other species include: Laboratory ecotoxicology bioassays using fish (including early life stages) and other invertebrates and/or follow-up *in-situ* caging studies (using yabbys, shrimp and fish) at different water depths during placement of rocks. This will help in validating the laboratory results under field conditions.

5 Conclusions

In the present study, the acute and chronic toxicity of contaminants (inorganics including metals) and physico-chemical stressors such as pH, EC, DO and turbidity released from excavated rock materials was assessed. A suite of standardised ecotoxicological bioassays under two different experimental set-ups were conducted with the following objectives:

3. Assess toxicity to aquatic organisms due to fine **suspended sediments** from excavated rock material interacting with the reservoir water and;
4. Assess toxicity to benthic organisms due to fine **deposited sediments** from excavated rock material interacting with the reservoir sediments.

In the first set of experiments, leachates from excavated rock and water with ratios from 1 to 10 were used for ecotoxicological assessment. Acute and chronic toxicity tests with representatives of four groups of aquatic life (a microalga, a water flea, a midge and blackworm) were carried out on leachates of excavated rock material prepared with water from Talbingo or Tantangara Reservoirs. Leachates of excavated rock had high levels of suspended solids (turbidity) that did not completely settle out of solution after 24 h. Therefore, the toxicity of leachates was assessed with water fleas, midges and blackworms on 'raw leachate' after 24 h settling and/or after '12-day settling' and/or 'filtered leachates'. Microalgae were only tested with filtered leachates. The toxicity tests using raw leachates were the 'worst case' scenarios unlikely to be encountered during placement activities.

In the second set of experiments, Sediment/excavated rock toxicity tests were carried out with two benthic species (midge and blackworms) and covered three excavated-rock and sediment mixture scenarios. 'Rock scenario' represented excavated rock as the dominant substrate in an area. 'Mixed scenario' indicated excavated rock mixing with sediments to form a smaller fraction of the substrate; and "Top scenario' specified thin layers of excavated rock material covering natural sediments to examine the effects of sedimentation on aquatic biota.

The acute and chronic toxicity data generated using one microalgae and three macroinvertebrate species was summarised by using the following ranking system:

Response NOT significantly different from **Control** and p>0.05	No toxicity
Significant difference and ≥80% response relative to **Control**	Low toxicity
Significant difference and 79-60% response relative to **Control**	Moderate toxicity
Significant difference and ≤59% response relative to **Control**	High toxicity

5.1 Leachate toxicity

The key results from leachate toxicity testing under different scenarios are summarised below.

5.1.1 Acute toxicity

- Among invertebrates, water fleas were the most sensitive test organisms during 48-h leachate exposures, as compared to midges and blackworms.
- Water fleas exhibited high toxicity with 100% mortality when exposed to raw leachates of all Baseline and Enriched samples representing seven geological zones (Table 26).
- 12-day settled leachates from Byron Baseline exhibited high toxicity whereas Felsic Baseline and Volcanic Baseline leachates indicated moderate toxicity.
- No toxicity was observed when water fleas were exposed to 12-day settled leachates from Ravine Enriched, Byron Enriched, Peppercorn Enriched and Shaw Baseline and Enriched samples (Table 26 A)
- In addition, water fleas showed low to no acute toxicity when exposed to filtered leachates from all seven zone (Table 26A).
- During 48 h exposure, midge larvae exhibited high acute toxicity to raw Enriched leachates from Byron, Ravine and Shaw and moderate toxicity to Volcanic Enriched leachate (Table 26 B).
- Blackworms did not exhibit any toxicity, expressing 100% survival when exposed to raw, 12-day settled and filtered leachates from all seven geological zones (Table 26 C).
- Raw leachates demonstrated very high turbidity. Values were 427-774 NTU in 1:10 Enriched leachates from Peppercorn, Volcanics and Shaw Gabbo zones. Higher turbidities (666-837 NTU) were present in 1:100 leachates for Byron, Felsic, Kelly Plains and Ravine zones

5.1.2 Chronic toxicity

Chronic toxicity of filtered leachates representing Scenario 3 was evaluated using a microalga and a water flea. The results are summarised below:

- Baseline filtered leachates of Shaw Gabbro and Peppercorn and Enriched samples of Ravine, Byron, Shaw Gabbro, Peppercorn and Felsic demonstrated low chronic toxicity by significantly inhibiting microalgal growth by ≤18%. The Enriched Volcanics sample showed high toxicity and inhibited microlagal growth to the greatest extent (47% inhibition, compared to the control, Table 26 D).
- Baseline filtered leachates from Ravine, Byron, Volcanics, Peppercorn and enriched filtered leachates representing Peppercorn and Kelly's zones did exhibit toxicity to microalga.
- Chronic water flea testing was conducted using only Enriched undiluted filtered leachates from seven geological zones. Leachate from Kelly's Plain Enriched excavated sample resulted in high toxicity due to significant suppression of water flea reproduction. Leachates from other six geological zones (Ravine, Byron, Shaw, Volcanics, Peppercorn and Felsic) did not exhibit any chronic toxicity to water fleas (Table 26 D).

The dissolved aluminium concentrations exceeded the 95% GV for all leachates tested and highest concentrations were observed for Felsic Enriched. Felsic Enriched leachates also had dissolved As, Cr, Cu and Zn exceeding 95% GVs. Volcanics baseline leachate measured three dissolved metals (Al, As and Cr) above DGVs. Based on integrated ranking, the leachates from Shaw Gabbro, Volcanics, Byron and Kelly’s Plain excavated rock material exhibited the highest toxicity to invertebrates and microalgae.

Based on an integrated ranking system, the raw leachates from enriched excavated rock materials from Ravine, Byron and Shaw zones exhibited high toxicity. Settling of some leachates at 4°C for 12 days reduced turbidity but fine colloidal particles were still found to be suspended in the leachate after this time. 12-day settled leachates from the Kellys (Enriched) and Byron (Baseline) zones exhibited moderate toxicity. This high turbidity of excavated rock material (between 200-500 NTU) and slow settling of the excavated rock materials in the placement area could exhibit acute toxicity to fish and macroinvertebrates inhabiting the reservoirs. Turbidity in the range of 50-200 NTU due to suspension of particulate material from excavated rock can also harm fish and other aquatic life during chronic long-term exposures by reducing food supplies, degrading spawning beds, and affecting gill function.

In Assignment P5, the ecotoxicological assessment was based on specific scenarios testing under laboratory conditions. The potential source of toxicity observed in aquatic and benthic biota during the tow experimental set-ups was associated with multistressors such as concentrations of metals, changes in water quality, elevated turbidity, and or elevated concentrations of suspended sediment. Following this project, modelling and refinement of the proposed excavated rock placement methods will be undertaken to determine how likely the tested experimental scenarios will be to conditions experienced within the reservoirs.

Table 26. Summary of ecotoxicological assessment of Baseline and Enriched leachates as three scenarios to water fleas (A), midges (B) and blackworms (C) and chronic toxicity to microalgae and water fleas (D). Three scenarios were tested (1) Raw –24 h settled leachate (2) settled-12-day settled leachate (3) Filtered – 0.45 µm filtered leachate. NT-No toxicity, LT-Low toxicity, MT Moderate toxicity, HT High toxicity and NA- not analysed.

A. Acute toxicity of leachates to waterfleas

Scenarios		Raw	Settled	Filtered
Ravine	B	HT	LT	LT
	E	HT	NT	NT
Byron	B	HT	HT	LT
	E	HT	NT	LT
Shaw	B	HT	NT	NT
	E	HT	NT	LT
Volcanics	B	HT	MT	LT
	E	HT	LT	NT
Peppercorn	B	HT	LT	NT
	E	HT	NT	LT
Kellys	E	HT	LT	NT
Felsic	B	HT	MT	NT
	E	HT	LT	HT

B. Acute toxicity of leachates to midge larvae

Scenarios		Raw	Settled	Filtered
Ravine	B	LT	NA	LT
	E	HT	LT	NT
Byron	B	LT	NA	LT
	E	HT	LT	NT
Shaw	B	LT	NA	NT
	E	HT	LT	LT
Volcanics	B	LT	NA	LT
	E	MT	LT	LT
Peppercorn	B	LT	NA	NT
	E	LT	NA	NT
Kellys	E	NT	MT	NT
Felsic	B	LT	NA	NT
	E	NT	NA	LT

C. Acute toxicity of leachates to blackworms

Scenarios		Raw	Settled	Filtered
Ravine	B	NT	NA	NT
	E	NT	NA	NT
Byron	B	NT	NA	NT
	E	NT	NA	NT
Shaw	B	NT	NA	NT
	E	NT	NA	NT
Volcanics	B	NT	NA	NT
	E	NT	NA	NT
Peppercorn	B	NT	NA	NT
	E	NT	NA	NT
Kellys	E	NT	NA	NT
Felsic	B	NT	NA	NT
	E	NT	NA	NT

D. Chronic toxicity of filtered leachates

Scenarios		Microalgae	Water fleas
Ravine	B	NT	NA
	E	LT	NT
Byron	B	NT	NA
	E	LT	NT
Shaw	B	LT	NA
	E	LT	NT
Volcanics	B	NT	NA
	E	HT	NT
Peppercorn	B	LT	NA
	E	NT	NT
Kellys	B	NT	NA
	E	NT	HT
Felsic	B	LT	NA
	E	LT	NT

5.2 Sediment and excavated rock combination toxicity

Ecotoxicological observations from excavated rock and reservoir sediment under three different scenarios can be summarised as follows:

- In general, excavated rock material (both Enriched and Baseline) mixed with sediments or on top of sediments did not affect survival of midge larvae, with all treatments exhibiting >80% survival (Table 27 A).
- Midge larvae exhibited high toxicity with significant reduced survival (30-60% relative of control) when exposed to 100% Enriched excavated rock (referred as Scenario 3) from Shaw Gabbro, Volcanics and Felsic zones over 7-day exposure (Table 27A).
- Blackworm biomass was the most sensitive indicator to detect toxicological responses after 28 days exposure to excavated rock and sediment in three different scenarios. .
- Exposure Scenarios 1 and 2 of Enriched Shaw Gabbo and Baseline Peppercorn resulted in significant reduction of the reproductive success in blackworms than in comparison to the reservoir sediment control treatments.
- Exposure to 100% Enriched excavated rock (Scenario 3) for 28 days caused 100% mortality of blackworms resulting in reproduction failure and zero biomass (Table 28).
- The biomass of blackworms was significantly reduced in half of the combinations of excavated rock and reservoir sediments (Table 28) with Peppercorn Baseline and Enriched, Shaw Gabbro and Kellys Plain Enriched samples exhibiting significant effects in Scenarios 1 and 2.
- Biomass in blackworms was also affected when exposed to Byron and Volcanics Baseline excavated rock material as Scenario1 and Ravine Baselines rock material when exposed as Scenario 2 (Table 28).
- In the blackworm chronic toxicity tests, nickel concentrations (ranging from 26-91 mg/kg) were above the sediment guideline levels in all combinations of sediment and excavated rock materials.
- Peppercorn, Shaw Gabbro and Volcanics excavated rock material exhibited the highest toxicity to the benthic macroinvertebrates tested in this study.

Macroinvertebrates such as midge and blackworms are present in the Talbingo and Tantangara Reservoirs and were used as test organisms in this study. Sediments mixed with excavated rock or top of reservoir sediments generally showed no toxicity to low toxicity during 7-day exposures to midge larvae and 28-day exposure to blackworms. Exposures to neat Enriched excavated rock material from all zones as a worst-case scenario with very low probability exhibited moderate toxicity to high toxicity. As an integrated toxicity assessment, Shaw (Enriched and Baseline), Volcanics (Enriched) and Peppercorn (Baseline) excavated material exhibited low to moderate level toxicity to blackworms and midge larvae when exposed as mixtures of sediment and excavated rock material mixtures.

100% raw leachates as suspended sediments in the reservoir and neat excavated rock material as sedimentation represent worst-case exposure scenarios tested in the present study. Increase in turbidity and metals and metalloids such Al that might be introduced to the water body as a consequence of suspended sediments from the excavated rock and/or due to sedimentation. These multistressors could result in low level of toxicological, physiological or physical impacts on fish and macroinvertebrates. Suggestions for collection of further biological assessment data for Talbingo and Tantangara reservoirs, including ecotoxicological effects and an ongoing in-situ monitoring program based on sufficient baseline data are provided.

Table 27. Summary of ecotoxicological assessment of Baseline and Enriched samples for midge larvae survival (A) and growth (B). Three scenarios were tested (1) Top –as a surface layer on top of reservoir sediment (2) Mixed – mixed with reservoir sediment (3) Rock - 100% Enriched excavated rock. NT-No toxicity, LT-Low toxicity, MT Moderate toxicity, HT High toxicity and NA- not analysed

		A. Midge Survival			**B. Midge Growth**		
Scenarios		**Top**	**Mixed**	**Rock**	**Top**	**Mixed**	**Rock**
Ravine	B	NT	NT	NA	NT	NT	NA
	E	NT	NT	NT	NT	NT	NT
Byron	B	NT	NT	NA	NT	NT	NA
	E	NT	NT	NT	NT	NT	LT
Shaw	B	NT	NT	NA	NT	NT	NA
	E	NT	NT	HT	NT	NT	NT
Volcanics	B	NT	NT	NA	NT	NT	NA
	E	NT	HT	HT	NT	NT	NT
Peppercorn	B	NT	NT	NA	NT	NT	NA
	E	NT	NT	NT	NT	NT	NT
Kellys	E	NT	NT	NT	NT	NT	NT
Felsic	B	NT	NT	NA	NT	NT	NA
	E	NT	NT	HT	NT	NT	NT

Table 28 Summary of ecotoxicological assessment of Baseline and Enriched samples for blackworm total biomass (A) and reproduction success (B). Three scenarios were tested (1) Top –as a surface layer on top of reservoir sediment (2) Mixed –mixed with reservoir sediment (3) Rock - 100% Enriched excavated rock. NT-No toxicity, LT-Low toxicity, MT Moderate toxicity, HT High toxicity and NA- not analysed

		A. Blackworm reproduction success			B. Blackworm biomass		
Scenarios		**Top**	**Mixed**	**Rock**	**Top**	**Mixed**	**Rock**
Ravine	B	NT	NT	NA	MT	NT	NA
	E	NT	NT	HT	NT	NT	HT
Byron	B	NT	NT	NA	NT	NT	NA
	E	NT	NT	HT	NT	NT	HT
Shaw	B	MT	MT	HT	HT	LT	NT
	E	NT	NT	NA	MT	NT	NA
Volcanics	B	NT	NT	HT	NT	NT	HT
	E	LT	MT	NA	MT	HT	NA
Peppercorn	B	MT	NT	HT	HT	MT	HT
	E	NT	NT	HT	LT	MT	HT
Kellys	E	NT	NT	NA	NT	NT	NA
Felsic	B	NT	NT	HT	NT	NT	HT
	E	NT	NT	NA	MT	NT	NA

6 Suggestions for further work

Suggestions for future study to fill knowledge gaps are dependent on the final excavated rock placement methodology but include:

1. High turbidity and/or suspended sediment of the rock material could also exhibit mortality in the early life stages of fish preventing successful development of fish eggs and larvae. This could be further investigated by conducting laboratory and field investigations using fish larvae (such as Murray cod and golden perch).
2. Lethal and sub-lethal impact of turbidity to adult fish (such as flathead gudgeon) could be investigated under variable concentration and duration of exposures.
3. Determining the turbidity tolerance limit for invertebrates such as shrimp, yabbies, and snails, with species relevant to the study area.
4. The turbidity tolerance limit for microalgae could be examined to understand indirect effects due to low food availability for fish and invertebrates.
5. Longer-term releases of substances from very fine excavated rock materials are predicted to remain suspended within the reservoir water for periods of many months (e.g. <4 µm particle size fraction). Long term *in-situ* toxicity testing on fish and macroinvertebrates inhabiting Tantangara/Talbingo reservoirs would add value to this assessment. In addition, monitoring of general water quality parameters such as pH, EC, temperature and turbidity, and in situ monitoring of dissolved aluminium should also be considered if field trials occur.
6. Testing of longer-term effects of dissolved aluminium release, including potential cycling from dissolved and precipitated forms if pH cycles up and down could also be investigated.

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Appendix A Conceptual model and lines of evidence

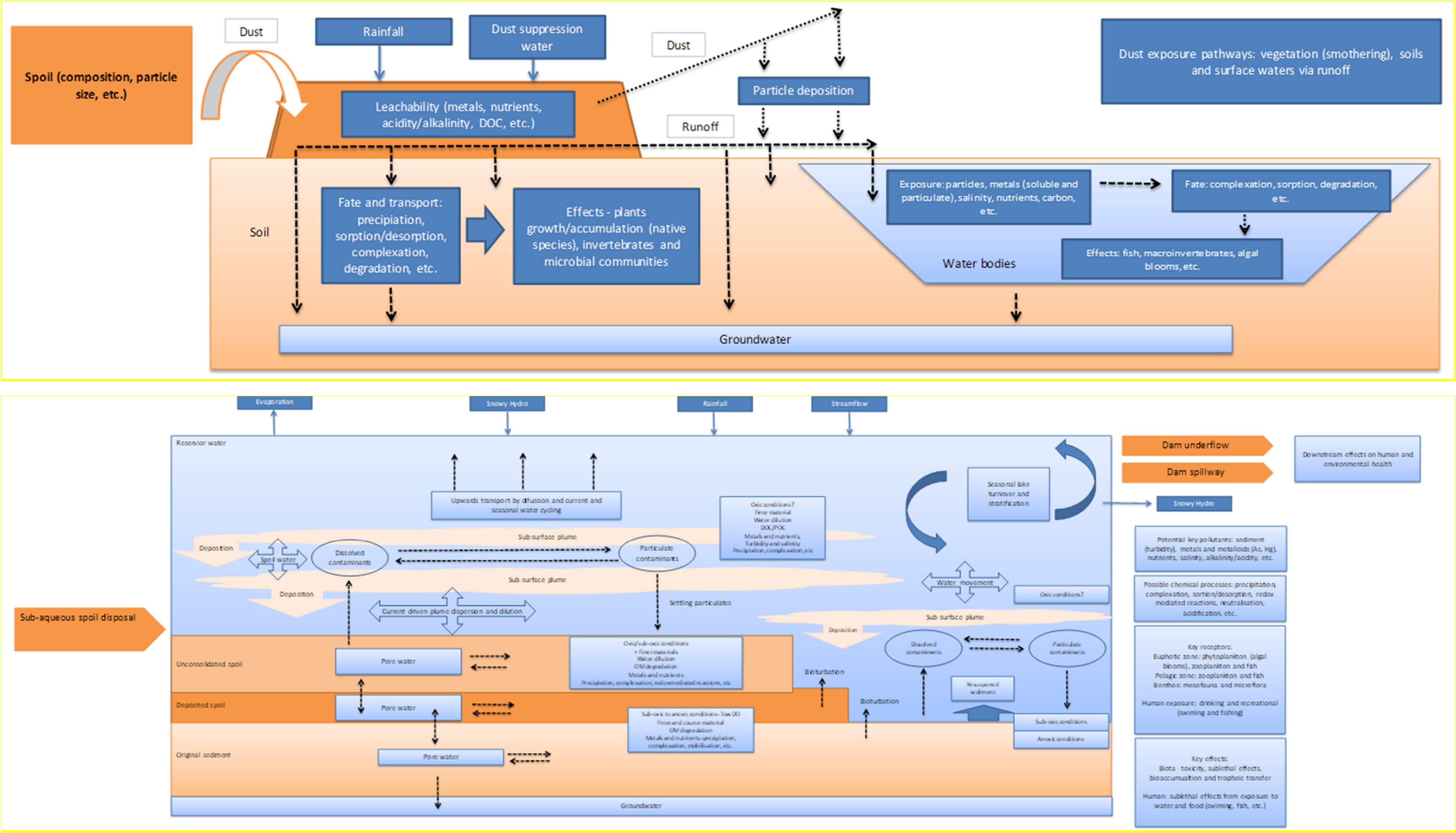


Figure A1. Two figures outlining the pressure-stressor-receptor pathways and connections developed by EMM and CSIRO (December 2017).

Table A1. Pressure-stressors-receptor pathways

Pathway	Natural	Extreme natural events	Spoil discharge (actute)	Spoil discharge (chronic)
Physical paths				
Lake water movement - general	Yes	Yes	Yes	Yes
Lake water movement - vertical mixing	Yes	Yes	Yes	Yes
Lake water movement - storm mixing	?	?	?	?
Rainfall	Yes	Yes	Yes	Yes
Evaporation	Yes	Yes	Yes	Yes
Stream flow - water	Yes	Yes	Yes	Yes
Stream flow - sediments	Yes	Yes	Yes	Yes
Snowy Hydro - water release to lake	Yes	Yes	Yes	Yes
Snowy Hydro - water take	Yes	Yes	Yes	Yes
Dam underflow	Yes	Yes	Yes	Yes
Dam spillway	No	Yes	?	?
Release of spoil water	No	No	Yes	No
Particle settling of natural particles	Yes	Yes	Yes	Yes
Particle settling of suspended/resuspended spoil	No	No	Yes	Yes
Particle settling - initial spoil deposition	No	No	Yes	No
Particle resuspension due to water movement	?	?	?	?
Sediment resuspension due to spoil addition	No	?	Yes	Yes
Surface plume formation	?	?	?	?
Sub-surface plume formation	?	?	?	?
Water 'ejected' during spoil consolidation	No	No	Yes	No
Smothering of benthos	No	?	?	No
Bioturbation	Yes	-	-	?
Slumping	?	?	?	?
Chemical paths				
Adsorption of contaminants in lake water onto suspended particles	Yes	Yes	Yes	Yes
Desorbtion of contaminants from suspended particles	Yes	Yes	Yes	Yes
Adsorption of contaminants from lake water onto spoil particles	No	No	Yes	Yes
Desorbtion of contaminants from spoil particles	No	No	Yes	Yes
Diffusion of contaminants from pore water to water column	Yes	Yes	Yes	Yes
Adsorption of contaminants in pore water onto natural sediment particles	Yes	Yes	Yes	Yes
Desorbtion of contaminants from natural sediment particles to pore water	Yes	Yes	Yes	Yes
Adsorption of contaminants in pore water onto spoil particles	No	No	Yes	Yes
Desorbtion of contaminants from spoil particles to pore water	No	No	Yes	Yes
Redox mediated chemical pathways (oxic, sub-oxic and anoxic conditions - spoil and sediments)	No	?	Yes	Yes
Biological paths				
Ingestion of suspended particulates	Yes	Yes	Yes	Yes
Ingestion of sediment particles on lake bed	Yes	Yes	Yes	Yes
Uptake of dissolved contaminants in water column	Yes	Yes	Yes	Yes
Uptake of dissolved contaminants in pore water	Yes	Yes	Yes	Yes
Ingestion of nekton	Yes	Yes	Yes	Yes
Ingestion of benthos	Yes	Yes	Yes	Yes
Human ingestion of fish	Yes	Yes	Yes	Yes
Human recreational contact	Yes	Yes	Yes	Yes

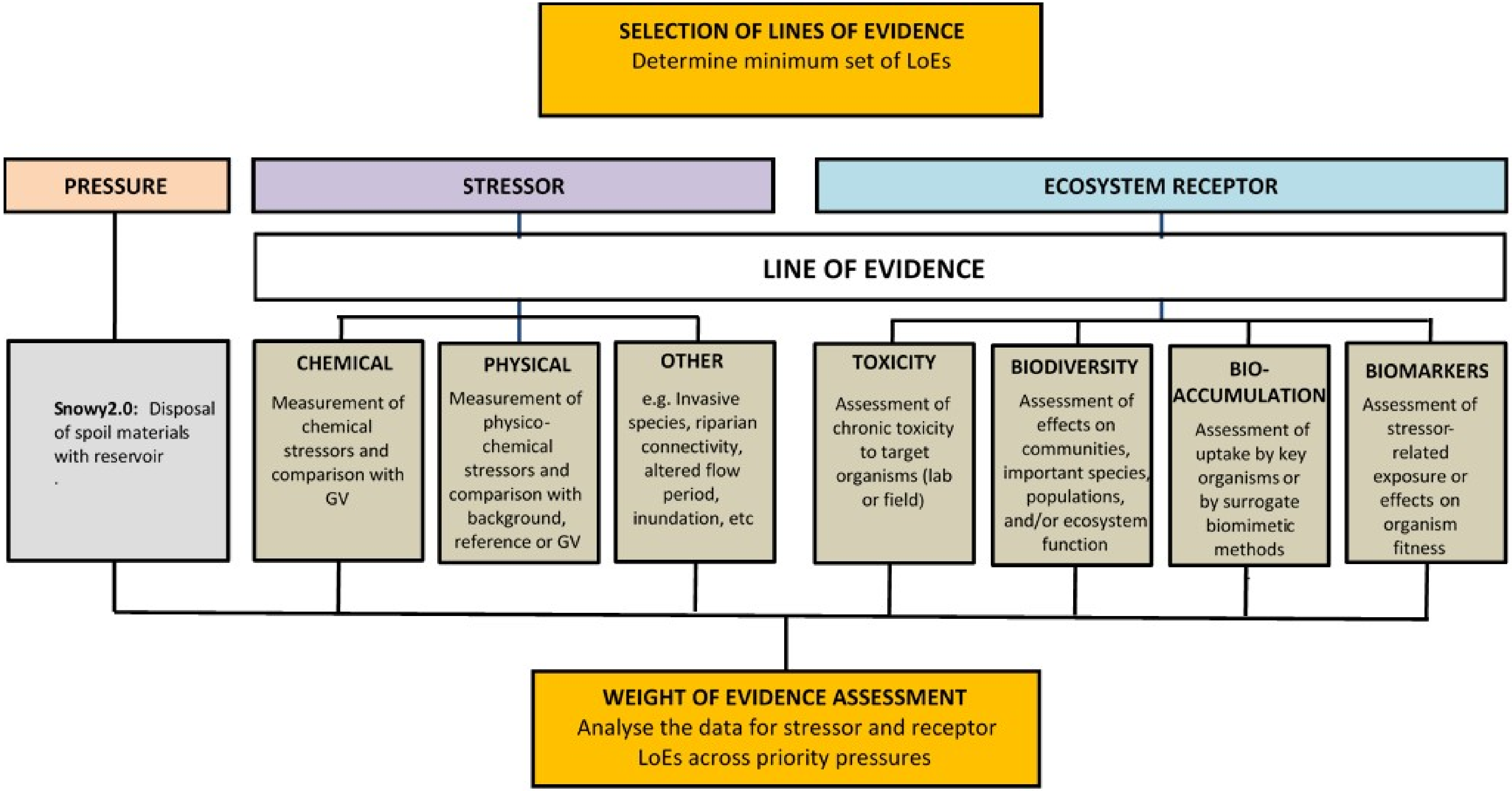


Figure A2. Lines of evidence used in water quality weight-of-evidence assessments

Appendix B Composition of excavated rock material

Table B1. Excavated rock materials - Ravine

Ravine – Baseline						
	Depth (m)					
Sample_ID	**Top**	**Bottom**	**Lithology**	**Major Geology (Surface)/ Zone**	**Placement Option**	**Classification**
BH6105-R-0063	160.57	161.00	Siltstone with a sandstone band	Yarrangobilly Limestone/Palaeozoic	Talbingo	Tunnel/surge shaft/powerhouse
BH4105-R-0362	200.7	201	Phyllite	Ravine bed	Talbingo	Tunnel/surge shaft/powerhouse
BH6105-R-0061	177.00	177.26	Siltstone with a chert band	Yarrangobilly Limestone/Palaeozoic	Talbingo	Tunnel/surge shaft/powerhouse
BH4105-R-0356	18.1	18.5	Siltstone	Ravine bed	Talbingo	Tunnel/surge shaft/powerhouse
BH4104-R-0291	376.61	377	Siltstone	Yarrangobilly Limestone/Palaeozoic	Talbingo	Tunnel/surge shaft/powerhouse
BH4105-R-0363	225.7	226	Interbedded phyllite/schist	Ravine bed	Talbingo	Tunnel/surge shaft/powerhouse
BH7105-R-0036	49.00	49.30	Siltstone	Yarrangobilly Limestone/Palaeozoic	Talbingo	Tunnel/surge shaft/powerhouse
BH6105-R-0060	*147.00*	*147.33*	*Siltstone*	*Yarrangobilly Limestone/Palaeozoic*	*Talbingo*	Tunnel/surge shaft/powerhouse
Ravine – Enriched						
BH6102-R-0045	162.00	162.15	Interbedded siltstone/sandstone	Yarrangobilly Limestone/Palaeozoic	Talbingo	Tunnel/surge shaft/powerhouse
BH7105-R-0039	15.00	15.30	Siltstone	Yarrangobilly Limestone/Palaeozoic	Talbingo	Tunnel/surge shaft/powerhouse
BH7105-R-0396	23	23.25	Siltstone	Ravine bed	Talbingo	Tunnel/surge shaft/powerhouse
BH4104-R-0294	871.56	871.82	Siltstone	Yarrangobilly Limestone/Palaeozoic	Talbingo	Tunnel/surge shaft/powerhouse
BH4105-R-0371	445.7	446	Interbedded phyllite/gneiss	Ravine bed	Talbingo	Tunnel/surge shaft/powerhouse
BH6101-R-0226	161	161.3	Sandstone/Siltstone	Yarrangobilly Limestone/Palaeozoic	Talbingo	Tunnel/surge shaft/powerhouse
BH7105-R-0038	*25.60*	*26.00*	*Conglomerate*	*Yarrangobilly Limestone/Palaeozoic*	*Talbingo*	Tunnel/surge shaft/powerhouse

Table B2. Excavated rock - Byron/Boraig and Shaw Hill Gabbro

	Depth (m)					
Sample_ID	**Top**	**Bottom**	**Lithology**	**Major Geology (Surface)/ Zone**	**Placement Option**	**Classification**
Byron/Boraig – Baseline						
BH5104-R-0122	472	472.3	Sandstone	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH5104-R-0133	727.63	727.83	Sandstone	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH5101-R-0055	*283.73*	*283.87*	*Siltstone*	*Yarrangobilly Limestone/Palaeozoic*	*Talbingo*	Top of surge shaft
BH5104-R-0116	282.53	282.8	Felsic ignimbrite	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH5105-R-0143	36	36	Sandstone	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH5104-R-0120	409	409.3	Conglomerate/sandstone	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH5104-R-0108	119.4	119.75	Mudstone	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
Byron/Boraig – Enriched						
BH5104-R-0138	822.7	823	Siltstone	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH5104-R-0114	239.15	239.4	Sandstone	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH5104-R-0109	131.1	131.35	Mudstone	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH5104-R-0113	227.4	227.67	Conglomerate	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH8106-R-0406	640.7	641	Interbedded sandstone/siltstone	Byron range group/ravine bed	Talbingo	Top of surge shaft
BH5104-R-0110	142.17	142.43	Conglomerate	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Top of surge shaft
BH5115-R-0388	261.35	261.6		Byron range group/boraig group/ravine bed	Talbingo	Top of surge shaft
Shaw Hill Gabbro – Baseline						
Sample_ID	**Depth fr (m)**	**Depth to (m)**	**Lithology**	**Major Geology (Surface)/ Zone**	**Placement Option**	**Classification**
BH4106-R-0270	96.75	97	Schist	Shaw Hill Gabbro	Talbingo	Tunnel alignment/headrace
BH4106-R-0271	124.75	125	Schist	Shaw Hill Gabbro	Talbingo	Tunnel alignment/headrace
BH4106-R-0272	162	162.2	Schist	Shaw Hill Gabbro	Talbingo	Tunnel alignment/headrace
BH4106-R-0281	76.71	77	Schist	Shaw Hill Gabbro	Talbingo	Tunnel alignment/headrace
Shaw Hill Gabbro – Enriched						
BH4106-R-0273	198.1	198.4	Diorite	Shaw Hill Gabbro	Talbingo	Tunnel alignment/headrace
BH4106-R-0274	230.37	230.78	Diorite	Shaw Hill Gabbro	Talbingo	Tunnel alignment/headrace
BH4106-R-0276	312.42	312.72	Diorite	Shaw Hill Gabbro	Talbingo	Tunnel alignment/headrace
BH4106-R-0278	383.15	383.5	Diorite	Shaw Hill Gabbro	Talbingo	Tunnel alignment/headrace

Table B3. Excavated rock - Gooandra Volcanics

Sample_ID	Depth (m)		Lithology	Major Geology (Surface)/ Zone	Placement Option	Classification
	Top	Bottom				
Gooandra Volcanics – Baseline						
BH4103-R-0001	360.30	360.60	Greenschist	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
BH4103-R-0003	*76.40*	*76.60*	*Schist*	*Gooandra Volcanics*	*Talbingo*	Tunnel alignment/headrace
BH4103-R-0011	325.00	325.40	Metasiltstone	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
BH4103-R-0012	246.16	246.56	Metasiltstone	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
BH4103-R-0014	173.62	173.90	Greenschist	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
BH4103-R-0018	*155.20*	*155.47*	*Greenschist*	*Gooandra Volcanics*	*Talbingo*	Tunnel alignment/headrace
BH4103-R-0019	318.15	318.47	Metasiltstone	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
BH4102-R-0312	472.25	472.55	Schist	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
Gooandra Volcanics – Enriched						
BH4103-R-0008	383.72	384.00	Greenschist	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
BH3110-R-0409	115.7	116	Metasandstone	Gooandra volcanics	Talbingo	Tunnel alignment/headrace
BH4103-R-0026	*117.65*	*117.93*	*Greenschist*	*Gooandra Volcanics*	*Talbingo*	Tunnel alignment/headrace
BH3110-R-0413	215	215.27	Metasandstone	Gooandra volcanics	Talbingo	Tunnel alignment/headrace
BH3110-R-0407	64.7	65	Interlaminated metasiltstone/metasandstone	Gooandra volcanics	Talbingo	Tunnel alignment/headrace
BH3110-R-0408	92	92.25	Metasiltstone	Gooandra volcanics	Talbingo	Tunnel alignment/headrace
BH3110-R-0411	172.75	173	Metasiltstone	Gooandra volcanics	Talbingo	Tunnel alignment/headrace
BH4103-R-0017	*82.37*	*82.68*	*Schist*	*Gooandra Volcanics*	*Talbingo*	Tunnel alignment/headrace

Table B4. Excavated rock - Peppercorn/Tantangara/Temperance formations

	Depth (m)					
Sample_ID	**Top**	**Bottom**	**Lithology**	**Major Geology (Surface)/ Zone**	**Placement Option**	**Classification**
Peppercorn/Tantangara/Temperance Formations - Baseline						
BH3101-R-0257	110.35	110.65	meta sandstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3101-R-0259	170.3	170.6	Meta Siltstone/Meta Sandstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3101-R-0261	201	201.3	Meta Siltstone/Meta Sandstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3106-R-0353	154	154.3	Interbedded sandstone/siltstone	Tantangara formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3104-R-0395	319	319.45	Silstone	Tantangara formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3101-R-0254	38	38.3	Meta Siltstone/Meta Sandstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3106-R-0352	129.39	129.69	Interbedded sandstone/siltstone	Tantangara formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH2102-R-0345	47.7	48	Interbedded sandstone/siltstone	Tantangara formation	Tantangara/Talbingo	Tunnel alignment/Headrace
Peppercorn/Tantangara/Temperance Formations - Enriched						
BH3102-R-0329	247.35	247.67	Meta Siltstone/Meta Sandstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3101-R-0263	253	253.3	Meta Siltstone/Meta Sandstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3102-R-0331	268	268.3	Meta Siltstone/Meta Sandstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3102-R-0320	67.6	67.9	meta siltstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3102-R-0322	116	116.28	meta siltstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3102-R-0321	81.7	82	meta siltstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3101-R-0255	61	61.3	Meta Siltstone/Meta Sandstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
BH3102-R-0319	35.25	35.55	meta siltstone	Tantangara Formation	Tantangara/Talbingo	Tunnel alignment/Headrace
Kellys Plain Volcanics - Not available until late in study testing period						
BH5102-R-0009, BH5102-R-0011, BH5102-R-0013					Tantangara/Talbingo	
BH1115-R-0003, BH1116-R-0005, BH1117-R-0007					Tantangara/Talbingo	

Table B5. Excavated rock - Felsics/granitoids/gniess/ignimbrites

Sample_ID	Depth (m)		Lithology	Major Geology (Surface)/ Zone	Placement Option	Classification
	Top	Bottom				
Felsics/granitoids/gniess/ignimbrites – Baseline						
BH4102-R-0315	524	524.3	Gneiss	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
BH4102-R-0316	546.4	546.7	Gneiss	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
BH4102-R-0318	599	599.3	Gneiss	Gooandra Volcanics	Talbingo	Tunnel alignment/headrace
BH4105-R-0370	430.7	431	Gneiss	Ravine bed	Talbingo	Tunnel alignment/headrace
BH5104-R-0115	256	256.3	Felsic ignimbrite	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Tunnel alignment/headrace
BH5103-R-0079	*512.57*	*512.80*	*Felsic volcanics*	*Sandstone/Shale/Limestone/Palaeozoic*	*Talbingo*	Tunnel alignment/headrace
BH7104-R-0234	86.4	86.65	Ignimbrite	Yarrangobilly Limestone/Palaeozoic	Talbingo	Tunnel alignment/headrace
Felsics/granitoids/gniess/ignimbrites – Enriched						
BH5105-R-0147	69	69.3	Ignimbrite	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Tunnel alignment/headrace
BH5103-R-0066	*342.40*	*342.61*	*Felsic volcanics*	*Sandstone/Shale/Limestone/Palaeozoic*	*Talbingo*	Tunnel alignment/headrace
BH5103-R-0080	*348.37*	*348.58*	*Felsic volcanics*	*Sandstone/Shale/Limestone/Palaeozoic*	*Talbingo*	Tunnel alignment/headrace
BH5105-R-0146	64.7	65	Ignimbrite	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Tunnel alignment/headrace
BH5105-R-0148	93.5	93.8	Ignimbrite	Sandstone/Shale/Limestone/Palaeozoic	Talbingo	Tunnel alignment/headrace

Appendix C Leachates of excavated rock material: microalgal toxicity test reports

Provided as supplementary information

Appendix D Leachates of excavated rock material: Supplementary information for the water flea (*Ceriodaphnia dubia*) acute and chronic toxicity tests

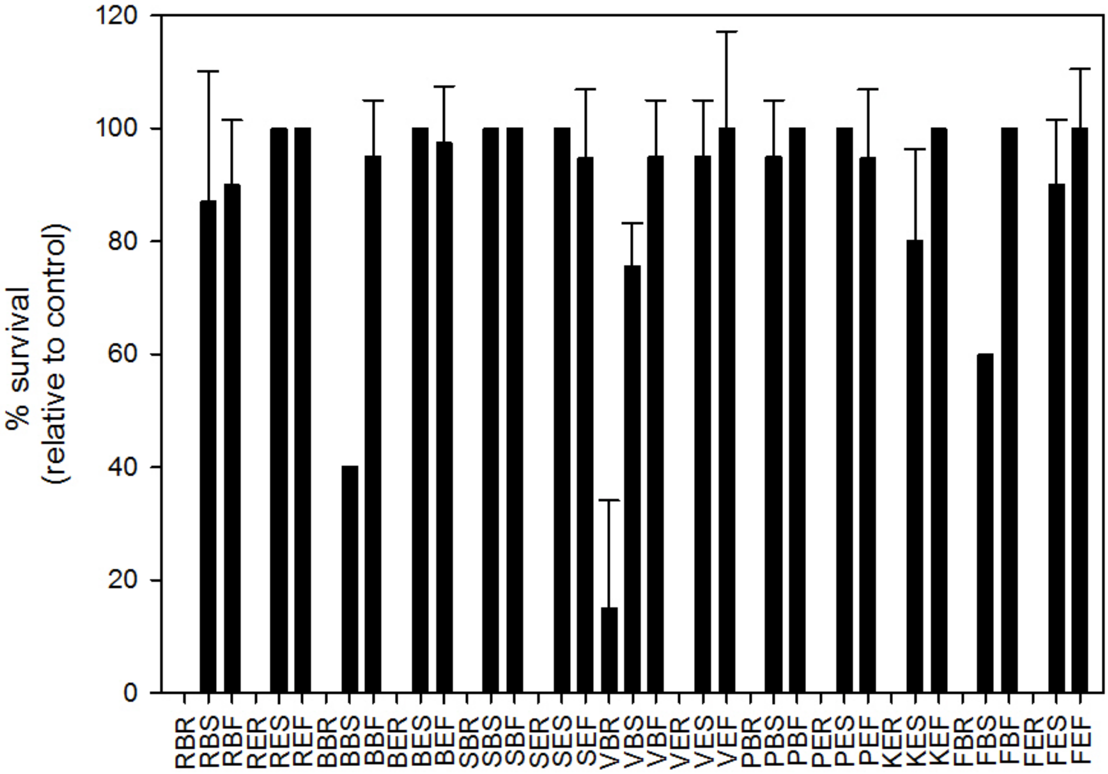


Figure D1. Summary data on the survival (acute toxicity) of water fleas (*Ceriodaphnia dubia*) for all leachates. Data expressed as relative to Reservior water control. First letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F) respectively; Second letter represents Baseline (B) or Enriched (E) excavated rock; Third letter represents raw (R), after 24 h settling (S) and filtered (F) fraction of leachate.

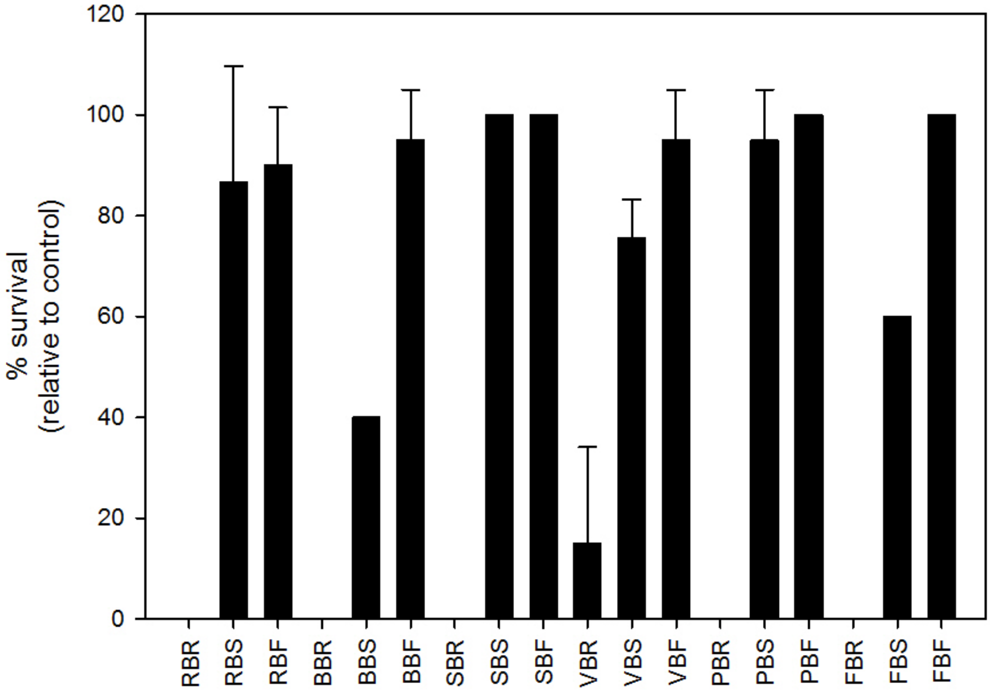


Figure D2. Summary data on survival (acute toxicity) of water fleas (*Ceriodaphnia dubia*) to leachates of Baseline material. Data expressed as relative to reservior water control. . First letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F) respectively; Second letter represents Baseline (B) excavated rock; Third letter represents raw (R), after 24 h settling (S) and filtered (F) fraction of leachate

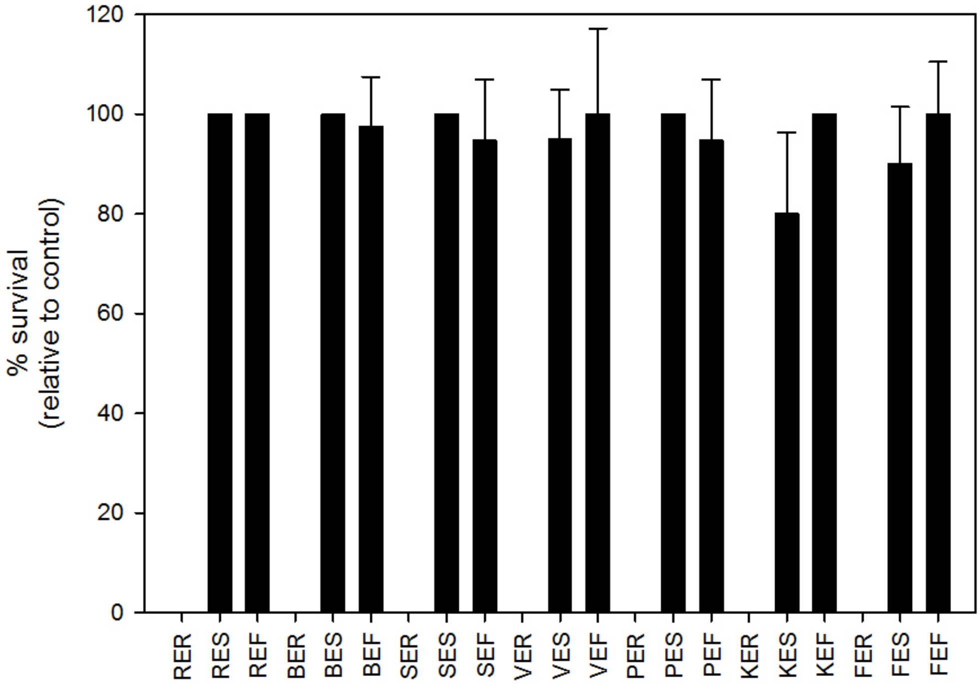


Figure D3. Summary data on survival (acute toxicity) of water fleas (*Ceriodaphnia dubia*) to leachates of Enriched material. Data expressed as relative to reservior water control. . First letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F) respectively; Second letter represents Enriched (E) excavated rock; Third letter represents raw (R), after 24 h settling (S) and filtered (F) fraction of leachate

Table D1. Supplementary data on survival (acute toxicity) of water fleas (*Ceriodaphnia dubia*) for toxicity test data for all leachates. NA indicates sample not analysed. First letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F) respectively; Second letter represents Baseline (B) or Enriched (E) excavated rock; Third letter represents raw (R), after 24 h settling (S) and filtered (F) fraction of leachate

	Total survival out of 5 after 48 hrs						
	A	B	C	D	Avg.	SD	p-value
Control	5	5	5	5	5	0	
RBR	0	0	NA		0.0	0.0	<0.001
RBS	0	4	5	5	3.5	2.4	
RBF	5	4	5	4	4.5	0.6	
RER	0	0	NA		0.0	0.0	<0.001
RES	5	5	5	5	5.0	0.0	
REF	5	5	5	5	5.0	0.0	
BBR	0	0	NA		0.0	0.0	<0.001
BBS	4	4	5	2	3.8	1.3	0.02
BBF	5	5	5	4	4.8	0.5	
BER	0	0	NA		0.0	0.0	<0.001
BES	5	5	5	5	5.0	0.0	
BEF	5	5	5	5	5.0	0.0	
SBR	0	0	NA		0.0	0.0	<0.001
SBS	2	5	5	5	4.3	1.5	
SBF	5	5	5	5	5.0	0.0	
SER	0	0	NA		0.0	0.0	<0.001
SES	5	5	5	5	5.0	0.0	
SEF	5	4	5	4	4.5	0.6	
VBR	0	0	NA		0.0	0.0	<0.001
VBS	4	3	4	4	3.8	0.5	0.001
VBF	4	5	5	5	4.8	0.5	
VER	0	0	NA		0.0	0.0	<0.001
VES	5	5	4	5	4.8	0.5	
VEF	5	5	5	4	4.8	0.5	
PBR	0	0	NA		0.0	0.0	<0.001
PBS	5	4	5	5	4.8	0.5	
PBF	5	5	5	5	5.0	0.0	
PER	0	0	NA		0.0	0.0	<0.001
PES	5	5	5	5	5.0	0.0	
PEF	4	4	5	5	4.5	0.6	
KER	0	0	NA		0.0	0.0	<0.001
KES	4	3	5	4	4.0	0.8	
KEF	5	5	5	5	5.0	0.0	
FBR	0	0	NA		0.0	0.0	<0.001
FBS	4	3	3	3	3.3	0.5	<0.001
FBF	5	4	5	5	4.8	0.5	
FER	0	0	NA		0.0	0.0	<0.001
FES	4	4	5	5	4.5	0.6	
FEF	5	5	4	5	4.8	0.5	

Table D2. Supplementary water quality data for the acute (survival) toxicity tests with the water flea (*Ceriodaphnia dubia*).

	Water Quality at test completion			
Treatment	pH	DO (% sat.)	Conductivity (µS/cm)	Temperature (º C)
RBR	7.8	92.8	102.4	24.0
RBS	7.6	93.9	119.3	24.0
RBF	7.8	93.0	95.1	24.0
RER	8.1	87.5	133.4	24.0
RES	7.8	93.1	143.7	24.0
REF	8.0	92.7	115.3	24.0
BBR	7.7	91.6	165.5	24.0
BBS	7.2	93.6	149.8	24.0
BBF	7.9	92.9	136.9	24.0
BER	8.0	88.1	203.6	24.0
BES	7.7	95.3	196.1	24.0
BEF	8.1	92.3	162.1	24.0
SBR	7.8	93.2	127.3	24.0
SBS	7.7	93.7	135.4	24.0
SBF	7.9	93.5	108.7	24.0
SER	8.1	90.0	101.8	24.0
SES	7.8	93.4	111.1	24.0
SEF	8.0	92.8	90.1	24.0
VBR	7.8	92.6	117.0	24.0
VBS	7.7	93.7	133.9	24.0
VBF	7.9	93.6	119.9	24.0
VER	8.0	90.9	113.3	24.0
VES	7.8	93.8	122.4	24.0
VEF	8.0	92.4	106.0	24.0
PBR	7.8	92.3	106.6	24.0
PBS	7.5	94.1	111.7	24.0
PBF	7.8	93.0	87.4	24.0
PER	8.0	88.8	124.4	24.0
PES	7.7	93.6	138.5	24.0
PEF	8.0	92.4	113.1	24.0
KER	8.0	88.5	113.9	24.0
KES	7.7	93.8	126.3	24.0
KEF	8.0	91.8	101.0	24.0
FBR	7.8	91.8	124.0	24.0
FBS	7.4	94.3	125.2	24.0
FBF	7.9	92.9	97.0	24.0
FER	8.1	85.8	157.4	24.0
FES	7.7	95.4	159.4	24.0
FEF	8.1	92.9	126.1	24.0

Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F); Baseline (B) or Enriched (E) excavated rock; raw (R), after 24 h settling (S) and filtered (F) fraction of leachate.

Table D3. Acute toxicity of Tantangara and Talbingo Reservoir water samples to the water flea, *Ceriodaphnia dubia*

	Total survival out of 5 after 48 hrs						Water Quality at test completion			
	A	B	C	D	Avg.	SD	pH	DO (% sat.)	Conductivity (µS/cm)	Temperature (° C)
TN3	5	5	5	5	5	0	8.0	108.5	32.1	24.0
TN2	5	4	5	5	4.75	0.5	7.9	105.5	31.4	24.0
TN1	3	5	5	5	4.5	1	7.8	104.5	31.0	24.0
TAL-PL2C	5	5	4	5	4.75	0.5	7.8	104.3	30.1	24.0
TAL-PL1C	4	5	5	5	4.75	0.5	7.7	107.1	30.4	24.0
TAL-PL2D	5	4	5	5	4.75	0.5	7.7	104.6	30.3	24.0
TAL-PL1D	4	5	5	4	4.5	0.57735	7.6	106.2	33.0	24.0

Table D4. Acute toxicity of pooled reservoir water samples to the water flea, *Ceriodaphnia dubia* and corresponding copper reference toxicity test results.

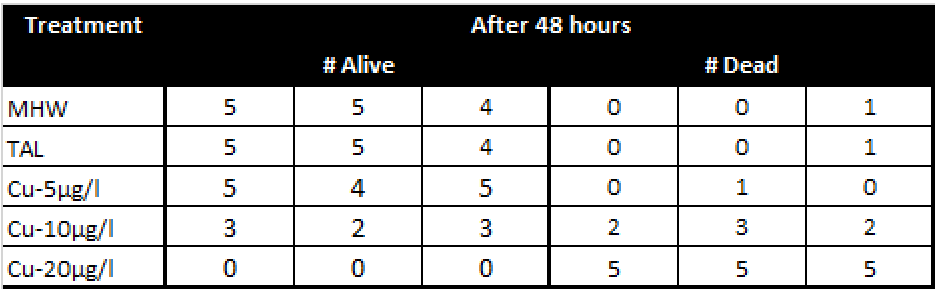
Treatment	After 24 hours # Alive				After 48 hours # Alive			
	A	B	C	D	A	B	C	D
MHW	5	5	5	5	5	5	5	4
TAL	4	4	5	5	4	4	5	5
TN	4	5	4	5	4	5	4	5
Cu-5µg/l	5	5	5	5	5	5	5	5
Cu-10µg/l	5	5	5	5	4	4	5	5
Cu-20µg/l	3	3	2	0	0	0	0	0

Table D5. Low electrical conductivity (EC) related acute toxicity to the water flea, *Ceriodaphnia dubia*

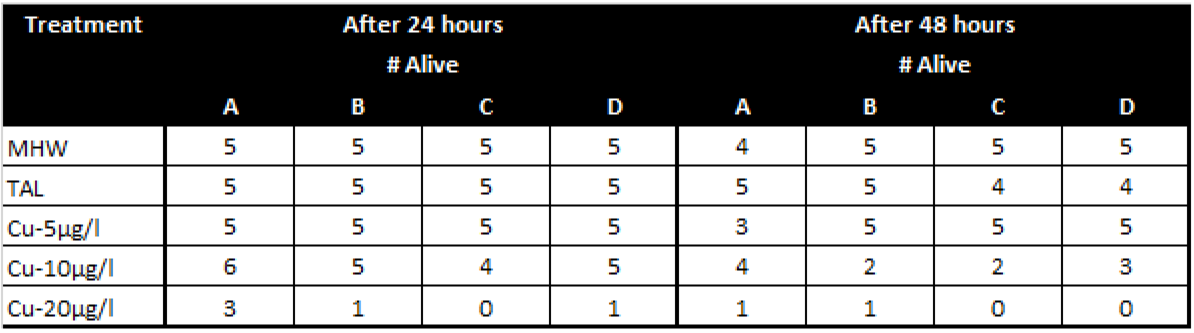
	Total survival out of 5 after 48 hrs						Water Quality at test completion			
	A	B	C	D	Avg.	SD	pH	DO (% sat.)	Conductivity (µS/cm)	Temperature (° C)
MHW	5	5	5	4	4.75	0.5	8.09	107.8	321	24.0
EC 20	5	5	4	4	4.5	0.58	7.38	109	28.9	24.0
EC 40	5	5	5	5	5	0	7.31	109	49.2	24.0
EC 60	5	5	5	4	4.75	0.5	7.23	109	69.2	24.0
EC 80	5	5	5	4	4.75	0.5	7.25	109	89.7	24.0
EC 120	5	5	5	5	5	0	7.36	108	132.7	24.0
EC 160	5	5	5	5	5	0	7.42	108	167.3	24.0
EC 240	5	5	5	4	4.75	0.5	7.51	110	264	24.0

Table D6. Copper reference toxicity tests and the effective concentration (EC in µg/L) of copper at 50%, 10% and 20% for the water flea (*Ceriodaphnia dubia*) during acute toxicity tests with leachates.

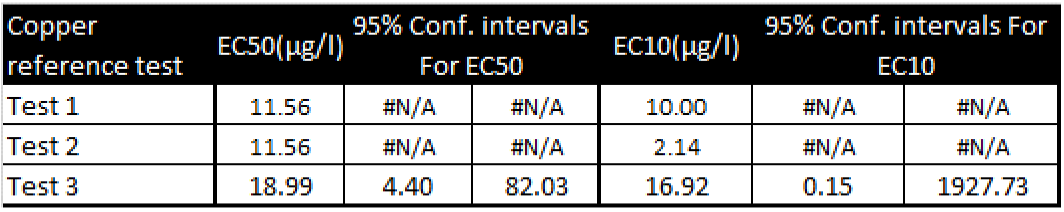
Treatment	After 24 hours # Alive				After 48 hours # Alive			
	A	B	C	D	A	B	C	D
MHW	5	5	5	5	5	5	5	4
TAL	4	4	5	5	4	4	5	5
TN	4	5	4	5	4	5	4	5
Cu-5µg/l	5	5	5	5	5	5	5	5
Cu-10µg/l	5	5	5	5	4	4	5	5
Cu-20µg/l	3	3	2	0	0	0	0	0



Treatment	After 48 hours					
	# Alive			# Dead		
MHW	5	5	4	0	0	1
TAL	5	5	4	0	0	1
Cu-5µg/l	5	4	5	0	1	0
Cu-10µg/l	3	2	3	2	3	2
Cu-20µg/l	0	0	0	5	5	5



Treatment	After 24 hours # Alive				After 48 hours # Alive			
	A	B	C	D	A	B	C	D
MHW	5	5	5	5	4	5	5	5
TAL	5	5	5	5	5	5	4	4
Cu-5µg/l	5	5	5	5	3	5	5	5
Cu-10µg/l	6	5	4	5	4	2	2	3
Cu-20µg/l	3	1	0	1	1	1	0	0



Copper reference test	EC50(µg/l)	95% Conf. intervals For EC50		EC10(µg/l)	95% Conf. intervals For EC10	
Test 1	11.56	#N/A	#N/A	10.00	#N/A	#N/A
Test 2	11.56	#N/A	#N/A	2.14	#N/A	#N/A
Test 3	18.99	4.40	82.03	16.92	0.15	1927.73

Table D7. Reproduction (chronic toxicity) of water flea (*Ceriodaphnia dubia*) to leachates (filtered) of Enriched material. Control represents moderately hard water (MHW) treatment and TAL and TN are Talbingo and Tantangara Reservoir waters. First letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F) respectively; Second letter Enriched (E) excavated rock; Third letter represents filtered (F) fraction of leachate.

	Total number of juveniles												
	A	B	C	D	E	F	G	H	I	J	Avg.	SD	p-value
MHW	14	21	16	17	14	15	18	16	15	17	16.3	2.110819	
TAL	13	13	19	14	18	8	13	10	10	4	12.2	4.467164	
TN	11	14	16	17	17	17	18	16	12	12	15	2.538591	
REF	12	24	16	15	15	17	21	10	10	0	14	6.6	
BEF	18	12	17	10	10	18	14	14	12	11	13.6	3.1	
SEF	16	17	15	15	19	19	12	12	15	19	15.9	2.6	
VEF	14	22	18	14	15	0	0	12	13	15	12.3	7.1	
PEF	16	13	9	14	12	15	13	12	13	13	13	1.9	
KEF	12	10	0	18	9	13	10	10	6	8	9.6	4.7	0.01
FEF	15	14	9	16	9	14	20	15	30	21	16.3	6.2	

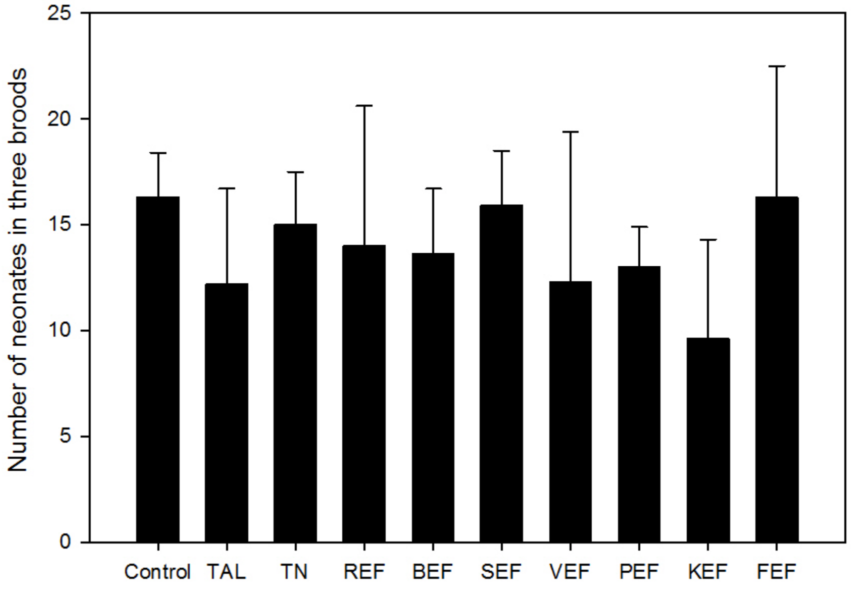


Figure D4. Reproduction (chronic toxicity) of the water flea (*Ceriodaphnia dubia*) to Enriched Filtered leachates. Control represents moderately hard water (MHW) treatment and TAL and TN are Talbingo and Tantangara Reservoir waters. First letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F) respectively; Second letter represents Enriched (E) excavated rock; Third letter represents filtered (F) fraction of leachate.

Table D8. Copper test run with water flea (*Ceriodaphnia dubia*) during chronic toxicity tests.

Treatment	After 24 hours # Alive				After 48 hours # Alive			
MHW Control	5	5	5	5	5	5	5	5
TAL	5	5	5	4	5	5	5	4
TN	5	5	5	4	5	5	5	5
Cu-5µg/l	5	5	5	5	5	5	5	5
Cu-10µg/l	5	5	5	5	4	3	3	4
Cu-20µg/l	4	5	4	3	1	3	0	2

Table D9. The effective concentration (µg/L) of copper at 50%, 10% and 20% for cladocerans (*Ceriodaphnia dubia*) during chronic toxicity tests.

	µg/l	95% Conf. intervals	
EC50	14.32	11.34	18.09
EC10	6.40	3.90	10.52
EC20	8.62	5.96	12.47

Table D10. Water quality data for the chronic (reproduction) toxicity tests with the water flea (*Ceriodaphnia dubia*). Control represents moderately hard water (MHW) treatment and TAL and TN are Talbingo and Tantangara Reservoir waters. Renewal of test solutions was done every second day.

		Water Quality at test completion			
Day	Treatment	pH	DO (% sat.)	Conductivity (µS/cm)	Temperature (º C)
0	MHW	7.67	96	309	24.0
	TAL	7.39	104.1	25.4	24.0
	TN	7.62	102.5	28.1	24.0
2	MHW	7.64	95.5	319	24.0
	TAL	7.91	96.4	38	24.0
	TN	8.02	95.9	41.2	24.0
4	MHW	7.93	96.9	360	24.0
	TAL	7.98	97.8	35	24.0
	TN	7.98	97.3	36.9	24.0
6	MHW	7.67	96	309	24.0
	TAL	7.84	95.4	33.3	24.0
	TN	7.71	95.9	36.5	24.0
8	MHW	7.9	99.4	376	24.0
	TAL	7.23	99.8	39.6	24.0
	TN	7.27	100.9	61	24.0

Table D11. Water quality data for the chronic (reproduction) toxicity tests with the water flea (*Ceriodaphnia dubia*). Leachates (filtered) of Enriched material (renewal of test solution every second day). First letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F) respectively; Second letter represents Enriched (E) excavated rock; Third letter represents filtered (F) fraction of leachate

		Water Quality			
Day	Treatment	pH	DO (% sat.)	Conductivity (µS/cm)	Temperature (º C)
0	REF	7.9	96.1	109.4	24.0
	BEF	8.2	92.2	148.8	24.0
	SEF	8.1	97.8	85.1	24.0
	VEF	8.4	97.9	106.8	24.0
	PEF	7.9	94.5	104.9	24.0
	KEF	7.9	91.5	90.8	24.0
	FEF	8.0	91.2	115.8	24.0
2	REF	8.6	102.9	126.5	24.0
	BEF	8.7	106	163.6	24.0
	SEF	8.3	98.1	103.1	24.0
	VEF	8.5	98.6	122.7	24.0
	PEF	8.2	97.9	121.1	24.0
	KEF	8.7	104.5	111.3	24.0
	FEF	8.7	106.6	131.7	24.0
4	REF	8.4	98.6	122.5	24.0
	BEF	8.4	99	162.7	24
	SEF	8.3	96.1	94.9	24.0
	VEF	8.2	95.1	118.7	24.0
	PEF	8.3	98.4	117.1	24.0
	KEF	8.4	98.1	105.5	24.0
	FEF	8.2	99.6	131.8	24.0
6	REF	7.9	92.6	141.3	24.0
	BEF	7.2	93.3	191.4	24.0
	SEF	7.8	91.2	119.1	24.0
	VEF	7.5	91.8	146.7	24.0
	PEF	7.7	90.9	151.2	24.0
	KEF	7.7	92.2	122.6	24.0
	FEF	8.0	92.3	158.9	24.0
8	REF	7.8	106.8	151.5	24.0
	BEF	7.9	108.5	193.1	24.0
	SEF	7.8	107.6	134	24.0
	VEF	7.8	106.9	156.6	24.0
	PEF	7.9	107.3	169.2	24.0
	KEF	7.8	106.4	137.5	24.0
	FEF	7.9	106	188.5	24.0

Appendix E Leachates of excavated rock material: Supplementary information for the midge (*Chironomus tepperi dubia*) acute toxicity tests

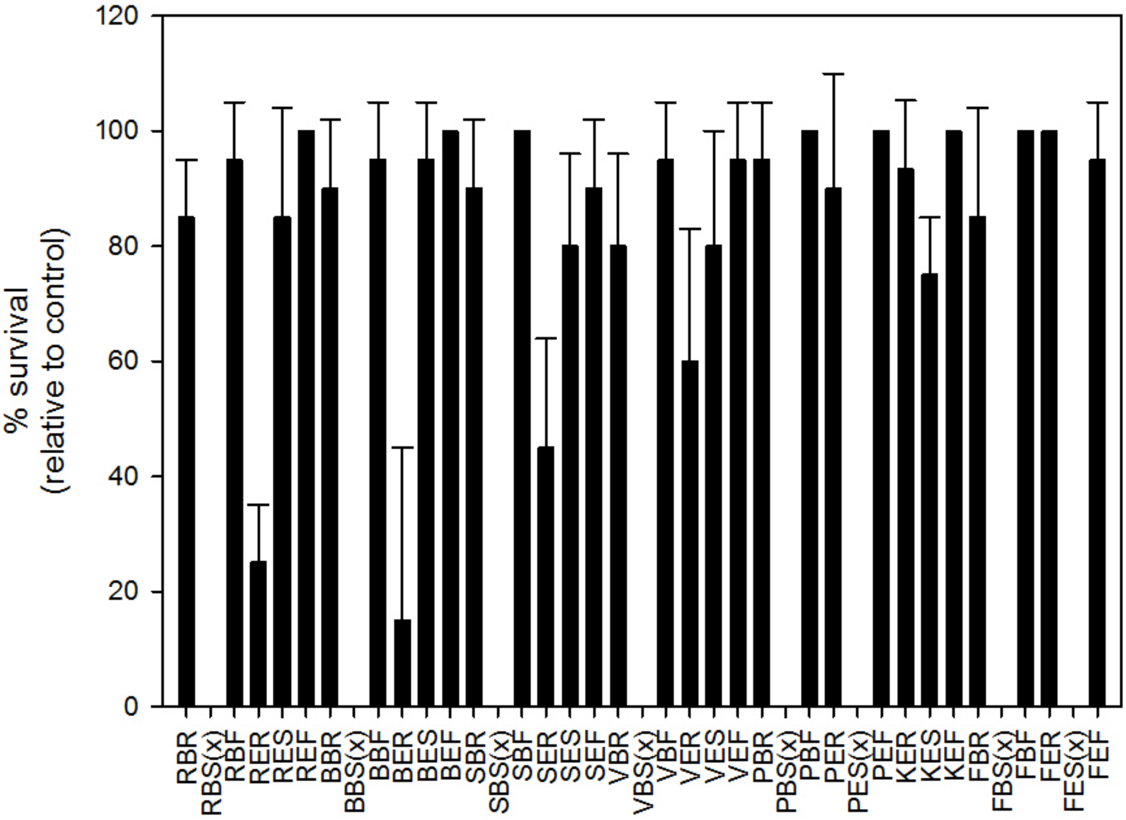


Figure E1. Summary data on survival (acute toxicity) of midges (*Chironomus tepperi*) for all leachates. Data expressed as relative to reservoir water control. (x) indicates sample was not tested. First letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F) respectively; Second letter represents Baseline (B) or Enriched (E) excavated rock; Third letter represents raw (R), after 24 h settling (S) and filtered (F) fraction of leachate

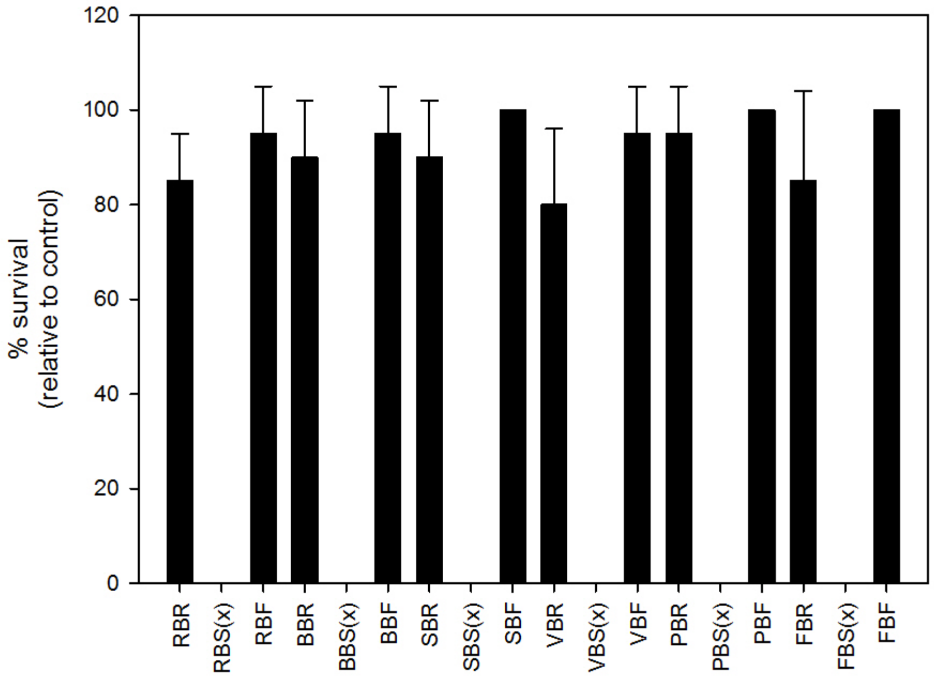


Figure E2. Summary data on survival (acute toxicity) of midges (*Chironomus tepperi*) for leachates of Baseline material. Data expressed as relative to reservoir water control. (x) indicates sample was not tested. First letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F) respectively; Second letter represents Baseline (B) excavated rock; Third letter represents raw (R), after 24 h settling (S) and filtered (F) fraction of leachate

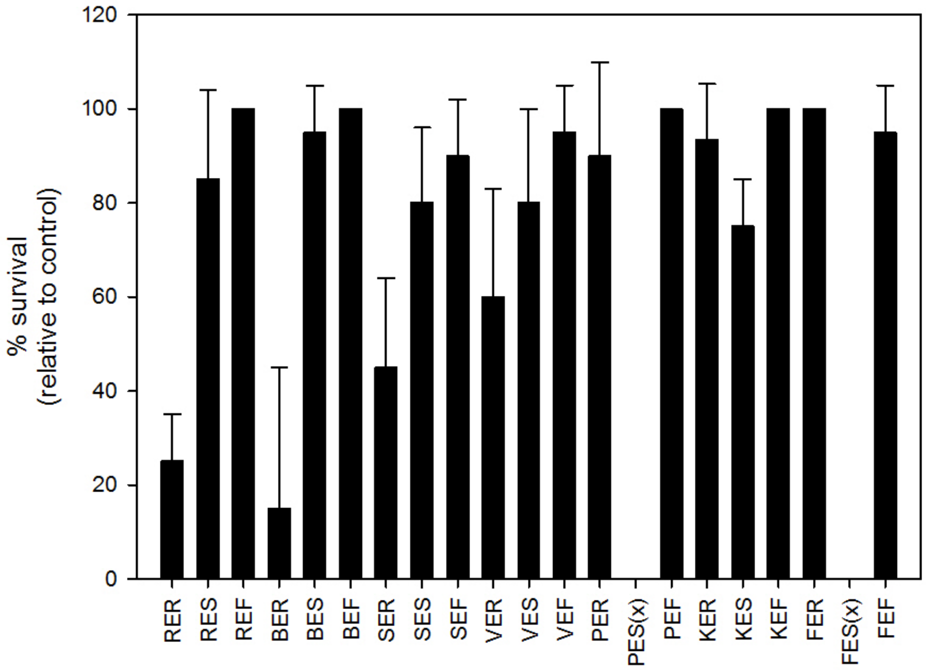
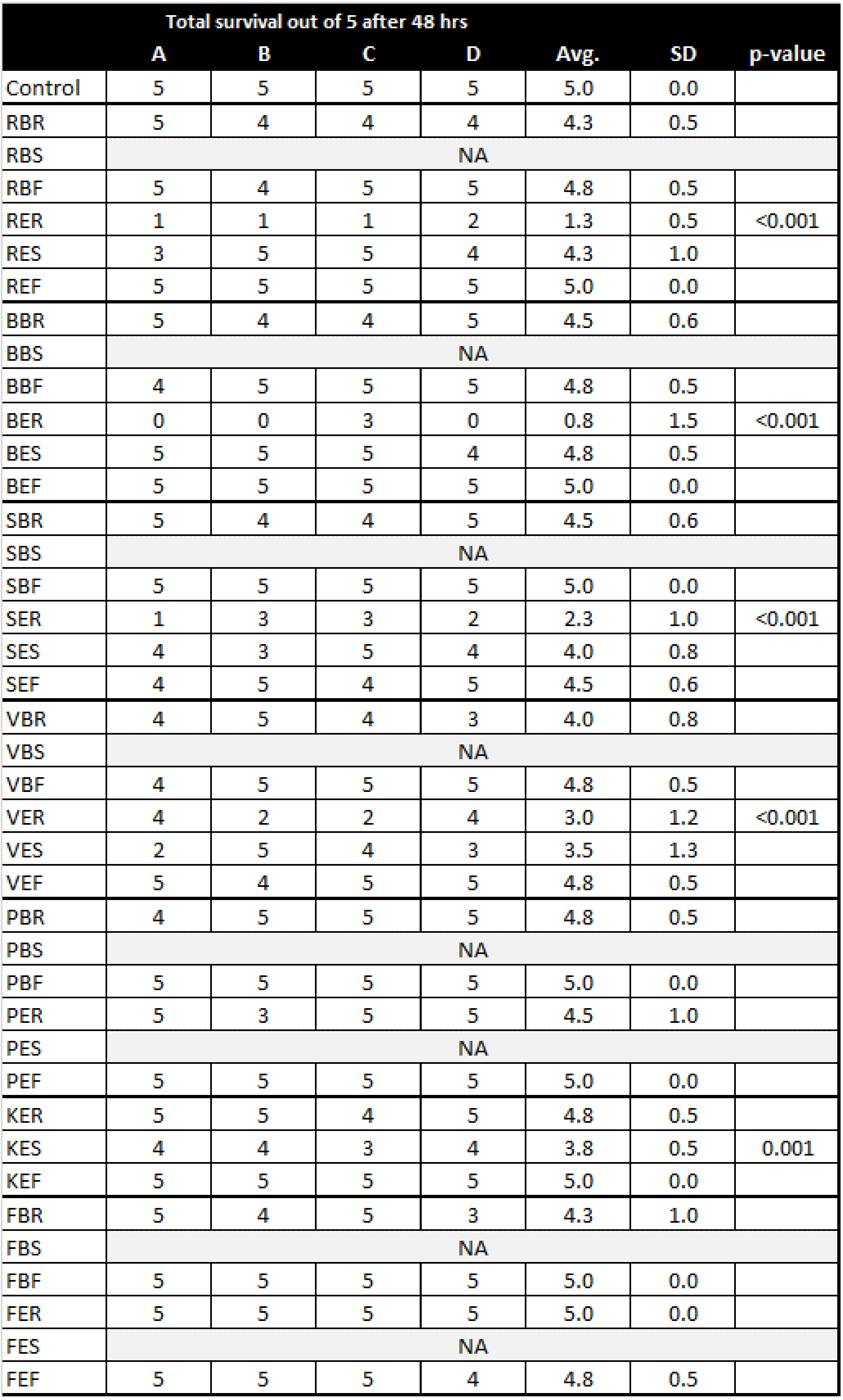


Figure E3. Summary data on survival (acute toxicity) of midges (*Chironomus tepperi*) for leachates of Enriched material. Data expressed as relative to reservoir water control. (x) indicates sample was not tested. First letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F) respectively; Second letter Enriched (E) excavated rock; Third letter represents raw (R), after 24 h settling (S) and filtered (F) fraction of leachate

Table E1. Supplementary survival data (acute toxicity) data for midges (*Chironomus tepperi*) toxicity tests for all leachates. NA sample not analysed. First letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F) respectively; Second letter represents Baseline (B) or Enriched (E) excavated rock; Third letter represents raw (R), after 24 h settling (S) and filtered (F) fraction of leachate



	Total survival out of 5 after 48 hrs						
	A	B	C	D	Avg.	SD	p-value
Control	5	5	5	5	5.0	0.0	
RBR	5	4	4	4	4.3	0.5	
RBS	NA						
RBF	5	4	5	5	4.8	0.5	
RER	1	1	1	2	1.3	0.5	<0.001
RES	3	5	5	4	4.3	1.0	
REF	5	5	5	5	5.0	0.0	
BBR	5	4	4	5	4.5	0.6	
BBS	NA						
BBF	4	5	5	5	4.8	0.5	
BER	0	0	3	0	0.8	1.5	<0.001
BES	5	5	5	4	4.8	0.5	
BEF	5	5	5	5	5.0	0.0	
SBR	5	4	4	5	4.5	0.6	
SBS	NA						
SBF	5	5	5	5	5.0	0.0	
SER	1	3	3	2	2.3	1.0	<0.001
SES	4	3	5	4	4.0	0.8	
SEF	4	5	4	5	4.5	0.6	
VBR	4	5	4	3	4.0	0.8	
VBS	NA						
VBF	4	5	5	5	4.8	0.5	
VER	4	2	2	4	3.0	1.2	<0.001
VES	2	5	4	3	3.5	1.3	
VEF	5	4	5	5	4.8	0.5	
PBR	4	5	5	5	4.8	0.5	
PBS	NA						
PBF	5	5	5	5	5.0	0.0	
PER	5	3	5	5	4.5	1.0	
PES	NA						
PEF	5	5	5	5	5.0	0.0	
KER	5	5	4	5	4.8	0.5	
KES	4	4	3	4	3.8	0.5	0.001
KEF	5	5	5	5	5.0	0.0	
FBR	5	4	5	3	4.3	1.0	
FBS	NA						
FBF	5	5	5	5	5.0	0.0	
FER	5	5	5	5	5.0	0.0	
FES	NA						
FEF	5	5	5	4	4.8	0.5	

Table E2. Supplementary water quality data for the acute (survival) toxicity tests with the midge (*Chironomus tepperi*). NA indicates sample not analysed. First letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F) respectively; Second letter represents Baseline (B) or Enriched (E) excavated rock; Third letter represents raw (R), after 24 h settling (S) and filtered (F) fraction of leachate

	Water Quality at test completion			
Treatment	pH	DO (% sat.)	Conductivity (µS/cm)	Temperature (° C)
RBR	8.1	85.2	120.9	24.0
RBS	NA			
RBF	7.9	90.1	93.3	24.0
RER	7.9	86.1	157.2	24.0
RES	7.8	95.3	152.4	24.0
REF	7.9	91.4	148.7	24.0
BBR	8.0	85.2	192.5	24.0
BBS	NA			
BBF	7.9	91.1	135.2	24.0
BER	7.8	84.0	244.0	24.0
BES	7.8	94.1	218.3	24.0
BEF	8.0	92.2	189.6	24.0
SBR	7.7	93.0	170.3	24.0
SBS	NA			
SBF	7.9	90.0	102.8	24.0
SER	7.9	86.8	144.2	24.0
SES	7.8	95.6	122.8	24.0
SEF	7.9	91.8	120.3	24.0
VBR	8.2	86.6	158.0	24.0
VBS	NA			
VBF	7.9	90.5	109.0	24.0
VER	7.9	89.6	120.2	24.0
VES	7.8	94.5	134.4	24.0
VEF	7.9	91.7	132.7	24.0
PBR	7.4	89.9	165.0	24.0
PBS	NA			
PBF	7.9	90.3	85.1	24.0
PER	7.9	85.4	164.2	24.0
PES	NA			
PEF	7.9	91.7	144.5	24.0
KER	7.7	93.0	144.7	24.0
KES	7.8	94.9	138.4	24.0
KEF	7.9	92.1	130.9	24.0
FBR	8.1	85.8	148.8	24.0
FBS	NA			
FBF	7.9	91.6	100.0	24.0
FER	8.0	85.9	191.8	24.0
FES	NA			
FEF	8.0	91.9	152.9	24.0

Table E3. Acute toxicity of reservoir water samples to the midge, *Chironomus tepperi*

	Total survival out of 5 after 48 hrs						Water Quality at test completion			
	A	B	C	D	Avg.	SD	pH	DO (% sat.)	Conductivity (µS/cm)	Temperature (^{o} C)
TN3	5	5	5	5	5	0	7.7	87.8	40.5	21
TN2	5	5	5	3	4.5	1.00	7.6	87.0	40.5	21
TN1	4	4	4	5	4.25	0.50	7.7	87.2	40.2	21
TAL-PL2C	4	5	4	5	4.5	0.58	7.7	87.6	41.7	21
TAL-PL1C	4	4	4	5	4.25	0.50	7.8	87.2	37.9	21
TAL-PL2D	5	5	4	5	4.75	0.50	7.9	87.4	34.3	21
TAL-PL1D	5	4	4	5	4.5	0.58	7.7	87.0	42.9	21

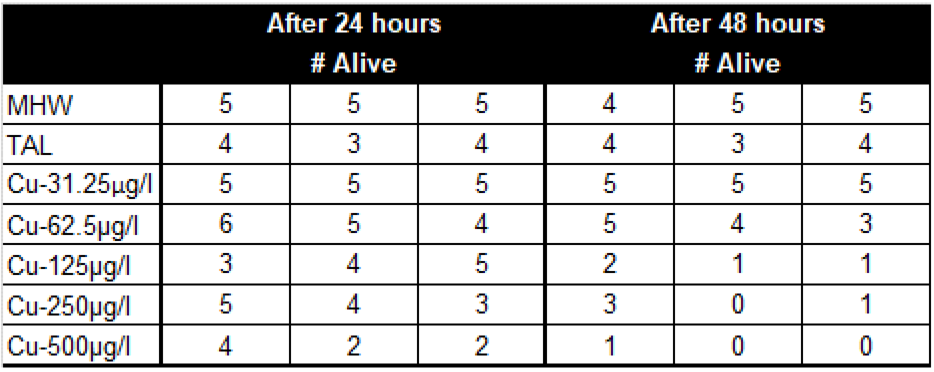
Table E4. Low electrical conductivity (EC) related acute toxicity to the midge, *Chironomus tepperi*

	Total survival out of 5 after 48 hrs						Water Quality at test completion			
	A	B	C	D	Avg.	SD	pH	DO (% sat.)	Conductivity (µS/cm)	Temperature (^{o} C)
MHW	5	5	5	4	4.75	0.5	7.59	88.8	312	21
6.25% MHW	5	5	4	4	4.5	0.58	7.8	89.8	35.3	21
12.5% MHW	5	5	5	5	5	0	7.78	88.8	59	21
25% MHW	5	5	5	4	4.75	0.5	7.81	87.8	97.5	21
50% MHW	5	5	5	4	4.75	0.5	7.76	87.2	172.8	21
75% MHW	5	5	5	5	5	0	7.72	87.4	241	21
100% MHW	5	5	5	5	5	0	7.59	88.8	312	21

Table E5. Low electrical conductivity (EC) as sodium chloride related acute toxicity to the midge, *Chironomus tepperi*

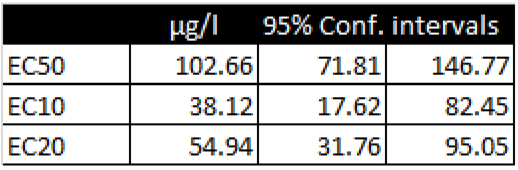
Concentration of NaCl	After 48 hours # Alive						Water Quality at test completion			
	A	B	C	D	Avg.	SD	pH	DO	Conductivity (µS/cm)	Temperature (^{o} C)
MHW	5	5	5	5	5	0	7.79	117.3	321	21
125mg/l	5	5	5	5	5	0	7.53	89.5	55.7	21
250mg/l	5	5	5	4	4.75	0.5	7.62	89.4	79.0	21
500mg/l	5	5	5	4	4.75	0.5	7.73	89.7	127.3	21
1000mg/l	5	5	5	5	5	0	7.79	89.7	238.0	21
2000mg/l	5	4	5	5	4.75	0.5	7.75	90.8	468.0	21

Table E6. Copper test run with the midge (*Chironomus tepperi*) during acute toxicity tests with leachates.



	After 24 hours # Alive			After 48 hours # Alive		
MHW	5	5	5	4	5	5
TAL	4	3	4	4	3	4
Cu-31.25µg/l	5	5	5	5	5	5
Cu-62.5µg/l	6	5	4	5	4	3
Cu-125µg/l	3	4	5	2	1	1
Cu-250µg/l	5	4	3	3	0	1
Cu-500µg/l	4	2	2	1	0	0

Table E7. The effective concentration (µg/L) of copper at 50%, 10% and 20% for the midge (*Chironomus tepperi*) during acute toxicity tests with leachates.



	µg/l	95% Conf. intervals	
EC50	102.66	71.81	146.77
EC10	38.12	17.62	82.45
EC20	54.94	31.76	95.05

Appendix F Leachates of excavated rock material: Supplementary information for blackworm (*Lumbriculus variegatus*) acute tests

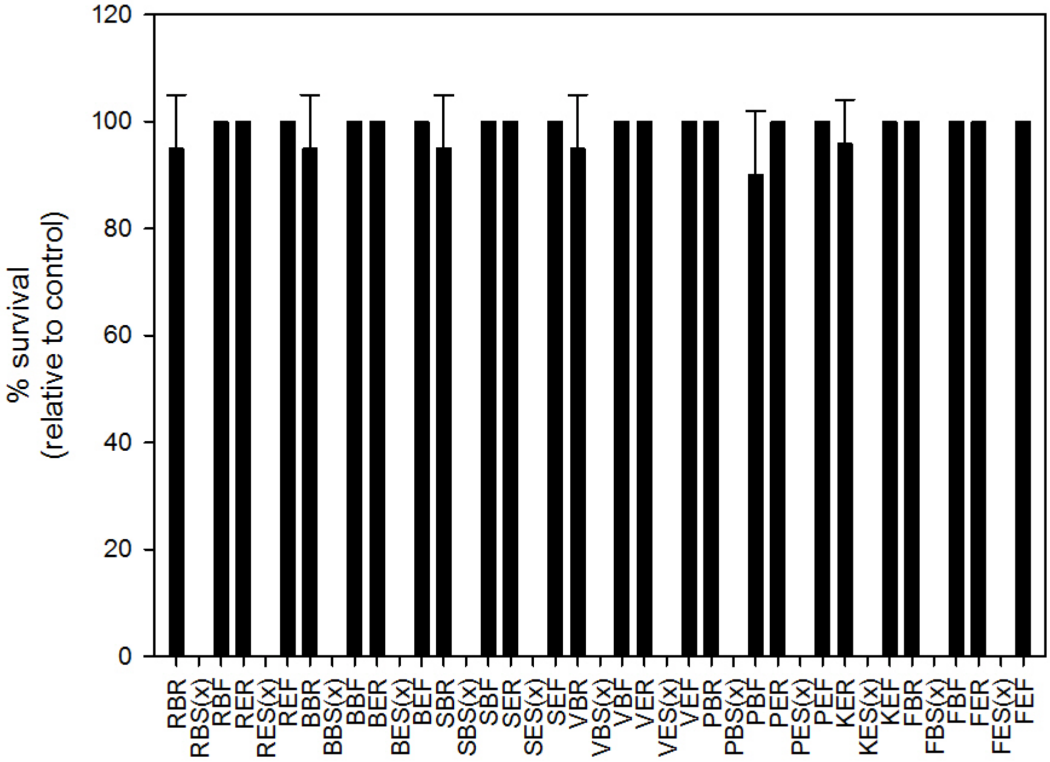


Figure F1. Summary data on survival (acute toxicity) of the blackworm (*Lumbriculus variegatus*) for all leachates. Data expressed as relative to reservoir water control. (x) indicates sample was not tested.. First letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F) respectively; Second letter represents Baseline (B) or Enriched (E) excavated rock; Third letter represents raw (R), after 24 h settling (S) and filtered (F) fraction of leachate

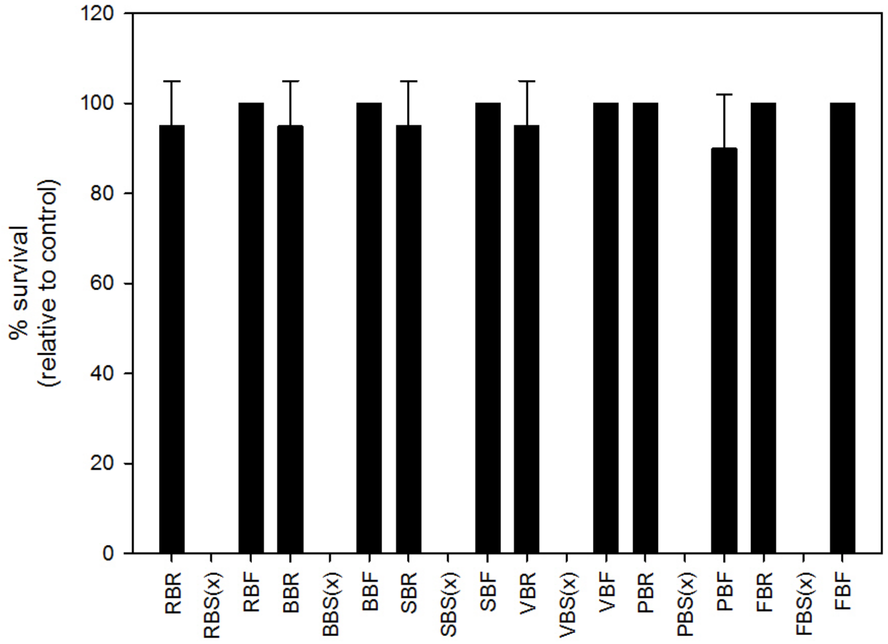


Figure F2. Summary data on survival (acute toxicity) of blackworm (*Lumbriculus variegatus*) for leachates of Baseline material. Data expressed as relative to reservoir water control. . (x) indicates sample was not tested. First letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F) respectively; Second letter represents Baseline (B) excavated rock; Third letter represents raw (R), after 24 h settling (S) and filtered (F) fraction of leachate

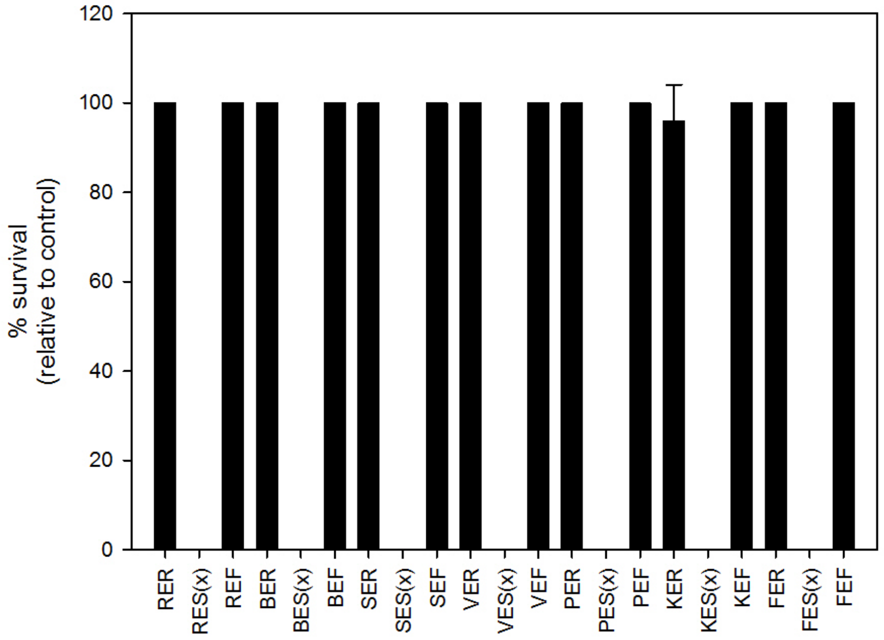
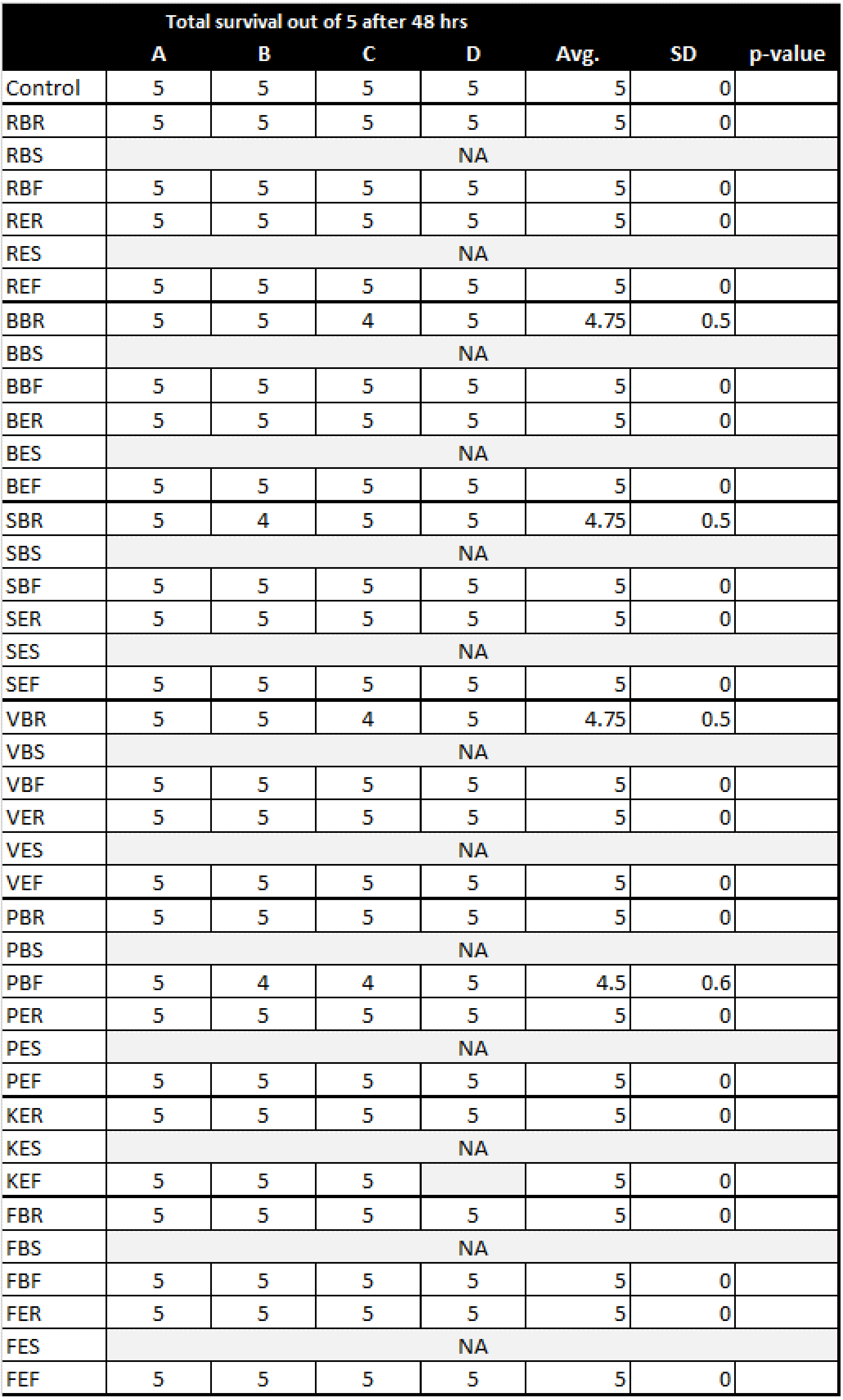


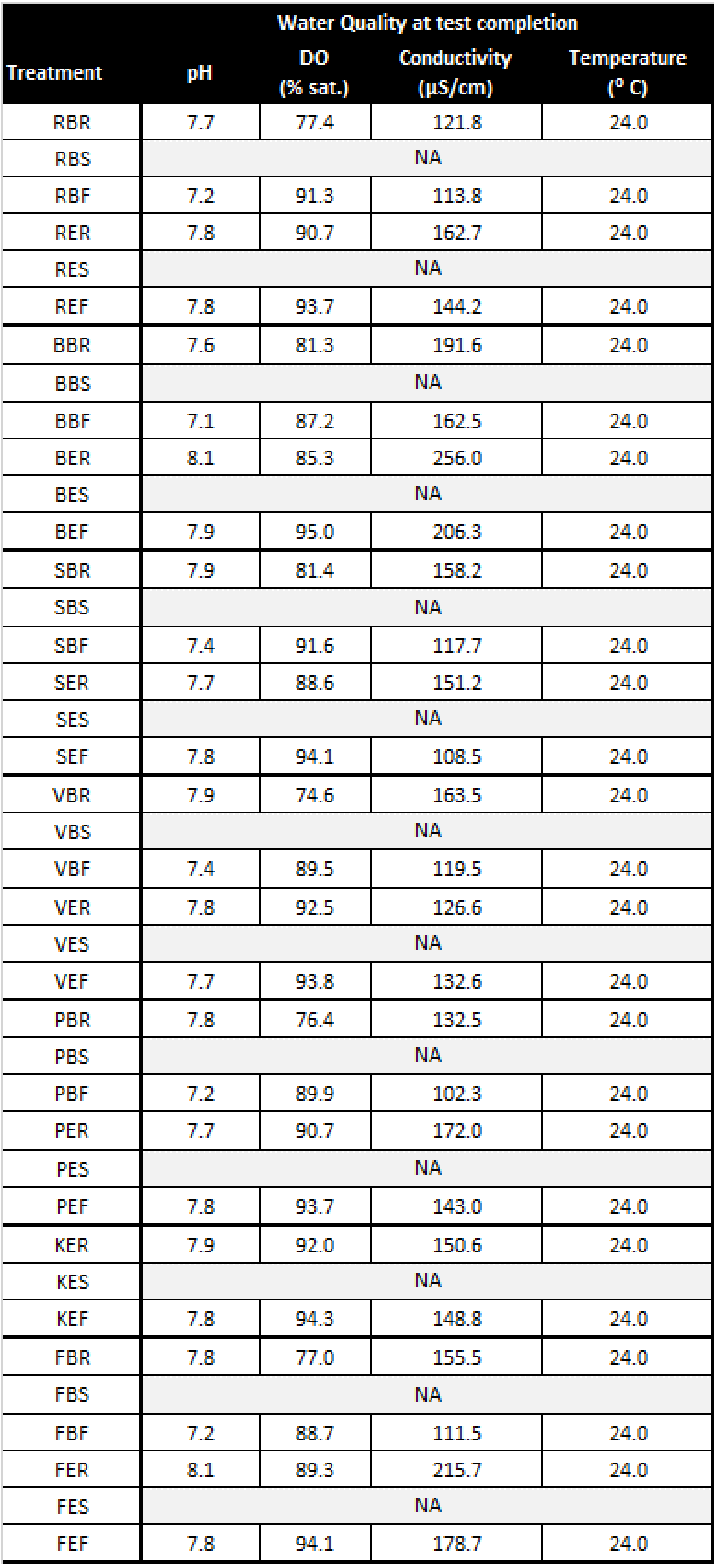
Figure F3. Summary data on survival (acute toxicity) of blackworm (*Lumbriculus variegatus*) for leachates of Enriched material. Data expressed as relative to reservoir water control. (x) indicates sample was not tested. First letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F) respectively; Second letter represents Enriched (E) excavated rock; Third letter represents raw (R), after 24 h settling (S) and filtered (F) fraction of leachate

Table F1. Summary of survival (acute toxicity) data for blackworm (*Lumbriculus variegatus*) toxicity tests for all leachates. NA indicates sample not analysed.. First letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F) respectively; Second letter represents Baseline (B) or Enriched (E) excavated rock; Third letter represents raw (R), after 24 h settling (S) and filtered (F) fraction of leachate



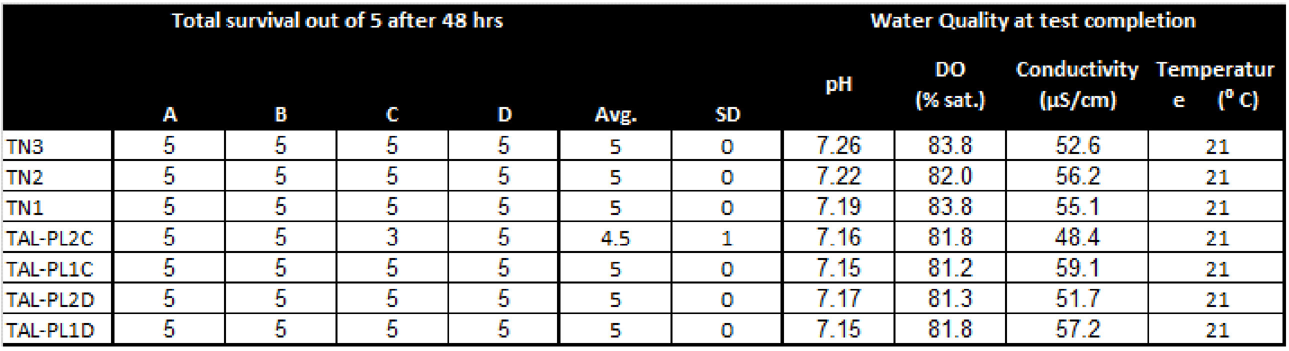
	Total survival out of 5 after 48 hrs						
	A	B	C	D	Avg.	SD	p-value
Control	5	5	5	5	5	0	
RBR	5	5	5	5	5	0	
RBS	NA						
RBF	5	5	5	5	5	0	
RER	5	5	5	5	5	0	
RES	NA						
REF	5	5	5	5	5	0	
BBR	5	5	4	5	4.75	0.5	
BBS	NA						
BBF	5	5	5	5	5	0	
BER	5	5	5	5	5	0	
BES	NA						
BEF	5	5	5	5	5	0	
SBR	5	4	5	5	4.75	0.5	
SBS	NA						
SBF	5	5	5	5	5	0	
SER	5	5	5	5	5	0	
SES	NA						
SEF	5	5	5	5	5	0	
VBR	5	5	4	5	4.75	0.5	
VBS	NA						
VBF	5	5	5	5	5	0	
VER	5	5	5	5	5	0	
VES	NA						
VEF	5	5	5	5	5	0	
PBR	5	5	5	5	5	0	
PBS	NA						
PBF	5	4	4	5	4.5	0.6	
PER	5	5	5	5	5	0	
PES	NA						
PEF	5	5	5	5	5	0	
KER	5	5	5	5	5	0	
KES	NA						
KEF	5	5	5		5	0	
FBR	5	5	5	5	5	0	
FBS	NA						
FBF	5	5	5	5	5	0	
FER	5	5	5	5	5	0	
FES	NA						
FEF	5	5	5	5	5	0	

Table F2. Supplementary water quality data for the acute (survival) toxicity tests with the blackworm (*Lumbriculus variegatus*). NA indicates sample not analysed. First letter represents the geological zone Ravine (R), Byron (B), Shaw Gabbro (S), Volcanics (V), Peppercorn (P), Kellys Plain (K) and Felsic (F) respectively; Second letter represents Baseline (B) or Enriched (E) excavated rock; Third letter represents raw (R), after 24 h settling (S) and filtered (F) fraction of leachate.



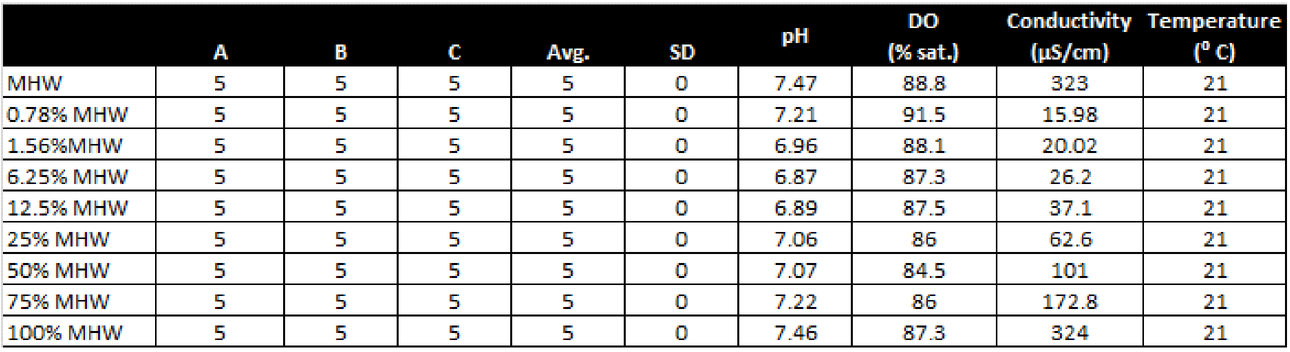
	Water Quality at test completion			
Treatment	pH	DO (% sat.)	Conductivity (µS/cm)	Temperature (° C)
RBR	7.7	77.4	121.8	24.0
RBS	NA			
RBF	7.2	91.3	113.8	24.0
RER	7.8	90.7	162.7	24.0
RES	NA			
REF	7.8	93.7	144.2	24.0
BBR	7.6	81.3	191.6	24.0
BBS	NA			
BBF	7.1	87.2	162.5	24.0
BER	8.1	85.3	256.0	24.0
BES	NA			
BEF	7.9	95.0	206.3	24.0
SBR	7.9	81.4	158.2	24.0
SBS	NA			
SBF	7.4	91.6	117.7	24.0
SER	7.7	88.6	151.2	24.0
SES	NA			
SEF	7.8	94.1	108.5	24.0
VBR	7.9	74.6	163.5	24.0
VBS	NA			
VBF	7.4	89.5	119.5	24.0
VER	7.8	92.5	126.6	24.0
VES	NA			
VEF	7.7	93.8	132.6	24.0
PBR	7.8	76.4	132.5	24.0
PBS	NA			
PBF	7.2	89.9	102.3	24.0
PER	7.7	90.7	172.0	24.0
PES	NA			
PEF	7.8	93.7	143.0	24.0
KER	7.9	92.0	150.6	24.0
KES	NA			
KEF	7.8	94.3	148.8	24.0
FBR	7.8	77.0	155.5	24.0
FBS	NA			
FBF	7.2	88.7	111.5	24.0
FER	8.1	89.3	215.7	24.0
FES	NA			
FEF	7.8	94.1	178.7	24.0

Table F3. Acute toxicity of Tantangara and Talbingo Reservoir water samples to the blackworm, *Lumbriculus variegatus*.



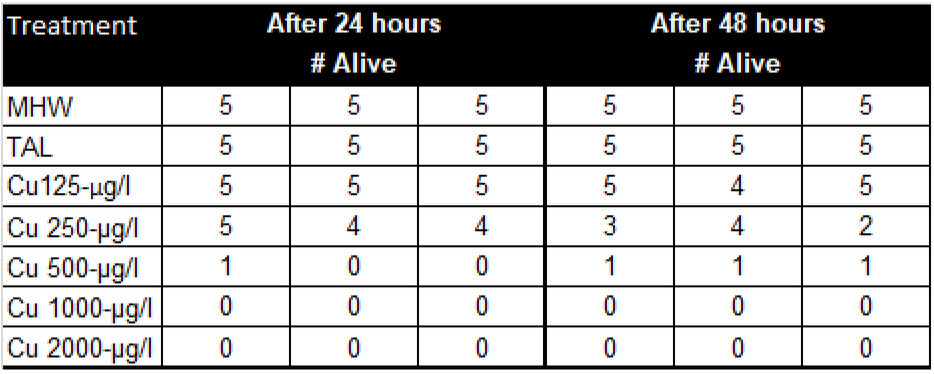
	Total survival out of 5 after 48 hrs						Water Quality at test completion			
	A	B	C	D	Avg.	SD	pH	DO (% sat.)	Conductivity (µS/cm)	Temperature (° C)
TN3	5	5	5	5	5	0	7.26	83.8	52.6	21
TN2	5	5	5	5	5	0	7.22	82.0	56.2	21
TN1	5	5	5	5	5	0	7.19	83.8	55.1	21
TAL-PL2C	5	5	3	5	4.5	1	7.16	81.8	48.4	21
TAL-PL1C	5	5	5	5	5	0	7.15	81.2	59.1	21
TAL-PL2D	5	5	5	5	5	0	7.17	81.3	51.7	21
TAL-PL1D	5	5	5	5	5	0	7.15	81.8	57.2	21

Table F4. Low electrical conductivity (EC) related acute toxicity to the blackworm, *Lumbriculus variegatus*.



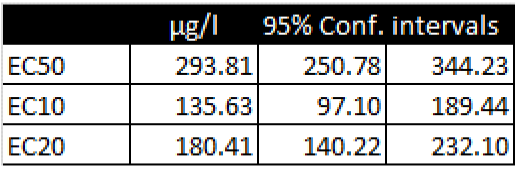
	A	B	C	Avg.	SD	pH	DO (% sat.)	Conductivity (µS/cm)	Temperature (° C)
MHW	5	5	5	5	0	7.47	88.8	323	21
0.78% MHW	5	5	5	5	0	7.21	91.5	15.98	21
1.56%MHW	5	5	5	5	0	6.96	88.1	20.02	21
6.25% MHW	5	5	5	5	0	6.87	87.3	26.2	21
12.5% MHW	5	5	5	5	0	6.89	87.5	37.1	21
25% MHW	5	5	5	5	0	7.06	86	62.6	21
50% MHW	5	5	5	5	0	7.07	84.5	101	21
75% MHW	5	5	5	5	0	7.22	86	172.8	21
100% MHW	5	5	5	5	0	7.46	87.3	324	21

Table F5. Copper reference toxicity tests with the blackworm (*Lumbriculus variegatus)* during acute toxicity tests with leachates.



Treatment	After 24 hours # Alive			After 48 hours # Alive		
MHW	5	5	5	5	5	5
TAL	5	5	5	5	5	5
Cu125-µg/l	5	5	5	5	4	5
Cu 250-µg/l	5	4	4	3	4	2
Cu 500-µg/l	1	0	0	1	1	1
Cu 1000-µg/l	0	0	0	0	0	0
Cu 2000-µg/l	0	0	0	0	0	0

Table F6. The effective concentration (µg/l) of copper at 50%, 10% and 20% for blackworm (*Lumbriculus variegatus*) during acute toxicity tests with leachates.



	µg/l	95% Conf. intervals	
EC50	293.81	250.78	344.23
EC10	135.63	97.10	189.44
EC20	180.41	140.22	232.10

Appendix G Excavated rock material in sediments: Supplimentary information on midge (*Chironomus tepperi*) toxicity tests

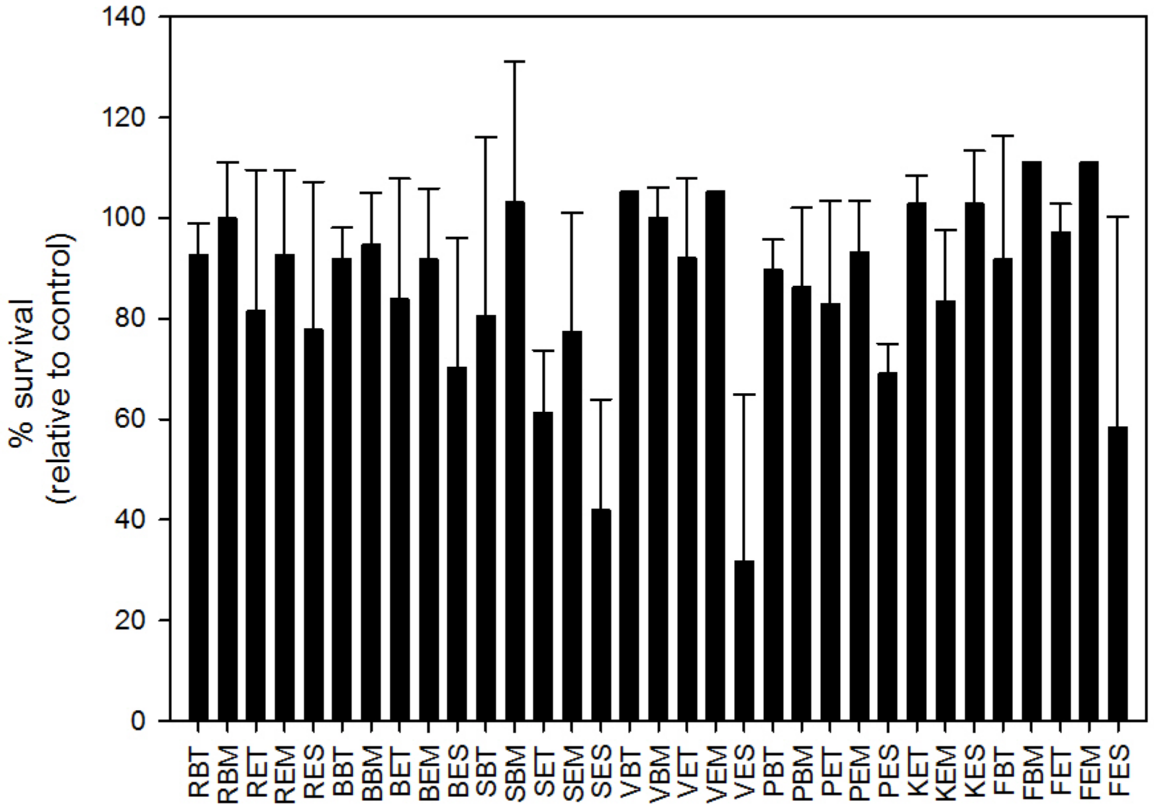


Figure G1. % Survival of midges (*Chironomus tepperi*) after 7-day exposure to excavated rock from seven geological zones (Abbreviations for treatments in Table G1)

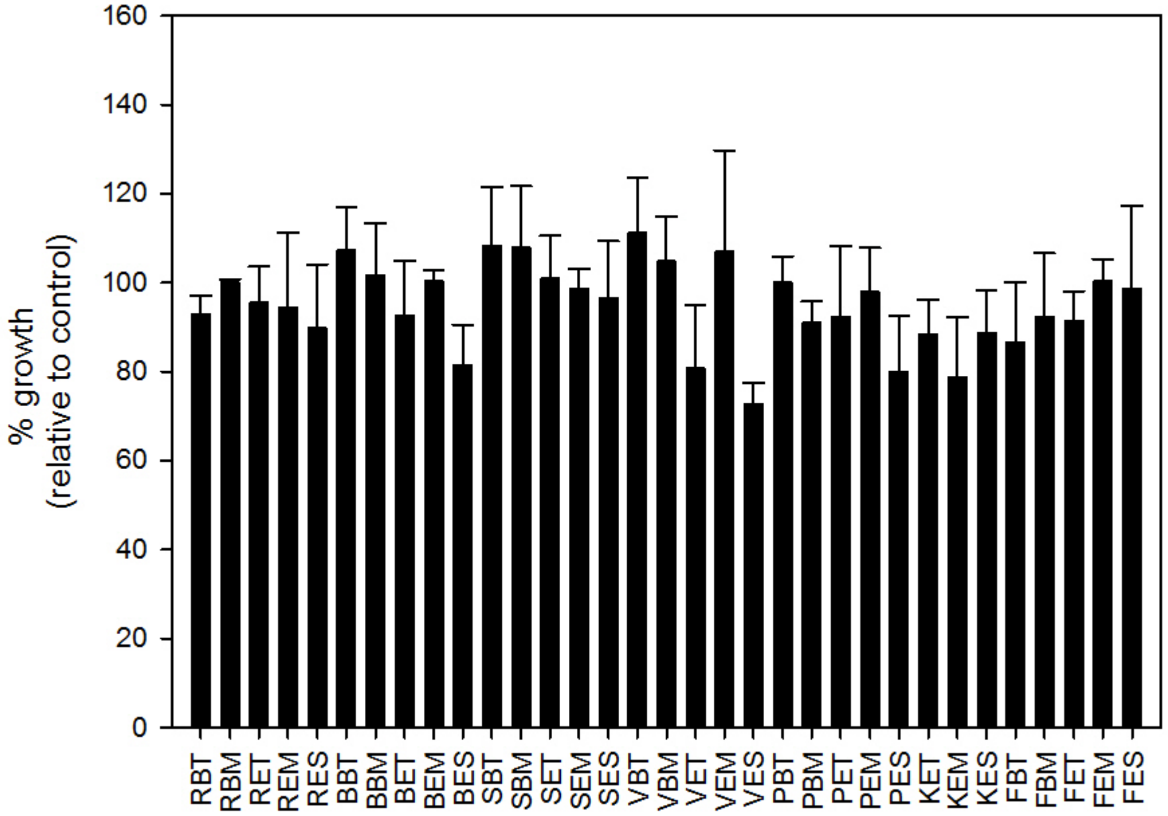


Figure G2. % Growth of midges (*Chironomus tepperi*) after 7-day exposure to excavated rock from seven geological zones (Abbreviations for treatments in Table G1)

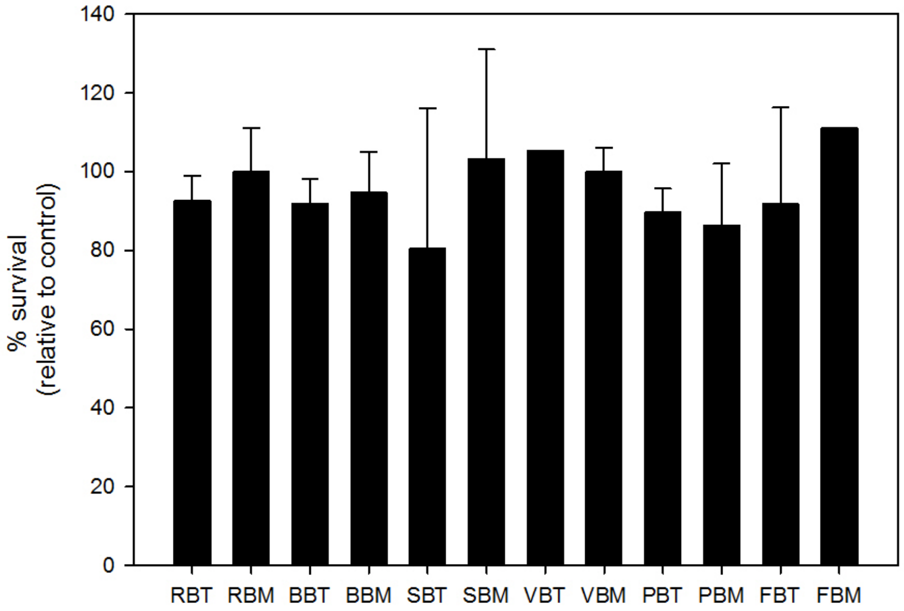


Figure G3. % Survival of midges (*Chironomus tepperi*) after 7-day exposure to Baseline excavated rock from seven geological zones (Abbreviations for treatments in Table G1)

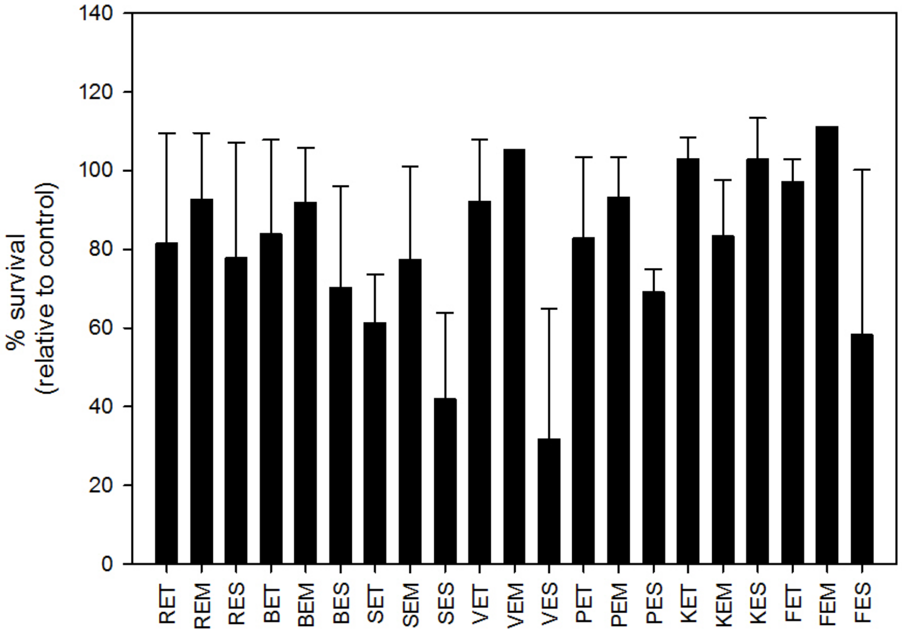


Figure G4. % Survival of midges (*Chironomus tepperi*) after 7-day exposure to Enriched excavated rock from seven geological zones (Abbreviations for treatments in Table G1)

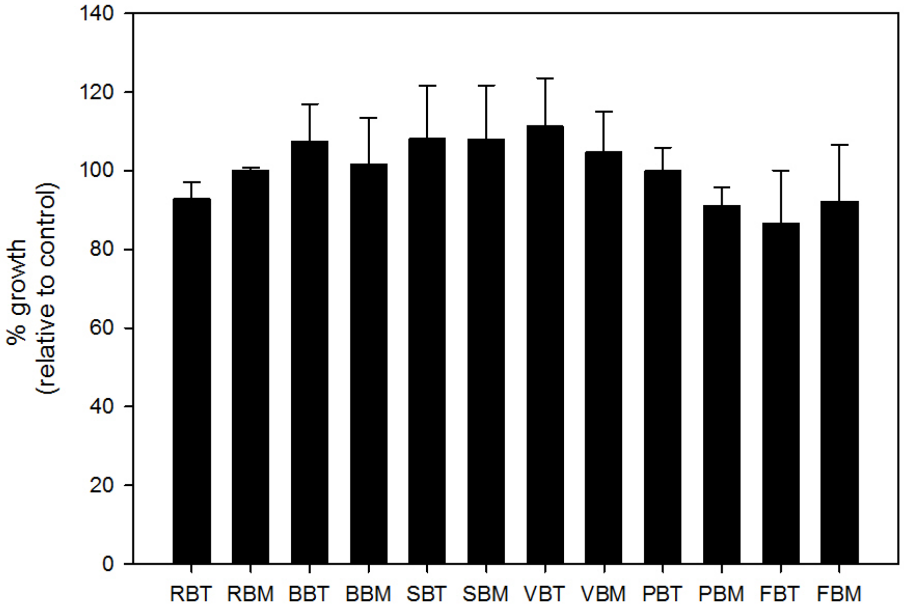


Figure G5. % Growth of midges (*Chironomus tepperi*) after 7-day exposure to Baseline excavated rock from seven geological zones (Abbreviations for treatments in Table G1)

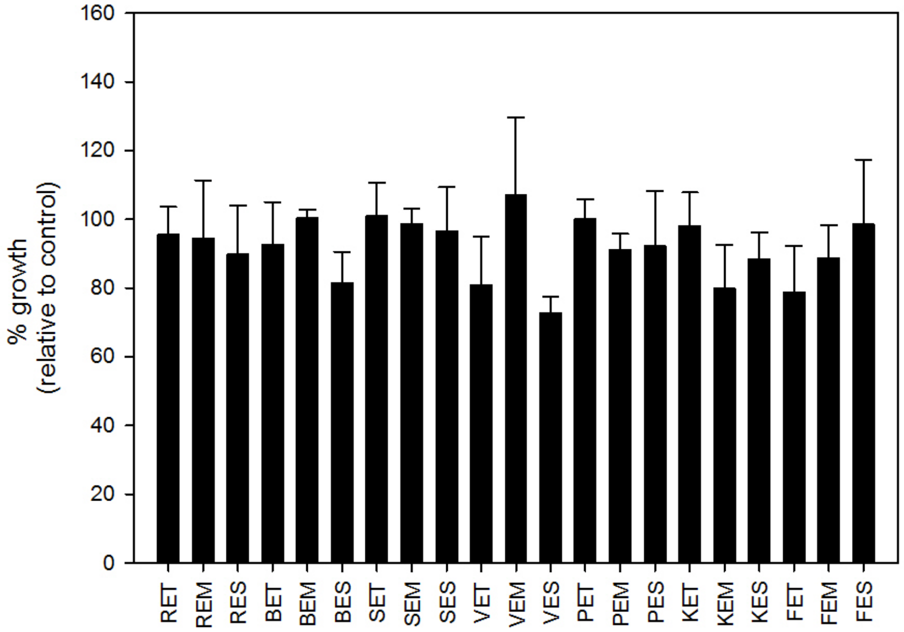


Figure G6. % Growth of midges (*Chironomus tepperi*) after 7-day exposure to Enriched excavated rock from seven geological zones (Abbreviations for treatments in Table G1)

Table G1. Supplementary survival data from midge sediment-excavated rock tests for seven geological zones.

	Total survival out of 10 after 7 days								
	# Alive								
	A	B	C	D	Total Alive	Avg	St.Dev	n	p-value
CONTROL	10	7	10	-	27	9.0	1.7	3	
RBT	9	8	8	-	25	8.3	0.6	3	
RBM	9	10	8	-	27	9.0	1.0	3	
RET	10	5	7	-	22	7.3	2.5	3	
REM	8	7	10	-	25	8.3	1.5	3	
RES	9	4	8	-	21	7.0	2.6	3	
CONTROL	10	7	10	10	37	9.3	1.5	4	
BBT	9	8	8	9	34	8.5	0.6	4	
BBM	9	10	8	8	35	8.8	1.0	4	
BET	10	5	7	9	31	7.8	2.2	4	
BEM	8	7	10	9	34	8.5	1.3	4	
BES	9	4	8	5	26	6.5	2.4	4	
CONTROL	7	7	7	10	31	7.8	1.5	4	
SBT	9	3	8	5	25	6.3	2.8	4	
SBM	8	9	5	10	32	8.0	2.2	4	
SET	6	4	5	4	19	4.8	1.0	4	
SEM	7	8	4	5	24	6.0	1.8	4	
SES	3	5	4	1	13	3.3	1.7	4	0.015
CONTROL	10	10	10	8	38	9.5	1.0	4	
VBT	10	10	10	10	40	10.0	0.0	4	
VBM	9	9	10	10	38	9.5	0.6	4	
VET	7	8	10	10	35	8.8	1.5	4	
VEM	10	10	10	10	40	10.0	0.0	4	
VES	7	4	1	0	12	3.0	3.2	4	<0.001
CONTROL	10	9	10	-	29	9.7	0.6	3	
PBT	9	9	8	-	26	8.7	0.6	3	
PBM	10	7	8	-	25	8.3	1.5	3	
PET	10	6	8	-	24	8.0	2.0	3	
PEM	10	9	8	-	27	9.0	1.0	3	
PES	7	7	6	-	20	6.7	0.6	3	
CONTROL	8	10	9	9	36	9.0	0.8	4	
KET	9	9	9	10	37	9.3	0.5	4	
KEM	9	6	8	7	30	7.5	1.3	4	
KES	8	10	9	10	37	9.3	1.0	4	
CONTROL	9	9	8	10	36	9.0	0.8	4	
FBT	9	9	5	10	33	8.3	2.2	4	
FBM	10	10	10	10	40	10.0	0.0	4	
FET	9	8	9	9	35	8.8	0.5	4	
FEM	10	10	10	10	40	10.0	0.0	4	
FES	6	9	6	0	21	5.3	3.8	4	0.038

Table G2. Supplementary growth data from midge sediment-excavated rock tests for seven geological zones

	Length(mm)							
	A	B	C	D	Avg Length	Std Dev	n	p value
CONTROL	15.21	14.56	14.53	-	14.77	0.39	3	
RBT	14.09	14.08	12.99	-	13.72	0.63	3	
RBM	14.66	14.88	14.81	-	14.78	0.11	3	
RET	15.24	12.90	14.22	-	14.12	1.18	3	
REM	16.20	14.40	11.23	-	13.94	2.52	3	
RES	11.08	15.31	13.38	-	13.26	2.12	3	
CONTROL	15.90	15.07	13.99	15.09	15.01	0.78	4	
BBT	15.02	17.78	17.18	14.43	16.10	1.62	4	
BBM	14.95	12.98	16.50	16.65	15.27	1.71	4	
BET	14.82	11.32	14.15	15.32	13.90	1.79	4	
BEM	15.58	15.34	14.82	14.48	15.05	0.50	4	
BES	10.79	11.97	13.55	12.59	12.23	1.15	4	0.037
CONTROL	10.95	13.68	9.94	14.90	12.37	2.31	4	
SBT	11.81	14.70	11.95	15.12	13.39	1.76	4	
SBM	13.45	15.57	12.19	12.16	13.34	1.60	4	
SET	12.91	13.33	11.07	12.59	12.48	0.98	4	
SEM	11.72	12.55	12.80	11.67	12.18	0.58	4	
SES	11.83	12.83	14.91	8.23	11.95	2.79	4	
CONTROL	12.83	13.96	12.93	14.52	13.56	0.82	4	
VBT	16.94	14.63	13.71	0.00	11.32	7.67	4	
VBM	14.58	12.50	15.12	14.67	14.22	1.17	4	
VET	8.31	12.08	10.75	12.72	10.97	1.95	4	
VEM	18.00	14.30	11.89	13.86	14.51	2.55	4	
VES	9.14	10.24	10.25	0.00	9.88	4.97	4	
CONTROL	15.46	10.26	14.39	-	13.37	2.75	3	
PBT	15.40	13.79	14.12	-	14.44	0.85	3	
PBM	12.84	14.11	13.97	-	13.64	0.70	3	
PET	14.54	15.76	11.11	-	13.80	2.41	3	
PEM	16.33	14.17	13.48	-	14.66	1.49	3	
PES	13.31	12.82	9.82	-	11.98	1.89	3	
CONTROL	15.94	13.23	16.25	16.52	15.49	1.52	4	
KET	14.04	15.19	13.13	12.39	13.69	1.21	4	
KEM	14.25	9.39	13.06	12.09	12.20	2.07	4	
KES	11.74	14.34	15.22	13.73	13.76	1.48	4	
CONTROL	16.85	13.35	14.41	14.18	14.70	1.51	4	
FBT	12.02	14.73	10.86	13.31	12.73	1.67	4	
FBM	16.10	11.99	13.10	13.00	13.55	1.77	4	
FET	14.00	12.81	14.56	12.98	13.59	0.83	4	
FEM	14.82	13.93	14.96	15.36	14.77	0.60	4	
FES	13.17	16.45	12.54	0.00	10.54	7.23	4	

Table G3. Water quality data for of the midge sediment-excavated rock toxicity tests for the seven geological zones

		Water Quality at Day 1				Water Quality at test completion			
Treatment	**Replicate**	**pH**	**DO (% saturation)**	**Conductivity (µS/cm)**	**Temperature (° C)**	**pH**	**DO (% saturation)**	**Conductivity (µS/cm)**	**Temperature (° C)**
Control	A	7.52	89	218	21	7.98	90.3	170	21
	B	7.54	89	217	21	7.41	89.2	160	21
	C	7.53	90.2	216	21	7.57	90.3	172	21
RBT	A	7.37	92.4	291	21	7.66	89.0	270	21
	B	7.82	92.4	317	21	7.58	90.1	239	21
	C	8.05	92.4	323	21	7.62	93.2	269	21
RBM	A	7.77	92.3	321	21	8.04	71	417	21
	B	7.62	89.9	237	21	8.01	75.5	418	21
	C	7.57	89.4	213	21	8.06	77.6	407	21
RET	A	7.86	90.2	240	21	8.09	82.1	410	21
	B	7.91	90.1	295	21	8.15	80.4	440	21
	C	8.05	91	298	21	7.91	54.6	465	21
REM	A	7.78	88.6	231	21	7.98	79	383	21
	B	7.68	89.1	223	21	7.96	72.8	402	21
	C	7.54	89.6	220	21	8.01	77	395	21
RES	A	8.05	91.5	323	21	8.21	8.21	457	21
	B	8.14	91.1	325	21	8.32	8.32	495	21
	C	8.17	91.7	325	21	8.3	8.3	505	21

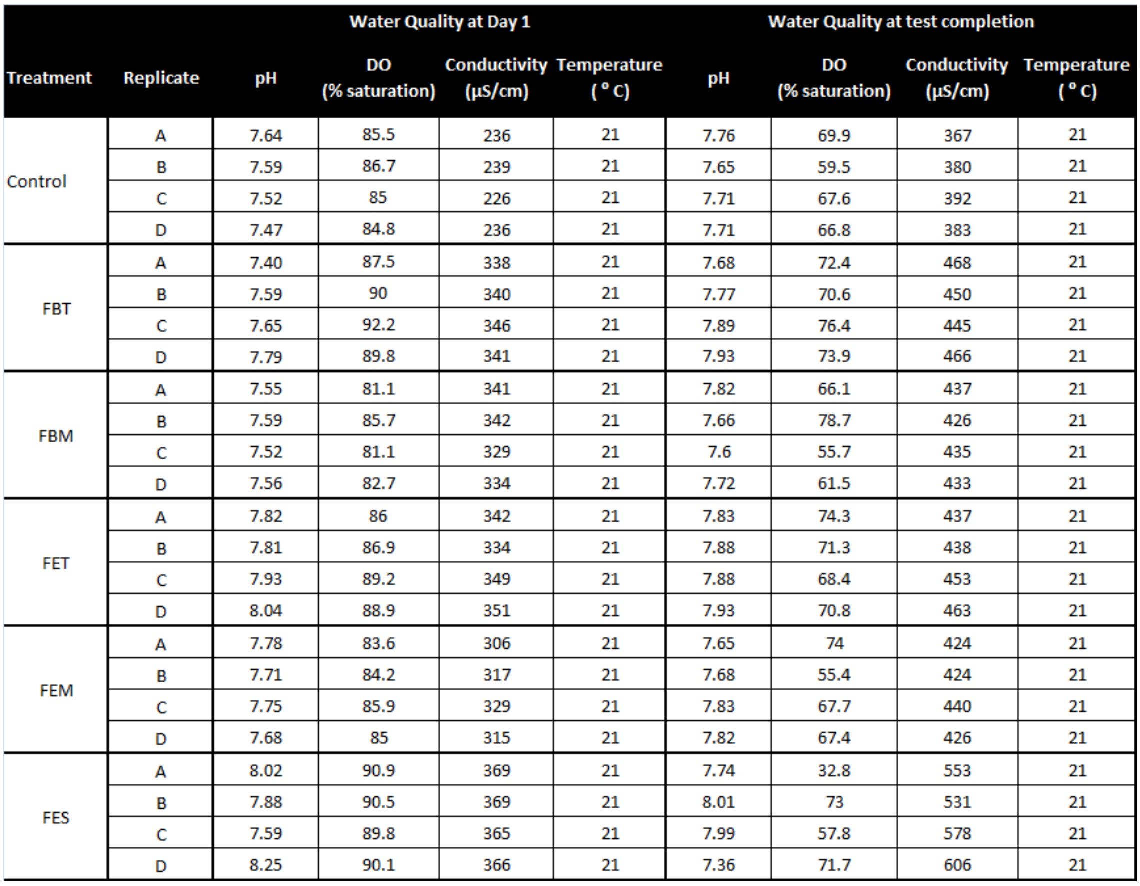
		Water Quality at Day 1				Water Quality at test completion			
Treatment	**Replicate**	**pH**	**DO (% saturation)**	**Conductivity (µS/cm)**	**Temperature (° C)**	**pH**	**DO (% saturation)**	**Conductivity (µS/cm)**	**Temperature (° C)**
Control	A	7.77	110.5	246	21	7.66	77.4	314	21
	B	7.79	107.9	224	21	7.64	77.8	305	21
	C	7.78	104.4	218	21	7.66	80.2	298	21
	D	7.69	103.2	234	21	7.43	74.9	316	21
BBT	A	8.09	110.9	350	21	7.88	72.7	371	21
	B	8.07	101.6	332	21	7.89	74.7	365	21
	C	8.07	103.4	346	21	7.79	78.6	371	21
	D	8.08	106.8	360	21	7.47	28	375	21
BBM	A	7.87	113.3	300	21	7.54	72.7	348	21
	B	7.84	110.5	286	21	7.45	68.3	364	21
	C	7.85	110.1	283	21	7.53	79	345	21
	D	7.86	109.9	303	21	7.43	72.7	344	21
BET	A	8.07	104.5	350	21	7.84	72.9	368	21
	B	8.09	98.9	350	21	7.61	65.6	369	21
	C	8.07	95.7	334	21	7.55	83	357	21
	D	8.08	101.9	346	21	7.88	78.3	359	21
BEM	A	7.95	114.3	275	21	7.69	70.8	338	21
	B	7.84	108.8	284	21	7.73	75.7	337	21
	C	7.86	109.3	278	21	7.68	78.3	330	21
	D	7.81	108.6	270	21	7.72	72	331	21
BES	A	8.28	88.6	469	21	7.97	63.5	578	21
	B	8.3	89.1	445	21	7.97	56.9	581	21
	C	8.37	88.5	445	21	8.09	69.8	569	21
	D	8.35	88.9	444	21	7.6	70.6	573	21

		Water Quality at Day 1				Water Quality at test completion			
Treatment	**Replicate**	**pH**	**DO (% saturation)**	**Conductivity (µS/cm)**	**Temperature (° C)**	**pH**	**DO (% saturation)**	**Conductivity (µS/cm)**	**Temperature (° C)**
Control	A	7.77	110.5	246	21	7.66	77.4	314	21
	B	7.79	107.9	224	21	7.64	77.8	305	21
	C	7.78	104.4	218	21	7.66	80.2	298	21
	D	7.69	103.2	234	21	7.43	74.9	316	21
SBT	A	8.25	91.5	328	21	7.79	81.9	512	21
	B	8.28	90.8	320	21	7.93	79.4	532	21
	C	8.31	91.7	328	21	7.88	79.4	493	21
	D	8.36	92.4	330	21	7.68	53.5	531	21
SBM	A	8	85.2	353	21	7.74	74.2	470	21
	B	8.02	86.1	353	21	7.89	77.6	473	21
	C	7.85	86.8	340	21	7.87	78.2	459	21
	D	8.08	86.9	344	21	7.9	69.1	434	21
SET	A	7.89	88	324	21	7.88	81.4	416	21
	B	7.54	91	327	21	7.52	69.7	445	21
	C	8.04	91.6	325	21	7.6	46.6	482	21
	D	8.75	91.5	325	21	7.58	54.5	476	21
SEM	A	8.04	89.6	271	21	7.65	67.4	449	21
	B	7.8	89	262	21	7.7	57.8	431	21
	C	7.74	89.7	265	21	7.54	52.1	442	21
	D	7.82	88.5	255	21	7.37	48.8	433	21
SES	A	7.47	91.9	329	21	7.66	36	576	21
	B	7.84	91.6	329	21	7.78	59.7	545	21
	C	8	91.4	331	21	7.72	54.6	544	21
	D	8.09	92.1	331	21	7.69	55.8	565	21

		Water Quality at Day 1				Water Quality at test completion			
Treatment	**Replicate**	**pH**	**DO (% saturation)**	**Conductivity (µS/cm)**	**Temperature (° C)**	**pH**	**DO (% saturation)**	**Conductivity (µS/cm)**	**Temperature (° C)**
Control	A	7.35	90.8	293	21	7.78	72.9	334	21
	B	7.25	84.7	255	21	7.80	77.4	307	21
	C	7.46	93	288	21	7.78	69.9	322	21
	D	7.45	92.9	297	21	7.80	69.7	326	21
VBT	A	7.48	90.2	311	21	7.92	77.1	401	21
	B	7.53	93.6	309	21	7.93	75.6	418	21
	C	7.67	92.5	303	21	7.98	80.2	386	21
	D	7.72	91.7	306	21	7.96	76.3	381	21
VBM	A	7.32	92	287	21	7.51	76.4	360	21
	B	7.47	92.1	285	21	7.68	73.6	350	21
	C	7.34	90.8	277	21	7.69	65.6	356	21
	D	7.64	89	274	21	7.76	74.9	336	21
VET	A	7.54	93.3	306	21	7.59	58.2	401	21
	B	7.69	93	305	21	7.66	56.4	418	21
	C	7.46	90.5	296	21	7.5	57.3	386	21
	D	7.49	92.2	316	21	7.8	70	381	21
VEM	A	7.44	88.5	272	21	7.78	75.5	382	21
	B	7.36	86.3	271	21	7.75	69.9	338	21
	C	7.4	89.3	271	21	7.75	67.7	355	21
	D	7.4	89.8	275	21	7.78	72.5	346	21
VES	A	8.07	89.4	395	21	7.7	59	620	21
	B	8.2	87.8	392	21	7.71	60.3	615	21
	C	8.13	89	391	21	7.72	66.9	631	21
	D	8.15	89.6	375	21	7.91	60.8	603	21

		Water Quality at Day 1				Water Quality at test completion			
Treatment	Replicate	pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (° C)	pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (° C)
Control	A	7.75	92.5	228	21	8.02	77.4	391	21
	B	7.66	92.3	220	21	8.09	80.1	407	21
	C	7.60	93.1	219	21	7.87	70.2	373	21
PBT	A	7.63	93.7	323	21	7.90	80.3	450	21
	B	7.92	93.9	343	21	8.15	83.6	445	21
	C	8.07	94.3	340	21	8.23	84.0	443	21
PBM	A	7.88	93	282	21	8.07	73.5	452	21
	B	7.84	92	288	21	8.09	78.9	448	21
	C	7.86	93.2	279	21	8.15	77	467	21
PET	A	8.09	93.5	352	21	8.23	79.2	477	21
	B	8.15	93.8	354	21	8.22	80.3	467	21
	C	8.15	93.7	352	21	8.07	62	492	21
PEM	A	7.91	91.4	251	21	8.09	73	446	21
	B	7.87	92.7	271	21	7.91	61.6	526	21
	C	7.85	91.8	275	21	8.08	76.6	452	21
PES	A	8.25	90.2	369	21	7.93	49.1	607	21
	B	8.21	88.5	367	21	7.8	2.9	666	21
	C	8.19	89.1	373	21	7.93	51.2	577	21

		Water Quality at Day 1				Water Quality at test completion			
Treatment	Replicate	pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (° C)	pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (° C)
Control	A	7.39	91	218	21	7.54	84.8	425	21
	B	7.37	91.1	221	21	8.02	49.5	458	21
	C	7.40	91.8	212	21	8.08	85.2	449	21
	D	7.44	91.1	222	21	8.12	86.2	424	21
KET	A	7.56	94.1	308	21	7.47	81.8	414	21
	B	7.82	93.9	302	21	7.87	84.2	410	21
	C	7.86	93.7	302	21	7.71	88	395	21
	D	7.92	93.5	294	21	7.75	74.4	388	21
KEM	A	7.39	92.4	213	21	7.9	86.3	377	21
	B	7.36	91.6	207	21	7.69	81.7	386	21
	C	7.39	91.8	207	21	7.8	87.2	366	21
	D	7.42	93	216	21	7.86	85	355	21
KES	A	7.94	92.4	333	21	7.82	85.6	378	21
	B	8.09	93	328	21	7.55	87.1	374	21
	C	8.11	92.7	332	21	7.54	86.9	383	21
	D	8.14	93	329	21	7.35	87.7	368	21



		Water Quality at Day 1				Water Quality at test completion			
Treatment	Replicate	pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (° C)	pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (° C)
Control	A	7.64	85.5	236	21	7.76	69.9	367	21
	B	7.59	86.7	239	21	7.65	59.5	380	21
	C	7.52	85	226	21	7.71	67.6	392	21
	D	7.47	84.8	236	21	7.71	66.8	383	21
FBT	A	7.40	87.5	338	21	7.68	72.4	468	21
	B	7.59	90	340	21	7.77	70.6	450	21
	C	7.65	92.2	346	21	7.89	76.4	445	21
	D	7.79	89.8	341	21	7.93	73.9	466	21
FBM	A	7.55	81.1	341	21	7.82	66.1	437	21
	B	7.59	85.7	342	21	7.66	78.7	426	21
	C	7.52	81.1	329	21	7.6	55.7	435	21
	D	7.56	82.7	334	21	7.72	61.5	433	21
FET	A	7.82	86	342	21	7.83	74.3	437	21
	B	7.81	86.9	334	21	7.88	71.3	438	21
	C	7.93	89.2	349	21	7.88	68.4	453	21
	D	8.04	88.9	351	21	7.93	70.8	463	21
FEM	A	7.78	83.6	306	21	7.65	74	424	21
	B	7.71	84.2	317	21	7.68	55.4	424	21
	C	7.75	85.9	329	21	7.83	67.7	440	21
	D	7.68	85	315	21	7.82	67.4	426	21
FES	A	8.02	90.9	369	21	7.74	32.8	553	21
	B	7.88	90.5	369	21	8.01	73	531	21
	C	7.59	89.8	365	21	7.99	57.8	578	21
	D	8.25	90.1	366	21	7.36	71.7	606	21

Table G4. Abbreviations used in blackworm and midge sediment toxicity tests

RBT	Ravine Baseline excavated rock on Top of reservoir sediment
RBM	Ravine Baseline excavated rock mixed with reservoir sediment
RET	Ravine Enriched excavated rock on Top of reservoir sediment
REM	Ravine Enriched excavated rock mixed with reservoir sediment
RES	Ravine Enriched Excavated rock
BBT	Byron Baseline excavated rock on Top of reservoir sediment
BBM	Byron Baseline excavated rock mixed with reservoir sediment
BET	Byron Enriched excavated rock on Top of reservoir sediment
BEM	Byron Enriched excavated rock mixed with reservoir sediment
BES	Byron Enriched Excavated rock
SET	Shaw Gabbro Enriched excavated rock on Top of reservoir sediment
SEM	Shaw Gabbro Enriched excavated rock mixed with reservoir sediment
SES	Shaw Gabbro Enriched Excavated rock
VBT	Volcanics Baseline excavated rock on Top of reservoir sediment
VBM	Volcanics Baseline excavated rock mixed with reservoir sediment
VET	Volcanics Enriched excavated rock on Top of reservoir sediment
VEM	Volcanics Enriched excavated rock mixed with reservoir sediment
VES	Volcanics Enriched Excavated rock
PBT	Peppercorn Baseline excavated rock on Top of reservoir sediment
PBM	Peppercorn Baseline excavated rock mixed with reservoir sediment
PET	Peppercorn Enriched excavated rock on Top of reservoir sediment
PEM	Peppercorn Enriched excavated rock mixed with reservoir sediment
PES	Peppercorn Enriched Excavated rock
KET	Kelly's Plains Enriched excavated rock on Top of reservoir sediment
KEM	Kelly's Plains Enriched excavated rock mixed with reservoir sediment
KES	Kelly's Plains Enriched Excavated rock
FBT	Felsics Baseline excavated rock on Top of reservoir sediment
FBM	Felsics Baseline excavated rock mixed with reservoir sediment
FET	Felsics Enriched excavated rock on Top of reservoir sediment
FEM	Felsics Enriched excavated rock mixed with reservoir sediment
FES	Felsics Enriched Excavated rock

Table G5. **Copper reference toxicity tests with the midge (*Chironomus tepperi*) during chronic toxicity tests.**

Treatment	After 24 hours				After 48 hours			
	# Alive				# Alive			
	A	B	C	D	A	B	C	D
MHW	5	5	5	5	5	5	5	5
31.25µg/l	5	5	5	5	5	5	5	5
62.5µg/l	4	3	5	3	5	5	5	5
125µg/l	5	3	4	4	4	3	3	3
250µg/l	1	3	4	4	1	0	2	1
500µg/l	0	0	1	0	0	0	0	0

Treatment	After 48 hours							
	# Alive				# Dead			
	A	B	C	D	A	B	C	D
MHW	5	4	5	5	0	1	0	0
31.25µg/l	4	5	5	4	1	0	0	1
62.5µg/l	3	3	4	4	2	2	1	1
125µg/l	2	1	1	2	3	4	4	3
250µg/l	1	1	1	0	4	4	4	5
500µg/l	0	0	0	0	5	5	5	5

Treatment	After 48 hours					
	# Alive			# Dead		
	A	B	C	A	B	C
MHW	5	5	5	0	0	0
31.25µg/l	5	5	5	0	0	0
62.5µg/l	4	5	4	1	0	1
125µg/l	2	2	3	3	3	2
250µg/l	2	0	2	3	5	3
500µg/l	0	0	0	5	5	5

Table G6. The effective concentration (µg/L) of copper at 50%, 10% and 20% for the midge (*Chironomus tepperi*) during chronic toxicity tests.

Copper reference test	EC50(µg/l)	95% Conf. intervals For EC50		EC10(µg/l)	95% Conf. intervals For EC10	
Test 1	96.51	#N/A	#N/A	36.23	#N/A	#N/A
Test 2	94.22	78.66	112.86	35.55	23.69	53.34
Test 3	130.97	102.96	166.60	48.64	29.83	79.30

Appendix H Excavated rock material in sediments: Supplimentary information on blackworm (*Lumbriculus variegatus*) toxicity tests

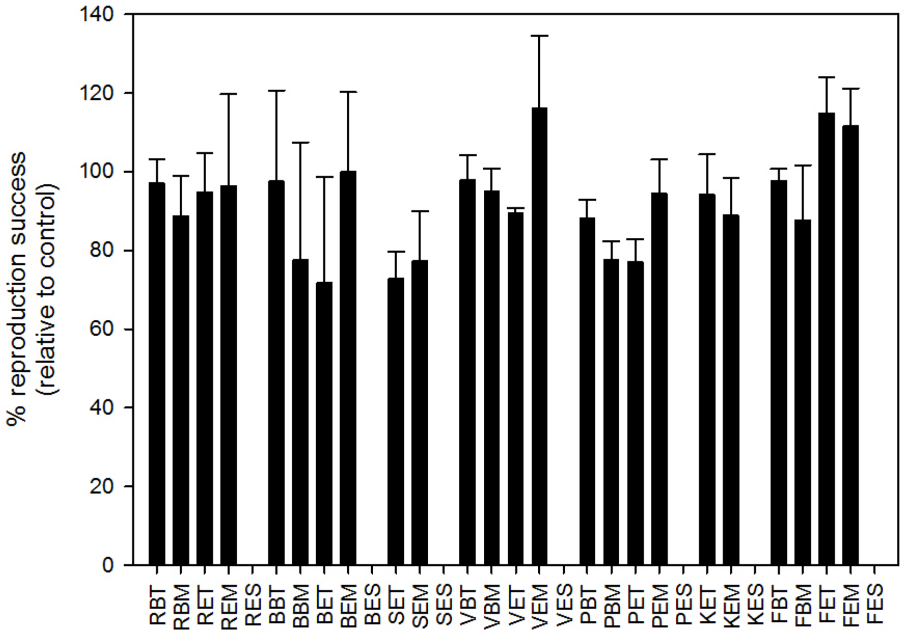


Figure H1. Reproduction success in the blackworm (*Lumbriculus variegatus*) after 28-day exposure to excavated rock from seven geological zones (Abbreviations for treatments in Table H4)

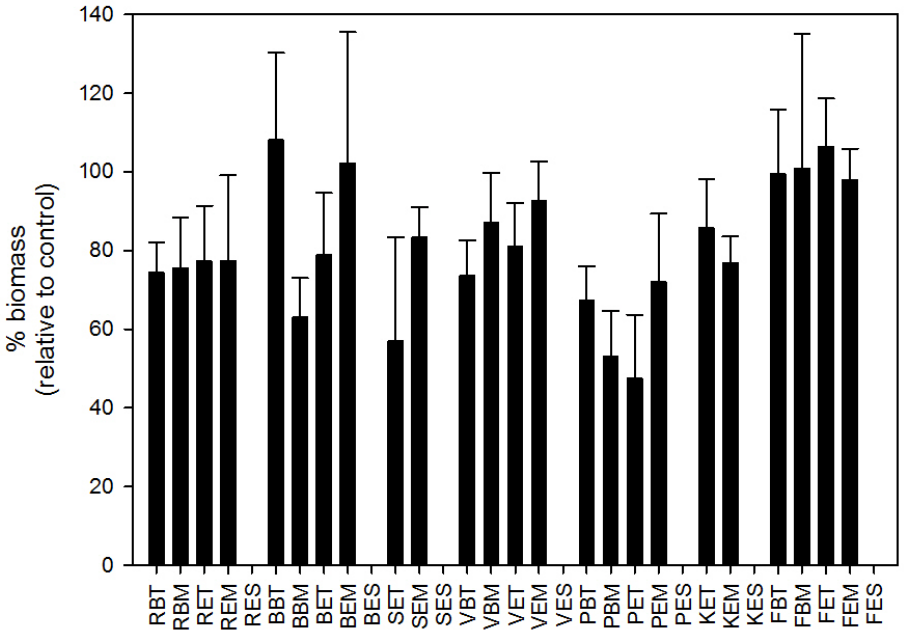


Figure H2. Total biomass of the blackworm (*Lumbriculus variegatus*) after 28-day exposure to excavated rock from seven geological zones (Abbreviations for treatments in Table H4)

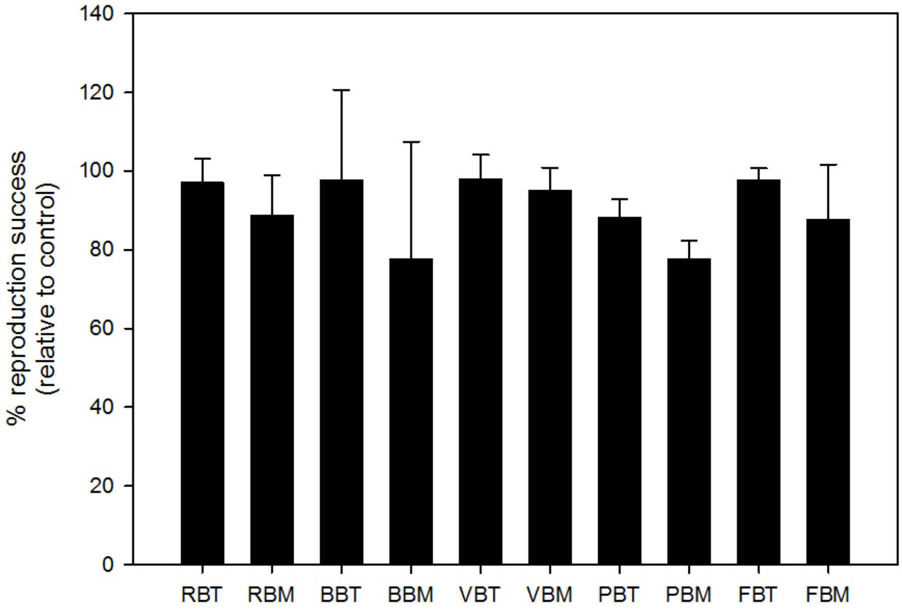


Figure H3: Reproduction success in the blackworm (*Lumbriculus variegatus*) after 28-day exposure to Baseline excavated rock from seven geological zones (Abbreviations for treatments in Table H4)

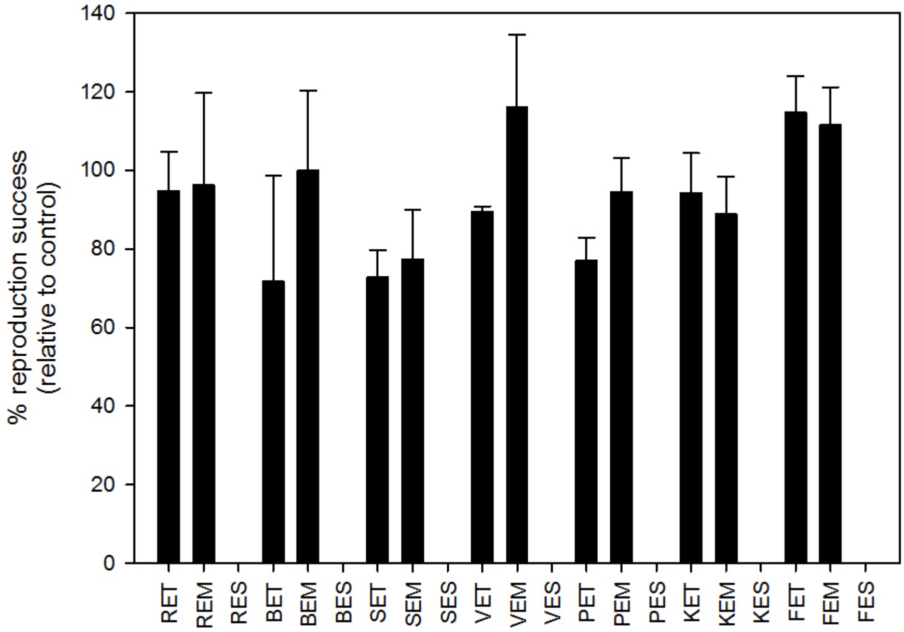


Figure H4: Reproduction success in the blackworm (*Lumbriculus variegatus*) after 28-day exposure to Enriched excavated rock from seven geological zones (Abbreviations for treatments in Table H4)

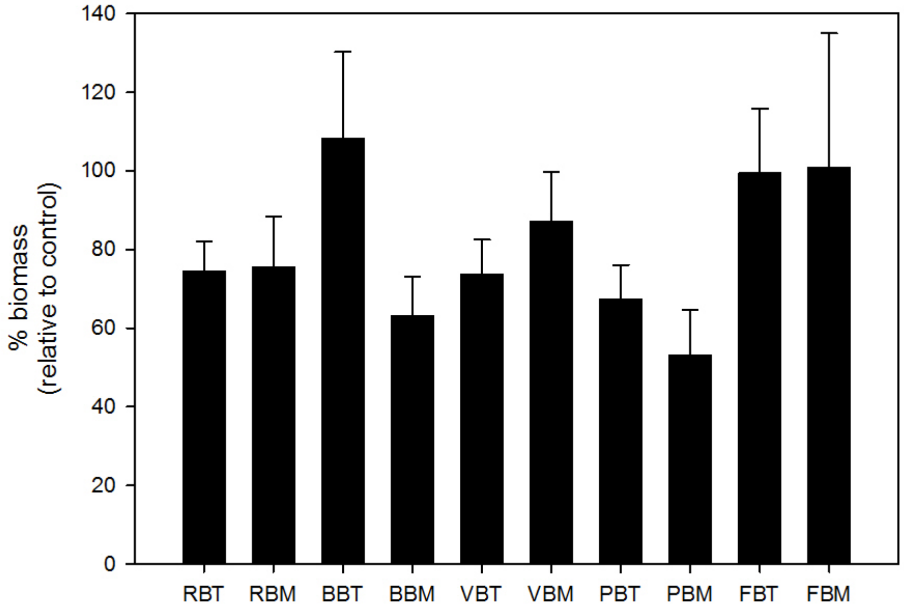


Figure H5: Total biomass of the blackworm (*Lumbriculus variegatus*) after 28-day exposure to Baseline excavated rock from seven geological zones (Abbreviations for treatments in Table H4)

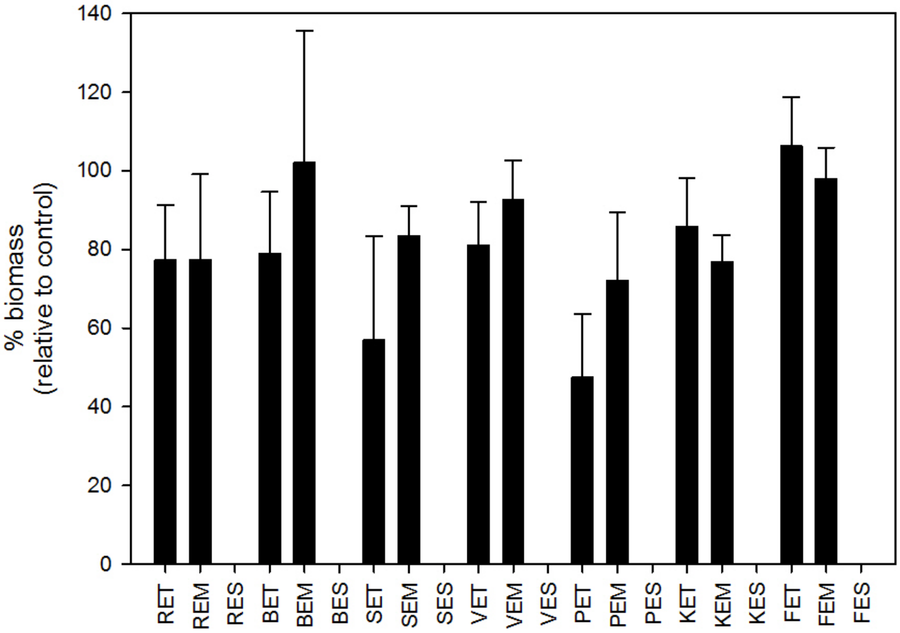
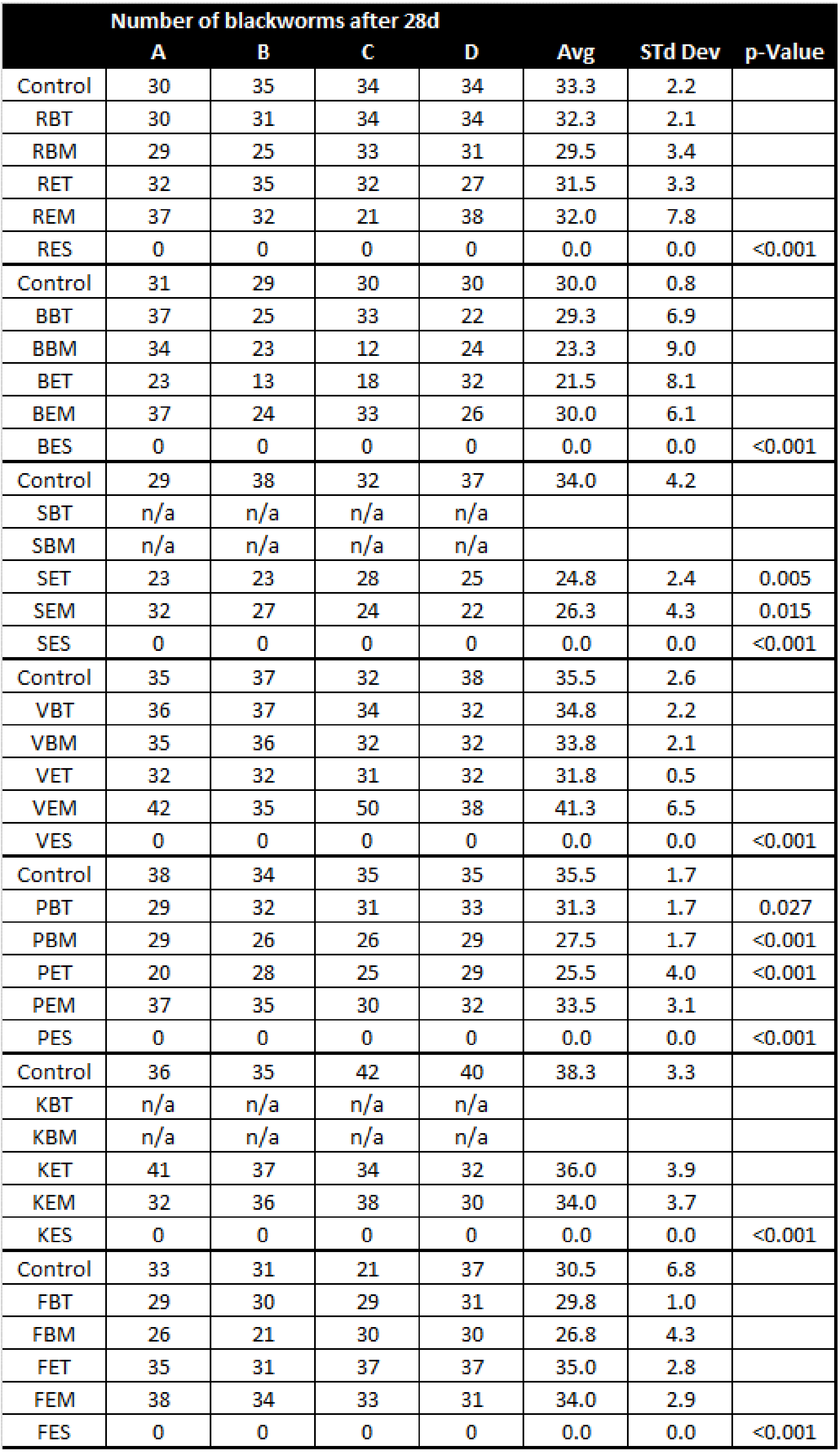


Figure H6: Total biomass of the blackworm (*Lumbriculus variegatus*) after 28-day exposure to Enriched excavated rock from seven geological zones (Abbreviations for treatments in Table H4)

Table H1. Supplementary data on the reproduction success in the blackworm (*Lumbriculus variegatus*) during 28-day sediment-excavated rock tests for seven geological zones.



	Number of blackworms after 28d						
	A	B	C	D	Avg	STd Dev	p-Value
Control	30	35	34	34	33.3	2.2	
RBT	30	31	34	34	32.3	2.1	
RBM	29	25	33	31	29.5	3.4	
RET	32	35	32	27	31.5	3.3	
REM	37	32	21	38	32.0	7.8	
RES	0	0	0	0	0.0	0.0	<0.001
Control	31	29	30	30	30.0	0.8	
BBT	37	25	33	22	29.3	6.9	
BBM	34	23	12	24	23.3	9.0	
BET	23	13	18	32	21.5	8.1	
BEM	37	24	33	26	30.0	6.1	
BES	0	0	0	0	0.0	0.0	<0.001
Control	29	38	32	37	34.0	4.2	
SBT	n/a	n/a	n/a	n/a			
SBM	n/a	n/a	n/a	n/a			
SET	23	23	28	25	24.8	2.4	0.005
SEM	32	27	24	22	26.3	4.3	0.015
SES	0	0	0	0	0.0	0.0	<0.001
Control	35	37	32	38	35.5	2.6	
VBT	36	37	34	32	34.8	2.2	
VBM	35	36	32	32	33.8	2.1	
VET	32	32	31	32	31.8	0.5	
VEM	42	35	50	38	41.3	6.5	
VES	0	0	0	0	0.0	0.0	<0.001
Control	38	34	35	35	35.5	1.7	
PBT	29	32	31	33	31.3	1.7	0.027
PBM	29	26	26	29	27.5	1.7	<0.001
PET	20	28	25	29	25.5	4.0	<0.001
PEM	37	35	30	32	33.5	3.1	
PES	0	0	0	0	0.0	0.0	<0.001
Control	36	35	42	40	38.3	3.3	
KBT	n/a	n/a	n/a	n/a			
KBM	n/a	n/a	n/a	n/a			
KET	41	37	34	32	36.0	3.9	
KEM	32	36	38	30	34.0	3.7	
KES	0	0	0	0	0.0	0.0	<0.001
Control	33	31	21	37	30.5	6.8	
FBT	29	30	29	31	29.8	1.0	
FBM	26	21	30	30	26.8	4.3	
FET	35	31	37	37	35.0	2.8	
FEM	38	34	33	31	34.0	2.9	
FES	0	0	0	0	0.0	0.0	<0.001

Table H2. Supplementary data on the biomass of the Blackworm ((*Lumbriculus variegatus)* during 28-day sediment-excavated rock tests for seven geological zones.

	Total Bioamass(mg) after 28d						
	A	B	C	D	Avg	STd Dev	p-Value
Control	64.9	70	59.1	70.1	66.0	5.2	
RBT	45.2	54.3	44.2	52.6	49.1	5.1	0.040
RBM	40	47.7	60.5	51.3	49.9	8.5	
RET	48	61.9	54.2	39.9	51.0	9.3	
REM	55.7	53.4	30.8	64.5	51.1	14.4	
RES	0	0	0	0	0.0	0.0	<0.001
Control	45.7	55.2	68	54.8	55.9	9.2	
BBT	70.8	53	71.1	46.8	60.4	12.4	0.007
BBM	39.1	36.3	27	38.6	35.3	5.6	
BET	43.8	31.8	50.2	50.7	44.1	8.8	
BEM	80.9	40.2	63	44.4	57.1	18.7	
BES	0	0	0	0	0.0	0.0	<0.001
Control	45.9	50.3	50.9	47.5	48.7	2.4	
SBT	n/a	n/a	n/a	n/a			
SBM	n/a	n/a	n/a	n/a			
SET	7.4*	17.2	23.7	42.1	27.7	12.9	0.046
SEM	40.2	45.8	37.3	39.1	40.6	3.7	0.002
SES	0	0	0	0	0.0	0.0	<0.001
Control	66.9	73	54.2	60.2	63.6	8.1	
VBT	43	44	44.8	55.2	46.8	5.7	0.007
VBM	56.2	66.1	47.3	52	55.4	8.0	
VET	60.2	50	52.7	43.1	51.5	7.1	
VEM	52	59.3	67.2	57.2	58.9	6.3	
VES	0	0	0	0	0.0	0.0	<0.001
Control	59.9	61.3	60.9	56.1	59.6	2.4	
PBT	43.2	32.2	41.9	42.9	40.1	5.3	0.003
PBM	35	21.8	31.6	37.7	31.5	6.9	<0.001
PET	11.4	31.9	17.4	35.6	24.1	11.5	<0.001
PEM	46.8	54.4	29.9	40.5	42.9	10.4	0.011
PES	0	0	0	0	0.0	0.0	<0.001
Control	69.5	67	74.1	73.4	71.0	3.3	
KBT	n/a	n/a	n/a	n/a			
KBM	n/a	n/a	n/a	n/a			
KET	73.6	59.5	56.8	53.6	60.9	8.8	0.046
KEM	54.2	51.1	61.4	51.7	54.6	4.7	0.002
KES	0	0	0	0	0.0	0.0	<0.001
Control	39.9	35.8	21	38.9	33.9	8.8	
FBT	39.9	36.9	28.8	29.1	33.7	5.6	0.007
FBM	18.8	44.4	31.6	41.8	34.2	11.6	
FET	38.7	30.6	34.9	39.9	36.0	4.2	
FEM	35.6	33.7	29.4	34.2	33.2	2.7	
FES	0	0	0	0	0.0	0.0	<0.001

Table H3. Water quality data for 28-d blackworm sediment toxicity test

		Water Quality at Day 1				Water Quality at test completion			
Treatment	Replicate	pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (° C)	pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (° C)
Control	A	7.39	89	289	21	7.98	90.3	170	21
	B	7.30	89	274	21	7.41	89.2	160	21
	C	7.26	90.2	285	21	7.57	90.3	172	21
	D	7.30	90.6	280	21	7.38	87.0	213	21
RBT	A	7.62	92.4	388	21	7.66	89.0	270	21
	B	7.71	92.4	382	21	7.58	90.1	239	21
	C	7.73	92.4	404	21	7.62	93.2	269	21
	D	7.80	92.4	398	21	7.4	91.3	271	21
RBM	A	7.74	92.3	304	21	7.68	76.9	187	21
	B	7.58	89.9	275	21	7.64	75.7	191	21
	C	7.52	89.4	294	21	7.51	77.9	169	21
	D	7.55	90.2	294	21	7.6	83.7	174	21
RET	A	7.71	90.2	378	21	7.64	80.7	275	21
	B	7.67	90.1	351	21	7.66	79.2	262	21
	C	7.65	91	375	21	7.62	82.6	246	21
	D	7.67	91.3	374	21	7.75	86.9	262	21
REM	A	7.58	88.6	303	21	7.66	73.7	210	21
	B	7.53	89.1	300	21	7.64	64.4	187	21
	C	7.53	89.6	299	21	7.71	81.9	223	21
	D	7.46	90.1	298	21	7.7	79.2	194	21
RES	A	7.47	91.5	500	21	8.72	106.6	754	21
	B	7.48	91.1	484	21	8.8	103.5	792	21
	C	7.65	91.7	507	21	8.87	113	699	21
	D	7.6	91.6	492	21	8.84	104.8	759	21

		Water Quality at Day 1				Water Quality at test completion			
Treatment	Replicate	pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (° C)	pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (° C)
Control	A	7.51	110.5	339	21	5.91	90.4	182	21
	B	7.36	107.9	351	21	6.03	90.3	190	21
	C	7.40	104.4	346	21	5.83	91.0	186	21
	D	7.33	103.2	362	21	6.65	88.7	171	21
BBT	A	7.79	95.9	527	21	7.98	88.7	316	21
	B	7.90	110.9	584	21	7.95	88.0	371	21
	C	7.95	101.6	531	21	7.98	86.9	312	21
	D	7.84	103.4	560	21	7.88	77.5	326	21
BBM	A	7.83	106.8	535	21	8.06	91.4	315	21
	B	7.8	113.3	503	21	8.05	91.2	318	21
	C	7.23	110.5	615	21	8.07	90.1	307	21
	D	7.48	110.1	568	21	8.09	90.3	296	21
BET	A	7.66	109.9	526	21	7.94	89.3	326	21
	B	7.82	104.5	570	21	8.03	90.1	347	21
	C	7.8	98.9	561	21	8.02	86.9	300	21
	D	7.99	95.7	542	21	7.97	87.7	314	21
BEM	A	7.63	101.9	536	21	8.31	89.6	311	21
	B	7.87	114.3	511	21	8.19	92.4	319	21
	C	7.64	108.8	584	21	8.12	92	318	21
	D	7.75	109.3	491	21	7.96	71.4	307	21
BES	A	8.22	88.6	670	21	8.49	88.5	888	21
	B	8.3	89.1	678	21	8.65	89.8	872	21
	C	8.32	88.5	683	21	8.65	88.9	880	21
	D	8.28	85.2	704	21	8.59	87.8	868	21

Treatment	Replicate	Water Quality at Day 1				Water Quality at test completion			
		pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (° C)	pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (° C)
Control	A	7.82	78.7	311	21	8.20	93.2	168	21
	B	7.74	67.4	319	21	8.35	96.0	185	21
	C	7.76	82.7	306	21	8.13	92.3	203	21
	D	7.71	79.5	325	21	8.55	101.6	177	21
SET	A	7.65	90.1	426	21	8.28	93.9	285	21
	B	7.98	90.2	416	21	8.73	100.6	255	21
	C	8.06	89.6	426	21	8.7	97	265	21
	D	8.14	89.3	436	21	8.59	95.4	288	21
SEM	A	8.09	91.6	351	21	8.55	92.2	248	21
	B	8.11	89.1	389	21	8.55	92.9	249	21
	C	8.1	86.1	391	21	8.54	92	235	21
	D	8.18	89	375	21	8.52	92.4	241	21
SES	A	8.13	72.9	511	21	8.74	87.7	641	21
	B	8.12	61.7	499	21	8.75	80.1	661	21
	C	8.09	76	504	21	8.69	87	641	21
	D	8	66.4	502	21	8.7	81.9	658	21

Treatment	Replicate	Water Quality at Day 1				Water Quality at test completion			
		pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (° C)	pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (° C)
Control	A	7.29	90.8	306	21	8.33	83.0	175	21
	B	7.23	84.7	320	21	8.02	78.4	176	21
	C	7.11	93	298	21	7.77	80.6	169	21
	D	7.13	92.9	295	21	7.67	83.6	171	21
VBT	A	7.84	90.2	373	21	7.15	86.8	328	21
	B	7.82	93.6	378	21	7.22	67.5	358	21
	C	7.76	92.5	367	21	7.40	80.5	309	21
	D	7.68	91.7	385	21	7.49	84.3	370	21
VBM	A	7.65	92	356	21	7.42	71.2	324	21
	B	7.62	92.1	329	21	7.57	79.5	293	21
	C	7.51	90.8	354	21	7.49	62.2	300	21
	D	7.55	89	361	21	7.63	75.6	302	21
VET	A	7.59	93.3	376	21	7.58	85.2	297	21
	B	7.68	93	361	21	7.64	85.3	285	21
	C	7.63	90.5	378	21	7.69	85.6	311	21
	D	7.68	92.2	366	21	7.71	85.9	302	21
VEM	A	7.45	88.5	351	21	7.77	86.3	290	21
	B	7.46	86.3	367	21	7.65	72.2	287	21
	C	7.51	89.3	353	21	7.62	72.9	291	21
	D	7.58	89.8	363	21	7.66	73.9	278	21
VES	A	7.18	89.4	510	21	8.39	74.1	891	21
	B	7.19	87.8	547	21	7.52	77.9	810	21
	C	7.27	89	518	21	7.51	81	696	21
	D	7.28	89.6	515	21	7.48	81.8	806	21

Treatment	Replicate	Water Quality at Day 1				Water Quality at test completion			
		pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (º C)	pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (º C)
Control	A	6.71	63.9	273	21	7.63	92.3	257	21
	B	6.79	71.4	272	21	7.66	89.3	242	21
	C	7.19	69.9	278	21	7.84	92.8	246	21
	D	7.20	71.2	286	21	7.89	92.4	259	21
PBT	A	7.65	85.5	361	21	7.89	92.2	200	21
	B	7.70	87.5	373	21	7.81	91.3	193	21
	C	7.70	88.4	360	21	7.82	90.4	198	21
	D	7.72	86.8	368	21	7.8	90.1	197	21
PBM	A	7.64	81.8	317	21	8.04	91.3	328	21
	B	7.55	80.4	323	21	8.17	89.3	321	21
	C	7.58	81	329	21	8.26	90.8	334	21
	D	7.57	77.9	310	21	8.24	90.5	332	21
PET	A	7.78	85.4	413	21	8.17	87.9	252	21
	B	7.84	84.2	390	21	8.03	85.3	262	21
	C	7.85	86.4	422	21	8.04	87.4	271	21
	D	7.89	86.1	419	21	8.1	88.7	260	21
PEM	A	7.59	71.6	372	21	7.3	54.7	151	21
	B	7.63	77.3	366	21	7.12	82.6	144	21
	C	7.66	78.5	372	21	6.99	83	145	21
	D	7.68	71.4	372	21	6.69	84.1	156	21
PES	A	7.46	53.1	607	21	8.48	68.2	908	21
	B	7.58	69.8	514	21	8.76	81.3	895	21
	C	7.53	66.3	463	21	8.76	78.6	880	21
	D	7.56	55.4	498	21	8.79	89.5	909	21

Treatment	Replicate	Water Quality at Day 1				Water Quality at test completion			
		pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (º C)	pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (º C)
Control	A	6.71	75.1	296	21	6.86	93.1	221.0	21
	B	6.81	80.3	294	21	7.25	92.2	219.6	21
	C	7.01	86.7	281	21	7.22	91.8	210.0	21
	D	7.03	79.0	303	21	7.15	91.6	252.0	21
KET	A	7.37	88.9	367	21	7.39	91.1	247	21
	B	7.48	88.8	371	21	7.62	89.8	264	21
	C	7.59	89.6	371	21	7.52	90.5	249	21
	D	7.65	90.6	380	21	7.57	91.3	278	21
KEM	A	7.57	85.2	303	21	7.52	91.5	276	21
	B	7.42	81.9	303	21	7.54	92.8	188.8	21
	C	7.44	87.4	286	21	7.55	91.2	184.2	21
	D	7.43	83.5	299	21	7.45	93.6	213.6	21
KES	A	7.53	92.4	492	21	8.8	107.4	548	21
	B	7.49	93	491	21	8.82	99.2	598	21
	C	7.3	92.7	470	21	8.51	91.2	586	21
	D	7.39	93	504	21	8.51	94.8	488	21

		Water Quality at Day 1				Water Quality at test completion			
Treatment	Replicate	pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (° C)	pH	DO (% saturation)	Conductivity (µS/cm)	Temperature (° C)
Control	A	7.61	85.5	270	21	7.27	82.4	171	21
	B	7.36	86.7	291	21	6.86	87.4	156	21
	C	7.30	85	275	21	7.65	97.3	143	21
	D	7.27	84.8	223	21	7.29	78.5	148	21
FBT	A	7.40	95.9	434	21	8.13	113.1	367	21
	B	7.57	87.5	425	21	8.27	101.0	350	21
	C	7.62	90	408	21	8.14	89.2	383	21
	D	7.65	92.2	427	21	8.29	99.2	380	21
FBM	A	7.64	89.8	468	21	7.85	105.7	318	21
	B	7.61	81.1	453	21	8.06	105.2	307	21
	C	7.76	85.7	443	21	8.04	95.8	312	21
	D	7.75	81.1	454	21	8.07	94.2	302	21
FET	A	7.82	82.7	441	21	8.15	111.2	288	21
	B	7.81	86	440	21	8.28	117	308	21
	C	7.72	86.9	407	21	8.17	93	330	21
	D	7.84	89.2	411	21	8.13	98.3	312	21
FEM	A	7.72	88.9	391	21	8.67	118.2	257	21
	B	7.69	83.6	394	21	8.35	97.3	279	21
	C	7.7	84.2	390	21	8.19	98.1	290	21
	D	7.69	85.9	403	21	8.11	93	321	21
FES	A	7.38	85	549	21	9.3	110.2	603	21
	B	7.42	83.6	550	21	9.2	112.2	621	21
	C	7.44	86.9	542	21	8.83	118.6	681	21

Table H4. Abbreviations used in blackworm and midge sediment toxicity tests

RBT	Ravine Baseline excavated rock on Top of reservoir sediment
RBM	Ravine Baseline excavated rock mixed with reservoir sediment
RET	Ravine Enriched excavated rock on Top of reservoir sediment
REM	Ravine Enriched excavated rock mixed with reservoir sediment
RES	Ravine Enriched Excavated rock
BBT	Byron Baseline excavated rock on Top of reservoir sediment
BBM	Byron Baseline excavated rock mixed with reservoir sediment
BET	Byron Enriched excavated rock on Top of reservoir sediment
BEM	Byron Enriched excavated rock mixed with reservoir sediment
BES	Byron Enriched Excavated rock
SET	Shaw Gabbro Enriched excavated rock on Top of reservoir sediment
SEM	Shaw Gabbro Enriched excavated rock mixed with reservoir sediment
SES	Shaw Gabbro Enriched Excavated rock
VBT	Volcanics Baseline excavated rock on Top of reservoir sediment
VBM	Volcanics Baseline excavated rock mixed with reservoir sediment
VET	Volcanics Enriched excavated rock on Top of reservoir sediment
VEM	Volcanics Enriched excavated rock mixed with reservoir sediment
VES	Volcanics Enriched Excavated rock
PBT	Peppercorn Baseline excavated rock on Top of reservoir sediment
PBM	Peppercorn Baseline excavated rock mixed with reservoir sediment
PET	Peppercorn Enriched excavated rock on Top of reservoir sediment
PEM	Peppercorn Enriched excavated rock mixed with reservoir sediment
PES	Peppercorn Enriched Excavated rock
KET	Kelly's Plains Enriched excavated rock on Top of reservoir sediment
KEM	Kelly's Plains Enriched excavated rock mixed with reservoir sediment
KES	Kelly's Plains Enriched Excavated rock
FBT	Felsics Baseline excavated rock on Top of reservoir sediment
FBM	Felsics Baseline excavated rock mixed with reservoir sediment
FET	Felsics Enriched excavated rock on Top of reservoir sediment
FEM	Felsics Enriched excavated rock mixed with reservoir sediment
FES	Felsics Enriched Excavated rock

Table H5. Copper reference toxicity tests with the blackworm (*Lumbriculus variegatus)* during sediment and excavated rock chronic toxicity tests.

Treatment	After 48 hours							
	# Alive				# Dead			
	A	B	C	D	A	B	C	D
MHW	5	5	5	5	0	0	0	0
TAL	5	5	5	5	0	0	0	0
Cu 31.25µg/l	5	5	5	5	0	0	0	0
Cu 62.5µg/l	4	5	5	4	1	0	0	1
Cu125µg/l	4	5	5	4	1	0	0	1
Cu 250µg/l	3	2	3	2	2	3	2	3
Cu 500µg/l	3	2	3	2	2	3	2	3
Cu 1000µg/l	0	0	0	0	5	5	5	5
Cu 2000µg/l	0	0	0	0	5	5	5	5

Treatment	After 48 hours							
	# Alive				# Dead			
	A	B	C	D	A	B	C	D
MHW	5	5	5	5	0	0	0	0
TAL	5	5	5	5	0	0	0	0
Cu 31.25µg/l	5	5	5	5	0	0	0	0
Cu 62.5µg/l	4	5	5	4	1	0	0	1
Cu125µg/l	5	4	3	5	0	1	2	0
Cu 250µg/l	2	3	3	3	3	2	2	2
Cu 500µg/l	3	3	3	2	2	2	2	3
Cu 1000µg/l	0	2	3	0	5	3	2	5
Cu 2000µg/l	0	0	0	0	5	5	5	5

Treatment	After 48 hours					
	# Alive			# Dead		
	A	B	C	A	B	C
MHW	5	5	5	0	0	0
TAL	5	5	5	0	0	0
Cu 31.25µg/l	5	5	5	0	0	0
Cu 62.5µg/l	4	5	4	1	0	1
Cu125µg/l	4	4	3	1	1	2
Cu 250µg/l	2	3	0	3	2	5
Cu 500µg/l	0	2	0	5	3	5
Cu 1000µg/l	1	0	0	4	5	5
Cu 2000µg/l	0	0	0	5	5	5

Table G6. The effective concentration (µg/L) of copper at 50%, 10% and 20% for blackworms (*Lumbriculus variegatus*) during chronic toxicity tests

Copper reference test	EC50(µg/l)	95% Conf. intervals For EC50		EC10(µg/l)	95% Conf. intervals For EC10	
Test 1	332.82	258.01	429.33	94.26	54.75	162.26
Test 2	376.37	249.67	567.38	66.64	26.17	169.69
Test 3	189.34	141.17	253.93	63.70	31.20	130.06

Appendix I SEM analyses of excavated rock

Provided as supplementary information

Appendix J XRD analyses of Baseline and Enriched excavated rock

Provided as supplementary information

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Annexure E Dissolved Aluminium assessment for Talbingo Reservoir

Australia's National
Science Agency

Dissolved aluminium assessment for Talbingo Reservoir

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August 2019

Prepared for Haskoning Australia (HKA) on behalf of Snowy Hydro Limited (SHL)

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Foreword

In November 2017, CSIRO was requested by Snowy Hydro Limited (SHL) to provide scientific expertise and capability in relation to identifying and assessing the environmental risks associated with the placement of excavated rocks from the development and operations of the proposed Snowy 2.0 scheme into Talbingo Reservoir and Tantangara Reservoir. EMM Consulting (EMM) was to prepare the Environmental Impact Statement (EIS) on behalf of SHL, and CSIRO would undertake a series of assignments to provide scientific information for the environmental risk assessment (ERA) associated with the handling of excavated rock materials from the proposed works. In December 2017, CSIRO worked with EMM to develop conceptual models of the proposed works (source, fate and receptors) to provide information to the ERA. As a result, CSIRO was commissioned to undertake an initial series of four assignments. In March 2018, Haskoning Australia (HKA) was engaged to provide additional capability, specifically to lead the project entitled: “Engineering Option for Placement of Excavated Rocks”. The draft work assignments that CSIRO had previously provided to SHL and EMM (in late January 2018) were subsequently updated to ensure that they would fulfil the needs of EIS requirements and of this project. These updated assignment(s) have now been completed. In August 2019, CSIRO were engaged to undertake a desktop assessment to estimate where and after how much time in Talbingo Reservoir would aluminium concentrations return to below default guideline values and to baseline concentrations. This report details the results and findings of that assessment.

Disclaimer

This Assignment Subcontract and all documents and information provided by CSIRO to HKA under this Assignment Subcontract are prepared: (i) as inputs for further scientific services to be performed for HKA by CSIRO under separate Assignment Subcontracts that has been agreed; and (ii) to assist HKA in its development of an excavated rock disposal and management plan as part of the environmental impact assessment process for the proposed Snowy 2.0 Pumped Hydro Electric Scheme(“Purpose”), and for no other purpose. This Assignment Subcontract does not involve the provision of advice or recommendations in relation to specific risks or mitigations associated with Excavated Rock disposal and management or design and construction of the Snowy 2.0 project, however, it is understood that the inputs provided by CSIRO are for the Purpose and are based on CSIRO’s professional skill, care and~~,~~ diligence in performing this Assignment Subcontract. In the course of performing this Assignment Subcontract, CSIRO may rely on stated assumptions and/or information provided by HKA or third parties which is not within the control of CSIRO, and this Assignment does not involve CSIRO verifying such assumptions or information except to the extent expressly stated herein. If CSIRO provides any forecasts or projections, CSIRO does not represent that they will be realised as forecast or projected and actual outcomes may vary materially from forecast or projected outcomes. Documents and information provided to HKA under this Assignment Subcontract are to be read as a whole, and if reproduced must be reproduced in full and no part should be read or relied upon out of context. CSIRO does not accept responsibility for, or liability arising from, any error in, or omission in connection with, stated assumptions or third party-supplied information, or reliance on documents or information provided under this Assignment by HKA other than for the Purpose, or by any other person.

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Acknowledgments

CSIRO would like to acknowledge the support from Haskoning Australia (HKA) and Snowy Hydro Limited (SHL) in acquiring information for this report. We thank Greg Britton and Arjen Overduin of HKA for discussions and provision of information on the hydrodynamic model for Talbingo Reservoir. We thank Graeme Batley and Brad Angel (CSIRO) for an internal review of the report.

Executive summary

Snowy Hydro Limited (SHL) are exploring options for the placement of excavated rock within the two reservoirs Talbingo and Tantangara, as part of a proposed Snowy 2.0 Pumped Hydro Electric Scheme (Snowy 2.0). The excavated rock placement should not compromise, within reasonable parameters, the ecological, chemical, physiochemical, or physical state of the environment in the reservoirs. Previously, CSIRO were engaged by Haskoning Australia (HKA) on behalf of SHL to provide a series of studies involving tests and data analysis to help inform an Environmental Impact Statement (EIS) for Snowy 2.0. CSIRO study Assignment P4, 'Environmental Categorisation of Excavated Rock Interactions with and Potential Impacts on Reservoir Waters and Sediments', identified that changes in water pH, conductivity and dissolved aluminium concentrations may occur in both Talbingo and Tantangara Reservoirs as a result of increases in concentrations of fine excavated rock materials.

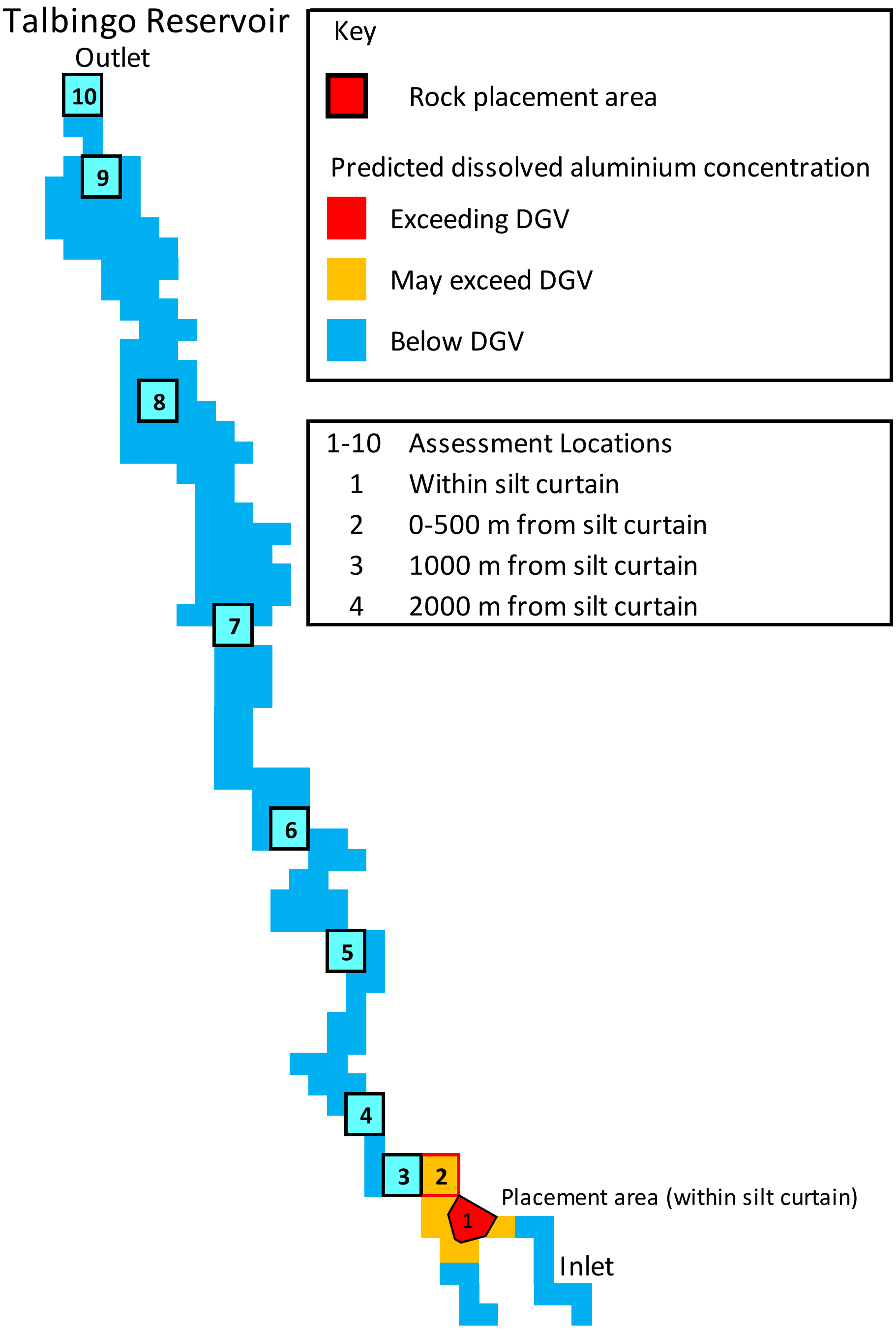
Here, CSIRO have been engaged to undertake a desktop assessment to estimate where and after how much time in Talbingo Reservoir aluminium concentrations would return to below default guideline values (GVs) and baseline concentrations. For the task, data from CSIRO Assignment P4 (Simpson et al., 2019) were summarised and used to develop relationships between the concentration of fine excavated rock materials suspended in Talbingo Reservoir water (mg/L) and concentrations of dissolved aluminium (µg/L). The relationships considered the water temperature and duration that the excavated rock materials were suspended within the water. Using these relationships, the hydrodynamic model for Talbingo Reservoir was used to predict total suspended solids concentrations (TSS, mg/L) of excavated rock within surface, middle and bottom waters at ten locations within the reservoir. The predictions were made for the 2-year duration of the proposed works (rock placement) and for 1-year following their completion, and considered the seasonal heating/cooling periods.

The assessment indicates that dissolved aluminium concentrations may exceed the default GV (DGV) of 55 µg/L within the placement area contained by the silt curtain (Location 1). Outside the silt curtain, a gradient (mixing zone) is expected to develop, along which dissolved aluminium released in Location 1 will dilute and some further aluminium release from particles will occur. In the 500 m space between Location 1 and Location 2, the dissolved aluminium concentrations may also exceed the DGV. Beyond Location 2, the dissolved aluminium concentrations are predicted to remain below the DGV, and within a factor of 2-3 of the background aluminium concentrations of 5-10 µg/L.

Significant uncertainty exists with the predictions on both the high side (higher dissolved aluminium) and low side (lower dissolved aluminium). CSIRO Assignment P4 (Simpson et al., 2019) describes a number of data/knowledge gaps that influence this uncertainty. Higher TSS concentrations and higher water pH are considered the primary drivers for higher dissolved aluminium concentrations. Lower water temperatures will result in lower dissolved aluminium concentrations. At Location 1 (placement area), should the pH not rise as high in the field environment as it did in the laboratory tests (CSIRO Assignment P4), then the dissolved aluminium concentrations in the field may be considerably lower within Location 1 that those predicted here.

Greater rates of water dilution will also lower dissolved aluminium concentrations in Location 1, and the export of the aluminium to locations further down the reservoir may not substantially increase the predicted concentrations at those locations. While difficult to estimate, the predictions may have 50% uncertainty on both the high or low sides for Location 1 and 2. At Locations 2-10, attenuation reactions that result in lower water pH may result in substantially lower aluminium release from TSS at locations further from the placement area. The dilutions may also be greater than those estimated for these predictions, resulting in lower dissolved aluminium concentrations. For the locations beyond Location 2, the predictions will have even greater uncertainty, but dissolved aluminium concentrations seem likely to be within a factor of 2-3 of the background concentrations.

Assessment summary: Depiction of area where dissolved aluminium may exceed the water quality default guideline value (DGV) of 55 µg/L.



1 Introduction

1.1 Background

Snowy Hydro Limited (SHL) are embarking on the development of the landmark Snowy 2.0 Pumped Hydro Electric Scheme (Snowy 2.0). To accomplish Snowy 2.0, SHL will require “drill-out” of 27 km of tunnels between the two reservoirs Talbingo and Tantangara. It is proposed that a large quantity of the excavated rock that is generated from this activity be placed in the Talbingo Reservoir. As part of an Environmental Impact Statement (EIS), the engineering options chosen for the management and disposal of the excavated rock should result in minimal adverse effects on the reservoir environment.

Haskoning Australia (HKA) were appointed lead consultant to manage and deliver an Engineering Option Assessment for Excavated Rock Placement for Snowy 2.0. CSIRO has been requested to provide scientific insight into the environmental impacts associated with the placement of excavated rock in Talbingo Reservoir.

CSIRO Assignment P4 (Simpson et al., 2019) determined the waters of this reservoir to have neutral pH (6.9-7.3), low conductivity (26-29 µS/cm), low turbidity (0.2-0.5 NTU), and dissolved aluminium concentrations of <10 µg/L (<0.45 µm filterable). Assignment P4 determined that the mixing of excavated rock materials (<75 µm) with the Talbingo Reservoir waters resulted in concentrations of dissolved aluminium frequently exceeding the Australian national DGV for freshwaters of 55 µg/L (ANZG, 2018), accompanied by an increased pH (from approximately pH 7 to 9.5) and conductivity (from approximately 30 to 150 µS/cm). Those studies investigated the influence of a range of rock-water mixing-leaching scenarios and conditions on dissolved aluminium release.

The CSIRO tests characterised differences in dissolved aluminium release that may occur due to differences in the concentration of solids in the water (liquid/solid ratio; L/S), time, repeat/successive leaching, rock particle size, temperature, and attenuation of substances released due to interactions with sediments. Without re-summarising those results, the more important observations were that dissolved aluminium release from fine rock into Talbingo water was lower at 6°C than at 21°C and greater with increased mixing duration, indicating ongoing release.

In this subsequent assignment, CSIRO has been requested to undertake a desktop assessment to estimate where and after how much time in Talbingo Reservoir aluminium concentrations return to below the DGV and baseline concentrations.

1.2 Methodology

Data used to construct relationships between the concentration of fine excavated rock materials suspended in Talbingo Reservoir water (mg/L) and concentrations of dissolved Al (µg/L) were taken entirely from Assignment P4 report (Simpson et al., 2019).

The hydrodynamic model for Talbingo Reservoir was used to predict total suspended solids concentrations (TSS, mg/L) of excavated rock within surface, middle and bottom waters at ten locations within the reservoir (data provided by HKA) (Figure 1). The particle size distribution of the TSS in the model was 12-15% clay (<4 µm) and 85-88% silt (4-63 µm).

Location 1 is within the placement area and separated by a silt curtain from Location 2 that was approximately 500 m down the reservoir (towards the outlet). In the hydrodynamic model, the silt curtain extended from the water surface to a depth of 15 m. The curtain should be impervious to rock material of all sizes (i.e. including clays) and was treated as impervious to water, although some water may pass through at a slowed flow rate. Significant amounts of TSS are predicted to pass below the silt curtain and some of this TSS is transported to Locations 2 to 10. Locations 3 and 4 were approximately 1000 and 2000 m beyond the silt curtain heading towards the reservoir outlet. Locations 5-9 continued towards to reservoir outlet, and the final Location 10 was nearest the reservoir outlet.

The CSIRO relationships and model predictions were then brought together to make predictions of concentrations of dissolved aluminium within the reservoir at the designated locations.

The quality of the CSIRO data and the hydrodynamic model, and associated assumptions influence the predicted dissolved aluminium concentrations. CSIRO Assignment P4 identified a number of data gaps, limited aluminium release data for fine excavated rock TSS concentrations <500 mg/L, aluminium release over longer durations, and potentially successively larger changes in water quality (e.g. increasing higher pH leading to higher dissolved aluminium concentrations) that may occur in the placement area if mixing of the waters where aluminium release first occurs with the broader reservoir waters is constrained (naturally or by the presence of the silt curtain). There may also be longer-term attenuation processes (reducing dissolved aluminium concentrations) that have not yet been adequately characterised, and were not included in this assessment.

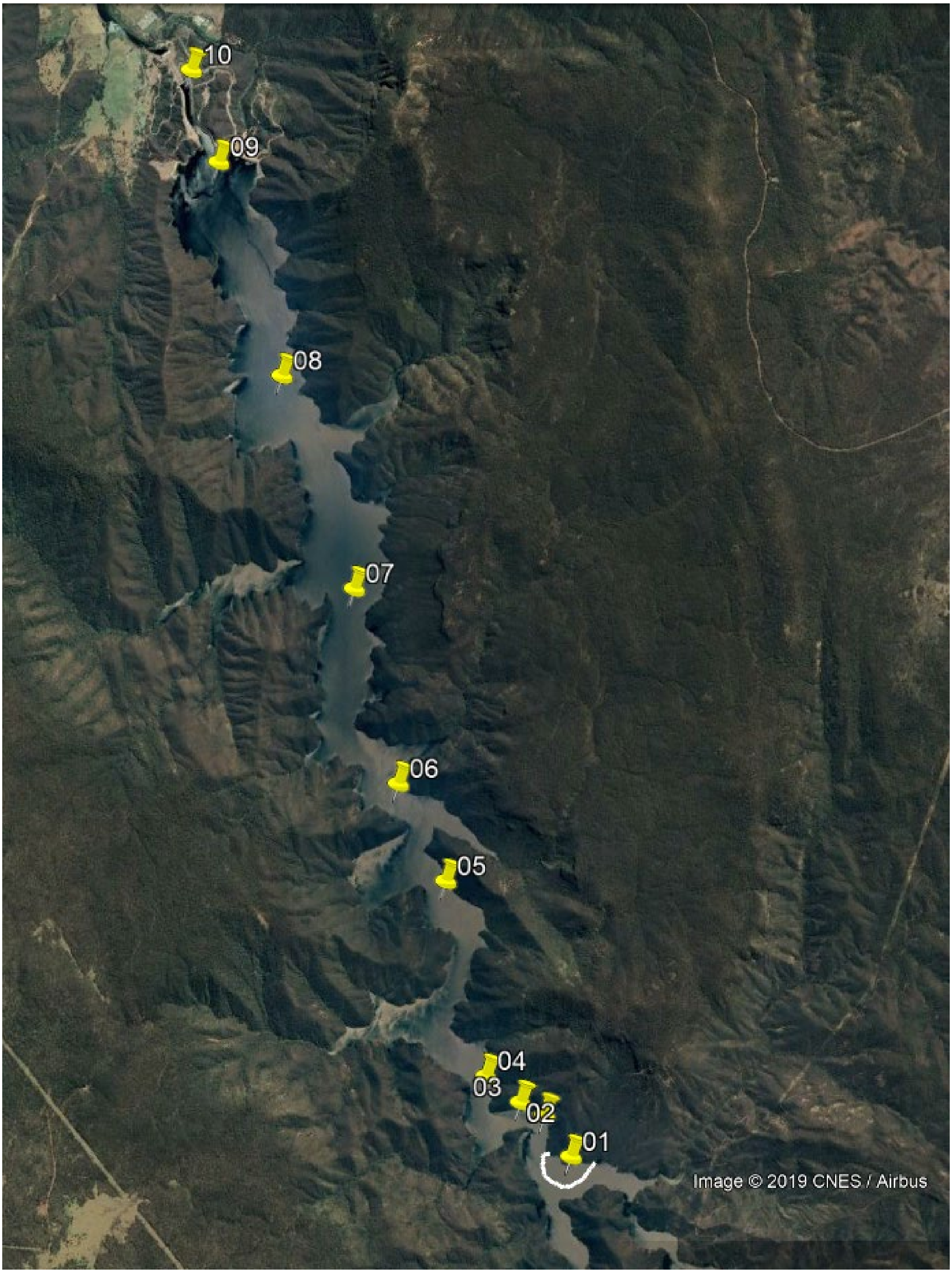


Figure 1. Locations with Talbingo Reservoir used in the study. The yellow pins indicate the locations used in the assessment, with Location 1 being closest to the reservoir inlet and Location 10 closest to the reservoir outlet. The white line depicts the location of a silt curtain.

1.2.1 Hydrodynamic model

In this report, we do not describe or discuss in detail any assumptions or possible limitations of the hydrodynamic model, but these may include factors such as changes in bathymetry (the placement area becoming shallower as rock is added resulting in warmer water temperatures), the rate and magnitude of dilution of waters within the placement area (through displacement from inflows of water or excavated rock, or dispersion throughout the reservoir), and the expected transmission of some water through the silt curtain (treated as impervious in the model).

Following release of aluminium from TSS (rock materials), a portion of the dissolved aluminium and fine rock will be dispersed and transported out from the placement area (Location 1), and then through the reservoir with the net flux towards the reservoir outlet (Location 10). The volume of water designated as the placement area (Location 1, within the silt curtain) is estimated to be 5,400,000 m^3 (5,400,000,000 Litre (L). HKA, personal communication). The hydrodynamic model output provided to CSIRO had TSS data at 6-h time intervals throughout the 2-year placement and 1-year post-placement periods. The model had ‘placement rate’ of TSS constant for 6-month periods, being 2.75, 1.5, 2.1, 1.1, 0.0, 0.0 kg/s, respectively. This data was converted to kg/d, then kg/6-h, and finally mg/6-h time interval in order to calculate TSS added in mg/L. During each 6-h interval, a portion of the TSS and dissolved aluminium is exported to the next location. To estimate this a simple model was created with %-retained/6-h as a variable and fitted to the TSS-time data predicted in the hydrodynamic model. For %-retained in Location 1, a value of 9% per day (or 97.75%/6-h) estimated from a conservative tracer modelling run by HKA (Figure 2) was used for the CSIRO predictions.

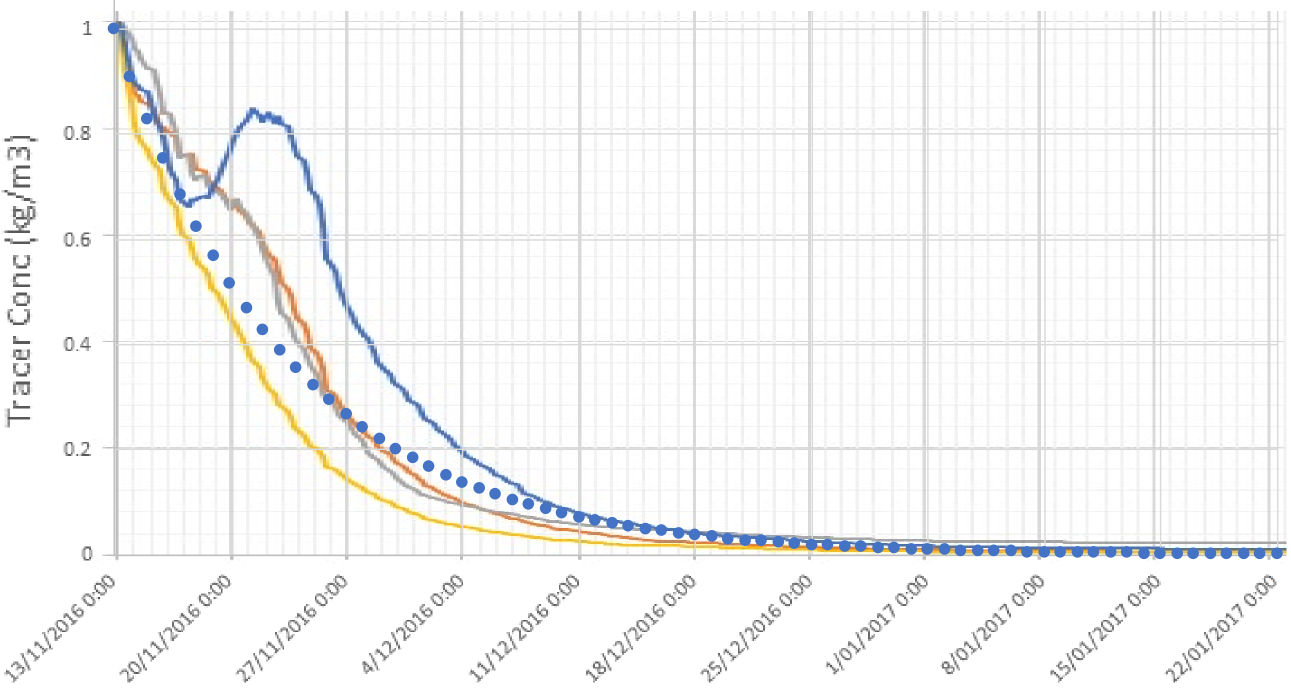


Figure 2. Rate of loss of tracer (normalised to 100% start) from Location 1. The four lines represent individual hydrodynamic model predictions of losses following ceasing of input (Background figure provided by HKA) at four different points within Location 1. The different position and shape of these lines reflects the variability of TSS within the water column. The dotted line is calculated as a loss of 9% of tracer/day (overlaid). Note: The start and end dates in this figure and later figures do not relate to proposed operations, but the duration is important.

Along the reservoir towards the outlet the values used were 15%/6-h for Location 2, 25%/6-h for Locations 3 and 4, and 40%/6-h for the remaining locations to the reservoir outlet (Figure 3).

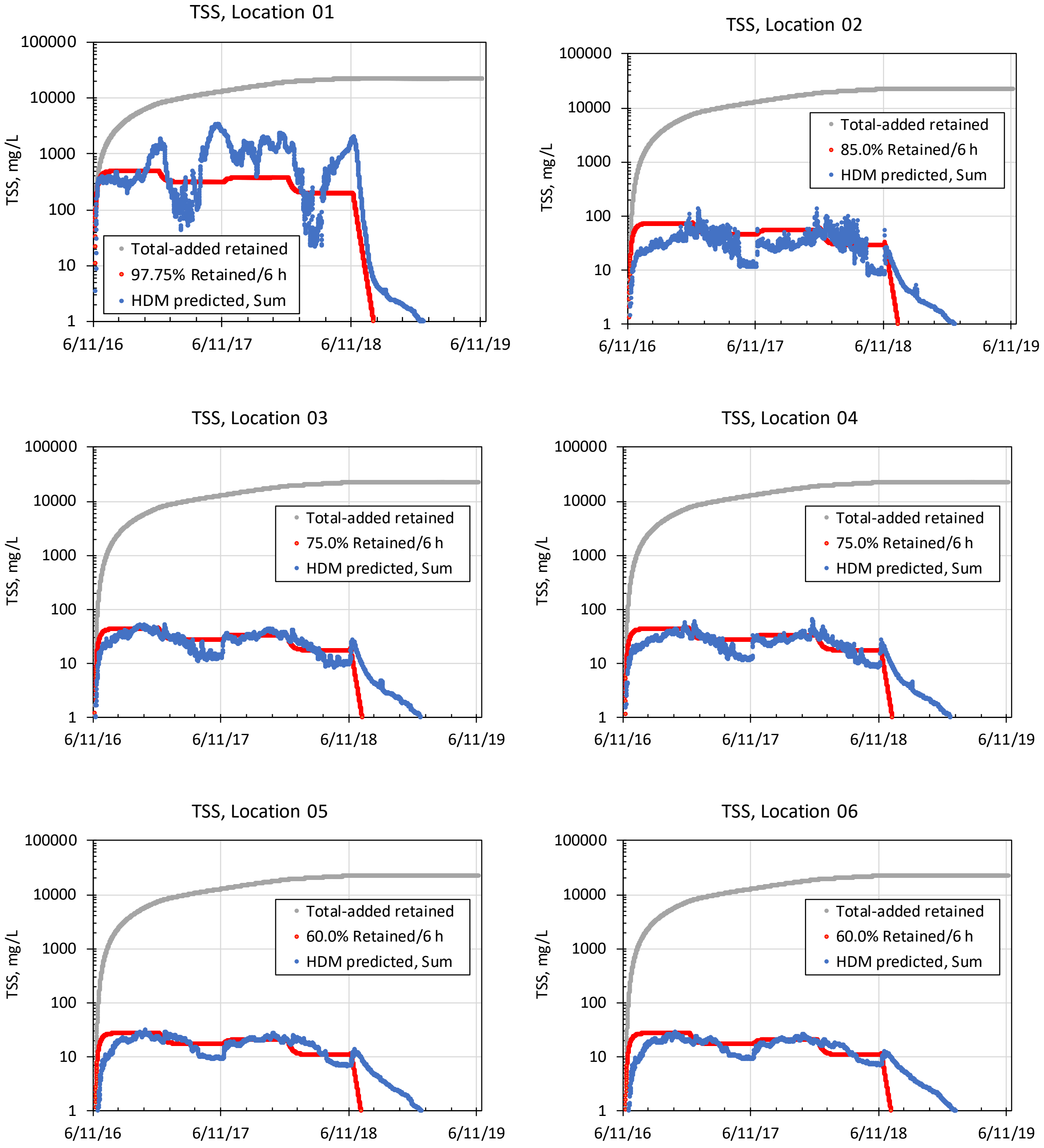


Figure 3. Total suspended solids (TSS) concentrations predicted from: (i) hydrodynamic model (HDM, sum of TSS in surface, middle and bottom waters), (ii) total added based on location placement rates and Location 01 volume or transfer to next locations (2, 3, 4, 5, …), and (iii) retention factor (incremental changes derived from CSIRO model).

1.2.2 Effect of water temperature

The majority of the CSIRO data for aluminium release were from experiments conducted at a water temperature of 21°C, and a fewer number of tests were conducted at 6°C (none at intermediate temperatures). Based on water temperature profiles (Figure 4, Appendix A), the surface water temperatures may range from 16 to 25°C in summer (heating), and 6 to 8°C in winter (cooling). The waters are cooler at greater depth, with summer water temperature being 10-16°C at mid-depth and 6-8°C at the bottom.

For the purpose of this desktop assessment, the data were analysed separately to create two models for aluminium release at 21°C (5 months heating; Dec 1-April 30) and 6°C (5 months cooling; June 1-Oct 30), respectively (Figure 4). Only with aluminium release predicted from the 21°C and 6°C models, release at intermediate temperatures was predicted using mixtures of the 21°C and 6°C model outputs. For the mixed temperature predictions, during the heating period aluminium release was predicted from the 21°C model in surface waters, as 50:50 of 21°C- and 6°C-models in middle waters, and 20:80 of 21°C and 6°C models in bottom waters. During the cooling period, the aluminium release was predicted as 20:80 of 21°C- and 6°C-models in surface and middle waters and by the 6°C models in bottom waters. There were two intermediate months, indicated by the step transitions in temperature in Figure 3. In May (1 month, as the waters were predicted began to cool rapidly, Figure 4) aluminium was predicted from the 80:20 of 21°C and 6°C models in surface waters, 30:70 of 21°C- and 6°C-models in middle waters, and 20:80 of 21°C and 6°C models in bottom waters. In November (1 month, as the waters warmed rapidly), the aluminium release was predicted from the 50:50 of 21°C and 6°C models in surface waters, 30:70 of 21°C and 6°C models in middle waters, and 20:80 of 21°C and 6°C models in bottom waters. These mixed models are expected to provide a better estimate of the possible aluminium release than the individual models.

1.2.3 Effect of duration

Lower amounts of aluminium release were observed for mixing durations <6 h than for longer durations, and some attenuation (low net aluminium release) may have been occurring at durations ≥336 h (2 weeks). However, the data set was not large enough to enable a wide range of mixing durations to be analysed separately across an adequate range of excavated rock concentrations. With the purpose of simulating mid- to longer-term aluminium releases within the immediate placement area (within the curtain), the data set comprised results from experiments with durations ranging from 24 to 336 h. A second data set was created with results from experiments with durations ≤18 h, and while the overlap of these two data sets is not ideal, it was necessary to construct meaningful relationships at both 21°C and 6°C.

For the predictions, the model derived from the longer durations (24 to 336 h) was used for predicting aluminium release within the waters behind the silt curtain (Location 1). For the other locations (2 to 10), a model derived from the shorter durations (≤18 h) was used for predicting aluminium release because the rock particles are predicted to be dispersing and being diluted at a greater rate at these locations (i.e. most particles will move beyond this location within 18 h).

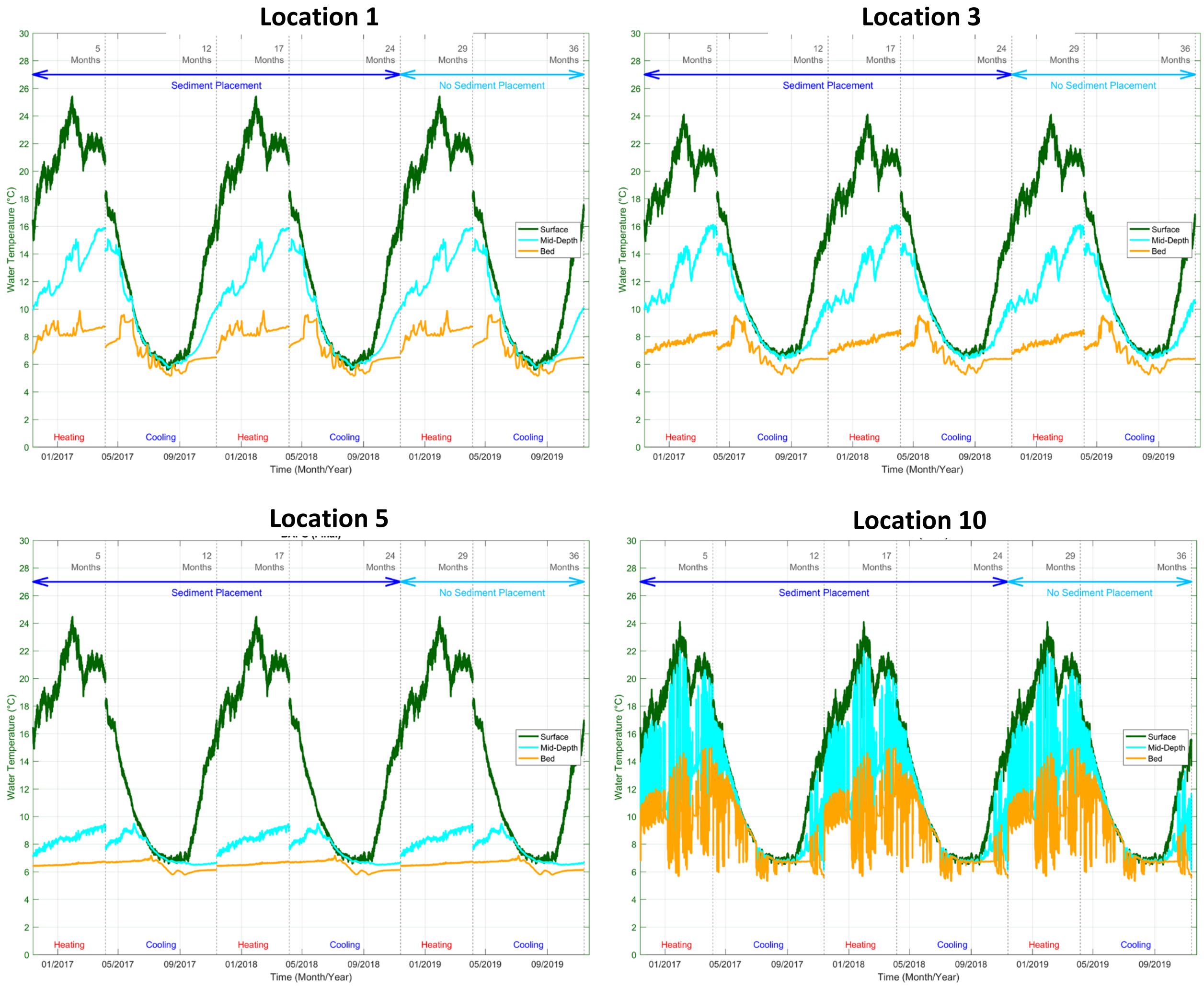


Figure 4. Temperature profiles for Talbingo Reservoir used in the hydrodynamic model and aluminium assessment at Locations 1, 3, 5 and 10 (Reservoir outlet). Larger images of profiles for all locations are shown in Appendix A.

1.2.4 Other factors

All of the rock materials were used in this assessment, although greater portions of those from the geological units designated as Ravine and Boraig may comprise the majority of the rock materials destined for placement in Talbingo Reservoir. The majority of CSIRO tests were conducted using rock material of particle size <75 µm, and the aluminium release data from these materials were considered a suitable estimate of what may occur from the TSS-rock material, whose concentrations were predicted by the hydrodynamic model. The <75 µm materials comprised 28±3% that was <6.3 µm (clay and fine silt), 18±3% that was <4 µm, and 6.3±2% that was <2 µm (clay). Dissolved aluminium release was negligible for rock materials >2 mm in size.

The aluminium release appeared to be controlled by dissolution from rock materials to form the highly soluble aluminate ion, $Al(OH)_4^-$. Consequently, waters with higher pH release aluminium faster and higher equilibrium concentrations are possible. In this desktop study, the water pH was not considered explicitly, and aluminium concentrations may be greater if the pH was to rise higher than that observed in the CSIRO tests due to sustained placement of fine rock materials without dilution and neutralisation, or aluminium concentrations may be lower if the pH remained lower.

2 Results

2.1 Excavated rock -dissolved aluminium relationships

There exists a high degree of variability in the dissolved aluminium concentrations across the excavated rock TSS concentrations, and the dissolved aluminium concentration range was greater for the tests conducted at 21°C than those at 6°C (Figure 5). The variability in the measured dissolved aluminium concentration at each TSS concentration is due to the combination of data sets with different rock types and test durations (Simpson et al., 2019). For neither of these variables was there sufficient data to develop individual models, beyond the test duration data sets described here. All tests were with materials of <75 µm particle size.

The lines in Figure 5 are the models calculated by curve-fitting (NCSS version 07.1.13, NCSS.COM) and are described further in Appendix B. The data enabled separate analysis and curve-fitting for experimental duration ranges of (i) 6-336 h (mid to long-term release), and (ii) ≤18 h (shorter-term release) at both 21°C and 6°C. For both of these data sets, it was possible to calculate the mean and upper confidence limit (95% Student's-t UCL, using NCSS) and run the curve-fitting with these data sets (Appendix B). A range of additional figures, including those for UCLs that were not significantly different to those for means are shown in Appendix B. The fit of the different curves was strongly influenced by the number of test data points at each TSS concentration. There was considerably greater aluminium release for TSS concentrations of 3.3 and 33 g/L. The data sets were not large enough to analyse relationships separately for individual times or rock types (i.e. there were not a sufficient number of pairs of TSS and dissolved aluminium concentrations for each variable). The curve-fitting was repeated for the 24-336-h data set (removing the overlapping 18-h data), which was eventually selected as better for predicting the mid to long-term aluminium release (Location 1) (Figure 5).

A visual comparison of the different curve fits shown in Figure 5 were an important consideration for which to use for predicting dissolved aluminium during the placement operations. There were also considerably fewer data at TSS concentrations <1 g/L, and that resulted in greater uncertainty for these lower TSS concentrations. For the final aluminium release predictions, the calculations used the predictions from two TSS-dissolved aluminium relationships: (i) the 24-336-h model (dashed purple line) and 6-336 UCL model (full red line) (comparing two models) for Location 1 (within the silt curtain) that generally had a TSS range of 200-2000 mg/L, (ii) the ≤18 h curve (solid green line) for the other locations (<100 mg/L TSS range). Considering the overall spread of the data and the uncertainty at the lower TSS concentrations, the actual dissolved aluminium concentrations may be within a factor of two of the predictions (higher or lower).

The curve-fits influence the predictions. For the mid to long-term release relationships with the 21°C data, the differences in curve-fits through the TSS data ranges of 50-500 mg/L and 1000-2000 mg/L have a particularly significant influence on the predicted dissolved aluminium concentrations. These fits are strongly influenced by data distributions, noting there was very limited data available at TSS concentration <1000 mg/L. For the shorter-term release relationships, the 24-336-h model (UCLs could not be calculated) provides a suitably conservative prediction of dissolved aluminium release.

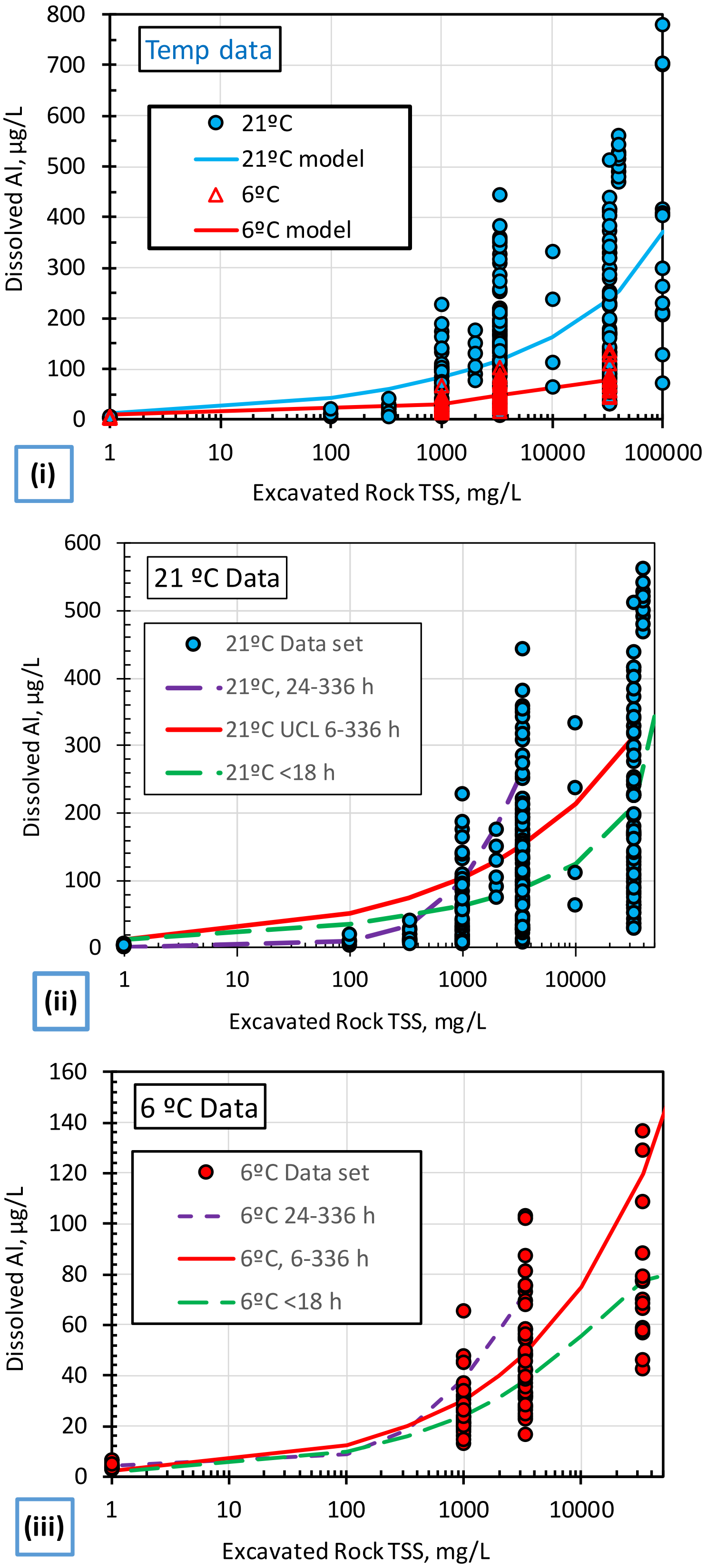


Figure 5. Relationship between excavated rock TSS concentration (mg/L) and dissolved Al (µg/L). (i) Comparison of models for the full data sets at 21°C and 6°C, respectively. For the aluminium release predictions the calculations used the predictions from (ii) the 24-336 h model (dashed purple line) and 6-336 UCL (full red line) for Location 1 (within the silt curtain) that generally had 200-2000 mg/L TSS range, (iii) the ≤18-h model (solid green line) for the other locations (<100 mg/L TSS range). Figures for mean and 95th percentiles (UCLs) are provided in Appendix B.

2.2 TSS (hydrodynamic model)-dissolved aluminium relationship

The TSS outputs from the hydrodynamic model are shown in Figure 6 and Appendix C. These profiles depict TSS concentration increases as a result of rock placement then decreasing when the placement ceases after 24 months. TSS concentration increases in the surface waters and mid-depth waters during the summer months owing to the warmer waters nearer the surface, and at some locations increased in deeper waters during the winter period owing to TSS settling out.

Using the predicted TSS concentrations to represent the concentrations of fine excavated rock, and models derived in Section 2.1 (excavated rock (mg/L)-dissolved Al (µg/L) relationships), dissolved aluminium concentration profiles were constructed for each location. Note here that the relationships represent the aluminium release due to rock placement and do not include any background aluminium that already existed in the reservoir waters (5-10 µg/L).

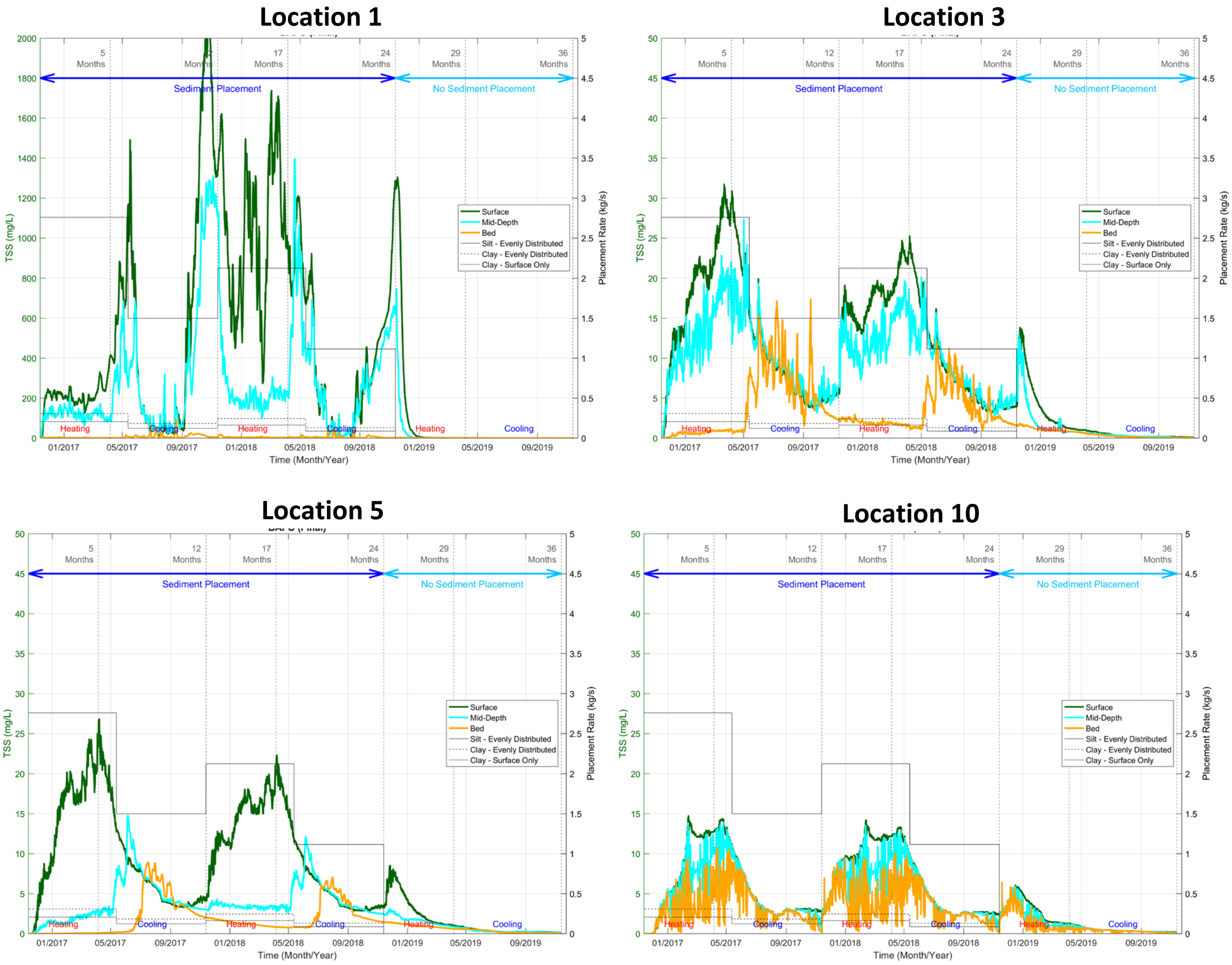


Figure 6. TSS profiles for Talbingo Reservoir used in the hydrodynamic model and aluminium assessment at Locations 1, 3, 5 and 10 (Reservoir outlet). Larger images of profiles for all locations are shown in Appendix C.

2.3.1 Predicted dissolved aluminium concentrations in Talbingo Reservoir

2.2.1 Predicted dissolved aluminium in the placement area (Location 1)

In Figure 7, the predicted dissolved aluminium concentrations are shown during (24 months) and following (12 months) for the rock placement period for Location 1. For this location, predictions based on two relationships for mid-long-term release were compared:
(i) 24-336-h relationship (dashed purple line), and (ii) 6-336-h UCL relationship (full red line) in Figure 5(ii). In addition, two scenarios are described:

(A) Aluminium release is predicted using the two relationships for mid to long-term release, representing a simple equilibrium-partitioning between TSS and dissolved aluminium.

(B) Ongoing additions of excavated rock result in higher dissolved aluminium due to release occurring into waters that already contain dissolved aluminium that has not yet been transported beyond the silt curtain (Location 1). For this scenario, 91%/day of the aluminium release accumulates in the waters within the silt curtain, and 9%/day of the dissolved aluminium is exported to Location 2, and additional release occurs from newly added rock materials (predicted using the two relationships for mid to long-term release).

A range of other scenarios were tested, and several of those are illustrated in Appendix D. Each has different assumptions and uncertainties. The greatest uncertainly relates to water pH. If the pH was to be rise to and be maintained at pH 9.5-10.5 within Location 1, the rate of aluminium release may be significantly greater (note, recommendations had been made to undertake such tests to fill this data/knowledge gap). Under such a scenario, the peak dissolved aluminium concentrations may be in the 300-420 µg/L range at Location 1 (Figure D2), and 40-90 µg/L range at Location 2 (Figure D3). Alternatively, if water inputs and dispersion results in the pH <9 (e.g. pH 8-9), then the aluminium release may be lower.

Based on the available data and for both relationships (i) and (ii), Scenario B represents the higher range of the aluminium release predictions for Location 1. Both Scenarios A and B, using both relationships, predict dissolved aluminium in the surface and middle depth waters to exceed the DGV of 55 µg/L during periods of higher water temperatures (close to summer months). Relationship (i) predicts steeper increases in dissolved aluminium concentrations and higher peak concentrations, compared to relationship (ii) that indicated higher average aluminium concentrations but lower peak concentrations.

Both relationships and scenarios predict that dissolved aluminium concentrations in the deeper waters should generally remain close to background concentrations (<10 µg/L), however, here we note that the hydrodynamic model predicts very low TSS concentrations in the bottom waters (Figure 6), which seem counterintuitive if the rock placement materials are depositing. Within the placement area, the formation of a dense layer of fine rock materials might be expected that is being disturbed and resuspended throughout the duration of the rock placement activities.

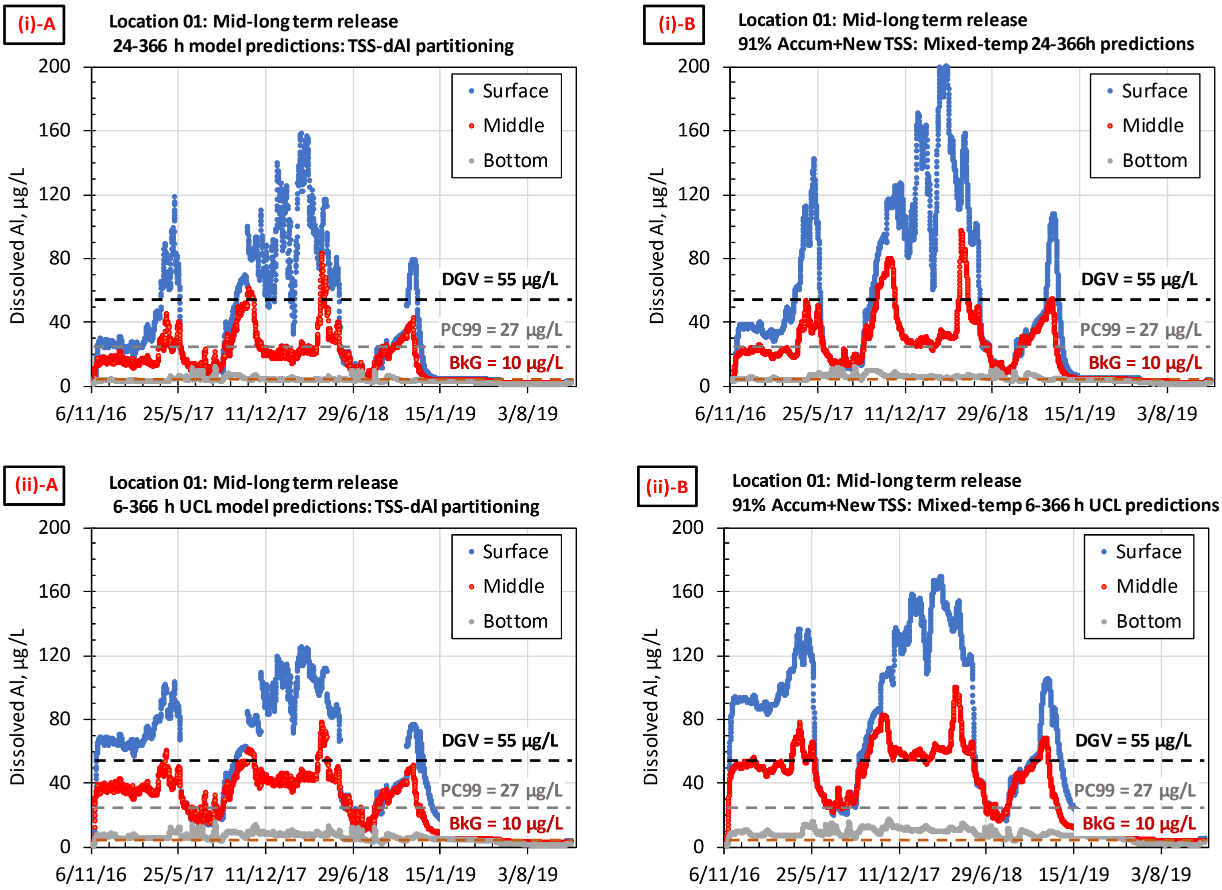


Figure 7. Predicted dissolved aluminium concentrations (µg/L) at Location 1 (J-Placement) during the rock placement period (24 months of placement and 12 months following placement): Mid to long-term release relationship (i) (24-336-h data) was used for the top figures and relationship (ii) (6-336 UCL data) for the bottom figure. Figures (iii) and (iv) Mixed-temperature model t=6-336 UCL data. Scenarios A (left figures) Aluminium release is predicted using the 'basic relationship', representing a simple equilibrium-partitioning between TSS and dissolved aluminium. Scenario B Ongoing additions of excavated rock result in higher dissolved aluminium due to release occurring into waters that already contain dissolved aluminium that has not yet been transported beyond the silt curtain.

2.2.2 Predicted dissolved aluminium concentrations at locations beyond the placement area (Locations 2, 3, 4, 5, 6 and 10)

For predictions of dissolved aluminium concentrations at locations beyond the placement area, the following two scenarios examined are:

(A) Aluminium release occurs from rock materials that are present as TSS (predicted using model for short-term release (≤18-h relationship, as most particles will move beyond this location within 18 h), and dilution occurs according to estimates from the hydrodynamic model (e.g. 15%/day dissolved aluminium is exported from Location 2 to Location 3).

(B) A portion of aluminium released from the previous location is transported to the new location (e.g. 9%/day of dissolved aluminium is exported from Location 1 to Location 2), and this dissolved aluminium is added to that predicted based on release from TSS and ongoing dilutions.

This approach to predicting dissolved aluminium was followed for Locations 2, 3 and 4 (Figure 8), and then Locations 5, 6 and then Location 10 (near reservoir outlet) (Figure 9). These predictions indicate that dissolved aluminium concentrations should not exceed the DGV at or beyond Location 2. Between Locations 1 and 2, there is expected to be a gradient in dissolved aluminium concentrations, and the DGV may be exceeded within this gradient (mixing zone). The predictions indicated that the dissolved aluminium released in the placement area and from particles transported through the reservoir should not contribute more than the existing background dissolved aluminium concentrations beyond Location 5.

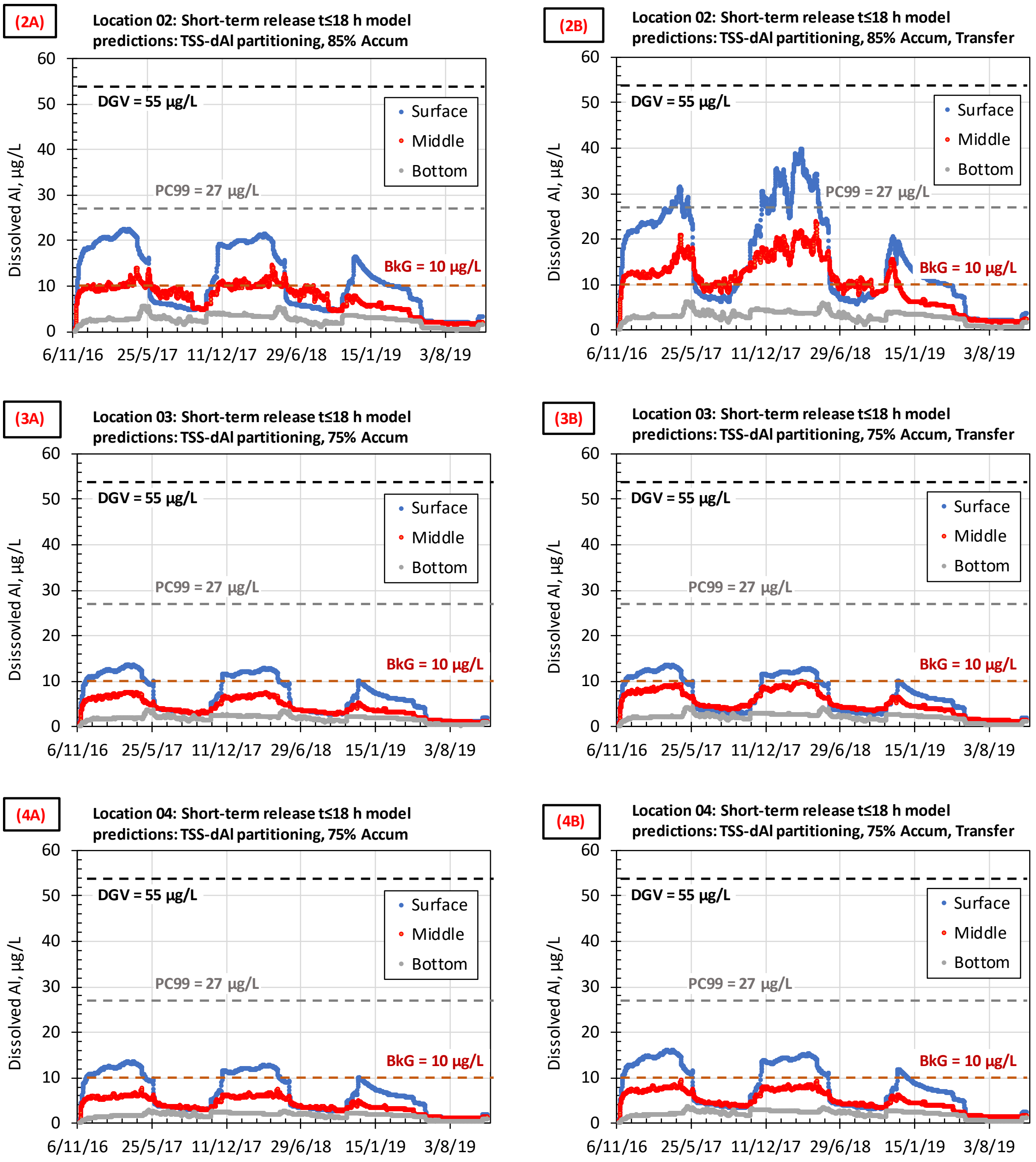


Figure 8. Predicted dissolved aluminium concentrations (µg/L) during the rock placement period (24 months of placement and 12 months following placement): Locations 2, 3 and 4. Mixed-temperature model t ≤18-h data. Scenarios A and B described in text using short term release relationships (≤18-h model), and dilution occurs according to estimates from the hydrodynamic model (e.g. 15%/day of aluminium is exported from Location 2 to 3).

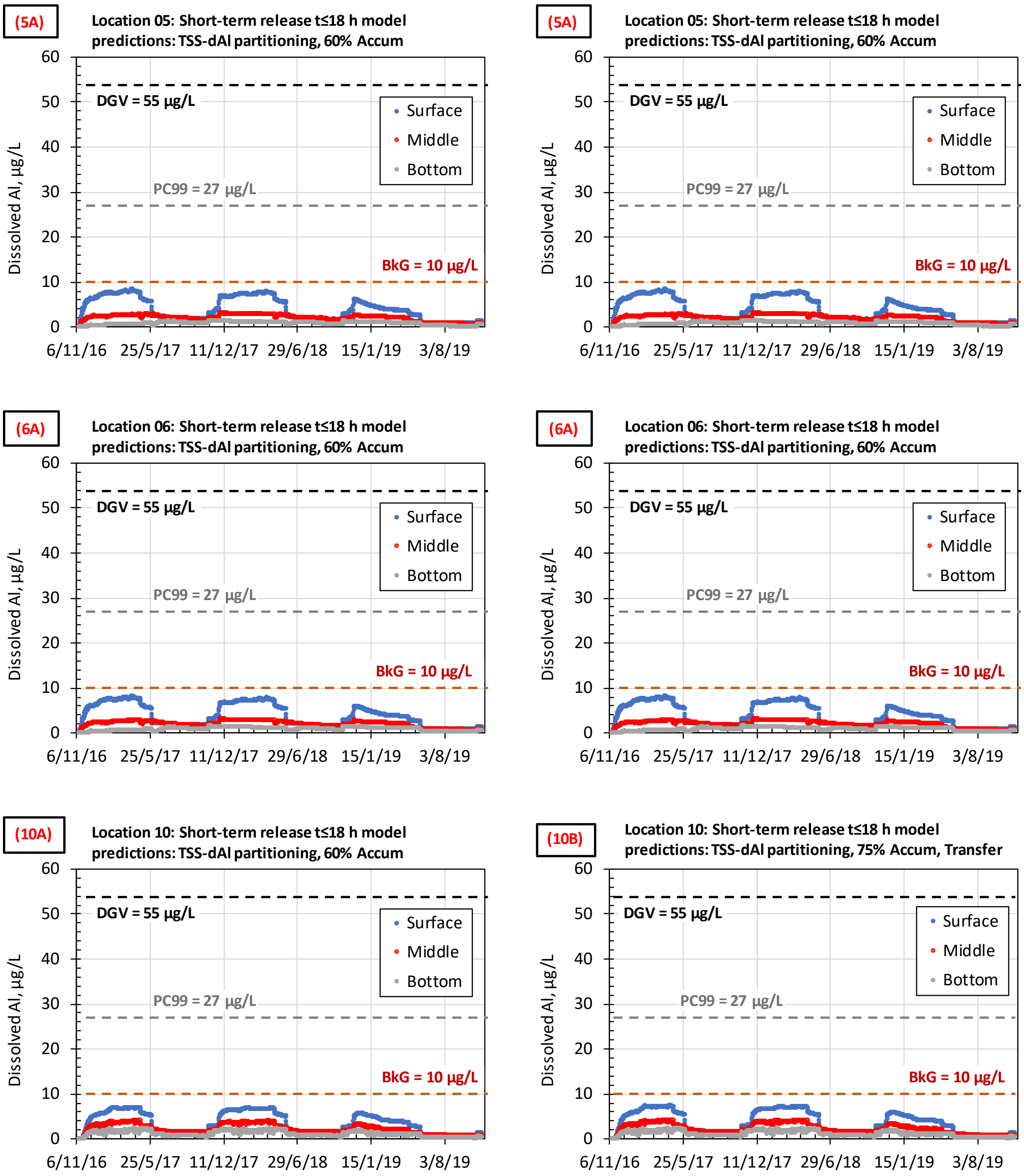


Figure 9. Predicted dissolved aluminium concentrations (µg/L) during the rock placement period (24 months of placement and 12 months following placement): Locations 5, 6, and 10 (Reservoir outlet). A and B described in Figure 8.

3 Dissolved aluminium summary

The assessment indicates that dissolved aluminium concentrations are likely to exceed the default GV (DGV) of 55 µg/L within the placement area contained by the silt curtain (Location 1). Outside the silt curtain, a gradient (mixing zone) is expected to develop, along which dissolved aluminium released in Location 1 will be diluted and further aluminium release from particles will occur. From Location 1 to Location 2, 500 m away, dissolved aluminium concentrations may also exceed the DGV. Beyond Location 2 the dissolved aluminium concentrations are predicted to remain below the DGV.

Significant uncertainty exists with the predictions on both the high side (higher dissolved aluminium) and low side (lower dissolved aluminium). CSIRO Assignment P4 (Simpson et al., 2019) described a number of data/knowledge gaps that influence this uncertainty. Higher TSS concentrations and higher water pH are considered the primary drivers for higher dissolved aluminium concentrations. Lower water temperatures will result in lower dissolved aluminium concentrations.

The great source of uncertainly for aluminium release relates to water pH. If the pH was to rise to and be maintained at pH 9.5-10.5 within Location 1, the rate of aluminium release may be significantly greater and peak dissolved aluminium concentrations of 300-420 µg/L may be reached at Location 1, and 40-90 µg/L at Location 2. Alternatively, if water inputs and dispersion results in the pH <9 (e.g. pH 8-9), then the aluminium releases may be lower than those predicted here. Greater rates of water dilution will also lower dissolved aluminium concentrations in Location 1, and the export of the aluminium to locations further down the reservoir may not substantially increase the predicted concentrations at those locations. While difficult to estimate, the predictions may have 50% uncertainty on both the high or low sides for Location 1 and 2.

The hydrodynamic model predicted low TSS in the bottom waters, and while this seems counterintuitive (gravity), the presence in the cooler bottom waters may not have a large influence on the predictions.

At Locations 3 to 10, attenuation reactions that result in lower water pH may result in substantially lower aluminium release from TSS at locations further from the placement area. The dilutions may also be greater than those estimated for these predictions, resulting in lower dissolved aluminium concentrations. For the locations beyond the silt curtain, the predictions will have even greater uncertainty, but dissolved aluminium concentrations seem likely to be within a factor of 2-3 of the background concentrations.

4 References

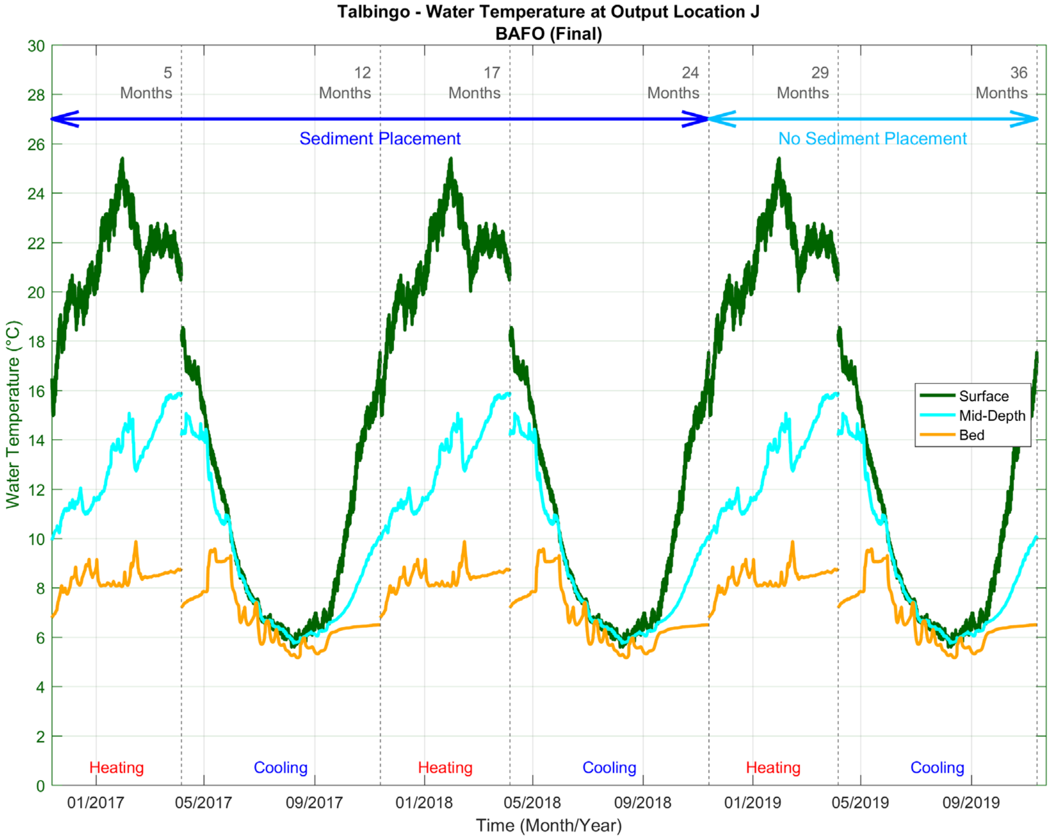
Simpson SL, Angel BM, Mudaliar P, King JJ, and Jarolimek CV (2019). Snowy 2.0 P4: Environmental Categorisation of Excavated Rock Interactions with and Potential Impacts on Reservoir Waters and Sediments. CSIRO Land and Water Report EP19176, Lucas Heights, NSW, Australia.

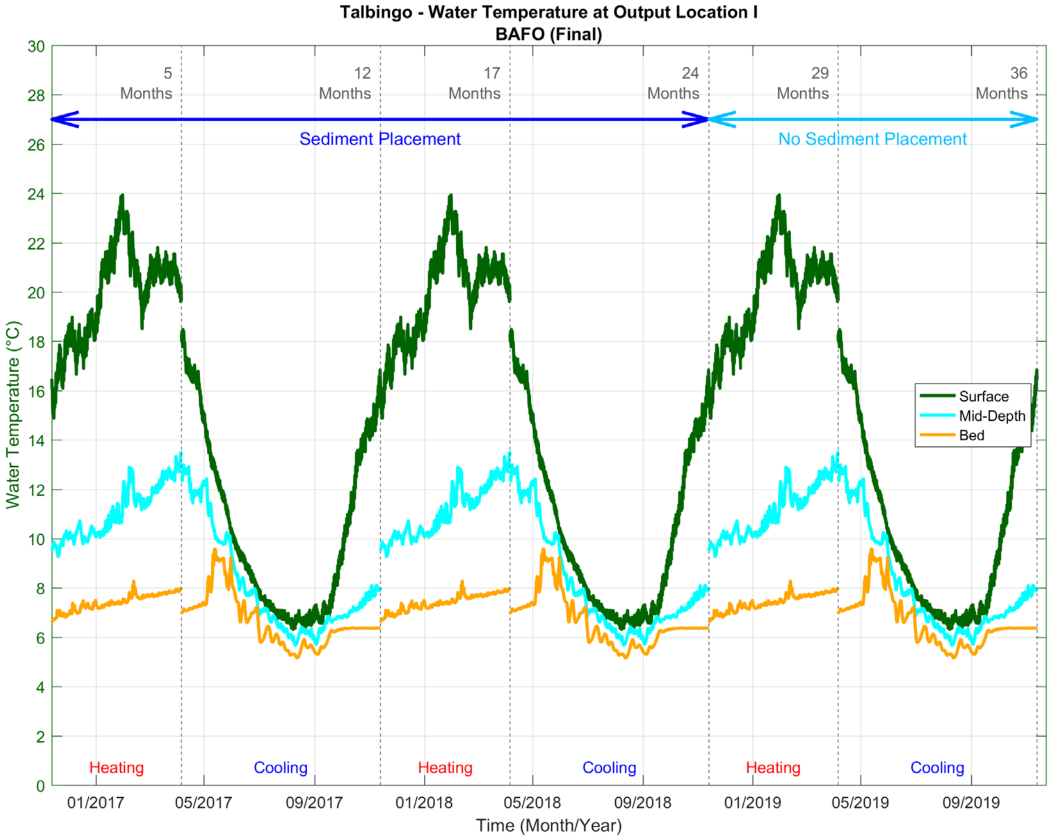
ANZECC/ARMCANZ (2000). Australian and New Zealand guidelines for fresh and marine water quality. Australia and New Zealand Environment and Conservation Council/Agricultural and Resource Management Council of Australia and New Zealand. Canberra, Australia.

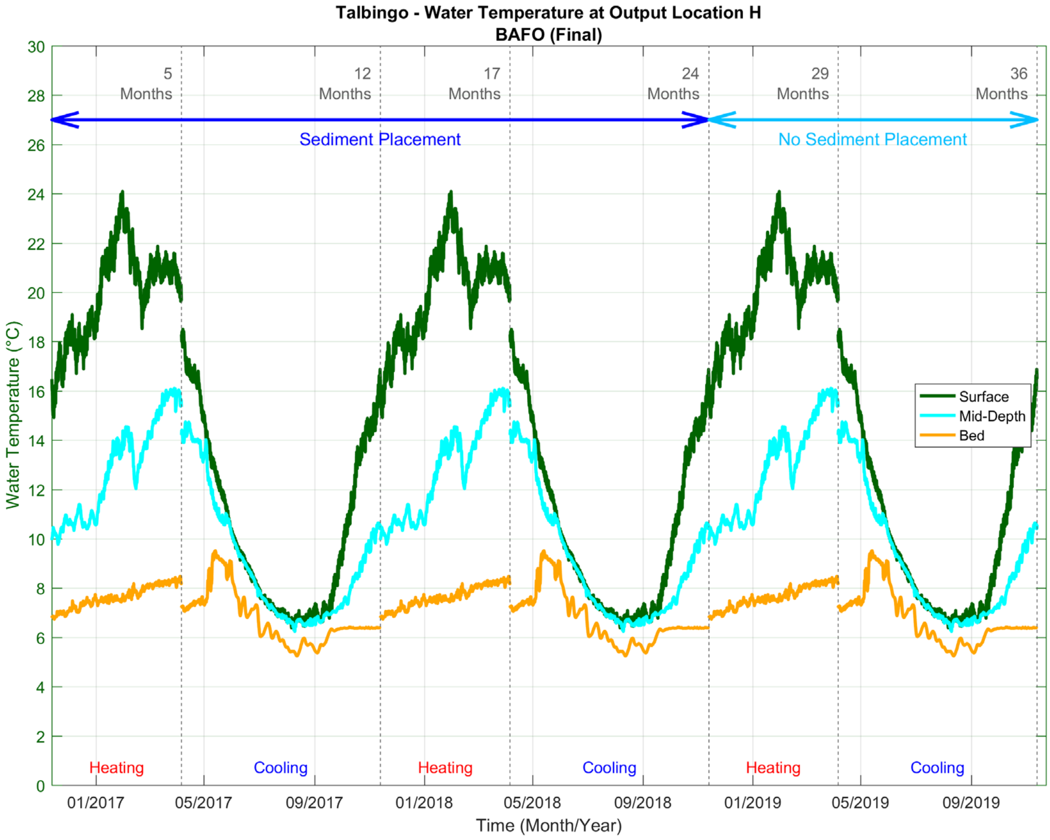
ANZG (2018). Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines.

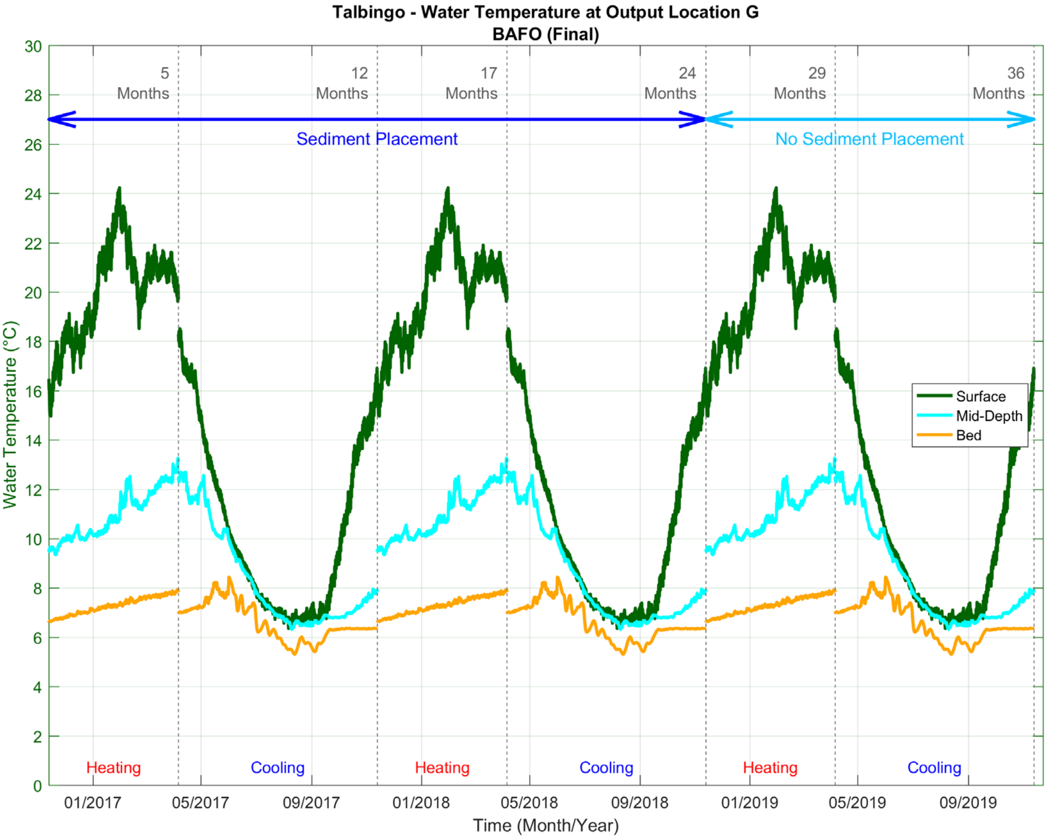
Appendix A Water temperature profiles for Talbingo Reservoir used in the hydrodynamic model and aluminium assessment

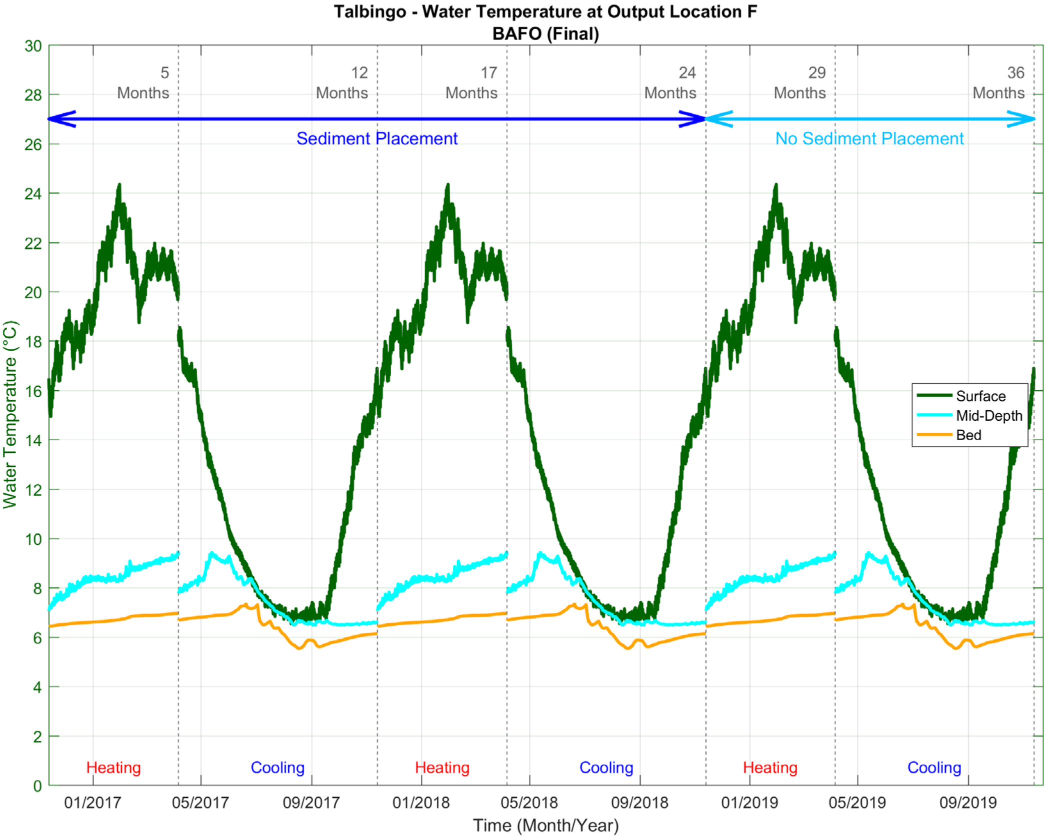
Note in the figures shown here the location names are in alphabetical order (J to A), being Location J = 1 (Placement area) to Location A = 10 (Reservoir outlet)

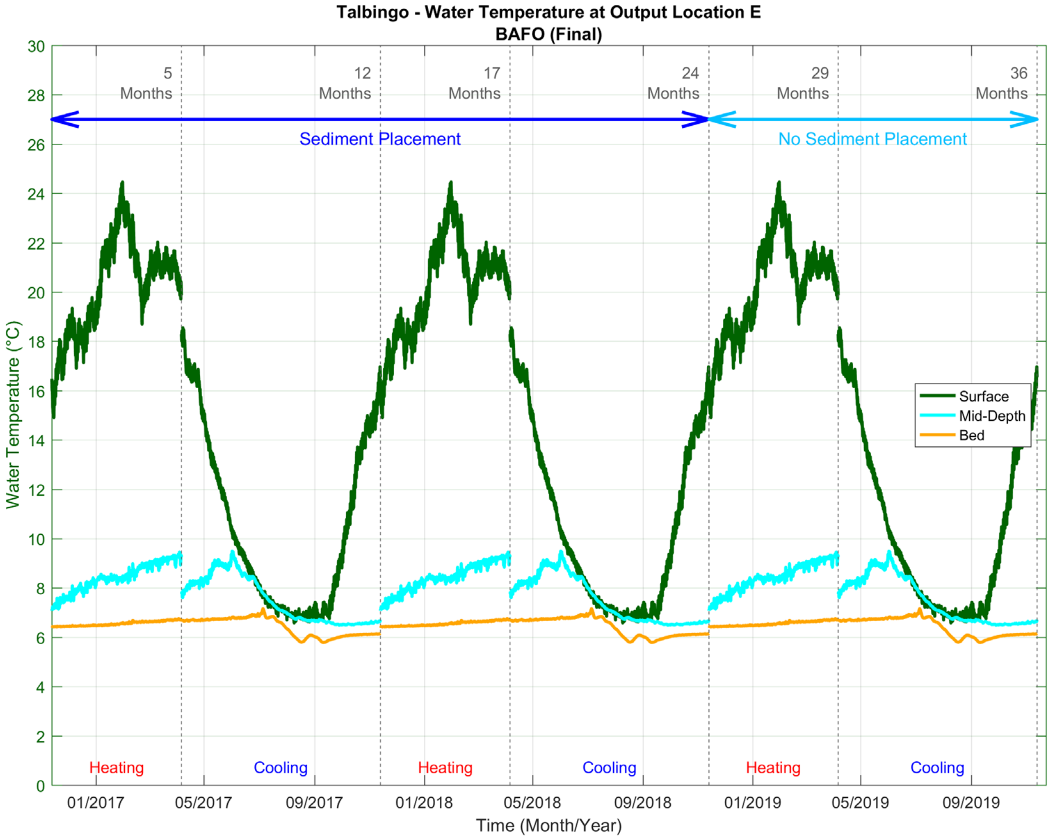


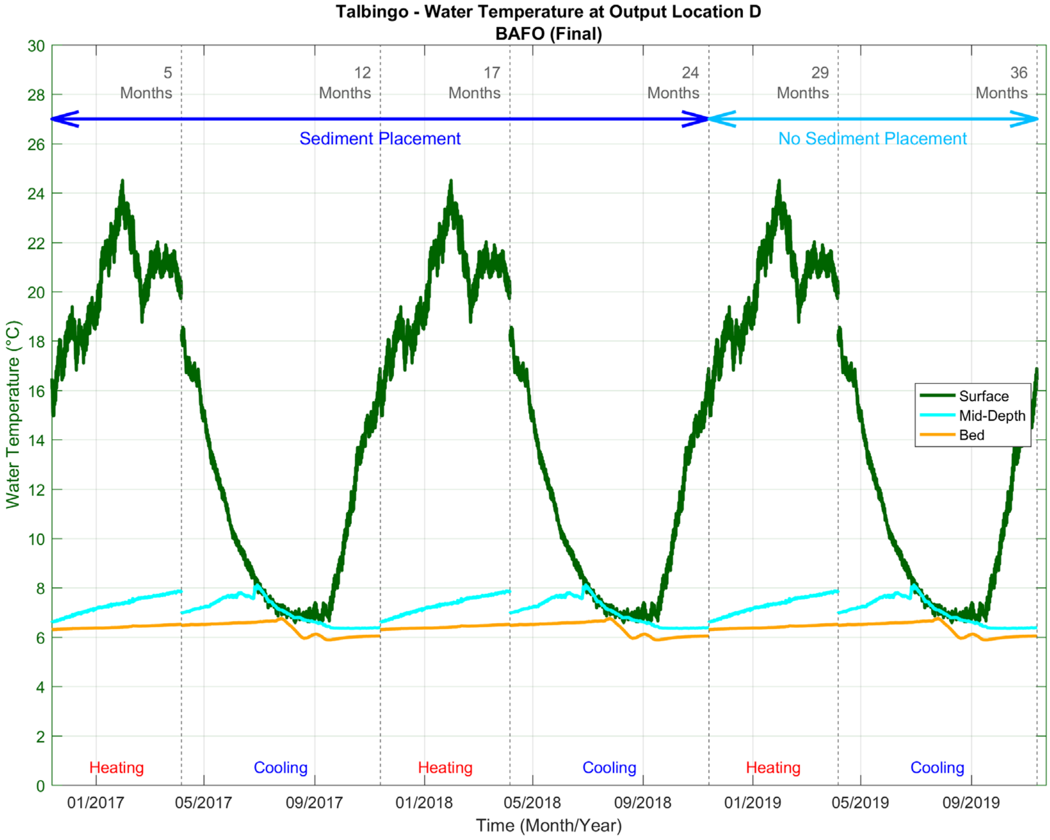

Talbingo - Water Temperature at Output Location I
BAFO (Final)
Water Temperature (°C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
5 Months
12 Months
17 Months
24 Months
29 Months
36 Months
Sediment Placement
No Sediment Placement
Surface
Mid-Depth
Bed
Heating
Cooling
Heating
Cooling
Heating
Cooling
01/2017
05/2017
09/2017
01/2018
05/2018
09/2018
01/2019
05/2019
09/2019
Time (Month/Year)

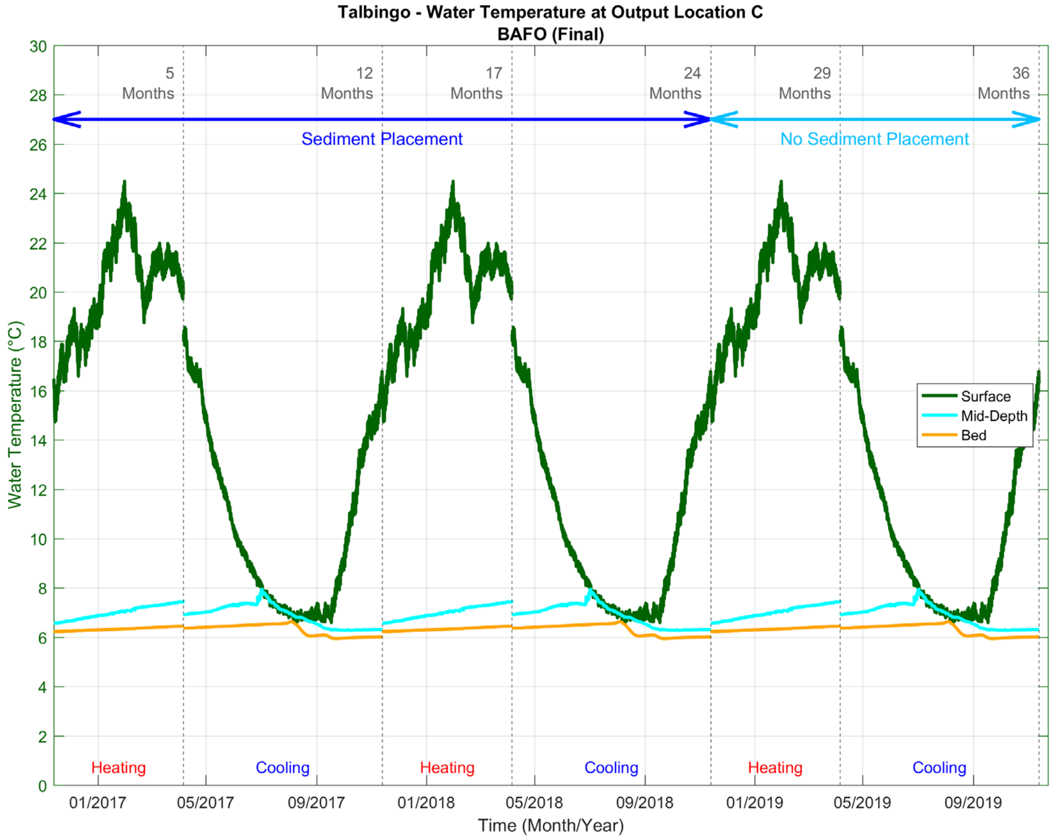

Talbingo - Water Temperature at Output Location H
BAFO (Final)
Water Temperature (°C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
5 Months
12 Months
17 Months
24 Months
29 Months
36 Months
Sediment Placement
No Sediment Placement
Surface
Mid-Depth
Bed
Heating
Cooling
Heating
Cooling
Heating
Cooling
01/2017
05/2017
09/2017
01/2018
05/2018
09/2018
01/2019
05/2019
09/2019
Time (Month/Year)

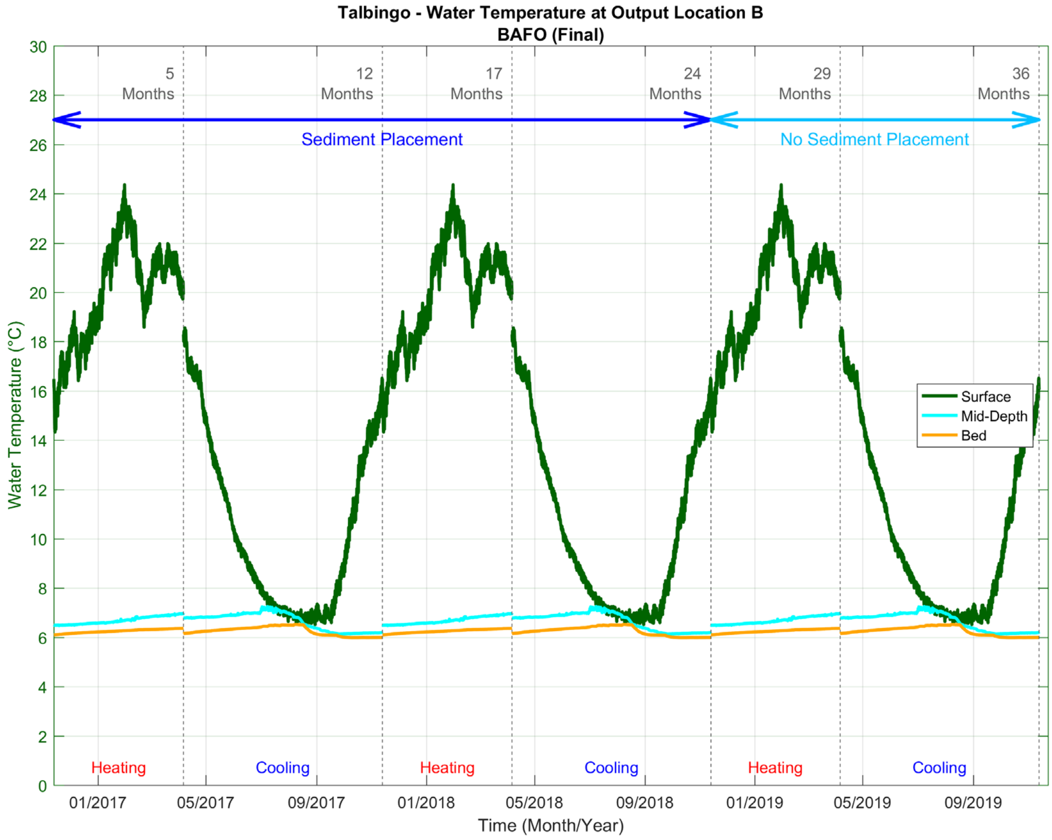

Talbingo - Water Temperature at Output Location G
BAFO (Final)
Water Temperature (°C)
Time (Month/Year)
5 Months
12 Months
17 Months
24 Months
29 Months
36 Months
Sediment Placement
No Sediment Placement
Heating
Cooling
Heating
Cooling
Heating
Cooling
Surface
Mid-Depth
Bed
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
01/2017
05/2017
09/2017
01/2018
05/2018
09/2018
01/2019
05/2019
09/2019

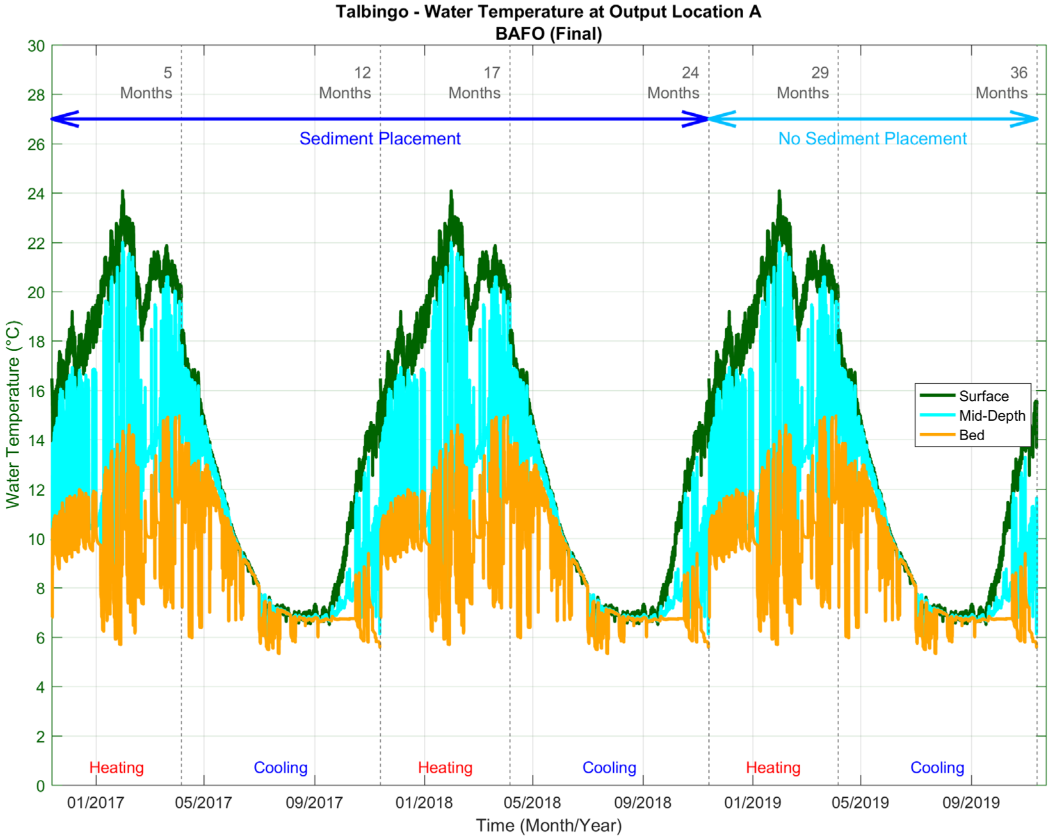

Talbingo - Water Temperature at Output Location F
BAFO (Final)
Water Temperature (°C)
Time (Month/Year)
5 Months
12 Months
17 Months
24 Months
29 Months
36 Months
Sediment Placement
No Sediment Placement
Heating
Cooling
Heating
Cooling
Heating
Cooling
Surface
Mid-Depth
Bed
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
01/2017
05/2017
09/2017
01/2018
05/2018
09/2018
01/2019
05/2019
09/2019


Talbingo - Water Temperature at Output Location E
BAFO (Final)
Water Temperature (°C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
5 Months
12 Months
17 Months
24 Months
29 Months
36 Months
Sediment Placement
No Sediment Placement
Surface
Mid-Depth
Bed
Heating
Cooling
Heating
Cooling
Heating
Cooling
01/2017
05/2017
09/2017
01/2018
05/2018
09/2018
01/2019
05/2019
09/2019
Time (Month/Year)


Talbingo - Water Temperature at Output Location D
BAFO (Final)
Water Temperature (°C)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
5 Months
12 Months
17 Months
24 Months
29 Months
36 Months
Sediment Placement
No Sediment Placement
Surface
Mid-Depth
Bed
Heating
Cooling
Heating
Cooling
Heating
Cooling
01/2017
05/2017
09/2017
01/2018
05/2018
09/2018
01/2019
05/2019
09/2019
Time (Month/Year)


Talbingo - Water Temperature at Output Location C
BAFO (Final)


Talbingo - Water Temperature at Output Location B
BAFO (Final)


Talbingo - Water Temperature at Output Location A
BAFO (Final)
Water Temperature (°C)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
5 Months
12 Months
17 Months
24 Months
29 Months
36 Months
Sediment Placement
No Sediment Placement
Surface
Mid-Depth
Bed
Heating
Cooling
Heating
Cooling
Heating
Cooling
01/2017
05/2017
09/2017
01/2018
05/2018
09/2018
01/2019
05/2019
09/2019
Time (Month/Year)

Appendix B Relationship between released dissolved aluminium and total suspended sediments

Relationships between released dissolved aluminium and TSS were calculated using curve-fitting (NCSS version 07.1.13, NCSS.COM), with the more suitable being either exponential Type-1 [Dissolved-Al(μg/L) = A*(TSS(mg/L)^B)*EXP(-C*(TSS(mg/L)] or PolyRatio(1,1) [Dissolved-Al(μg/L) = (A+B*(TSS(mg/L)))/(1+C*(TSS(mg/L)))].

There exists a high degree of variability in the dissolved aluminium concentrations across the excavated rock TSS concentrations, and the dissolved aluminium concentration range was greater for the tests conducted at 21 ºC than those at 6 ºC (Figure B1).

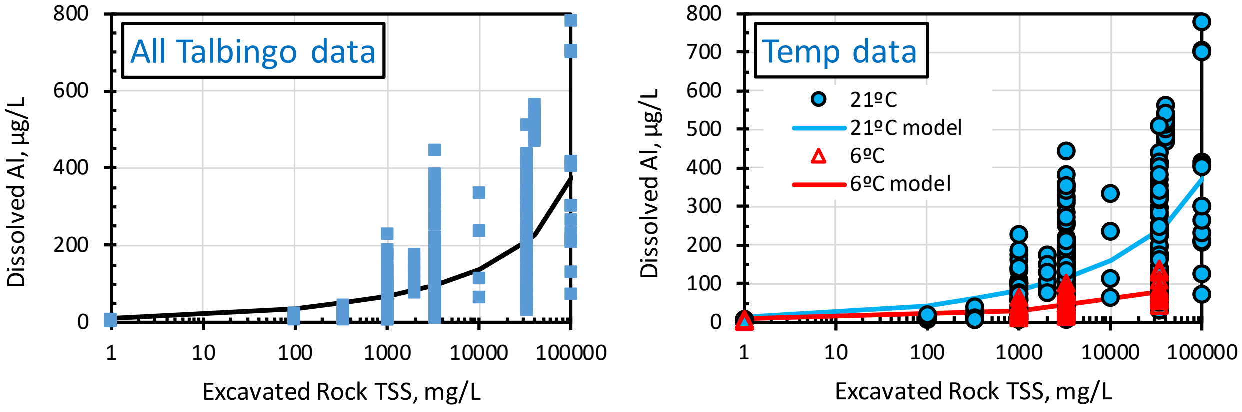


Figure B1. Relationship between excavated rock TSS concentration (mg/L) and dissolved Al (µg/L): (i) All data for Talbingo Reservoir, and (ii) data separated into tests at 21°C and 6°C respectively. The lines shown here are from curve-fitting through the entire data set, being a little lower than the mean and UCL shown in next figures.

The data enabled separate analysis and release prediction for experiments with durations (i) ranging from 6 to 336 h (mid to long-term release), and (ii) ≤18 h (shorter-term release) at both 21°C and 6°C (Figure B2). For both data sets, it was possible to calculate the mean and upper confidence limit (95% Student's-t UCL, using NCSS) and run the curve-fitting with these data sets (Figure B2).

The fit of the different curves was strongly influenced by the number of test data points at each TSS concentration. There were considerably greater aluminium release data for TSS concentrations of 3.3 and 33 mg/L. The data sets were not large enough to analyse relationships separately for individual times or rock types (i.e. there was not a sufficient number of pairs of TSS and dissolved aluminium for each variable). The 6-336-h time range provided the larger data set and the relatively similar mean and UCL for dissolved aluminium shown in Figure B2). While a considerable number of data points have dissolved aluminium concentrations above the mean and

UCL lines, it is expected that the mean should provide a reasonable estimate of dissolved aluminium release over the long duration of the rock placement, noting that comparison against GVs is recommended to involve using the 95th percentile of the test distribution. Similar points can be made about the relationships derived from the ≤18-h data, with a note that this was a smaller data set. The curve-fitting was repeated for the 24- to 336-h data set (removing the overlapping 18-h data), which was eventually selected as better for predicting the mid to long-term aluminium release (Location 1).

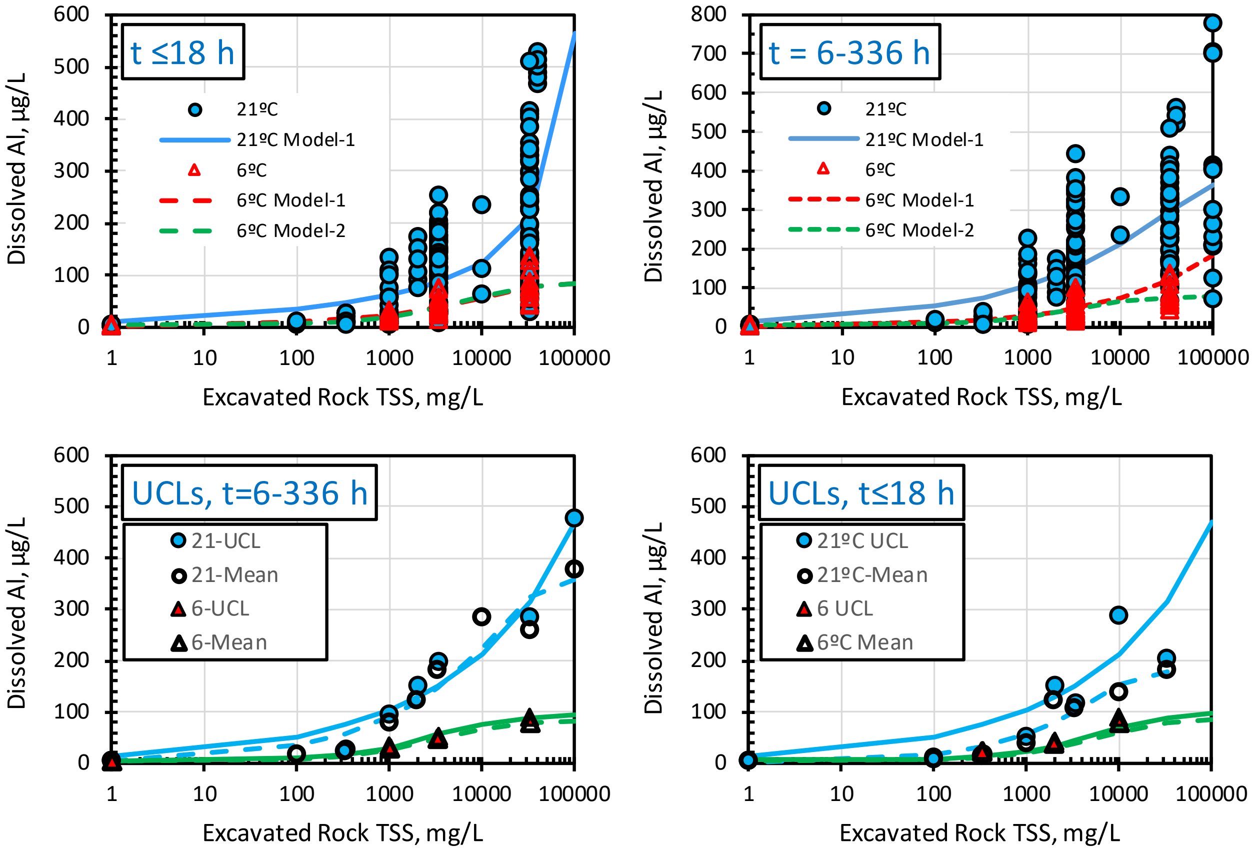


Figure B2. Relationship between excavated rock TSS concentration (mg/L) and dissolved Al (µg/L): (i) Data for Talbingo Reservoir separated as (i) 6 to 336 h (mid to long-term release), and (ii) ≤18 h, showing all data in top two figures and mean (curve fits = dashed lines) and UCLs (solid lines).

Data set purpose: mid to long-term release in main ER disposal area

21°C Talbingo t=6-336 h					6°C Talbingo t=6-336 h					
	Model-1	UCL	Mean	SE-Mean		Model-1	Model-2	UCL	Mean	SE-Mean
ER TSS, mg/L	Dissolved aluminium, µg/L				ER TSS, mg/L	Dissolved aluminium, µg/L				
100000	364	477	378	57	100000	184	80			
33300	294	285	259	16	33300	120	77	90.4	78	7.2
10000	213		285		10000	75	66			
3330	154	198	181	10	3330	49	48	52.9	47	3.4
2000	132	153	122	16	2000	40	39			
1000	107	96	79	10	1000	30	27	33.5	29	2.5
333	77	29	22	3.6	333	20	14			
100	53		16		100	12	8			
1	13	4.6	4.2	0.2	1	2	5	4.6	4.2	0.2

Data set purpose: 24-336 h mid to long-term release in main ER disposal area

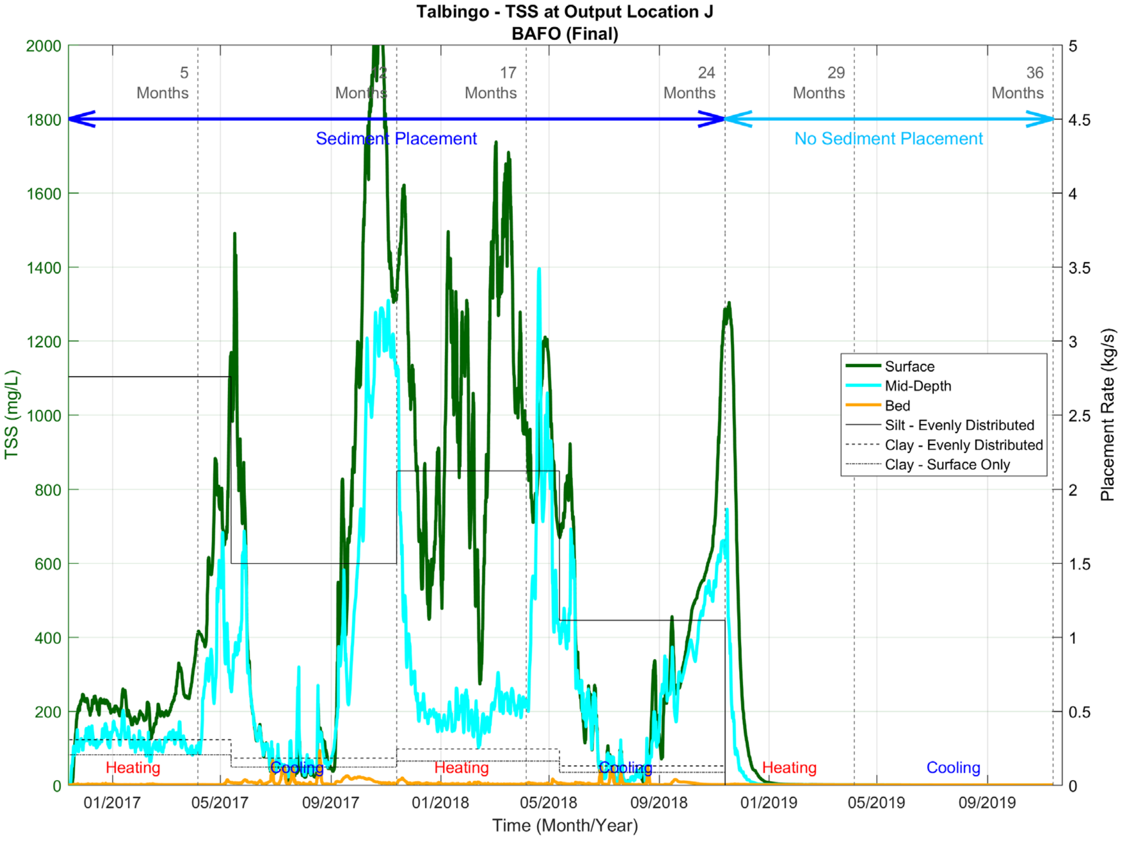
21°C Talbingo t=24-336 h					6°C Talbingo t=24-336 h					
	Model-1	Model 2				Model-1	Model-2			
ER TSS, mg/L	Dissolved aluminium, µg/L				ER TSS, mg/L	Dissolved aluminium, µg/L				
100000		870			100000					
33300		748			33300					
10000		502			10000					
3330	**260**	260			3330		**73**			
2000	**181**	176			2000		**58**			
1000	**99**	99			1000		**39**			
333	**34**	38			333		**19**			
100	**10**	14			100		**9**			
1	**0**	4			1		**4**			

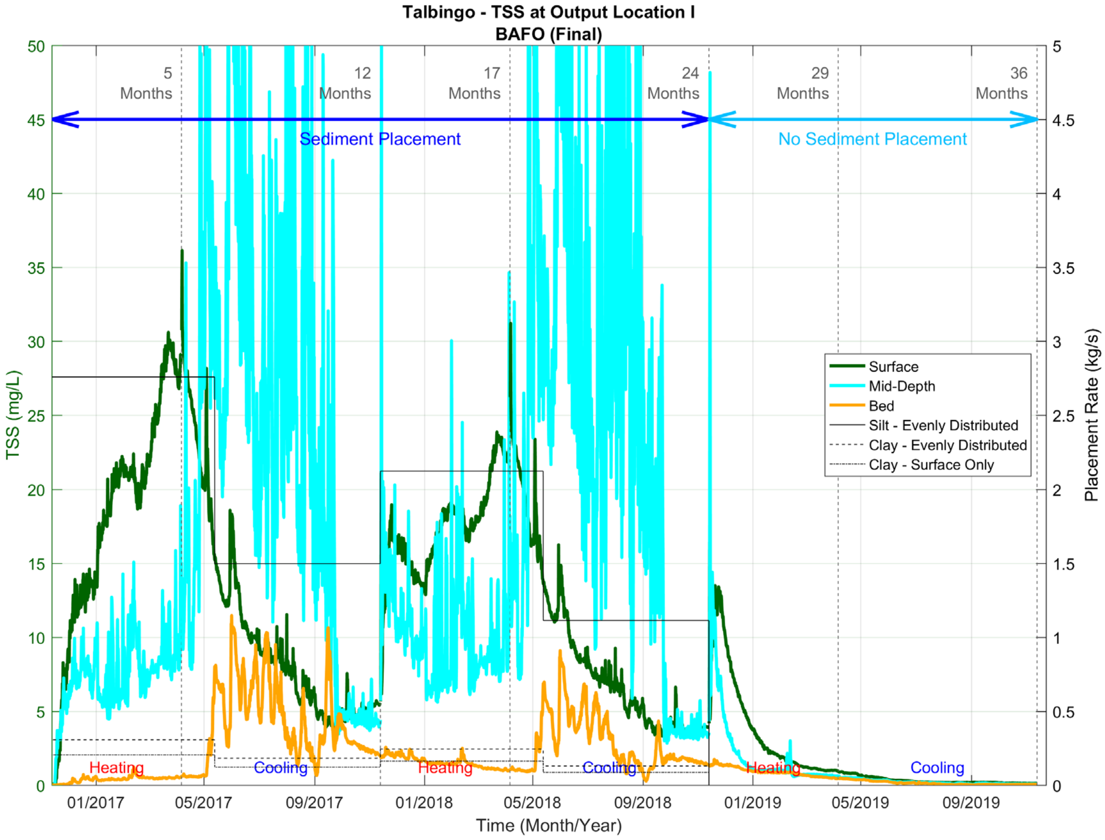
Data set purpose: ≤18 h short-term, reoccurring release, and representing release further from ER disposal area

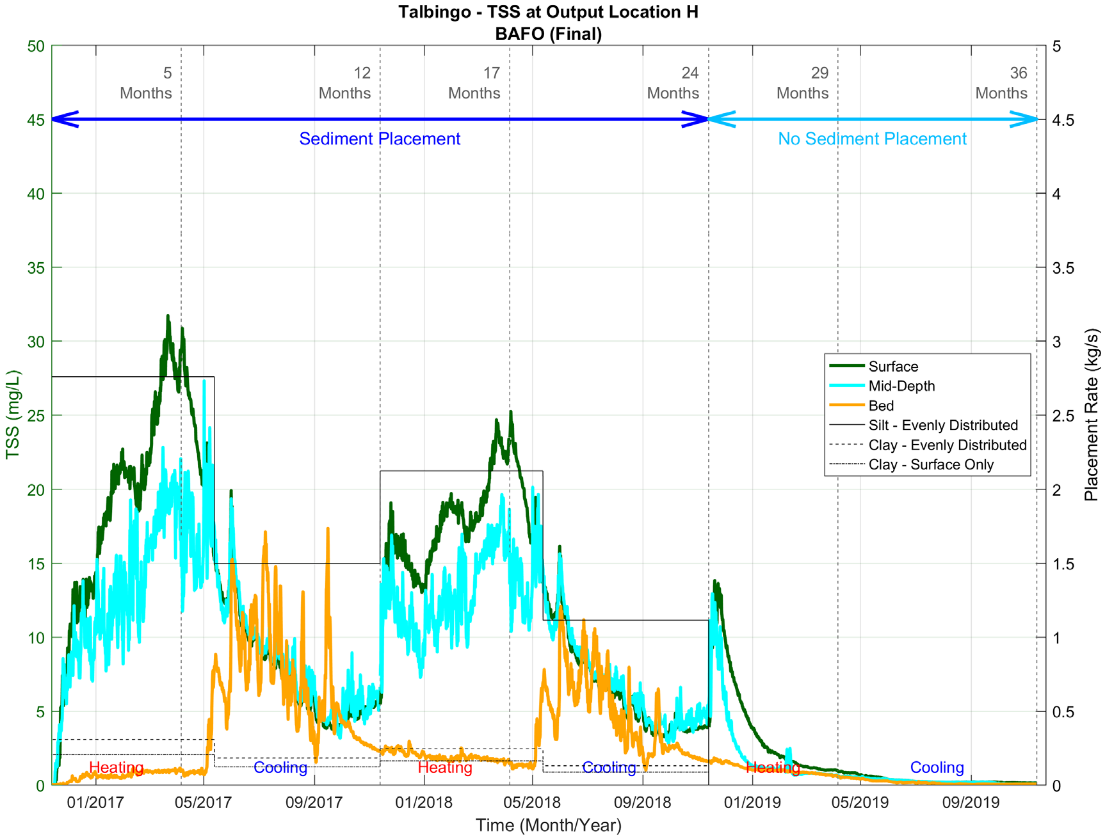
21°C Talbingo t ≤18 h					6°C Talbingo t ≤18 h					
	Model-1	UCL	Mean	SE-Mean		Model-1	Model-2	UCL	Mean	SE-Mean
ER TSS, mg/L	Dissolved aluminium, µg/L				ER TSS, mg/L	Dissolved aluminium, µg/L				
100000	564				100000	83	84			
33300	212	205	181	14	33300	78	77	90	78	7.2
10000	124	150	137	52	10000	55	61			
3330	88	118	106	7.2	3330	38	39	43	38	2.6
2000	77	85	122	16	2000	31	29			
1000	64	51	39	7.4	1000	24	19	25	22	1.5
333	48	18	15	1.8	333	16	10			
100	36	13	9	1.5	100	10	7			
1	12	4.6	4.2	0.2	1	2	5	4.6	4.2	0.2

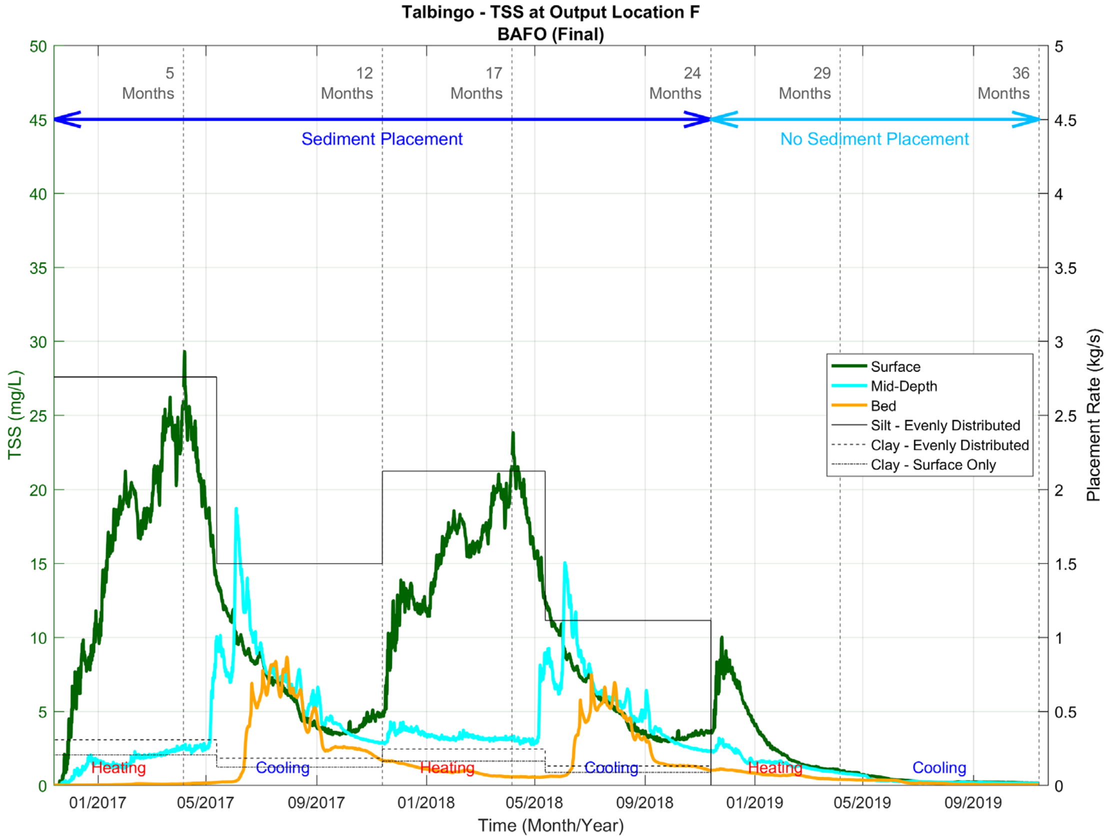
Appendix C TSS profiles for Talbingo Reservoir used in the hydrodynamic model and aluminium assessment

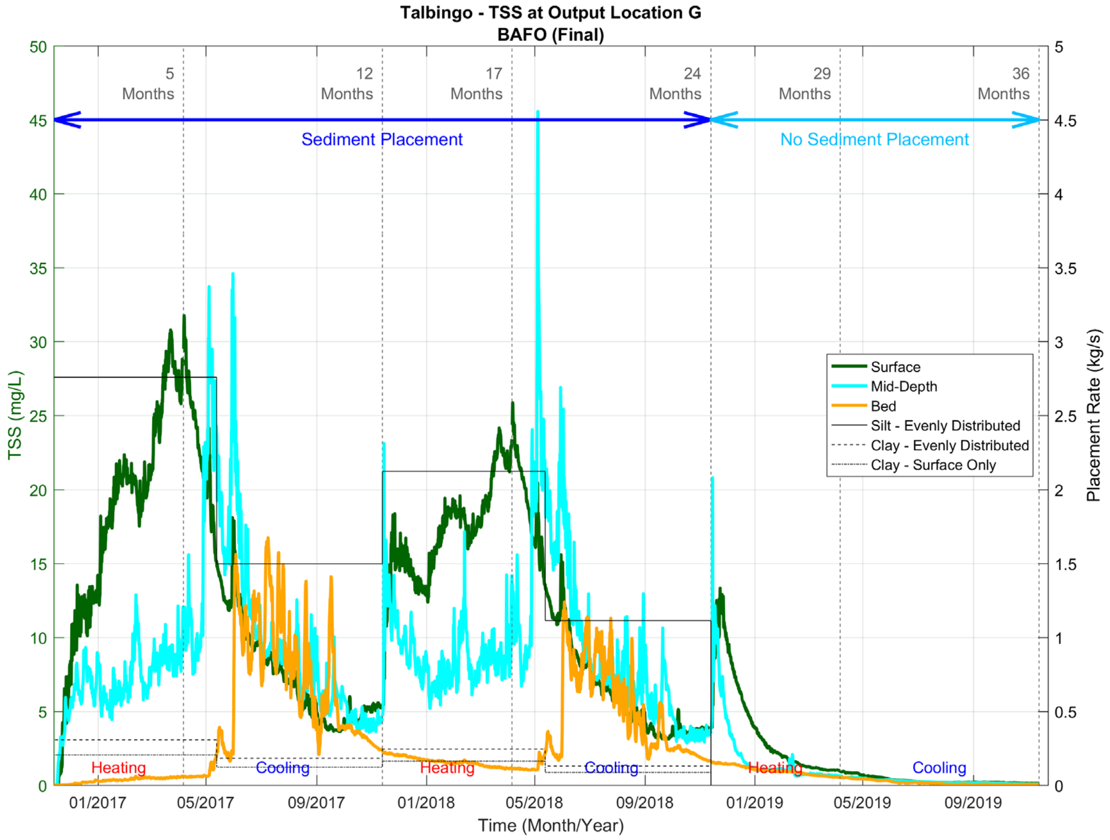
Note in the figures shown here the location names are alphabetical (J to A), being Location J = 1 (Placement area) to Location A = 10 (Reservoir outlet)

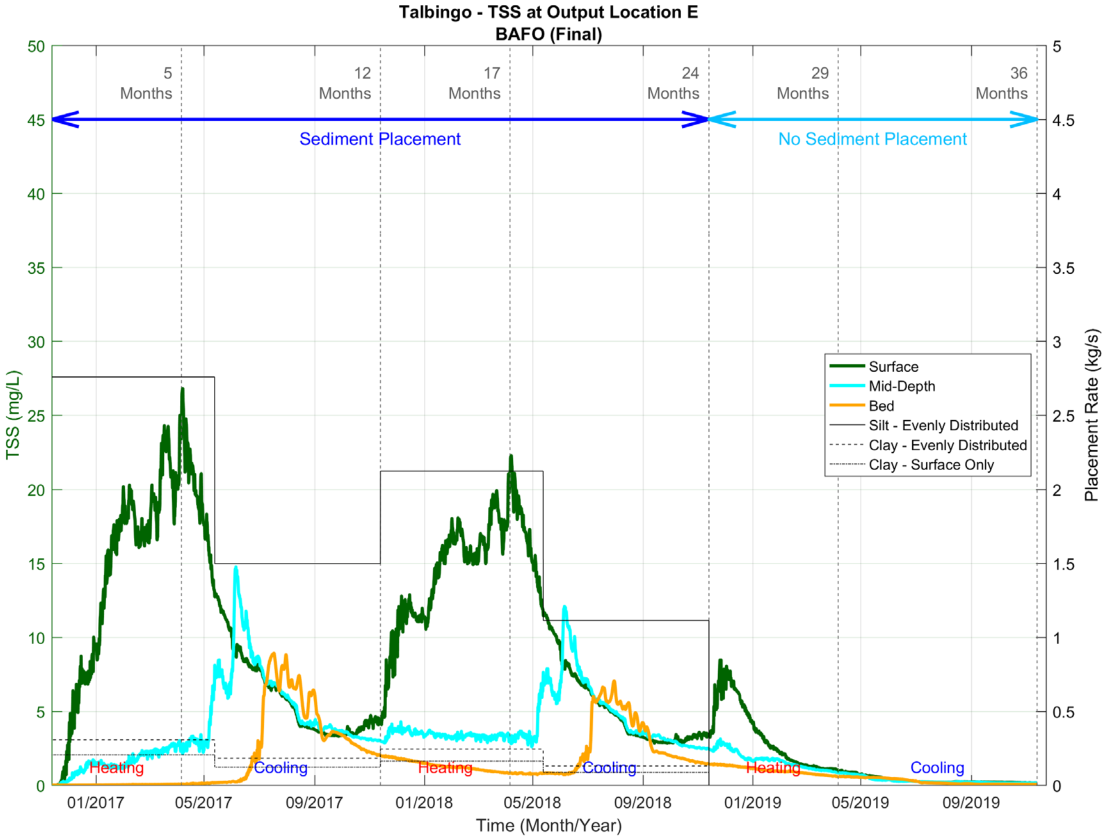


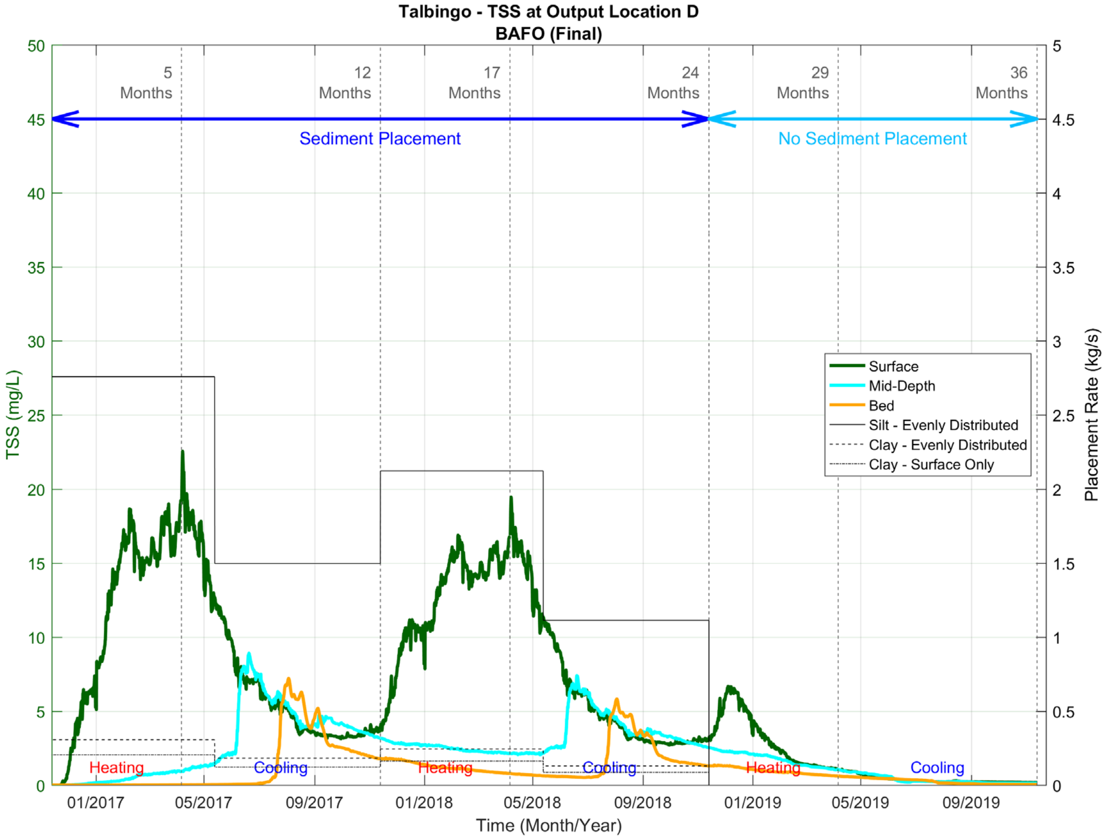

Talbingo - TSS at Output Location I
BAFO (Final)
TSS (mg/L)
Placement Rate (kg/s)
Time (Month/Year)
50
45
40
35
30
25
20
15
10
5
0
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
01/2017
05/2017
09/2017
01/2018
05/2018
09/2018
01/2019
05/2019
09/2019
5 Months
12 Months
17 Months
24 Months
29 Months
36 Months
Sediment Placement
No Sediment Placement
Heating
Cooling
Heating
Cooling
Heating
Cooling
Surface
Mid-Depth
Bed
Silt - Evenly Distributed
Clay - Evenly Distributed
Clay - Surface Only

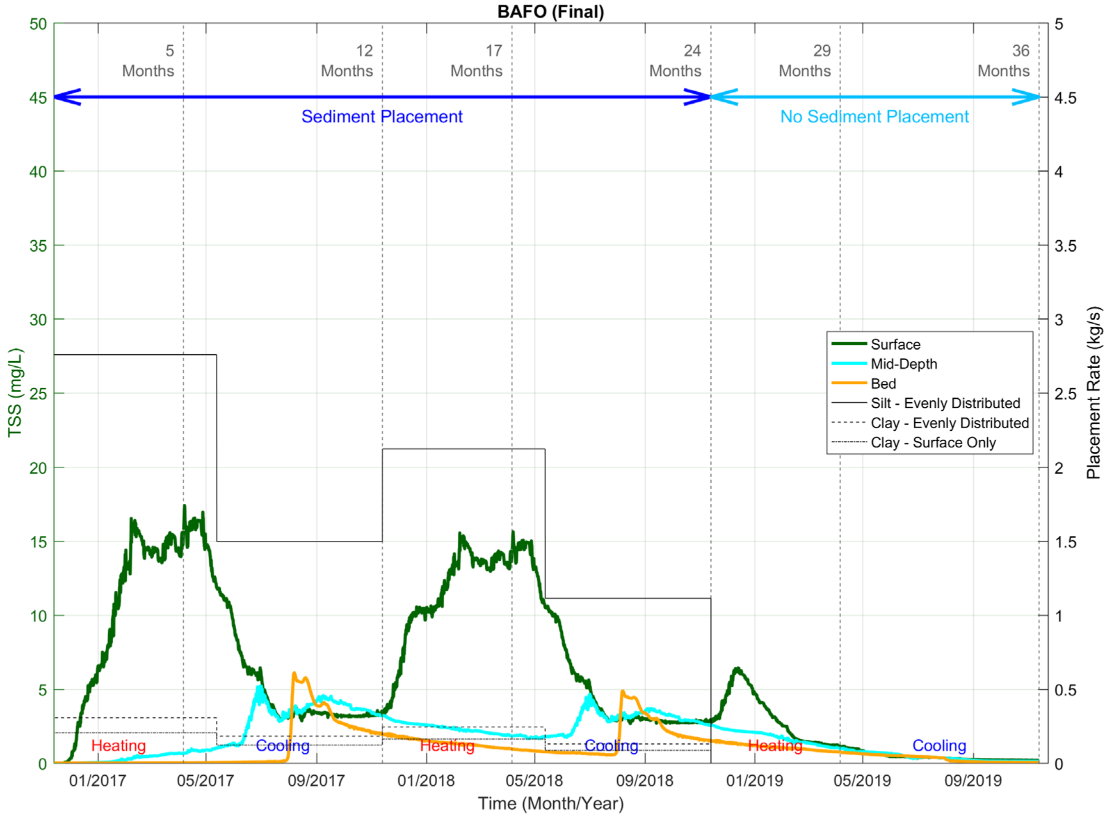

Talbingo - TSS at Output Location H
BAFO (Final)
TSS (mg/L)
Placement Rate (kg/s)
Time (Month/Year)
50
45
40
35
30
25
20
15
10
5
0
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
01/2017
05/2017
09/2017
01/2018
05/2018
09/2018
01/2019
05/2019
09/2019
5 Months
12 Months
17 Months
24 Months
29 Months
36 Months
Sediment Placement
No Sediment Placement
Heating
Cooling
Heating
Cooling
Heating
Cooling
Surface
Mid-Depth
Bed
Silt - Evenly Distributed
Clay - Evenly Distributed
Clay - Surface Only


Talbingo - TSS at Output Location F
BAFO (Final)
5 Months
12 Months
17 Months
24 Months
29 Months
36 Months
Sediment Placement
No Sediment Placement
Heating
Cooling
Heating
Cooling
Heating
Cooling
Surface
Mid-Depth
Bed
Silt - Evenly Distributed
Clay - Evenly Distributed
Clay - Surface Only
TSS (mg/L)
0
5
10
15
20
25
30
35
40
45
50
Placement Rate (kg/s)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
01/2017
05/2017
09/2017
01/2018
05/2018
09/2018
01/2019
05/2019
09/2019
Time (Month/Year)

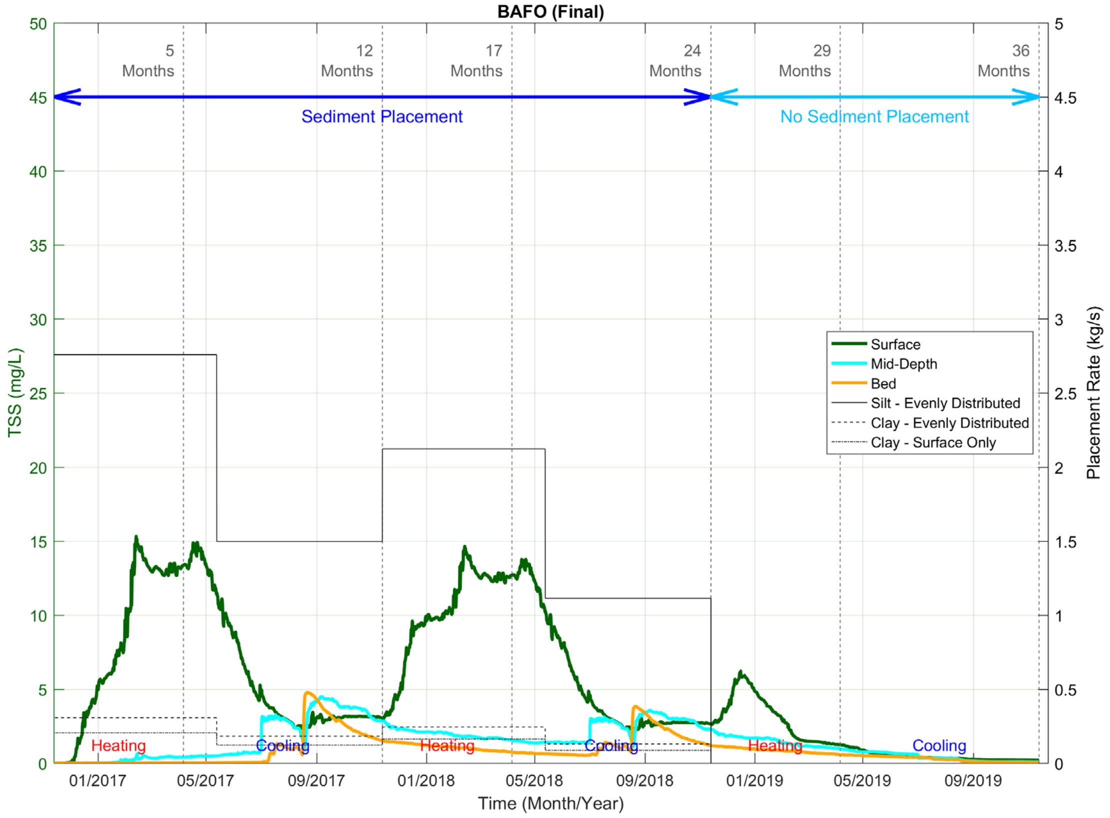

Talbingo - TSS at Output Location G
BAFO (Final)
5 Months
12 Months
17 Months
24 Months
29 Months
36 Months
Sediment Placement
No Sediment Placement
Heating
Cooling
Heating
Cooling
Heating
Cooling
Surface
Mid-Depth
Bed
Silt - Evenly Distributed
Clay - Evenly Distributed
Clay - Surface Only
TSS (mg/L)
0
5
10
15
20
25
30
35
40
45
50
Placement Rate (kg/s)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
01/2017
05/2017
09/2017
01/2018
05/2018
09/2018
01/2019
05/2019
09/2019
Time (Month/Year)


Talbingo - TSS at Output Location E
BAFO (Final)
TSS (mg/L)
Placement Rate (kg/s)
Time (Month/Year)
0
5
10
15
20
25
30
35
40
45
50
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5 Months
12 Months
17 Months
24 Months
29 Months
36 Months
Sediment Placement
No Sediment Placement
Heating
Cooling
Heating
Cooling
Heating
Cooling
01/2017
05/2017
09/2017
01/2018
05/2018
09/2018
01/2019
05/2019
09/2019
Surface
Mid-Depth
Bed
Silt - Evenly Distributed
Clay - Evenly Distributed
Clay - Surface Only

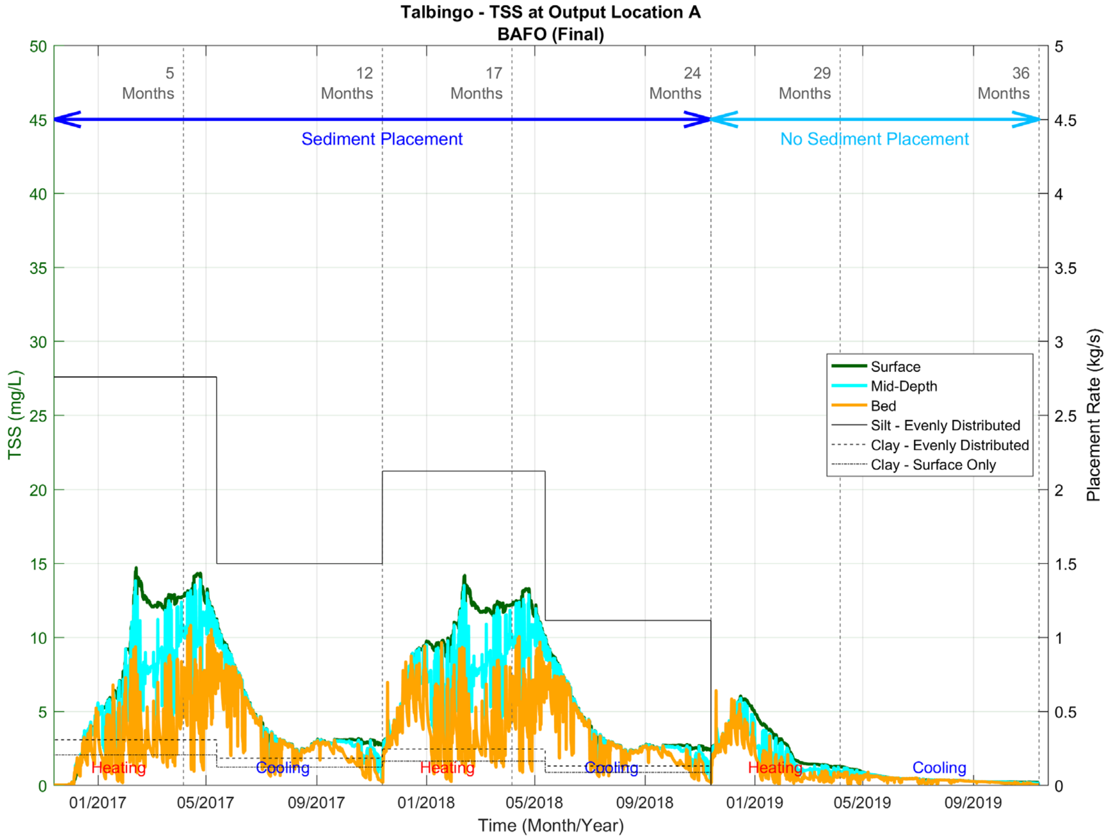

Talbingo - TSS at Output Location D
BAFO (Final)
TSS (mg/L)
Placement Rate (kg/s)
Time (Month/Year)
0
5
10
15
20
25
30
35
40
45
50
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5 Months
12 Months
17 Months
24 Months
29 Months
36 Months
Sediment Placement
No Sediment Placement
Heating
Cooling
Heating
Cooling
Heating
Cooling
01/2017
05/2017
09/2017
01/2018
05/2018
09/2018
01/2019
05/2019
09/2019
Surface
Mid-Depth
Bed
Silt - Evenly Distributed
Clay - Evenly Distributed
Clay - Surface Only



Talbingo - TSS at Output Location C
BAFO (Final)



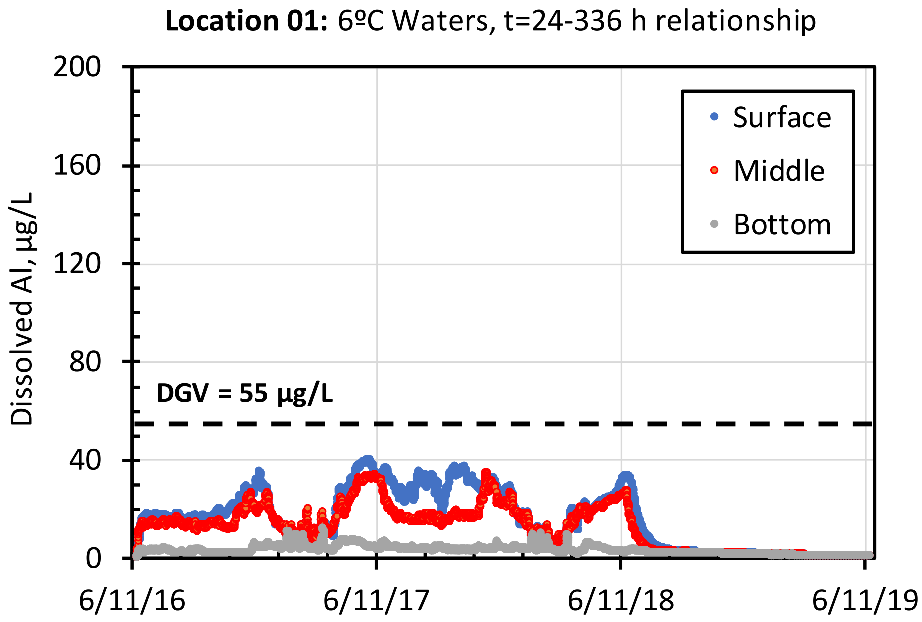
Talbingo - TSS at Output Location B
BAFO (Final)


Talbingo - TSS at Output Location A
BAFO (Final)
5 Months
12 Months
17 Months
24 Months
29 Months
36 Months
Sediment Placement
No Sediment Placement
Surface
Mid-Depth
Bed
Silt - Evenly Distributed
Clay - Evenly Distributed
Clay - Surface Only
Heating
Cooling
Heating
Cooling
Heating
Cooling
TSS (mg/L)
Placement Rate (kg/s)
0
5
10
15
20
25
30
35
40
45
50
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
01/2017
05/2017
09/2017
01/2018
05/2018
09/2018
01/2019
05/2019
09/2019
Time (Month/Year)

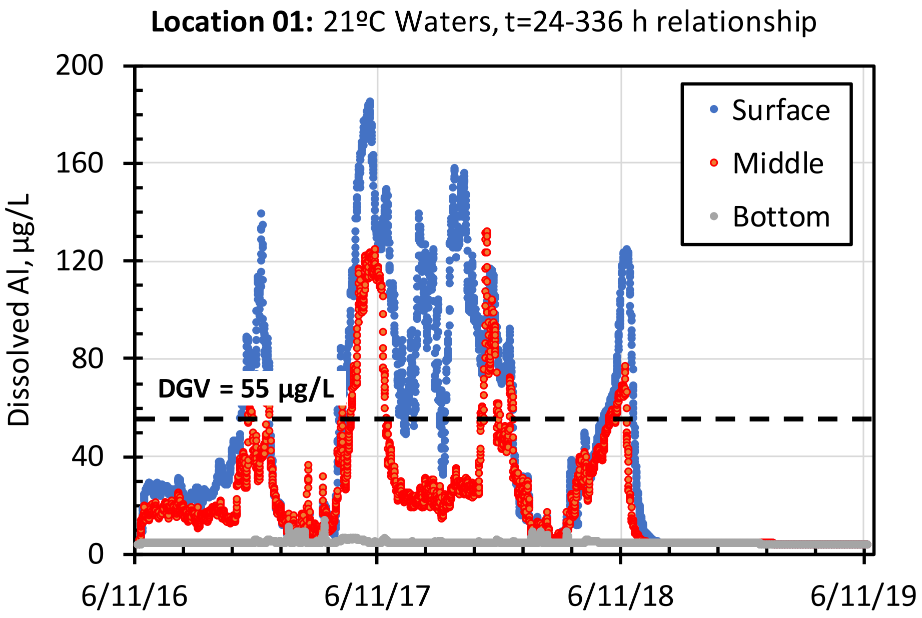
Appendix D Additional figures

Influence of water temperature

- The figures below illustrate the predicted lower dissolved aluminium concentrations that may occur at Location 1 if all of the fine rock material (TSS) was in cooler waters (6°C), compared to all being in warmer waters (21°C).



Location 01: 6ºC Waters, t=24-336 h relationship

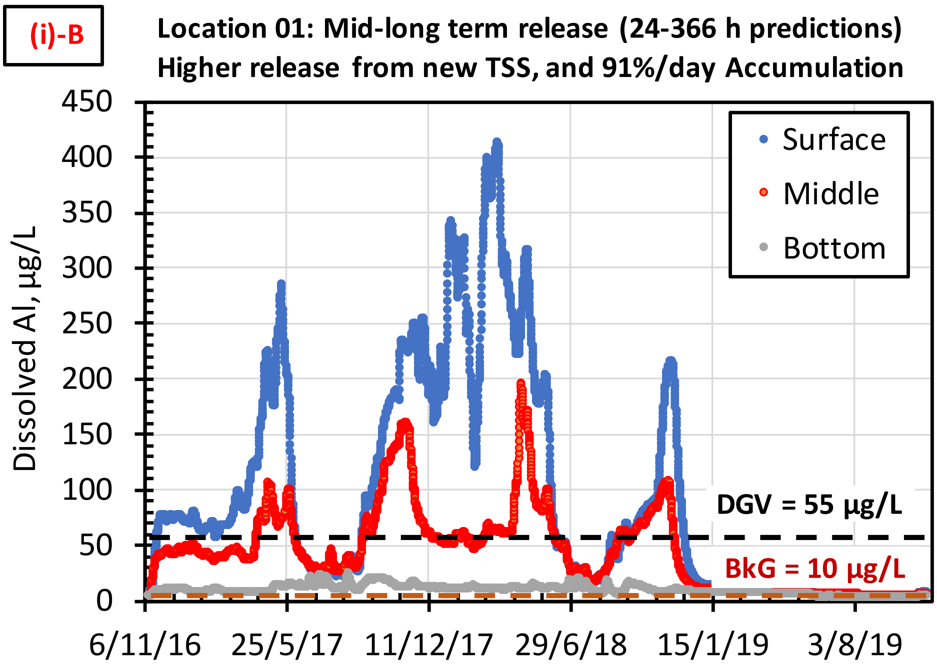


Location 01: 21ºC Waters, t=24-336 h relationship

Figure D1. Predictions of dissolved aluminium concentrations at for Location 1 for waters at all depths being 21°C and 6°C, respectively.

Influence of higher levels of aluminium release at Locations 1 and 2

- This provides an indication of how higher amounts of dissolved aluminium release may influence dissolved aluminium concentrations at Locations 1 and 2. The rate of release per 6-h period is twice that shown in the main text.
- This scenario might exist if the continuous addition of fine rock material results in higher water pH being maintained within these two regions.



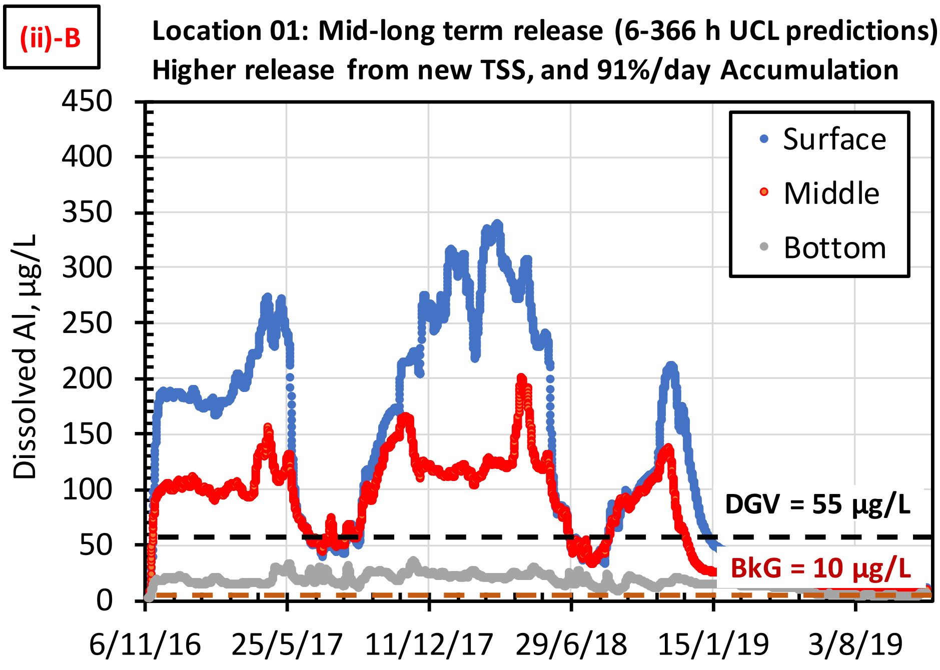


Figure D2. Predictions of dissolved aluminium concentrations at for Location 1 when factoring in a rate of aluminium release that is twice that used in Figure 7 predictions

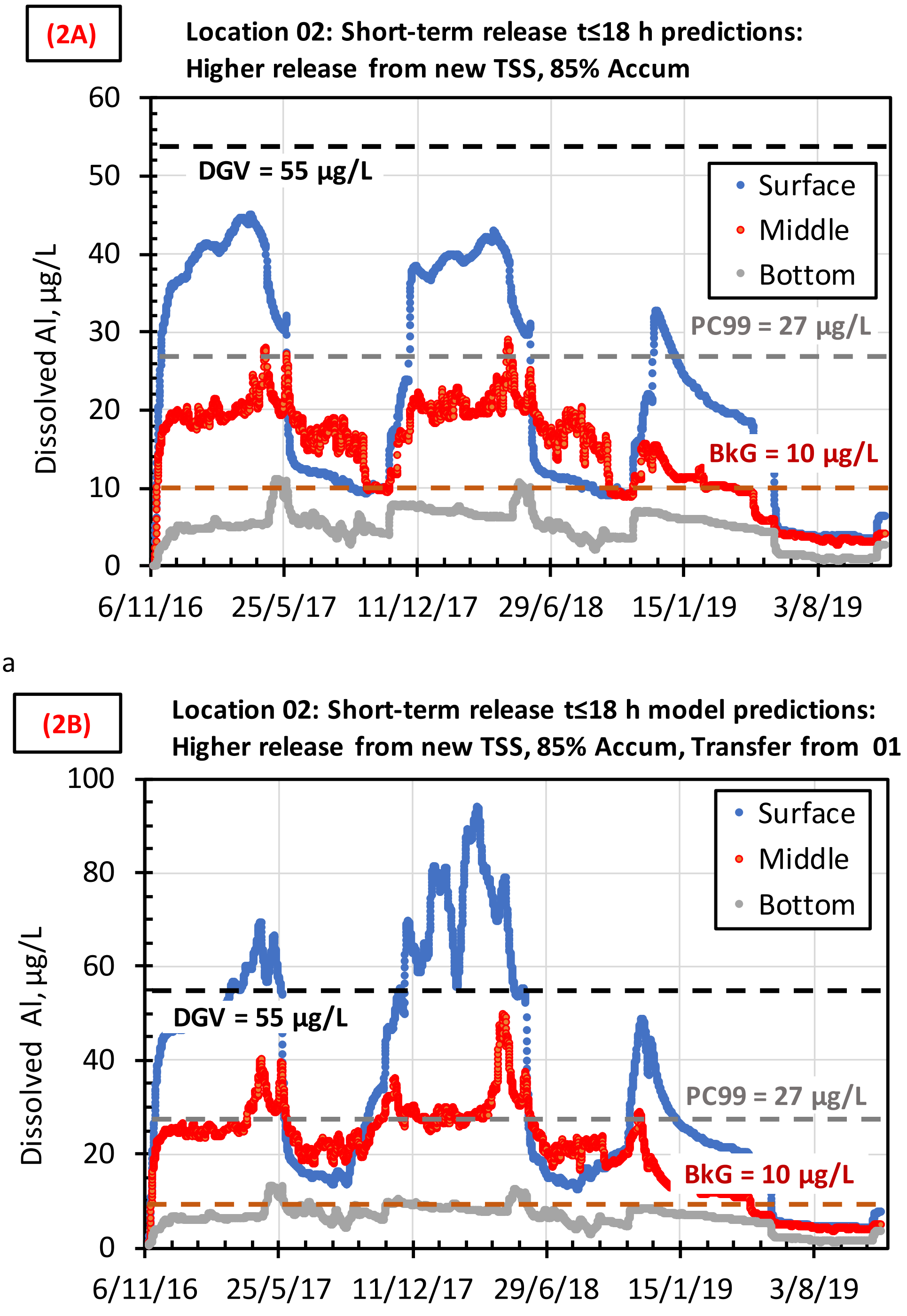


Figure D3. Predictions of dissolved aluminium concentrations at for Location 2 when factoring in a rate of aluminium release that is twice that used in Figure 8 predictions.

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