REPORT

Tonkin+Taylor

Sludge Disposal Site in Rarotonga

Environmental Impact Assessment

Prepared for
To Tatou Vai Limited
Prepared by
Tonkin & Taylor International Ltd
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Executive summary

The Cook Islands Government is upgrading Rarotonga's water infrastructure, through the Te Mato Vai (TMV) project. Currently, the water supply is untreated with the exception of coarse screening at the in-stream intakes. The infrastructure upgrades include the improvement of ten water intake structures and the construction of a new water treatment plant (WTP) for each intake.

The water treatment process produces a residual sludge comprised of materials removed from the incoming water (e.g., sediment and organic matter) and the coagulant used (Polyaluminium chloride (PACl)) to settle sediment and other entrained materials. This sludge material requires periodic disposal in order for the WTPs to continue to operate.

To Tatou Vai Limited (TTV) has commissioned Tonkin & Taylor International Limited (T+TI) to undertake an independent EIA to assess the potential environmental impacts from the disposal of water treatment plant sludge to land. The disposal site, referred to as '88H', is a dedicated facility on Vaiauara Road directly west of the Rarotonga Waste Facility. The site proposed is an area of historic clean filling which has low ecological values. The Vaiauara Stream, an ephemeral watercourse, is adjacent to the proposed disposal site.

The objective of the site 88H sludge disposal project is to develop a dedicated sludge disposal facility that provides a practical solution for the sludge, security to TTV for sludge disposal and has low environmental impacts. The proposed design includes the construction of a soil platform that disposal 'pits' will be excavated into. These will subsequently be filled with sludge and covered with soil prior to a new pit being opened.

This EIA has been prepared by T+TI on behalf of TTV to meet the requirements of the Environment Act 2003 and in accordance with the Terms of Reference (ToR) agreed with the National Environment Service (NES). This EIA report draws the following conclusions:

- The impacts to surface water quality and aquatic ecology are expected to be low. This is due to contaminant discharges to surface water generally being avoided through the facility design and site management. This includes cleanwater diversions, stabilising disturbed soil, backfilling the pits prior to large rainfall events and leachate capture and disposal to the septage ponds at the Rarotonga Waste Facility;
- The impacts to terrestrial ecology are expected to be low due to the limited vegetation removal and poor quality of the existing habitat;
- The impacts to land and groundwater quality are expected to be low due to the nature of the contaminants present in the sludge, environmental context (e.g., rainfall dispersal of contaminants) and facility design (e.g., establishing the monofill in natural mineral soils);
- Social and cultural heritage – the impacts on social and cultural heritage are considered to be low; and
- The disposal of the sludge to landfill and use in agriculture were considered as alternative options. However, the disposal to a dedicated facility is the preferred option at this point in time.

Overall, the proposed disposal facility will provide an acceptable solution for the management of the sludge. It will provide TTV with security of disposal and contribute to the wider project objectives of achieving potable water.

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1 Glossary and abbreviations

Term	Definition
coagulant	A chemical added to water which helps finer particles clump together in larger particles, which then sink to the bottom of the settling tank.
coarse screening	A screen which blocks leaves and other detritus from entering the water treatment system.
EIA	Environmental Impact Assessment
floc	Larger particles made from a combination of finer particles
flocculation	The process of adding a coagulant to the water to improve the ability of fine particles to combine into larger particles known as 'floc'. This process speeds settlement of suspended sediments out of the water.
IWRMP	Cook Islands National Integrated Water Resources Management Policy 2014
NWP	National Water Policy 2016
NES	National Environment Service
NSDP	Te Kaveinga Nui: National Sustainable Development Plan 2016 – 2020
NZ	New Zealand
PACl	Poly Aluminium Chloride – a coagulant
potable water	water that is safe to drink
reticulated water supply network	Piped water network
settling process	The process of allowing heavy particles in raw water (e.g., soil) to settle for later removal. This is undertaken in settling tanks, which are described in Section 5.1 of this EIA.
settling pond	A pond that is used to settle and hold the sludge formed in the settling and/or backwash processes.
supernatant	The clear water/liquid overlying settled material (sludge) in the settling pond.
the Regulations	The Environment (Permits and Consent) Regulations 2011
T+TI	Tonkin & Taylor International Limited
TMV	Te Mato Vai
TOR	Terms of Reference
TTV	To Tatou Vai (Ltd)
WTP	Water treatment plant
Watercare	Watercare Services Limited, New Zealand

2 Introduction

The Cook Islands Government has upgraded Rarotonga's water infrastructure, through the Te Mato Vai (TMV) project. Currently, the water supply is untreated with the exception of coarse screening at the in-stream intakes. The infrastructure upgrades include the improvement of ten water intake structures and the construction of a new water treatment plant (WTP) for each intake. Operational trials of each of the new WTPs are currently underway.

The water treatment process produces a residual sludge comprised of materials removed from the incoming water (e.g., sediment and organic matter) and the coagulant used (Polyaluminium chloride (PACl)) to settle sediment and other entrained materials. This Environmental Impact Assessment (EIA) addresses the management of water treatment sludge from the 10 WTPs at a disposal facility on Vaiauara Road, directly west of the Rarotonga Waste Facility. The objective of the project is to develop a dedicated sludge disposal facility that provides a practical solution for the sludge, security to To Tatou Vai Limited (TTV) for sludge disposal and has low environmental impacts.

An EIA is a process of evaluating the likely environmental impacts of a proposed project or development, taking into account inter-related socio-economic, cultural and human-health impacts, both beneficial and adverse. This report documents the assessment and provides recommendations for managing any residual impacts through the implementation of appropriate Environmental Management Plans.

This EIA has been prepared by Tonkin & Taylor International Limited (T+TI) on behalf of TTV to meet the requirements of the Environment Act 2003. This report has been prepared in accordance with the Terms of Reference (ToR) agreed with the National Environment Service (NES). Once accepted by the NES the EIA will be published with public comment feedback invited for a period of no less than 30 days.

2.1 Scope of this assessment

This Environmental Impact Assessment (EIA) considers the potential environmental impacts from the disposal of water treatment sludge generated during the operation of the WTPs. As noted above, the sludge material will be disposed of to land. The report is structured as follows:

Section 1: Glossary

Section 2: Introduction (this section)

Section 3: Policy and legal framework

Section 4: Environmental setting

Section 5: Overview of the sludge disposal process

Section 6: Analysis of Alternatives

Section 7: Community, Landowner and Stakeholder Consultation

Section 8: Impact Assessment

Section 9: Operational Environmental Management Plan

Section 10: Conclusion and Recommendations

Section 11: References

Section 12: Applicability statement

All relevant matters required to be included by the TOR have been addressed in this EIA. **Appendix A** provides a table listing how the TOR has been addressed, cross-referenced to relevant sections of this EIA report.

3 Policy and legal framework

This section reviews the policy and legal framework relevant to the use of PACl, including:

- National laws and related government approvals (Section 3.1);
- Relevant policy framework (Section 3.2);
- Industry policies or codes of practice (Section 3.3);
- Health, safety, hazard and risk management standards (Section 3.4);
- Multilateral Environmental Agreements (Section 3.5);
- Agreements between the government and TTV (Section 3.6);
- Environmental policies of financing organisations (Section 3.7); and
- TTV's environmental management and compliance record (Section 3.8).

3.1 Environment Act 2003

The Environment Act 2003 provides for the protection, conservation, and management of the environment in a sustainable manner. This Act provides the legal framework for assessing the environmental impacts of development.

Section 36 of Part 5 (Environmental Impact Assessment) states that:

> *(1) No person shall undertake any activity which causes or is likely to cause significant environmental impacts except in accordance with a project permit issued under this section.*
>
> *(2) A person who proposes to undertake an activity of the kind referred to in subsection (1) shall apply to the permitting authority for a project permit in respect of the activity in accordance with the procedures (if any) prescribed by regulations.*
>
> *(3) Every application for a project permit shall be submitted to the Service and shall include an environmental impact assessment, setting out details of-*
>
> > *(a) the impact of the project upon the environment and in particular -*
> >
> > > *(i) the adverse effects that the project will have on the environment; and*
> > >
> > > *(ii) a justification for the use or commitment of depletable or non-renewable resources (if any) to the project: and*
> > >
> > > *(iii) a reconciliation of short-term uses and long-term productivity of the affected resources; and*
> >
> > *(b) the proposed action to mitigate adverse environmental effects and the proposed plan to monitor environmental impacts arising out of the project; and*
> >
> > *c) the alternatives to the proposed project.*

It is the intention of this report to comply with the requirements of section 36 as set out above and the agreed TOR which are attached to this EIA (see **Appendix A**).

The Environment (Permits and Consent) Regulations 2011 (the Regulations) have been drafted but not formally adopted i.e., they provide an indication of intent but carry no legal weight. The regulations provide for the development of standards and requirements for the management of discharges into air, water, land and marine ecosystems.

The Regulations state in Paragraph 21 of Part 4 that:

An environment impact assessment shall be required if, on undertaking a review pursuant to the requirements of regulation 19, it is determined by the National Environment Service that:

(a) There is a reasonable likelihood that the project or activity is likely to cause significant environmental impacts;
(b) There is a reasonable likelihood that the project or activity may be significantly affected, or is likely to be significantly affects, by impacts from the environment.

The regulations stipulate that all projects or activities with significant environmental impacts listed in Schedule 3 of the Regulations shall require an EIA.

3.2 Relevant policy framework

Three policy documents are of particular relevance to this proposal:

- Te Kaveinga Nui: National Sustainable Development Plan 2016 – 2020 (NSDP), and
- Cook Islands National Integrated Water Resources Management Policy 2014 (IWRMP).
- National Water Policy 2016.

3.2.1 Te Kaveinga Nui: National Sustainable Development Plan 2016-2020

The NSDP articulates the national vision and development outcomes desired by Cook Islanders.

Goal 4 of the NSDP is “Sustainable management of water and sanitation”. The NSDP states:

> *Water and sanitation are basic necessities for our health, economy and environment. With the impacts of climate change and the inherent limited freshwater reserves, preserving and managing fresh water is a key development issue*.

The NSDP aims to improve access to sufficient and safe water. Indicator 4.1 is “Percentage of population with access to sufficient and safe water in their homes”. This indicator looks at Cook Islanders’ access to sufficient and safe water in their homes. The NSDP considers this a fundamental right and basic human need that is of the highest priority, reflected in the country’s recent significant investment in water infrastructure.

The TMV project seeks to implement the NSDP by provision of potable (safe) water via a reticulated water system. The role of water treatment sludge management in producing potable water is set out in Section 5.

3.2.2 Cook Islands National Integrated Water Resources Management Policy 2014

The purpose of the IWRMP is to establish policies that will guide planning, actions and efforts in ensuring the sustainable integrated water resources management across the Cook Islands.

Policy Objective 1 of the IWRMP is, “Reliable, potable water for all who reside in the Cook Islands and the establishment of standards for water quality and resource management.” This objective is supported by policies, including:

> *1.1 Drinking Water for Human Consumption: We will ensure all persons in the Cook Islands shall have access to reliable, safe, and potable drinking water.*
>
> *1.2 Water for Domestic Usage: We will have reliable access to safe water for bathing, cooking, and cleaning for all persons in the Cook Islands.*
>
> *1.3 We will have reliable access to safe water ‘fit for purpose’ for Business and Commerce to use in a manner consistent with efforts to conserve fresh water resources and minimise any waste water to ensure the economic viability and environmental sustainability of the country.*

> *1.4 We will have adequate, appropriate, and reliable water for horticultural and agricultural production.*

The management of water treatment sludge as a component of a reticulated water system to provide potable drinking water is set out in Section 5.

3.2.3 National Water Policy 2016

The purpose of the National Water Policy (NWP) 2016 is to establish objectives that will guide planning and actions to ensure:

- That water resources are protected from contamination and are managed in an integrated, equitable and sustainable way;
- All of the population has access to safe drinking water; and
- Public health risks associated with unsafe drinking water are identified and managed.

The document integrates aspects of the sanitation and Integrated Water Resources Management policies, bringing together government policies for water resources management, infrastructure, water supply, drinking-water safety planning and sanitation.

The vision of the NWP is *'To protect, enhance and improve the resilience, quality and sustainability of the Cook Islands water resources to ensure the health of the people and the environment'.* To fulfil this overall vision a number of objectives have been developed. Those most relevant to this proposal include:

- Objective 1: Ensure safe and sustainable management of water supply;
- Objective 3: Ensure access to reliable, safe drinking water for all who reside in the Cook Islands;
- Objective 5: Ensure sustainable management of both inland and coastal water resources; and
- Objective 6: Actively engage communities in the sustainable management of water resources.

The TMV project will contribute to the realisation of the NWP vision. The role of water treatment sludge management in producing potable water is set out in Section 5, the potential impacts to surface water and groundwater resources are assessed in Section 8, and community engagement is outlined in Section 7.

3.3 Industry policies / codes of practise

The following industry policies / codes of practise are relevant to this report:

- US Environmental Protection Agency (2018). Final aquatic life ambient water quality criteria for aluminium 2018. Washington, D.C. EPA 440-4-89-001; and
- World Health Organisation (WHO) Guidelines for Drinking Water Quality - Fourth Edition 2017. These guidelines are referenced during the consideration of impacts to groundwater.

3.4 Health, safety, hazard, and risk management standards

The Employment Relations Act (ERA) 2012 addresses workplace health and safety (WHS). Part 7 provides for a general duty of care for both employers and employees. The Cook Islands Government is currently drafting new legislation that will address workplace health and safety and workers compensation.

During construction and operation TTV will undertake activities in accordance with the prevailing legislation and their existing Health and Safety Management planning and systems. This applies during construction and operations with any subcontractors employed at the site required to work in accordance with TTV systems and procedures.

TTVs focus is on identifying and where possible eliminating risk with robust mitigation strategies put in place where risks cannot be mitigated. Mitigation options may include (in order of preference):

1 Controlling the hazard primarily through the use of engineering control measures;
2 Minimizing the hazard through the design and use of safe work procedures, for example lock-out and tag-out; and
3 Providing appropriate personal protective equipment (PPE).

3.5 Multilateral Environmental Agreements

There are no multilateral environmental agreements relevant to this proposal.

3.6 Agreements between the government and TTV

There are no existing agreements relevant to this proposal.

3.7 Environmental policies of financing organisations

Not applicable, requirements are reflected in the Environment Act.

3.8 TTV's environmental management and compliance record

To Tatou Vai is currently being established so has no existing environmental management or compliance records to report.

4 Environmental setting

4.1 Site location

The proposed sludge disposal site (herein referred to as 'the site') is located in the north-western part of Rarotonga and has been named site '88H'. The site and the ten water treatment locations are shown in Figure 4.1 below. The site is located within the Vairauara Stream catchment as shown in Figure 4.2. The site is slightly sloping and is bound to the north by the access road and the Vairauara Stream (refer to Figure 4.3).

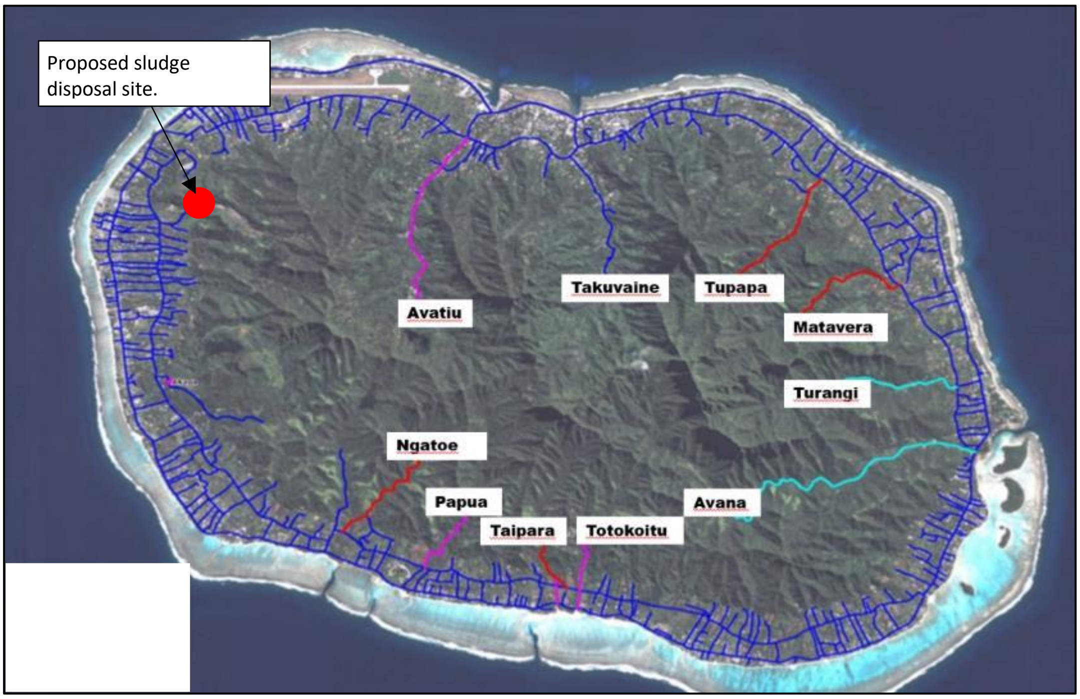


Figure 4.1: Aerial plan showing the approximate location of each of the water takes. Source: GHD, 2014

Figure 4.2: Approximate sludge disposal site location (red rectangle)

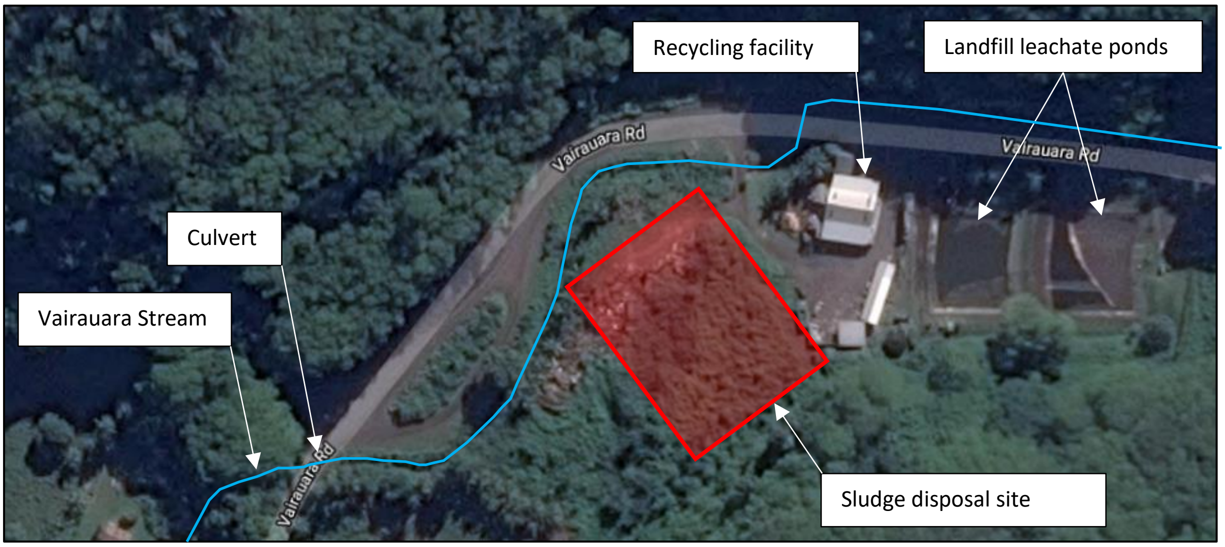


Figure 4.3: Approximate sludge disposal site

4.2 Description of the baseline environment

This section provides information on the baseline environment, including a description of:

- Climate;
- Topography, geology and soils;
- Catchment characteristics;
- Water quality;
- Ecological values; and
- Social and cultural context.

4.2.1 Climate

The Cook Islands experiences a tropical climate with two seasons:

- Wet season: Typically November to May, characterised by high humidity, sudden downpours, strong winds and tropical cyclones (hurricanes); and
- Dry season: Typically June to October, characterised by cooler temperatures.

In the Southern Cook Islands (including Rarotonga and Aitutaki) there is a slight difference between the wet (warmer) and dry (cooler) months.

Climate projections for the Cook Islands (Pacific Climate Change Science Programme, 2013) indicate:

- Temperatures will increase in the order of 0.5 – 1.0°C by 2030 (high emissions scenario);
- Changing rainfall patterns and more extreme rainfall days; and
- Sea level will rise in the order of 40-150 mm by 2030 under a high emissions scenario.

4.2.2 Topography, geology and soils

Rarotonga has a land area of 67.4 km^2, a circumference of 32 km and maximum elevation of 652 m. The central part of the island consists of mountains with narrow valleys covered in tropical vegetation. Surrounding this is a flat coastal ring which has been developed for residential, commercial, and agricultural purposes. Fringing the island is an upraised coral reef and lagoons.

The interior upland sediment is basaltic volcano bedrock which produces dark red clay-rich sediments through the process of weathering. These sediments generally have a low fertility due to nutrient deficiencies. Conversely, sediment on the coastal ring is nutrient rich due to naturally high concentrations of phosphorus.

GHD Limited undertook intrusive field investigations of the site (refer to Appendix B). They found that the site has been filled to a depth of approximately 3 m above natural ground level to form a 'platform' (refer to Figure 4.4). The test pits encountered metal of various origins, glass, cans, plastics, fabric, timbers and logs and tires. The fill is mostly mixed with a matrix of sandy partly organic friable soil, and it was assumed that this is the natural soil from the area. Overall, the fill material appears permeable and should readily drain.

Figure 4.4: Site 88H fill platform *Source: GHD, 2020*

4.2.3 Catchment characteristics

The site is located within the catchment of the Vairauara Stream. The catchment area above the site is approximately 60 ha and the headwaters of the catchment are covered with native vegetation. Immediately upstream of the proposed site is the Rarotonga Waste Facility (Arorangi Landfill) and the TM Heather and Raro Mining quarry sites.

Downstream of the site there are residential dwellings, located off Vairauara Road, and the Rarotonga Prison. The sludge disposal site is approximately 150 m or more away from the nearest residential dwelling. Other activities in the catchment include horticulture and agricultural activities such as small-scale pig, goat, and poultry farming.

A site visit was undertaken by the project management unit on 26 March 2021. In summary, the following was noted (refer to **Appendix D**):

- Two groundwater monitoring bores are present in the vicinity of the sludge disposal site. These were installed by T+TI in 2014 and at the time ground water levels were 4 m and 10 m below ground level for the upgradient and downgradient monitoring bores, respectively. Both monitoring wells are upgradient of the sludge disposal site based on the inferred groundwater contours;

- The stream was mostly dry, with two puddles of water present between the recycling facility and the downstream culvert underneath Vairauara Road (refer to Figure 4.6).
- The stream had a slim flow approximately 50 m downstream of the culvert and disappeared into the ground approximately 100 m downstream of the culvert.

To date, surface water quality monitoring has been unable to occur due to the lack of flow within the Vairauara Stream. It is expected that the stream remains dry for most of the year and only flows during spells of heavy rain.

Figure 4.5: Satellite imagery showing the site location and surrounding landscape.

Figure 4.6: Vairauara Stream in the vicinity of the sludge disposal site

4.2.4 Water quality

Surface water runoff across Rarotonga often contains fine soil particles and organic matter that makes the water look murky and cloudy. Due to the small size and weight of this material it takes a long time for it to settle to the bottom of the receiving water body.

The water quality of the streams also varies depending on the level of recent rainfall. Water samples taken from the water intakes on Rarotonga, analysed at Watercare Services Limited (T+TI, 2021), found samples taken during wet weather are characterised by:

- high turbidity (fine suspended solids);
- high colour (brackish-brown); and
- a variable low to moderate soluble iron and manganese content.

Samples taken from the same water intake sites under dry weather conditions had low turbidity and colour content, and both iron and manganese concentrations were below the WHO aesthetic guideline values.

An ecological assessment has been prepared to assess the potential impacts from the proposed sludge disposal facility (refer to Appendix E for the complete assessment). This assessment noted that water quality (bacteria, nutrients, dissolved oxygen) of the streams on Rarotonga has been consistently poor from 2006 to 2013.

The high bacteria concentrations are likely due to adjacent farming land uses, where waste from farmed animals is washed into streams during heavy rainfall. The high nutrient concentrations are likely due to farming and naturally high phosphorus from the volcanic geology. The faster flowing streams on the island have higher dissolved oxygen whereas slower or stagnant water typically has lower dissolved oxygen.

Groundwater quality samples were taken by T+TI in 2014 from the two monitoring bores near to the site. The analytical results indicated that all determinants were below the WHO drinking water guidelines for both aesthetic issues and human health, with the exception of hardness within all three wells monitored (the third being a control well), which exceeded the aesthetic guideline only (T+TI, 2014).

4.2.5 Ecological values

An ecological assessment has been prepared to assess the potential impacts from the proposed sludge disposal facility (refer to Appendix E for the complete assessment). In summary, the assessment notes that the Vairauara Stream is unlikely to have sufficient habitat for aquatic flora and fauna due to the stream's intermittent flows. Some short-lived aquatic macroinvertebrates may be able to make use of the stream for short periods of time when flows are present.

In terms of terrestrial ecological values, the vegetation and habitat around the site is modified and of low value. Various introduced trees and plants are located around the site and some native hibiscus is present in the wider site area, but outside the disposal site. The disposal area is almost completely dominated by 'mile a minute', an invasive creeper (refer to Figure 4.7).

The areas of gravel, open spaces and inorganic material provide basking habitat for the inland blue tailed skink (*Emoia impar*,) which is an introduced, naturalised species. While none were captured, large numbers of these skinks were observed in May 2021. Pacific pigeon (rupe) can be seen and heard in the area as well as large populations of wild chickens and myna birds. While several terrestrial invertebrate species were identified during the site visit, it is highly unlikely there are any that are threatened or rare (under the IUCN classification system).

Figure 4.7: Panoramic view of the proposed disposal area

4.2.6 Social and cultural context

The proposed disposal facility is located inland, away from residential settlements which are generally located on lower land, near the back road / main road. The surrounding area is occupied by agricultural land, infrastructure (landfill, recycling and quarrying) and the Rarotonga Prison. No physical cultural sites in the surrounding area.

There are significant cultural values attached to land and water in the Cook Islands and there is a fundamental link between these values and the relationship between land and identity (Coffey, 2019).

A number of people have expressed strong opposition to the addition of chemicals into the water treatment process, some of which will be present in the sludge, there are also a number of people who have expressed support for the upgrade. A safe, reliable and potable drinking water supply has well established social benefits, supporting public health outcomes at local, regional and national levels (WHO, 2011). This is further supported by the Cook Islands national policy framework, including the NSDP and the IWRM. Therefore, on balance, the proposed management of sludge is considered to be appropriate in relation to social and cultural values.

5 Overview of sludge disposal process

As outlined above, the sludge to be disposed of is generated during the water treatment process. Therefore, this section initially provides an overview of the water treatment process and then outlines the sludge disposal process.

5.1 Summary of the water treatment process

The water treatment process is the same across all ten WTPs and relies on gravity. In summary, the treatment process includes:

1. An intake weir to provide screening of coarse material at the in-stream intake;
2. Sedimentation (settling). The incoming water passes through a settling tank where sediment and other fine particles, including some microbiological contaminants (e.g. *E.Coli*), settle to the base of the tank. The coagulant (Polyaluminium chloride (PACl)) is added at this stage to help contaminants clump together, allowing faster settling to the bottom of the tank. The coagulant also assists in the removal of any microorganisms present;
3. Filtration. The water leaving the settling tank is passed through a sand filter for further removal of suspended materials including microbiological contaminants;
4. Provision for the disinfection of treated water if required (e.g., with chlorine). This is not currently implemented, if implemented in future, this would occur after filtration and therefore, will impact the sludge characteristics;
5. The treated water from the filter is either delivered directly to the reticulation network or piped into reservoirs for storage.

The water treatment process generates two types of waste material which is directed to settling ponds at the WTP sites. The two waste products are:

1. The solids that settle on the bottom of the settling tanks ('sludge'), as a result of the settling process. When sludge has accumulated in the settling tank the liquid above the sludge, 'supernatant', is removed and discharged directly to the adjacent stream using a mid-level drain. The remaining supernatant (below the mid level drain) and sludge is then conveyed to the settling ponds for further treatment; and
2. Backwash water from the cleaning of the sand filters (known as backwashing), where the flow of water is reversed to flush out entrained particles. The backwash water is conveyed directly to the settling ponds for treatment.

On some sites, two ponds have been constructed to treat sludge and backwash water separately (respectively known as 'scour ponds' and 'backwash ponds'). On other sites, one combined pond holds both sludge and backwash water ('sludge ponds').

The ponds are designed to remove sediment through a second settling process, before releasing water back to the nearest waterway. The ponds have been designed to decant through manually adjusted pipes once the water level in the ponds is high enough (refer to Figure 5.2). Additionally, some of the ponds are configured in two compartments to allow sludge to dry in one compartment while new backwash and/or settling plant sludge is directed to a second pond (refer to Figure 5.3).

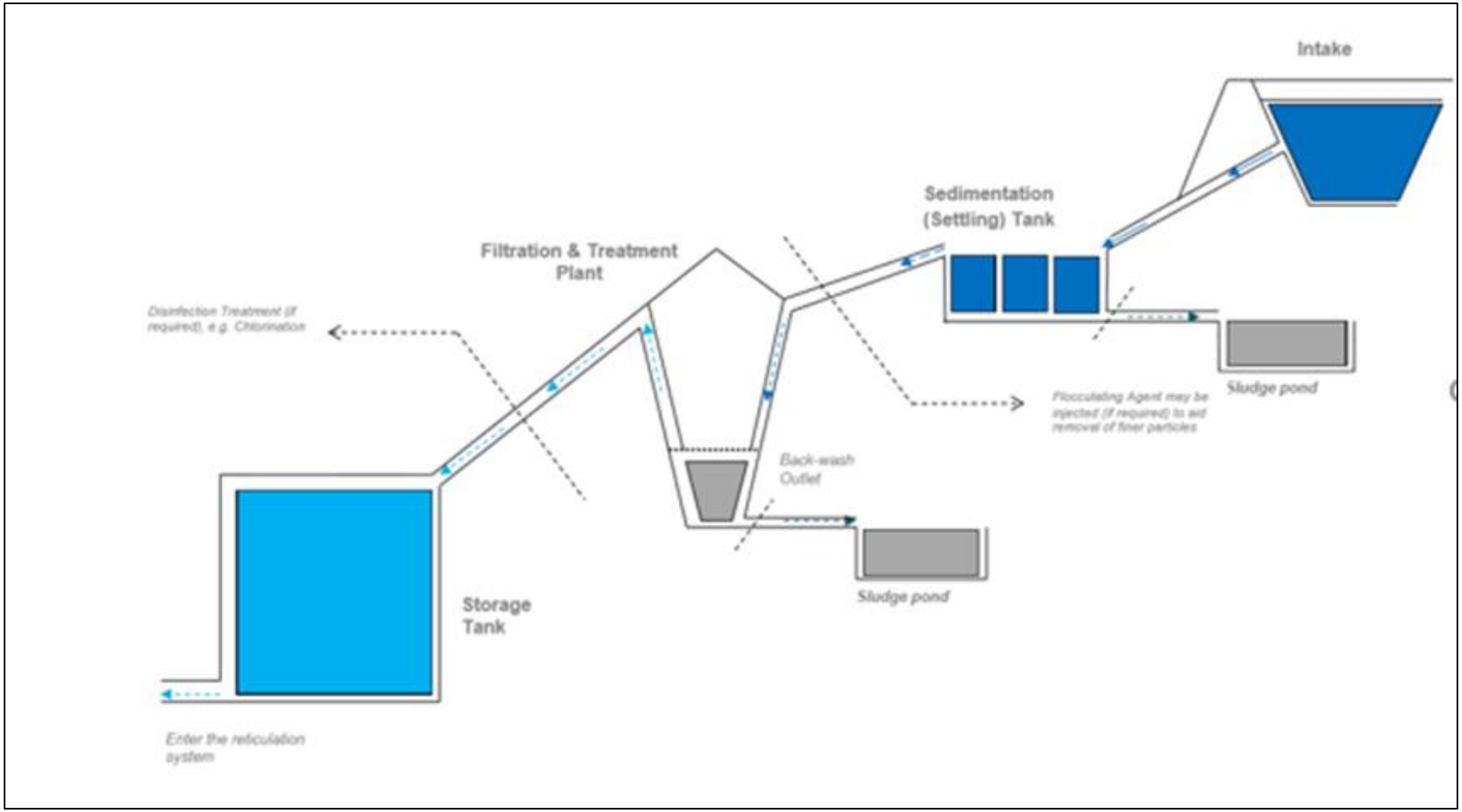


Figure 5.1: Indicative diagram of how the gravity operated water supply and treated system works. Source GHD, EIA 2014.

Figure 5.2: Scour pond on the Ngatoe catchment. *Source: GHD, 2020*

Figure 5.3: Photo of a settling pond showing the two compartments, at the Avana Water Treatment Plant.

5.2 Sludge characteristics

5.2.1 PACl sludge

The PACl sludge generated at the water treatment plants could be in two forms. Either a solids and water slurry that has 2-3% solids content and is pumpable. Or a dewatered sludge with >15% solids that will be similar in nature to soil.

GHD have undertaken sampling of the sludge from five of the ten water treatment plant sites and nearby natural soils to characterise the sludge (refer to the full report in Appendix F). The purpose of report was to complete preliminary work to inform disposal options, including use of the sludge in agriculture and disposal to a monofill, such as that proposed in this report.

In summary, the key findings relevant to this proposal are:

- The majority of the PACl sludge content is the natural fine particles that enter the water intakes and become separated as sludge as part of the water treatment process;
- The concentrations of the majority of the parameters tested were comparable between the natural soils and PACl sludge, with the exception of chloride and total recoverable aluminium content (this is expected as PACl adds aluminium and chloride) and total sulphur and sulphate; and
- The results indicate that the PACl sludge could be successfully disposed of in a monofill that is established in mineral soil geology (as opposed to sands) on the island. In this setting the PACl sludge would not represent a risk for leaching of trace elements or nutrient compounds.

5.2.2 Water treatment sludge versus wastewater treatment sludge

It is important to note that water treatment sludge, such as the PACl sludge that is the subject of this EIA, is different to wastewater treatment sludge. The two can be confused where a preliminary search of literature or web-based material using keywords such as water treatment sludge is likely to generate information covering both water treatment and wastewater treatment sludge. These are different materials and require different management to manage potential environmental impacts.

Wastewater treatment sludge consists of solids removed from wastewater (sewage) and biomass generated during the treatment process. Appropriate management of wastewater treatment sludge may include anaerobic digestion, dewatering, drying, lime stabilisation, land application (of stabilised sludge) and/or disposal to landfill.

5.3 Sludge disposal process

Sludge will be removed from the settling ponds at each of the WTP sites as it accumulates. Where time and operating conditions allow the sludge will be allowed to dry within the settling ponds to a point where it can be handled as a soil like product. This material will be removed via an excavator and transported to the sludge disposal site via a tip truck. As the sludge material is dry, no further dewatering will be required, and the material can be placed directly into the disposal facility.

In some cases, for example where sludge generation rates are high or during wet weather, the sludge will be a high-water content slurry that requires removal using a vacuum truck. Once onsite, this material will require dewatering prior to placement in the disposal facility. The dewatering process is discussed in further detail below.

5.4 Sludge disposal facility

A concept design for the sludge disposal facility has been prepared (refer to Appendix G for complete plans). In summary, the sludge disposal facility will include:

1. Stripping topsoil and clearance of existing vegetation over the proposed sludge disposal facility footprint;
2. The construction of a 0.5 m thick intermediate cover fill layer over the existing ground that is to be covered by the disposal facility. The intermediate cover will be a compacted, low permeability, fill material comprised of natural mineral soils (silty or clayey material);
3. The construction of a 1.5 - 2 m high edge bund with compacted low permeability fill (permeability in the order of k ~ 1 x 10^{-7}m/s). The edge bund will be located along the down-gradient edge of the facility;
4. Installation of a perimeter piped drain (perforated pipe with drainage gravel surround) at the inner toe of the edge bund. The drain will be within the ‘trench’ which will remain open

throughout the sludge disposal. The purpose of the perimeter pipe drain is to capture any excess ‘leachate’ from the sludge disposal facility area and direct this to a concrete leachate collection sump. Leachate within the collection sump will be discharged to the Rarotonga Waste Facility septage ponds;

- The ‘leachate’ is limited to the excess water contained within the sludge potentially containing fine sediment and PACl. Rainwater falling directly on the open part of the disposal area will also contribute to ‘leachate’;
- The ‘leachate’ from the sludge monofill area is different to that generated in a municipal waste landfill (like the Rarotonga Waste Facility). This is because the sludge is predominantly sediment with limited organic material or other materials. As such, a ‘leachate’ will not be produced as would be expected with a municipal solid waste landfill;

5 The construction of a 1.5 - 2 m high soil platform adjacent to the edge bund above the 0.5 m thick intermediate soil cover. This will be constructed out of cleanfill, being natural silty or clayey mineral soils sourced on the island;

6 The progressive excavation of pits in the 1.5 – 2 m high soil platform. Each pit will be approximately 6 m x 6 m. Sludge with ~ 15% dry solids will be disposed directly into these pits. Trucks will drive onto the soil platform and be able to tip directly into the excavated pits. As such, only one pit will be operational and filled at any one time;

7 Gravel will be placed on the platform to form a metalled access track for the trucks to drive on and the remaining areas of the platform that are not being utilised for access will be grassed to minimise sediment runoff and dust discharges. Rainwater falling on the platform will be diverted as clean stormwater away from the open trench and pit;

8 Placement of 0.3 m thick intermediate cover (clean natural silty or clayey mineral soil) over the disposed sludge once a pit is full; and

9 Once the ‘first lift’ of sludge disposal has been completed across the proposed sludge disposal facility, the process described above will be repeated for a ‘second-lift’ on top of the first lift.

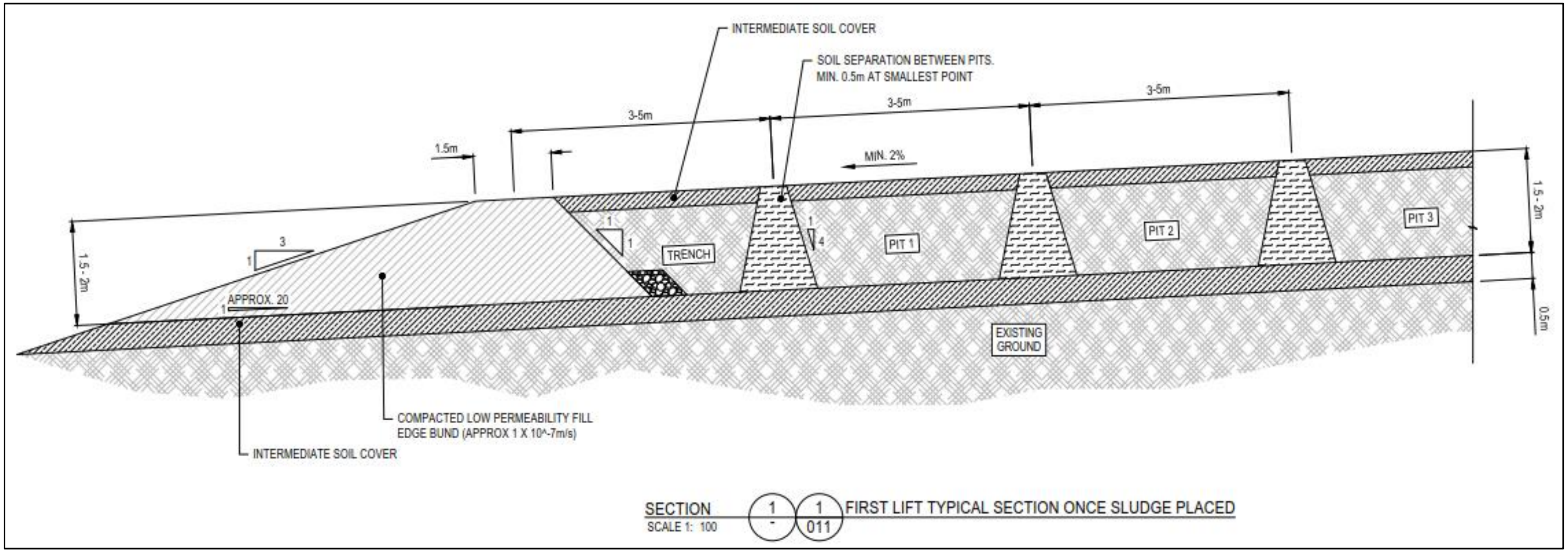


Figure 5.4: Typical cross section of 'lift one' of the sludge disposal facility.

5.5 Timeline for implementation, operation and expected lifespan of the disposal facility

5.5.1 Timeline for implementation and lifespan

Construction of the sludge disposal facility is expected to commence in late 2021. Construction will require the haulage of clean fill to the site for the soil platform and use of an excavator, bulldozer and 10-ton vibratory sheeps foot compactor to form the platform. Minor works will also be required to construct the leachate collection system. Construction is expected to take 2-3 months and the facility is expected to be operational by late 2021.

Approximately 700 m^3 of sludge is expected to arrive at the facility each year. Each disposal pit will have a capacity of approximately 50 - 60 m^3 and therefore is expected to be in operation for 1 month prior to a new pit being excavated. The proposed sludge disposal facility has a usable pit footprint of approximately 3,000 m^2. In total the bottom layer of the facility is expected to have 100 pits and a lifespan of approximately 8 years. The next layer will have a smaller usable pit footprint, of about 1,500 m^2, providing sufficient space for 50 pits thus giving an additional capacity and lifespan of approximately 4 years. As such, the facility will have a total capacity of approximately 6,000 - 9,000 m^3 and a lifespan of 8 -12 years.

Given the topographical and footprint constraints, only two lifts are proposed at the facility.

5.5.2 Operation of the sludge disposal facility

There is no requirement for a permanent staff member to be onsite. Trucks will be able to access the site to dispose of sludge Monday-Friday between 7am-5pm and will tip directly into the open trench. Approximately 100 truck movements are expected to the site annually with weekly movements varying depending on operational requirements.

Once operational an excavator will only be required onsite to excavate a new pit and cover the old pit with cleanfill. As an extra precaution, a water cart can be used to dampen dry soils if dust becomes an issue onsite. Notwithstanding this, it is unlikely that this will be needed as only 1 pit will be operational at a time and the pits have a small footprint (40 m^2 (6 m x 6 m)). The rest of the soil platform will be stabilised by gravel (as metal access for trucks) or grassed and therefore is unlikely to generate dust.

The sludge disposal facility has been designed and will be operated to minimise the generation of 'leachate' during operation. In summary, the measures to be undertaken include:

- Stabilising all exposed soil on the platform with gravel or grass;
- Grading the soil platform to divert clean stormwater way from the operational trench and pits or alternatively installing stormwater cut-off drains or bunds;
- Having one pit open at a time to minimise the area that may capture rainfall and therefore generate 'leachate'; and
- The implementation of wet weather protocols should a large storm event be forecast. This will include the backfilling of the open pit with cleanfill prior to the storm event arriving at the site.

5.5.3 Sludge dewatering

As noted in Section 5.3, the sludge that arrives onsite as a slurry will require dewatering. It is proposed that geobags or a similar arrangement will be used to dewater sludge to around 15% dry solids. The geobags act as a sieve to retain fine sediment while allowing water to escape. This water will be similar in nature to the supernatant in the sludge ponds at each WTP that will periodically discharge to the adjacent stream[1]. The geobags will be placed within the trench adjacent to the edge bund that is open to dewater. As such, all excess water that does not absorb into the dryer surrounding soil or infiltrate to ground will drain via the perimeter piped drain to a concrete collection sump. This will be periodically removed via a sucker truck and discharged to the landfill leachate ponds nearby. Alternatively, a temporary soft hose and pump may be used to pump the sludge disposal facility leachate to the landfill leachate ponds.

Once the sludge has dewatered sufficiently the geobag will be opened and the sludge deposited in the pits.

5.6 Predicted resource and public infrastructure requirements

The predicted resource and public infrastructure requirements are outlined below in Table 5.1.

Table 5.1: Predicted resource and public infrastructure requirements

Resource	Comment
Energy	No electricity is required for the day to day operation of the sludge disposal facility. The leachate pond will be periodically emptied via a sucker truck or portable generator powered pump.
Water	Where required water will be used to dampen down dry sludge material to minimise dust generation. This will occur infrequently and only during dry conditions.
Labour	The disposal facility will not require permanent staff. Labour will be required during construction, including excavator and bulldoze operator, concrete truck operator, haulage of soil and for the installation of pipework. The labour required during operation is limited to the truck drivers hauling the sludge and the excavator operator to open and close trenches.
Transport	Sludge will be transported to the site from the ten WTPs across the island. It is expected that transport movements will vary depending on operational requirements with a total of around 100 truck movements annually.
Minerals	No mineral extraction is required.
Hazardous materials	No hazardous materials will be stored onsite.
Waste Outputs	The sludge disposal process will not generate any waste.
Activity cost estimates	TTV have estimated that $180,000 is required for the operation of the sludge disposal facility. This estimate will be revised once the detailed design is prepared.

5.7 Justification and benefits for the proposed activity

5.7.1 Benefits to the community – locally, island and country wide

As set out on the Te Mato Vai webpage:[2]

> *The purpose of the Te Mato Vai project is to replace Rarotonga's aging water network, improve storage and introduce treatment to provide our people with a reliable and safe water supply.*
>
> *Addressing a number of environmental and health risks associated with the island's current water network, it is one of the largest and most important projects ever to be undertaken in*

[1] Subject to the approval of this activity by the Island Environmental Authority.
[2] See https://www.totatouvai.co/te-mato-vai-1

the Cook Islands. The Te Mato Vai project is a development milestone for the Cook Islands and will have significant national health, economic and environmental benefits.

The sludge is a by-product from the water treatment process and requires disposal. As such, the sludge disposal supports the effective operation of the WTPs, and therefore, effective water treatment to provide a potable water supply for Rarotonga. Having reliable access to a safe potable water supply will have health benefits for the community.

Additionally, the creation of a purpose-built sludge disposal facility will ensure that an appropriate sludge disposal location is available for use. This will assist with the management and minimisation of any potential adverse effects from the sludge on the environment or the community (refer to the impact assessment in Section 8).

5.7.2 Consistency of the activity with national development objectives and plans

As set out in Section 3, the National Sustainable Development Plan (NSDP) 2016 – 2020, the Integrated Water Resources Management Policy (IWRMP) and the National Water Policy (NWP) 2016 are relevant to this proposal.

The NSDP articulates the national vision and development outcomes desired by Cook Islanders. The TMV project seeks to implement the NSDP, particularly Goal 4, by improving access to sufficient and safe water via a reticulated water system. The use of PACl as a component of this water system, and the subsequent sludge disposal that is required, is consistent with the direction contained in the NSDP.

The IWRMP document sets out its purpose as, "to establish policies that will guide planning, actions and efforts in ensuring the sustainable integrated water resources management across the Cook Islands". Policy Objective 1 of the IWRMP is, "Reliable, potable water for all who reside in the Cook Islands and the establishment of standards for water quality and resource management". The use of PACl in water treatment to provide potable drinking water, and the subsequent sludge disposal that is required, is consistent with the relevant objectives of the IWRMP, particularly Objective 1.

The vision of the NWP is 'to protect, enhance and improve the resilience, quality and sustainability of the Cook Islands water resources to ensure the health of the people and the environment'. This vision is supported by a number of objectives, in particular:

- Objective 1: Ensure Safe and sustainable management of water supply;
- Objective 3: Ensure access to reliable, safe drinking water for all who reside in the Cook Islands;
- Objective 5: Ensure sustainable management of both inland and coastal water resources; and
- Objective 6: Actively engage communities in the sustainable management of water resources

As noted above, the use of PACl in water treatment to provide potable water is consistent with Objectives 1 and 3. The sludge disposal is required to support the continued treatment of water, and therefore, will contribute to these objectives being met. The potential impacts to surface water and groundwater resources have been assessed as low and acceptable (refer to Section 8), as such, the proposal is consistent with Objective 5. Additionally, TTV has consulted the community to understand their views on the proposed water treatment and sludge disposal (refer to Section 7), which is consistent with Objective 6.

5.7.3 The need for disposal of water treatment sludge

As noted above, the sludge is a by-product from the water treatment process. As such, the sludge disposal is required for the effective operation of the WTPs, and therefore, effective water treatment to provide a potable water supply for Rarotonga.

6 Analysis of alternatives

A thorough assessment of alternatives to the use of PACl as a coagulant is provided in the EIA for the discharge of supernatant to streams (Tonkin & Taylor Ltd, 2021). Therefore, a further assessment of the use of PACl is not required and the analysis below is limited to the alternative options for sludge disposal.

6.1 Alternatives options for the disposal of sludge

These options for sludge disposal have been identified through a review of PACl water treatment sludge management internationally and with consideration of suitable locations or users on Rarotonga. The options identified include:

- Disposal of water treatment sludge to a dedicated facility;
- Use of water treatment sludge in agriculture (as a soil amendment); and
- Disposal of water treatment sludge to landfill.

Retaining sludge in ponds or in the general water treatment plant area has not been considered. This is because the sludge ponds would fill with sludge rendering them unusable to manage the sludge that is generated on an ongoing basis through water treatment. Also, there is limited space at each of the water treatment plants for the storage or disposal of water treatment sludge.

In all cases , the sludge to be disposed of will need to be in a dewatered state (around 15% dry solids). As outlined in Section 5.3, in some cases the sludge removed from the WTP ponds will have a high liquid content and will require additional dewatering. Therefore, the disposal option needs to be able to provide for the dewatering of sludge to be a viable alternative.

6.1.1 Disposal in a dedicated facility

The disposal of dewatered sludge in a dedicated monofill is common internationally and is considered an appropriate option for Rarotonga. The proposed option, site 88H, is a dedicated monofill.

Dewatering of low solid content sludge could take place at the disposal site. Dewatering could be undertaken within the disposal facility (e.g., within the open trench) to utilise the disposal facilities leachate drainage and capture infrastructure. Alternatively, a dedicated pad for dewatering could be constructed. However, given the relatively low quantity of material requiring dewatering, a more pragmatic approach would be to place the geobags in the disposal trenches.

6.1.2 Use in agriculture

GHD has characterised the sludge to assess potential disposal options (refer to Appendix F for the complete report). This included the use of the sludge in agriculture. In summary, the preliminary work completed by GHD concluded that the sludge could likely be used in an agronomic application. The sludge would likely have fertiliser value as a source of plant available sulphur but would require blending with other materials to provide a complete growing medium.

However, the real-world performance for use in agriculture is yet to be tested. Also, the sludge would need to be blended with natural soil (e.g., ploughing the material into the topsoil) and the cost of doing so may be impractical for farmers. There is also uncertainty around the number of farmers who would accept the sludge and the NES approvals to dispose of the sludge in this manner. An additional location would also be required for dewatering prior to use in agriculture.

This option requires more detailed investigation to determine whether it is viable in a Cook Islands context.

6.1.3 Disposal to landfill

The disposal of the sludge to the Rarotonga Waste Facility was investigated prior to commencing the concept development for the proposed disposal facility. Permanent disposal to landfill was not a viable option due to limited capacity being available at the Waste Facility.

Notwithstanding the above, temporary storage at the Rarotonga Waste Facility is being investigated again as a temporary solution while a longer-term option is implemented. A separate EIA will be prepared addressing the temporary management of sludge at the Rarotonga Waste Facility.

There are no other landfills on Rarotonga.

6.2 Advantages and disadvantages of alternative disposal options

The advantages and disadvantages for each of the disposal options are outlined in Table 6.1.

Table 6.1: Advantages and disadvantages of alternative disposal options

Disposal option	Advantages	Disadvantages
88H sludge disposal facility (i.e. monofill)	• A feasible and practical concept design has been prepared; • Provision to receive the sludge for multiple years; • Low risk of adverse impact on groundwater; • Low risk of dust nuisance to neighbours; • Acceptable establishment and operational cost; • Low labour requirements; and • Dewatering can take place on site.	• Requires trucks to transport sludge from across the island; and • Site requires design and construction with associated cost and timeline implications.
Alternative dedicated sludge disposal facility (i.e. monofill)	• Subject to location and design can deliver similar benefits to site 88H.	• Requires trucks to transport sludge from across the island; • Site requires design and construction with associated cost and timeline implications; and • Alternative sites have not been identified to date.

Disposal option	Advantages	Disadvantages
Use in agriculture	• Beneficial use of sludge rather than disposal and management. • Sludge has some agronomic value. • Sludge is incorporated into soils with potential to beneficially use sludge over an extended period of time.	• Trials have not been conducted yet. Therefore, the effectiveness of sludge as a component of soil has not been established; • There is uncertainty whether there are sufficient sites available to accept the sludge that is being generated; • Labour required to plough the sludge into the soil. This may be cost prohibitive for some sites; • The sludge is unlikely to be suitable for use in organic farming systems; • It is not clear what approvals would be required for agricultural use of sludge on Rarotonga; • An additional location is required for sludge dewatering.
Landfill	• Makes use of an existing disposal facility. • Dewatering can take place on site. • The Rarotonga Waste Facility is designed to managed mixed municipal waste (i.e., can accept the sludge). • Low risk of adverse impact on groundwater or surface water	• Cost of landfill disposal fees; • Utilises valuable landfill space better used for municipal wastes; and • Requires trucks to transport sludge from across the island.

6.3 Explanation for choice of the preferred option

The assessment presented in Table 6.1 suggests that a dedicated disposal site, and site 88H in particular, is preferable to disposal of sludge to the Rarotonga Waste Facility or use in agricultural. The key reasons for this assessment are:

- A dedicated site can manage environmental impacts and provide a long-term secure disposal option;
- The Rarotonga Waste Facility is approaching capacity with remaining ‘airspace’ better utilised for mixed municipal waste from across Rarotonga; and
- While preliminary work indicates that there is potential for sludge to be beneficially re-used in agriculture, further work is required to realise this possibility.

7 Community, Landowner and Stakeholder Consultation

7.1 Consultation undertaken in relation to this EIA process

The consultation for the sludge disposal facility has focussed on land owners and leaseholders for the proposed site. This has involved discussions regarding the proposed operations and anticipated impacts.

To Tatou Vai have had multiple conversations with the broader community regarding the broader project. These are documented in the Environmental Impact Assessment for water treatment plant operations and are also relevant here.

7.2 Consultation undertaken in relation to Te Mato Vai

In addition to the consultation undertaken specifically in relation to this project, broader consultation was undertaken in relation to the Te Mato Vai project between April 2019 to June 2019. The first meetings were held with the intake landowners as a way of on-going respect and strengthening relationships with the landowners. These were then followed by meetings with the members of the House of Ariki, Koutu Nui and Religious Advisory Council (RAC), and Members of Parliament, before going public to the Vakas, followed by the non-government organisations and the Chamber of Commerce. In addition, feedback on the project was gathered via social media (Te Mato Vai Facebook page) and traditional media including newspaper articles (GHD, 2019).

This consultation largely focussed on disinfection of the treated water, particularly on chlorination. No feedback relating to sludge disposal was received during this early consultation.

8 Impact Assessment

This impact assessment details negative and positive, immediate, short-term and long-term, permanent and temporary impacts that may arise from the disposal of sludge containing PACl. The impact assessment considers:

- A toxicity, fate and transport assessment of PACl (reflecting the analysis in the site discharge EIA);
- All relevant aspects of the environment identified in Section 4 and how they are likely to be changed or affected by the use of PACl, either directly or indirectly. In particular:
  - Impacts on surface water quality;
  - Impacts on ecological values;
  - Impacts of contaminants on land and groundwater;
  - Impacts on social and cultural heritage;
  - Health and safety impacts;
- The nature of the changes or effects, including negative consequences and/or benefits;
- The scale and magnitude of the changes likely to occur (over what area, or on what scale);
- The changes or effects that will arise at different stages of the water treatment process (settlement, drying and disposal);
- Environmental hazards (e.g., flooding) and how they are likely to change or affect the project, either directly or indirectly; and
- Environmental change processes (e.g., climate change) and how they are likely to change or affect the project, either directly or indirectly.

8.1 Toxicity assessment

As noted above, GHD has sampled and analysed the sludge at five of the WTPs to characterise the contaminant concentrations (refer to Appendix F for the complete report). Samples of nearby natural soils were also taken for comparison. The results are summarised as follows:

- The pH of the PACl sludge samples was near neutral, ranging from slightly alkaline to slightly acidic. The pH values for the PACl sludge fell within the range of the natural soil samples;
- The electrical conductivity values of the PACl sludge samples were slightly higher than the electrical conductivity values of the natural soil. However, this is not considered to be a concern for disposal in a monofill or for agronomic applications;
- The extractable Aluminium (Al) concentrations measured in the PACl sludge samples were all less than the laboratory detection limit, as was the case for the extractable Al concentrations measured in the soil samples;
- The Olsen Phosphorus (P) levels measured in the PACl sludge samples were in the low range for agronomic soils (3 to 19 mg/L). The Olsen P levels measured in the soil samples were generally higher than the sludge samples, with a range from 6 mg/L to 27 mg/L;
- The chloride concentrations of the PACl sludge samples were moderate to high and high when compared to the natural soil samples (four out of five of the soil samples were below the laboratory protection limit). The Chloride concentration of the Taipara sludge sample (227 mg/kg) was approaching the range (350 mg/kg) that can cause damage to sensitive crops such as lettuce, beans, and strawberries. However, the chloride concentration was not considered to be of concern for disposal in a monofill;

- The Soluble Salts concentrations measured in the five PACl sludge samples were all low (less than 0.07 %). The Soluble Salts concentrations measured in the soil samples were all less than 0.05%;
- The Sulphur (Sulphate) concentrations measured in the PACl sludge samples were high, at 140 to 576 mg/kg, compared with a highly variable range of <1 to 33 mg/kg in the five soil samples. The sulphate concentrations were not considered to be of concern for disposal in a monofill founded in natural mineral soils (as opposed to sands). In natural mineral soils on the island the silts and clays of the highly weathered volcanic soils have a high cation exchange capacity. As a result, the sulphate will tend to react with soil cations (magnesium, calcium, sodium, potassium) and produce benign compounds;
- The Sulphur (Extractable Organic Sulphur) concentrations were low in four out of the five PACl sludge samples and less than the analytical level of detection (< 2 mg/kg). In contrast, the organic sulphur content in the Taipara sludge sample was 27 mg/kg. The Sulphur (Extractable Organic Sulphur) concentrations in the natural soils were at or below laboratory detection limits. Organic forms of sulphur will only release plant available sulphur slowly as the organic matter decomposes naturally by mineralisation. The extractable organic sulphur values of the sludge samples were not considered to be a concern for disposal in a monofill;
- The Total Sulphur concentrations measured in the PACl sludge samples were high, at 2,690 to 4,520 mg/kg, compared with a variable range of 142 to 491 mg/kg in the five soil samples. This results indicate the source of the sulphur is the PACl product. Provided the monofill is founded in natural mineral soils this was not considered to be a concern for disposal in a monofill; and
- The total recoverable Aluminium content of the PACl sludge samples were high compared with the natural soil samples. However, as noted above, the extractable Al content of the PACL sludge samples could not be differentiated from the natural soils.

Overall, the GHD assessment concludes that the PACI sludge can be successfully disposed of in a monofill.

8.2 Fate and transport assessment

The disposal facility has been designed to contain all of the sludge within the disposal pits (refer to Section 5). Once a pit is enclosed and capped, mobilisation of the sludge as dust or sediment runoff within stormwater will be avoided.

During operation, there is the potential for small dust discharges of sludge should the onsite conditions be dry. However, as outlined in Section 5.5, a water cart will be used to minimise this potential pathway and the potential for dust discharges to be generated will be limited due to the small size of operational pits.

Rainwater that falls directly into the open trench and pit during operations will either percolate down through the underlying soils or be captured in the leachate drains and sump and be removed from the facility. As the trench will be 1.5 – 2 m in depth, and all clean water discharges will be diverted (i.e., there is no contributing catchment), the trench will be able to contain most rainfall events. Overflows of stormwater from the open pit due to extreme rainfall events will be avoided via backfilling of the open pit with cleanfill prior to the storm event arriving at the site where practical.

However, should backfilling not occur, the stormwater that has combined with the sludge in the pit could discharge into the Vairauara Stream in extreme events or percolate through the underlying soil. Similarly, discharges from an overflowing leachate collection sump in extreme events would discharge into the Vairauara Stream or percolate through the underlying soil.

8.3 Impacts to surface water quality and aquatic ecology

The sludge disposal facility has the potential to impact surface water quality through the discharge of sediment and PACl sludge via stormwater runoff and the discharge of leachate. As such, the key contaminants of concern are sediment, aluminium and chloride from the PACl within the sludge. Sediment can smother aquatic habitats, while the pH and dissolved aluminium concentrations could impact freshwater biota.

The nearest stream is the Vairauara Stream which only flows after heavy rainfall. To minimise the potential for sediment discharges, the sludge facility will be setback at least 10 m from the stream and grass cover will be established over the soil platform to stabilise the soil. Additionally, cleanwater will be diverted away from the open trench and pits to minimise the risk of disturbed sediment or PACl sludge being mobilised via stormwater runoff.

Stormwater and leachate within the trench and pit will be captured and will either infiltrate to ground or drain to the leachate sump. This liquid will be discharged to the Rarotonga Waste Facility septic treatment ponds. If a large rainfall event is forecast that cannot be contained within the open pit, the pit will be backfilled with cleanfill and stabilised. This will avoid PACl sludge being mobilised via stormwater and avoid discharges to the Vairauara Stream.

Should the leachate sump overflow, the liquid will discharge to the Vairauara Stream. The ecological assessment (refer to Appendix E) considered the risk posed from such a discharge. In summary, the assessment concludes that the pH of the leachate is unlikely to have adverse effects on any freshwater fauna that may be present, noting that the stream is dry for the majority of the year. Also, Chloride is not considered to be of concern as it will rapidly dilute in stormwater during a heavy rainfall event when a leachate discharge could occur.

Additionally, the ecological assessment noted that the USEPA (2018) developed environmental protection guidelines for aluminium in surface water. The guidelines that could be applied to Rarotonga are up to a concentration of 290 - 630 µg/L (0.29 - 0.63 mg/L). Testing of the leachate generated during dewatering in geobags indicated that the dissolved aluminium concentrations of the leachate were 0.033 mg/L and 0.059 mg/L for a single bag and double bag straining, respectively. These values represent the concentration of the discharge without any further dilution from rainfall events, which would be occurring when discharges would be expected. Therefore, should a discharge occur, the potential contaminants would be diluted and be well below the USEPA guideline values in the receiving environment.

Overall, sediment, PACl sludge and leachate discharges to surface water will likely be avoided entirely or minimised to such an extent that the impacts on surface water quality and ecology are low and considered to be acceptable.

8.4 Impacts on terrestrial ecology

The ecological assessment attached in Appendix E considers the potential impacts on terrestrial ecology. In summary, the assessment notes that the vegetation that will be cleared within the impact area is exotic, of low ecological value and provides poor quality habitat for indigenous fauna. However, it is known to support the naturalised inland blue-tailed skink.

To minimise harm to skinks the habitat suitability will be reduced prior to construction commencing. This will include the removal of inorganic material from the site which provide refugia and cover. Vegetation will then be reduced using a scrub cutter or mulching head. Any ground-dwelling birds that may be present will also self-relocate to surrounding areas upon commencement of these pre-works activities.

Overall, the terrestrial ecological values of the site are low and appropriate measures will be undertaken to minimise adverse effects. As such, the impacts are low and considered to be acceptable.

8.5 Impacts of contaminants on land and groundwater

As noted above in Section 8.1, testing shows that most parameters tested for are comparable between the natural soils and the PACl sludge. Therefore, the potential impacts on the existing land beneath the sludge disposal facility are expected to be low.

Total recoverable aluminium, chloride and total sulphur and sulphate were higher than the natural soil samples. Notwithstanding this, the GHD report (refer to Appendix F) concluded that the sludge could be successfully disposed of in a monofill established in natural mineral soils on the island. In this setting the PACl sludge would not represent a risk for leaching of trace elements or nutrient compounds however the design proposed incorporates a liner and capping to provide a high standard of containment of the dewatered sludge. The GHD report noted:

- The total recoverable aluminium does not represent an environmental risk as the extractable (plant available) Aluminium content of the sludge samples was no different than the natural soils;
- The Chloride concentrations were approaching levels that can cause damage to sensitive crops. However, the chloride concentrations will reduce naturally due to rainfall percolation and dilution and dispersion are not of concern; and
- In terms of total sulphur and sulphate, provided the disposal facility will be founded in natural mineral soils, the sulphate will react with soil cations (magnesium, calcium, sodium, potassium) and produce benign compounds.

In terms of the last two points, the growing of crops on top of the sludge disposal facility is highly unlikely and therefore, any potential impacts to the land from chloride are considered to be low. Additionally, a 500 mm layer of natural mineral soils will be placed at the base of the soil platform and disposal facility, therefore mitigating the sulphate concentrations.

We are not aware of any groundwater use in the immediate vicinity of the site that could be affected the proposal. Notwithstanding this, dissolved aluminium in drinking water is managed for aesthetic rather than health purposes. WHO notes that the aluminium at concentrations in excess of 0.1 – 0.2 mg/l (100 - 200 µg/L) often leads to consumer complaints as a result of deposition of aluminium hydroxide floc and the exacerbation of discoloration of water by iron[3]. The testing of the leachate undertaken to date indicates that the dissolved aluminium concentrations are an order of were 0.033 mg/L and 0.059 mg/L (refer to the discussion in section 8.3). This is prior to any dilution within groundwater and some aluminium is expected to be removed as it binds to soil particles as it percolates through the soil. As such, any aesthetic impacts to potential users of groundwater from dissolved aluminium are expected to be low.

Overall, for these reasons, the potential impacts of contaminants on the land and groundwater beneath the sludge disposal facility are considered to be low and acceptable.

8.6 Impacts on human communities

Dust and noise from the operation of the sludge facility could have impacts on nearby dwellings and communities. The nearest sensitive receptor is a dwelling located 150 m downstream of the site.

[3] Guidelines for Drinking-water Quality, fourth edition incorporating the first addendum, WHO, 2017.

To minimise the potential for dust generation the majority of the platform will be stabilised with grass and a water cart will be used to dampen dry soils. The dampening of exposed material will mean dust discharges will be avoided beyond the immediate site area.

To avoid noise disturbance to nearby dwellings the following protocols will be implemented:

- Trucks will only access the site to dispose of sludge Monday-Friday between 7am-5pm; and
- All machinery onsite will be maintained to minimise machinery noise.

Overall, the potential impacts from dust and noise can be mitigated to a level where the impacts are low and considered to be acceptable.

8.7 Impacts on social and cultural heritage

This section of the EIA addresses the positive and negative impacts on social and cultural values from the management of water treatment sludge.

The creation of sludge is an unavoidable consequence of the water treatment process that is designed to produce potable water. The management of sludge at the site

The proposed disposal facility is located inland, away from residential settlements which are generally located on lower land, near the back road / main road. The surrounding area is occupied by agricultural, infrastructure (landfill, recycling and quarrying) and the Rarotonga Prison.

The disposal of sludge at the site is not anticipated to have a direct negative impact on these activities given the low impacts immediately adjacent to disposal facility. In addition, the management sludge at this site has no direct negative impact on physical cultural sites.

We note that there has been strong opposition to the addition of chemicals to the water treatment process (including PACl) expressed by some community members and landowners. A clear statement of cultural values relating to the management water treatment sludge is not available. We note there are significant cultural values attached to land and water in the Cook Islands and there is a fundamental link between these values and the relationship between land and identity (Coffey, 2019).

However, we note that while a number of people are strongly opposed to the addition of chemicals into the water treatment process, some of which will be present in the sludge, there are also a number of people who have expressed support for the upgrade. While some have expressed the view that the water does not require treatment as they do not get sick from it, the evidence unfortunately indicates that there is regular microbiological contamination above safe levels, and this increases the risk of water-related health issues.

A safe, reliable and potable drinking water supply has well established social benefits, supporting public health outcomes at local, regional and national levels (WHO, 2011). This is further supported by the Cook Islands national policy framework, including the NSDP and the IWRM. Therefore, on balance, the proposed management of sludge is considered to be appropriate in relation to social and cultural values.

9 Operation Environmental Management Plan (OEMP)

The following section provides a draft 0perational Environmental Management Plan framework (OEMP Framework) that includes the following:

- Environmental performance objectives for the activity;
- Responsible parties;
- Monitoring plan;
- Relevant government agencies;
- Staffing and equipment requirements; and
- Process for engagement with stakeholders.

These matters will be addressed in the Operations Manual for sludge disposal site.

9.1 Environmental performance objectives for the activity

The following environmental performance objectives are proposed for the sludge disposal facility:

- No discharges of PACl sludge to the Vairauara Stream;
- No adverse impacts associated with dust from the operation of the sludge disposal facility; and
- No discharges of leachate from the leachate collection sump to the Vairauara Stream.

9.2 Responsible parties

The Operations Manual will clearly note who will have responsibility for overseeing the implementation of different mitigation measures, incident response, environmental monitoring and reporting.

9.3 Monitoring plan

As outlined in Section 8, the sludge disposal facility is expected to have low impacts on the environment and surrounding communities. As such, the monitoring undertaken will be proportionate to the low level of effects expected. The final monitoring plan will be developed as part of the OEMP. Notwithstanding this, the following monitoring will likely be undertaken:

- Visual inspections weekly for dust discharges that may become a nuisance to surrounding properties;
- Visual inspections weekly of the leachate collection sump to monitor when this will need to be emptied to the Rarotonga Waste Facility septage ponds. An inspection will also occur after significant storm events;
- Weekly inspections of erosion and sediment controls for the soil platform to ensure they are functioning correctly to minimise sediment discharges to the Vairauara Stream. These inspections will continue until the disturbed areas have been stabilised with grass or by another method; and
- Surface water monitoring with sampling approach reflecting the lack stream flow except during significant rainfall.

9.4 Relevant government agencies

The Operations Manual produced by TTV will clearly note the names of the government agencies and key contacts that TTV will report their outcomes and monitoring results to.

9.5 Staffing and equipment requirement

The Operations Manual will clearly note staffing and equipment requirements, any training programmes or capacity development necessary to ensure successful OEMP implementation.

9.6 Process for engaging with stakeholders

A process for managing and responding to stakeholder concerns or complaints will be incorporated into the Operations Manual. This includes paying the landowner and the lease for the use of the land and the impact of sludge on it.

9.7 Process for emergency or incident response

The Operations Manual will outline the emergency and incident response processes.

9.8 Review and audits

Provision is to be made for periodic review of the OEMP and independent audits of the site once the activity becomes operational.

10 Conclusions and Recommendations

The Cook Islands Government has upgraded Rarotonga's water infrastructure, through the Te Mato Vai (TMV) project. The infrastructure upgrades include the improvement of ten water intake structures and the construction of a new water treatment plant (WTP) for each intake. The water treatment process produces a residual sludge comprised of materials removed from the incoming water (e.g., sediment and organic matter) and the coagulant used (Polyaluminium chloride (PACl)) to settle sediment and other entrained materials.

TTV have commissioned T+TI to undertake an independent EIA to assess the potential environmental impacts from the disposal of water treatment plant sludge to land. The disposal site is a dedicated facility on Vaiauara Road, directly west of the Rarotonga Waste Facility.

This EIA report draws the following conclusions:

- The impacts to surface water quality and aquatic ecology are expected to be low. This is due to contaminant discharges to surface water generally being avoided through the facility design and site management;
- The impacts to terrestrial ecology are expected to be low due to the limited vegetation removal and poor quality of the existing habitat;
- The impacts to land and groundwater quality are expected to be low due to the nature of the contaminants present in the sludge, environmental context (e.g., rainfall dispersal of contaminants), and facility design; and
- Social and cultural heritage – the impacts on social and cultural heritage are considered to be low; and
- The disposal of the sludge to landfill and use in agriculture were considered as alternative options. However, the disposal to a dedicated facility is the preferred option at this point in time.

Overall, the proposed disposal facility will provide an acceptable solution for the management of the sludge. It will provide TTV with security of disposal and contribute to the wider project objective of improving access to potable water.

The monitoring plan set out in Section 9.3 provides appropriate monitoring to check that the environmental impacts are as expected.

11 References

Coffey, (2019), Mei Te Vai Ki Te Vai Wastewater Project Social-Cultural Impact Assessment.

GHD (2014) Draft Environmental Impact Assessment Report undertaken for the Detailed Design for Stage 2

Tonkin & Taylor International Ltd, (2014), Rarotonga Groundwater Investigations and Monitoring Project: WMI Factual Report.

Tonkin & Taylor International Ltd, (2021), Draft Environmental Impact Assessment Report undertaken for on-site supernatant discharges.

World Health Organization (2017), Guidelines for drinking-water quality: fourth edition incorporating the first addendum.

US Environmental Protection Agency (2018). Final aquatic life ambient water quality criteria for aluminium 2018. Washington, D.C. EPA 440-4-89-001.

12 Applicability

This report has been prepared for the exclusive use of our client To Tatou Vai Limited, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

We understand and agree that our client will submit this report as part of an application for approvals under the Environment Act and that the National Environmental Service and Environment Authority will use this report for the purpose of assessing that application.

Tonkin & Taylor International Ltd

Environmental and Engineering Consultants

Report prepared by:	Authorised for Tonkin & Taylor International Ltd by:
	C.J. Freer
....	....
Alex Gifford	Chris Freer
Senior Planner	Project Director

Appendix A: Terms of Reference requirements

The following table provides a summary of the information required in the Terms of Reference and a quick reference to its location in this report.

Off-site disposal of PACl sludge: Terms of Reference for site 88H	Location within the report
Executive summary The Executive Summary should present a concise, non-technical outline of the proposed project comprising of each sections *[sic]* of the EIA report. And it should include the following; • the title of the proposal; • name and contact details of the proponent, and a discussion of previous projects undertaken by the proponent and their commitment to effective environmental management; • a concise statement of the aims and objectives of the proposal; • the legal framework, decision-making authorities and advisory agencies; • an outline of the background to and need for the proposal, including the consequences of not proceeding with the proposal; • an outline of the alternative options considered and reasons for the selection of the proposed development option; • a brief description of the proposal (pre-construction, construction and operational activities) and the existing environment, utilizing visual aids where appropriate; • an outline of the principal environmental impacts predicted and the proposed environmental management strategies (including waste minimization and management) and commitments to minimize the significance of these impacts; • include the results of impact and risk assessments, the proposed management/mitigation actions, and the conclusions reached for the project. The structure of the Executive Summary should generally follow that of the EIA but focus on key issues to enable the reader to obtain a clear understanding of the proposal and its potential adverse and beneficial environmental, social and economic impacts and the management measures to be implemented by the proponent to mitigate all residual impacts. The Executive summary should be written as a stand-alone, able to be reproduced on request and distributed to interested parties who may not wish to read or purchase the EIA as a whole. Present a concise, non-technical outline of the proposed management and disposal of water treatment sludge and each chapter of the EIA report. Include the results of impact and risk assessments, the proposed management/ mitigation actions, and the conclusions reached.	Executive summary
Table of contents A clear table of contents should be given	Table of contents
Glossary List acronyms/abbreviations.	Section 1

Off-site disposal of PACl sludge: Terms of Reference for site 88H	Location within the report
Section 1: Introduction Provide a high-level overview of the TMV project, water treatment process and generation of water treatment sludge. Provide a description to the proposed management and disposal of water treatment sludge including the purpose and objectives. This should also include information on: Project purpose and objectives (including environmental performance objectives), Profile of proponents, contacts details etc.	Section 2
Section 2: Policy and legal framework Outline the relevant policies and laws that apply to the management and disposal of water treatment sludge and identify any approvals needed from government agencies. For example: • National laws and related government approvals • Multilateral Environmental Agreements • Industry policies or codes of practice • Health, safety, hazard and risk management standards • Current agreements between government and the proponent • Environment policies, if any, of any financing organizations involved in the project • The proponents environmental management and compliance record.	Section 3
Section 3: Activity description and justification Present a detailed description of the proposed activity, including: • The location of the sludge disposal site, size and layout, including a description of proximity to watercourses, towns/villages, transport infrastructure and cultural/ecological assets • The sludge disposal facility infrastructure and design. • Method used to process sludge prior to entering the facility (the drying of sludge in scour ponds and digging out the ponds). • The transportation of dried sludge. • Any processing of sludge at the disposal facility. • The predicted resource and public infrastructure requirements, including for example, energy, water, labour, transport, minerals, hazardous materials. • Predicted type and quantity of waste outputs (liquid, solid and gas emissions) arising from sludge disposal. • Timeline for implementation, operation and expected lifespan of the disposal facility. • Activity cost estimates. • Project benefits.	Section 4 and 5
Section 4: Analysis of alternatives: • Alternatives to the disposal of sludge at this site (already canvassed to some degree in PACl EIA) • Advantages and disadvantages of alternatives (cost, practicality, feasibility). • Explanation for choice of the preferred option.	Section 6
Section 5: Provide justification for the activity and its benefits • Benefits to the local area, island, country (more efficient/cost-effective infrastructure, improved environmental outcomes, improved treatment outcomes). • Consistency of the activity with national development objectives and plans. • The need for disposal of water treatment sludge.	Section 5

Off-site disposal of PACl sludge: Terms of Reference for site 88H	**Location within the report**
Section 6 – Description of the baseline environment Detail baseline (existing) environmental conditions relevant to where sludge will be disposed. The level of examination and effort will depend on the scale of the activity, its physical setting and its area of influence. Where relevant, the following aspects of the environment should be described: • Climate (temperature, rainfall, winds, extreme weather events, climate change projections). • Topography, geology and soils (landscape gradient or slope, seismic characteristics, areas vulnerable to landslides, erosion). • Sensitive environmental areas or land uses immediately surrounding the sludge disposal locations. Identify any high value or threatened flora, fauna or herpetofauna that may be present immediately surrounding these areas. • Water (surface and groundwater quantity and quality; site hydrology; local catchment area; downstream water uses/users; areas vulnerable to flooding, inundation or storm surges). • Air (existing sources of air emissions or odour; ambient air quality, location of nearest sensitive receptors). • Social context of the areas surrounding where sludge disposal will occur (towns/villages; housing; transport and other community infrastructure; cultural traditions and community activities). • Cultural resources and heritage (objects or sites of social/cultural significance, cultural values or beliefs relevant to the disposal of sludge). • Noise (eg baseline noise levels and noise pollution, location of nearest sensitive receptors. • Plant life (e.g. plant species and communities within the project and surrounding area; native, endemic, threatened, invasive or culturally-significant species; areas subject to previous habitat clearing or disturbance; species, plant communities or habitat vulnerable to environmental hazards and environmental change) • Animal life (e.g. animal species and communities within the project and surrounding area; native, endemic, threatened, migratory, invasive or culturally-significant species; habitat within and adjacent to the project area suitable for species of conservation significance; species, animal communities or habitat vulnerable to environmental hazards and environmental • Human communities (e.g. towns/villages/settlements; population and local demographics; housing; energy and water resource; transport and other infrastructure; cultural traditions and community structure; marginalised groups; community health status; health care facilities; landscape and visual amenity; recreation; elements of human communities vulnerable to environmental hazards and environmental change) • Local and national economy (e.g. skills, livelihoods and employment; economic and business conditions; distribution of income; major sectors and industries; elements of the economy vulnerable to environmental hazards and environmental change)	Section 4

Off-site disposal of PACl sludge: Terms of Reference for site 88H	**Location within the report**
Section 7: Impact assessment Assess and describe the potential impacts of the activity on the environment, social and cultural values identified in Section 7. The impact assessment should detail negative and positive; immediate, short-term and long-term; permanent and temporary impacts. The impact assessment should consider: • A toxicity, fate and transport assessment of PACL (reflecting the analysis in the site discharge EIA). • All relevant aspects of the environment identified in Section 7 and how they are likely to be • changed or affected by the use of PACL, either directly or indirectly. • The nature of the changes or effects, including negative consequences and/or benefits. • The scale and magnitude of the changes likely to occur (over what area, or on what scale). • The changes or affects that will arise at different stages of the water treatment process (settlement, drying and disposal). • Explain the methods used for the impact assessment, such as modelling, site surveys, or review of existing information or previous studies. In conducting the impact assessment give consideration to: • all relevant environmental hazards, and how they are likely *to change or affect the project*, either directly or indirectly (e.g. weather-related hazards such as heavy rain, cyclones; water-related hazards such as flooding, tidal waves; geological hazards such as landslides, ground failure, earthquakes, tsunami) • environmental change processes, and how they are likely *to change or affect the project*, either directly or indirectly (e.g. climate change and associated processes such as sea level rise, increased cyclone intensity; loss of land etc.)	Section 8

Off-site disposal of PACl sludge: Terms of Reference for site 88H	Location within the report
Section 8: Operation environmental management Provide a draft environmental management plan framework (EMP Framework) that includes the following: • Provisions for all phases of the project, from construction through to operation, decommissioning, closure and post-closure. • Environmental performance objectives for the activity. • Who will have responsibility for overseeing the implementation of different mitigation measures, incident response, environmental monitoring and reporting. • A monitoring plan, including performance criteria for measuring the extent of environmental impacts, and/or the success of mitigation measures. • The names of the government agencies the proponent will report their outcomes and monitoring results to. • Staffing and equipment requirements, any training programmes or capacity development necessary to ensure successful EMP implementation. • A process for managing and responding to stakeholder concerns or complaints. • Provision for periodic review of the EMP during each stage and once the activity becomes operational. • Environmental management expectations and requirements to be placed on project contractors • Provisions for independent auditing (especially in the case of high-risk projects) • A process for responding to unanticipated or emergency incidents • Compensation measures for affected parties for impacts that cannot be mitigated or adequately managed The different elements of the EMP will be cross referenced to relevant text in the EIA.	Section 9
Section 9: Community, landowner and stakeholder consultation Landowner and stakeholder engagement for the sludge disposal will be led by TTV. The EIA should include a summary of this consultation including: • Meetings, workshops or other forms of consultation held to date. • The outcomes of consultation, including issues and concerns raised by different groups or affected parties. • A discussion of how issues and concerns have been addressed. • An overview of future planned consultation and engagement activities.	Section 7
Section 10: Conclusions and recommendations Present the main conclusions of the EIA report and the proponent's suggested recommendations for progressing with the activity, including key environmental management and mitigation measures that should be undertaken.	Section 10
References Appropriately reference all information sources that have been used or consulted during EIA report preparation.	Section 11

Off-site disposal of PACl sludge: Terms of Reference for site 88H	Location within the report
Appendices Include appendices that support the main text, including: • Relevant environmental studies and reports. • Detailed technical information. • A table listing how this TOR has been addressed, cross-referenced to relevant sections of the EIA report. • A table listing environmental mitigation/management commitments made by the proponent. • Evidence of activity support from stakeholders.	Following Section 12, Appendix A - H

Appendix B: GHD field investigations

TE MATO VAI

Memorandum

5 December 2020

To	TTV Attn: Greg Longman		
Copy to	Angelia Williams, Sione Likiliki, Peter Free		
From	Matt Boyd	Tel	28851
Subject	Arorangi Preliminary Geotechnical Investigation		

1 Introduction

To Tatou Vai (TTV) have requested assistance to investigate a block of land for disposal potential for water treatment sludge. Major Projects Procurement Support (MPPS) have requested GHD assist TTV in a preliminary geotechnical investigation of the proposed site.

1.1 Scope and limitations

This report has been prepared by GHD Limited (GHD) for TTV and may only be used and relied on by TTV for the purpose agreed between GHD and TTV as set out in this report.

GHD otherwise disclaims responsibility to any person other than TTV arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible. GHD accepts no responsibility for other use of the data. This report presents the results of a geotechnical investigation prepared for the purpose of this commission. The data and advice provided relate only to the proposed development described herein.

The advice tendered in this report is based on information obtained from the investigation locations tests points and sample points and is not warranted in respect to the conditions that may be encountered across the site at other than these locations. It is emphasised that the actual characteristics of the subsurface materials may vary significantly between adjacent test points and sample intervals and at locations other than where observations, explorations and investigations have been made. Subsurface conditions, including groundwater levels and contaminant concentrations can change with time. This should be borne in mind when assessing the data. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

An understanding of the geotechnical site conditions depends on the integration of many pieces of information, some regional, some site specific, some structure specific and some experienced based. Hence this report should not be altered, amended or abbreviated, issued in part and issued incomplete in any way without prior checking and approval by GHD. GHD accepts no responsibility for any circumstances which arise from the issue of the report which have been modified in any way as outlined above.

2 Site Description

The proposed land for investigation is Block 88H Arorangi.

Figure 1 Site Plan

The land block is immediately downhill from the existing Arorangi Landfill. The block is slightly sloping, with an elevated vegetated platform . The site is bounded to the north by the Quarry access road and the stream, and to the south by the historic quarry rockface.

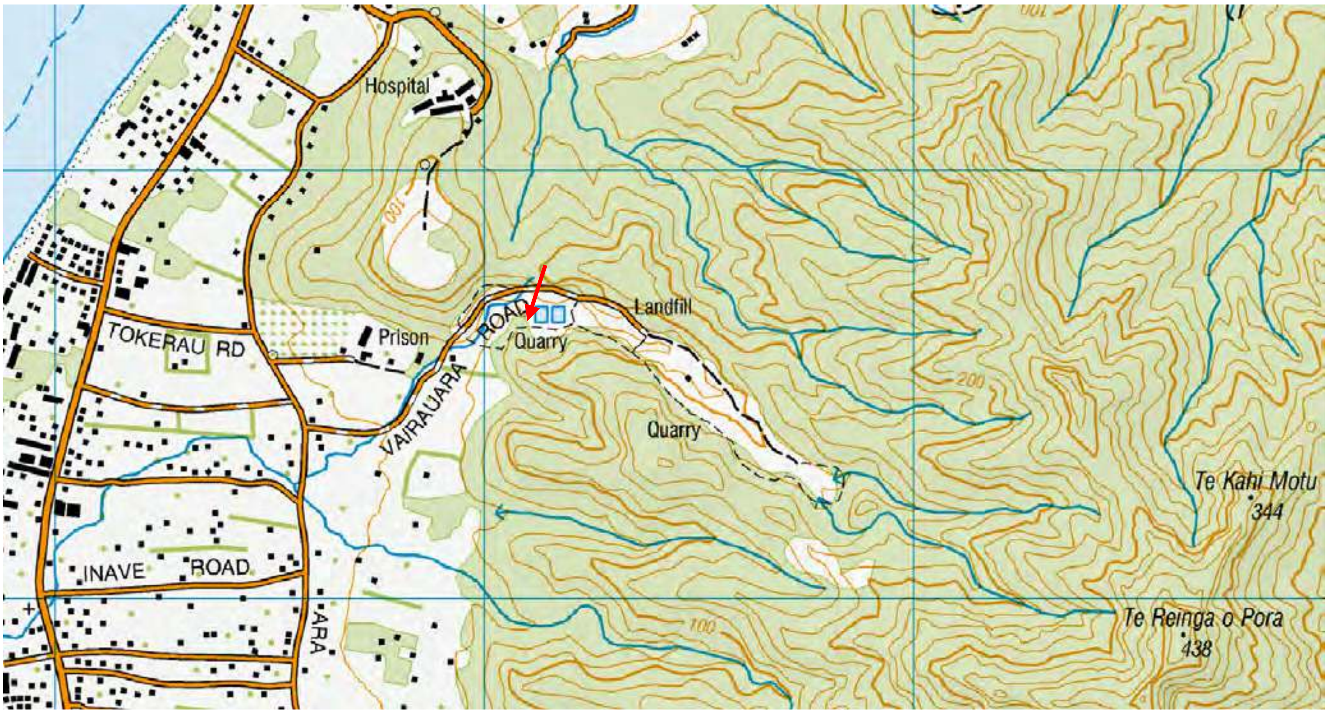


Figure 2 Topographic Plan of valley

3 Geological Setting

According to Wood and Hay 1970 the site is at the boundary of two geological units. According to the geolgical map the site is underlain by the Nikao Gravels, but is close to the boundary with the Te Manga Group basalt (Figure 3).

The Soils map of Rarotonga (Figure 4) indicates that the site is underlain by the Pokoinu Hill Soils, consisting of a dark reddish brown to dark brown, friable, well-structured, clay loam with ash horizons and stones.

Figure 3 Geological Map of the Site (Wood &Hay, 1970. Geology of the Cook Islands, NZ Geological Survey Bulletin 82)

Raemaru Flows **(R)**: light olive-green to grey dense soda phonolite, minor light-brown to yellow phonolitic ash. Prominent columnar cleavage at Black Rock. Late Pliocene to early Pleistocene.

Te Manga Group **(Ma)**: grey to black basalt, ankaramite, limburgite, in flows, dikes and pyroclastics, dipping generally seaward comprising the bulk of the primitive volcano. Near sea level includes palagonitic ash beds. Late Pliocene.

Nikao Gravels **(Nk)**: weathered volcanic gravel and sand of coastal terraces and fans; older and higher depostis (Nko) more deeply weathered. Late Pleistocene.

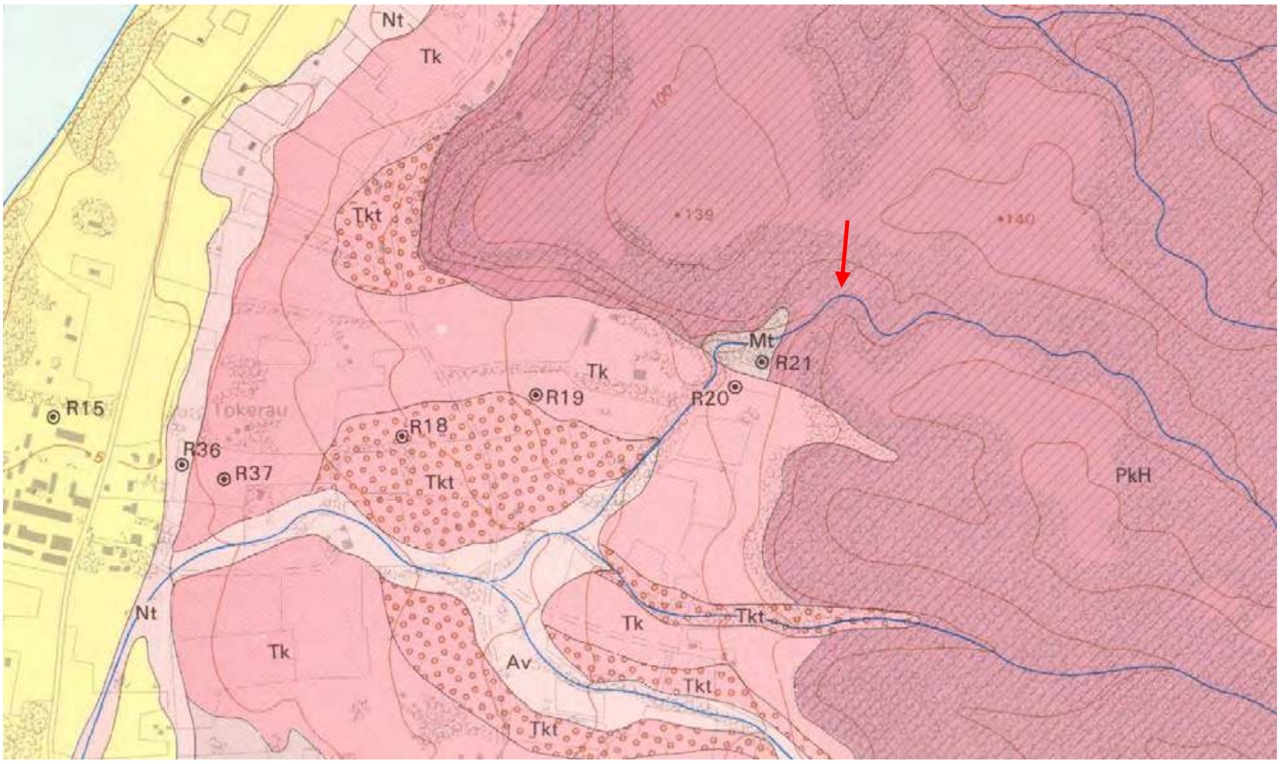


Figure 4 Soils Map of the Site (Leslie, 1980. Soil Map of Rarotonga, Cook Islands. New Zealand Soil Bureau Map 163)

4 Field Investigation

Three test pit excavations were undertaken into the elevated platform at the site. The test pits penetrated 1.9 m depth and terminated at the extent of reach of the excavator. The elevated platform is estimated to be around 3 metres thick on average. The test pits encountered fill in all excavations, and did not encounter the natural soils below the fill platform.

Figure 5 Site 88H fill Platform

The site was heavily overgrown with vegetation and the investigation began by stripping the vegetation as best as practicable across the site.

Figure 6 Site before and after clearance

Only half of the site was accessible with the 3.5 T excavator, as the other half of the site contained large logs and voids. It is presumed that the other half of the site also contains fill, as the historic aerial photos indicate filling in this area.

Figure 7 Approximate Area Investigated

The lot size in total, including the stream channel appears to be around 10,500 m^2. Approximately 1,500 m^2 was investigated.

Logs of each of the test pits are presented in Appendix A.

5 Summary of Findings

The 88H site has been filled to a depth of approximately 3 m above the natural ground level with “cleanfill”, being waste material that is not suitable for disposal in the landfill. The testpits encountered metal of various origins, glass, cans, plastics, fabric, timbers and logs and tires. Typically for cleanfill no organic material, such as timber and logs are permitted, as overtime these decompose and create voids and potentially gas issues. True Cleanfill typically only allows inert materials which will not create any runoff or leachate. The fill here is termed “cleanfill” but it is noted that it would not meet the criteria typically applied for cleanfill.

The fill is mostly mixed with a matrix of sandy partly organic friable soil. From the soils maps and geological mapping, it is assumed that this is natural soil from the area.

6 Recommendations

The initial investigation indicates that the land has already been used as a “cleanfill” disposal site. On this basis utilisation of the site for water treatment sludge disposal on top of the “cleanfill” should be suitable. The fill observed in the investigation appeared mostly inert, however given the variable nature of the material some contamination may be present.

It is envisaged that the sludge would be disposed on top of the surface of the existing platform. The soil / “cleanfill” mix appears permeable and should readily drain. It is likely that imported soil fill material will be required to top the “cleanfill” and create a working layer and bunding. Onto this slightly sloping sludge drying bays could be created. The elevated platform offers benefit in the respect that surface water flows should be able to be controlled readily with basic bunding. Overland flows from further up the valley will not impact on the sludge disposal site. An additional benefit is that any infiltration of water through the base of the beds would result in any dissolved aluminium readily binding to the fill soil. This would alleviate the need for any potential lining on the beds. Given the likely permeable nature of the deeper basaltic underlying rocks, it is important that a barrier of soil separates the sludge from the rock to ensure there is no transfer of aluminium to the deep groundwater aquifer, the “clean fill” platform provides this.

It is recommended that a design for the sludge beds be undertaken with investigation of the balance of the site being undertaken concurrently. The following should be considered during the design of the sludge drying beds:

The orientation, size, depth and shape need to be considered for access for placing and reworking the sludge, while maximising drying potential.

Slope of the bed and drainage of any water shed from the sludge

Stormwater control and ponding on the site to avoid concentrating the flows.

Consideration for the requirement for under drains

Baseline groundwater chemistry

Investigation of the potential runoff coming from the landfill

Investigation into the stream channel and consideration of any pathway for sludge or supernatant to migrate to the stream.

6.1 Further investigation

It is recommended that an investigation with a larger excavator be undertaken to penetrate the interface between the “cleanfill” and the natural underlying soils.

It is noted that onsite groundwater monitoring wells are present, assumably associated with the landfill and its consent. It is recommended that data from these wells be reviewed to determine if a baseline level of groundwater and groundwater chemistry if possible be established, and then consideration be given to establishing downstream groundwater monitoring if required for the proposed sludge beds.

Regards

Matt Boyd
Deputy Project Manager

Appendix A
Test Pit Logs

Appendix B
Photos of the Site

Arorangi Test Pit Log

Test Pit 1

Site:	Arorangi Quarry	Logged:	MB
Job No.:	12504023	Processed:	MB
Coordinates:		Excavator:	Hyundai 35Z-9
Lat:	-21.218466	Size:	3.5 Tonne
Long:	-159.818607	Bucket:	350mm Trench Bucket, 3x Teeth
Commenced:	26/11/2020		
Completed:	26/11/2020		

Log of Test Pit

Depth	Soil/Rock Description
0 m – 1.9 m	FILL. Organic soil, friable, slightly sandy, with plastic, metal, rubber, wood, Coral boulders, glass, fabric inclusions. ["Clean Fill"].

1.9 m

Limit of excavation with 3.5 T excavator

Test Pit 2

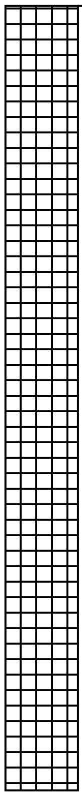
Arorangi Test Pit Log

Site:	Arorangi Quarry	Logged:	MB
Job No.:	12504023	Processed:	MB
Coordinates:		Excavator:	Hyundai 35Z-9
Lat:	-21.216811	Size:	3.5 Tonne
Long:	-159.818486	Bucket:	350mm Trench Bucket, 3x Teeth
Commenced:	26/11/2020		
Completed:	26/11/2020		

Log of Test Pit

Depth

0 m



1.9 m

Soil/Rock Description

FILL. Brown soil ~ 60%, friable, somewhat organic, slightly sandy, some clayey, with plastic, metal, rubber, wood, Coral boulders, glass, fabric inclusions. ["Clean Fill"].

1.9 m

Limit of excavation with 3.5 T excavator

Arorangi Test Pit Log

Test Pit 3

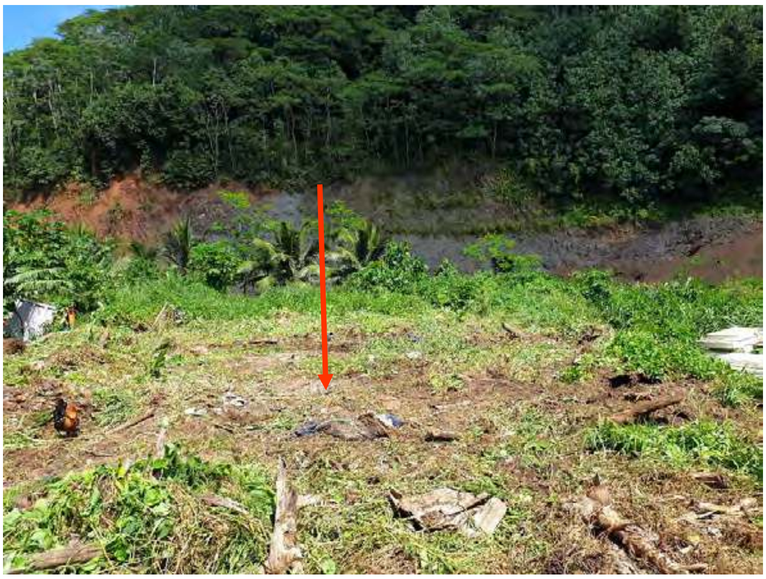
Site:	Arorangi Quarry	Logged:	MB
Job No.:	12504023	Processed:	MB
Coordinates:		Excavator:	Hyundai 35Z-9
Lat:	-21.216956	Size:	3.5 Tonne
Long:	-159.818436	Bucket:	350mm Trench Bucket, 3x Teeth
Commenced:	26/11/2020		
Completed:	26/11/2020		

Log of Test Pit

Depth	Soil/Rock Description
0 m – 1.9 m	FILL. Organic soil, friable, slightly sandy, with plastic, metal, rubber, wood, Coral boulders, glass, fabric inclusions. ["Clean Fill"].

1.9 m

Limit of excavation with 3.5 T excavator



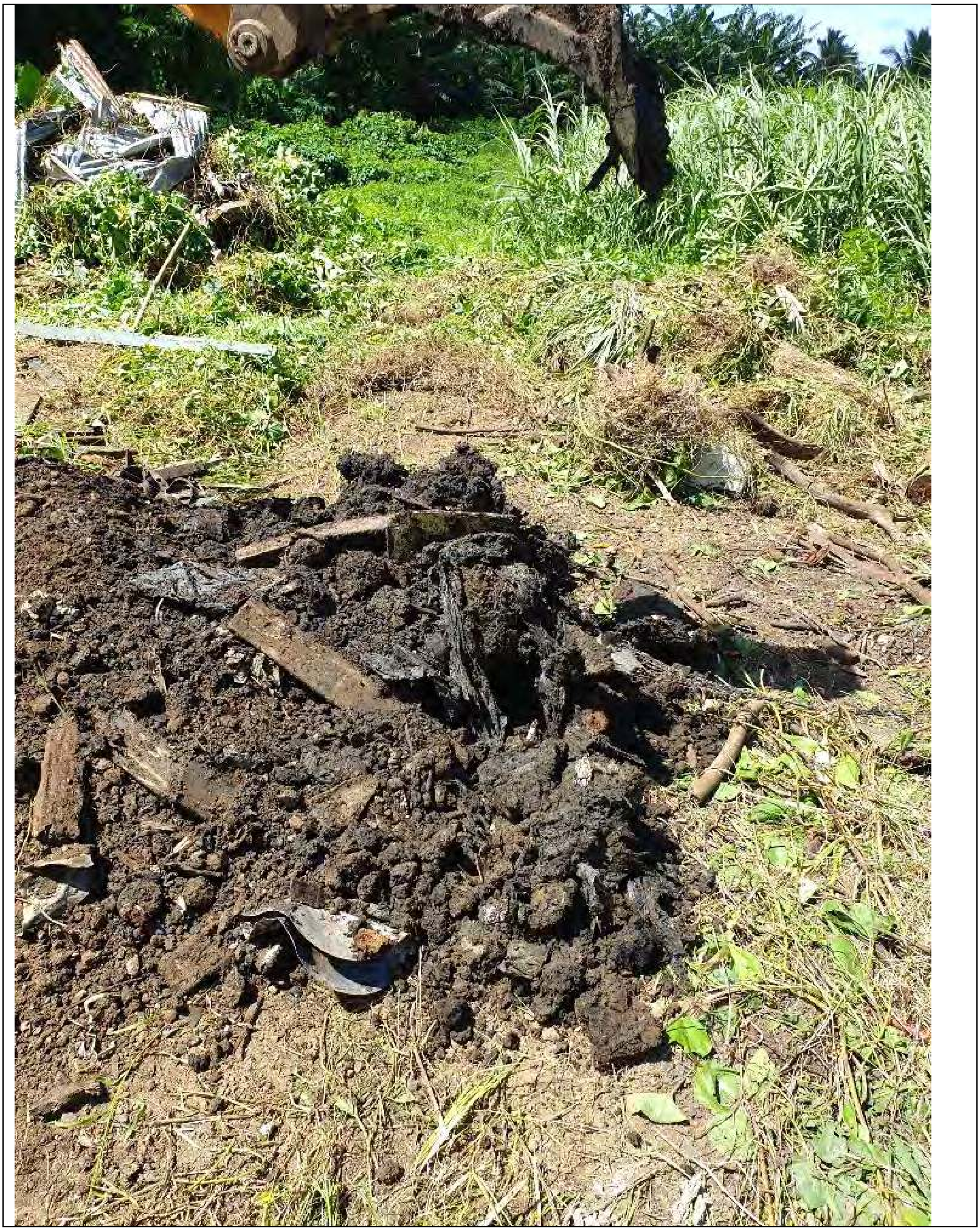
Site Photos of 88H




HYUNDAI
9


HYUNDAI
35z-9


HYUNDAI



Appendix C: GHD Te Mato Vai PACl trial report

Te Mato Vai
PACI trial report

March 2021

Executive summary

Introduction

The Te Mato Vai project constructed ten new water treatment plants ("intakes") at different locations in Rarotonga. The plants use the coagulant Polyaluminium Chloride (PACl), settling tanks and automated valveless gravity (AVG) filters to remove dirt, sediments, and some microorganisms from the raw water.

The commissioning includes a period of 6 months where the plants' performance is closely monitored. The first goal is to ensure that the plants produce water that is treated to an acceptable standard. The second goal is to gain operational experience with the plants and find out how their performance can be optimised in different conditions.

This report summarises the results of the PACl trials so far (further future results will be added to this report at the completion of the trial) and provides a recommendation as to how the plants could be operated in the future.

This report contains results about:

- the treated water quality of all plants
- environmental monitoring data from discharges to the environment
- observations about water treatment plant residuals ("sludge")

The treated water quality requirements

During the PACl trial, the requirements for the treated water that is supplied to the drinking water network are as follows:

- The turbidity after the AVG should be lower than the raw stream turbidity[1]
- The E. coli concentration after the AVG generally should be lower than the raw stream concentration.
- The dissolved aluminium concentration after the AVG should be lower than 0.2 mg/L, and must not be higher than 0.3 mg/L.

To monitor the treatment plants' performance, samples of the above three water quality parameters (and others[2]) are taken frequently from the raw stream water (water that feeds the plant), after the settling tank, and after the automatic valveless gravity (AVG) filter.

The presented results in this report include data from 28 September 2020 to 17 January 2021, unless otherwise stated.

Water quality improvement

The plants were typically operated with a **PACl dose** of 15 to 20 mg/L[3] during dry weather, and 15 to 35 mg/L during wet weather.

The treatment plants increase the water quality significantly in both dry weather and also wet weather. In dry weather conditions, when the streams have a low turbidity, the most noticeable

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[1] After the trial, the drinking water quality will need to comply with the Cook Islands Drinking Water Standard (CIDWS), which are currently in draft awaiting finalisation. The compliance value in the draft is 1 NTU.

[2] Other water quality parameters that were measured frequently included pH, the concentration of total coliforms, temperature, iron, manganese, and true and apparent colour

[3] 15 milligrams of PACl powder per one litre of water

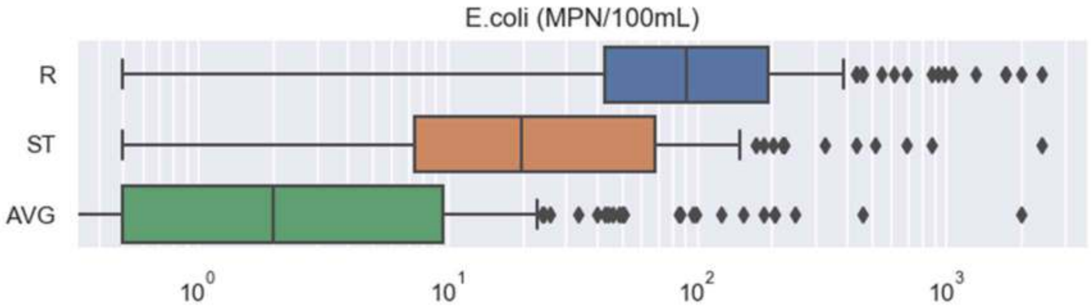
benefit of the plants is a reduction of the *E. coli* concentration (as an indicator organism for other harmful microorganisms).

During rain events, both the reduction in turbidity and E. coli is significant.

The table below summarises **turbidity** results from all plants for when the plants are treating water. All plants perform equally well in terms of turbidity removal.

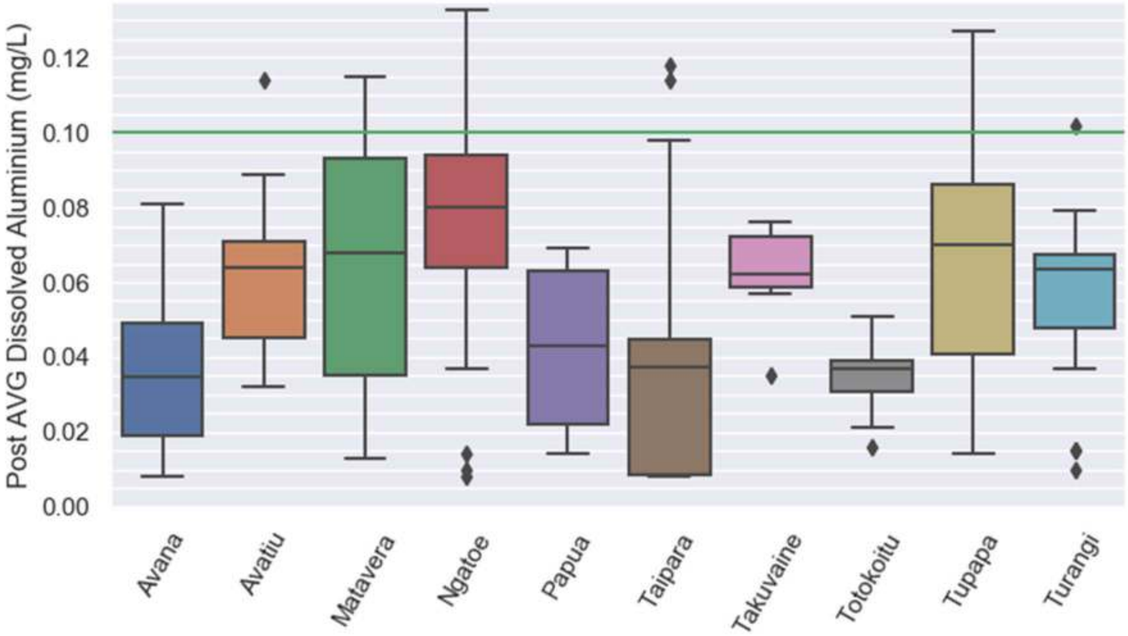
	Raw turbidity	Settled turbidity	Filtered turbidity
No of measurements	768	766	774
Average	2.01	0.84	0.38
Min	0.04	0.01	0.01
Median	0.92	0.37	0.2
Max	133	18	6

The graph below shows the reduction of ***E. coli*** through the plants. The median concentration in the raw water (R) is 90 organisms per 100 mL[4]. After the settling tank (ST), the concentration reduces to 20, and the median in the treated water (AVG) is 2. This is a significant improvement in water quality. All plants perform equally well in terms of reduction of *E. coli*.



The average **dissolved aluminium** concentration in the treated water was 0.061 mg/L, well below the maximum value of 0.3 mg/L. The highest concentration that was measured so far is 0.133 mg/L. The figure below shows the dissolved aluminium concentrations in the treated water for all plants. The green line is the target value of 0.1 mg/L. All plants perform equally well.

[4] MPN/100 mL, most probable number of E. coli in 100 mL of tested water



Results from the environmental discharge monitoring

The peak sampling has shown that all direct discharges to the streams were below the ANZECC target value of 0.055 mg/L of dissolved aluminium at 50 m below discharge.

There are a few instances where the concentration at 50 m downstream of discharge is above the ANZECC target value. In all these instances, the plants were not discharging during the time of sampling and the 50 m downstream sample was taken from the raw stream water only. The data shows that the elevated concentrations are likely caused by the natural background concentrations being elevated.

At this point, we have not seen any measurements that we believe are of environmental concern.

Water treatment residuals (sludge)

The experience from the trial so far is that the sludge is drying well in both the dedicated scour ponds and in the combined ponds[5] with duty and standby arrangements. The plants can be operated in a way that allows substantial drying in the scour and combined standby ponds, with both configurations reaching more than 14% dried solids (DS). At this point there are no concerns about the ability of either pond configuration to dry the residuals, and the removal of the dried residuals by digger or spade is feasible.

The left figure below shows the naturally dried residuals in the Tupapa standby pond (measured at 13 to 18% DS). The right figure shows dried residuals in the Ngatoe scour pond, measured at 18% DS.

[5] Scour ponds only receive residuals from the settling tank, where as the combined ponds receive residuals from both the settling tank and the AVG backwashes. Combined ponds are always in a duty – standby arrangement. The duty tank receives the frequent AVG backwashes, while the standby pond is kept dry to dry the residuals.

A preliminary estimate of the residuals production for Ngatoe and Tupapa is approx. 8 to 8.5 m^3 per year, at 15% DS in the ponds. This is based on the measured volumes during two (rather dry) months of the trial. We expect this volume to increase slightly once more data during rainier months becomes available. However, it seems that the overall residuals production of the plants is less than previously anticipated, and in a range that is manageable.

It was also noted that different plants grow in the dried residuals. An analysis of the residuals for extractable aluminium returned a concentration of less than the analytical detection limit. Based on this and other information, it is likely that the residuals could be utilised as a soil amendment in a variety of local applications, including for agricultural soils. This is currently being investigated, and laboratory analysis data and further information will be available soon.

Recommendation

Overall, there doesn't seem to be an obvious reason to stop the PACl dosing and in fact there is a strong health reason for the dosing to continue, therefore we highly recommend that the plants be kept running with PACl to provide safer water to the population of Rarotonga.

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Glossary and abbreviations

Term	Description
AVG	Automatic valveless gravity filters
Coagulation and flocculation	Coagulation and flocculation involves the addition of compounds, such as PACl, to raw water. This promotes the clumping of fine soils (dirt or silt) into larger floc (clusters) so that they can be more easily separated from the water.
Commissioning	Process of bringing new infrastructure into working condition
E. coli	*Escherichia coli* are bacteria, which almost exclusively live in the gut of warm-blooded animals (including humans). They serve as an indicator organism – if *E. coli* is detected, the likelihood that other pathogens of faecal origin are present in the water is high. Most strains of *E. coli* are not pathogenic, but there are exceptions, such as the strain O157:H7 which is very dangerous to humans.
Pathogens	Any organism that has the potential to make humans sick. The most common pathogens are viruses, bacteria, and protozoans. Other organisms of concern are endospores, fungi and helminths (parasitic worms).
PMU	Te Mato Vai's Project Management Unit.

Polyaluminium chloride (PACl)	PACl is a commonly used coagulant in water treatment systems.
Raw water	Water sourced directly from the natural environment that has not been treated or filtered in any way.
TMV	Te Mato Vai
Trunk main	Pipeline that delivers water from the treatment plants to the reticulation network. Each trunk main has a flowmeter that measures the flow from the plant to the network. No connections to the trunk main are allowed above the flowmeter.
Turbidity	Turbidity in water is caused by the presence of suspended particles that reduce the clarity of the water. Increases in turbidity measurements are often used as an indicator for increased concentrations of water constituents, such as bacteria and other pathogens.
WHO	World Health Organisation

1. Introduction

1.1 Introduction

The Te Mato Vai project constructed ten new water treatment plants (“intakes”) at different locations in Rarotonga. The plants use the coagulant Polyaluminium Chloride (PACl), settling tanks and automated valveless gravity (AVG) filters to remove dirt, sediments, and some microorganisms from the raw water.

Figure 1 – Summary of the water treatment process in the new treatment plants

As part of the commissioning process for the new plants, their performance is tested. The first goal of the testing is to ensure that the plants produce water that is treated to an acceptable standard. The second goal is to gain operational experience with the plants and find out how their performance can be optimised in different conditions. This testing was done while the plants were disconnected from the public water supply (off-line) and connected to the public supply (on-line). This test is referred to as the PACl trial.

PACl will initially be introduced for a 6-month trial period, during which the water treatment results are monitored. The results of the trial will inform the government and stakeholders how to operate the plants in the future.

1.2 Purpose of this report

This report summarises the results of the PACl trials so far and provides a recommendation as to how the plants should be operated in the future.

This report contains results detailing;

- the treated water quality of all plants
- environmental monitoring data from discharges to the environment
- observations about water treatment plant residuals ("sludge")

1.3 The PACl trial process explained

The trial has two phases – an **offline**, pre-network connected phase, and an **online**, network connected phase.

In the **offline** phase, all treated water is stored in the plant's storage tank, and no water is released to the drinking water network. The plant is only operated during working hours. This allows safe monitoring of the treated water quality without discharging it to the water supply system. The water is tested for turbidity, dissolved aluminium, pH and *E. coli*.

If acceptable results are achieved for the **offline trial,** the results are forwarded to To Tatou Vai (TTV). TTV compare the results to the World Health Organisation (WHO) drinking water standards and judge if the water is safe for human consumption. TTV decides then if the plants can be connected to the drinking water network, to start the **online** trial phase.

In the **online** phase, the plants are usually operated at all times, and the water quality monitoring continues.

Seven of the ten treatment plants go through the complete **offline** and **online** phase. Three treatment plants (Taipara, Takuvaine, Totokoitu) start directly with the **online** trial, because they do not have a storage tank, or the storage tank size does not allow sufficient time to perform the offline trial (less than a couple of hours). Those plants are started after the treated water quality results from other plants are known and the experience has been gained, making it safe to start the plants online.

Table 1 presents the dates when the PACl trials were started at each plant, and when it was connected to the drinking water network.

Table 1 – Key dates for all plants

Plant	Start of offline PACl trial	Connected to network
Ngatoe	28/09/2020	1/10/2020
Matavera	5/10/2020	8/10/2020
Tupapa	12/10/2020	16/10/2020
Turangi	19/10/2020	22/10/2020
Papua	27/10/2020	31/10/2020
Avana	2/11/2020	6/11/2020
Taipara ([1])	9/11/2020	9/11/2020
Takuvaine ([2])	16/11/2020	16/11/2020
Avatiu	23/11/2020	27/11/2020
Totokoitu ([1])	30/11/2020	30/11/2020

(1) This plant started directly to the network because it does not have a storage tank to capture the treated water.

(2) This plant started directly to the network because the storage tank size did not allow sufficient time to perform the offline trial.

1.4 Environmental conditions

The PACl trial occurred in a rather dry period, compared to the historical average (of 122 years) of the same months. Especially November, December and January were unusually dry.

Table 2 presents the monthly rainfall that was measured at the airport weather station during the PACl trial period, and Table 3 presents the long term average rainfall for each month.

The low rainfall likely means that the residuals (sludge) production in the plants during this time will also have been less than average.

Table 2 – Rainfall data (mm/month) during the trial compared to the historical average for that month

	Aug 20	Sept 20	Oct 20	Nov 20	Dec 20	Jan 21	Feb 21
Rainfall in 2020/2021	179	90	102	79	77	52	173 (*)
Historical average (122 years)	115	106	118	147	212	241	220
(*) Data collected up until 18 Feb 2021, the final monthly total will thus be higher							

Table 3 – Averaged rainfall data for each month for the past 122 years (mm/month)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
241	220	242	193	157	103	105	115	106	118	147	212

2. Treated water quality

2.1 The treated water quality requirements

During the PACl trial, the requirements for the treated water that is supplied to the drinking water network are as follows:

- The turbidity after the AVG should be lower than the raw stream turbidity.
- The E. coli concentration after the AVG generally should be lower than the raw stream concentration.
- The dissolved aluminium concentration after the AVG should be lower than 0.2 mg/L, and must not be higher than 0.3 mg/L.

If the treated water quality meets the turbidity, E. coli and dissolved aluminium requirements, it can be discharged to the drinking water network with the approval of TTV, the network operator.

After the trial, the drinking water quality will need to comply with the Cook Islands Drinking Water Standard (CIDWS), which are currently in draft awaiting finalisation.

The treatment plants are capable of delivering a treated water turbidity of below 1 NTU[6] which will meet the CIDWS.

What samples are taken during the trial

When the plants are started for the first time (**offline** or **online**), water quality samples are taken multiple times per day to monitor the treated water quality. After the plants start the online trial[7] samples are taken at least twice a week for the first month, then at least weekly for the rest of the trial period.

The plants have been designed for manual non-automated operation, based on a gravity system without power. As such all sampling is done by hand, and there are no continuous data measurements.

2.2 Turbidity

Table 4 presents summary statistics for the turbidities over all plants from the start of the trial until 17 January 2021. The raw data is shown in the individual plant reports in Appendix A. The data shows a clear reduction in turbidity for each plant. The reporting period contained a few dirty water (rain) events. The plants generally handled those well. The next section 2.3 provides further detail on operation during rain events.

Table 4 – Turbidity summary statistics in NTU for all plants from the start of the trial until 17 Jan 2021, when plants were treating water.

	Raw turbidity	Settled turbidity	Filtered turbidity
No of measurements	768	766	774
Average	2.01	0.84	0.38
Std Dev	6.72	1.70	0.65
Min	0.04	0.01	0.01
5%	0.29	0.07	0.02
25%	0.55	0.25	0.12
50%	0.92	0.37	0.2
75%	1.53	0.72	0.39
95%	5.09	2.99	1.17
Max	133	18	6

[6] Nephelometric turbidity unit, a standard measurement for cloudiness or haziness of water, caused by large numbers of individual particles that are generally invisible to the naked eye, similar to smoke in air. The measurement of turbidity is a key test of water quality.

[7] For plants that start directly with the online trial, the testing frequency is initially high until the treated water quality is stable. After a few days, the testing frequency follows the above described pattern.

Figure 2 presents a boxplot with statistical data for the post AVG turbidity for all plants. The box represents the 25th and 75th percentile, and the line within the box the median value. All plants perform equally well in terms of turbidity removal, and there are only a few measurements above 1 NTU in the treated water. The Papua graph is based on 23 measurements, and most of them originate from the plant start up, which is why the box shows a wider range of values than the other plants. Shortly after its trial start, Papua was unfortunately shut off due to a lack of network demand. It was restarted on 27 January. Since then, the average post AVG turbidity was around 0.25 NTU.

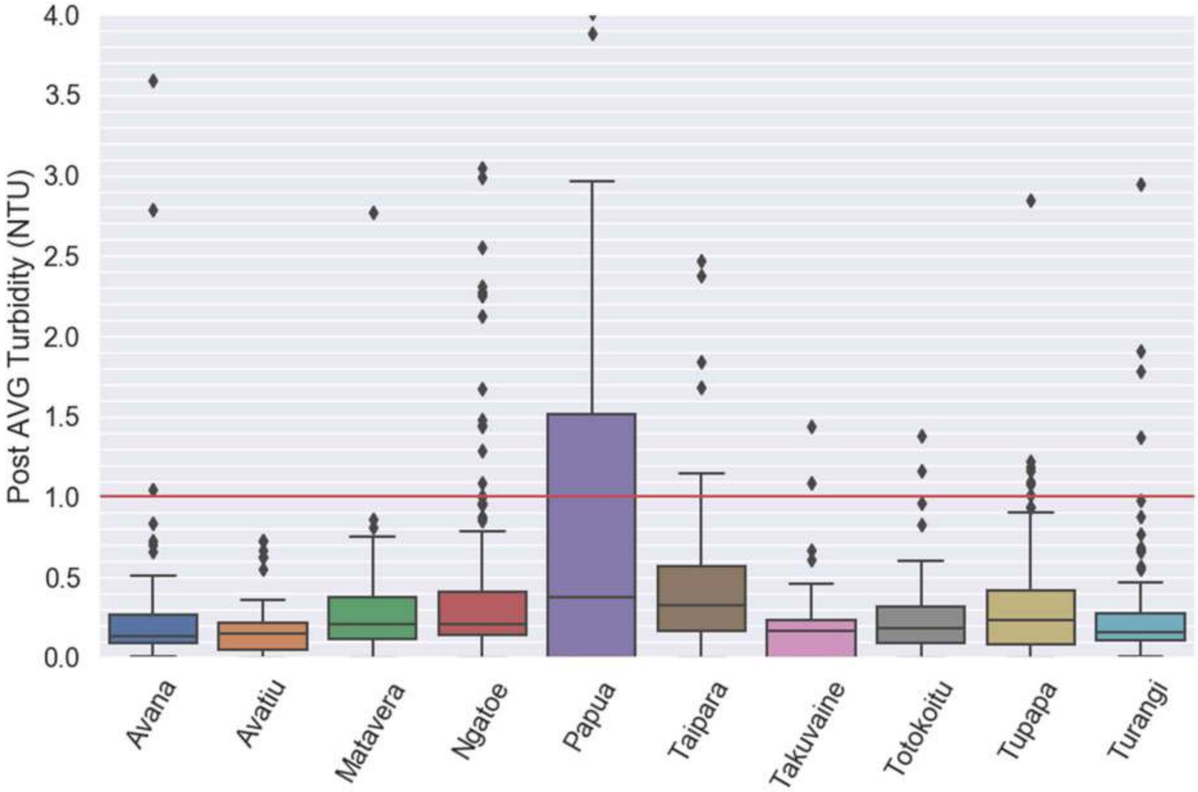


Figure 2 – Statistical plots for the post AVG turbidity for each plant from start of trial to 17 January 2021, when plants were treating water.

NB: A few values are outside the graph limits, the highest being 6 NTU. See report text for an explanation for Papua.

2.3 Operation during dry weather and rain weather

During dry weather periods, the plants were mostly operated with a PACl dose of 15 mg/L[8]. During rain events in the trial period so far, the plants were mostly operated with PACl dose rates between 15 and 35 mg/L. The turbidity results during rain weather are slightly higher than during dry weather, but still acceptable.

Monitoring by the contractor was not specified to include high frequency collection of samples, and typically concerned plant performance over a longer duration. As such there is limited high frequency data available that shows the turbidity development through the plant during a rain event.

To address this, the project management unit (PMU) carried out one dedicated measuring campaign at the Totokoitu plant for a large rain event on 18 Feb 2021.

[8] 15 milligrams of PACl powder per litre of water

Totokoitu rainfall data from 18 Feb 2021

On 18 Feb 2021, a total of 84.5 mm of rain fell (measured by the airport). The maximum intensity was between 2 and 3 am, with 33 mm measured in that hour.

The Totokoitu PACl dose was set to 25 mg/L, and turbidity (and pH and dissolved aluminium) measurements were taken throughout the day. Figure 3 presents the results of those measurements.

Just before 11:00 am, it was discovered that the PACl dosing bar was partially blocked and the PACl flow was significantly reduced[9]. The dose could have been lower than 5 mg/L. The treated turbidity during this time was above 5 NTU, which is sub optimal. The PACl dosing bar was unblocked once the issue was discovered.

Following a jar test, the PACl dose was set to 35 mg/L at around 11:00 am. The settling tank and AVG turbidity improved significantly from around 3:00 pm onwards, despite the stream turbidity remaining high. This lag matches the hydraulic residence time in the settling tank of around 3 to 3 and a half hours.

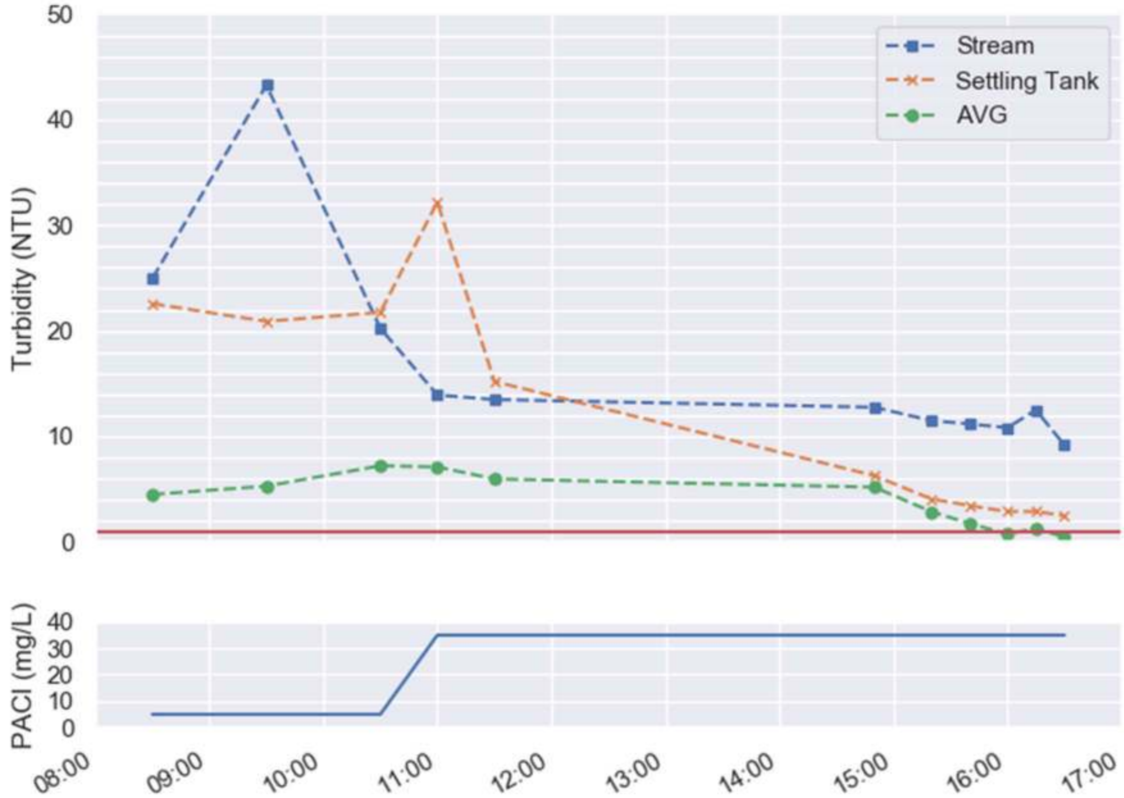


Figure 3 – Turbidity measurements during a heavy rain event (Totokoitu, 18 Feb 2021)

NB: The red line in the top figure shows the 1 NTU target value for the treated turbidity. See text for further details

2.4 PACl dose rates

The PACl dose rates during the trial so far ranged from 10 to 40 mg/L (as solid PACl). During dry weather, the PACl doses are set to mostly 15 or 20 mg/L, and are increased during rain events.

[9] The PACl dosing bars were modified as a result of this observation, and no more blockages were observed since then.

Table 5 presents statistics for the used PACl doses for all plants between the start of the trial and 17 Jan 2021.

Table 5 – PACl dose statistics for all plants from the start of the trial until 17 Jan 2021

	PACl dose (mg/L as active)
No of measurements	479
Average	20.4
Min	10
50%	20
Max	40

2.5 Dissolved aluminium

The average dissolved aluminium in the treated water is 0.061 mg/L, and the highest concentration was 0.133 mg/L. Those concentrations are well below the maximum value of 0.3 mg/L. Table 6 presents the measured data for all plants, when the plants were treating water.

Table 6 – Dissolved aluminium summary statistics in mg/L for all plants from start of the trial until 17 Jan 2021, when the plants were treating water.

	Stream	Post Settling Tank	Post AVG
No of measurements	83	145	165
Average	0.024	0.074	0.061
Std Dev	0.033	0.040	0.029
Min	0.003	0.008	0.008
5%	0.008	0.016	0.013
25%	0.012	0.051	0.038
50%	0.018	0.074	0.064
75%	0.023	0.090	0.079
95%	0.061	0.124	0.112
Max	0.280(1)	0.286(2)	0.133

(1) Measured at Turangi on 21 Oct 2020. The next highest measurements are 0.170 and 0.150, also at Turangi.

(2) Measured at Ngatoe on 19 Oct 2020. The next two highest measurements are 0.284 and 0.172

Figure 4 presents a boxplot[10] with statistical data for the post AVG dissolved aluminium concentration for all plants while they were operating. All plants are generally below the 0.1 mg/L target value.

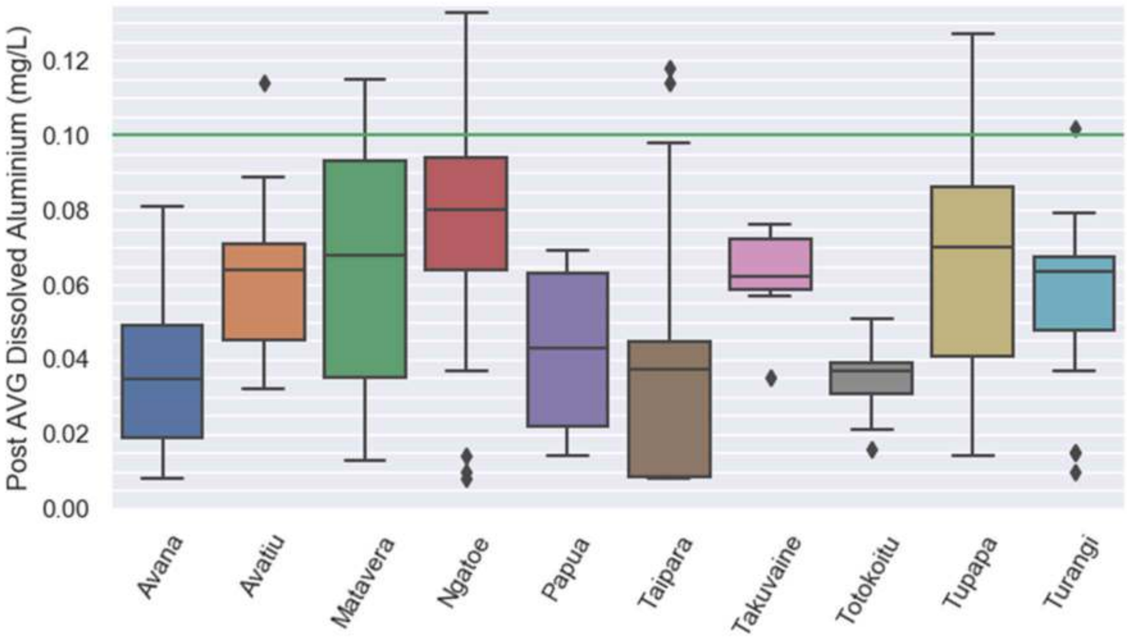


Figure 4 – Statistical plots for the post AVG dissolved aluminium (mg/L) for each plant from the start of the trial to the 17 January 2021, when the plant was treating water.

NB: The green line represents 0.1 mg/L.

2.6 Escherichia coli (*E. coli*)

Table 7 presents the measured *E. coli* concentrations for all plants when water was treated with PACl.

The data shows that the *E.coli* concentration in the settling tank and post AVG is significantly lower than the concentrations in the stream – PACl removes a significant fraction of the microorganisms, but cannot remove them completely.

Table 7 – *E. coli* summary statistics in most probable number (MPN) / 100 mL for all plants from start of the trial until 17 Jan 2021, when plants were treating water.

	Stream	Post Settling Tank	Post AVG
No of measurements	101	102	110
Average	240.3	88.7	41.7
Std Dev	429.3	268.2	197.3
Min	< 1	< 1	< 1

10 The box represents the 25th and 75th percentile, and the line within the box the median value

	Stream	Post Settling Tank	Post AVG
5%	16.0	1.0	< 1
25%	42.6	7.4	< 1
50%	90.8	19.8	2.0
75%	193.5	67.7	9.6
95%	1,046.2	320.5	171.6
Max	2,419.6(2)	2,419.6	1,986.6(1)

(1) Measured at Taipara on 9 Nov 2020. The next highest measurement is 461.1 (at Papua on 3 Nov 2020)

(2) Measured at Turangi on 20 Oct 2020 and the corresponding post AVG was < 1 MPN/100mL

Figure 5 presents a boxplot[10] with statistical data for the *E. coli* concentrations (MPN/100 mL) in the raw water, post settling tank and post AVG for all plants. All plants perform equally well in terms of reduction of *E. coli*.

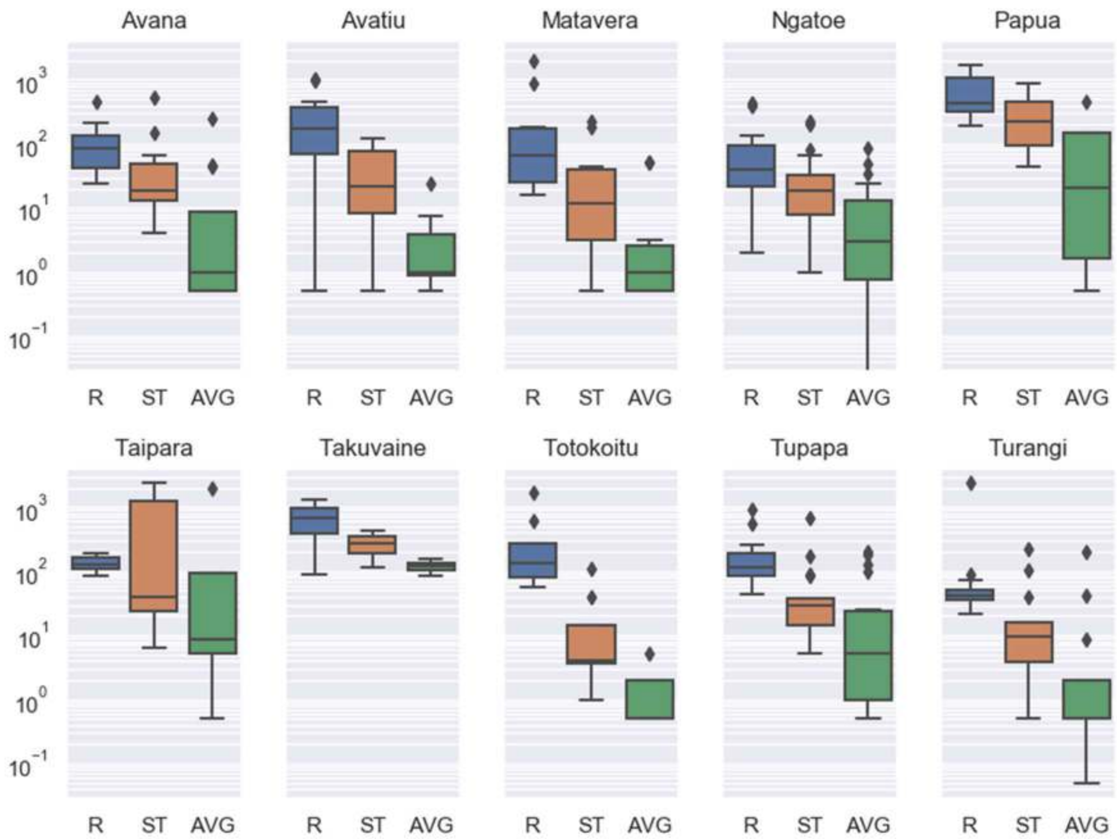


Figure 5 – *E. coli* concentrations (MPN/100 mL) in the raw water (R), post settling tank (ST) and post AVG for each plant, when plants were treating water.

Taipara and Takuvaine were on bypass for some time during the trial period, and there is limited data available (refer to the monthly reports in Appendix A). For Taipara, the latest post January and February 2021 results for the post AVG *E. coli* concentration (not part of this data set) are 7 MPN/100 mL. The Takuvaine graph is only based on two measurements from the first two days when the plant was started. We have no concerns about Takuvaine's performance, data of which will be included in future reports.

2.7 pH

The pH of treated water should usually be between 6.5 and 8.5. Table 8 presents summary statistics for the pH values measured across the plants, from the start of the trial until 17 January 2021. The treated water pH is mostly influenced by the raw water pH. As expected, the addition of PACl decreases the pH slightly, but not significantly.

Table 8 – pH summary statistics for all plants from start of the trial until 17 Jan 2021, when the plants were treating water.

	Stream	Post Settling Tank	Post AVG
No of measurements	274	253	283
Average	7.4	7.2	7.2
Std Dev	0.4	0.3	0.3
Min	6.0	6.2	6.2
5%	6.8	6.7	6.7
25%	7.1	7.0	7.0
50%	7.3	7.2	7.2
75%	7.7	7.4	7.4
95%	8.0	7.7	7.8
Max	8.4	9.0	8.2

2.8 Conclusions

Overall, the treatment plants increase the water quality compared to the stream water. Figure 6 presents the difference in raw and treated turbidity, and *E. coli*.

In dry weather conditions, when the streams have a low turbidity, the most noticeable benefit of the plants is a reduction of the *E. coli* concentration (as an indicator organism).

During rain events, both the reduction in turbidity and *E. coli* is significant.

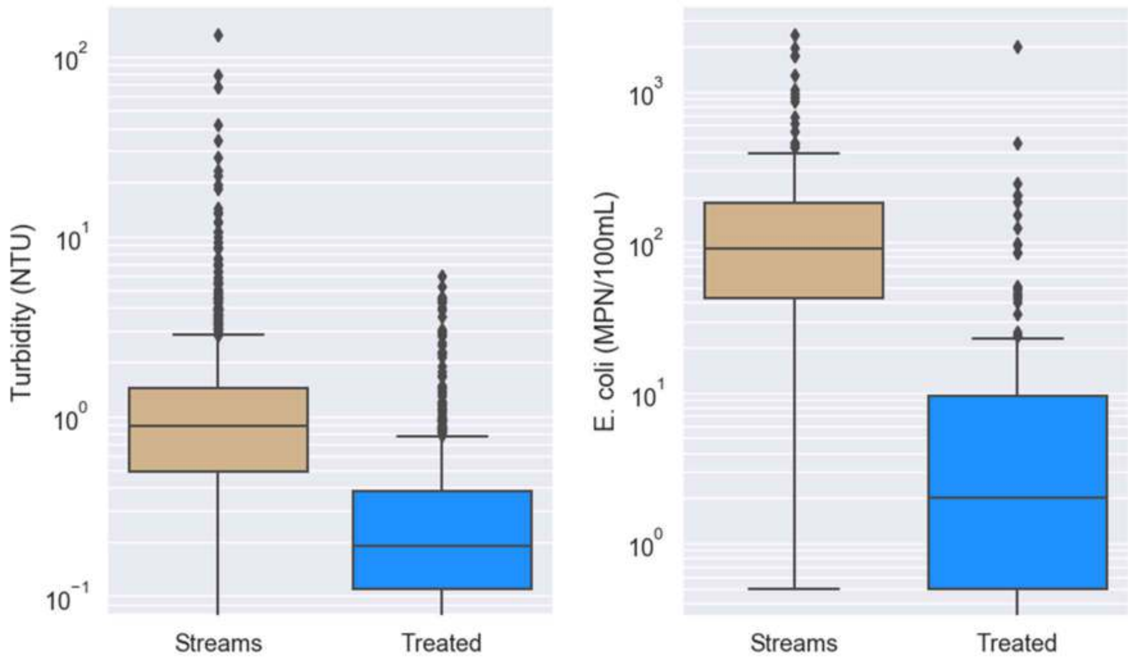


Figure 6 – Improvement of water quality in terms of turbidity and E. coli during the trial (data until 17 Jan 2021)

In summary, the plants successfully meet the treated water requirements. The turbidity is below 1 NTU in almost all cases, the plants significantly reduce the number of *E. coli* in the treated water, and the average dissolved aluminium concentration across all plants is 0.064 mg/L, well within the target range.

3. Treated water quantity

The water output of the plants is measured by the magflow meter after the AVG filter. For most plants, the magflow measures the water flow even when the settling tank and/or the AVG filter themselves are bypassed.

Table 9 presents the average flow through the plants, from 29 October 2020 to 14 February 2021. The data originates from a more or less daily reading of the flowmeter after the AVG. It includes days when the plants were operational, and also days when they were on bypass[11]. It does not include days where the streams were too low to abstract water. The mean flow is compared to the design flow of the plants. Overall, during this period, approximately 76% of the theoretical maximum design flow was delivered.

This period includes an unusually dry November, December and January, where the available water was limited by the low stream flow for some intakes.

Table 9 – Average flow taken from streams between 29 October 2020 and 14 Feb 2021

Plant	Mean flow	Design flow	Design flow	Mean flow as a percentage of design flow

[11] When on bypass, water is still abstracted through the intake structure, but it bypasses the settling tank and AVG (and no PACl is dosed). It is still measured at the magflow meter before going into the supply network.

	(L/s)	(L/s)	(m^3/d)	
Avana	22.5	39.4	3,400	57 %
Avatiu	13.1	23.1	2,000	56 %
Matavera	14.4	13.9	1,200	104 %
Ngatoe	15.8	23.1	2,000	68 %
Papua	18.9	23.1	2,000	82 %
Taipara	21.0	13.9	1,200	151 %
Takuvaine ([1])	n/a	34.7	3,000	37 %
Totokoitu	11.0	23.1	2,000	47 %
Tupapa	15.9	13.9	1,200	114 %
Turangi	26.0	34.7	3,000	75 %
Overall			21,000	76 %
([1]) This plant was put on bypass shortly after the start of its PACl trial and remained on bypass until mid February				

4. Discharges to the environment

4.1 Introduction

The plants discharge supernatant from the ponds to the streams. The water going into the ponds originates from the AVG backwashes (approximately once every day), or from the less frequent de-sludging of the settling tanks.

Some plants have three ponds in total – one scour pond (which receives the settling tank residuals), and two AVG backwash ponds (which receive the AVG backwash water). Other plants have two ponds which receive water from both sources. Refer to Table 10 for the configuration of each plant.

De-sludging of the settling tanks is a manual operation that will always be carried out under operator supervision. The discharge of the supernatant to the stream will also be carried out under operator supervision.

The AVG backwashes occur automatically. Each pond has a decant arm which floats on the top of the pond, and slowly discharges the top water layer to the stream. This provides time for any solids in the AVG backwash that discharges to settle. Currently the discharge of AVG backwash water to the streams is a manual process (the decant arms stay up, or are plugged until an operator manually lowers them, or opens the outlet). Eventually it is anticipated that the decant arms will be left floating on the pond surface free to drain once the operational EIA has determined the long term allowable dissolved aluminium levels that can be discharged without environmental harm.

Table 10 – Pond configuration for each plant

Plant	Two AVG backwash ponds (duty / standby)	Single scour pond	Two combined AVG backwash / scour ponds (duty / standby)
Avana	no	no	yes
Avatiu	yes	yes	no
Matavera	no	no	yes
Ngatoe	yes	yes	no
Papua	no	no	yes
Taipara	no	no	yes
Takuvaine	yes	yes	no
Totokoitu	no	no	yes
Tupapa	no	no	yes
Turangi	no	no	yes

During the PACl trial (and afterwards), the dissolved aluminium concentrations, pH and turbidity in both the ponds and the stream were measured to understand the impact of the plants on the streams.

Two sampling methods are used when sampling in the streams.

Peak sampling is undertaken during a discharge from the pond to the stream. The sample is taken at a time when the discharged water from the pond has reached the specific sample location[12].

Background samples are taken in the stream, but not necessarily when a discharge from the ponds to the stream occurs. They measure how the background concentration in the stream is influenced by the infrequent pond discharges, as well as the natural dissolved aluminium level upstream of the treatment plants.

The environmental sampling is done weekly for the first month of the trial, then fortnightly for the remainder of the trial. During the trial, the PMU will collect at least two peak samples per plant.

The stream sampling locations are listed in Table 11 below and presented in Appendix B.

Table 11 – Stream sampling locations

Sample point in the stream	Peak sampling	Background sampling
Ponds	yes	yes
20m above the discharge point	yes	yes

[12] We use a floating object to determine when pond water has reached the specific location. The floating object is used to determine the velocity of the stream. Considering this velocity and the distance to the sampling point, we calculate the earliest time that the pond discharge will reach the sampling point.

Sample point in the stream	Peak sampling	Background sampling
At the point of discharge	yes	no
20m below the discharge point	yes	yes
50m below the discharge point (1)	yes	yes
Midway to the lagoon	yes	no
100m above the lagoon	yes	no
(1) This is the compliance point where the target concentration should not be exceeded		

4.2 Environmental limits and background concentration

The impact associated with the use of PACl in water treatment is related to the bioavailability of aluminium in the receiving environment. Aluminium bioavailability is directly correlated with the concentration of the actively toxic form of aluminium (Al^{3+}) in the discharged water. Factors such as pH, dissolved organic carbon (DOC), temperature and hardness regulate the solubility of Al^{3+} in water, with pH having the greatest influence on toxicity. The solubility of Al^{3+} drastically increases at a pH lower than 5.5 or higher than 9. However, solubility is very low when pH is between 5.5 and 9[13]. This is the reason why pH is measured alongside dissolved aluminium.

The ANZECC guideline value for dissolved aluminum in streams is less than 0.055 mg/L. The TMV project's goal is that the discharges from the treatment plants to the streams do not cause harm to the environment. As a result, the initial target value is set to 0.055 mg/L at 50 m below the discharge point.

As outlined in section 2.1, the target aesthetic guideline value for dissolved aluminium in the drinking water is below 0.2 mg/L, and must not be above 0.3 mg/L. Both values are significantly higher than the conservative ANZECC guideline value.

The September 2020 Te Mato Vai Aquatic Ecology Baseline Report concluded that dissolved aluminum levels of up to 0.290 mg/L or greater (potentially up to 0.630 mg/L) would not result in environmental harm.

Monitoring during the trial and some historic readings have shown that the natural dissolved aluminum concentrations can be greater than the ANZECC limit, when measured upstream of the treatment plants (i.e. unaffected by any previous discharges from the plants). The highest naturally occurring dissolved aluminum concentration upstream of the plants measured to date is 0.280 mg/L at Turangi (refer also to Table 6). We observed that elevated concentrations are often concurrent with rainfall events, but not always. Some high concentrations were measured several days after the last rainfall.

Figure 7 presents all dissolved aluminium concentrations that were measured upstream of the plants between the start of the PACl trial and 15 Feb 2021. The elevated concentrations are visible at all sample locations.

[13] Refer to the Te Mato Vai Aquatic Ecology Baseline Report from September 2020

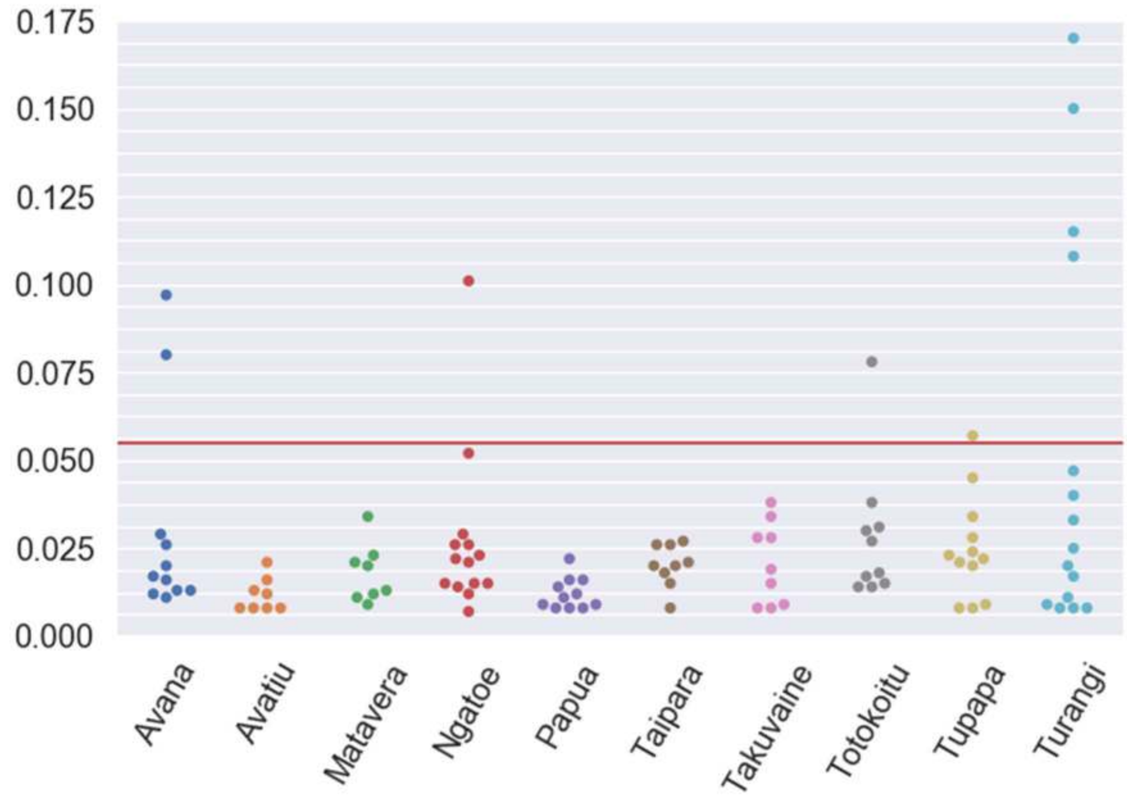


Figure 7 – Dissolved aluminium concentration (mg/L) in the streams, upstream of the intakes (data from 7 Oct 2020 to 15 Feb 2021).

NB: The red line shows the 0.055 mg/L target value in the stream for discharges from the plants

4.3 Water quality in ponds

The settling tank de-sludging process produces more residuals in the ponds than the AVG backwash process. The measurements during the trial allow a comparison of the supernatant quality of both processes. However, the concentrations in the ponds are ultimately less important because the compliance point for discharges to the environment is in the streams, 50 m downstream of the pond discharge point.

All results from the AVG filter backwash ponds and discharges to the stream are presented as part of the monthly reports in Appendix A.

To date, there is more data available for AVG backwashes than for the de-sludging of the settling tanks. The de-sludging has occurred at most twice for each plant so far, where as AVG backwashing occur almost daily.

For plants with combined AVG and scour ponds, once the ponds received settling tank residuals from the de-sludging process, all subsequent measurements were put into the “de-sludging” category.

Figure 8 presents the dissolved aluminium concentrations and the pH for supernatant in the pond that originates from the AVG backwashes and the de-sludging of the settling tanks. The three highest dissolved aluminium values for the de-sludging were measured at Tupapa. The single pH point was also measured at Tupapa, when the dissolved aluminium concentration in the pond was 0.148 mg/L.

The data suggests that the dissolved aluminium concentrations may generally be slightly higher for de-sludging of the settling tanks compared to the AVG backwashes. However, the difference does not seem to be overly significant, and did not result in higher stream dissolved aluminium concentrations, as section 4.4 will show.

The pH concentrations are also within normal ranges and well within the pH 5.5 to 9 range where aluminium is generally less soluble.

Table 12 presents summary statistics for the dissolved aluminium, pH and turbidity concentrations for pond supernatant for both processes over all ten plants.

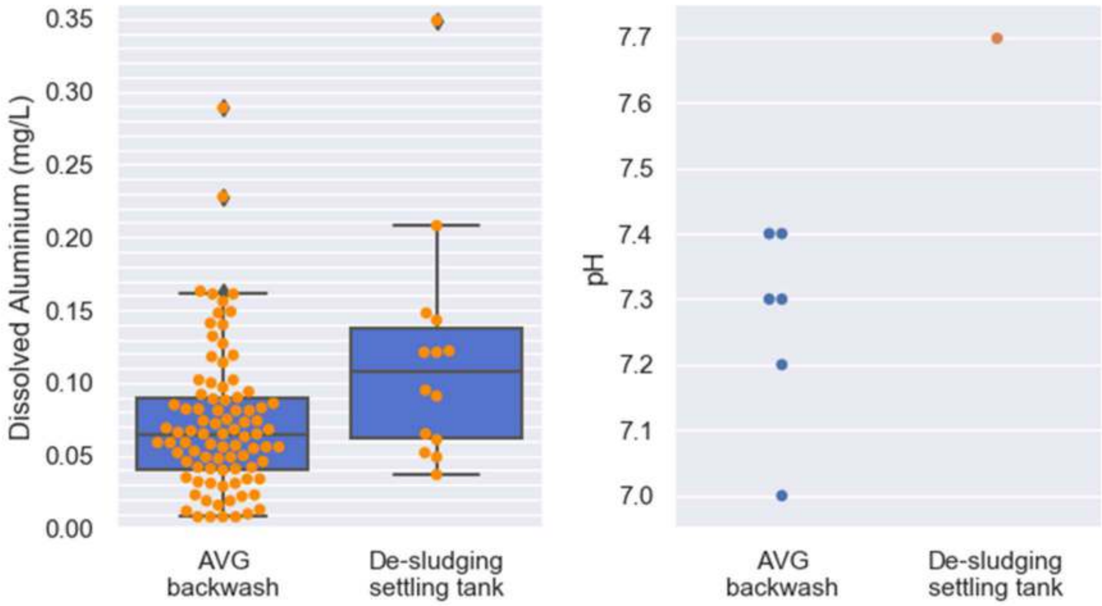


Figure 8 – Comparison of dissolved aluminium and pH in pond supernatant for the AVG backwash process and settling tank de-sludging process

Table 12 – Pond summary statistics for all plants from start of the trial until 17 Jan 2021.

	Dissolved Aluminium (mg/L)	pH	Turbidity (NTU)
No of measurements	99	7	7
Average	0.080	7.3	7.8
Std Dev	0.057	0.2	16.0
Min	0.008	7.0	1.0
5%	0.013	7.1	1.0
25%	0.044	7.3	1.4
50%	0.067	7.3	1.7
75%	0.099	7.4	2.4
95%	0.161	7.5	31.6

	Dissolved Aluminium (mg/L)	pH	Turbidity (NTU)
Max	0.349	7.7	44.1

4.4 Measurements in the streams

The raw data for peak samples and background samples are contained in the individual monthly reports for each plant (refer to Appendix A).

Table 14 contains the results of all peak sampling measurements that were carried out up to the writing of this report. The outstanding peak samples (two per) will be collected before the end of the trial.

There are a total of 29 pH measurements for the ponds and the stream locations. All pH were within the range of 7 and 7.7.

The monitoring of releases from the treatment plant has shown that at 50 m downstream of the point of release, no elevation of dissolved aluminum is occurring as a result of any discharge, with results consistently showing lower readings than in the ponds.

There are a few instance where the level at 50 m downstream of discharge is above the ANZECC target value. All those instances are listed in Table 13. The treatment plants were not discharging during the time of sampling and the 50 m downstream sample was taken from the raw stream water only. The data shows that the elevated concentrations are likely caused by the natural background concentrations being elevated (refer also to section 4.2).

Table 13 – Samples where the dissolved aluminium concentration is above 0.055 mg/L 50 m downstream of the discharge point.

NB: The plants did not discharge to the stream at the time, and the reason for the elevated concentrations is most likely the concentration in the stream itself.

Intake	Date	Pond 1 (upper)	Stream, upstream	Stream, at pond	Stream, 20m down-stream	Stream, 50m down-stream	Stream flow (L/s)
Ngatoe	2020-11-02	0.100	0.101			0.074	
Turangi	2020-11-25	0.063	0.150		0.097	0.143	15
Turangi	2020-11-26	0.065	0.170	0.125	0.158	0.086	15
Turangi	2020-12-07	0.049	0.108	0.105	0.090	0.079	10
Avana	2021-02-02	0.121	0.080		0.084	0.069	25
Avana	2021-02-02	0.122	0.097		0.075	0.087	25

The dissolved aluminium concentrations along the streams that were measured so far during the trial are presented in Figure 9.

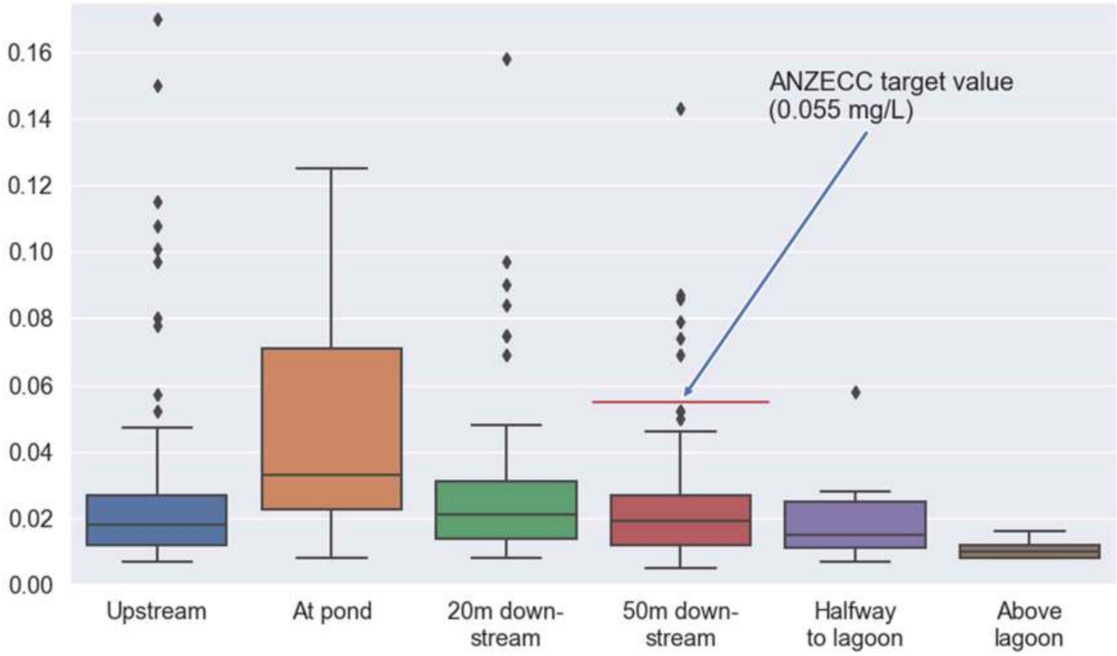


Figure 9 – Dissolved aluminium concentrations (in mg/L) along all streams, including peak and background samples.

NB: Instances where the concentration exceeded 0.055 mg/L 50 m downstream are described in Table 13.

Table 14 – Peak stream sample results for dissolved aluminium to date of report (in mg/L)

Intake	Date	Pond 1 (upper)	Pond 2 (lower)	Scour Pond	Stream, upstream	Stream, at pond	Stream, 20m down	Stream, 50m down (#)	Stream, halfway to lagoon	Stream, 100m above lagoon	Stream flow (L/s)
Ngatoe	2020-10-07	0.083	0.102		0.022	0.023	0.026	0.008	0.008	0.008	
Matavera	2020-10-09	0.118	0.102		0.009	0.027	0.033	0.016	No flow	No flow	
Ngatoe	2020-10-12	0.016	0.049		0.012	0.020	0.016	0.015	0.015	0.014	
Tupapa	2020-10-16	0.082			0.009	0.022	0.025	0.022	No flow	No flow	
Turangi	2020-10-22	0.074			0.017	0.040	0.026	0.027	No flow	No flow	
Papua	2020-10-30	0.013			0.008		0.008	0.008	0.008	0.008	
Avana	2020-11-05	0.067			0.017	0.104	0.014	0.005	0.007	0.011	65
Taipara	2020-11-12		0.058		0.008	0.082	0.035	0.044	0.011	0.009	20
Takuvaine	2020-11-19	0.075			0.038	0.030	0.012	0.027	0.058	0.016	14
Avatiu	2020-11-26	0.086			0.008	0.034	0.034	0.031	0.025	0.011	15
Ngatoe	2020-12-02			0.061	0.014	0.037	0.019	0.027	0.011	0.008	20
Totokoitu	2020-12-03	0.019	0.040		0.018	0.018	0.037	0.037	0.025	0.012	80
Turangi	2020-12-23		0.023		0.025	0.026	0.042	0.034	No flow	No flow	20
Totokoitu	2021-01-20	0.010	0.019		0.078	0.054	0.032	0.013	0.028	0.027	15
Totokoitu	2021-01-22	0.053	0.022		0.038	0.076	0.041	0.052	0.016	0.020	10

(#) Compliance point, target value 0.055 mg/L dissolved aluminium

4.5 Settling tank overflow test results

Introduction

The settling tank at each plant is designed to overflow at the inlet if there is low demand to return raw stream water back to the stream. As part of the court appointed expert witness review it was agreed to manually trigger an overflow in at least one of the high-energy intakes[14] and a low energy intake, as part of the trial and test the water to ensure water with elevated dissolved aluminium was not passing back into the stream. Environmental testing for dissolved aluminium was undertaken at three locations

- in the settling tank overflow chamber
- in the stream, upstream of the discharge point, and
- in the stream, 50 meters downstream of the discharge point.

Testing was undertaken at the beginning of the overflow, after 1 hour and then after 2 hours of continuous overflow.

Results

Results of the overflow test are presented in Table 15 and Table 16. They confirm that dissolved aluminium concentrations are not elevated within the overflow chamber. The dissolved aluminium concentrations in the stream were below the limit during the test.

Note that 0.008 mg/L is the limit of detection – the actual concentration could be lower than that.

Significance

The test results prove that the plants operate as designed with regards to the automatic PACl shut-off mechanism, and that any discharges of dissolved aluminium to the stream are minimal. The shut-off mechanisms are working well and no issues have been observed so far.

Table 15 – Settling tank overflow test results for Ngatoe

Time	Settling tank overflow chamber	In stream (upstream of discharge)	In stream (50 m downstream)	Less than 0.055 mg/L target value
Start of overflow	0.008	0.008	0.008	OK
After 1 hour	0.008	0.008	0.023	OK
After 2 hours	0.013	0.019	0.009	OK

Table 16 – Settling tank overflow test results for Papua

Time	Settling tank overflow chamber	In stream (Upstream of discharge)	In stream (50 m downstream)	Less than 0.055 mg/L target value
Start of overflow	0.008	0.016	0.016	OK
After 1 hour	0.008	0.008	0.008	OK
After 2 hours	0.008	0.008	0.017	OK

[14] The high-energy intakes according to the expert witness are Avatiu, Papua, Taipara, Takuvaine, Totokoitu, and Turangi.

4.6 Conclusions

So far, the peak sampling has shown that all direct discharges to the streams were below the target value of 0.055 mg/L of dissolved aluminium at 50 m below discharge.

Some streams have at times natural dissolved aluminium concentrations that are above the target value. This would suggest that the flora and fauna in the stream is accustomed to those elevated concentrations. The ecological stream assessment[13] also suggests that the environment can tolerate higher concentrations than the conservative 0.055 mg/L, up to as high as 0.630 mg/l for short durations.

The measurements for dissolved aluminium will continue accordingly for the trial duration. At this point, we have not seen any measurements that we believe are of environmental concern.

5. Water treatment residuals (sludge)

5.1 Introduction

During the process of treating the water, the Te Mato Vai water treatment plants remove dirt, solids and microorganisms from the source water with the help of PACl. This creates a waste product called residuals or sludge. Over time, the residuals accumulate in the settling tank. The residuals are then discharged to the scour pond or combined ponds, in a process called de-sludging.

The backwashing of the AVG produces a (significantly) smaller fraction of residuals[15]. These are regularly discharged into the AVG backwash or combined ponds, whenever the AVG backwashes.

The environmental sampling of both discharges is described in the previous section 4.

Table 17 presents the date of the first de-sludging activity for each plant.

Table 17 – Dates of the first de-sludging of the settling tank for each plant

Plant	Start of PACl Trial	Desludging of settling tank
Avana	2/11/2020	22/12/2020
Avatiu	23/11/2020	21/01/2021
Matavera	5/10/2020	27/11/2020
Ngatoe	28/09/2020	1/12/2020
Papua	27/10/2020	3/12/2020
Taipara	9/11/2020	17/12/2020
Takuvaine	16/11/2020	10/12/2020
Totokoitu	30/11/2020	19/01/2021
Tupapa	12/10/2020	8/12/2020

[15] Because most of the particles were removed in the settling tank and do not reach the AVG.

Plant	Start of PACI Trial	Desludging of settling tank
Turangi	19/10/2020	21/12/2020

5.2 Pond configurations and management (scour, AVG, combined)

As already described in section 4.1 and Table 10, there are two possible pond configurations for each plant. Ngatoe, Avatiu and Takuvaine have a dedicated scour pond (for settling tank sludge) and two AVG backwash ponds (duty and standby pond). All other plants have two combined AVG backwash and settling tank residuals ponds (duty and standby pond). The plants are operated so that the duty pond receives the AVG backwash and the standby pond receives the desludging residuals which allow the residuals to dry.

Figure 10 – Tupapa combined ponds

Figure 11 – Ngatoe scour pond

5.3 Residuals production

Settling tank de-sludging frequency

During the trial, we observed anaerobic[16] activity in the residuals at the bottom of the settling tank. The restriction of oxygen is influenced by the depth of the residuals within the tank, and the formation of new residuals that act as a blanket. It is estimated that the anaerobic activity may start at residuals depth of greater than around 300 to 500 mm. Issues with taste and odour can then occur if the plant is stopped and water left to stagnate. Desludging more frequently can assist to limit the anaerobic build-up of residuals.

The second factor that influences the de-sludging frequency is the volume of residuals in the settling tank. As the residuals volume increases, the hydraulic retention time (HRT) and thus settling time decreases, resulting in floc carry over to the AVG. This increases the AVG backwash frequency.

Overall, it is recommended that the settling tanks should be de-sludged every four to six weeks to keep the plants operating at their optimum.

Residuals production in the settling tanks

The build-up and total suspended solids (TSS, g/m^3) concentration of residuals in the settling tank over time was measured with a Cerlic multi tracker, with multiple measurements taken along the length of the settling tank to determine a residuals depth profile. Table 18 and Table 19 summarise the measurements and calculations for Ngatoe and Tupapa, respectively, from

[16] In the absence of free oxygen

the start of operation until shortly before the first settling tank de-sludging. This includes roughly the months of October and November 2020.

Separate volumes and TSS were measured for the lighter residuals blanket ("fluff") and for the heaver sludge. The combination of volumes (m^3) and TSS (g/m^3) allows an estimation of the total dried solids (DS) that are deposited in the settling tank over time. By assuming a drying performance of 15 %DS (150 kg DS/1000 kg residuals) in the ponds, the total annual residuals volume can be estimated. As the residuals blanket evolves over time, so does the estimate for the total volume per year. Averaging the numbers in the last column of Table 18 and Table 19 results in 7.9 m^3/year for Ngatoe and 8.3 m^3/year for Tupapa.

However, the residuals production depends on the raw water quality, with more residuals produced during the wetter months of the year. We expect that the actual volume over a whole year will be higher than those figures. For a rough estimate, if residuals production were proportional to rainfall amount, we would expect those volumes to increase by approximately 80% (refer to Table 3).

Overall, this calculation depends on a few simplifications and parameters that were not determined with absolute precision (volume and TSS concentration in the sludge blanket). The drying performance of 15% DS is a realistic estimation (refer to section 5.4).

Table 18 – Estimated sludge production at Ngatoe.

Days in operation	Volume fluff (m^3)	Volume sludge (m^3)	Total dried solids (kg)	Total volume at 15% DS (m^3)	Est. total volume per year (m^3)
31	6.5	29.5	78.4	0.5	5.6
34	1.5	51.9	130.8	0.8	8.5
42	2.2	44.3	181.8	1.1	9.6
47	5.4	45.2	191.4	1.2	9.0
51	4.2	46.4	193.8	1.2	8.4
56	9.6	35.3	160.4	1.0	6.3

NB: The average of the last column is approx. 7.9 m^3/year

Table 19 – Estimated sludge production at Tupapa.

Days in operation	Volume fluff (m^3)	Volume sludge (m^3)	Total dried solids (kg)	Total volume at 15% DS (m^3)	Est. total volume per year (m^3)
11	6.0	5.6	28.2	28.2	5.7
23	6.5	31.6	139.6	139.6	13.4
24	11.3	20.3	103.7	103.7	9.6
30	23.2	15.1	106.8	106.8	7.9
34	28.4	13.1	109.1	109.1	7.1

39	5.7	36.5	157.2	157.2	8.9
44	13.9	31.9	155.4	155.4	7.8
51	16.8	26.5	139.5	139.5	6.1

NB: The average of the last column is approx. 8.3 m^3/year

Residuals production from the AVGs

The production of residuals by the AVGs was not measured separately, but as observed during the trial and as expected, it is a far smaller fraction compared to the production in the settling tanks.

5.4 Residuals drying in the ponds

The residuals drying conditions are slightly different in the dedicated scour ponds and the combined ponds. For the plants to operate as intended, it is important that reasonable dried sludge is produced by both types of ponds.

This section contains visual observations of the drying in both type of ponds, dried solids measurements data, and information from a shaking test, and two spadeability tests.

Drying in a dedicated scour pond

Ngatoe has a dedicated scour pond. The settling tank was de-sludged on 2 Dec 2020 (Figure 12), and residuals deposited in the scour pond. Figure 13 from 10 Dec 2020 shows that the residuals dry well. Figure 14 shows the scour pond submerged after a heavy rain event. This temporary submergence did not affect the sludge drying. Figure 15 and Figure 16 show the sludge on 12 Jan 2021. On 26 Jan 2021, the dried solids content was measured at 14% DS (Figure 18, Table 20).

Figure 12 – Ngatoe scour pond after desludging (2 Dec 2020)

Figure 13 – Ngatoe scour pond after supernatant has dried (10 Dec 2020)

Figure 14 – Ngatoe scour pond after a heavy rain (12 Dec 2020)

Figure 15 – Ngatoe scour pond (12 Jan 2021)

Figure 16 - Ngatoe scour pond(12 Jan 2021). Residuals are dry at the top and wetter at the bottom

Drying in a combined pond

We monitored the Matavera and Tupapa plants to understand the drying performance in a combined pond.

The Matavera settling tank was de-sludged for the second time on 28 Jan 2021. The pond with the settling tank residuals was then put on standby to allow for drying. Figure 19 shows the residuals consistency approximately two days later. A dried solids analysis of two samples showed 2.5 and 5.4% DS (Table 21).

Figure 17 shows the sludge at the Tupapa standby pond approx. at the start of Feb 2021. Figure 20 shows the Tupapa standby pond on 11 Feb 2021, when a dried solids analysis for two samples showed 13 and 18% DS, respectively (Table 22).

Figure 17 – Dried residuals in the Tupapa standby pond (Feb 2021, measured at 13-18% DS)

Figure 18 – Dried residuals in the Ngatoe scour pond (25 Jan 2021, measured at 18% DS)

Figure 19 - Matavera pond approximately two days after discharging settling tank residuals (1 Feb 2021). The pond is in standby (drying) mode.

Figure 20 - Tupapa upstream (standby) pond on 11 Feb 2021

Total solids (dried solids) measurements

Dried solids (DS) tests were performed according to APHA Standard Methods[17] 2540 G (Total Solids) for residuals in both dedicated scour ponds, and combined AVG backwash/scour ponds.

Table 20 presents results for the Ngatoe scour pond.

[17] American Public Health Association's "Standard Methods for the Examination of Water and Wastewater"

Table 21 presents results for the Matavera combined pond, a few days after the pond was put on standby.

Table 22 presents results for the Tupapa standby pond after it had been on standby for a while.

Table 20 – Dried solids (% DS) results for residuals from the Ngatoe scour pond

Sample	N1	N2	N3	N4
Description of sample	Sampled below desiccated crust	Sampled below desiccated crust	Sampled below desiccated crust	Sampled below desiccated crust
Date Start	26/01/2021	26/01/2021	26/01/2021	26/01/2021
Time Drying	22.5 hrs	22.5 hrs	22.5 hrs	22.5 hrs
Temperature (ºC)	104 ºC	104 ºC	104 ºC	104 ºC
Mass of container and wet soil C (g)	55.17	58.899	49.489	47.68
Mass of container and dried soil A (g)	15.486	16.226	14.773	13.515
Mass of container B (g)	8.843	7.723	8.726	8.751
%Total Solids $= \frac{(A-B)\times 100}{C-B}$	14.3	15.0	14.8	12.2

Table 21 – Dried solids (% DS) results for residuals from the Matavera combined pond

Sample	M1	M2	M3
Description of sample	Liquid sludge sample	Full sample	Side of pond sample
Date Start	11/02/2021	11/02/2021	15/02/2021
Time Drying	19 hrs	19 hrs	18 hrs
Temperature (ºC)	104 ºC	104 ºC	104 ºC
Mass of container and wet soil C (g)	86.02	97.16	86.91
Mass of container and dried soil A (g)	10.45	13.47	14.159
Mass of container B (g)	8.63	8.65	8.676
%Total Soilds $= \frac{(A-B)\times 100}{C-B}$	2.4	5.4	7.0

Table 22 – Dried solids (% DS) results for residuals from the Tupapa combined pond

Sample	T1	T2
Description of sample	Full sample	Full sample
Date Start	11/02/2021	11/02/2021
Time Drying	19 hrs	19 hrs
Temperature (ºC)	104 ºC	104 ºC
Mass of container and wet soil C (g)	90.28	82.05
Mass of container and dried soil A (g)	23.14	18.12
Mass of container B (g)	8.64	8.6
$\%\text{Total Solids} = \frac{(A-B)\times 100}{C-B}$	17.8	13.0

Spade test

Samples of residuals were tested for "spadability" by undertaking a simplified tilt table test using a spade in the field.

Samples of residuals were dug from the ponds and then tilted on the spade to determine at what angle they would fall off the spade. Observations were also made of the stickiness of the sludge.

The tests were carried out on 11 Feb 2021 at both Tupapa and Matavera plants, see Figure 21 and Figure 22.

The spade tests showed that there was an optimum level of drying for "spadeability". When the water content is too high the sludge is liquid and unable to be collected on a spade. The sludge then dries to an intermediate state which is jelly like and spadable (approx. 7% DS). With further drying the sludge can become sticky and adhere to the spade, which may be more difficult to remove, sticking to excavator machinery and transport trucks (approx. 14% DS).

Figure 21 – Spade test at Matavera (approx. 3% DS)

Figure 22 – Spade test at Tupapa (approx. 13-18% DS)

Shaking test

The shaking test shows if water is liberated from sludge when shaking it vigorously. The jar test was conducted at the upstream standby pond (in drying mode) at Tupapa.

A sample of residuals was placed into a glass jar and shaken two ways. Shaking was undertaken first by vigorous tapping on the side of the glass, then second by vigorous shaking. In between each action the jar was opened, and the surface of the sludge was examined for free water. In both instances no free water developed on the surface of the sludge.

Figure 23 - Shaking test at Tupapa

5.5 Conclusions

The experience from the trial suggests that the optimal settling tank de-sludging frequency seems to be around 4 to 6 weeks.

The experience from the trial so far is that the sludge is drying well in both the dedicated scour ponds and in the combined ponds with duty and standby arrangements. The plants can be operated in a way that allows substantial drying in the scour and combined standby ponds, with both configurations reaching more than 14% DS. At this point there are no concerns about the ability of either pond configuration to dry the residuals.

Spadeability is good at approximately 7% DS. At 18 % DS the sludge becomes sticky and it may be more work to remove it from the ponds. However, this appears manageable.

A preliminary estimate of the residuals production for Ngatoe and Tupapa is approx. 8 to 8.5 m^3 per year, at 15% DS in the ponds. This is based on the measured volumes during two (rather dry) months of the trial. We expect this volume to increase once more data during rainier months becomes available. If the sludge production were proportional to rainfall amount, the increase could be around 80%.

This mass and volume calculation depends on a few assumptions, and the ongoing operation will provide more details. However, it seems that the overall residuals production of the plants is less than previously anticipated, and in a range that is manageable.

It was also noted that different plants grow in the dried residuals (e.g. Figure 16, Figure 17, Figure 18, Figure 20, and Figure 22). An analysis of the residuals for extractable aluminium returned a concentration of less than the analytical detection limit. Based on this and other information, it is likely that the residuals could be utilised as a soil amendment in a variety of local applications, including for agricultural soils. This is currently being investigated, and laboratory analysis data and further information will be available soon.

6. Operation without PACl

During the trial, we gained some insight into what the consequences of operating the plants without PACl would be. We have experience with running the settling tanks without PACl. There is limited experience with running the AVG filters without PACl.

Water usage

The settling tanks at Turangi and Avana were operated without PACl for a while (and the AVG was bypassed). PACl removes microorganisms and other particles from the raw water (refer to sections 2.2 about reduction of turbidity and 2.6 about reduction of *E. coli*). Without PACl, most of those microorganisms remain in the water. We observed an increase in the build-up of algae mats, slime and other particles in the settling tank. As a result, the settling tank had to be drained and cleaned (water blasted) about every two to three weeks, which is approximately double the frequency of the settling tank de-sludging (refer to section 5.3).

Cleaning the settling tank more frequently uses more water, which may be important in drought conditions.

In addition to higher cleaning intervals for the settling tank, the AVG filter would also backwash more frequently because more particles enter the filter bed. This increases both the water that is not going to supply (wasted), and the loss of sand media[18].

Water quality

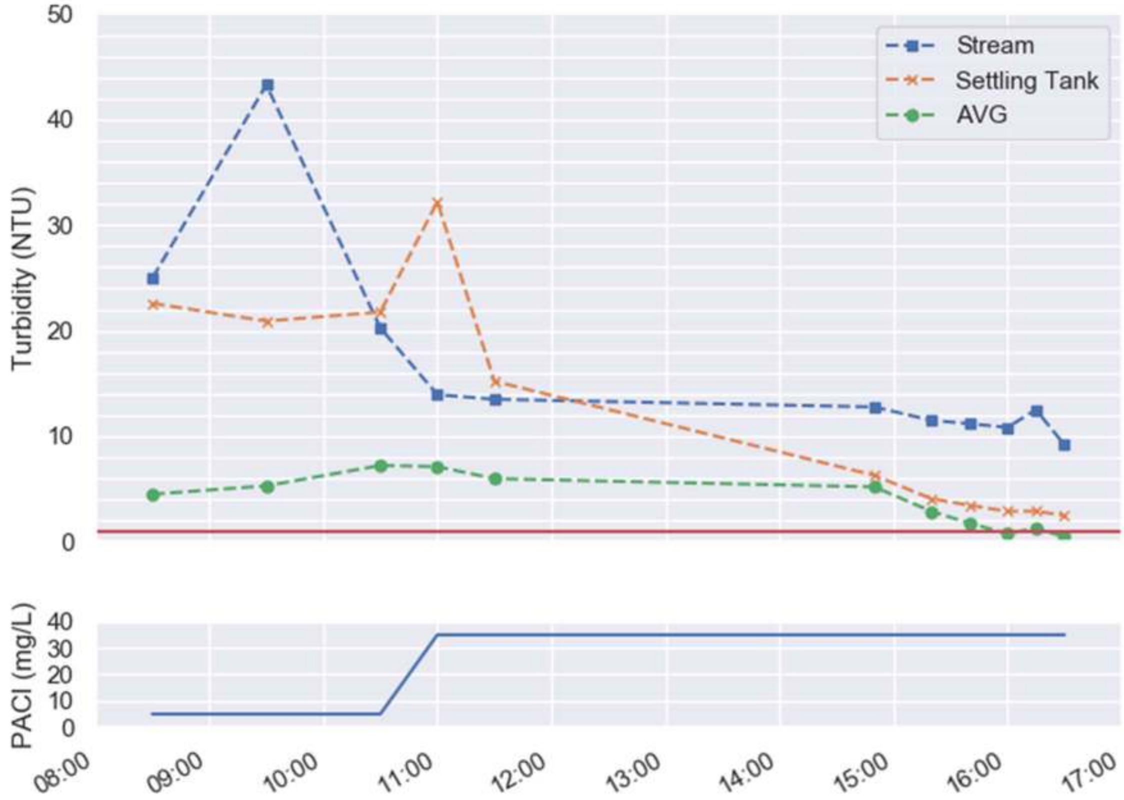
The treated water quality would decrease if PACl were not used. While passing the water through the settling tank and AVG would likely result in a better water quality compared to the raw stream water, it would be nowhere near as good as the water quality that is produced by using PACl. During dry weather, this would be most apparent in the lack of *E. coli* reduction, and during rainy weather the lack of both *E. coli* and turbidity reduction.

Any rapid filtration (such as used in the AVG) requires coagulation pre-treatment. If particles are not properly destabilized (by the coagulant), the natural negative surface charge on the particles and filter media grains cause repulsive electrostatic forces that prevent contact between particles and media. Properly designed and operated rapid filters can fail quickly if the coagulant feed breaks down.

This was inadvertently demonstrated when we monitored the water quality during a rain event at Totokoitu (see section 2.3). Figure 3 from that section is reproduced below. While the PACl dosing system was blocked, the post settling tank turbidity was similar to the raw water turbidity, and the treated water turbidity was significantly above the target value of 1 NTU.

After the PACl delivery line was unblocked, the water quality off the settling tank and AVG filter increased rapidly[19] and met the 1 NTU target value.

[18] During every backwash, a small fraction of filter sand is washed out with the backwash water.
[19] The three to four hour lag is caused by the time it takes the water to travel through the settling tank and AVG



During the drought in January 2021, TTV put multiple plants on bypass. As a result, untreated stream water was supplied to the drinking water network. Anecdotally, there were increased complaints about the water quality during this period.

7. Summary and recommendation

The experience from the trial suggests that the plants operate very well with PACl. In dry weather conditions, when the streams have a low turbidity, the most noticeable benefit of the plants is a reduction of the *E. coli* concentration (as an indicator organism).

During rain events, both the reduction in turbidity and *E. coli* is significant.

The residuals that are produced by the plants dry well in both pond configurations, resulting in a significant volume reduction. The produced residuals volumes are smaller than previously anticipated, and the removal of the dried residuals by digger or spade is feasible.

The sampling for dissolved aluminium in the streams did not show elevated concentrations that were caused by discharges from the plants. All samples that were taken while the plants discharge to the stream were measured below 0.055 mg/L, the target value. Where the target value was exceeded, it was because of the natural aluminium background concentration of the streams.

At this point, we have not seen any measurements that we believe are of environmental concern.

Overall, there doesn't seem to be an obvious reason to stop the PACl dosing, and we highly recommend that the plants be kept running with PACl to provide safer water to the population of Rarotonga.

Appendix A

Latest version of the monthly reports for all plants

TE MATO VAI

Memorandum

28 February 2021

To	Avana Landowners
Copy to	Angelia Williams, Sione Likiliki, National Environmental Service, To Tatou Vai
From	Matt Boyd — Tel 28851
Subject	PACl Trial Results Memo 2 - Avana

1 Summary of trial results from the Avana intake

The Avana intake started the polyaluminium chloride (PACl) trial on 2 November 2020, and To Tatou Vai (TTV) approved to connect the intake to the drinking water network on 6 November 2020 after reviewing results of the off-line trial (see the next section for more details about the trial stages).

During both stages of the trial, the contractor monitors the treatment plant and discharges to the environment.

To date, the intake delivers treated water that meets the requirements. The measured discharges to the environment also meet the requirements.

2 Purpose of this memorandum

The Cook Islands Government directed the Te Mato Vai project contractor McConnell Dowell to carry out water treatment commissioning trials at all the intakes progressively. The first of the trials commenced on Monday 28 September 2020 at Ngatoe Intake. The commissioning trial begins with polyaluminium chloride (PACl) first dosed into the settling tank/s which are located below the intakes. The active component of the PACl is aluminium which dissolves into the water and causes dirt to settle out of suspension.

This memo describes the trial process and presents an interim report of the results to date.

3 Trial Process

The first stage of the trial is undertaken while the network is **off-line**, that means that none of the raw water that is dosed with the PACl leaves the site and instead is stored in the storage tanks located just below the settling tanks. This stage of the trial continues for a few to several days while samples are taken and tested for dissolved aluminium, turbidity, pH and E.coli.

If acceptable results are achieved for the **off-line trial** the results are forwarded to To Tatou Vai (TTV) for their approval to discharge the treated water to the network. TTV compare the results to the World Health Organisation (WHO) drinking water standards and provide permission based on what is safe for human consumption. If

their permission to release is received, the second stage of the trial (the **on-line trial**) is started. The **on-line trial** is when the treated water is then discharged to the network.

It should be noted that two of the treatment plants don't have storage tanks, and at one of the sites the tank is too small to receive an adequate volume of water for an **off-line trial**. For these three treatment plants results from other plants will be used to assess whether or not the dosing can go directly **on-line**. These plants will still have regular dissolved aluminium, turbidity, pH and E.coli samples taken to ensure they meet the WHO drinking water standards and they will be some of the last plants to be trialled.

Once the **on-line trial** has started (when treated water enters the pipe network), it will continue at each intake for the remaining trial period which could be as long as six months, depending on when we receive sufficient data to determine how to best operate the plants in the future. The Contractor will do regular testing of the treated water for dissolved aluminium initially per day at each treatment plant for the first part of the trial and eventually reduced testing to once per week.

Additional to the treated water tests, Environmental sampling of the water discharging from the ponds is done for dissolved aluminium, turbidity, and pH, in the streams. Results from these tests are sent to the National Environment Service (NES). The stream is sampled while a discharge from the pond to the stream occurs, and also background sampling in the stream when no discharge occurs is undertaken.

The stream sampling locations are listed below and presented in Appendix A.

- 20m above the discharge point
- At the point of discharge
- 20m below the discharge point
- 50m below the discharge point (note this is the point where the target concentration should not be exceeded)
- Midway to the lagoon
- 100m above the lagoon

NES and the Landowners will be advised of all the above results. This environmental sampling will be conducted initially weekly then fortnightly after the initial discharge sample.

4 Results

4.1 Intake performance

The requirements for the treated water that is supplied to the drinking water network are as follows:

- The turbidity after the AVG should be lower than the raw stream turbidity.
- The E. coli concentration after the AVG generally should be lower than the raw stream concentration.
- The dissolved aluminium concentration after the AVG should be lower than 0.2 mg/L, and must not be higher than 0.3 mg/L.

If the treated water quality meets the turbidity, E. coli and dissolved aluminium requirements, it can be discharged to the drinking water network with the approval of TTV the network operator.

Table 1 presents the results to date from the **off-line** and **on-line trial**. The results are compared to the limits for discharge.

Cells that are greyed out indicate that no sample was taken at that time for the parameter in question.

To date, the intake has delivered treated water that met all requirements.

Table 1 Treated water quality results for the off-line and on-line trial at Avana.

	Turbidity (NTU)			E.Coli (MPN/100 mL)			Dissolved Aluminium (mg/L)			Comments
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	Stream	Post AVG	Status	Stream	Post AVG	Status	Post Settling Tank	Post AVG	Status	
2/11/2020 13:00	1.76	0.06	OK	214.3	248.9	Not OK				First day of trial. Plant is still starting up. Future results indicate no issues with plant performance.
2/11/2020 15:30	1.30	0.15	OK					0.008	OK	
3/11/2020 13:00	0.38	0.17	OK				0.035	0.020	OK	
3/11/2020 14:00	0.55	0.26	OK	95.9	45.7	OK	0.100	0.030	OK	
3/11/2020 15:00	0.69	0.26	OK				0.032	0.049	OK	
3/11/2020 – 6/11/2020	Off-line trial finished on 3/11/2020. TTV approved discharge of treated water to network on 6/11/2020. Trial is now an on-line trial.									
7/11/2020 7:49	0.70	0.13	OK							
8/11/2020 7:51	0.31	0.01	OK							
9/11/2020 10:19	14.4	4.31	OK							
10/11/2020 11:50	1.66	1.05	OK	461.1	<1	OK	0.049	0.050	OK	
11/11/2020 22:30	0.74	0.03	OK							
12/11/2020 0:00	1.57	0.84	OK	75.9	<1	OK	0.043	0.035	OK	
13/11/2020 11:14	1.00	0.05	OK							
14/11/2020 11:31	1.19	0.17	OK							
15/11/2020 12:08	0.40	0.10	OK							
16/11/2020 9:36	1.57	0.03	OK							
17/11/2020 11:00	0.76	0.24	OK	99	1	OK	0.033	0.049	OK	
18/11/2020 10:26	1.12	0.40	OK							
19/11/2020 9:55	1.71	0.66	OK	37.9	8.5	OK	0.048	0.042	OK	
20/11/2020 10:27	1.85	0.46	OK							
21/11/2020 10:05	1.32	0.51	OK							
22/11/2020 9:40	0.53	0.18	OK							
23/11/2020 15:15	0.47	0.11	OK							
24/11/2020 12:18	0.48	0.03	OK							
25/11/2020 11:44	0.37	0.09	OK							
26/11/2020 12:00	0.56	0.11	OK	55.7	<1	OK	0.039	0.016	OK	
27/11/2020 14:50	0.24	0.05	OK							
1/12/2020 11:00	1.13	0.14	OK	24.1	1	OK	0.085	0.008	OK	
1/12/2020 13:21	0.25	0.09	OK							
2/12/2020 13:10	1.23	0.11	OK							
3/12/2020 10:02	1.02	0.17	OK							
4/12/2020 8:28	0.51	0.18	OK							
5/12/2020 11:15	2.12	0.49	OK							
6/12/2020 10:02	1.45	0.7	OK							
7/12/2020 11:49	0.98	0.31	OK							
8/12/2020 13:46	0.36	0.07	OK	37.3	1	OK	0.042	0.034	OK	
9/12/2020 10:42	0.29	0.05	OK							
10/12/2020 8:51	1.31	0.28	OK							
11/12/2020 13:53	4.76	0.37	OK							
12/12/2020 8:28	0.56	0.05	OK							
13/12/2020 8:24	1.32	0.32	OK							
14/12/2020 11:17	0.77	0.09	OK							
15/12/2020 12:40	0.37	0.18	OK	150	<1	OK	0.047	0.022	OK	
16/12/2020 8:00	3.26	0.22	OK							

	Turbidity (NTU)			E.Coli (MPN/100 mL)			Dissolved Aluminium (mg/L)			Comments
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	Stream	Post AVG	Status	Stream	Post AVG	Status	Post Settling Tank	Post AVG	Status	
17/12/2020 15:00	0.57	0.09	OK							
18/12/2020 14:47	1.59	0.49	OK							
19/12/2020 10:40	0.74	0.09	OK							
20/12/2020 22:20	0.18	0.11	OK							
21/12/2020 10:29	0.13	0.01	OK							
22/12/2020 14:31		0.12						0.008	OK	Settling tank de-sludging, plant on bypass
22/12/2020 15:37	0.57	0.09	OK							Settling tank de-sludging, plant on bypass
23/12/2020 9:18	0.8	0.73	OK		44.1	Not OK				PACl not yet restarted
24/12/2020 8:50	2.67	3.59	Not OK							Sampled just before PACl was restarted
25/12/2020 9:17	0.42	0.38	OK							
26/12/2020 8:00	0.53	0.13	OK							
27/12/2020 8:10	0.56	0.13	OK							
28/12/2020 10:44	0.9	0.11	OK							
29/12/2020 10:57	0.54	0.07	OK	148.3(*)	2	OK	0.068	0.042	OK	(*) measured post settling tank
30/12/2020 9:12	2.22	0.11	OK							
31/12/2020 10:13	21.9	2.79	OK							
1/01/2021 19:16	1.39	0.42	OK							
2/01/2021 11:05	0.94	0.28	OK							
3/01/2021 10:50	2.23	0.19	OK							
4/01/2021 9:01	0.8	0.11	OK							
5/01/2021 11:10	0.61	0.1	OK				0.048	0.049	OK	
6/01/2021 9:06	0.58	0.13	OK							
7/01/2021 9:05	0.38	0.16	OK							
8/01/2021 14:29	0.59	0.13	OK							
9/01/2021 11:48	0.58	0.12	OK							
10/01/2021 8:39	0.51	0.15	OK							
11/01/2021 11:36	0.62	0.17	OK							
12/01/2021 9:57	1.18	0.24	OK							
13/01/2021 15:22	0.59	0.14	OK							
14/01/2021 9:19	0.44	0.13	OK							
15/01/2021 11:57	0.55	0.13	OK							
16/01/2021 9:23	0.99	0.11	OK							

Notes:

Between 21 Oct 2020 and 2 Nov 2020, a shortage of laboratory supplies for dissolved aluminium tests resulted in testing for dissolved aluminium reduced to the key compliance samples.

4.2 Environmental Monitoring

For discharges from the ponds to the stream, the environmental requirements are that the dissolved aluminium 50 m downstream from the discharge point should be at or below 0.055 mg/L. Dissolved aluminium is monitored at several points as presented in Appendix A.

Results of the peak and background sampling monitoring discharges from the ponds to the stream are presented in Table 2. The row with the blue title indicates the location where the concentration should be at or below 0.055 mg/L. A green cell indicates that the value is below the target concentration. Cells that are greyed out indicate that no sample was taken at that time for the location in question.

The PMU uses two sampling methods.

Peak sampling is undertaken during a discharge from the pond to the stream. The sample is taken at a time when the discharged water from the pond has reached the specific sample location[1].

Background samples are taken in the stream, but not necessarily when a discharge from the ponds to the stream occurs. They measure how the background concentration in the stream is influenced by the infrequent pond discharges, as well as the natural dissolved aluminium level upstream of the treatment plants.

4.2.1 Naturally Occurring Dissolved Aluminium

The ANZECC guideline value for dissolved aluminum in streams is less than 0.055 mg/L at 50 m below the discharge point. The TMV project's goal is that the discharges from the treatment plants to the streams do not cause harm to the environment. Monitoring during the trial and some historic readings have shown that the natural dissolved aluminum levels can sometimes be greater than the ANZECC limit when measured upstream of the treatment plants. The September 2020 Te Mato Vai Ecology Baseline Report concludes that dissolved aluminum levels of up to 0.290 mg/L or greater (potentially up to 0.630 mg/L) would not result in environmental harm. Natural occurring dissolved aluminum levels have been measured to date up to 0.170 mg/L following rainfall events. The monitoring of releases from the treatment plant has shown that at 50 m downstream of the point of release, no elevation of dissolved aluminum is occurring as a result of any discharge, with results consistently showing lower readings than in the ponds. In the instance where the level at 50 m downstream of discharge is above the ANZECC limit, the data shows that this is likely the result of the natural background levels being elevated in a rainfall event. In most instances the treatment plants were not discharging during the time of sampling and the 50 m downstream sample was taken from the raw stream water only.

The results are considered acceptable despite being above the ANZECC limit provided a net decrease in dissolved aluminum is maintained 50 m downstream of any discharge point.

[1] We use a floating object to determine when pond water has reached the specific location. The floating object is used to determine the velocity of the stream. Considering this velocity and the distance to the sampling point, we calculate the earliest time that the pond discharge will reach the sampling point.

Table 2 Dissolved aluminium results (mg/L) from the Avana stream sampling.

Sample Date			5 November 2020		10 November 2020		17 November 2020		24 November 2020	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Peak	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)		0.067		0.141		0.068		0.065	
Pond	In Pond 2 (Downstream Pond)									
Stream	In Stream (20 m upstream of Pond)		0.017		0.020		0.016		0.026	
Stream	In Stream (at pond)		0.014							
Stream	In Stream (20 m downstream of Pond)		0.014		0.026		0.031		0.016	
Stream	In Stream (50 m downstream of Pond)	0.055	0.005	**OK**	0.016	**OK**	0.008	**OK**	0.012	**OK**
Stream	In Stream (1/2 way to lagoon)		0.007							
Stream	In Stream (100 m from lagoon)		0.011							

Table 3 Dissolved aluminium results (mg/L) from the Avana stream sampling (Cont.)

Sample Date			8 December 2020		21 December 2020		6 January 2021		18 January 2021	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)		0.081		0.163		0.095		0.091	
Pond	In Pond 2 (Downstream Pond)									
Stream	In Stream (20 m upstream of Pond)		0.013		0.013		0.029		0.012	
Stream	In Stream (at pond)									
Stream	In Stream (20 m downstream of Pond)		0.026		0.017		0.022		0.016	
Stream	In Stream (50 m downstream of Pond)	0.055	0.008	**OK**	0.021	**OK**	0.013	**OK**	0.016	**OK**
Stream	In Stream (1/2 way to lagoon)									
Stream	In Stream (100 m from lagoon)									

4.3 Settling tank overflow test results

The settling tank at each intake is designed to overflow at the inlet if there is low demand to return raw stream water back to the stream. As part of the court appointed expert witness review it was agreed to manually trigger an overflow in at least one intake as part of the trial and test the water to ensure water with elevated dissolved aluminium was not passing back into the stream. This overflow test is only required at one intake because all intakes are constructed in the same way.

Environmental testing for dissolved aluminium was undertaken at three locations

- in the settling tank overflow chamber
- in the stream, upstream of the discharge point, and
- in the stream, 50 meters downstream of the discharge point.

Testing was undertaken at the beginning of the overflow, after 1 hour and then after 2 hours of continuous overflow.

Results

Results of the overflow test are presented in Table 4 and Table 5 showing that dissolved aluminium levels are not elevated above the limit due to the discharge.

Table 4 Settling tank overflow test results for Ngatoe

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.008	0.008	OK
After 1 hour	0.008	0.008	0.023	OK
After 2 hours	0.013	0.019	0.009	OK

Table 5 Settling tank overflow test results for Papua

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.016	0.016	OK
After 1 hour	0.008	0.008	0.008	OK
After 2 hours	0.008	0.008	0.017	OK

Regards

Matt Boyd
Deputy Project Manager

Appendix A
Environmental Sampling Location Diagram

Environmental Sampling in Stream

1. Sample in the Pond (day before proposed release)

Done once per plant

Sample in the ponds for Al concentration

Testing:

- Dissolved Aluminium
- Turbidity
- pH

2 samples, 1 per pond at star locations ★ (red)

2. Environmental Peak Sampling (manual discharge to stream)

1 to 2 times at each plant at different stream conditions.

Sampled during a controlled release from the ponds to the stream,

Timed sampling based on stream flow rate 60 mins after initial release.

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 8 samples per test at star locations ★ (red) ★ (red/yellow) ★ (yellow)

3. Environmental Background Sampling (automatic discharge to stream)

- No less than weekly for first month
- No less than fortnightly for remaining months

These samples are taken in the stream, regardless of if a discharge is occurring or not.

This sampling serves to monitor the background dissolved aluminium concentrations in the stream.

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 5 samples per test at star locations ★ (red) ★ (red/yellow)

4. Settling Tank Overflow to Stream

done twice in total for trial including a high energy plant

First part: contained in chamber (control). Raw water and chamber and at 50 m downstream of discharge.

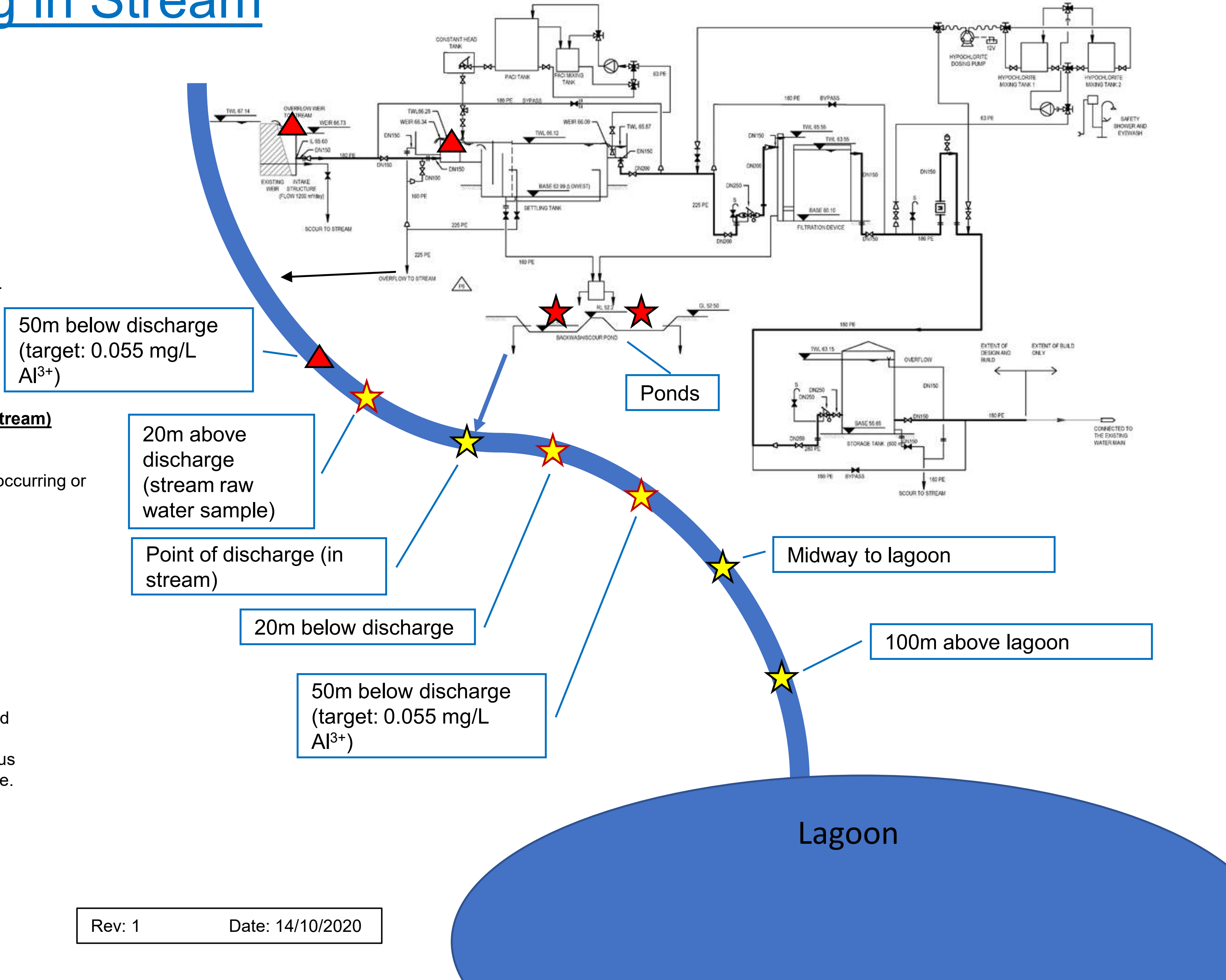
Second part: if first part ok: discharge to stream. Start, Plus 1 hour, plus 2 hours, Raw water and chamber and at 50 m downstream of discharge.

Samples locations:

- raw water and
- water going into the overflow chamber (within settling tank)
- 50 m downstream of discharge

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 9 samples per test at locations ▲ (red)



Rev: 1 Date: 14/10/2020

Memorandum

28 February 2021

To	Avatiu Landowners
Copy to	Angelia Williams, Sione Likiliki, National Environmental Service, To Tatou Vai
From	Matt Boyd Tel 28851
Subject	PACl Trial Results Memo 2 - Avatiu

1 Summary of trial results from the Avatiu intake

The Avatiu intake started the polyaluminium chloride (PACl) trial on 23 November 2020, and To Tatou Vai (TTV) approved to connect the intake to the drinking water network on 27 November 2020 after reviewing results of the off-line trial (see the next section for more details about the trial stages).

During both stages of the trial, the contractor monitors the treatment plant and discharges to the environment.

To date, the intake delivers treated water that meets the requirements. The measured discharges to the environment also meet the requirements.

2 Purpose of this memorandum

The Cook Islands Government directed the Te Mato Vai project contractor McConnell Dowell to carry out water treatment commissioning trials at all the intakes progressively. The first of the trials commenced on Monday 28 September 2020 at Ngatoe Intake. The commissioning trial begins with polyaluminium chloride (PACl) first dosed into the settling tank/s which are located below the intakes. The active component of the PACl is aluminium which dissolves into the water and causes dirt to settle out of suspension.

This memo describes the trial process and presents an interim report of the results to date.

3 Trial Process

The first stage of the trial is undertaken while the network is **off-line**, that means that none of the raw water that is dosed with the PACl leaves the site and instead is stored in the storage tanks located just below the settling tanks. This stage of the trial continues for a few to several days while samples are taken and tested for dissolved aluminium, turbidity, pH and E.coli.

If acceptable results are achieved for the **off-line trial** the results are forwarded to To Tatou Vai (TTV) for their approval to discharge the treated water to the network. TTV compare the results to the World Health Organisation (WHO) drinking water standards and provide permission based on what is safe for human consumption. If

their permission to release is received, the second stage of the trial (the **on-line trial**) is started. The **on-line trial** is when the treated water is then discharged to the network.

It should be noted that two of the treatment plants don't have storage tanks, and at one of the sites the tank is too small to receive an adequate volume of water for an **off-line trial**. For these three treatment plants results from other plants will be used to assess whether or not the dosing can go directly **on-line**. These plants will still have regular dissolved aluminium, turbidity, pH and E.coli samples taken to ensure they meet the WHO drinking water standards and they will be some of the last plants to be trialled.

Once the **on-line trial** has started (when treated water enters the pipe network), it will continue at each intake for the remaining trial period which could be as long as six months, depending on when we receive sufficient data to determine how to best operate the plants in the future. The Contractor will do regular testing of the treated water for dissolved aluminium initially per day at each treatment plant for the first part of the trial and eventually reduced testing to once per week.

Additional to the treated water tests, Environmental sampling of the water discharging from the ponds is done for dissolved aluminium, turbidity, and pH, in the streams. Results from these tests are sent to the National Environment Service (NES). The stream is sampled while a discharge from the pond to the stream occurs, and also background sampling in the stream when no discharge occurs is undertaken.

The stream sampling locations are listed below and presented in Appendix A.

- 20m above the discharge point
- At the point of discharge
- 20m below the discharge point
- 50m below the discharge point (note this is the point where the target concentration should not be exceeded)
- Midway to the lagoon
- 100m above the lagoon

NES and the Landowners will be advised of all the above results. This environmental sampling will be conducted initially weekly then fortnightly after the initial discharge sample.

4 Results

4.1 Intake performance

The requirements for the treated water that is supplied to the drinking water network are as follows:

- The turbidity after the AVG should be lower than the raw stream turbidity.
- The E. coli concentration after the AVG generally should be lower than the raw stream concentration.
- The dissolved aluminium concentration after the AVG should be lower than 0.2 mg/L, and must not be higher than 0.3 mg/L.

If the treated water quality meets the turbidity, E. coli and dissolved aluminium requirements, it can be discharged to the drinking water network with the approval of TTV the network operator.

Table 1 presents the results to date from the **off-line** and **on-line trial**. The results are compared to the limits for discharge.

Cells that are greyed out indicate that no sample was taken at that time for the parameter in question.

To date, the intake has delivered treated water that met all requirements.

Table 1 Treated water quality results for the off-line and on-line trial at Avatiu.

	Turbidity (NTU)			E.Coli (MPN/100 mL)			Dissolved Aluminium (mg/L)			Comments
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	Stream	Post AVG	Status	Stream	Post AVG	Status	Post Settling Tank	Post AVG	Status	
23/11/2020 13:00	0.42	0.02	OK				0.084	0.089	OK	
23/11/2020 14:00	0.45	0.05	OK				0.081	0.064	OK	
23/11/2020 15:00	0.28	0.02	OK	222.4	6.2	OK	0.06	0.068	OK	
23/11/2020 16:00	0.40	0.02	OK				0.081	0.064	OK	
24/11/2020 14:00	0.49	0.18	OK				0.091	0.07	OK	
24/11/2020 15:00	0.51	0.22	OK	348.8	7.5	OK	0.076	0.054	OK	
24/11/2020 16:00	0.65	0.23	OK				0.086	0.071	OK	
25/11/2020 13:00		0.15					0.058	0.077	OK	
25/11/2020 14:00		0.01					0.042	0.114	OK	
25/11/2020 15:00	0.24	0.22	OK	77.6	1	OK	0.117	0.061	OK	
25/11/2020 16:00		0.02					0.061	0.059	OK	
25 – 27/11/2020	The pre-network connected trial finished on 25 November. The intake was connected to the network on 27/11 after receiving TTV's approval.									
27/11/2020 14:55	3.91	0.09	OK							
29/11/2020 19:33	0.66	0.16	OK							
30/11/2020 12:57	0.36	0.19	OK							
1/12/2020 9:59	0.21	0.08	OK	90.8	1	OK				
2/12/2020 9:34	0.55	0.18	OK							
3/12/2020 11:44	3.98	0.63	OK	1046.2	1	OK	0.061	0.042	OK	
4/12/2020 10:01	0.39	0.16	OK							
5/12/2020 8:43	3.35	0	OK							
6/12/2020 7:11	0.51	0.01	OK							
7/12/2020 9:45	0.51	0.31	OK							
8/12/2020 13:38	0.3	0.02	OK	131.4	<1	OK	0.055	0.042	OK	
10/12/2020 10:46	0.8	0.08	OK	461.1	24.3	OK	0.017	0.037	OK	
11/12/2020 9:00	0.15	0	OK							
12/12/2020 6:41	1.08	0.08	OK							
13/12/2020 7:01	0.25	0.25	OK							
14/12/2020 14:13	0.38	0.11	OK							
15/12/2020 9:34	0.87	0.14	OK							
15/12/2020 12:50	0.25	0.73	Not OK	<1	1	Not OK	0.024	0.041	OK	< 1 NTU, ok (*)
16/12/2020 12:50	0.25	0.73	Not OK							< 1 NTU. Ok (*)
17/12/2020 10:41	0.39	0.09	OK	214.3	3.1	OK				
18/12/2020 9:38	0.08	0.36	Not OK							< 1 NTU. Ok (*)
19/12/2020 2:30	0.34	0.14	OK							
20/12/2020 13:00	0.49	0.04	OK							
21/12/2020 13:13	0.1	0.03	OK							
22/12/2020 10:33	0.39	0.09	OK	50.4	<1	OK	0.042	0.032	OK	
23/12/2020 11:12	0.98	0.19	OK							
24/12/2020 10:00	0.44	0.28	OK							
24/12/2020 10:00	0.44	0.28	OK							
25/12/2020 8:06	0.35	0.05	OK							
26/12/2020 8:42	0.46	0.08	OK							
27/12/2020 11:20	0.78	0.07	OK							
28/12/2020 8:38	0.31	0.15	OK							
29/12/2020 8:20	4.28	0.3	OK	980.4	<1	OK	0.089	0.078	OK	
30/12/2020 8:45	0.55	0.22	OK							
31/12/2020 9:57	0.26	0.01	OK							

	Turbidity (NTU)			E.Coli (MPN/100 mL)			Dissolved Aluminium (mg/L)			Comments
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	Stream	Post AVG	Status	Stream	Post AVG	Status	Post Settling Tank	Post AVG	Status	
1/01/2021 8:21	0.75	0.2	OK							
2/01/2021 8:00	0.73	0.15	OK							
3/01/2021 8:00	0.92	0.17	OK							
4/01/2021 8:32	0.21	0.05	OK							
5/01/2021 9:45	1.78	0.14	OK	28.8	2	OK				
6/01/2021 9:10	0.85	0.25	OK				0.075	0.064	OK	
7/01/2021 9:25	1.19	0.55	OK							
8/01/2021 8:50	0.04	0.31	Not OK							< 1 NTU, ok (*)
9/01/2021 8:09	1.32	0.21	OK							
10/01/2021 12:45	0.78	0.21	OK							
11/01/2021 13:06	1.57	0.67	OK							
12/01/2021 10:00	0.35	0.21	OK							
13/01/2021 9:17	0.49	0.13	OK							
14/01/2021 8:47	0.74	0.19	OK							
15/01/2021 8:20	1.47	0.32	OK							
16/01/2021 7:38	1.23	0.63	OK							
17/01/2021 6:52	0	0	OK							

(*) Despite the post AVG turbidity being above the raw stream turbidity, it is less than 1 NTU. This is acceptable.

4.2 Environmental Monitoring

For discharges from the ponds to the stream, the environmental requirements are that the dissolved aluminium 50 m downstream from the discharge point should be at or below 0.055 mg/L. Dissolved aluminium is monitored at several points as presented in Appendix A.

Results of the peak and background sampling monitoring discharges from the ponds to the stream are presented in Table 2. The row with the blue title indicates the location where the concentration should be at or below 0.055 mg/L. A green cell indicates that the value is below the target concentration. Cells that are greyed out indicate that no sample was taken at that time for the location in question.

The PMU uses two sampling methods.

Peak sampling is undertaken during a discharge from the pond to the stream. The sample is taken at a time when the discharged water from the pond has reached the specific sample location[1].

Background samples are taken in the stream, but not necessarily when a discharge from the ponds to the stream occurs. They measure how the background concentration in the stream is influenced by the infrequent pond discharges, as well as the natural dissolved aluminium level upstream of the treatment plants.

4.2.1 Naturally Occurring Dissolved Aluminium

The ANZECC guideline value for dissolved aluminum in streams is less than 0.055 mg/L at 50 m below the discharge point. The TMV project's goal is that the discharges from the treatment plants to the streams do not cause harm to the environment. Monitoring during the trial and some historic readings have shown that the natural dissolved aluminum levels can sometimes be greater than the ANZECC limit when measured upstream of the treatment plants. The September 2020 Te Mato Vai Ecology Baseline Report concludes that dissolved aluminum levels of up to 0.290 mg/L or greater (potentially up to 0.630 mg/L) would not result in environmental harm. Natural occurring dissolved aluminum levels have been measured to date up to 0.170 mg/L following rainfall events. The monitoring of releases from the treatment plant has shown that at 50 m downstream of the point of release, no elevation of dissolved aluminum is occurring as a result of any discharge, with results consistently showing lower readings than in the ponds. In the instance where the level at 50 m downstream of discharge is above the ANZECC limit, the data shows that this is likely the result of the natural background levels being elevated in a rainfall event. In most instances the treatment plants were not discharging during the time of sampling and the 50 m downstream sample was taken from the raw stream water only.

The results are considered acceptable despite being above the ANZECC limit provided a net decrease in dissolved aluminum is maintained 50 m downstream of any discharge point.

[1] We use a floating object to determine when pond water has reached the specific location. The floating object is used to determine the velocity of the stream. Considering this velocity and the distance to the sampling point, we calculate the earliest time that the pond discharge will reach the sampling point.

Table 2 Dissolved aluminium results (mg/L) from the Avatiu stream sampling.

Sample Date			26 November 2020		1 December 2020		9 December 2020		16 December 2020	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Peak	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)		0.086							
Pond	In Pond 2 (Downstream Pond)								0.072	
Stream	In Stream (20 m upstream of Pond)		0.008		0.012		0.013		0.008	
Stream	In Stream (at pond)		0.034							
Stream	In Stream (20 m downstream of Pond)		0.034		0.023		0.012		0.013	
Stream	In Stream (50 m downstream of Pond)	0.055	0.031	**OK**	0.015	**OK**	0.011	**OK**	0.015	**OK**
Stream	In Stream (1/2 way to lagoon)		0.025							
Stream	In Stream (100 m from lagoon)		0.011							

Table 3 Dissolved aluminium results (mg/L) from the Avatiu stream sampling (Cont.)

Sample Date			29 December 2020		13 January 2021		27 January 2021	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)							
	In Pond 2 (Downstream Pond)		0.056					
Stream	In Stream (20 m upstream of Pond)		0.008		0.008		0.016	
	In Stream (at pond)							
	In Stream (20 m downstream of Pond)		0.008		0.019		0.015	
	In Stream (50 m downstream of Pond)	0.055	0.008	**OK**	0.008	**OK**	0.008	**OK**
	In Stream (1/2 way to lagoon)							
	In Stream (100 m from lagoon)							

4.3 Settling tank overflow test results

The settling tank at each intake is designed to overflow at the inlet if there is low demand to return raw stream water back to the stream. As part of the court appointed expert witness review it was agreed to manually trigger an overflow in at least one intake as part of the trial and test the water to ensure water with elevated dissolved aluminium was not passing back into the stream. This overflow test is only required in one intake because all intakes are constructed in the same way.

Environmental testing for dissolved aluminium was undertaken at three locations

- in the settling tank overflow chamber
- in the stream, upstream of the discharge point, and
- in the stream, 50 meters downstream of the discharge point.

Testing was undertaken at the beginning of the overflow, after 1 hour and then after 2 hours of continuous overflow.

Results

Results of the overflow test are presented in Table 4 and Table 5 showing that dissolved aluminium levels are not elevated above the limit due to the discharge.

Table 4 Settling tank overflow test results for Ngatoe

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.008	0.008	OK
After 1 hour	0.008	0.008	0.023	OK
After 2 hours	0.013	0.019	0.009	OK

Table 5 Settling tank overflow test results for Papua

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.016	0.016	OK
After 1 hour	0.008	0.008	0.008	OK
After 2 hours	0.008	0.008	0.017	OK

Regards

Matt Boyd
Deputy Project Manager

Appendix A
Environmental Sampling Location Diagram

Environmental Sampling in Stream

1. Sample in the Pond (day before proposed release)

Done once per plant
Sample in the ponds for Al concentration

Testing:

- Dissolved Aluminium
- Turbidity
- pH

2 samples, 1 per pond at star locations ★ (red)

2. Environmental Peak Sampling (manual discharge to stream)

1 to 2 times at each plant at different stream conditions.
Sampled during a controlled release from the ponds to the stream,
Timed sampling based on stream flow rate 60 mins after initial release.

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 8 samples per test at star locations ★ (red) ★ (red outline, yellow) ★ (yellow)

3. Environmental Background Sampling (automatic discharge to stream)

- No less than weekly for first month
- No less than fortnightly for remaining months

These samples are taken in the stream, regardless of if a discharge is occurring or not.
This sampling serves to monitor the background dissolved aluminium concentrations in the stream.

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 5 samples per test at star locations ★ (red) ★ (red outline, yellow)

4. Settling Tank Overflow to Stream

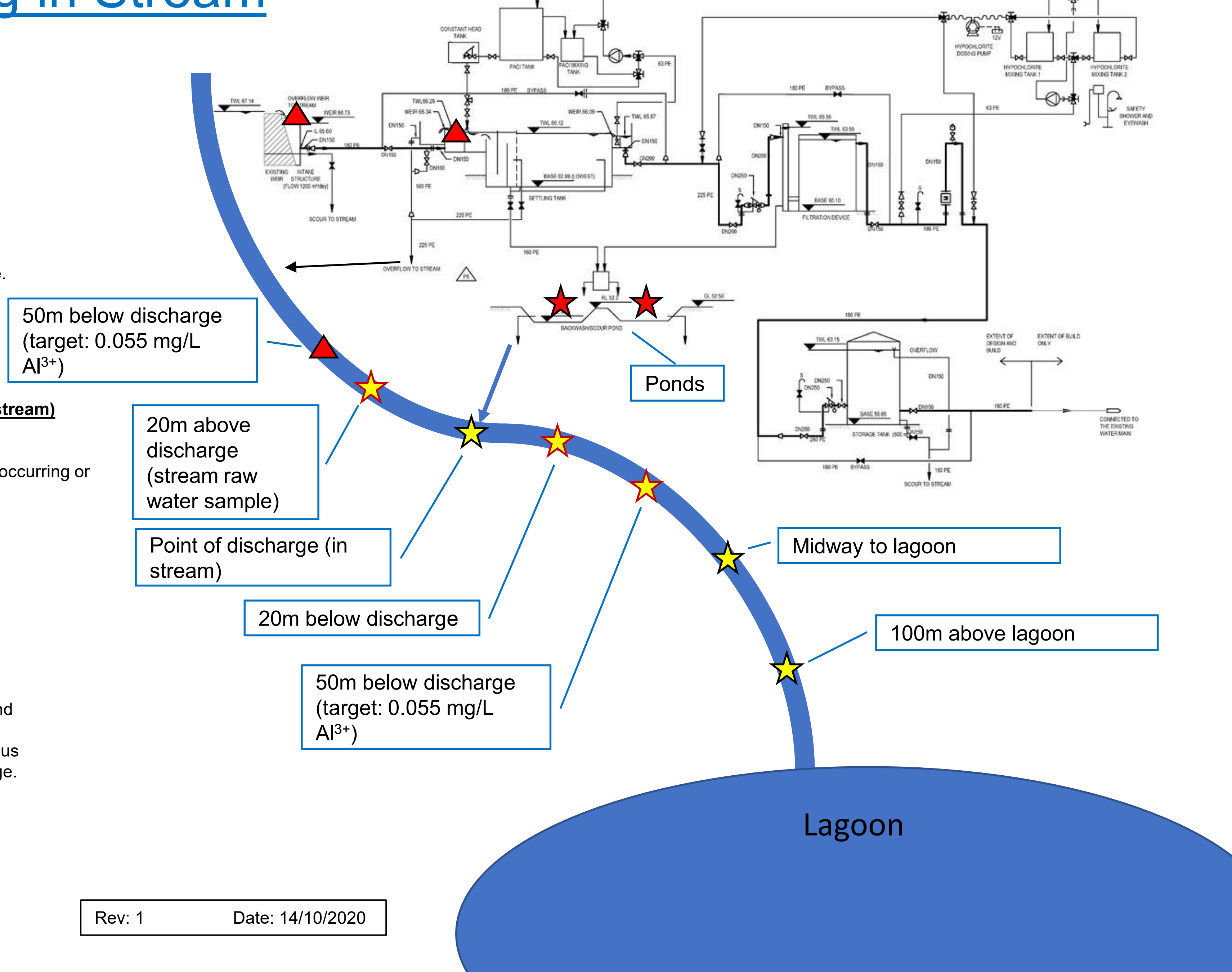
done twice in total for trial including a high energy plant
First part: contained in chamber (control). Raw water and chamber and at 50 m downstream of discharge.
Second part: if first part ok: discharge to stream. Start, Plus 1 hour, plus 2 hours, Raw water and chamber and at 50 m downstream of discharge.

Samples locations:

- raw water and
- water going into the overflow chamber (within settling tank)
- 50 m downstream of discharge

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 9 samples per test at locations ▲ (red)



Rev: 1 Date: 14/10/2020

Memorandum

28 February 2021

To	Matavera Landowners
Copy to	Angelia Williams, Sione Likiliki, National Environmental Service, To Tatou Vai
From	Matt Boyd Tel 28851
Subject	PACl Trial Results Report 3 - Matavera

1 Summary of trial results from the Matavera intake

The Matavera intake started the polyaluminium chloride (PACl) trial on 5 October 2020. The trial was stopped on 6 October 2020 because the trunk main (the pipeline between the intake and the ring main) needed repairs. After reviewing results from the trial, TTV approved the plant being connected to the network on 8 October 2020. However, the intake was only restarted on 4 December 2020.

Due to the outage, there is no new trial data available since the last report. Trial data will be presented in the next report.

2 Purpose of this memorandum

The Cook Islands Government directed the Te Mato Vai project contractor McConnell Dowell to carry out water treatment commissioning trials at all the intakes progressively. The first of the trials commenced on Monday 28 September 2020 at Ngatoe Intake. The commissioning trial begins with polyaluminium chloride (PACl) first dosed into the settling tank/s which are located below the intakes. The active component of the PACl is aluminium which dissolves into the water and causes dirt to settle out of suspension.

This memo describes the trial process and presents an interim report of the results to date.

3 Trial Process

The first stage of the trial is undertaken while the network is **off-line**, that means that none of the raw water that is dosed with the PACl leaves the site and instead is stored in the storage tanks located just below the settling tanks. This stage of the trial continues for a few to several days while samples are taken and tested for dissolved aluminium, turbidity, pH and E.coli.

If acceptable results are achieved for the **off-line trial** the results are forwarded to To Tatou Vai (TTV) for their approval to discharge the treated water to the network. TTV compare the results to the World Health Organisation (WHO) drinking water standards and provide permission based on what is safe for human consumption. If their permission to release is received, the second stage of the trial (the **on-line trial**) is started. The **on-line trial** is when the treated water is then discharged to the network.

It should be noted that two of the treatment plants don't have storage tanks, and at one of the sites the tank is too small to receive an adequate volume of water for an **off-line trial**. For these three treatment plants results from other plants will be used to assess whether or not the dosing can go directly **on-line**. These plants will still have regular dissolved aluminium, turbidity, pH and E.coli samples taken to ensure they meet the WHO drinking water standards and they will be some of the last plants to be trialled.

Once the **on-line trial** has started (when treated water enters the pipe network), it will continue at each intake for the remaining trial period which could be as long as six months, depending on when we receive sufficient data to determine how to best operate the plants in the future. The Contractor will do regular testing of the treated water for dissolved aluminium initially per day at each treatment plant for the first part of the trial and eventually reduced testing to once per week.

Additional to the treated water tests, Environmental sampling of the water discharging from the ponds is done for dissolved aluminium, turbidity, and pH, in the streams. Results from these tests are sent to the National Environment Service (NES). The stream is sampled while a discharge from the pond to the stream occurs, and also background sampling in the stream when no discharge occurs is undertaken.

The stream sampling locations are listed below and presented in Appendix A.

- 20m above the discharge point
- At the point of discharge
- 20m below the discharge point
- 50m below the discharge point (note this is the point where the target concentration should not be exceeded)
- Midway to the lagoon
- 100m above the lagoon

NES and the Landowners will be advised of all the above results. This environmental sampling will be conducted initially weekly then fortnightly after the initial discharge sample.

4 Results

4.1 Intake performance

The requirements for the treated water that is supplied to the drinking water network are as follows:

- The turbidity after the AVG should be lower than the raw stream turbidity.
- The E. coli concentration after the AVG generally should be lower than the raw stream concentration.
- The dissolved aluminium concentration after the AVG should be lower than 0.2 mg/L, and must not be higher than 0.3 mg/L.

If the treated water quality meets the turbidity, E. coli and dissolved aluminium requirements, it can be discharged to the drinking water network with the approval of TTV the network operator.

Table 1 presents the results to date from the **off-line** and **on-line trial**. The results are compared to the limits for discharge.

Cells that are greyed out indicate that no sample was taken at that time for the parameter in question.

To date, the intake has delivered treated water that met all requirements.

Table 1 Treated water quality results for the off-line and on-line trial at Matavera.

	Turbidity (NTU)			E.Coli (MPN/100 mL)			Dissolved Aluminium (mg/L)			Comments
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	**Stream**	**Post AVG**	**Status**	**Stream**	**Post AVG**	**Status**	**Post Settling Tank**	**Post AVG**	**Status**	
5/10/2020 14:00	0.32	0.3	OK				0.114	0.107	OK	
5/10/2020 15:00	0.35	0.25	OK	53.7	1	OK	0.127	0.068	OK	
5/10/2020 16:00	0.37	0.12	OK				0.105	0.115	OK	
6/10/2020 14:00		0.38					0.098	0.093	OK	
6/10/2020 15:00		0.31					0.131	0.108	OK	
6 - 8/10/2020	The plant was stopped on 6/10 to allow works on the trunk main. The plant resumed operation on 5 Dec 2020. On 8/10, after reviewing data, TTV approved the connection of the plant to the network, once the plant is restarted.									
5/12/2020 12:55	3.28	0.72	OK							
6/12/2020 8:26	0.72	0.54	OK							
7/12/2020 10:46	1.78	0.52	OK							
8/12/2020 11:18	1.48	0.26	OK	122.3	<1	OK	0.046	0.033	OK	
9/12/2020 12:05	0.64	0.03	OK							
10/12/2020 11:49	1.17	0.72	OK							
11/12/2020 13:30	23.45	0.86	OK							
12/12/2020 7:34	0.99	0.04	OK							
13/12/2020 7:33	0.94	0.06	OK							
14/12/2020 15:27	0.74	0.10	OK							
15/12/2020 10:45	1.16	0.24	OK	79.8	2	OK	0.033	0.013	OK	
16/12/2020 10:05	1.04	0.46	OK							
17/12/2020 12:32	0.79	0.12	OK	1986.3	3.1	OK				
18/12/2020 11:23	0.33	0.08	OK							
19/12/2020 12:15	2.77	0.13	OK							
20/12/2020 23:20	0.13	0.16	Not OK							< 1 NTU, ok (*)
21/12/2020 11:33	1.12	0.12	OK							
22/12/2020 12:33	79.00	0.12	OK	16	<1	OK	0.07	0.038	OK	
23/12/2020 10:15	0.45	0.13	OK	16	<1	OK	0.07	0.038	OK	
24/12/2020 10:35	1.98	0.14	OK							
25/12/2020 7:00	0.67	0.08	OK							
26/12/2020 10:55	1.30	0.75	OK							
27/12/2020 9:14	0.33	0.08	OK							
28/12/2020 9:46	1.81	0.34	OK							
29/12/2020 9:15	0.30	0.14	OK	218.7(#)	50.4	OK	0.089	0.081	OK	(#) measured post settling tank
30/12/2020 10:37	1.47	0.37	OK							
31/12/2020 8:47	0.47	0.05	OK							
1/01/2021 9:55	1.64	0.20	OK							
2/01/2021 10:00	0.09	0.17	Not OK							< 1 NTU, ok (*)
3/01/2021 21:50	1.75	0.35	OK							

	Turbidity (NTU)			E.Coli (MPN/100 mL)			Dissolved Aluminium (mg/L)			Comments
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	**Stream**	**Post AVG**	**Status**	**Stream**	**Post AVG**	**Status**	**Post Settling Tank**	**Post AVG**	**Status**	
4/01/2021 6:35	0.40	0.07	OK							
5/01/2021 9:54	0.61	0.13	OK	866.4	2	OK	0.074	0.079	OK	
6/01/2021 10:26	0.91	0.19	OK							
7/01/2021 11:00	0.55	0.13	OK							
8/01/2021 10:18	0.86	0.01	OK							
9/01/2021 10:30	0.76	0.23	OK							
10/01/2021 10:09	0.67	0.25	OK							
11/01/2021 10:53	0.92	0.75	OK							
12/01/2021 11:24	0.69	0.27	OK							
13/01/2021 12:30	0.72	0.14	OK							
14/01/2021 10:46	1.37	0.19	OK							
15/01/2021 10:05	1.09	0.28	OK							
16/01/2021 8:34	0.84	0.23	OK							
17/01/2021 7:39	0.94	0.30	OK							

Notes:

(*) Despite the post AVG turbidity being above the raw stream turbidity, it is less than 1 NTU. This is acceptable.

Between 21 Oct 2020 and 2 Nov 2020, a shortage of laboratory supplies for dissolved aluminium tests resulted in testing for dissolved aluminium reduced to the key compliance samples.

4.2 Environmental Monitoring

For discharges from the ponds to the stream, the environmental requirements are that the dissolved aluminium 50 m downstream from the discharge point should be at or below 0.055 mg/L. Dissolved aluminium is monitored at several points as presented in Appendix A.

Results of the peak and background sampling monitoring discharges from the ponds to the stream are presented in Table 2. The row with the blue title indicates the location where the concentration should be at or below 0.055 mg/L. A green cell indicates that the value is below the target concentration. Cells that are greyed out indicate that no sample was taken at that time for the location in question.

The PMU uses two sampling methods.

Peak sampling is undertaken during a discharge from the pond to the stream. The sample is taken at a time when the discharged water from the pond has reached the specific sample location[1].

Background samples are taken in the stream, but not necessarily when a discharge from the ponds to the stream occurs. They measure how the background concentration in the stream is influenced by the infrequent pond discharges, as well as the natural dissolved aluminium level upstream of the treatment plants.

4.2.1 Naturally Occurring Dissolved Aluminium

The ANZECC guideline value for dissolved aluminum in streams is less than 0.055 mg/L at 50 m below the discharge point. The TMV project's goal is that the discharges from the treatment plants to the streams do not cause harm to the environment. Monitoring during the trial and some historic readings have shown that the natural dissolved aluminum levels can sometimes be greater than the ANZECC limit when measured upstream of the treatment plants. The September 2020 Te Mato Vai Ecology Baseline Report concludes that dissolved aluminum levels of up to 0.290 mg/L or greater (potentially up to 0.630 mg/L) would not result in environmental harm. Natural occurring dissolved aluminum levels have been measured to date up to 0.170 mg/L following rainfall events. The monitoring of releases from the treatment plant has shown that at 50 m downstream of the point of release, no elevation of dissolved aluminum is occurring as a result of any discharge, with results consistently showing lower readings than in the ponds. In the instance where the level at 50 m downstream of discharge is above the ANZECC limit, the data shows that this is likely the result of the natural background levels being elevated in a rainfall event. In most instances the treatment plants were not discharging during the time of sampling and the 50 m downstream sample was taken from the raw stream water only.

The results are considered acceptable despite being above the ANZECC limit provided a net decrease in dissolved aluminum is maintained 50 m downstream of any discharge point.

[1] We use a floating object to determine when pond water has reached the specific location. The floating object is used to determine the velocity of the stream. Considering this velocity and the distance to the sampling point, we calculate the earliest time that the pond discharge will reach the sampling point.

Table 2 Dissolved aluminium results (mg/L) from the Matavera stream sampling.

	Sample Date		9 October 2020		21 October 2020		7 December 2020		22 December 2020	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Peak	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)		0.118						0.065	
Pond	In Pond 2 (Downstream Pond)		0.102							
sStream	In Stream (20 m upstream of Pond)		0.009		0.02		0.021		0.012	
sStream	In Stream (at pond)		0.027							
sStream	In Stream (20 m downstream of Pond)		0.033				0.019		0.013	
sStream	In Stream (50 m downstream of Pond)	0.055	0.016	**OK**	0.013	**OK**	0.012	**OK**	0.008	**OK**
sStream	In Stream (1/2 way to lagoon)		No Stream Flow							
sStream	In Stream (100 m from lagoon)		No Stream Flow							

Table 3 Dissolved aluminium results (mg/L) from the Matavera stream sampling (Cont.)

		Sample Date	13 January 2021		27 January 2021	
	Sample Location	Limit	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)		0.143		0.119	
	In Pond 2 (Downstream Pond)					
Stream	In Stream (20 m upstream of Pond)		0.011		0.034	
	In Stream (at pond)					
	In Stream (20 m downstream of Pond)		0.009		0.019	
	In Stream (50 m downstream of Pond)	0.055	0.016	**OK**	0.052	**OK**
	In Stream (1/2 way to lagoon)					
	In Stream (100 m from lagoon)					

Notes:

Between 21 Oct 2020 and 2 Nov 2020, a shortage of laboratory supplies for dissolved aluminium tests resulted in testing for dissolved aluminium reduced to the key compliance samples.

4.3 Settling tank overflow test results

The settling tank at each intake is designed to overflow at the inlet if there is low demand to return raw stream water back to the stream. As part of the court appointed expert witness review it was agreed to manually trigger an overflow in at least one intake as part of the trial and test the water to ensure water with elevated dissolved aluminium was not passing back into the stream. This overflow test is only required in one intake because all intakes are constructed in the same way.

Environmental testing for dissolved aluminium was undertaken at three locations

- in the settling tank overflow chamber
- in the stream, upstream of the discharge point, and
- in the stream, 50 meters downstream of the discharge point.

Testing was undertaken at the beginning of the overflow, after 1 hour and then after 2 hours of continuous overflow.

Results

Results of the overflow test are presented in Table 4 and Table 5 showing that dissolved aluminium levels are not elevated above the limit due to the discharge.

Table 4 Settling tank overflow test results for Ngatoe

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.008	0.008	OK
After 1 hour	0.008	0.008	0.023	OK
After 2 hours	0.013	0.019	0.009	OK

Table 5 Settling tank overflow test results for Papua

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.016	0.016	OK
After 1 hour	0.008	0.008	0.008	OK
After 2 hours	0.008	0.008	0.017	OK

Regards

Matt Boyd
Deputy Project Manager

Appendix A

Environmental Sampling

Environmental Sampling in Stream

1. Sample in the Pond (day before proposed release)

Done once per plant

Sample in the ponds for Al concentration

Testing:

- Dissolved Aluminium
- Turbidity
- pH

2 samples, 1 per pond at star locations ★

2. Environmental Peak Sampling (manual discharge to stream)

1 to 2 times at each plant at different stream conditions.

Sampled during a controlled release from the ponds to the stream,

Timed sampling based on stream flow rate 60 mins after initial release.

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 8 samples per test at star locations ★ ★ ★

3. Environmental Background Sampling (automatic discharge to stream)

- No less than weekly for first month
- No less than fortnightly for remaining months

These samples are taken in the stream, regardless of if a discharge is occurring or not.

This sampling serves to monitor the background dissolved aluminium concentrations in the stream.

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 5 samples per test at star locations ★ ★

4. Settling Tank Overflow to Stream

done twice in total for trial including a high energy plant

First part: contained in chamber (control). Raw water and chamber and at 50 m downstream of discharge.

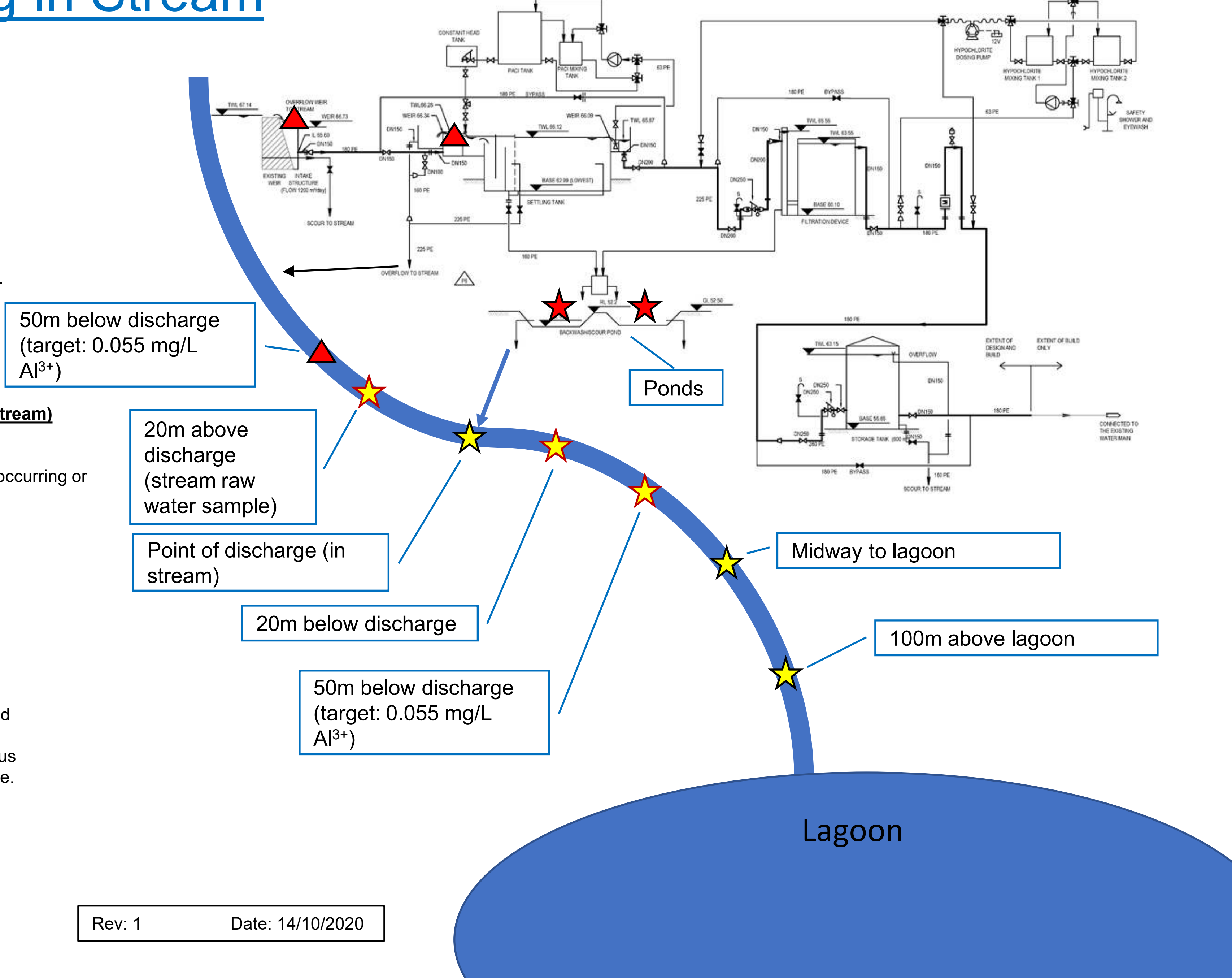
Second part: if first part ok: discharge to stream. Start, Plus 1 hour, plus 2 hours, Raw water and chamber and at 50 m downstream of discharge.

Samples locations:

- raw water and
- water going into the overflow chamber (within settling tank)
- 50 m downstream of discharge

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 9 samples per test at locations ▲



Rev: 1 Date: 14/10/2020

TE MATO VAI

Memorandum

28 February 2021

To	Ngatoe Aronga Mana and Caretakers
Copy to	Angelia Williams, Sione Likiliki, National Environmental Service, To Tatou Vai
From	Matt Boyd — Tel 28851
Subject	PACl Trial Results Memo 3 - Ngatoe

1 Summary of trial results from the Ngatoe intake

The Ngatoe intake started the polyaluminium chloride (PACl) trial on 28 September 2020, and To Tatou Vai (TTV) approved to connect the intake to the drinking water network on 1 October 2020 after reviewing results of the off-line trial (see the next section for more details about the trial stages).

During both stages of the trial, the contractor monitors the treatment plant and discharges to the environment.

To date, the intake delivers treated water that meets the requirements. The measured discharges to the environment also meet the requirements.

2 Purpose of this memorandum

The Cook Islands Government directed the Te Mato Vai project contractor McConnell Dowell to carry out water treatment commissioning trials at all the intakes progressively. The first of the trials commenced on Monday 28 September 2020 at Ngatoe Intake. The commissioning trial begins with polyaluminium chloride (PACl) first dosed into the settling tank/s which are located below the intakes. The active component of the PACl is aluminium which dissolves into the water and causes dirt to settle out of suspension.

This memo describes the trial process and presents an interim report of the results to date.

3 Trial Process

The first stage of the trial is undertaken while the network is **off-line**, that means that none of the raw water that is dosed with the PACl leaves the site and instead is stored in the storage tanks located just below the settling tanks. This stage of the trial continues for a few to several days while samples are taken and tested for dissolved aluminium, turbidity, pH and E.coli.

If acceptable results are achieved for the **off-line trial** the results are forwarded to To Tatou Vai (TTV) for their approval to discharge the treated water to the network. TTV compare the results to the World Health Organisation (WHO) drinking water standards and provide permission based on what is safe for human consumption. If

their permission to release is received, the second stage of the trial (the **on-line trial**) is started. The **on-line trial** is when the treated water is then discharged to the network.

It should be noted that two of the treatment plants don't have storage tanks, and at one of the sites the tank is too small to receive an adequate volume of water for an **off-line trial**. For these three treatment plants results from other plants will be used to assess whether or not the dosing can go directly **on-line**. These plants will still have regular dissolved aluminium, turbidity, pH and E.coli samples taken to ensure they meet the WHO drinking water standards and they will be some of the last plants to be trialled.

Once the **on-line trial** has started (when treated water enters the pipe network), it will continue at each intake for the remaining trial period which could be as long as six months, depending on when we receive sufficient data to determine how to best operate the plants in the future. The Contractor will do regular testing of the treated water for dissolved aluminium initially per day at each treatment plant for the first part of the trial and eventually reduced testing to once per week.

Additional to the treated water tests, Environmental sampling of the water discharging from the ponds is done for dissolved aluminium, turbidity, and pH, in the streams. Results from these tests are sent to the National Environment Service (NES). The stream is sampled while a discharge from the pond to the stream occurs, and also background sampling in the stream when no discharge occurs is undertaken.

The stream sampling locations are listed below and presented in Appendix A.

- 20m above the discharge point
- At the point of discharge
- 20m below the discharge point
- 50m below the discharge point (note this is the point where the target concentration should not be exceeded)
- Midway to the lagoon
- 100m above the lagoon

NES and the Landowners will be advised of all the above results. This environmental sampling will be conducted initially weekly then fortnightly after the initial discharge sample.

4 Results

4.1 Intake performance

The requirements for the treated water that is supplied to the drinking water network are as follows:

- The turbidity after the AVG should be lower than the raw stream turbidity.
- The E. coli concentration after the AVG generally should be lower than the raw stream concentration.
- The dissolved aluminium concentration after the AVG should be lower than 0.2 mg/L, and must not be higher than 0.3 mg/L.

If the treated water quality meets the turbidity, E. coli and dissolved aluminium requirements, it can be discharged to the drinking water network with the approval of TTV the network operator.

Table 1 presents the results to date from the **off-line** and **on-line trial**. The results are compared to the limits for discharge.

Cells that are greyed out indicate that no sample was taken at that time for the parameter in question.

To date, the intake has delivered treated water that met all requirements.

Table 1 Treated water quality results for the off-line and on-line trial at Ngatoe.

	Turbidity (NTU)			**E.Coli (MPN/100 mL)**			**Dissolved Aluminium (mg/L)**			**Comments**
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	Stream	Post AVG	Status	Stream	Post AVG	Status	Post Settling Tank	Post AVG	Status	
28/09/2020 13:00	0.88	0.19	OK				0.105	0.087	OK	Plant Start
28/09/2020 14:00	0.97	0.14	OK				0.099	0.071	OK	
28/09/2020 15:00	0.81	0.11	OK				0.078	0.052	OK	
28/09/2020 16:00	0.97	0.21	OK	25.9			0.079	0.097	OK	
29/09/2020 13:00	0.85	0.22	OK				0.087	0.084	OK	
29/09/2020 14:00	0.72	0.19	OK	2	24.1	Not OK	0.075	0.049	OK	Sample taken after a rain event. The stream was already clear again, but the rain event water was still running through the AVG. Rechecked hour later
29/09/2020 15:00	0.85	0.14	OK				0.075	0.063	OK	
29/09/2020 16:00	0.87	0.17	OK				0.087	0.014	OK	
30/09/2020 13:00	0.78	0.23	OK				0.107	0.079	OK	
30/09/2020 14:00	0.79	0.19	OK	131.4	0	OK	0.1	0.064	OK	
30/09/2020 15:00	0.75	0.25	OK				0.116	0.092	OK	
30/09/2020 16:00	0.78	0.19	OK				0.078	0.073	OK	
30/09/2020 – 1/10/2020		TTV approved discharge of treated water to network. Trial is now an on-line trial.								
1/10/2020 13:00	0.85	0.19	OK				0.1	0.084	OK	
1/10/2020 14:00	1.17	0.15	OK	18.5	6.3	OK	0.117	0.093	OK	
1/10/2020 15:00	0.94	0.02	OK				0.172	0.133	OK	
1/10/2020 16:00	1.09	0.28	OK				0.072	0.129	OK	
2/10/2020	AVG bypassed as part of the trial. "Post AVG" samples taken without AVG operating.									
6/10/2020 16:00		0.31	OK					0.130	OK	AVG shut off
7/10/2020 10:00	0.53	0.51	OK							AVG shut off
7/10/2020 11:00	0.52	0.29	OK							AVG shut off
7/10/2020 12:00	0.58	0.26	OK							AVG shut off
7/10/2020 13:00	0.64	0.31	OK							AVG shut off
7/10/2020 14:00	0.53	0.16	OK							AVG shut off
7/10/2020 15:00	0.48	0.19	OK							AVG shut off
7/10/2020 16:00	0.59	0.18	OK							AVG shut off
8/10/2020 14:00	0.83	0.08	OK	28.8	0	OK				AVG shut off
10/10/2020 11:00	2.46	0.21	OK							AVG shut off
10/10/2020 15:00	1.70	0.22	OK							AVG shut off
11/10/2020 8:00	3.07	0.46	OK							AVG shut off
13/10/2020 13:00	1.24	0.55	OK	73.8	48.7	OK	0.08	0.082	OK	AVG restart
15/10/2020 13:30	0.83	0.32	OK				0.065	0.064	OK	
17/10/2020 11:00	0.86	0.18	OK							
18/10/2020 11:40	0.71	0.29	OK							
19/10/2020 13:00	0.21	0.88	Not OK				0.083	0.071	OK	Cleaned walls of settling tank, stirred up and raised turbidity, still low so ok.
19/10/2020 14:00	0.48	0.01	OK	10.9	<1	OK	0.286	0.061	OK	
19/10/2020 15:00	0.32	0.16	OK				0.113	0.071	OK	
19/10/2020 16:00	0.27	0.17	OK				0.088	0.095	OK	
20/10/2020 9:40	0.99	0.87	OK	98.5	1	OK	0.119	0.105	OK	

	Turbidity (NTU)			E.Coli (MPN/100 mL)			Dissolved Aluminium (mg/L)			Comments
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	Stream	Post AVG	Status	Stream	Post AVG	Status	Post Settling Tank	Post AVG	Status	
20/10/2020 15:00	1.82	0.21	OK							
21/10/2020 13:00	0.42	0.00	OK				0.1	0.037	OK	
21/10/2020 14:00	0.54	0.09	OK	44.3	3	OK	0.081	0.084	OK	
21/10/2020 15:00	0.60	0.00	OK	36.4	<1	OK	0.095	0.079	OK	
21/10/2020 16:00	0.37	0.12	OK				0.085	0.072	OK	
22/10/2020 11:24	2.81	0.41	OK	107.6	3.1	OK	0.015	0.094	OK	
23/10/2020 10:00	5.58	0.85	OK							
24/10/2020 9:25	1.26	0.01	OK							
27/10/2020 11:30	5.44	2.28	OK							
28/10/2020 11:40	1.22	0.12	OK	435.2	3	OK				
29/10/2020 11:40	2.04	0.17	OK							
30/10/2020 11:52	1.41	0.17	OK	18.9	<1	OK		0.072	OK	
31/10/2020 7:34	3.65	0.74	OK							
1/11/2020 7:57	4.01	0.77	OK							
2/11/2020 9:12	12.20	0.08	OK							
3/11/2020 9:05	3.17	0.50	OK	387.7	17.1	OK		0.089	OK	
4/11/2020 12:00	5.55	0.79	OK							
5/11/2020 9:32	1.35	2.14	Not OK							Sample was taken after an AVG backwash. Temporary elevated turbidity concentrations after an AVG backwashes are normal. (1)
7/11/2020 10:22	2.62	0.70	OK							
8/11/2020 10:19	2.70	0.96	OK							
9/11/2020 8:56	19.40	0.18	OK							
10/11/2020 13:22	1.27	2.99	Not OK	62.4	9.4	**OK**				Sample was taken after an AVG backwash. Temporary elevated turbidity concentrations after an AVG backwashes are normal. (1)
11/11/2020 9:10	0.74	0.15	OK							
12/11/2020 13:26	2.04	0.56	OK							
17/11/2020 12:10	1.42	0.47	OK	91.1	2	OK	0.125	0.108	OK	
18/11/2020 12:10	1.71	0.10	OK							
19/11/2020 14:19	2.04	1.00	OK							
20/11/2020 9:57	1.63	0.19	OK							
21/11/2020 8:40	0.82	0.13	OK							
22/11/2020 8:32	0.77	0.39	OK							
23/11/2020 14:30	0.85	0.26	OK							
24/11/2020 12:22	0.88	0.01	OK							
25/11/2020 9:56	0.59	0.17	OK							
26/11/2020 9:56	0.92	0.01	OK							
27/11/2020 14:55	3.91	0.09	OK							
28/11/2020 12:18	0.64	0.01	OK							
29/11/2020 19:17	0.59	0.04	OK							
30/11/2020 9:56	0.71	0.18	OK							
1/12/2020 11:04	1.13	0.14	OK							De-sludging of settling tank
After the de-sludging, the plant was not operating and on bypass until 11 December 2020.										
11/12/2020 10:32	1.90	3.05	Not OK							Sample was taken after an AVG back-

	Turbidity (NTU)			E.Coli (MPN/100 mL)			Dissolved Aluminium (mg/L)			Comments
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	Stream	Post AVG	Status	Stream	Post AVG	Status	Post Settling Tank	Post AVG	Status	
										wash. Temporary elevated turbidity concentrations after an AVG backwashes are normal. (1)
12/12/2020 10:04	0.94	0.52	OK							
13/12/2020 9:56	1.00	0.42	OK							
14/12/2020 9:39	0.81	0.14	OK							
15/12/2020 9:56	0.82	0.23	OK	73.8	85	Not OK	0.014	0.052	OK	There was an issue with the PACl dosing, with no PACl being dosed when operators arrived and to take the water quality samples. The issue was corrected.
16/12/2020 13:40	3.55	0.61	OK							
17/12/2020 11:52	0.56	0.06	OK							
18/12/2020 13:08	1.04	0.65	OK							
19/12/2020 8:32	0.66	0.26	OK							
20/12/2020 8:45	0.48	0.10	OK							
21/12/2020 9:22	0.59	0.01	OK							
22/12/2020 0:00							0.08	0.072	OK	
23/12/2020 11:00	0.59	0.16	OK	23.1	1	OK				
23/12/2020 11:11	0.59	0.16	OK							
24/12/2020 9:12	0.90	0.54	OK							
25/12/2020 6:00	0.78	0.11	OK							
26/12/2020 7:30	0.71	0.03	OK							
27/12/2020 6:22	0.83	0.06	OK							
28/12/2020 10:00	0.69	0.17	OK							
29/12/2020 9:30	0.76	0.18	OK	121	5.2	OK	0.105	0.094	OK	
30/12/2020 10:30	10.60									
31/12/2020 11:16	1.41	0.51	OK							
1/01/2021 7:22	1.36	0.01	OK							
2/01/2021 7:11	1.46	0.00	OK							
3/01/2021 13:00	1.07	0.23	OK							
5/01/2021 10:04	1.06	0.20	OK	29.2	1	OK				
6/01/2021 14:57	0.69	0.12	OK				0.096	0.08	OK	
7/01/2021 10:51	0.47	0.17	OK							
8/01/2021 9:49	0.54	0.17	OK							
9/01/2021 7:16	1.16	0.28	OK							
10/01/2021 13:46	0.90	0.15	OK							
11/01/2021 10:03	0.74	0.21	OK							
12/01/2021 14:47	1.16	0.11	OK							
13/01/2021 14:23	0.85	0.13	OK				0.095	0.099	OK	
14/01/2021 13:34	0.73	0.27	OK							
15/01/2021 9:06	0.79	0.21	OK							
16/01/2021 10:44	1.20	0.33	OK							
17/01/2021 9:50	0.57	0.25	OK							

Notes:

1) After an AVG backwash, the turbidity of the treated water is slightly higher for a short time (usually less than 15 minutes to an hour) compared to the normal turbidity values. As the particles settle in the filter bed, the turbidity improves again to normal concentrations.

Between 21 Oct 2020 and 2 Nov 2020, a shortage of laboratory supplies for dissolved aluminium tests resulted in testing for dissolved aluminium reduced to the key compliance samples.

4.2 Environmental Monitoring

For discharges from the ponds to the stream, the environmental requirements are that the dissolved aluminium 50 m downstream from the discharge point should be at or below 0.055 mg/L. Dissolved aluminium is monitored at several points as presented in Appendix A.

Results of the peak and background sampling monitoring discharges from the ponds to the stream are presented in Table 2. The row with the blue title indicates the location where the concentration should be at or below 0.055 mg/L. A green cell indicates that the value is below the target concentration. Cells that are greyed out indicate that no sample was taken at that time for the location in question.

The PMU uses two sampling methods.

Peak sampling is undertaken during a discharge from the pond to the stream. The sample is taken at a time when the discharged water from the pond has reached the specific sample location[1].

Background samples are taken in the stream, but not necessarily when a discharge from the ponds to the stream occurs. They measure how the background concentration in the stream is influenced by the infrequent pond discharges, as well as the natural dissolved aluminium level upstream of the treatment plants.

4.2.1 Naturally Occurring Dissolved Aluminium

The ANZECC guideline value for dissolved aluminum in streams is less than 0.055 mg/L at 50 m below the discharge point. The TMV project's goal is that the discharges from the treatment plants to the streams do not cause harm to the environment. Monitoring during the trial and some historic readings have shown that the natural dissolved aluminum levels can sometimes be greater than the ANZECC limit when measured upstream of the treatment plants. The September 2020 Te Mato Vai Ecology Baseline Report concludes that dissolved aluminum levels of up to 0.290 mg/L or greater (potentially up to 0.630 mg/L) would not result in environmental harm. Natural occurring dissolved aluminum levels have been measured to date up to 0.170 mg/L following rainfall events. The monitoring of releases from the treatment plant has shown that at 50 m downstream of the point of release, no elevation of dissolved aluminum is occurring as a result of any discharge, with results consistently showing lower readings than in the ponds. In the instance where the level at 50 m downstream of discharge is above the ANZECC limit, the data shows that this is likely the result of the natural background levels being elevated in a rainfall event. In most instances the treatment plants were not discharging during the time of sampling and the 50 m downstream sample was taken from the raw stream water only.

The results are considered acceptable despite being above the ANZECC limit provided a net decrease in dissolved aluminum is maintained 50 m downstream of any discharge point.

[1] We use a floating object to determine when pond water has reached the specific location. The floating object is used to determine the velocity of the stream. Considering this velocity and the distance to the sampling point, we calculate the earliest time that the pond discharge will reach the sampling point.

Table 2 Dissolved aluminium results (mg/L) from the stream sampling.

Sample Date			7 October 2020		12 October 2020		19 October 2020		27 October 2020	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Peak	D.Alu mg/L	Peak	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)		0.083		0.016		0.149		0.114	
Pond	In Pond 2 (Downstream Pond)		0.102		0.049		0.082			
Stream	In Stream (20 m upstream of Pond)		0.022		0.012		0.007		0.052	
Stream	In Stream (at pond)		0.023		0.020					
Stream	In Stream (20 m downstream of Pond)		0.026		0.016		0.041			
Stream	In Stream (50 m downstream of Pond)	0.055	0.008	**OK**	0.015	**OK**	0.022	**OK**	0.050	**OK**
Stream	In Stream (1/2 way to lagoon)		0.008		0.015					
Stream	In Stream (100 m from lagoon)		0.008		0.014					

Table 3 Dissolved aluminium results (mg/L) from the stream sampling (Cont.).

Sample Date			2 November 2020		4 November 2020		16 November 2020		30 November 2020		2 December 2020	
	Sample Location	**Limit**	**Result**	**Status**	**Result**	**Status**	**Result**	**Status**	**Result**	**Status**	**Result**	**Status**
		D.Alu mg/L	**D.Alu mg/L**	**Back-ground**	**D.Alu mg/L**	**Bank-ground**	**D.Alu mg/L**	**Back-ground**	**D.Alu mg/L**	**Back-ground**	**D.Alu mg/L**	**Back-ground**
Pond	In Pond 1 (Upstream Pond)		0.100		0.089		0.097		0.056			
	In Pond 2 (Downstream Pond)				0.085		0.092		0.161			
Stream	In Stream (20 m up-stream of Pond)		0.101		0.023		0.015		0.015		0.014	
	In Stream (at pond)										0.037	
	In Stream (20 m down-stream of Pond)				0.022		0.027		0.035		0.019	
	In Stream (50 m down-stream of Pond)	0.055	0.074	Natural back-ground level is above dis-charge limit. Down-stream showing dilution so OK.	0.025	**OK**	0.020	**OK**	0.009	**OK**	0.027	**OK**
	In Stream (1/2 way to la-goon)										0.011	
	In Stream (100 m from lagoon)										0.008	

Table 4 Dissolved aluminium results (mg/L) from the stream sampling (Cont.)

Sample Date			15 December 2020		30 December 2020		12 January 2021		25 January 2021	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)		0.046		0.066		0.127		0.132	
	In Pond 2 (Downstream Pond)		0.081		0.042		0.050		0.056	
Stream	In Stream (20 m upstream of Pond)		0.026		0.015		0.015		0.029	
	In Stream (at pond)									
	In Stream (20 m downstream of Pond)		0.024		0.017		0.017		0.034	
	In Stream (50 m downstream of Pond)	0.055	0.020	**OK**	0.023	**OK**	0.023	**OK**	0.033	**OK**
	In Stream (1/2 way to lagoon)									
	In Stream (100 m from lagoon)									

Table 5 Dissolved aluminium results (mg/L) from the stream sampling (Cont.)

Sample Date			8 February 2021	
	Sample Location	Limit	Result	Status
		D.Alu mg/L	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)		0.059	
	In Pond 2 (Downstream Pond)		0.073	
Stream	In Stream (20 m upstream of Pond)		0.008	
	In Stream (at pond)			
	In Stream (20 m downstream of Pond)		0.016	
	In Stream (50 m downstream of Pond)	0.055	0.024	**OK**
	In Stream (1/2 way to lagoon)			
	In Stream (100 m from lagoon)			

Notes:

Between 21 Oct 2020 and 2 Nov 2020, a shortage of laboratory supplies for dissolved aluminium tests resulted in testing for dissolved aluminium reduced to the key compliance samples.

4.3 Settling tank overflow test results

The settling tank at each intake is designed to overflow at the inlet if there is low demand to return raw stream water back to the stream. As part of the court appointed expert witness review it was agreed to manually trigger an overflow in at least one intake as part of the trial and test the water to ensure water with elevated dissolved aluminium was not passing back into the stream. This overflow test is only required in one intake because all intakes are constructed in the same way.

Environmental testing for dissolved aluminium was undertaken at three locations

- in the settling tank overflow chamber
- in the stream, upstream of the discharge point, and
- in the stream, 50 meters downstream of the discharge point.

Testing was undertaken at the beginning of the overflow, after 1 hour and then after 2 hours of continuous overflow.

Results

Results of the overflow test are presented in Table 6 and Table 7 showing that dissolved aluminium levels are not elevated above the limit due to the discharge.

Table 6 Settling tank overflow test results for Ngatoe

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.008	0.008	OK
After 1 hour	0.008	0.008	0.023	OK
After 2 hours	0.013	0.019	0.009	OK

Table 7 Settling tank overflow test results for Papua

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.016	0.016	OK
After 1 hour	0.008	0.008	0.008	OK
After 2 hours	0.008	0.008	0.017	OK

Regards

Matt Boyd
Deputy Project Manager

Appendix A
Environmental Sampling Location Diagram

Environmental Sampling in Stream

1. Sample in the Pond (day before proposed release)

Done once per plant

Sample in the ponds for Al concentration

Testing:

- Dissolved Aluminium
- Turbidity
- pH

2 samples, 1 per pond at star locations

2. Environmental Peak Sampling (manual discharge to stream)

1 to 2 times at each plant at different stream conditions.

Sampled during a controlled release from the ponds to the stream,

Timed sampling based on stream flow rate 60 mins after initial release.

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 8 samples per test at star locations

3. Environmental Background Sampling (automatic discharge to stream)

- No less than weekly for first month
- No less than fortnightly for remaining months

These samples are taken in the stream, regardless of if a discharge is occurring or not.

This sampling serves to monitor the background dissolved aluminium concentrations in the stream.

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 5 samples per test at star locations

4. Settling Tank Overflow to Stream

done twice in total for trial including a high energy plant

First part: contained in chamber (control). Raw water and chamber and at 50 m downstream of discharge.

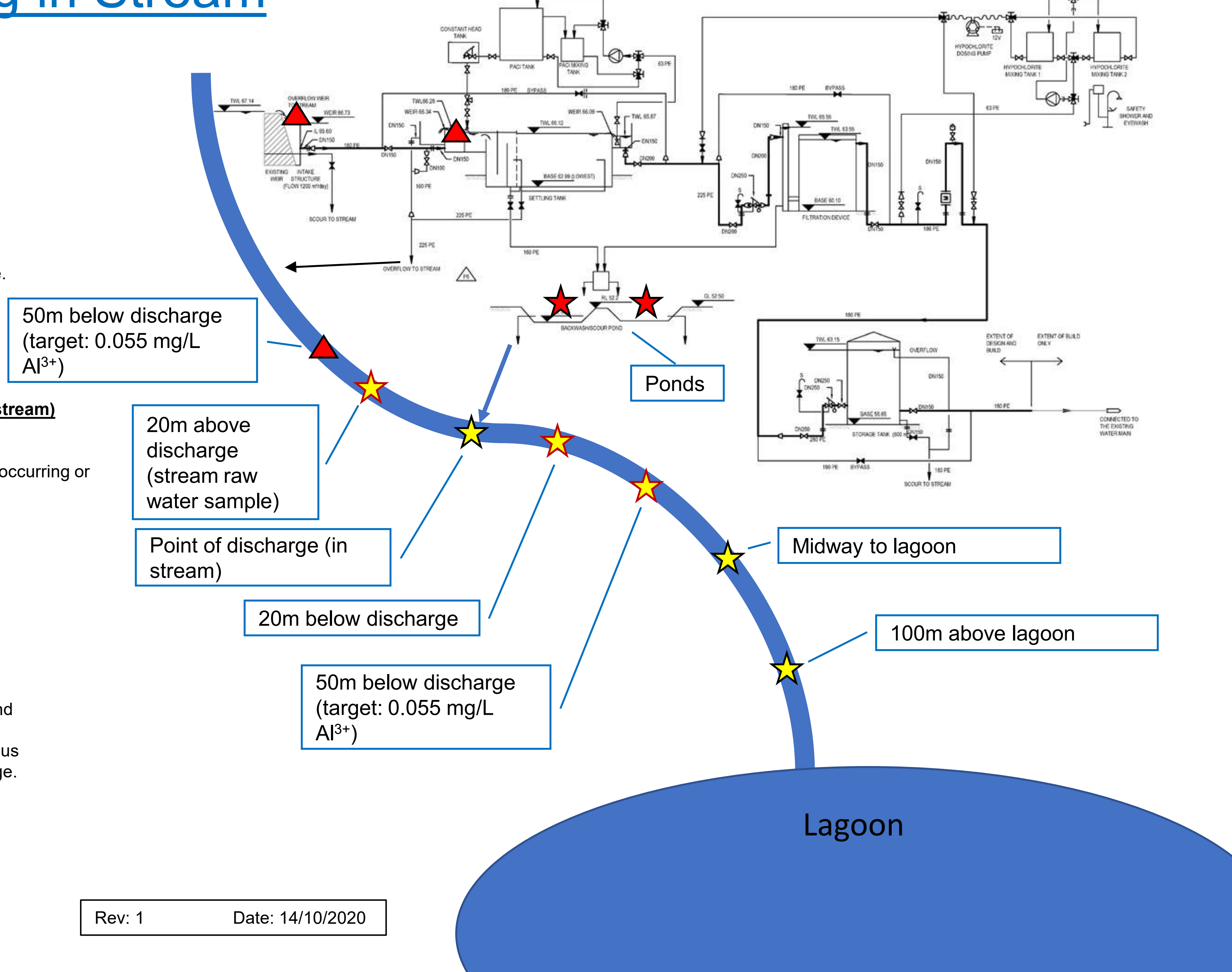
Second part: if first part ok: discharge to stream. Start, Plus 1 hour, plus 2 hours, Raw water and chamber and at 50 m downstream of discharge.

Samples locations:

- raw water and
- water going into the overflow chamber (within settling tank)
- 50 m downstream of discharge

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 9 samples per test at locations



Rev: 1 Date: 14/10/2020

Memorandum

28 February 2021

To	Papua Landowners
Copy to	Angelia Williams, Sione Likiliki, National Environmental Service, To Tatou Vai
From	Matt Boyd Tel 28851
Subject	PACl Trial Results Memo 3 - Papua

1 Summary of trial results from the Papua intake

The Papua intake started the poly aluminium chloride (PACl) trial on 27 October 2020, and To Tatou Vai (TTV) approved to connect the intake to the drinking water network on 31 October 2020 after reviewing results of the off-line trial (see the next section for more details about the trial stages).

Since 4 November 2020, the plant was disconnected from the network. This was expected to happen when the network is receiving a good supply of water from the other intakes that are located slightly higher in the hills. Papua will be brought back online when the network pressure falls.

During both stages of the trial, the contractor monitors the treatment plant and discharges to the environment.

To date, the intake delivers treated water that meets the requirements. The measured discharges to the environment also meet the requirements.

2 Purpose of this memorandum

The Cook Islands Government directed the Te Mato Vai project contractor McConnell Dowell to carry out water treatment commissioning trials at all the intakes progressively. The first of the trials commenced on Monday 28 September 2020 at Ngatoe Intake. The commissioning trial begins with polyaluminium chloride (PACl) first dosed into the settling tank/s which are located below the intakes. The active component of the PACl is aluminium which dissolves into the water and causes dirt to settle out of suspension.

This memo describes the trial process and presents an interim report of the results to date.

3 Trial Process

The first stage of the trial is undertaken while the network is **off-line**, that means that none of the raw water that is dosed with the PACl leaves the site and instead is stored in the storage tanks located just below the settling tanks. This stage of the trial continues for a few to several days while samples are taken and tested for dissolved aluminium, turbidity, pH and E.coli.

If acceptable results are achieved for the **off-line trial** the results are forwarded to To Tatou Vai (TTV) for their approval to discharge the treated water to the network. TTV compare the results to the World Health Organisation (WHO) drinking water standards and provide permission based on what is safe for human consumption. If their permission to release is received, the second stage of the trial (the **on-line trial**) is started. The **on-line trial** is when the treated water is then discharged to the network.

It should be noted that two of the treatment plants don't have storage tanks, and at one of the sites the tank is too small to receive an adequate volume of water for an **off-line trial**. For these three treatment plants results from other plants will be used to assess whether or not the dosing can go directly **on-line**. These plants will still have regular dissolved aluminium, turbidity, pH and E.coli samples taken to ensure they meet the WHO drinking water standards and they will be some of the last plants to be trialled.

Once the **on-line trial** has started (when treated water enters the pipe network), it will continue at each intake for the remaining trial period which could be as long as six months, depending on when we receive sufficient data to determine how to best operate the plants in the future. The Contractor will do regular testing of the treated water for dissolved aluminium initially per day at each treatment plant for the first part of the trial and eventually reduced testing to once per week.

Additional to the treated water tests, Environmental sampling of the water discharging from the ponds is done for dissolved aluminium, turbidity, and pH, in the streams. Results from these tests are sent to the National Environment Service (NES). The stream is sampled while a discharge from the pond to the stream occurs, and also background sampling in the stream when no discharge occurs is undertaken.

The stream sampling locations are listed below and presented in Appendix A.

- 20m above the discharge point
- At the point of discharge
- 20m below the discharge point
- 50m below the discharge point (note this is the point where the target concentration should not be exceeded)
- Midway to the lagoon
- 100m above the lagoon

NES and the Landowners will be advised of all the above results. This environmental sampling will be conducted initially weekly then fortnightly after the initial discharge sample.

4 Results

4.1 Intake performance

The requirements for the treated water that is supplied to the drinking water network are as follows:

- The turbidity after the AVG should be lower than the raw stream turbidity.
- The E. coli concentration after the AVG generally should be lower than the raw stream concentration.
- The dissolved aluminium concentration after the AVG should be lower than 0.2 mg/L, and must not be higher than 0.3 mg/L.

If the treated water quality meets the turbidity, E. coli and dissolved aluminium requirements, it can be discharged to the drinking water network with the approval of TTV the network operator.

Table 1 presents the results to date from the **off-line** and **on-line trial**. The results are compared to the limits for discharge.

Cells that are greyed out indicate that no sample was taken at that time for the parameter in question.

To date, the intake has delivered treated water that met all requirements.

Table 1 Treated water quality results for the off-line and on-line trial at Papua.

	Turbidity (NTU)			**E.Coli (MPN/100 mL)**			**Dissolved Aluminium (mg/L)**			**Comments**
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	**Stream**	**Post AVG**	**Status**	**Stream**	**Post AVG**	**Status**	**Post Settling Tank**	**Post AVG**	**Status**	
27/10/2020 13:00	4.58	1.34	Ok							
27/10/2020 14:00	3.98	0.48	Ok							
27/10/2020 15:00	3.45	0.01	Ok	435.2	39.9	Ok		0.052	Ok	
28/10/2020 12:00	1.58	0.35	Ok							
28/10/2020 13:00	1.57	0.37	Ok							
28/10/2020 14:00	2.08	0.38	Ok	193.5	2	Ok		0.069	Ok	Storage tank full, intake shut down
31/10/2020	TTV approved the discharge of treated water to network. At the completion of the off-line trial, the plant was shut down for to allow works on the pipeline. The works were completed on 1 November, and the plant was restarted on the 3 November 2020.									
03/11/2020	10.62	2.96	OK	1732.9	461.1	OK		0.067	OK	
4/11/2020	The intake was shut down on 4 November 2020, the plant was disconnected from the network. This is expected to happen when the network is receiving good supply from the other intakes that are located slightly higher. Papua will be brought back online when the network pressure falls.									

Notes:

Between 21 Oct 2020 and 2 Nov 2020, a shortage of laboratory supplies for dissolved aluminium tests resulted in testing for dissolved aluminium reduced to the key compliance samples.

4.2 Environmental Monitoring

For discharges from the ponds to the stream, the environmental requirements are that the dissolved aluminium 50 m downstream from the discharge point should be at or below 0.055 mg/L. Dissolved aluminium is monitored at several points as presented in Appendix A.

Results of the peak and background sampling monitoring discharges from the ponds to the stream are presented in **Error! Reference source not found.**. The row with the blue title indicates the location where the concentration should be at or below 0.055 mg/L. A green cell indicates that the value is below the target concentration. Cells that are greyed out indicate that no sample was taken at that time for the location in question.

The PMU uses two sampling methods.

Peak sampling is undertaken during a discharge from the pond to the stream. The sample is taken at a time when the discharged water from the pond has reached the specific sample location[1].

Background samples are taken in the stream, but not necessarily when a discharge from the ponds to the stream occurs. They measure how the background concentration in the stream is influenced by the infrequent pond discharges, as well as the natural dissolved aluminium level upstream of the treatment plants.

4.2.1 Naturally Occurring Dissolved Aluminium

The ANZECC guideline value for dissolved aluminum in streams is less than 0.055 mg/L at 50 m below the discharge point. The TMV project's goal is that the discharges from the treatment plants to the streams do not cause harm to the environment. Monitoring during the trial and some historic readings have shown that the natural dissolved aluminum levels can sometimes be greater than the ANZECC limit when measured upstream of the treatment plants. The September 2020 Te Mato Vai Ecology Baseline Report concludes that dissolved aluminum levels of up to 0.290 mg/L or greater (potentially up to 0.630 mg/L) would not result in environmental harm. Natural occurring dissolved aluminum levels have been measured to date up to 0.170 mg/L following rainfall events. The monitoring of releases from the treatment plant has shown that at 50 m downstream of the point of release, no elevation of dissolved aluminum is occurring as a result of any discharge, with results consistently showing lower readings than in the ponds. In the instance where the level at 50 m downstream of discharge is above the ANZECC limit, the data shows that this is likely the result of the natural background levels being elevated in a rainfall event. In most instances the treatment plants were not discharging during the time of sampling and the 50 m downstream sample was taken from the raw stream water only.

The results are considered acceptable despite being above the ANZECC limit provided a net decrease in dissolved aluminum is maintained 50 m downstream of any discharge point.

[1] We use a floating object to determine when pond water has reached the specific location. The floating object is used to determine the velocity of the stream. Considering this velocity and the distance to the sampling point, we calculate the earliest time that the pond discharge will reach the sampling point.

TE MATO VAI

Memorandum

Table 2 Dissolved aluminium results (mg/L) from the Papua stream sampling.

Sample Date			30 October 2020		4 November 2020		11 November 2020		2 December 2020	
	Sample Location	**Limit**	**Result**	**Status**	**Result**	**Status**	**Result**	**Status**	**Result**	**Status**
		D.Alu mg/L	**D.Alu mg/L**	**Peak**	**D.Alu mg/L**	**Back-ground**	**D.Alu mg/L**	**Back-ground**	**D.Alu mg/L**	**Background**
Pond	In Pond 1 (Upstream Pond)		0.013							
	In Pond 2 (Downstream Pond)				No water		No water			
Stream	In Stream (20 m upstream of Pond)		0.008		0.016		0.016		0.014	
	In Stream (at pond)									
	In Stream (20 m downstream of Pond)		0.008		0.011		0.008		0.021	
	In Stream (50 m downstream of Pond)	0.055	0.008	**OK**	0.019	**OK**	0.010	**OK**	0.015	**OK**
	In Stream (1/2 way to lagoon)		0.008							
	In Stream (100 m from la-goon)		0.008							

Table 3 Dissolved aluminium results (mg/L) from the Papua stream sampling (Cont.)

Sample Date			16 December 2020		30 December 2020		12 January 2021	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)							
	In Pond 2 (Downstream Pond)							
Stream	In Stream (20 m upstream of Pond)		0.008		0.022		0.009	
	In Stream (at pond)							
	In Stream (20 m downstream of Pond)		0.075		0.008		0.020	
	In Stream (50 m downstream of Pond)	0.055	0.014	**OK**	0.009	**OK**	0.020	**OK**
	In Stream (1/2 way to lagoon)							
	In Stream (100 m from lagoon)							

Table 4 Dissolved aluminium results (mg/L) from the Papua stream sampling (Cont.)

Sample Date			25 January 2021		8 February 2021	
	Sample Location	Limit	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)					
	In Pond 2 (Downstream Pond)					
Stream	In Stream (20 m upstream of Pond)		0.011		0.008	
	In Stream (at pond)					
	In Stream (20 m downstream of Pond)		0.020		0.028	
	In Stream (50 m downstream of Pond)	0.055	0.023	**OK**	0.008	**OK**
	In Stream (1/2 way to lagoon)					
	In Stream (100 m from lagoon)					

Notes:

Between 21 Oct 2020 and 2 Nov 2020, a shortage of laboratory supplies for dissolved aluminium tests resulted in testing for dissolved aluminium reduced to the key compliance samples.

4.3 Settling tank overflow test results

The settling tank at each intake is designed to overflow at the inlet if there is low demand to return raw stream water back to the stream. As part of the court appointed expert witness review it was agreed to manually trigger an overflow in at least one intake as part of the trial and test the water to ensure water with elevated dissolved aluminium was not passing back into the stream. This overflow test is only required in one intake because all intakes are constructed in the same way.

Environmental testing for dissolved aluminium was undertaken at three locations

- in the settling tank overflow chamber
- in the stream, upstream of the discharge point, and
- in the stream, 50 meters downstream of the discharge point.

Testing was undertaken at the beginning of the overflow, after 1 hour and then after 2 hours of continuous overflow.

Results

Results of the overflow test are presented in Table 5 and Table 6 showing that dissolved aluminium levels are not elevated above the limit due to the discharge.

Table 5 Settling tank overflow test results for Ngatoe

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.008	0.008	OK
After 1 hour	0.008	0.008	0.023	OK
After 2 hours	0.013	0.019	0.009	OK

Table 6 Settling tank overflow test results for Papua

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.016	0.016	OK
After 1 hour	0.008	0.008	0.008	OK
After 2 hours	0.008	0.008	0.017	OK

Regards

Matt Boyd
Deputy Project Manager

Appendix A

Environmental Sampling

Environmental Sampling in Stream

1. Sample in the Pond (day before proposed release)

Done once per plant

Sample in the ponds for Al concentration

Testing:

- Dissolved Aluminium
- Turbidity
- pH

2 samples, 1 per pond at star locations ★

2. Environmental Peak Sampling (manual discharge to stream)

1 to 2 times at each plant at different stream conditions.

Sampled during a controlled release from the ponds to the stream,

Timed sampling based on stream flow rate 60 mins after initial release.

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 8 samples per test at star locations ★ ☆ ☆

3. Environmental Background Sampling (automatic discharge to stream)

- No less than weekly for first month
- No less than fortnightly for remaining months

These samples are taken in the stream, regardless of if a discharge is occurring or not.

This sampling serves to monitor the background dissolved aluminium concentrations in the stream.

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 5 samples per test at star locations ★ ☆

4. Settling Tank Overflow to Stream

done twice in total for trial including a high energy plant

First part: contained in chamber (control). Raw water and chamber and at 50 m downstream of discharge.

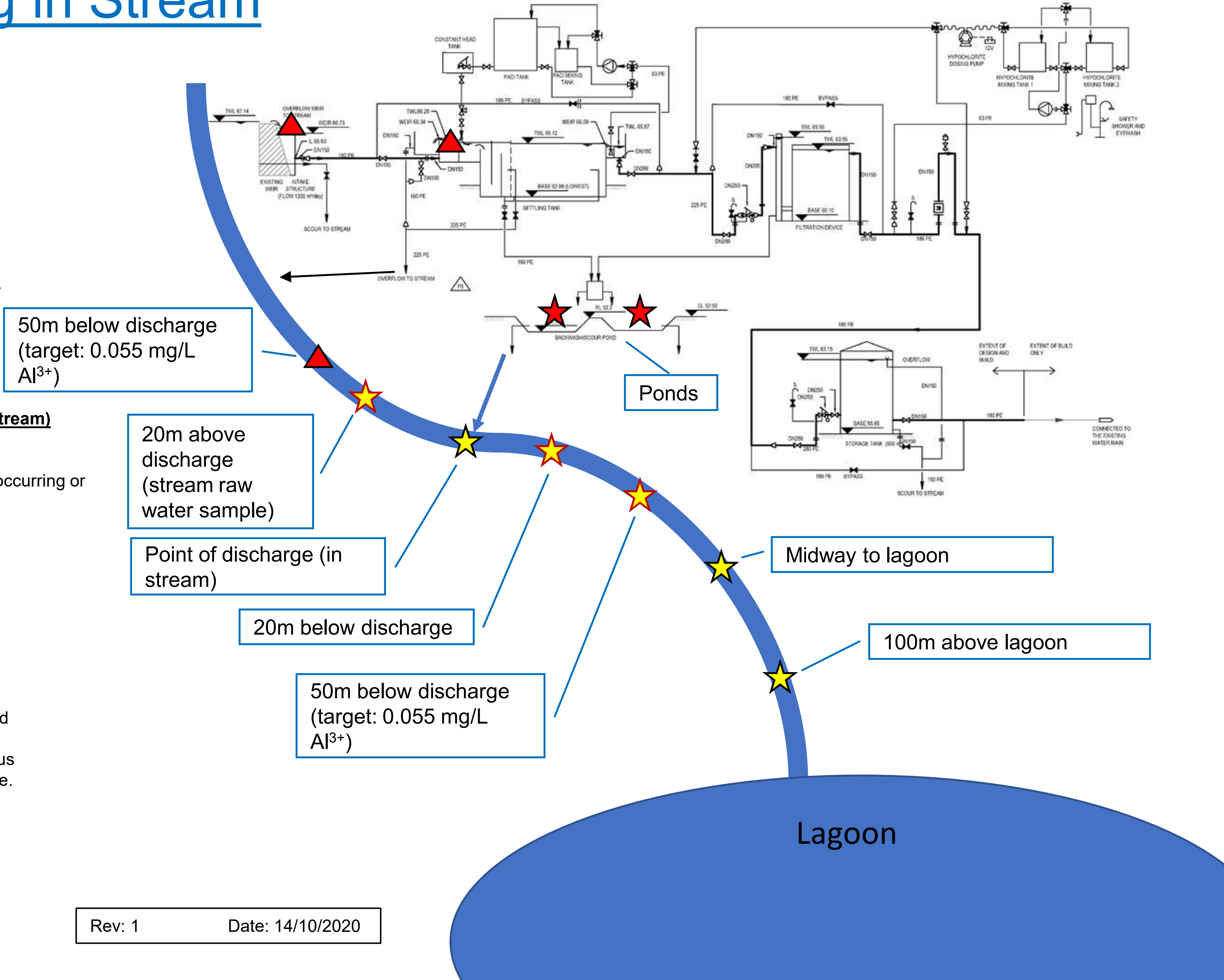
Second part: if first part ok: discharge to stream. Start, Plus 1 hour, plus 2 hours, Raw water and chamber and at 50 m downstream of discharge.

Samples locations:

- raw water and
- water going into the overflow chamber (within settling tank)
- 50 m downstream of discharge

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 9 samples per test at locations ▲



Rev: 1 Date: 14/10/2020

TE MATO VAI

Memorandum

28 February 2021

To	Taipara Landowners
Copy to	Angelia Williams, Sione Likiliki, National Environmental Service, To Tatou Vai
From	Matt Boyd — Tel 28851
Subject	PACl Trial Results Memo 2 - Taipara

1 Summary of trial results from the Taipara intake

The Taipara intake started the polyaluminium chloride (PACl) trial on 9 November 2020. Considering PACl trial results from other intakes, TTV approved that Taipara was connected directly to the network (on-line trial) because it does not have a storage tank to hold water from the off-line trial.

During all stages of the trial, the contractor monitors the treatment plant and discharges to the environment.

To date, the intake delivers treated water that meets the requirements. The measured discharges to the environment also meet the requirements.

2 Purpose of this memorandum

The Cook Islands Government directed the Te Mato Vai project contractor McConnell Dowell to carry out water treatment commissioning trials at all the intakes progressively. The first of the trials commenced on Monday 28 September 2020 at Ngatoe Intake. The commissioning trial begins with polyaluminium chloride (PACl) first dosed into the settling tank/s which are located below the intakes. The active component of the PACl is aluminium which dissolves into the water and causes dirt to settle out of suspension.

This memo describes the trial process and presents an interim report of the results to date.

3 Trial Process

The first stage of the trial is undertaken while the network is **off-line**, that means that none of the raw water that is dosed with the PACl leaves the site and instead is stored in the storage tanks located just below the settling tanks. This stage of the trial continues for a few to several days while samples are taken and tested for dissolved aluminium, turbidity, pH and E.coli.

If acceptable results are achieved for the **off-line trial** the results are forwarded to To Tatou Vai (TTV) for their approval to discharge the treated water to the network. TTV compare the results to the World Health Organisation (WHO) drinking water standards and provide permission based on what is safe for human consumption. If

their permission to release is received, the second stage of the trial (the **on-line trial**) is started. The **on-line trial** is when the treated water is then discharged to the network.

It should be noted that two of the treatment plants don't have storage tanks, and at one of the sites the tank is too small to receive an adequate volume of water for an **off-line trial**. For these three treatment plants results from other plants will be used to assess whether or not the dosing can go directly **on-line**. These plants will still have regular dissolved aluminium, turbidity, pH and E.coli samples taken to ensure they meet the WHO drinking water standards and they will be some of the last plants to be trialled.

Once the **on-line trial** has started (when treated water enters the pipe network), it will continue at each intake for the remaining trial period which could be as long as six months, depending on when we receive sufficient data to determine how to best operate the plants in the future. The Contractor will do regular testing of the treated water for dissolved aluminium initially per day at each treatment plant for the first part of the trial and eventually reduced testing to once per week.

Additional to the treated water tests, Environmental sampling of the water discharging from the ponds is done for dissolved aluminium, turbidity, and pH, in the streams. Results from these tests are sent to the National Environment Service (NES). The stream is sampled while a discharge from the pond to the stream occurs, and also background sampling in the stream when no discharge occurs is undertaken.

The stream sampling locations are listed below and presented in Appendix A.

- 20m above the discharge point
- At the point of discharge
- 20m below the discharge point
- 50m below the discharge point (note this is the point where the target concentration should not be exceeded)
- Midway to the lagoon
- 100m above the lagoon

NES and the Landowners will be advised of all the above results. This environmental sampling will be conducted initially weekly then fortnightly after the initial discharge sample.

4 Results

4.1 Intake performance

The requirements for the treated water that is supplied to the drinking water network are as follows:

- The turbidity after the AVG should be lower than the raw stream turbidity.
- The E. coli concentration after the AVG generally should be lower than the raw stream concentration.
- The dissolved aluminium concentration after the AVG should be lower than 0.2 mg/L, and must not be higher than 0.3 mg/L.

If the treated water quality meets the turbidity, E. coli and dissolved aluminium requirements, it can be discharged to the drinking water network with the approval of TTV the network operator.

Considering PACl trial results from other intakes, TTV approved that Taipara was connected directly to the network (on-line trial) because it does not have a storage tank to hold water from the off-line trial.

Table 1 presents the results to date from the **on-line trial**. The results are compared to the limits for discharge.

Cells that are greyed out indicate that no sample was taken at that time for the parameter in question.

To date, the intake has delivered treated water that met all requirements.

Table 1 Treated water quality results for the off-line and on-line trial at Taipara.

	Turbidity (NTU)			E.Coli (MPN/100 mL)			Dissolved Aluminium (mg/L)			Comments
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	Stream	Post AVG	Status	Stream	Post AVG	Status	Post Settling Tank	Post AVG	Status	
9/11/2020 13:00	9.27	0.52	OK				0.014	0.008	OK	
9/11/2020 14:00	6.90	0.98	OK				0.008	0.008	OK	
9/11/2020 15:00	3.94	2.47	OK	195.6	1986.6	Not OK	0.109	0.118	OK	High rain event, the settling tank contained high E. coli water at the start of the trial. First day of trial. The following samples show that the plant is performing fine.
9/11/2020 16:00	3.74	1.68	OK				0.098	0.098	OK	
10/11/2020 13:00	1.93	0.32	OK				0.052	0.035	OK	
10/11/2020 14:00	1.82	0.30	OK	129.6	8.6	OK	0.026	0.038	OK	
10/11/2020 15:00	1.79	0.66	OK				0.015	0.041	OK	
11/11/2020 9:43	1.04	0.11	OK							
12/11/2020 14:35	2.18	0.57	OK							
13/11/2020 10:04	1.33	0.12	OK							
14/11/2020 12:38	1.25	0.01	OK							
15/11/2020 10:51	1.93	0.14	OK							
16/11/2020 10:26	1.88	0.70	OK							
17/11/2020 9:30	1.27	0.52	OK	48.8	60.2	Not OK	0.037	0.037	OK	We suspect that this sample was taken after an AVG backwash. All adjacent samples indicate that the plant is performing fine.
18/11/2020 9:56	2.57	0.74	OK							
19/11/2020 12:56	5.62	1.84	OK	36.4	6.3	OK	0.055	0.008	OK	
20/11/2020 9:41	1.90	0.59	OK							
21/11/2020 9:15	0.75	0.25	OK							
24/11/2020 12:21	0.82	0.10	OK		1					
The plant was on bypass from 25 November until 30 December 2020 due to an air entrainment issue in the trunk main (the pipeline connecting the plant with the ring main). This is an operational issue unrelated to the plants. TTV installed an air valve, and the plant could resume operation. On the 17 December 2020, the settling tank was de-sludged.										
30/12/2020 11:34	1.79	0.64	OK							
31/12/2020 9:50	2.66	0.30	OK							
1/01/2021 7:36	0.78	0.02	OK							
2/01/2021 7:51	0.59	0.31	OK							
3/01/2021 11:50	1.58	0.14	OK							
4/01/2021 7:33	1.21	0.41	OK							
4/01/2021 8:50	0.87	0.07	OK							

	Turbidity (NTU)			E.Coli (MPN/100 mL)			Dissolved Aluminium (mg/L)			Comments
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG con-centration is below 0.2 mg/L			
Date / Time	Stre am	Post AVG	Status	Stream	Post AVG	Status	Post Settling Tank	Post AVG	Status	
5/01/2021 14:08	1.14	0.28	OK	83.9	<1	OK				
6/01/2021 11:27	1.11	0.26	OK				0.047	0.047	OK	
7/01/2021 10:05	2.57	0.17	OK							
8/01/2021 10:39	0.92	0.16	OK							
9/01/2021 14:51	1.28	0.18	OK							
10/01/2021 7:15	0.86	0.15	OK							
11/01/2021 15:38	1.25	0.49	OK							
12/01/2021 14:24	0.88	0.17	OK							
13/01/2021 11:47	0.89	0.45	OK							
14/01/2021 11:54	1.20	0.17	OK							
15/01/2021 10:21	1.22	0.30	OK							
16/01/2021 10:11	0.89	0.29	OK							
17/01/2021 8:57	0.92	0.38	OK							

Notes:

Between 21 Oct 2020 and 2 Nov 2020, a shortage of laboratory supplies for dissolved aluminium tests resulted in testing for dissolved aluminium reduced to the key compliance samples.

4.2 Environmental Monitoring

For discharges from the ponds to the stream, the environmental requirements are that the dissolved aluminium 50 m downstream from the discharge point should be at or below 0.055 mg/L. Dissolved aluminium is monitored at several points as presented in Appendix A.

Results of the peak and background sampling monitoring discharges from the ponds to the stream are presented in Table 2. The row with the blue title indicates the location where the concentration should be at or below 0.055 mg/L. A green cell indicates that the value is below the target concentration. Cells that are greyed out indicate that no sample was taken at that time for the location in question.

The PMU uses two sampling methods.

Peak sampling is undertaken during a discharge from the pond to the stream. The sample is taken at a time when the discharged water from the pond has reached the specific sample location[1].

Background samples are taken in the stream, but not necessarily when a discharge from the ponds to the stream occurs. They measure how the background concentration in the stream is influenced by the infrequent pond discharges, as well as the natural dissolved aluminium level upstream of the treatment plants.

4.2.1 Naturally Occurring Dissolved Aluminium

The ANZECC guideline value for dissolved aluminium in streams is less than 0.055 mg/L at 50 m below the discharge point. The TMV project's goal is that the discharges from the treatment plants to the streams do not cause harm to the environment. Monitoring during the trial and some historic readings have shown that the natural dissolved aluminum levels can sometimes be greater than the ANZECC limit when measured upstream of the treatment plants. The September 2020 Te Mato Vai Ecology Baseline Report concludes that dissolved aluminum levels of up to 0.290 mg/L or greater (potentially up to 0.630 mg/L) would not result in environmental harm. Natural occurring dissolved aluminum levels have been measured to date up to 0.170 mg/L following rainfall events. The monitoring of releases from the treatment plant has shown that at 50 m downstream of the point of release, no elevation of dissolved aluminum is occurring as a result of any discharge, with results consistently showing lower readings than in the ponds. In the instance where the level at 50 m downstream of discharge is above the ANZECC limit, the data shows that this is likely the result of the natural background levels being elevated in a rainfall event. In most instances the treatment plants were not discharging during the time of sampling and the 50 m downstream sample was taken from the raw stream water only.

The results are considered acceptable despite being above the ANZECC limit provided a net decrease in dissolved aluminum is maintained 50 m downstream of any discharge point.

[1] We use a floating object to determine when pond water has reached the specific location. The floating object is used to determine the velocity of the stream. Considering this velocity and the distance to the sampling point, we calculate the earliest time that the pond discharge will reach the sampling point.

Table 2 Dissolved aluminium results (mg/L) from the Taipara stream sampling.

	Sample Date		12 November 2020		17 November 2020		23 November 2020		3 December 2020	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Peak	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)									
	In Pond 2 (Downstream Pond)		0.058							
Stream	In Stream (20 m upstream of Pond)		0.008		0.021		0.020		0.020	
	In Stream (at pond)		0.082							
	In Stream (20 m downstream of Pond)		0.035		0.025		0.015		0.014	
	In Stream (50 m downstream of Pond)	0.055	0.044	**OK**	0.028	**OK**	0.021	**OK**	0.023	**OK**
	In Stream (1/2 way to lagoon)		0.011							
	In Stream (100 m from lagoon)		0.009							

Table 3 Dissolved aluminium results (mg/L) from the Taipara stream sampling (Cont.)

Sample Date			15 December 2020		12 January 2021		25 January 2021		8 February 2021	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)								0.156	
Pond	In Pond 2 (Downstream Pond)				0.094					
Stream	In Stream (20 m upstream of Pond)		0.026		0.018		0.015		0.027	
Stream	In Stream (at pond)									
Stream	In Stream (20 m downstream of Pond)		0.021		0.016		0.009		0.008	
Stream	In Stream (50 m downstream of Pond)	0.055	0.023	**OK**	0.016	**OK**	0.017	**OK**	0.021	**OK**
Stream	In Stream (1/2 way to lagoon)									
Stream	In Stream (100 m from la-goon)									

Notes:

Between 21 Oct 2020 and 2 Nov 2020, a shortage of laboratory supplies for dissolved aluminium tests resulted in testing for dissolved aluminium reduced to the key complian+

ce samples.

4.3 Settling tank overflow test results

The settling tank at each intake is designed to overflow at the inlet if there is low demand to return raw stream water back to the stream. As part of the court appointed expert witness review it was agreed to manually trigger an overflow in at least one intake as part of the trial and test the water to ensure water with elevated dissolved aluminium was not passing back into the stream. This overflow test is only required in one intake because all intakes are constructed in the same way.

Environmental testing for dissolved aluminium was undertaken at three locations

- in the settling tank overflow chamber
- in the stream, upstream of the discharge point, and
- in the stream, 50 meters downstream of the discharge point.

Testing was undertaken at the beginning of the overflow, after 1 hour and then after 2 hours of continuous overflow.

Results

Results of the overflow test are presented in Table 4 and Table 5 showing that dissolved aluminium levels are not elevated above the limit due to the discharge.

Table 4 Settling tank overflow test results for Ngatoe

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.008	0.008	OK
After 1 hour	0.008	0.008	0.023	OK
After 2 hours	0.013	0.019	0.009	OK

Table 5 Settling tank overflow test results for Papua

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.016	0.016	OK
After 1 hour	0.008	0.008	0.008	OK
After 2 hours	0.008	0.008	0.017	OK

Regards

Matt Boyd
Deputy Project Manager

Appendix A
Environmental Sampling Location Diagram

Environmental Sampling in Stream

1. Sample in the Pond (day before proposed release)

Done once per plant

Sample in the ponds for Al concentration

Testing:

- Dissolved Aluminium
- Turbidity
- pH

2 samples, 1 per pond at star locations ★

2. Environmental Peak Sampling (manual discharge to stream)

1 to 2 times at each plant at different stream conditions.

Sampled during a controlled release from the ponds to the stream,

Timed sampling based on stream flow rate 60 mins after initial release.

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 8 samples per test at star locations ★ ☆ ☆

3. Environmental Background Sampling (automatic discharge to stream)

- No less than weekly for first month
- No less than fortnightly for remaining months

These samples are taken in the stream, regardless of if a discharge is occurring or not.

This sampling serves to monitor the background dissolved aluminium concentrations in the stream.

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 5 samples per test at star locations ★ ☆

4. Settling Tank Overflow to Stream

done twice in total for trial including a high energy plant

First part: contained in chamber (control). Raw water and chamber and at 50 m downstream of discharge.

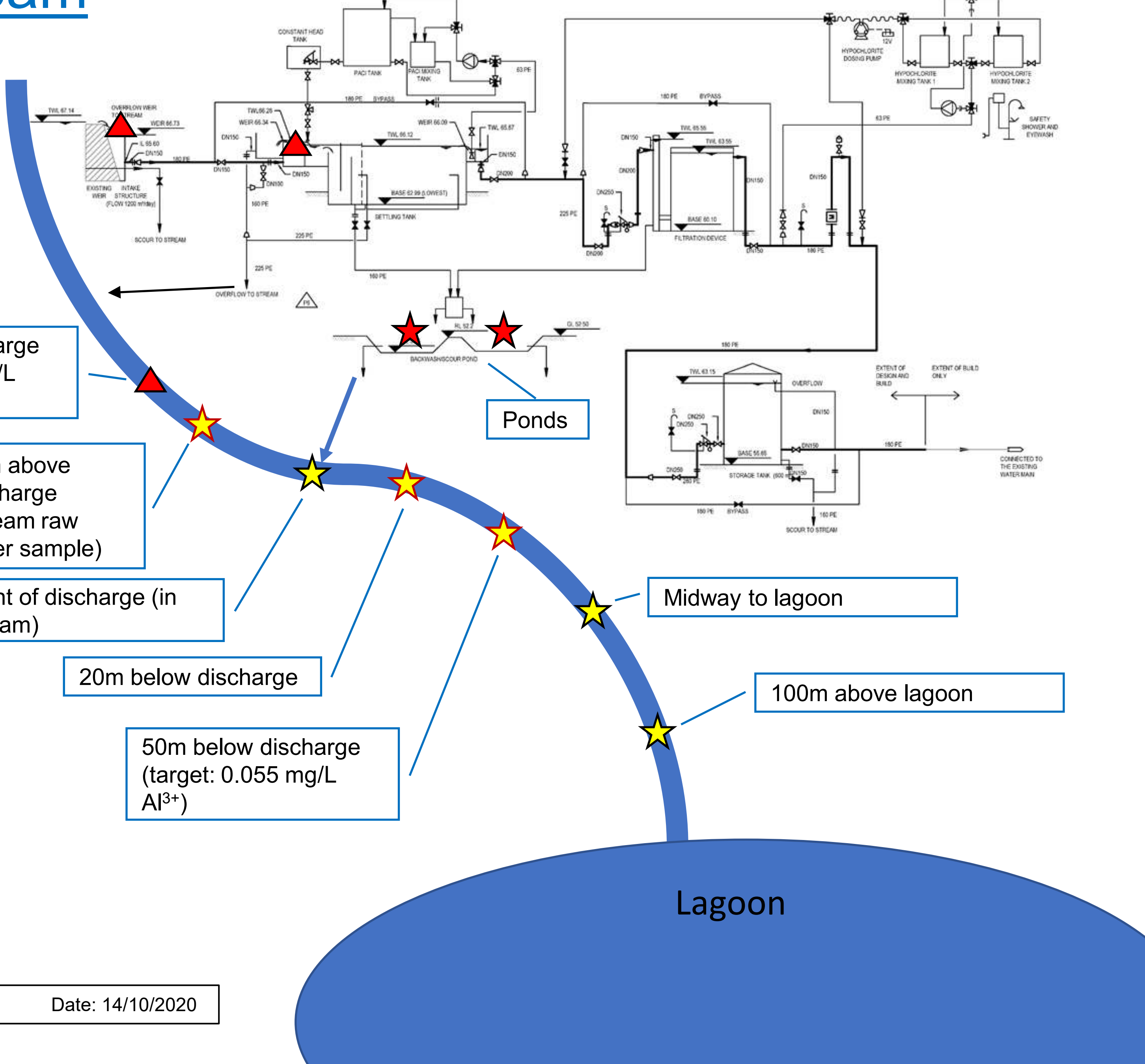
Second part: if first part ok: discharge to stream. Start, Plus 1 hour, plus 2 hours, Raw water and chamber and at 50 m downstream of discharge.

Samples locations:

- raw water and
- water going into the overflow chamber (within settling tank)
- 50 m downstream of discharge

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 9 samples per test at locations ▲



Rev: 1 Date: 14/10/2020

TE MATO VAI

Memorandum

28 February 2021

To	Takuvaine Landowners
Copy to	Angelia Williams, Sione Likiliki, National Environmental Service, To Tatou Vai
From	Matt Boyd Tel 28851
Subject	PACl Trial Results Memo 2 - Takuvaine

1 Summary of trial results from the Takuvaine intake

The Takuvaine intake started the polyaluminium chloride (PACl) trial on 16 November 2020. Considering PACl trial results from other intakes, TTV approved that Takuvaine was connected directly to the network (on-line trial) because its storage tank volume is too small to enable an off-line trial.

During all stages of the trial, the contractor monitors the treatment plant and discharges to the environment.

The intake was shut down and put into a full bypass by TTV network management staff on 19 November 2020 as part of their drought response and efforts to maintain supply to consumers high up the Takuvaine valley. The plant was not shut down due to PACl trial activities or treatment plant operation or performance. The treatment plant was restarted on 18 February 2021. Treatment plant performance data will be presented in the next report.

2 Purpose of this memorandum

The Cook Islands Government directed the Te Mato Vai project contractor McConnell Dowell to carry out water treatment commissioning trials at all the intakes progressively. The first of the trials commenced on Monday 28 September 2020 at Ngatoe Intake. The commissioning trial begins with polyaluminium chloride (PACl) first dosed into the settling tank/s which are located below the intakes. The active component of the PACl is aluminium which dissolves into the water and causes dirt to settle out of suspension.

This memo describes the trial process and presents an interim report of the results to date.

3 Trial Process

The first stage of the trial is undertaken while the network is **off-line**, that means that none of the raw water that is dosed with the PACl leaves the site and instead is stored in the storage tanks located just below the settling tanks. This stage of the trial continues for a few to several days while samples are taken and tested for dissolved aluminium, turbidity, pH and E.coli.

If acceptable results are achieved for the **off-line trial** the results are forwarded to To Tatou Vai (TTV) for their approval to discharge the treated water to the network. TTV compare the results to the World Health Organisation (WHO) drinking water standards and provide permission based on what is safe for human consumption. If their permission to release is received, the second stage of the trial (the **on-line trial**) is started. The **on-line trial** is when the treated water is then discharged to the network.

It should be noted that two of the treatment plants don't have storage tanks, and at one of the sites the tank is too small to receive an adequate volume of water for an **off-line trial**. For these three treatment plants results from other plants will be used to assess whether or not the dosing can go directly **on-line**. These plants will still have regular dissolved aluminium, turbidity, pH and E.coli samples taken to ensure they meet the WHO drinking water standards and they will be some of the last plants to be trialled.

Once the **on-line trial** has started (when treated water enters the pipe network), it will continue at each intake for the remaining trial period which could be as long as six months, depending on when we receive sufficient data to determine how to best operate the plants in the future. The Contractor will do regular testing of the treated water for dissolved aluminium initially per day at each treatment plant for the first part of the trial and eventually reduced testing to once per week.

Additional to the treated water tests, Environmental sampling of the water discharging from the ponds is done for dissolved aluminium, turbidity, and pH, in the streams. Results from these tests are sent to the National Environment Service (NES). The stream is sampled while a discharge from the pond to the stream occurs, and also background sampling in the stream when no discharge occurs is undertaken.

The stream sampling locations are listed below and presented in Appendix A.

- 20m above the discharge point
- At the point of discharge
- 20m below the discharge point
- 50m below the discharge point (note this is the point where the target concentration should not be exceeded)
- Midway to the lagoon
- 100m above the lagoon

NES and the Landowners will be advised of all the above results. This environmental sampling will be conducted initially weekly then fortnightly after the initial discharge sample.

4 Results

4.1 Intake performance

The requirements for the treated water that is supplied to the drinking water network are as follows:

- The turbidity after the AVG should be lower than the raw stream turbidity.
- The E. coli concentration after the AVG generally should be lower than the raw stream concentration.
- The dissolved aluminium concentration after the AVG should be lower than 0.2 mg/L, and must not be higher than 0.3 mg/L.

If the treated water quality meets the turbidity, E. coli and dissolved aluminium requirements, it can be discharged to the drinking water network with the approval of TTV the network operator.

Using PACl trial results from other intakes, TTV approved that Takuvaine was connected directly to the network (on-line trial) because its storage tank volume is too small to enable an off-line trial.

Table 1 presents the results to date from the **on-line trial**. The results are compared to the limits for discharge.

Cells that are greyed out indicate that no sample was taken at that time for the parameter in question.

To date, the intake has delivered treated water that met all requirements.

Table 1 Treated water quality results for the off-line and on-line trial at Takuvaine.

	Turbidity (NTU)			**E.Coli (MPN/100 mL)**			**Dissolved Aluminium (mg/L)**			**Comments**
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	Stream	Post AVG	Status	Stream	Post AVG	Status	Post Settling Tank	Post AVG	Status	
16/11/2020 11:00	1.89	1.09	OK							
16/11/2020 13:00	3.66	0.23	OK				0.064	0.072	OK	
16/11/2020 15:00	3.89	0.22	OK	686.7	85.7	OK	0.052	0.072	OK	
17/11/2020 14:00	5.12	0.25	OK				0.055	0.06	OK	
17/11/2020 15:00	3.68	0.22	OK	1299.7	153.9	OK	0.051	0.035	OK	
17/11/2020 16:00	2.70	0.18	OK				0.087	0.062	OK	
19/11/2020	The intake was shut down and put into a full bypass by TTV network management staff on 19 November 2020 as part of their drought response and efforts to maintain supply to consumers high up the Takuvaine valley. The plant was not shut down due to PACl trial activities or treatment plant operation or performance. The treatment plant was restarted on 18 February 2021. Treatment plant performance data will be presented in the next report.									
19/11/2020 14:44	4.28	0.61								Plant on bypass, no PACl dosed
20/11/2020 12:24	1.95	0.67								Plant on bypass, no PACl dosed
26/11/2020 10:45	1.16	1.44								Plant on bypass, no PACl dosed
5/01/2021 10:50				91.1						Plant on bypass, no PACl dosed

Notes:

Between 21 Oct 2020 and 2 Nov 2020, a shortage of laboratory supplies for dissolved aluminium tests resulted in testing for dissolved aluminium reduced to the key compliance samples.

4.2 Environmental Monitoring

For discharges from the ponds to the stream, the environmental requirements are that the dissolved aluminium 50 m downstream from the discharge point should be at or below 0.055 mg/L. Dissolved aluminium is monitored at several points as presented in Appendix A.

Results of the peak and background sampling monitoring discharges from the ponds to the stream are presented in Table 2. The row with the blue title indicates the location where the concentration should be at or below 0.055 mg/L. A green cell indicates that the value is below the target concentration. Cells that are greyed out indicate that no sample was taken at that time for the location in question.

The PMU uses two sampling methods.

Peak sampling is undertaken during a discharge from the pond to the stream. The sample is taken at a time when the discharged water from the pond has reached the specific sample location[1].

Background samples are taken in the stream, but not necessarily when a discharge from the ponds to the stream occurs. They measure how the background concentration in the stream is influenced by the infrequent pond discharges, as well as the natural dissolved aluminium level upstream of the treatment plants.

4.2.1 Naturally Occurring Dissolved Aluminium

The ANZECC guideline value for dissolved aluminum in streams is less than 0.055 mg/L at 50 m below the discharge point. The TMV project's goal is that the discharges from the treatment plants to the streams do not cause harm to the environment. Monitoring during the trial and some historic readings have shown that the natural dissolved aluminum levels can sometimes be greater than the ANZECC limit when measured upstream of the treatment plants. The September 2020 Te Mato Vai Ecology Baseline Report concludes that dissolved aluminum levels of up to 0.290 mg/L or greater (potentially up to 0.630 mg/L) would not result in environmental harm. Natural occurring dissolved aluminum levels have been measured to date up to 0.170 mg/L following rainfall events. The monitoring of releases from the treatment plant has shown that at 50 m downstream of the point of release, no elevation of dissolved aluminum is occurring as a result of any discharge, with results consistently showing lower readings than in the ponds. In the instance where the level at 50 m downstream of discharge is above the ANZECC limit, the data shows that this is likely the result of the natural background levels being elevated in a rainfall event. In most instances the treatment plants were not discharging during the time of sampling and the 50 m downstream sample was taken from the raw stream water only.

The results are considered acceptable despite being above the ANZECC limit provided a net decrease in dissolved aluminum is maintained 50 m downstream of any discharge point.

[1] We use a floating object to determine when pond water has reached the specific location. The floating object is used to determine the velocity of the stream. Considering this velocity and the distance to the sampling point, we calculate the earliest time that the pond discharge will reach the sampling point.

Table 2 Dissolved aluminium results (mg/L) from the Takuvaine stream sampling.

Sample Date			19 November 2020		24 November 2020		1 December 2020		9 December 2020	
	Sample Location	**Limit**	**Result**	**Status**	**Result**	**Status**	**Result**	**Status**	**Result**	**Status**
		D.Alu mg/L	**D.Alu mg/L**	**Peak**	**D.Alu mg/L**	**Background**	**D.Alu mg/L**	**Background**	**D.Alu mg/L**	**Background**
Pond	In Pond 1 (Upstream Pond)		0.075							
	In Pond 2 (Downstream Pond)									
Stream	In Stream (20 m upstream of Pond)		0.038		0.015		0.008		0.008	
	In Stream (at pond)		0.030							
	In Stream (20 m downstream of Pond)		0.012		0.025		0.013		0.009	
	In Stream (50 m downstream of Pond)	0.055	0.027	**OK**	0.025	**OK**	0.012	**OK**	0.008	**OK**
	In Stream (1/2 way to lagoon)		0.058							
	In Stream (100 m from lagoon)		0.016							

Table 3 Dissolved aluminium results (mg/L) from the Takuvaine stream sampling (Cont.)

Sample Date			22 December 2020		6 January 2021		19 January 2021		3 February 2021	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)									
	In Pond 2 (Downstream Pond)									
Stream	In Stream (20 m upstream of Pond)		0.009		0.019		0.034		0.028	
	In Stream (at pond)									
	In Stream (20 m downstream of Pond)		0.008		0.022		0.012		0.026	
	In Stream (50 m downstream of Pond)	0.055	0.008	**OK**	0.009	**OK**	0.012	**OK**	0.025	**OK**
	In Stream (1/2 way to lagoon)									
	In Stream (100 m from lagoon)									

Notes:

Between 21 Oct 2020 and 2 Nov 2020, a shortage of laboratory supplies for dissolved aluminium tests resulted in testing for dissolved aluminium reduced to the key compliance samples.

4.3 Settling tank overflow test results

The settling tank at each intake is designed to overflow at the inlet if there is low demand to return raw stream water back to the stream. As part of the court appointed expert witness review it was agreed to manually trigger an overflow in at least one intake as part of the trial and test the water to ensure water with elevated dissolved aluminium was not passing back into the stream. This overflow test is only required in one intake because all intakes are constructed in the same way.

Environmental testing for dissolved aluminium was undertaken at three locations

- in the settling tank overflow chamber
- in the stream, upstream of the discharge point, and
- in the stream, 50 meters downstream of the discharge point.

Testing was undertaken at the beginning of the overflow, after 1 hour and then after 2 hours of continuous overflow.

Results

Results of the overflow test are presented in Table 4 and Table 5 showing that dissolved aluminium levels are not elevated above the limit due to the discharge.

Table 4 Settling tank overflow test results for Ngatoe

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.008	0.008	OK
After 1 hour	0.008	0.008	0.023	OK
After 2 hours	0.013	0.019	0.009	OK

Table 5 Settling tank overflow test results for Papua

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.016	0.016	OK
After 1 hour	0.008	0.008	0.008	OK
After 2 hours	0.008	0.008	0.017	OK

Regards

Matt Boyd
Deputy Project Manager

Appendix A
Environmental Sampling Location Diagram

Environmental Sampling in Stream

1. Sample in the Pond (day before proposed release)
Done once per plant
Sample in the ponds for Al concentration
Testing:
- Dissolved Aluminium
- Turbidity
- pH

2 samples, 1 per pond at star locations

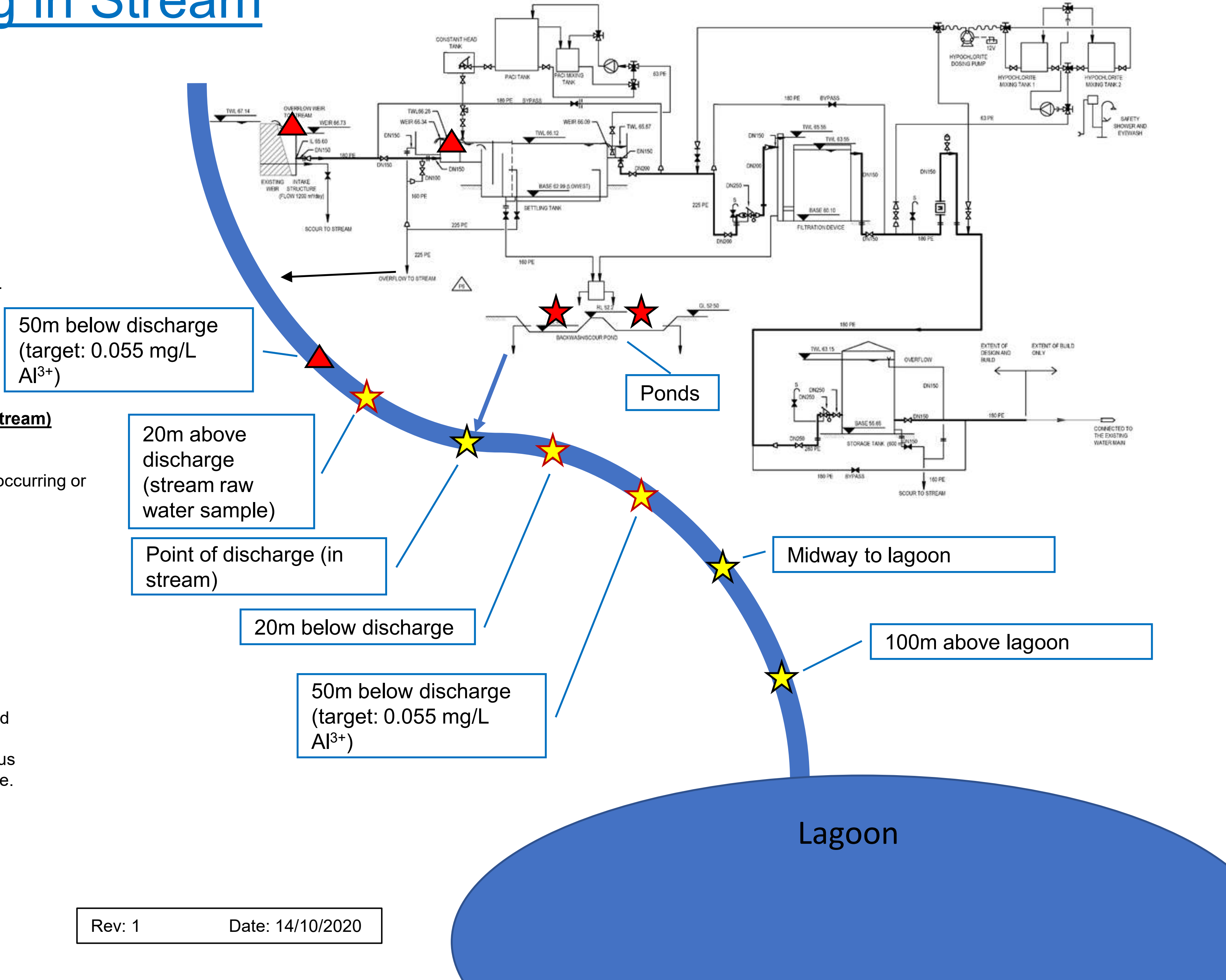
2. Environmental Peak Sampling (manual discharge to stream)
1 to 2 times at each plant at different stream conditions.
Sampled during a controlled release from the ponds to the stream,
Timed sampling based on stream flow rate 60 mins after initial release.
Testing:
- Dissolved Aluminium
- Turbidity
- pH
- 8 samples per test at star locations

3. Environmental Background Sampling (automatic discharge to stream)
- No less than weekly for first month
- No less than fortnightly for remaining months

These samples are taken in the stream, regardless of if a discharge is occurring or not.
This sampling serves to monitor the background dissolved aluminium concentrations in the stream.
Testing:
- Dissolved Aluminium
- Turbidity
- pH
- 5 samples per test at star locations

4. Settling Tank Overflow to Stream
done twice in total for trial including a high energy plant
First part: contained in chamber (control). Raw water and chamber and at 50 m downstream of discharge.
Second part: if first part ok: discharge to stream. Start, Plus 1 hour, plus 2 hours, Raw water and chamber and at 50 m downstream of discharge.
Samples locations:
- raw water and
- water going into the overflow chamber (within settling tank)
- 50 m downstream of discharge

Testing:
- Dissolved Aluminium
- Turbidity
- pH
- 9 samples per test at locations



Rev: 1 Date: 14/10/2020

Memorandum

28 February 2021

To	Totokoitu Landowners
Copy to	Angelia Williams, Sione Likiliki, National Environmental Service, To Tato Vai
From	Matt Boyd — Tel 28851
Subject	PACl Trial Results Memo 1 - Totokoitu

1 Summary of trial results from the Ngatoe intake

The Totokoitu intake started the polyaluminium chloride (PACl) trial on 30 November 2020. Considering PACl trial results from other intakes, To Tatou Vai (TTV) approved that Totokoitu was connected directly to the network (on-line trial) because it does not have a storage tank to hold water from the off-line trial.

During both stages of the trial, the contractor monitors the treatment plant and discharges to the environment

2 Purpose of this memorandum

The Cook Islands Government directed the Te Mato Vai project contractor McConnell Dowell to carry out water treatment commissioning trials at all the intakes progressively. The first of the trials commenced on Monday 28 September 2020 at Ngatoe Intake. The commissioning trial begins with polyaluminium chloride (PACl) first dosed into the settling tank/s which are located below the intakes. The active component of the PACl is aluminium which dissolves into the water and causes dirt to settle out of suspension.

This memo describes the trial process and presents an interim report of the results to date.

3 Trial Process

The first stage of the trial is undertaken while the network is **off-line**, that means that none of the raw water that is dosed with the PACl leaves the site and instead is stored in the storage tanks located just below the settling tanks. This stage of the trial continues for a few to several days while samples are taken and tested for dissolved aluminium, turbidity, pH and E.coli.

If acceptable results are achieved for the **off-line trial** the results are forwarded to To Tatou Vai (TTV) for their approval to discharge the treated water to the network. TTV compare the results to the World Health Organisation (WHO) drinking water standards and provide permission based on what is safe for human consumption. If their permission to release is received, the second stage of the trial (the **on-line trial**) is started. The **on-line trial** is when the treated water is then discharged to the network.

It should be noted that two of the treatment plants don't have storage tanks, and at one of the sites the tank is too small to receive an adequate volume of water for an **off-line trial**. For these three treatment plants results from other plants will be used to assess whether or not the dosing can go directly **on-line**. These plants will still have regular dissolved aluminium, turbidity, pH and E.coli samples taken to ensure they meet the WHO drinking water standards and they will be some of the last plants to be trialled.

Once the **on-line trial** has started (when treated water enters the pipe network), it will continue at each intake for the remaining trial period which could be as long as six months, depending on when we receive sufficient data to determine how to best operate the plants in the future. The Contractor will do regular testing of the treated water for dissolved aluminium initially per day at each treatment plant for the first part of the trial and eventually reduced testing to once per week.

Additional to the treated water tests, Environmental sampling of the water discharging from the ponds is done for dissolved aluminium, turbidity, and pH, in the streams. Results from these tests are sent to the National Environment Service (NES). The stream is sampled while a discharge from the pond to the stream occurs, and also background sampling in the stream when no discharge occurs is undertaken.

The stream sampling locations are listed below and presented in Appendix A.

- 20m above the discharge point
- At the point of discharge
- 20m below the discharge point
- 50m below the discharge point (note this is the point where the target concentration should not be exceeded)
- Midway to the lagoon
- 100m above the lagoon

NES and the Landowners will be advised of all the above results. This environmental sampling will be conducted initially weekly then fortnightly after the initial discharge sample.

4 Results

4.1 Intake performance

The requirements for the treated water that is supplied to the drinking water network are as follows:

- The turbidity after the AVG should be lower than the raw stream turbidity.
- The E. coli concentration after the AVG generally should be lower than the raw stream concentration.
- The dissolved aluminium concentration after the AVG should be lower than 0.2 mg/L, and must not be higher than 0.3 mg/L.

If the treated water quality meets the turbidity, E. coli and dissolved aluminium requirements, it can be discharged to the drinking water network with the approval of TTV the network operator.

Table 1 presents the results to date from the **off-line** and **on-line trial**. The results are compared to the limits for discharge.

Cells that are greyed out indicate that no sample was taken at that time for the parameter in question.

To date, the intake has delivered treated water that met all requirements.

Table 1 Treated water quality results for the off-line and on-line trial at Totokoitu.

	Turbidity (NTU)			E.Coli (MPN/100 mL)			Dissolved Aluminium (mg/L)			Comments
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	Stream	Post AVG	Status	Stream	Post AVG	Status	Post Settling Tank	Post AVG	Status	
30/11/2020 12:00	1.05	0.56	OK							
30/11/2020 13:00	1.14	0.19	OK				0.057	0.05	OK	
30/11/2020 14:00	1.32	0.25	OK				0.016	0.051	OK	
30/11/2020 15:00	1.06	0.04	OK	66.3	<1	OK	0.05	0.038	OK	
30/11/2020 16:00	0.99	0.09	OK				0.059	0.026	OK	
1/12/2020 9:00	1.78	0.10	OK							
1/12/2020 10:00	0.98	0.32	OK							
1/12/2020 11:00	1.42	0.32	OK							
1/12/2020 12:00	1.84	0.53	OK							
1/12/2020 13:00	1.73	0.50	OK	55.6	<1	OK	0.051	0.031	OK	
1/12/2020 14:00	1.45	0.60	OK				0.033	0.039	OK	
1/12/2020 15:00	1.06	0.50	OK				0.052	0.037	OK	
1/12/2020 16:00	1.36	0.58	OK				0.042	0.037	OK	
3/12/2020 10:40	68.3	0.07	OK							
4/12/2020 8:38	0.86	0.18	OK							
6/12/2020 12:49	3.17	0.96	OK							
7/12/2020 16:06	1.43	0.18	OK							
8/12/2020 11:30	1.25	0.01	OK	613.1	<1	OK	0.019	0.016	OK	
8/12/2020 13:43	1.25	0.01	OK							
9/12/2020 9:50	1.61	0.03	OK							
10/12/2020 9:40	1.65	0.41	OK	83.9	<1	OK	0.016	0.032	OK	
11/12/2020 11:15	2.72	1.16	OK							
12/12/2020 9:31	1.96	0.08	OK							
13/12/2020 10:50	1.67	0.29	OK							
14/12/2020 16:08	1.49	0.14	OK							
17/12/2020 13:52	0.75	0.02	OK	98.8	<1	OK				
18/12/2020 13:35	3.89	0.27	OK							
19/12/2020 9:45	2.86	0.09	OK							
20/12/2020 10:00	1.4	0	OK							
21/12/2020 9:51	0.98	0.01	OK							
22/12/2020 0:00				166.4	2	OK	0.02	0.021	OK	
23/12/2020 10:16	2.71	0.32	OK	166.4	2	OK				
24/12/2020 8:54	4.51	1.38	OK							
25/12/2020 7:55	0.72	0	OK							
26/12/2020 7:12	1.7	0.09	OK							
27/12/2020 7:18	133	0.06	OK							
28/12/2020 10:11	2.11	0.15	OK							
29/12/2020 11:29	1.37	0.26	OK	1732.9	5.1	OK	0.051	0.044	OK	
30/12/2020 9:15	1.14	0.18	OK							

	Turbidity (NTU)			E.Coli (MPN/100 mL)			Dissolved Aluminium (mg/L)			Comments
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	Stream	Post AVG	Status	Stream	Post AVG	Status	Post Settling Tank	Post AVG	Status	
31/12/2020 8:50	34.4	0.83	OK							
1/01/2021 8:11	2.19	0	OK							
2/01/2021 8:17	1.65	0.11	OK							
3/01/2021 23:20	2.83	0.24	OK							
4/01/2021 8:07	1.23	0.16	OK							
5/01/2021 11:47	1.62	0.11	OK				0.056	0.036	OK	
6/01/2021 10:26	1.02	0.46	OK							
7/01/2021 9:59	1.29	0.13	OK							
8/01/2021 12:23	1.04	0.21	OK							
9/01/2021 14:06	1.64	0.17	OK							
10/01/2021 7:41	1.53	0.21	OK							
11/01/2021 12:39	1.21	0.17	OK							
12/01/2021 11:45	1.16	0.22	OK							
13/01/2021 12:33	0.85	0.18	OK							
14/01/2021 11:14	1.02	0.27	OK							
15/01/2021 11:04	1.09	0.21	OK							
16/01/2021 9:59	0.79	0.16	OK							
17/01/2021 8:44	0.89	0.33	OK							

Notes:

Between 21 Oct 2020 and 2 Nov 2020, a shortage of laboratory supplies for dissolved aluminium tests resulted in testing for dissolved aluminium reduced to the key compliance samples.

4.2 Environmental Monitoring

For discharges from the ponds to the stream, the environmental requirements are that the dissolved aluminium 50 m downstream from the discharge point should be at or below 0.055 mg/L. Dissolved aluminium is monitored at several points as presented in Appendix A.

Results of the peak and background sampling monitoring discharges from the ponds to the stream are presented in Table 2. The row with the blue title indicates the location where the concentration should be at or below 0.055 mg/L. A green cell indicates that the value is below the target concentration. Cells that are greyed out indicate that no sample was taken at that time for the location in question.

The PMU uses two sampling methods.

Peak sampling is undertaken during a discharge from the pond to the stream. The sample is taken at a time when the discharged water from the pond has reached the specific sample location[1].

Background samples are taken in the stream, but not necessarily when a discharge from the ponds to the stream occurs. They measure how the background concentration in the stream is influenced by the infrequent pond discharges, as well as the natural dissolved aluminium level upstream of the treatment plants.

4.2.1 Naturally Occurring Dissolved Aluminium

The ANZECC guideline value for dissolved aluminum in streams is less than 0.055 mg/L at 50 m below the discharge point. The TMV project's goal is that the discharges from the treatment plants to the streams do not cause harm to the environment. Monitoring during the trial and some historic readings have shown that the natural dissolved aluminum levels can sometimes be greater than the ANZECC limit when measured upstream of the treatment plants. The September 2020 Te Mato Vai Ecology Baseline Report concludes that dissolved aluminum levels of up to 0.290 mg/L or greater (potentially up to 0.630 mg/L) would not result in environmental harm. Natural occurring dissolved aluminum levels have been measured to date up to 0.170 mg/L following rainfall events. The monitoring of releases from the treatment plant has shown that at 50 m downstream of the point of release, no elevation of dissolved aluminum is occurring as a result of any discharge, with results consistently showing lower readings than in the ponds. In the instance where the level at 50 m downstream of discharge is above the ANZECC limit, the data shows that this is likely the result of the natural background levels being elevated in a rainfall event. In most instances the treatment plants were not discharging during the time of sampling and the 50 m downstream sample was taken from the raw stream water only.

The results are considered acceptable despite being above the ANZECC limit provided a net decrease in dissolved aluminum is maintained 50 m downstream of any discharge point.

[1] We use a floating object to determine when pond water has reached the specific location. The floating object is used to determine the velocity of the stream. Considering this velocity and the distance to the sampling point, we calculate the earliest time that the pond discharge will reach the sampling point.

Table 2 Dissolved aluminium results (mg/L) from the Totokoitu stream sampling.

Sample Date			3 December 2020		8 December 2020		15 December 2020		22 December 2020	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Peak	D.Alu mg/L	Peak	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)		0.019		0.008		0.031		0.041	
Pond	In Pond 2 (Downstream Pond)		0.040		0.012		0.034		0.008	
Stream	In Stream (20 m upstream of Pond)		0.018		0.015		0.014		0.027	
Stream	In Stream (at pond)		0.018		0.024					
Stream	In Stream (20 m downstream of Pond)		0.037		0.033		0.031		0.008	
Stream	In Stream (50 m downstream of Pond)	0.055	0.037	**OK**	0.026	**OK**	0.039	**OK**	0.011	**OK**
Stream	In Stream (1/2 way to lagoon)		0.025		0.012					
Stream	In Stream (100 m from lagoon)		0.012		0.013					

Table 3 Dissolved aluminium results (mg/L) from the Totokoitu stream sampling (Cont.)

Sample Date			6 January 2021		18 January 2021		20 January 2021		22 January 2021	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Peak	D.Alu mg/L	Peak
Pond	In Pond 1 (Upstream Pond)		0.289		0.055		0.010		0.053	
	In Pond 2 (Downstream Pond)						0.019		0.022	
Stream	In Stream (20 m upstream of Pond)		0.031		0.017		0.078		0.038	
	In Stream (at pond)						0.054		0.076	
	In Stream (20 m downstream of Pond)		0.020		0.028		0.032		0.041	
	In Stream (50 m downstream of Pond)	0.055	0.018	**OK**	0.016	**OK**	0.013	**OK**	0.052	**OK**
	In Stream (1/2 way to lagoon)						0.028		0.016	
	In Stream (100 m from lagoon)						0.027		0.020	

Table 4 Dissolved aluminium results (mg/L) from the Totokoitu stream sampling (Cont.)

Sample Date			2 February 2021	
	Sample Location	Limit	Result	Status
		D.Alu mg/L	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)		0.023	
	In Pond 2 (Downstream Pond)		0.029	
Stream	In Stream (20 m upstream of Pond)		0.030	
	In Stream (at pond)			
	In Stream (20 m downstream of Pond)		0.048	
	In Stream (50 m downstream of Pond)	0.055	0.018	**OK**
	In Stream (1/2 way to lagoon)			
	In Stream (100 m from lagoon)			

Notes:

Between 21 Oct 2020 and 2 Nov 2020, a shortage of laboratory supplies for dissolved aluminium tests resulted in testing for dissolved aluminium reduced to the key compliance samples.

4.3 Settling tank overflow test results

The settling tank at each intake is designed to overflow at the inlet if there is low demand to return raw stream water back to the stream. As part of the court appointed expert witness review it was agreed to manually trigger an overflow in at least one intake as part of the trial and test the water to ensure water with elevated dissolved aluminium was not passing back into the stream. This overflow test is only required in one intake because all intakes are constructed in the same way.

Environmental testing for dissolved aluminium was undertaken at three locations

- in the settling tank overflow chamber
- in the stream, upstream of the discharge point, and
- in the stream, 50 meters downstream of the discharge point.

Testing was undertaken at the beginning of the overflow, after 1 hour and then after 2 hours of continuous overflow.

Results

Results of the overflow test are presented in Table 5 and Table 6 showing that dissolved aluminium levels are not elevated above the limit due to the discharge.

Table 5 Settling tank overflow test results for Ngatoe

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.008	0.008	OK
After 1 hour	0.008	0.008	0.023	OK
After 2 hours	0.013	0.019	0.009	OK

Table 6 Settling tank overflow test results for Papua

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.016	0.016	OK
After 1 hour	0.008	0.008	0.008	OK
After 2 hours	0.008	0.008	0.017	OK

Regards

Matt Boyd
Deputy Project Manager

Appendix A
Environmental Sampling Location Diagram

Environmental Sampling in Stream

1. Sample in the Pond (day before proposed release)

Done once per plant

Sample in the ponds for Al concentration

Testing:

- Dissolved Aluminium
- Turbidity
- pH

2 samples, 1 per pond at star locations

2. Environmental Peak Sampling (manual discharge to stream)

1 to 2 times at each plant at different stream conditions.

Sampled during a controlled release from the ponds to the stream,

Timed sampling based on stream flow rate 60 mins after initial release.

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 8 samples per test at star locations

3. Environmental Background Sampling (automatic discharge to stream)

- No less than weekly for first month
- No less than fortnightly for remaining months

These samples are taken in the stream, regardless of if a discharge is occurring or not.

This sampling serves to monitor the background dissolved aluminium concentrations in the stream.

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 5 samples per test at star locations

4. Settling Tank Overflow to Stream

done twice in total for trial including a high energy plant

First part: contained in chamber (control). Raw water and chamber and at 50 m downstream of discharge.

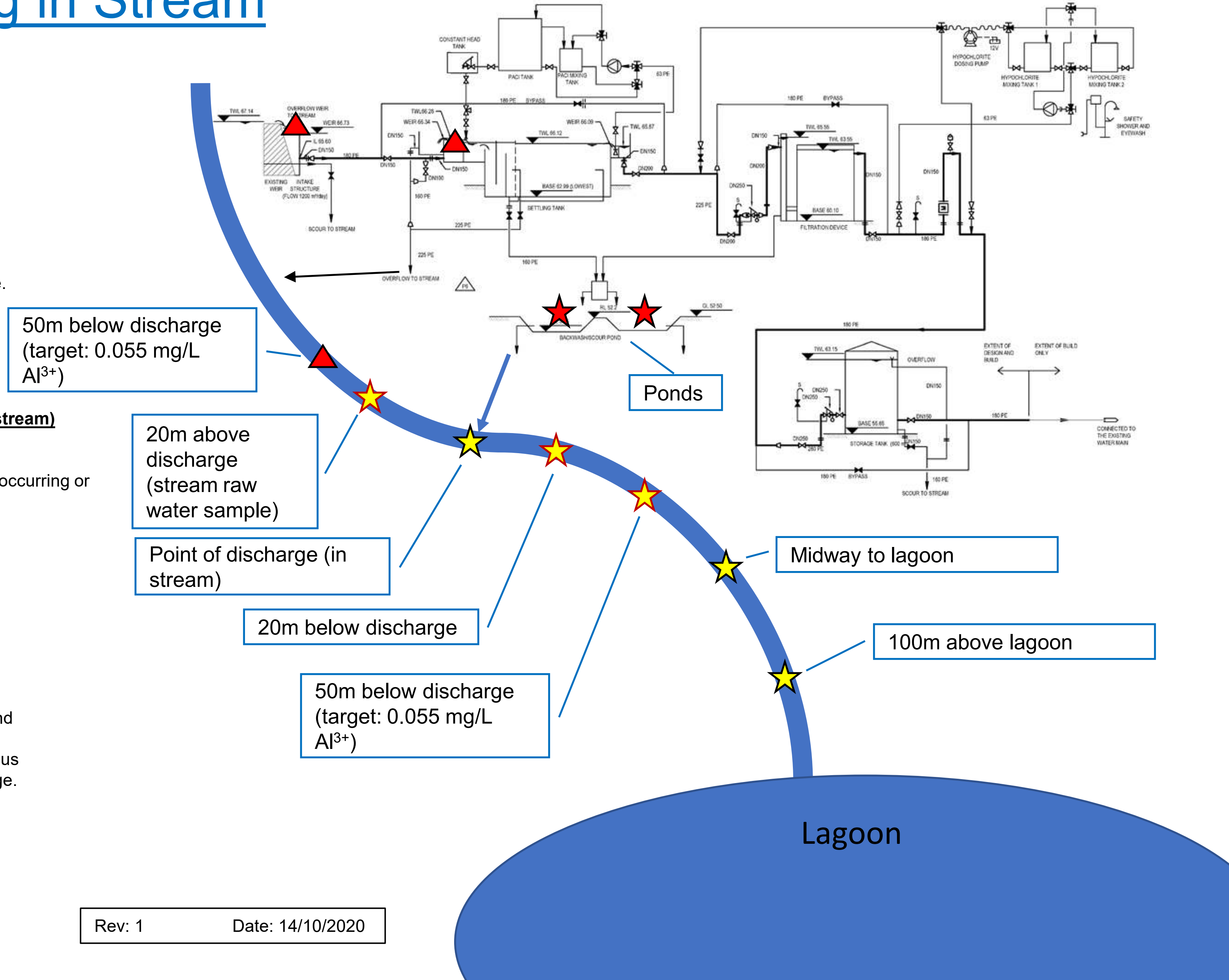
Second part: if first part ok: discharge to stream. Start, Plus 1 hour, plus 2 hours, Raw water and chamber and at 50 m downstream of discharge.

Samples locations:

- raw water and
- water going into the overflow chamber (within settling tank)
- 50 m downstream of discharge

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 9 samples per test at locations



Rev: 1 Date: 14/10/2020

TE MATO VAI

Memorandum

28 February 2021

To	Tupapa Landowners		
Copy to	Angelia Williams, Sione Likiliki, National Environmental Service, To Tatou Vai		
From	Matt Boyd	Tel	28851
Subject	PACl Trial Results Memo 2 - Tupapa		

1 Summary of trial results from the Tupapa intake

The Tupapa intake started the polyaluminium chloride (PACl) trial on 12 October 2020, and To Tatou Vai (TTV) approved to connect the intake to the drinking water network on 16 October 2020 after reviewing results of the off-line trial (see the next section for more details about the trial stages).

During both stages of the trial, the contractor monitors the treatment plant and discharges to the environment.

To date, the intake delivers treated water that meets the requirements. The measured discharges to the environment also meet the requirements.

2 Purpose of this memorandum

The Cook Islands Government directed the Te Mato Vai project contractor McConnell Dowell to carry out water treatment commissioning trials at all the intakes progressively. The first of the trials commenced on Monday 28 September 2020 at Ngatoe Intake. The commissioning trial begins with polyaluminium chloride (PACl) first dosed into the settling tank/s which are located below the intakes. The active component of the PACl is aluminium which dissolves into the water and causes dirt to settle out of suspension.

This memo describes the trial process and presents an interim report of the results to date.

3 Trial Process

The first stage of the trial is undertaken while the network is **off-line**, that means that none of the raw water that is dosed with the PACl leaves the site and instead is stored in the storage tanks located just below the settling tanks. This stage of the trial continues for a few to several days while samples are taken and tested for dissolved aluminium, turbidity, pH and E.coli.

If acceptable results are achieved for the **off-line trial** the results are forwarded to To Tatou Vai (TTV) for their approval to discharge the treated water to the network. TTV compare the results to the World Health Organisation (WHO) drinking water standards and provide permission based on what is safe for human consumption. If

their permission to release is received, the second stage of the trial (the **on-line trial**) is started. The **on-line trial** is when the treated water is then discharged to the network.

It should be noted that two of the treatment plants don't have storage tanks, and at one of the sites the tank is too small to receive an adequate volume of water for an **off-line trial**. For these three treatment plants results from other plants will be used to assess whether or not the dosing can go directly **on-line**. These plants will still have regular dissolved aluminium, turbidity, pH and E.coli samples taken to ensure they meet the WHO drinking water standards and they will be some of the last plants to be trialled.

Once the **on-line trial** has started (when treated water enters the pipe network), it will continue at each intake for the remaining trial period which could be as long as six months, depending on when we receive sufficient data to determine how to best operate the plants in the future. The Contractor will do regular testing of the treated water for dissolved aluminium initially per day at each treatment plant for the first part of the trial and eventually reduced testing to once per week.

Additional to the treated water tests, Environmental sampling of the water discharging from the ponds is done for dissolved aluminium, turbidity, and pH, in the streams. Results from these tests are sent to the National Environment Service (NES). The stream is sampled while a discharge from the pond to the stream occurs, and also background sampling in the stream when no discharge occurs is undertaken.

The stream sampling locations are listed below and presented in Appendix A.

- 20m above the discharge point
- At the point of discharge
- 20m below the discharge point
- 50m below the discharge point (note this is the point where the target concentration should not be exceeded)
- Midway to the lagoon
- 100m above the lagoon

NES and the Landowners will be advised of all the above results. This environmental sampling will be conducted initially weekly then fortnightly after the initial discharge sample.

4 Results

4.1 Intake performance

The requirements for the treated water that is supplied to the drinking water network are as follows:

- The turbidity after the AVG should be lower than the raw stream turbidity.
- The E. coli concentration after the AVG generally should be lower than the raw stream concentration.
- The dissolved aluminium concentration after the AVG should be lower than 0.2 mg/L, and must not be higher than 0.3 mg/L.

If the treated water quality meets the turbidity, E. coli and dissolved aluminium requirements, it can be discharged to the drinking water network with the approval of TTV the network operator.

Table 1 presents the results to date from the **off-line** and **on-line trial**. The results are compared to the limits for discharge.

Cells that are greyed out indicate that no sample was taken at that time for the parameter in question.

To date, the intake has delivered treated water that met all requirements.

Table 1 Treated water quality results for the off-line and on-line trial at Tupapa.

	Turbidity (NTU)			E.Coli (MPN/100 mL)			Dissolved Aluminium (mg/L)			Comments
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	**Stream**	**Post AVG**	**Status**	**Stream**	**Post AVG**	**Status**	**Post Settling Tank**	**Post AVG**	**Status**	
12/10/2020 13:00	5.03	0.62	OK				0.102	0.127	OK	
12/10/2020 14:00	3.84	0.58	OK	920.8	204.6	OK	0.069	0.108	OK	
12/10/2020 15:00	2.63	0.38	OK				0.089	0.083	OK	
12/10/2020 16:00	2.29	1.1	OK				0.108	0.086	OK	
13/10/2020 13:00	0.78	0.04	OK				0.074	0.064	OK	
13/10/2020 14:00	0.65	0.08	OK	150	<1	OK	0.036	0.018	OK	
14/10/2020 13:00	0.39	0.11	OK				0.106	0.073	OK	
14/10/2020 14:00	0.36	0.05	OK	93.3	1	OK	0.078	0.065	OK	
14/10/2020 15:00	0.36	0.28	OK				0.060	0.041	OK	
14/10/2020 16:00	0.56	0.05	OK				0.045	0.035	OK	
16/10/2020	TTV approved discharge of treated water to network . Trial is now an on-line trial.									
17/10/2020 8:30	0.59	0.14	OK							
18/10/2020 10:40	0.43	0.2	OK							
19/10/2020 13:00	0.76	0.21	OK							
20/10/2020 10:50	0.64	0.39	OK	547.5	2	OK	0.024	0.017	OK	
21/10/2020 14:40	0.62	0.16	OK							
22/10/2020 10:21	0.46	0.17	OK	123.6	<1	OK				
23/10/2020 8:35	3.05	0.27	OK							
24/10/2020 11:25	0.23	0.06	OK							
25/10/2020 10:50	0.21	0.05	OK							
26/10/2020 10:10	0.27	0.07	OK							
27/10/2020 9:20	7.02	1.16	OK							
28/10/2020 13:00	1.32	0.08	OK	261.3	9.7	OK				
29/10/2020 11:57	1.04	0.16	OK	44.3	<1	OK				
30/10/2020 9:00	0.79	0.15	OK	48	<1	OK		0.052	OK	
31/10/2020 9:13	0.75	0.17	OK							
1/11/2020 9:00	0.16	0.09	OK							
2/11/2020 11:39	3.07	0.01	OK							
3/11/2020 13:00	1.32	0.08	OK	261.3	9.7	OK				
4/11/2020 13:52	4.6	0.3	OK							
5/11/2020 10:00	1.22	0.32	OK	98.5	1	OK				
7/11/2020 9:16	1.61	1.08	OK							
8/11/2020 9:07	0.63	0.39	OK							
9/11/2020 12:02	1.06	0.46	OK							
10/11/2020 9:00	1.22	0.63	OK	73.8	3	OK	0.069	0.07	OK	
12/11/2020 10:56	0.91	0.45	OK							
13/11/2020 12:45	0.35	0.15	OK							
14/11/2020 12:38	1.25	0.01	OK							
15/11/2020 15:24	0.81	0.03	OK							
16/11/2020 11:06	1.01	0.23	OK							
17/11/2020 10:30	1.11	0.45	OK	75.4	9.8	OK	0.105	0.095	OK	
18/11/2020 12:14	1.08	0.19	OK							
19/11/2020 11:39	0.47	0.17	OK							
20/11/2020 11:47	1.15	0.43	OK							
21/11/2020 11:35	1.37	0.82	OK							
22/11/2020 10:50	0.65	0.33	OK							
23/11/2020 16:25	0.91	0.25	OK							
24/11/2020 12:14	0.65	0.04	OK							

	Turbidity (NTU)			E.Coli (MPN/100 mL)			Dissolved Aluminium (mg/L)			Comments
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	**Stream**	**Post AVG**	**Status**	**Stream**	**Post AVG**	**Status**	**Post Settling Tank**	**Post AVG**	**Status**	
25/11/2020 13:36	0.38	0.19	OK							
27/11/2020 14:43	0.64	0.01	OK							
1/12/2020 9:15	0.4	0.17	OK	79.8	5.2	OK	0.14	0.102	OK	
2/12/2020 14:55	0.65	0.45	OK							
3/12/2020 12:05	1.31	0.57	OK							
4/12/2020 9:28	1.09	0.4	OK							
5/12/2020 13:30	2.92	2.85	OK							
6/12/2020 7:52	2.66	0.21	OK							
7/12/2020 8:55	0.53	0.24	OK							
7/12/2020 9:52	0.53	0.24	OK							
8/12/2020 9:38	1.01	0.75		111.9	125.9		0.052	0.04		De-sludging of settling tank
10/12/2020 11:11	0.99	1.01								Plant by-passed, no PACl dosed
14/12/2020 15:02	0	0								Plant by-passed, no PACl dosed
15/12/2020 12:08	1.31	0.61		125	186		0.014	0.014		Plant by-passed, no PACl dosed
16/12/2020 10:12	0.24	0.01	OK							Plant re-started
17/12/2020 11:42	0.84	0.08	OK							
18/12/2020 10:37	0.36	0.39	Not OK							< 1 NTU. Ok (*)
19/12/2020 12:40	0.61	0.19	OK							
20/12/2020 23:50	0.38	0.03	OK							
21/12/2020 12:03	0.92	0.09	OK							
22/12/2020 0:00				119.6	22.8	OK	0.074	0.065	OK	
23/12/2020 10:39	1.4	0.25	OK							
24/12/2020 8:51	1.26	0.81	OK							
24/12/2020 10:51	1.26	0.81	OK							
25/12/2020 7:34	0.88	0.22	OK							
26/12/2020 10:11	0.87	0.36	OK							
27/12/2020 9:30	0.53	0.21	OK							
28/12/2020 9:44	0.8	0.28	OK							
29/12/2020 10:18	1.28	0.27	OK	206.4	98.7	OK	0.089	0.078	OK	
30/12/2020 9:48	0.72	0.23	OK							
31/12/2020 9:53	1.06	0.15	OK							
1/01/2021 9:29	1.74	0.69	OK							
2/01/2021 9:15	1.39	0.38	OK							
3/01/2021 9:15	1.67	0.33	OK							
4/01/2021 7:14	0.53	0.12	OK							
5/01/2021 11:45	2.12	0.27	OK	106.6	25.6	OK				
6/01/2021 9:56	1.1	0.39	OK				0.08	0.077	OK	
7/01/2021 10:20	0.91	0.86	OK							
8/01/2021 9:50	0.67	0.4	OK							
9/01/2021 9:47	1.21	0.94	OK							
10/01/2021 10:51	0.52	0.31	OK							
11/01/2021 14:16	2.25	0.18	OK							
12/01/2021 10:58	1.05	0.28	OK							
13/01/2021 12:03	0.7	0.35	OK							
14/01/2021 9:49	1.42	0.33	OK							
15/01/2021 8:59	1.22	0.31	OK							
16/01/2021 8:08	0.86	0.22	OK							
16/01/2021 9:08	0.86	0.22	OK							

	Turbidity (NTU)			E.Coli (MPN/100 mL)			Dissolved Aluminium (mg/L)			Comments
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	**Stream**	**Post AVG**	**Status**	**Stream**	**Post AVG**	**Status**	**Post Settling Tank**	**Post AVG**	**Status**	
17/01/2021 7:19	0.76	0.27	OK							

Notes:

(*) Despite the post AVG turbidity being above the raw stream turbidity, it is less than 1 NTU. This is acceptable.

Between 21 Oct 2020 and 2 Nov 2020, a shortage of laboratory supplies for dissolved aluminium tests resulted in testing for dissolved aluminium reduced to the key compliance samples.

4.2 Environmental Monitoring

For discharges from the ponds to the stream, the environmental requirements are that the dissolved aluminium 50 m downstream from the discharge point should be at or below 0.055 mg/L. Dissolved aluminium is monitored at several points as presented in Appendix A.

Results of the peak and background sampling monitoring discharges from the ponds to the stream are presented in Table 2. The row with the blue title indicates the location where the concentration should be at or below 0.055 mg/L. A green cell indicates that the value is below the target concentration. Cells that are greyed out indicate that no sample was taken at that time for the location in question.

The PMU uses two sampling methods.

Peak sampling is undertaken during a discharge from the pond to the stream. The sample is taken at a time when the discharged water from the pond has reached the specific sample location[1].

Background samples are taken in the stream, but not necessarily when a discharge from the ponds to the stream occurs. They measure how the background concentration in the stream is influenced by the infrequent pond discharges, as well as the natural dissolved aluminium level upstream of the treatment plants.

4.2.1 Naturally Occurring Dissolved Aluminium

The ANZECC guideline value for dissolved aluminum in streams is less than 0.055 mg/L at 50 m below the discharge point. The TMV project's goal is that the discharges from the treatment plants to the streams do not cause harm to the environment. Monitoring during the trial and some historic readings have shown that the natural dissolved aluminum levels can sometimes be greater than the ANZECC limit when measured upstream of the treatment plants. The September 2020 Te Mato Vai Ecology Baseline Report concludes that dissolved aluminum levels of up to 0.290 mg/L or greater (potentially up to 0.630 mg/L) would not result in environmental harm. Natural occurring dissolved aluminum levels have been measured to date up to 0.170 mg/L following rainfall events. The monitoring of releases from the treatment plant has shown that at 50 m downstream of the point of release, no elevation of dissolved aluminum is occurring as a result of any discharge, with results consistently showing lower readings than in the ponds. In the instance where the level at 50 m downstream of discharge is above the ANZECC limit, the data shows that this is likely the result of the natural background levels being elevated in a rainfall event. In most instances the treatment plants were not discharging during the time of sampling and the 50 m downstream sample was taken from the raw stream water only.

The results are considered acceptable despite being above the ANZECC limit provided a net decrease in dissolved aluminum is maintained 50 m downstream of any discharge point.

[1] We use a floating object to determine when pond water has reached the specific location. The floating object is used to determine the velocity of the stream. Considering this velocity and the distance to the sampling point, we calculate the earliest time that the pond discharge will reach the sampling point.

Table 2 Dissolved aluminium results (mg/L) from the Tupapa stream sampling.

Sample Date			16 October 2020		20 October 2020		27 October 2020		4 November 2020	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Peak	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)		0.082		0.148		0.088			
	In Pond 2 (Downstream Pond)		No water		0.035				0.042	
Stream	In Stream (20 m upstream of Pond)		0.009		0.022		0.034		0.057	
	In Stream (at pond)		0.022							
	In Stream (20 m downstream of Pond)		0.025		0.014				0.047	
	In Stream (50 m downstream of Pond)	0.055	0.022	**OK**	0.012	**OK**	0.035	**OK**	0.039	**OK**
	In Stream (1/2 way to lagoon)		No flow							
	In Stream (100 m from lagoon)		No flow							

Table 3 Dissolved aluminium results (mg/L) from the stream sampling (Cont.).

Sample Date			18 November 2020		30 November 2020		16 December 2020		29 December 2020	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)						0.228			
	In Pond 2 (Downstream Pond)		0.014		0.161		0.065		0.349	
Stream	In Stream (20 m upstream of Pond)		0.045		0.021		0.024		0.008	
	In Stream (at pond)									
	In Stream (20 m downstream of Pond)		0.069		0.025		0.008		0.013	
	In Stream (50 m downstream of Pond)	0.055	0.037	**OK**	0.010	**OK**	0.016	**OK**	0.008	**OK**
	In Stream (1/2 way to lagoon)									
	In Stream (100 m from lagoon)									

Table 4 Dissolved aluminium results (mg/L) from the stream sampling (Cont.).

Sample Date			13 January 2021		27 January 2021		11 February 2021	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)							
	In Pond 2 (Downstream Pond)		0.208		0.121		0.148	
Stream	In Stream (20 m upstream of Pond)		0.023		0.028		0.008	
	In Stream (at pond)							
	In Stream (20 m downstream of Pond)		0.008		0.034		0.017	
	In Stream (50 m downstream of Pond)	0.055	0.023	**OK**	0.014	**OK**	0.019	**OK**
	In Stream (1/2 way to lagoon)							
	In Stream (100 m from lagoon)							

Notes:

Between 21 Oct 2020 and 2 Nov 2020, a shortage of laboratory supplies for dissolved aluminium tests resulted in testing for dissolved aluminium reduced to the key compliance samples.

4.3 Settling tank overflow test results

The settling tank at each intake is designed to overflow at the inlet if there is low demand to return raw stream water back to the stream. As part of the court appointed expert witness review it was agreed to manually trigger an overflow in at least one intake as part of the trial and test the water to ensure water with elevated dissolved aluminium was not passing back into the stream. This overflow test is only required in one intake because all intakes are constructed in the same way.

Environmental testing for dissolved aluminium was undertaken at three locations

- in the settling tank overflow chamber
- in the stream, upstream of the discharge point, and
- in the stream, 50 meters downstream of the discharge point.

Testing was undertaken at the beginning of the overflow, after 1 hour and then after 2 hours of continuous overflow.

Results

Results of the overflow test are presented in Table 5 and Table 6 showing that dissolved aluminium levels are not elevated above the limit due to the discharge.

Table 5 Settling tank overflow test results for Ngatoe

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.008	0.008	OK
After 1 hour	0.008	0.008	0.023	OK
After 2 hours	0.013	0.019	0.009	OK

Table 6 Settling tank overflow test results for Papua

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.016	0.016	OK
After 1 hour	0.008	0.008	0.008	OK
After 2 hours	0.008	0.008	0.017	OK

Regards

Matt Boyd
Deputy Project Manager

Appendix A
Environmental Sampling

Environmental Sampling in Stream

1. Sample in the Pond (day before proposed release)

Done once per plant

Sample in the ponds for Al concentration

Testing:

- Dissolved Aluminium
- Turbidity
- pH

2 samples, 1 per pond at star locations ★ (red)

2. Environmental Peak Sampling (manual discharge to stream)

1 to 2 times at each plant at different stream conditions.

Sampled during a controlled release from the ponds to the stream,

Timed sampling based on stream flow rate 60 mins after initial release.

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 8 samples per test at star locations ★ (red) ★ (red/yellow) ★ (yellow)

3. Environmental Background Sampling (automatic discharge to stream)

- No less than weekly for first month
- No less than fortnightly for remaining months

These samples are taken in the stream, regardless of if a discharge is occurring or not.

This sampling serves to monitor the background dissolved aluminium concentrations in the stream.

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 5 samples per test at star locations ★ (red) ★ (red/yellow)

4. Settling Tank Overflow to Stream

done twice in total for trial including a high energy plant

First part: contained in chamber (control). Raw water and chamber and at 50 m downstream of discharge.

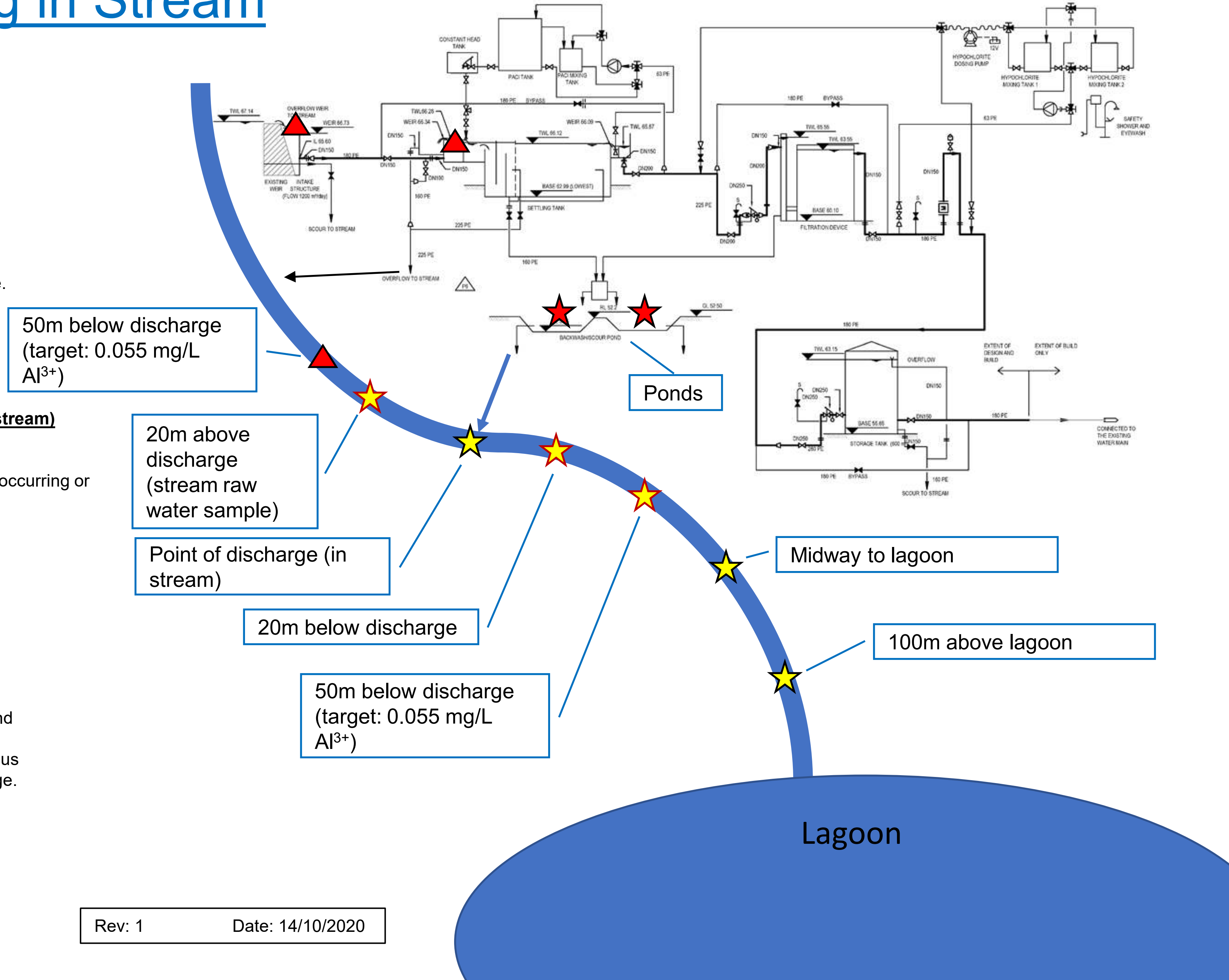
Second part: if first part ok: discharge to stream. Start, Plus 1 hour, plus 2 hours, Raw water and chamber and at 50 m downstream of discharge.

Samples locations:

- raw water and
- water going into the overflow chamber (within settling tank)
- 50 m downstream of discharge

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 9 samples per test at locations ▲ (red)



Rev: 1 Date: 14/10/2020

Memorandum

28 February 2021

To	Turangi Landowners
Copy to	Angelia Williams, Sione Likiliki, National Environmental Service, To Tatou Vai
From	Matt Boyd — Tel 28851
Subject	PACl Trial Results Memo 3 - Turangi

1 Summary of trial results from the Turangi intake

The Turangi intake started the polyaluminium chloride (PACl) trial on 19 October 2020, and To Tatou Vai (TTV) approved to connect the intake to the drinking water network on 22 October 2020 after reviewing results of the off-line trial (see the next section for more details about the trial stages).

During both stages of the trial, the contractor monitors the treatment plant and discharges to the environment.

To date, the intake delivers treated water that meets the requirements. The measured discharges to the environment also meet the requirements.

2 Purpose of this memorandum

The Cook Islands Government directed the Te Mato Vai project contractor McConnell Dowell to carry out water treatment commissioning trials at all the intakes progressively. The first of the trials commenced on Monday 28 September 2020 at Ngatoe Intake. The commissioning trial begins with polyaluminium chloride (PACl) first dosed into the settling tank/s which are located below the intakes. The active component of the PACl is aluminium which dissolves into the water and causes dirt to settle out of suspension.

This memo describes the trial process and presents an interim report of the results to date.

3 Trial Process

The first stage of the trial is undertaken while the network is **off-line**, that means that none of the raw water that is dosed with the PACl leaves the site and instead is stored in the storage tanks located just below the settling tanks. This stage of the trial continues for a few to several days while samples are taken and tested for dissolved aluminium, turbidity, pH and E.coli.

If acceptable results are achieved for the **off-line trial** the results are forwarded to To Tatou Vai (TTV) for their approval to discharge the treated water to the network. TTV compare the results to the World Health Organisation (WHO) drinking water standards and provide permission based on what is safe for human consumption. If

their permission to release is received, the second stage of the trial (the **on-line trial**) is started. The **on-line trial** is when the treated water is then discharged to the network.

It should be noted that two of the treatment plants don't have storage tanks, and at one of the sites the tank is too small to receive an adequate volume of water for an **off-line trial**. For these three treatment plants results from other plants will be used to assess whether or not the dosing can go directly **on-line**. These plants will still have regular dissolved aluminium, turbidity, pH and E.coli samples taken to ensure they meet the WHO drinking water standards and they will be some of the last plants to be trialled.

Once the **on-line trial** has started (when treated water enters the pipe network), it will continue at each intake for the remaining trial period which could be as long as six months, depending on when we receive sufficient data to determine how to best operate the plants in the future. The Contractor will do regular testing of the treated water for dissolved aluminium initially per day at each treatment plant for the first part of the trial and eventually reduced testing to once per week.

Additional to the treated water tests, Environmental sampling of the water discharging from the ponds is done for dissolved aluminium, turbidity, and pH, in the streams. Results from these tests are sent to the National Environment Service (NES). The stream is sampled while a discharge from the pond to the stream occurs, and also background sampling in the stream when no discharge occurs is undertaken.

The stream sampling locations are listed below and presented in Appendix A.

- 20m above the discharge point
- At the point of discharge
- 20m below the discharge point
- 50m below the discharge point (note this is the point where the target concentration should not be exceeded)
- Midway to the lagoon
- 100m above the lagoon

NES and the Landowners will be advised of all the above results. This environmental sampling will be conducted initially weekly then fortnightly after the initial discharge sample.

4 Results

4.1 Intake performance

The requirements for the treated water that is supplied to the drinking water network are as follows:

- The turbidity after the AVG should be lower than the raw stream turbidity.
- The E. coli concentration after the AVG generally should be lower than the raw stream concentration.
- The dissolved aluminium concentration after the AVG should be lower than 0.2 mg/L, and must not be higher than 0.3 mg/L.

If the treated water quality meets the turbidity, E. coli and dissolved aluminium requirements, it can be discharged to the drinking water network with the approval of TTV the network operator.

Table 1 presents the results to date from the **off-line** and **on-line trial**. The results are compared to the limits for discharge.

Cells that are greyed out indicate that no sample was taken at that time for the parameter in question.

To date, the intake has delivered treated water that met all requirements.

Table 1 Treated water quality results for the off-line and on-line trial at Turangi.

	Turbidity (NTU)			E.Coli (MPN/100 mL)			Dissolved Aluminium (mg/L)			Comments
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	**Stream**	**Post AVG**	**Status**	**Stream**	**Post AVG**	**Status**	**Post Settling Tank**	**Post AVG**	**Status**	
19/10/2020 13:00	0.44	0.23	OK				0.070	0.102	OK	
19/10/2020 14:00	0.32	0.11	OK	41.4	8.6	OK	0.090	0.079	OK	
19/10/2020 15:00	0.38	0.17	OK				0.098	0.066	OK	
19/10/2020 16:00	0.32	0.28	OK				0.090	0.067	OK	
20/10/2020 13:00	0.33	0.02	OK				0.062	0.050	OK	
20/10/2020 14:00	0.74	0.10	OK	2419.6	1	OK	0.167	0.047	OK	
20/10/2020 15:00	0.72	0.06	OK				0.073	0.075	OK	
20/10/2020 16:00	0.19	0.09	OK				0.086	0.056	OK	
21/10/2020 13:00	0.43	0.15	OK				0.086	0.067	OK	
21/10/2020 14:30	0.42	6.00	Not OK					0.048	OK	Caused by manual backwash, Re-checked half an hour later - ok (see next measurement)
21/10/2020 15:00	0.39	0.13	OK				0.068	0.072	OK	
21/10/2020 16:00	0.41	0.13	OK				0.058	0.069	OK	
22/10/2020	TTV approved discharge of treated water to network . Trial is now an on-line trial.									
22/10/2020 12:35	0.80	0.07	OK	21.3	<1	OK	0.069	0.050	OK	
23/10/2020 10:56	2.15	1.37	OK							
23/10/2020 16:30		0.40								
24/10/2020 10:40	0.39	0.06	OK							
25/10/2020 9:45	0.23	0.12	OK							
26/10/2020 9:30	0.20	0.08	OK							
27/10/2020 10:22	3.96	0.42	OK							
28/10/2020 10:30	0.56	0.12	OK							
29/10/2020 10:45	0.51	0.21	OK	42.6	<1	OK				
30/10/2020 10:30	0.24	0.16	OK	35	<1	OK		0.046	OK	
31/10/2020 8:38	2.22	0.22	OK							
1/11/2020 10:30	3.29	0.88	OK							
2/11/2020 12:31	1.09	0.57	OK							
3/11/2020 10:54	4.34	0.35	OK	90.8	204.6	Not OK		0.010		We think this is a result of a high rain event during the night, and a backwash by the AVG just before the sample was taken. Results in adjacent days do not indicate a problem.
5/11/2020 11:54	0.63	0.28	OK	39.3	2	OK				
7/11/2020 8:37	0.90	0.66	OK							
8/11/2020 8:29	0.19	0.13	OK							
9/11/2020 11:18	2.70	2.95	Not OK							We suspect that this sample was

	Turbidity (NTU)			E.Coli (MPN/100 mL)			Dissolved Aluminium (mg/L)			Comments
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	**Stream**	**Post AVG**	**Status**	**Stream**	**Post AVG**	**Status**	**Post Settling Tank**	**Post AVG**	**Status**	
										taken after an AVG backwash. The measurements in the adjacent days do not indicate a problem with the plant performance.
10/11/2020 10:55	0.45	0.98	Not OK	22.8	<1	OK	0.067	0.062	OK	We suspect that this sample was taken after an AVG backwash. The measurements in the adjacent days do not indicate a problem with the plant performance.
11/11/2020 11:29	0.41	0.09	OK							
12/11/2020 16:23	1.00	0.55	OK	23.1	1	OK				
13/11/2020 11:39	1.08	0.07	OK							
14/11/2020 10:36	0.39	0.09	OK							
15/11/2020 13:11	0.53	0.07	OK							
16/11/2020 10:26	0.32	0.04	OK							
18/11/2020 10:57	0.64	0.19	OK							
19/11/2020 11:42	0.47	0.01	OK	35	<1	OK	0.073	0.067	OK	
20/11/2020 10:57	1.03	0.40	OK							
21/11/2020 10:54	0.99	0.45	OK							
22/11/2020 10:15	0.83	0.17	OK							
23/11/2020 15:50	1.20	0.12	OK							
24/11/2020 12:17	0.38	0.01	OK							
25/11/2020 12:37	0.29	0.17	OK							
26/11/2020 10:58		0.01								
27/11/2020 14:48	0.59	0.03	OK							
1/12/2020 10:00	2.40	0.23	OK	44.1	<1	OK	0.054	0.065	OK	
2/12/2020 14:06	0.81	0.29	OK							
3/12/2020 10:38	1.49	0.19	OK							
4/12/2020 8:57	0.58	0.27	OK							
6/12/2020 9:04	1.79	0.23	OK							
7/12/2020 11:16	1.21	0.77	OK							
8/12/2020 10:17	0.67	0.11	OK	74.3	<1	OK	0.085	0.015	OK	
9/12/2020 11:27	2.84	0.04	OK							
10/12/2020 14:24	1.31	1.91	Not OK							We suspect that this sample was taken after an AVG backwash. The measurements in the adjacent days do not indicate a problem

	Turbidity (NTU)			E.Coli (MPN/100 mL)			Dissolved Aluminium (mg/L)			Comments
Treatment quality requirement	Passes when post AVG is lower than stream			Generally post AVG is lower than stream			Passes when post AVG concentration is below 0.2 mg/L			
Date / Time	**Stream**	**Post AVG**	**Status**	**Stream**	**Post AVG**	**Status**	**Post Settling Tank**	**Post AVG**	**Status**	
										with the plant performance.
11/12/2020 12:39	1.02	0.12	OK							
12/12/2020 7:59	1.26	0.15	OK							
13/12/2020 7:56	1.15	0.23	OK							
14/12/2020 12:16	0.38	0.11	OK							
15/12/2020 11:23	1.45	0.35	OK	53	<1	OK	0.048	0.037	OK	
16/12/2020 8:55	0.35	0.01	OK							
17/12/2020 11:46	0.20	0.05	OK							
18/12/2020 15:26		0.43								
19/12/2020 11:20	6.97	0.12	OK							
20/12/2020 22:50	0.44	0.15	OK							
21/12/2020 11:01	0.18	0.07		42	85.5					Plant bypassed, no PACL dosed
22/12/2020 14:08		0.20						0.015		Plant bypassed, no PACL dosed
23/12/2020 9:44	0.50	0.40			42.6					Plant bypassed, no PACL dosed
24/12/2020 10:09	1.20	1.78								Plant bypassed, no PACL dosed
25/12/2020 10:09	1.57	0.69	OK							
26/12/2020 8:38	0.50	0.07	OK							
27/12/2020 8:16	0.54	0.05	OK							
28/12/2020 10:40	1.54	0.16	OK							
29/12/2020 10:09	0.51	0.03	OK	37.4	3	OK	0.066	0.056	OK	
30/12/2020 9:44	1.90	0.33	OK							
31/12/2020 9:36	1.25	0.03	OK							
1/01/2021 10:20	0.79	0.17	OK							
2/01/2021 10:30	0.86	0.19	OK							
3/01/2021 10:30	0.61	0.27	OK							
4/01/2021 9:59	0.53	0.18	OK							
5/01/2021 10:34	0.43	0.29	OK	18.7	< 1	OK	0.056	0.051	OK	
6/01/2021 11:01	0.72	0.18	OK							
7/01/2021 11:43	0.18	0.01	OK							
8/01/2021 11:00	1.23	0.08	OK							
9/01/2021 12:38	0.57	0.19	OK							
10/01/2021 9:32	0.57	0.47	OK							
11/01/2021 10:11	0.51	0.07	OK							
12/01/2021 11:58	0.41	0.16	OK							
13/01/2021 14:11	0.76	0.14	OK	43.5	3.1	OK	0.086	0.081	OK	
14/01/2021 11:30	0.59	0.32	OK							
15/01/2021 10:35	1.04	0.25	OK							
17/01/2021 8:02	0.63	0.27	OK							

Notes:

Between 21 Oct 2020 and 2 Nov 2020, a shortage of laboratory supplies for dissolved aluminium tests resulted in testing for dissolved aluminium reduced to the key compliance samples.

4.2 Environmental Monitoring

For discharges from the ponds to the stream, the environmental requirements are that the dissolved aluminium 50 m downstream from the discharge point should be at or below 0.055 mg/L. Dissolved aluminium is monitored at several points as presented in Appendix A.

Results of the peak and background sampling monitoring discharges from the ponds to the stream are presented in Table 2. The row with the blue title indicates the location where the concentration should be at or below 0.055 mg/L. A green cell indicates that the value is below the target concentration. Cells that are greyed out indicate that no sample was taken at that time for the location in question.

The PMU uses two sampling methods.

Peak sampling is undertaken during a discharge from the pond to the stream. The sample is taken at a time when the discharged water from the pond has reached the specific sample location[1].

Background samples are taken in the stream, but not necessarily when a discharge from the ponds to the stream occurs. They measure how the background concentration in the stream is influenced by the infrequent pond discharges, as well as the natural dissolved aluminium level upstream of the treatment plants.

4.2.1 Naturally Occurring Dissolved Aluminium

The ANZECC guideline value for dissolved aluminum in streams is less than 0.055 mg/L at 50 m below the discharge point. The TMV project's goal is that the discharges from the treatment plants to the streams do not cause harm to the environment. Monitoring during the trial and some historic readings have shown that the natural dissolved aluminum levels can sometimes be greater than the ANZECC limit when measured upstream of the treatment plants. The September 2020 Te Mato Vai Ecology Baseline Report concludes that dissolved aluminum levels of up to 0.290 mg/L or greater (potentially up to 0.630 mg/L) would not result in environmental harm. Natural occurring dissolved aluminum levels have been measured to date up to 0.170 mg/L following rainfall events. The monitoring of releases from the treatment plant has shown that at 50 m downstream of the point of release, no elevation of dissolved aluminum is occurring as a result of any discharge, with results consistently showing lower readings than in the ponds. In the instance where the level at 50 m downstream of discharge is above the ANZECC limit, the data shows that this is likely the result of the natural background levels being elevated in a rainfall event. In most instances the treatment plants were not discharging during the time of sampling and the 50 m downstream sample was taken from the raw stream water only.

The results are considered acceptable despite being above the ANZECC limit provided a net decrease in dissolved aluminum is maintained 50 m downstream of any discharge point.

[1] We use a floating object to determine when pond water has reached the specific location. The floating object is used to determine the velocity of the stream. Considering this velocity and the distance to the sampling point, we calculate the earliest time that the pond discharge will reach the sampling point.

Table 2 Dissolved aluminium results (mg/L) from the Turangi stream sampling.

Sample Date			22 October 2020		28 October 2020		2 November 2020	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Peak	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)		0.074		0.069		0.057	
Pond	In Pond 2 (Downstream Pond)							
Stream	In Stream (20 m upstream of Pond)		0.017		0.020		0.008	
Stream	In Stream (at pond)		0.040					
Stream	In Stream (20 m downstream of Pond)		0.026					
Stream	In Stream (50 m downstream of Pond)	0.055	0.027	**OK**	0.020	**OK**	0.008	**OK**
Stream	In Stream (1/2 way to lagoon)		No flow					
Stream	In Stream (100 m from lagoon)		No flow					

Table 3 Dissolved aluminium results (mg/L) from the stream sampling (Cont.).

Sample Date			9 November 2020		10 November 2020		25 November 2020		26 November 2020	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Bank-ground	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)		0.090		0.068		0.063		0.065	
	In Pond 2 (Downstream Pond)									
Stream	In Stream (20 m upstream of Pond)		0.008		0.040		0.150		0.170	
	In Stream (at pond)								0.125	
	In Stream (20 m downstream of Pond)		0.018		0.018		0.097		0.158	
	In Stream (50 m downstream of Pond)	0.055	0.019	**OK**	0.019	**OK**	0.143	Caused by high natural stream con-centrations of aluminium in the raw water on that day	0.086	Caused by high natural stream con-centrations of aluminium in the raw water on that day
	In Stream (1/2 way to lagoon)								No flow	
	In Stream (100 m from la-goon)								No flow	

Table 4 Dissolved aluminium results (mg/L) from the stream sampling (Cont.).

Sample Date			7 December 2020		21 December 2020		23 December 2020		6 January 2021	
	Sample Location	Limit	Result	Status	Result	Status	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Background	D.Alu mg/L	Background	D.Alu mg/L	Peak	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)		0.049						0.041	
	In Pond 2 (Downstream Pond)						0.023		0.048	
Stream	In Stream (20 m upstream of Pond)		0.108		0.033		0.025		0.047	
	In Stream (at pond)		0.105				0.026		0.022	
	In Stream (20 m downstream of Pond)		0.090		0.018		0.042		0.041	
	In Stream (50 m downstream of Pond)	0.055	0.079	Caused by high natural stream concentrations of aluminium in the raw water on that day	0.020	**OK**	0.034	**OK**	0.031	**OK**
	In Stream (1/2 way to lagoon)		0.019				No flow			
	In Stream (100 m from lagoon)						No flow			

Table 5 Dissolved aluminium results (mg/L) from the stream sampling (Cont.).

Sample Date			19 January 2021		3 February 2021	
	Sample Location	Limit	Result	Status	Result	Status
		D.Alu mg/L	D.Alu mg/L	Background	D.Alu mg/L	Background
Pond	In Pond 1 (Upstream Pond)		0.059		0.032	
	In Pond 2 (Downstream Pond)		0.059		0.052	
Stream	In Stream (20 m upstream of Pond)		0.008		0.009	
	In Stream (at pond)		0.008			
	In Stream (20 m downstream of Pond)		0.029		0.008	
	In Stream (50 m downstream of Pond)	0.055	0.016	**OK**	0.008	**OK**
	In Stream (1/2 way to lagoon)					
	In Stream (100 m from lagoon)					

Notes:

Between 21 Oct 2020 and 2 Nov 2020, a shortage of laboratory supplies for dissolved aluminium tests resulted in testing for dissolved aluminium reduced to the key compliance samples.

4.3 Settling tank overflow test results

The settling tank at each intake is designed to overflow at the inlet if there is low demand to return raw stream water back to the stream. As part of the court appointed expert witness review it was agreed to manually trigger an overflow in at least one intake as part of the trial and test the water to ensure water with elevated dissolved aluminium was not passing back into the stream. This overflow test is only required in one intake because all intakes are constructed in the same way.

Environmental testing for dissolved aluminium was undertaken at three locations

- in the settling tank overflow chamber
- in the stream, upstream of the discharge point, and
- in the stream, 50 meters downstream of the discharge point.

Testing was undertaken at the beginning of the overflow, after 1 hour and then after 2 hours of continuous overflow.

Results

Results of the overflow test are presented in Table 6 and Table 7 showing that dissolved aluminium levels are not elevated above the limit due to the discharge.

Table 6 Settling tank overflow test results for Ngatoe

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.008	0.008	OK
After 1 hour	0.008	0.008	0.023	OK
After 2 hours	0.013	0.019	0.009	OK

Table 7 Settling tank overflow test results for Papua

Time	Settling tank overflow chamber	Upstream of discharge	50m downstream of discharge	Limit < 0.055 D.Alu mg/L
Start of overflow	0.008	0.016	0.016	OK
After 1 hour	0.008	0.008	0.008	OK
After 2 hours	0.008	0.008	0.017	OK

Regards

Matt Boyd
Deputy Project Manager

Appendix A
Environmental Sampling
Diagram

Environmental Sampling in Stream

1. Sample in the Pond (day before proposed release)

Done once per plant

Sample in the ponds for Al concentration

Testing:

- Dissolved Aluminium
- Turbidity
- pH

2 samples, 1 per pond at star locations

2. Environmental Peak Sampling (manual discharge to stream)

1 to 2 times at each plant at different stream conditions.

Sampled during a controlled release from the ponds to the stream,

Timed sampling based on stream flow rate 60 mins after initial release.

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 8 samples per test at star locations

3. Environmental Background Sampling (automatic discharge to stream)

- No less than weekly for first month
- No less than fortnightly for remaining months

These samples are taken in the stream, regardless of if a discharge is occurring or not.

This sampling serves to monitor the background dissolved aluminium concentrations in the stream.

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 5 samples per test at star locations

4. Settling Tank Overflow to Stream

done twice in total for trial including a high energy plant

First part: contained in chamber (control). Raw water and chamber and at 50 m downstream of discharge.

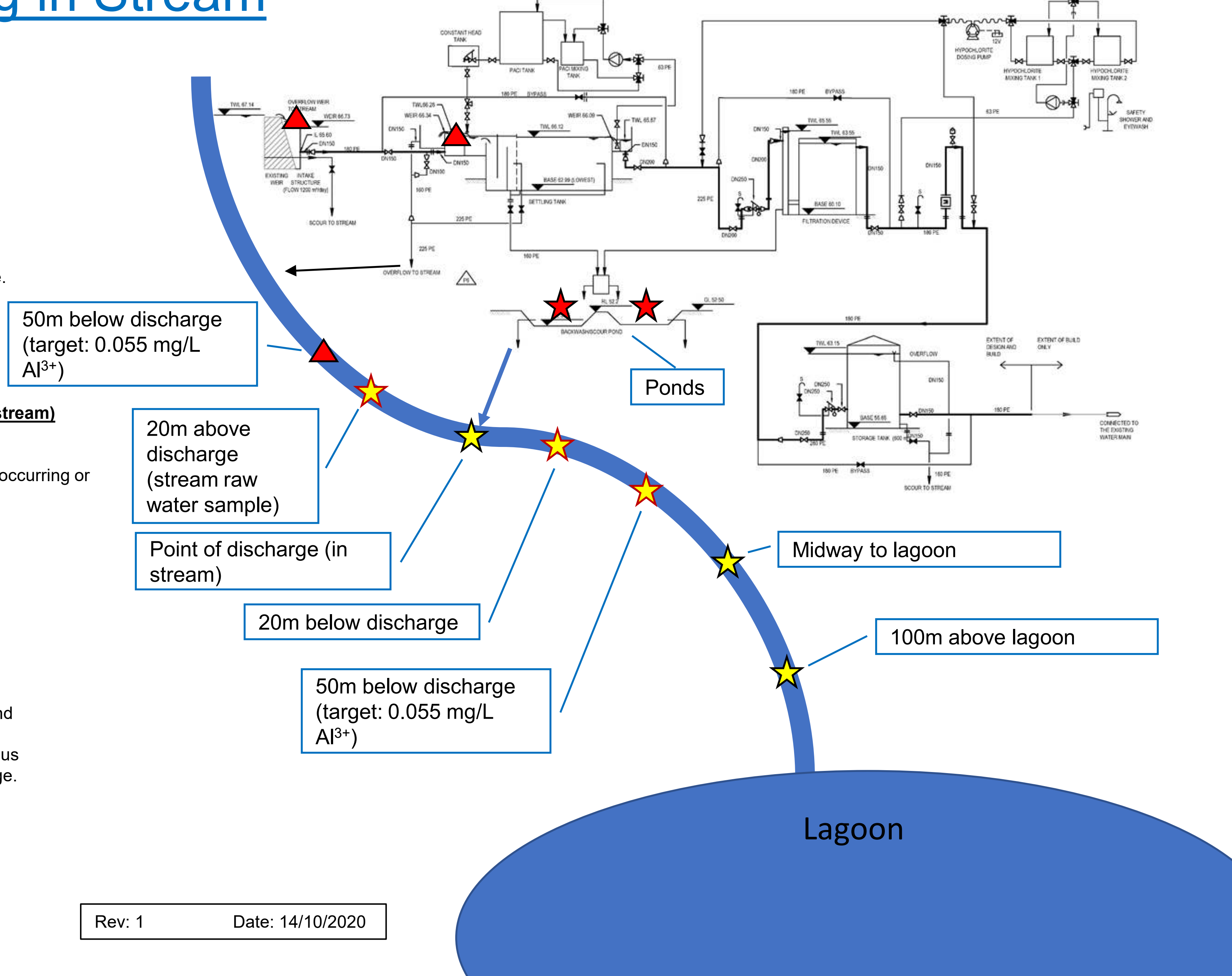
Second part: if first part ok: discharge to stream. Start, Plus 1 hour, plus 2 hours, Raw water and chamber and at 50 m downstream of discharge.

Samples locations:

- raw water and
- water going into the overflow chamber (within settling tank)
- 50 m downstream of discharge

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 9 samples per test at locations



Rev: 1 Date: 14/10/2020

Appendix B

Schematic of environmental sampling locations in the stream

Environmental Sampling in Stream

1. Sample in the Pond (day before proposed release)

Done once per plant
Sample in the ponds for Al concentration
Testing:

- Dissolved Aluminium
- Turbidity
- pH

2 samples, 1 per pond at star locations

2. Environmental Peak Sampling (manual discharge to stream)

1 to 2 times at each plant at different stream conditions.
Sampled during a controlled release from the ponds to the stream,
Timed sampling based on stream flow rate 60 mins after initial release.
Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 8 samples per test at star locations

3. Environmental Background Sampling (automatic discharge to stream)

- No less than weekly for first month
- No less than fortnightly for remaining months

These samples are taken in the stream, regardless of if a discharge is occurring or not.
This sampling serves to monitor the background dissolved aluminium concentrations in the stream.
Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 5 samples per test at star locations

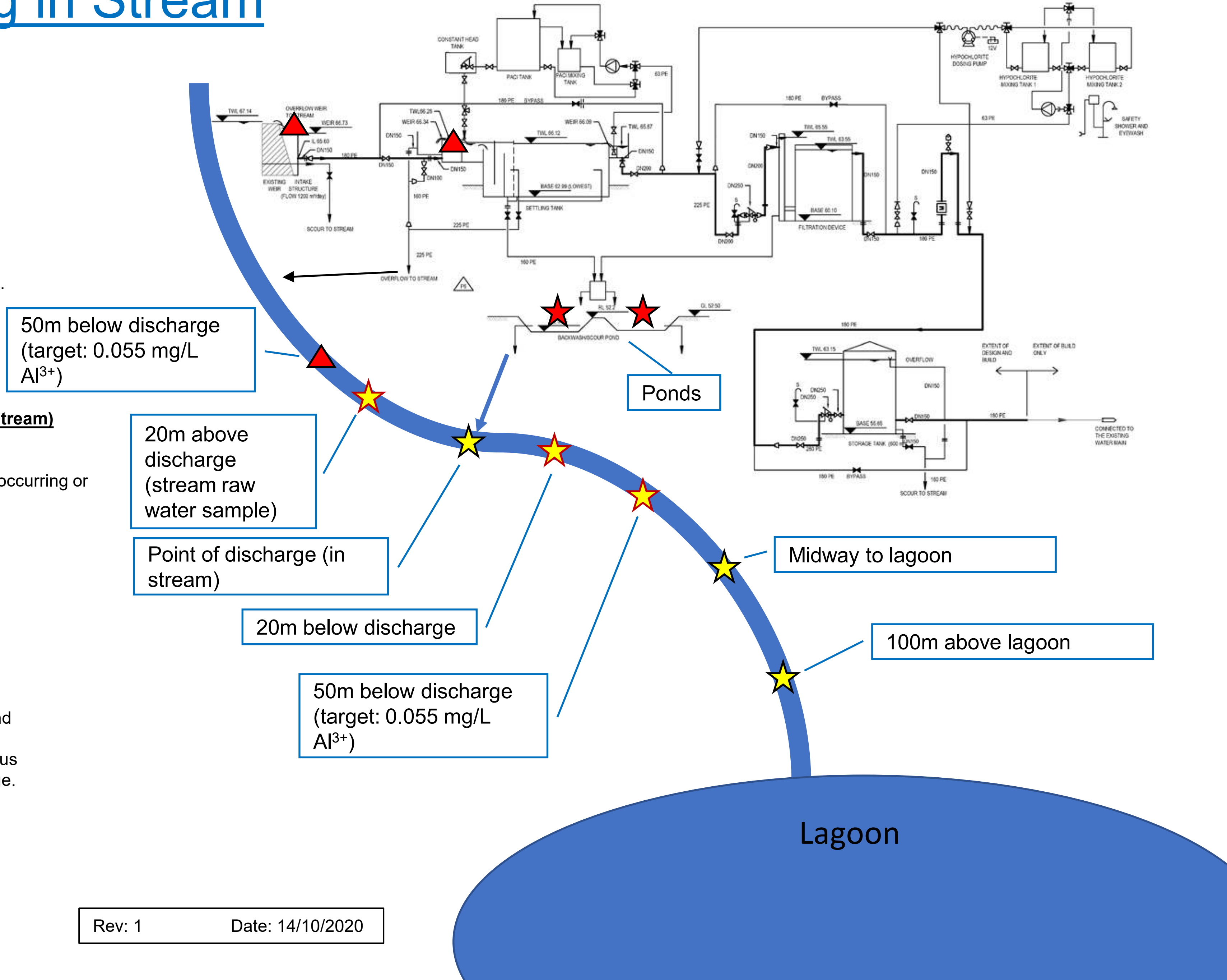
4. Settling Tank Overflow to Stream

done twice in total for trial including a high energy plant
First part: contained in chamber (control). Raw water and chamber and at 50 m downstream of discharge.
Second part: if first part ok: discharge to stream. Start, Plus 1 hour, plus 2 hours, Raw water and chamber and at 50 m downstream of discharge.
Samples locations:

- raw water and
- water going into the overflow chamber (within settling tank)
- 50 m downstream of discharge

Testing:

- Dissolved Aluminium
- Turbidity
- pH
- 9 samples per test at locations



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Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
Final	A Fischer	P Free		P Free	P Free	20-03-21

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Appendix D: Site visit report

Site visit date: 26.03.2021	Site name: Landfill section 88H	Time: 10:30am
Weather: Fine / Sunny	Attendees: Sam Napa Senior, Raututi Taringa & Kara Lomaiviti	Subject: Sampling at 88H

Kia Orana,

A site visit took place on the above mentioned date and time to familiarize the team about 88H site. At this stage the **Two bore holes** are the only known sources of sampling points.

More on sample point to be confirmed by WTM.

Borehole One, located at the north side of landfill

View of borehole One from existing formed road.

Bore hole Two located at South side of landfill.

Other observations:

The stream was mostly dry. First available spots of water were located at about 50m downstream from **bore hole Two**

Second puddle of water were located approximately 100m downstream from bore hole Two and within 3 meters from culvert crossing.

The stream had quite a thin, slim flow at approximately 50m downstream from **culvert crossing** however, disappear into underground at about after 100m. The main back road stream stretch was all dry.

Should the same whether condition persist over the weekend, based on observation there should be sufficient water collected from these identified spots for analysis by Monday 29th March.

For collecting samples from boreholes.
Rau have highlighted that a reasonable size pump and hose lines will be required to suck water out of these bore holes. A specification on similar pump & hose can be obtained from ICI who have previously done similar work on these bore holes. Rau can assist us in getting specs for these tools.

The team will await the next step moving forward.

Regards
Kara
(Lab Inventory Supervisor)

Appendix E: Ecological Assessment

REPORT

Tonkin+Taylor

Sludge Disposal Site in Rarotonga

Ecology and Water Quality Effects Assessment

Prepared for
To Tatou Vai Limited
Prepared by
Tonkin & Taylor Ltd
Date
July 2021
Job Number
1013086

Exceptional thinking together
www.tonkintaylor.co.nz

Document Control

Title: Sludge Disposal Site in Rarotonga					
Date	**Version**	**Description**	**Prepared by:**	**Reviewed by:**	**Authorised by:**
7 July 2021	1	Draft for TTV review	JQU	DCM	CHP
Aug 21	2	FOR ISSUE			CHP

Distribution:

To Tatou Vai Limited	1 PDF copy
Tonkin & Taylor Ltd (FILE)	1 electronic copy

Table of contents

No table of contents entries found.

1 Introduction

1.1 Project background

The Cook Islands Government is currently upgrading Rarotonga's water infrastructure through the Te Mato Vai (TMV) project. TMV is currently upgrading ten water intakes and has constructed a water treatment plant (WTP) at each intake. The water treatment process includes the use of a flocculant (Polyaluminium chloride (PACl)) to reduce concentrations of suspended solids. The use of a flocculant produces a residual sludge comprised of materials removed from the incoming water and the PACl. This water treatment sludge (hereafter 'sludge') requires disposal. A sludge disposal site has been identified and is located in the north-western part of Rarotonga.

1.2 Purpose of this report

This Ecology and Water Quality Effects Assessment Report (EWQAR) has been prepared to describe the existing ecological and water quality values of the proposed sludge disposal site and considers the potential ecological and water quality impacts from the disposal of sludge (and associated discharges) at the site.

This EWQAR is prepared by Tonkin + Taylor (T+T) on behalf of To Tatou Vai Limited (TTV) in accordance with the Environmental Act 2003. This report has been undertaken in accordance with the Terms of Reference (TOR) agreed by TTV with the National Environment Service (NES) for the Project.

This report includes:

- Introduction, including background to the project and description of the proposed sludge disposal activity;
- Methodology, for the assessment of ecological values and approach to determining the potential effects;
- Environmental context, providing an overview of the ecological and water quality values of Rarotonga based on desktop assessment;
- Field survey results, to outline the ecological and water quality values of the disposal site;
- Impact assessment, to provide an assessment of the potential impact to ecology and water quality, resulting from the construction and operation of the sludge disposal facility; and
- Summary and conclusion, to provide an overview of the findings.

1.3 Acknowledgements, assumptions and limitations

This report has been prepared with specific reference to the Aquatic Ecology Baseline Report, prepared by GHD in support of the TMV project (GHD, 2020). The background information pertaining to the wider Rarotonga environment is considered to be relevant to the assessment of the sludge disposal site. The previous work undertaken by GHD is acknowledged at this time and has been central to the further assessment presented in this report.

The assessment undertaken within this EWQAR relies on field and desktop information. The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report.

2 Methodology

A review of existing information regarding the site was undertaken. There are limited databases or wider knowledge regarding biodiversity and ecological values for the area. Information from the GHD report (2020) was referred to and relied upon.

A field survey was undertaken by a contractor to T+T over three days in May 2021. This followed an initial site visit by that same contractor in March 2021. The field survey involved a site walkover and visual observation of the terrestrial vegetation present, incidental observations of terrestrial fauna and an inspection of the stream at the site.

Detailed stream investigations were not undertaken as the stream was not flowing during either of the site visits.

An impact assessment was conducted to identify the potential impacts of the construction and operation of the sludge disposal facility on the existing terrestrial and aquatic values at the disposal site and downstream of the discharge locations. The assessment involved:

- Identifying the nature of the potential risks from the construction and operation of the sludge disposal; and
- Describing the sensitivity of the receiving environment based on the existing ecological values.

There are no published guidelines for water quality in the Cook Islands. The assessment of potential effects on surface water was compared against the guideline ranges given in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality 2000 (ANZECC 2000) – Tropical Australia Lowland River. These guidelines were chosen as a comparison for these sites as the Rarotongan environment closely resembles that of tropical Australia in respect of rainfall and climate. The site is located <150 m above sea level and therefore is considered a lowland site.

3 Environmental setting and values

Rarotonga is one of the Southern Group of the Cook Islands and has a land area of 67.4 km^2, a circumference of 32 km and elevation of 652 m (Parakoti & Davie 2007). The central part of the island consists of mountains with narrow valleys covered in tropical vegetation. Surrounding this is a flat coastal ring which has been developed for residential, commercial and agricultural purposes. Fringing the island is upraised coral reef and lagoons.

The interior upland sediment is basaltic volcano bedrock which produces dark red clay-rich sediments through the process of weathering (Parakoti & Davie 2007). These sediments are comparatively less fertile due to nutrient deficiencies. Conversely, sediment of the coastal ring is nutrient rich due to the naturally high concentrations of phosphorus.

There are twelve water catchments in Rarotonga, however no large rivers or lakes exist (Nath. et al. 2006). These catchments comprise of streams, wetlands and a few small freshwater lakes with streams shown on Figure 3.1. The three major streams on Rarotonga are Takuvaine, Avatiu (both on the northern side of the island) and Avana (on the eastern side).

3.1 Location

The proposed sludge disposal site (herein referred to as 'the site') is located in the north-western part of Rarotonga. The site is located within the Vairauara Stream catchment as shown in Figure 3.2.

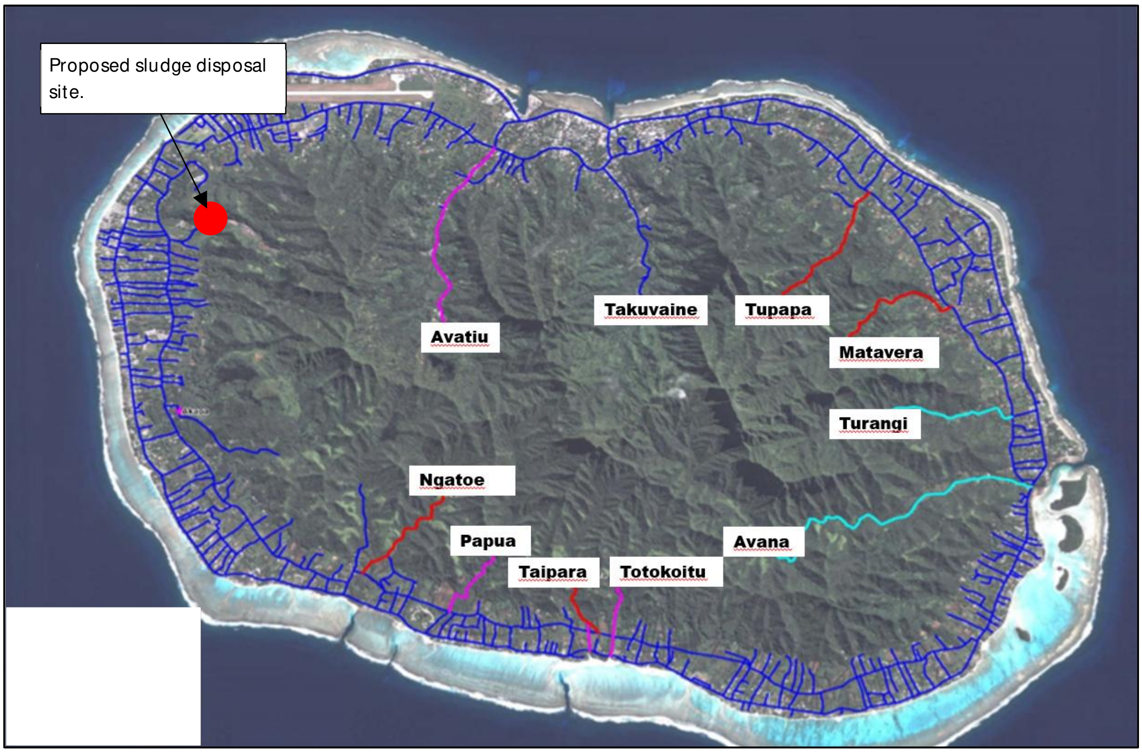

Figure 3.1: Aerial plan showing the approximate location of each of the water takes and stream catchments. Source: GHD, 2014

Figure 3.2: Approximate sludge disposal site with the Vairauara Stream alignment shown. The Vairauara Stream is the immediate receiving environment for discharges that may occur.

3.2 Climate

The Cook Islands experiences a tropical climate with two seasons:

- Wet season: Typically November to May, characterised by high humidity, sudden downpours, strong winds and tropical cyclones (hurricanes); and
- Dry season: Typically June to October, characterised by cooler temperatures.

In the Southern Cook Islands (including Rarotonga and Aitutaki) there is only a slight difference between the wet (warmer) and dry (cooler) months.

3.3 Water Quality

Rarotonga has the largest population of the Cook Islands and the lagoon surrounding the island has been subject to long term inflow of land-based pollution and overfishing (McCormack 2002). Many of the streams of the island do not flow permanently; in January 2021 only three of eight streams surveyed were flowing during sampling. The remaining five either had only stagnant water or no water (Ministry of Marine Resources 2021).

Water quality (bacteria, nutrients, dissolved oxygen) of the streams on Rarotonga has been consistently poor from 2006 to 2013 (George et. al. 2007; Ministry of Marine Resources 2011, 2012, 2013). Bacteria (enterococci) concentrations are extremely high, often reading >500 cells/100 mL (George et al. 2007; Ministry of Marine Resources 2011, 2012, 2013, 2021). The high concentrations are likely due to adjacent land use practices, where waste from pig, goat and poultry farms are washed into the streams during farming processes and/or heavy rain.

Nutrient concentrations have been consistently elevated in most streams (George et al. 2007; Ministry of Marine Resources 2011, 2012, 2013). This is likely due to farming and the naturally high concentrations of phosphorus from the volcanic geology of Rarotonga.

Dissolved oxygen concentrations are variable amongst the streams depending on flow characteristics (George et al. 2007; Ministry of Marine Resources 2011, 2012, 2013, 2021). Faster flowing streams have a higher dissolved oxygen concentration whereas slower or stagnant water typically have much lower concentrations.

Water clarity in the streams has been consistently good with total suspended solids predominantly less than 6 mg/L (George et al. 2007; Ministry of Marine Resources 2011, 2012, 2013, 2021).

3.4 Freshwater ecology

3.4.1 Aquatic flora

There are eight species of freshwater aquatic plants known or expected to occur on Rarotonga (Natural Heritage Trust, 2007). Four of these species (*Azolla filiculoides, Nymphaea capensis cvs., Pistia stratiotes and Eichhornia crassipes*) are considered to be invasive weed species. There are no threatened freshwater aquatic plant species recorded on Rarotonga.

3.4.2 Aquatic macroinvertebrates

There is currently limited published knowledge on aquatic macroinvertebrate communities of Rarotonga (Natural Heritage Trust, 2007). Currently, there are nine classes and 23 families known to or expected to occur in the area. There are no pollution sensitive taxa currently known from Rarotonga.

3.4.3 Aquatic fauna

Due to the remoteness of Rarotonga, the diversity of freshwater fish species is very low. There are ten native species and four introduced species of freshwater fish known to occur in the area (Table 3.1) (Natural Heritage Trust, 2007).

In addition to the fish recorded in Table 3.1, two species of freshwater turtle species are known to occur within Rarotonga. These are the common long-necked tortoise (*Chelodina longicollis*) and the red-eared slider turtle (*Trachemys scripta elegans*). The common long-necked tortoise was a naturalised species, however is now assumed to be extinct from Rarotonga (and possibly the Cook Islands). The red-eared slider turtle is introduced and not yet naturalised. It is recognised as being potentially invasive and is found in wetland ponds.

Table 3.1: Freshwater fish species known to occur in Rarotonga

Common name	Scientific name	Prevalence
Native		
Giant longfin eel	*Anguilla marmorata*	Uncommon
Polynesian longfinned eel	*Anguilla megastoma*	Uncommon
Pacific shortfinned eel	*Anguilla obscura*	Very common
Eyespot goby	*Awaous ocellaris*	Rare
Dusky sleeper	*Eleotris fusca*	Uncommon
Shorttail river pipefish	*Microphis brachyurus*	Rare
Peppered goby	*Redigobius bikolanus*	Rare
Red-tailed goby	*Sicyopterus lagocephalus*	Common
Brokeline goby	*Stiphodon elegans*	Common
Latticed goby	*Stiphodon* n.sp.watson	Rare; endemic (new species), only recorded in Rarotonga
Introduced		
Western mosquitofish	*Gambusia affinis*	Common

Mozambique tilapia	*Oreochromis mossambicus*	Very common
Shortfin molly	*Poecilia mexicana*	Uncommon
Guppy	*Poecilia reticulata*	Common

Source: 2007 (July) The Cook Islands Natural Heritage Trust Biodiversity Database.

3.5 Terrestrial ecology

3.5.1 Flora

Rarotonga has the richest terrestrial flora and fauna of the Cook Islands group (McCormack, 2002) and includes 170 species of native flowering plants, with only 12 endemic species (McCormack, 2002). Most of these native plants are confined to the steep upper inland areas where indigenous dominated terrestrial ecosystems still remain. Conversely, the coastal lowlands and low volcanic inlands are primarily modified or disturbed ecosystems and dominated by introduced species. This historic and ongoing land use and habitat modification has resulted in the localised extinction or extirpation of a number of native and endemic plant species in Rarotonga.

3.5.2 Fauna

3.5.2.1 Mammals

Rarotonga has only one native mammal, the Pacific fruit bat (*Pteropus tonganus)*. The Pacific fruit bat is classified as native, locally endangered, however is widespread throughout the Pacific Islands and classified by the IUCN as 'Least Concern' (Lavery et al, 2020).

Additional mammals include common introduced domestic and agricultural species and rodents including house mouse, pacific rat, brown rat and ship rat, all recorded as pests (Natural Heritage Trust, 2007).

3.5.2.2 Birds

Twenty-one species of birds are recorded in Rarotonga, including forest, lowland and coastal species (Table 3.2) (Natural Heritage Trust, 2007). Some of these are identified as being globally endangered to some degree.

Table 3.2: Bird species known to occur in Rarotonga

Common name	Scientific name	Cook Island Status	Habitat
Marsh Harrier	*Circus aeruginosus*	Native, vagrant potential invasive potential pest	Land
Domestic fowl	*Gallus gallus*	Introduced, naturalised	Land
Common peafowl	*Pavo cristatus*	Introduced, not naturalised	Land
Pacific golden-plover	*Pluvialis fulva*	Native, migrant	Land
Masked lapwing	*Vanellus miles*	Native, vagrant	Land, wet grasslands
Common sandpiper	*Actitis hypoleucos*	Native, vagrant	Land, wet grasslands
Spotted sandpiper	*Actitis macularia*	Native, vagrant	Land coastal
Ruddy turnstone	*Arenaria interpres*	Native, migrant	Land coastal
Sanderling	*Calidris alba*	Native, migrant	Land coastal

Pectoral sandpiper	*Calidris melanotos*	Native, vagrant	Land
Bar-tailed godwit	*Limosa lapponica*	Native, migrant	Land coastal
Bristle-thighed curlew	*Numenius tahitiensis*	Native, migrant, globally endangered (seriously)	Land
Wandering tattler	*Tringa incana*	Native, migrant	Land coastal
Pacific pigeon	*Ducula pacifica*	Native	Land
Cook Islands Fruit-Dove	*Ptilinopus rarotongensis*	Native (endemic), globally endangered (moderately)	Central hills
Long-tailed cuckoo	*Eudynamis taitensis*	Native, migrant	Land
Chattering kingfisher	*Todiramphus tuta*	Native	Land
Rarotonga flycatcher	*Pomarea dimidiatea*	Native (endemic), Globally endangered (seriously)	Mountains
Chestnut-breasted mannikin	*Lonchura castaneothorax*	Introduced, naturalised	Land
Common myna	*Acridotheres tristis*	Introduced, naturalised	Horticultural, villages, forest margins
Rarotonga starling	*Aplonis cinerascens*	Native (endemic), globally endangered (moderately)	Mountains

Source: 2007 (July) The Cook Islands Natural Heritage Trust Biodiversity Database.

3.5.2.3 Lizards

Ten species of lizards are known to occur in Rarotonga, with most of these found across a range of habitats (Table 3.3)(Natural Heritage Trust, 2007). Of these species, most are introduced, naturalised and only one is locally endangered being the tree gecko which is found in the mountains.

Table 3.3: Lizard species known to occur in Rarotonga

Common name	**Scientific name**	**Cook Island Status**	**Habitat**
Stumped toe gecko	*Gehyra mutilata*	Introduced, Naturalised	Lowlands round dwellings and in forests
Oceanic gecko	*Gehyra oceanica*	Introduced, Naturalised	Coastal to mountains on trees and dwellings
House gecko	*Hemidactylus frenatus*	Introduced, Naturalised	Coastal – lowlands, around dwellings
Tree gecko	*Hemiphylldactylus typus*	Introduced, Naturalised Locally endangered	Mountains
Mournful gecko	*Lepidodactylus lugubris*	Introduced, naturalised Pest – household nuisance	Coastal to mountains (mid-elevation)
Snake-eyed skink	*Cryptoblepharus poecilopleurus*	Introduced, naturalised	Coastal

Coastal blue-tailed skink	*Emoia cyanura*	Introduced, naturalised	Coastal lowlands, coralline soils
Inland blue-tailed skink	*Emoia impar*	Introduced, naturalised	Swampland to mountains, volcanic soils
Dandy skink	*Emoia trossula*	Introduced, Naturalised Native (Rarotonga)	Mountains and horticultural zone
Moth skink	*Lipinia noctua*	Introduced, Naturalised	Coastal to mountains (mid-elevation), under bark and debris

Source: 2007 (July) The Cook Islands Natural Heritage Trust Biodiversity Database.

4 Ecological values of the site

4.1 Overview

The site has been subject to previous land use modification including vegetation clearance, stockpiling organic and inorganic materials (Photograph 4.1, Photograph 4.2). As such, the existing ecological values on site are low and not representative of an intact ecosystem. Observations from a local landowner indicated that the site has historically been used for farming and planting local crops. The Vairauara Stream that flows adjacent to the site is reported to flow only periodically following heavy rain.

The catchment area is approximately 60 ha and the headwaters are in the mountains, covered in native vegetation. Parts of the mid to upper catchment are modified, with a road leading to Rarotonga Waste Facility (Arorangi Landfill) and the TM Heather and Raro Mining quarry sites. Existing septage ponds for the landfill are located midway between the proposed sludge disposal area and the landfill.

Downstream of the site the topography flattens out, with dwellings, horticultural and agricultural land use to Ara Tapu (ring road). Resorts and commercial facilities operate on the seaward side of Ara Tapu.

Photograph 4.1: Evidence of dumped inorganic material within vegetation, May 2021.

Photograph 4.2: Materials within the proposed disposal area, May 2021.

4.2 Freshwater values

The site is adjacent to the Vairauara Stream which flows along the Vairauara Road, to the north west of the proposed sludge disposal facility.

During the May 2021 site visit the stream had very little water present, with only a few small, isolated shallow pools (Photograph 4.3, Photograph 4.4). This was observed to be the case in March 2021 as well. The site visit was undertaken near the end of the wet season, when stream flows would be expected to be present. Anecdotal evidence from the nearby landowner indicates that the stream rarely flows, only following heavy rainfall events. This is typical for streams with short catchments on this side of the island (refer to a similar Environmental Impact Assessment, prepared by Tauei Enuarurutini Teauariki Lands Incorporated and Island Quarrying Limited, 2017).

The stream comprises a bed of cobbles and gravels, and it currently appears to follow a relatively natural alignment. Scouring and undermining of the stream banks were observed, indicating that heavy flows may periodically impact the stream channel. The lack of intermittent or continuous flow indicates that it is unlikely to have sufficient habitat for aquatic flora or fauna. Some short-lived aquatic macroinvertebrates may be able to make use of the stream for short periods of time when flows are present. It is expected that the flows will be further reduced upstream and that there is not sufficient habitat upstream to warrant consideration of migrating fish.

While there are not expected to be regular flows within the Vairauara Stream consideration of the aquatic ecology reporting previously conducted across Rarotonga was reviewed to identify potential aquatic ecological values of the Vairauara Stream and to inform this impact assessment (GHD 2020).

Photograph 4.3: Vairauara Stream, May 2021

Photograph 4.4: Culvert along Vairauara Stream, some shallow pools of water present in foreground, May 2021.

4.3 Terrestrial values

4.3.1 Terrestrial flora

The site is located at the entrance to a valley system and the vegetation and habitat within the site is modified and of low value. This reflects habitat on the valley floor both downslope and upslope toward the top of Vairauara Road.

Various introduced plants and trees are located within the site but predominately outside the disposal area and include bread fruit tree, chestnut tree, coconut trees, albizia tree, poboc tree. Some native hibiscus (*Hibiscus tiliaceus*) are also present but no native plants are known to occur within the disposal area.

Within the disposal area, the terrestrial vegetation values are limited due to historic land use and the stockpiling/dumping of material. The disposal area is almost completely dominated by mile a minute, an invasive creeper.

Outside the disposal area and on the hillslopes toward the centre of the island, the vegetation complex grades into original indigenous dominated forest cover that is of high ecological value.

Photograph 4.5: Panoramic photograph of proposed disposal area, May 2021.

4.3.2 Terrestrial fauna

The areas of gravel, open spaces and inorganic material provide basking habitat for the inland blue tailed skink (*Emoia impar*,) which is an introduced, naturalised species. While none were captured, large numbers of these skinks were observed in May 2021.

Pacific pigeon (rupe) can be seen and heard in the area as well as large population of wild chickens and myna birds. Pacific pigeon feed on berries and would be present in the tall stature woody vegetation outside of the disposal area.

While several terrestrial invertebrate species were identified during the site visit, it is highly unlikely there are any that are threatened or rare (under the IUCN classification system).

5 Ecology and water quality effects assessment

5.1 Nature of potential risks

The proposed sludge disposal activity is described in full in the EIA report (at section 5). A range of controls are proposed which will avoid or minimise potential effects on the ecological and water quality values of the site. Potential risks to freshwater and terrestrial environments are outlined within this section, and recommendations are made to address these risks.

5.1.1 Overview

GHD has undertaken sampling of the sludge from five of the ten water treatment plant sites and nearby natural soils to characterise the physical and chemical characteristics of the sludge relative to background soils. GHD prepared a report to inform disposal options, including use of the sludge in agriculture and disposal to a monofill, such as that proposed at this site.

In summary, the key findings relevant to this proposal are:

- The majority of the PACl sludge content is the natural fine particles carried by the streams that enters the water intakes and become separated as sludge as part of the water treatment process;
- The concentrations of the majority of the chemical parameters tested were comparable between the natural soils and PACl sludge, with the exception of chloride and total recoverable aluminium content (this is expected as PACl adds aluminium and chloride) and total sulphur and sulphate;
- GHD considered that the results indicate that the PACl sludge could be successfully disposed of in a monofil that is established in mineral soil geology (as opposed to sands) on the island. In this setting the PACl sludge would not represent a risk for leaching of trace elements or nutrient compounds;
- Containment such as a liner or capping is not required to contain hazardous substances; and
- Dust nuisance and protecting waterways from suspended sediments (via runoff) are the two main environmental considerations for disposal to a monofill.

5.1.2 Sludge characteristics

The sludge generated at the water treatment plants could be in two forms. Either a solids and water slurry that has 2-3 % solids content and is pumpable or a dewatered sludge with >15 % solids that will be similar in nature to soil.

Sludge material will reach the disposal site in two potential forms:

- Material that has had time to dry in settling ponds at the WTP locations will be removed via an excavator and transported to the sludge disposal site via a tip truck. As the sludge material is dry, no further dewatering will be required, and the material can be placed directly into the disposal facility.
- Material that arrives onsite as a slurry will require further dewatering. Slurry will be pumped into geobags which will allow water to be filtered through the bags while retaining the solids. Dewatered water, will be directed to a collection sump, stored and periodically pumped and disposed of to adjacent landfill septage ponds. The dewatered sludge will be disposed of at the disposal facility.

5.1.3 Sludge disposal facility

A concept design for the construction and operation of the sludge disposal facility has been prepared (refer to Appendix G of the EIA for complete plans). In summary:

1. Stripping topsoil and clearance of existing vegetation over the proposed sludge disposal facility footprint;
2. The construction of a 0.5 m thick intermediate cover layer over the existing ground that is to be covered by the disposal facility. The intermediate cover will be a compacted, low permeability, fill material comprised of natural mineral soils (silty or clayey material);
3. The construction of a 1.5 -2 m high edge bund with compacted low permeability fill. The edge bund will be located along the down-gradient edge of the facility;
4. Installation of perimeter piped drain (perforated pipe with drainage gravel surround) at the inner toe of the edge bund. The drain will be within the 'trench' which will remain open throughout the sludge disposal. The purpose of the perimeter pipe drain is to capture any excess 'leachate' from the sludge disposal facility area and direct this to a concrete leachate collection sump. Leachate within the collection sump will be discharged to the Rarotonga Waste Facility septage ponds;
   - The 'leachate' is limited to the excess water contained within the sludge potentially containing fine sediment and PACl. Rainwater falling directly on the open part of the disposal area will also contribute to 'leachate';
   - The 'leachate' from the sludge monofill area is different to that generated in a municipal waste landfill (like the Rarotonga Waste Facility). This is because the sludge is predominantly sediment with limited organic material or other materials. As such, a 'leachate' will not be produced as would be expected with a municipal solid waste landfill;
   - The sludge that arrives onsite as a slurry will require dewatering. It is proposed that geobags or a similar arrangement will be used to dewater sludge to around 15% dry solids. The geobags act as a sieve to retain fine sediment while allowing water to escape. This water will be similar in nature to the supernatant in the sludge ponds at each WTP that will periodically discharged to the adjacent streams at those WTP locations[1]. The geobags will be placed within the trench adjacent to the edge bund that is open to dewater. As such, all excess water that does not absorb into the dryer surrounding soil or infiltrate to ground will drain via the perimeter piped drain to a concrete collection sump. This will be periodically removed via a sucker truck and discharged to the landfill leachate ponds nearby. Alternatively, a temporary soft hose and pump may be used to pump the sludge disposal facility leachate to the landfill leachate ponds. Once the sludge has dewatered sufficiently the geobag will be opened and the sludge deposited in the pits.
5. The construction of a 1.5 - 2 m high soil platform adjacent to the edge bund above the 0.5 m thick intermediate soil cover. This will be constructed out of cleanfill, being natural silty or clayey mineral soils sourced on the island;
6. The progressive excavation of pits in the 1.5 – 2 m high soil platform. Each pit will be approximately 6 m x 6 m. Sludge with ~ 15 % dry solids will be disposed directly into these pits. Trucks will drive onto the soil platform and be able to tip directly into the excavated pits. As such, only one pit will be operational and filled at any one time;
7. Gravel will be placed on the platform to form a metalled access track for the trucks to drive on and the remaining areas of the platform that are not being utilised for access will be grassed

[1] Subject to the approval of this activity by the Island Environmental Authority.

to minimise sediment runoff and dust discharges. Rainwater falling on the platform will be diverted as clean stormwater away from the open trench and pit;

8 Placement of 0.3 m thick intermediate cover (clean natural silty or clayey mineral soil) over the disposed sludge once a pit is full; and

9 Once the 'first lift' of sludge disposal has been completed across the proposed sludge disposal facility, the process described above will be repeated for a 'second-lift' on top of the first lift.

5.2 Risks to the freshwater environment

As the stream system adjacent to the site is typically dry, the potential water quality and ecology risks to this environment are low. Notwithstanding, during periods of flow, there is the potential for contaminants to enter the stream and affect aquatic biodiversity. The potential risk is described in the following sections for activities during construction and operation of the sludge disposal activity.

5.2.1 During construction

During the initial clearance of the site and construction of the sludge disposal facility, open earthworks areas have the potential to generate sediment during rain events, which can discharge into streams and ultimately the marine environment.

Measures are proposed to reduce the potential for an uncontrolled discharge of sediment laden water. During construction, clean water diversions will be located around the works area to reduce clean water (runoff) entering the works area. This will minimise the amount of sediment-laden run off being generated within the site and prevent that runoff from entering the stream receiving environment.

5.2.2 During operation

There are two potential sources of contamination to the stream environment during operation of the sludge disposal facility. These are potential discharges of sediment laden water from the surface of the working area of the sludge disposal facility and potential leachate generated from inside the sludge disposal facility.

5.2.2.1 Potential sediment laden water discharges

During operation, the area of open, unstabilised soil will be kept to a minimum; the working platform of the sludge disposal facility will have three main parts as follows:

1 The open disposal trench and pit will be no more than 450 m^2 and 40 m^2 respectively and any sediment laden runoff generated within the trench and pit will be dealt with through the mechanisms described below.

2 Vehicle access across the surface of the disposal platform will be gravelled to reduce potential for sediment generation.

3 Trenches that are full and closed, or to be used in the future, will be closed over and grassed to reduce potential for sediment generation.

The surface of the disposal facility will be gently graded to the outer edge of the site and stormwater runoff will be directed away from the open trench/pit. Any runoff from the grassed or gravelled surface of the disposal facility will be directed to the side of the disposal facility. This mimics the pre-development state and therefore it is expected that there will be no more sediment generated during operation than pre-construction.

5.2.2.2 Potential leachate discharges

It is expected that 'leachate' will be generated within the trench/pit, which will effectively be the liquid within the sludge draining away either to ground or to underfill drainage, leaving behind only solids. The leachate is expected to comprise some fine sediments, total recoverable aluminium, chloride, total sulphur and sulphate. As is described in the Characterisation of PACl Sludge Samples Report (Wallis, 2021), the sludge is expected to have similar characteristics to natural soils of Rarotonga with the exception of aluminium and chloride concentrations. Further, given the similarities to natural soils, the sludge would not represent a risk for leaching of trace elements or nutrient compounds. The amount of discharge generated will depend on the viscosity of the sludge and any surface water that enters the trench.

The leachate will discharge from the pit/trench via two potential pathways. For the most part, it is expected that the leachate will discharge to ground (and local groundwater) via a layer of placed soil of at least 0.5 m thick in the base of the trench/pit. For discharge in excess of the soakage capacity, leachate will be collected in perforated underfill drains which will discharge to the existing landfill septage ponds.

If a major rain event was forecast, the open pit will be closed/covered over with soil, to reduce the potential for additional leachate generation.

In the unlikely scenario that the capacity of the drainage network is overwhelmed during a rain event, it is possible that leachate and sediment laden water could enter the receiving environment. The potential effects of this are assessed in the following section.

5.2.2.3 Sludge contaminant assessment

Streams are most at risk of being impacted by contaminants during periods of low flow, when the assimilative capacity of the stream is reduced. The Vairauara Stream does not flow year-round and is typically dry, expected to flow only following heavy rainfall events. Therefore, there are limited aquatic fauna that could be affected if a discharge was to occur. Notwithstanding, implementing the measures outlined above reduces the potential for either sediment laden water, or leachate, to enter the receiving environment.

In the absence of existing water quality data, the following assessment relies water quality data from other sites across Rarotonga (as reported in GHD 2020) and on the characteristics of the sludge leachate (GHD, 2021). The assessment also considers that discharges would likely occur only during periods of elevated rainfall. The key contaminants of concern reported by to be within the sludge are aluminium and chloride.

When added to a body of water, aluminium quickly forms large precipitates of aluminium hydroxide that grow in size eventually adhering to the sediments. Aluminium coagulants can also bind small particles including algal and cyanobacterial cells into the flocks and thus, directly reduce biomass from the water column (Jancula & Marsálek 2012). Aluminium bioavailability is directly correlated with the concentration of the actively toxic form of aluminium (Al^{+3}) in the discharged water. Factors such as pH, dissolved organic carbon (DOC), temperature and hardness regulate the solubility of Al^{+3} in water, with pH having the greatest influence on toxicity.

The active toxic component of PACl, the free cationic aluminium ion (Al 3+), solubility drastically increases at a pH lower than 5.5. Solubility also increases when pH is greater than 9. However, solubility is very low when pH is between 5.5 and 9. The toxicity of aluminium therefore depends on the pH of the receiving environment, with a higher toxicity at pH <5.5 and >9.0.

A near neutral pH was reported for most of the waterways of Rarotonga and is expected to be the same at Vairauara Stream. The pH of the sludge was also assessed as being 'around neutral', with all results being above 6.5 (GHD, 2021).

Based on the assessment of pH presented above, the trigger value has been selected based on a pH >6.5. The ANZECC default trigger value for toxicity of dissolved aluminium at pH >6.5 is 0.055 mg/L for protection of 95 % of aquatic species and 0.08 mg/L for protection of 90 % of aquatic species. GHD (2020) reported that the specific pH, hardness and DOC observed in the receiving environments within Rarotonga suggests long-term environmental protection is likely to be provided for concentrations of dissolved aluminium up to 290-630 µg/L (USEPA 2018).

Leachate from sludge was strained through geobags and tested to identify what the potential concentration of dissolved aluminium could be. Dissolved aluminium concentrations were 0.033 mg/L and 0.059 mg/L for a single bag and double bag straining, respectively. These values represent the concentration of the discharge without any further dilution from rainfall events, which would be the time when discharges would be expected. Therefore, it is considered that potential contaminants would be diluted and well below the guideline values in the receiving environment.

Increased concentrations of chloride can contribute to changes in aquatic environments, how it rapidly dilutes in water. As the discharge would only occur during periods of very high rainfall, chloride is not considered to be of concern for aquatic ecological values.

On this basis, the leachate is unlikely to have adverse effects on freshwater fauna that may be intermittently present and in the unlikely event that a discharge occurs. Overall, sediment and sludge discharges to surface water can be avoided entirely or minimised to such an extent that any ecological effects will below and considered to be acceptable.

5.3 Risk to the terrestrial environment

Clearance of the exotic vegetation and inorganic material on the surface will be required to facilitate the construction of the disposal facility. The inorganic materials buried within the site will be left in-situ and topped with a layer of topsoil underneath the sludge disposal facility. The area to be cleared is estimated to be approximately 0.5 ha and will be restricted to the area that has been historically modified, thereby reducing the potential for higher value ecosystems and associated species to be affected.

The vegetation that will be cleared within the disposal area is exotic and of low ecological value, and provides poor quality habitat for indigenous fauna but is known to support the naturalised inland blue-tailed skink.

To minimise harm to skinks, the habitat suitability of the site will be reduced prior to the commencement of works to encourage lizards self-relocate to more suitable habitat nearby. The existing habitat within the disposal area used by blue-tailed skinks is primarily inorganic material which provide refugia or cover. To this end, inorganic material should first be removed and vegetation should then be reduced in stature using a scrub cutter or a mulching head.

Any ground-dwelling birds that may be present will also self-relocate to surrounding areas upon commencement of these pre-works activities.

Overall, the potential effects of the construction and operation of the disposal facility on terrestrial flora and fauna can be minimised or managed to such an extent that any ecological effects will below and considered to be acceptable.

6 Summary and conclusion

The Government of the Cook Islands is in the process of upgrading Rarotonga's water supply system. A sludge by-product of the water treatment process requires disposal. It is proposed to create a sludge disposal facility within the Vairauara Stream catchment adjacent to existing landfill and quarrying activities.

The construction of the facility will result in the clearance of approximately 0.5 ha weedy vegetation on a former rubbish dump area. The existing fauna values are low, and the impacts of the displacement of fauna are manageable through pre-construction site clearance.

During construction there is a risk of sediment laden water entering the Vairauara Stream adjacent to the site. During operation, there is a risk of sediment laden water and leachate entering the Vairauara Stream. Measures are proposed which will reduce the potential for generation of runoff or leachate from the site.

In the event that some runoff or leachate were to enter the Vairauara Stream, this would be during heavy rainfall events and the potential impact on the aquatic environment is considered to be low based on the concentrations within the environment being below the derived guidelines for the protection of aquatic ecosystems.

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8 Applicability

This report has been prepared for the exclusive use of our client To Tatou Vai Limited, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

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Appendix F: GHD sludge characterisation report

Characterisation of PACl Sludge Samples

Water treatment management in Rarotonga

Cook Islands, Ministry of Finance and Economic Management

→ The Power of Commitment

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Executive summary

The upgraded water treatment intakes around Rarotonga have now nearly completed a six-month trial for the use of polyaluminium chloride (PACl). Polyaluminium chloride (PACl) is used to treat the water supply for Rarotonga. PACl sludge is a residual from the treatment process. To characterise the sludge and assess potential disposal options we sampled sludge from five water treatment plants around the island. We also sampled subsoil from the catchments of the five water treatment plants. The soil samples were taken for comparison with the PACl sludge, because the majority of the content of PACl sludge is the natural fine soil particles that enter the water intakes and become separated as sludge as part of the water treatment process.

The samples were taken from the PACl sludge storage ponds and from subsoil near the upstream edges of the water supply catchments. A broad suite of analyses was performed on the samples by the IANZ accredited Hill Laboratories of Hamilton, New Zealand. The parameters tested included pH, electrical conductivity, calcium chloride extractable aluminium, phosphorus, chloride, other metals and sulphur.

Our tests showed that most parameters were comparable between the soils and the PACl sludge. The chloride and total recoverable Aluminium content of the PACl sludge samples were higher than the natural soil samples. This result was expected, since PACl adds chloride and aluminium. However, from an environmental perspective these differences do not represent a hazard in the sludge because the extractable (plant available) Aluminium content of the sludge samples was no different than the natural soils, and the chloride levels were not of concern given the high rainfall regime of Rarotonga.

The total sulphur and sulphate contents of the PACl sludge samples were consistently higher than the soil samples. Sulphur is used in the production of the PACl product, however the level of sulphur we measured in the PACl sludge was not enough to lower the pH. Both the soils and sludge samples had pH near neutral to alkaline. The sulphur in the sludge would act as fertiliser if used in agronomic applications, because sulphur is an important plant nutrient that is deficient in Rarotonga soils. The sulphur content of the sludge we sampled would in fact be available at luxury levels (more than plant growth requirements), depending on the rate that sludge is applied to land.

Sulphate sulphur could reduce the availability of some trace elements for plant growth, although this effect can be mitigated if the PACl sludge is mixed (ploughed) into the soil. These micronutrients are only needed in very small amounts for plants. Trace elements can be readily added to phosphorus fertiliser, including compost.

We consider that the soil amendment rate (tonnes per hectare ploughed into the root zone) for PACl sludge could be high, because the material does not pose a hazard for people or for crops. The only practical constraint and consideration is the need for trace element fertiliser due to sulphur induced trace element deficiencies. We recommend that an application and fertiliser regime should be developed in conjunction with the Cook Islands Ministry of Agriculture.

Our results also indicate that PACl sludge could be successfully disposed in a monofill, established in mineral soil geology on the island. In this setting the PACl sludge would not represent a risk for leaching of trace elements or nutrient compounds. Containment (liner or capping) is not required to contain hazardous materials. The environmental considerations for design of a monofill are:

1. The need to manage dust nuisance; and
2. The need to protect waterways from unintentional discharges of stormwater, since elevated levels of suspended solids would be expected in runoff from the sludge.

This report is subject to, and must be read in conjunction with, the limitations set out in Section 1.2 and the assumptions and qualifications contained throughout the Report.

Contents

Table index

Appendices

1. Introduction

1.1 Purpose of this report

The water treatment systems currently being commissioned at Rarotonga use Polyaluminium Chloride or “PACl”. This process produces a sludge referred to as “PACl sludge”. To Tatou Vai (TTV), the Rarotonga water authority wishes to evaluate reuse options for the sludge, including land based options. On 5 March 2021 GHD Ltd took samples of PACl sludge and natural soils from Rarotonga to help characterise the material and assess suitable land based disposal options. The results of laboratory testing were documented in a report by Wallis Environmental Services Ltd (29 March 2021). Further characterisation was recommended by Wallis Environmental Services and endorsed by Tonkin and Taylor Ltd (T&T) on behalf of To Tatou Vai (Chris Purchas T&T, at a meeting held on 7 April 2021). This report presents the findings for samples of soil and PACl sludge taken in April 2021.

1.2 Scope and limitations

This report: has been prepared by GHD for Cook Islands, Ministry of Finance and Economic Management *and may only be used and relied on by Cook Islands, Ministry of Finance and Economic Management for the purpose agreed between GHD and Cook Islands, Ministry of Finance and Economic Management as set out in section 1.1 of this report.*

GHD otherwise disclaims responsibility to any person other than Cook Islands, Ministry of Finance and Economic Management arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section(s) 1.3 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

1.3 Assumptions

This report is based upon sampling at specific sampling locations, and the results from these locations are assumed to be representative of the material sampled. Field heterogeneity in natural soils and other media sampled is to be expected.

2. Methods

2.1 Sampling

Five PACl sludge samples and five soil samples were collected between 24 April and 27 April 2021. The samples were collected as pairs; in each of the five water supply catchments. A PACl sludge sample was taken from the sludge storage pond and a sample of soil was taken from the subsoil within the water supply catchment area (from the edges of the rivers just upgradient from the water intake screens). The subsoil samples were taken from depths around 0.5m to 0.8m below the surrounding ground surface. Samples were taken from the river banks, after digging into the bank about 250 mm.

The quantity of PACl sludge material required for the laboratory analyses was established based upon advice from Wallis Environmental Services Ltd (Memorandum dated 4 March 2021) and calculated by assuming a dry density of 2 % by weight. On that basis, 5 kg of material was required to obtain 100 g dry sample.

The Chain of Custody form is attached (Appendix A) and a summary of the samples collected is provided in Table 2.1.

Table 2-1 Sludge and soil samples

Sample number	Location	Description of sample	Depth
MPIS 0011	Avana Sludge pond	Water treatment sludge from settlement tank	Sample of full sludge column
MPIS 0012	Takuvaine Sludge pond	Water treatment sludge from settlement tank	Sample of full sludge column
MPIS 0013	Avatiu sludge pond	Water treatment sludge from settlement tank	Sample of full sludge column
MPIS 0014	Taipara sludge pond	Water treatment sludge from settlement tank	Sample of full sludge column
MPIS 0015	Papua sludge pond	Water treatment sludge from settlement tank	Sample of full sludge column
MPIS 0016	Avana water catchment	Subsoil from 0.5m to 0.8m depth within the water catchment	0.5 to 0.8 m below ground level dug in from river bank
MPIS 0017	Takuvaine water catchment	Subsoil from 0.5m to 0.8m depth within the water catchment	0.5 to 0.8 m below ground level dug in from river bank
MPIS 0018	Avatiu water catchment	Subsoil from 0.5m to 0.8m depth within the water catchment	0.5 to 0.8 m below ground level dug in from river bank
MPIS 0019	Taipara catchment area	Subsoil from 0.5m to 0.8m depth within the water catchment	0.5 to 0.8 m below ground level dug in from river bank
MPIS 0020	Papua catchment area	Subsoil from 0.5m to 0.8m depth within the water catchment	0.5 to 0.8 m below ground level dug in from river bank

2.2 Laboratory analysis

The suite of analyses was provided to GHD from Wallis Environmental Services Ltd (Memorandum dated 4 March 2021). The laboratory test regime was informed by discussions with Hill Laboratories Ltd of Hamilton New Zealand (Ms Ara Heron).

The analyses were based upon consideration of the potential contaminants of concern, as follows:

- pH
- Electrical conductivity (EC)
- Calcium Chloride extractable Aluminium

- Olsen Phosphorus
- Chloride
- Soluble Salts
- Extractable Sulphur
- Total Sulphur, and
- Metals/Minerals in Solid suite (TRACE level of detection).

3. RESULTS AND DISCUSSION

The Hill Laboratories analytical test reports are attached in Appendix B, as received.

The summary of results for all analytes other than the trace elements is provided below. Elevated concentrations of analytes are highlighted.

3.1 pH

The pH of the five PACl sludge samples was near neutral. The pH of the five soil samples ranged from slightly alkaline to slightly acidic.

The pH values for the PACl sludge fell within the range of the natural soil samples.

The pH values are not considered to be a concern for disposal in a monofill or for agronomic applications as they are within the range of the natural soils on Rarotonga.

For agronomic applications, the pH values are higher than optimal for plant uptake of nutrients. This is also the case for four of the five native mineral soils sampled. As such, the sludge would not exacerbate the existing (alkaline) pH conditions of the native soils. Some crops may benefit from trace element fertiliser amendments to compensate for the elevated pH conditions.

3.2 Electrical conductivity (EC)

The EC values of the five PACl sludge samples were 0.13 to 0.21 mS/cm, slightly higher than the EC range of the soil samples. The EC values of the sludge are not considered to be a concern for disposal in a monofill or for agronomic applications.

3.3 Calcium Chloride extractable Aluminium

The extractable Aluminium (Al) concentrations measured in the PACl sludge samples were all less than the laboratory detection limit, as was the case for the extractable Al concentrations measured in the soil samples.

The extractable Al values are not considered to be a concern for disposal in a monofill or for agronomic applications.

3.4 Olsen Phosphorus

The Olsen Phosphorus (P) levels measured in the PACl sludge samples were in the low range for agronomic soils (3 to 19 mg/L).

The Olsen P levels measured in the soil samples were generally higher than the sludge samples, with a range from 6 mg/L to 27 mg/L.

The Olsen P values of the sludge are not considered to be a concern for disposal in a monofill or for agronomic applications. The values are less than optimal for plant growth. Some phosphorus fertiliser would likely be necessary for most agronomic situations (as is the case for the natural soils).

3.5 Chloride

The Chloride concentrations of the five PACl sludge samples were moderate to high.

The Chloride concentrations of four of the five soil samples were less than the laboratory detection limit (10 mg/kg), and chloride was detected at a low concentration (15 mg/kg) in the Avana soil sample.

The Chloride concentrations for the PACl sludge samples were high compared with the natural soil samples.

The Chloride concentration of the Taipara sludge sample (227 mg/kg) is approaching the range (350 mg/kg) that can cause damage to sensitive crops such as lettuce, beans and strawberries (refer to Chloride Basics (spectrumanalytic.com)).

The Chloride concentration is not considered to be a concern for disposal in a monofill.

Although the sludge Chloride levels are elevated when compared to the requirements for soil used to grow plants, if the sludge is mixed in with the native soils the chloride availability (and hence plant toxicity) will be reduced by interaction with soil cations. This mixing process will ameliorate and moderate the potential Chloride effect of the sludge. In addition, even without mixing the Chloride, concentrations will reduce in the natural environment as salts are gradually diminished due to rainfall percolation and dilution/ dispersion.

3.6 Soluble salts

The Soluble Salts concentrations measured in the five PACl sludge samples were all low (less than 0.07 %). The Soluble Salts concentrations measured in the soil samples were all less than 0.05%.

The Soluble Salts values of the two sludge samples are not considered to be a concern for disposal in a monofill or for agronomic applications.

3.7 Sulphur (Sulphate)

The Sulphate concentrations measured in the PACl sludge samples were high, at 140 to 576 mg/kg, compared with a highly variable range of <1 to 33 mg/kg in the five soil samples.

The Sulphate concentrations in the sludge are not considered to be a concern for disposal in a monofill founded in natural mineral soils (as opposed to sands). In natural mineral soils on the island the silts and clays of the highly weathered volcanic soils have a high cation exchange capacity. As a result, the sulphate will tend to react with soil cations (magnesium, calcium, sodium, potassium) and produce benign compounds.

The Sulphate concentrations in the sludge are also not considered to be a concern for agronomic applications. The sulphate values are higher than optimal for plant growth. The level of available sulphur in the sludge will provide a luxury level of sulphur for plant uptake. The high sulphur level would be expected to lower the soil pH when applied to natural soil. However (as mentioned for pH), the natural mineral soils generally have a high pH buffering capacity and as such the pH change that might result from amendment with sludge would tend to be moderated by the soil buffering capacity.

Adding a high sulphur content sludge to soil could lead to induced soil deficiency for other trace elements because the sulphate may react with soil cations. For example, sulphur will react with positively charged ions such as calcium, sodium, magnesium and potassium, reducing the availability of these essential micronutrients for plant uptake. If the sludge is mixed in with the native soils this effect will be moderated by the lower sulphur content of the natural soils.

3.8 Sulphur (Extractable Organic Sulphur)

The sludge and soil samples were analysed for extractable organic sulphur to help interpret the source and nature of the elevated sulphur in the sludge samples. Four of the measured extractable organic sulphur concentrations in the sludge samples were low, and less than the analytical level of detection (< 2 mg/kg). By contrast, the organic sulphur content in the Taipara sludge sample was 27 mg/kg. The measured extractable organic sulphur concentrations in the soil samples were low, either at or less than the analytical level of detection (< 2 mg/kg).

Organic forms of sulphur will only release plant available sulphur slowly as the organic matter decomposes naturally by mineralisation. The extractable organic sulphur values of the sludge samples are not considered to be a concern for disposal in a monofill or for agronomic applications.

3.9 Sulphur (“Total” Sulphur)

The sludge and soil samples were analysed for “Total” Sulphur to help interpret the source and nature of the elevated sulphur in the sludge samples. Hill Laboratories notes that the levels from this method are referred to as “Totals” in quotation marks as they will be a slight under-estimation of the true Totals for some elements.

The “Total” Sulphur concentrations measured in the PACl sludge samples were high, at 2,690 to 4,520 mg/kg, compared with a variable range of 142 to 491 mg/kg in the five soil samples. These results indicate that the source of the sulphur in the sludge is the PACl product rather than the natural soil. These results also correlate with the findings for sulphate, as described above.

The “Total” Sulphur concentrations in sludge are an order of magnitude higher than the sulphate sulphur concentrations. This indicates that in a monofill or agronomic application the sludge will continue to release sulphate over time (which will also be available for plant uptake). The preceding commentary regarding Sulphate Sulphur also applies to “Total Sulphur.”

3.10 Metals/minerals in solid suite (TRACE level of detection)

Overall, the “total recoverable” trace element results for the two PACl sludge samples were generally as expected. The total recoverable Aluminium content of the PACl sludge samples were high compared with the natural soil samples. However, as noted above, the extractable Al content of the sludge samples could not be differentiated from the natural soils.

The “total recoverable” concentrations of some trace elements measured in the sludge samples were lower than the corresponding values measured in the natural soils (eg for barium, lead and cadmium). This may result from interactions between these (positively charged) cations and the (negatively charged) sulphate in the sludge that reduce the concentrations of the trace element that are measured in the nitric/hydrochloric acid digest.

The concentrations of total recoverable metals are not considered to be a concern for disposal in a monofill or for agronomic applications.

4. CONCLUSIONS AND RECOMMENDATIONS

These results indicate that PACl sludge could be successfully disposed of in a monofill or used in an agronomic application. The sludge would have fertiliser value as a source of plant available sulphur in an agronomic situation.

In a monofill established in mineral soil geology on the island, the PACl sludge would not represent a risk for leaching of trace elements or nutrient compounds. Containment (liner or capping) is not required to contain hazardous materials. The environmental considerations for design of a monofill are:

1. The need to manage dust nuisance, and
2. The need to protect waterways from unintentional discharges of stormwater, since elevated levels of suspended solids would be expected in runoff from the sludge.

For agronomic applications, incorporating the sludge into natural soil by mixing (eg ploughing the material into the topsoil) would have some advantages compared to a broadacre spreading process on the soil surface. The main advantage arises because the sludge lacks structure and PACl sludge has been reported in other studies to develop water repellency when dried (which can inhibit rainfall infiltration). Mixing the sludge would also reduce the propensity of the sludge to induce trace element deficiencies due to the elevated sulphur content.

The source of the elevated sulphur is believed to be the PACl product that is used in the water treatment process. The supplier of the PACl product has indicated that their production process utilises sulphuric acid, which is a source of sulphur.

We consider that the soil amendment rate (tonnes per hectare ploughed into the root zone) for PACl sludge could be high, because the material does not pose a hazard for people or for crops. The only practical constraint and consideration is the need for trace element fertiliser due to sulphur induced trace element deficiencies. We recommend that an application and fertiliser regime should be developed in conjunction with the Cook Islands Ministry of Agriculture.

Appendices

Appendix A

Laboratory Chain of Custody Form

Job No: Date Recv: 05-May-21 13:04
260 4062
Ministry for Prima[ry Industries]
Mana[gement] Received by: Rory Standen
3126040621

Biosecurity Authority/ Clearance Certificate

Pursuant to Sections 25 and 26 of the Biosecurity Act 1993

C2021/551723

CUSMOD Release No.:
BACC No.: B2021/172959
NZCS Entry No.:

All Biosecurity Requirements Met?
NO

Each Authority contained in this document identifies the goods that are covered by the Authority, a Transitional Facility that you are authorised to take the goods to, and any conditions which the authorisation is subject to.

Removal of these goods to a place other than the Transitional Facility authorised, or otherwise than in accordance with the conditions specified, is an offence.

Any clearance or Authority that is contained in this document, and that relates to agricultural compounds or veterinary medicines, also constitutes permission to remove these goods under the conditions contained within the Agricultural Compounds and Veterinary Medicines Act 1997.

Authority Issued To: R J Hill Laboratories Limited, Private Bag 3205, , Hamilton 3240

Importer: R J Hill Laboratories Limited, Private Bag 3205, , Hamilton 3240
Contact: Mariette Komene
Agent: Importer Acting As Agent, Peter Free, , -
Contact: 0274298232
Arrival Method: **Flight:** NZ941 **Date:** 29/04/2021

IDENTIFIERS:

B/L:NZ94129042021;Sub B/L:PAXFREEPETER;
Sub B/L:BACC017508;

AUTHORITY

To be taken to: R J Hill Laboratories Limited, 28 Duke Street, Frankton, Hamilton
For: Further action at Transitional Facility as per IHS/Permit/CTO Direction
By: Containment Verifier, -
Authority Conditions:
As per permit number; 2020076763.
This BACC replaces the manual BACC that it was processed at the border on (BACC# 017508).
The cartons were picked up from AKL ITB by NZ Couriers on the 03/05/2021 at 1600.

Authorising Inspector: Clement, Stephen **Location:** Auckland - Airport **Date:** 03/05/2021

GOODS COVERED BY THIS AUTHORITY:

No.	Line Type	Country of Origin	Line Details
1	Miscellaneous	COOK ISLANDS	Soil,Soil for scientific analysis,Soil and Sludge Samples,10.000 kilograms

Line Identifiers: **Sub B/L:BACC017508; B/L:NZ94129042021; Sub B/L:PAXFREEPETER;**

Issued By: Stephen Clement
Location: Auckland - Airport

Signed: [signature]
Signing Date: 03/05/2021

Hamilton, New Zealand | W www.hill-laboratories.com

Name	Peter Free	**Primary Contact**	Peter Free
Address	GHD Ltd	**Submitter** (if different)	
	134 Queens Street East, Hastings	Company	GHD Limited
Postcode	4122	Address	134 Queens Street East, Hastings
Email	Peter.Free@ghd.com		
Phone	027 429 8232	Fax	
Client Reference		Email	
Additional Client Ref	PMU Services 12504023		
Quote No		Order No	
Date Sampled	~~10/12/2020~~ 24-4-21		

Results To — Reports will be emailed to Primary Contact by default. Additional Reports will be sent as specified below.

☑ Email Primary Contact ☐ Email Client ☐ Email Submitter
☐ Email Other
☐ Other

Charge To ☐ Client ☑ Submitter (Company)
☐ Other

SOIL SAMPLE DETAILS

Recommended Profiles are outlined below, and on the reverse of this sheet. *Please indicate your requested tests with a ✓*

Sample Identification	Sample Depth (mm)	Dairy (D), Drystock (DS) OR Crop Type (Specify)	Soil Code*	Rec. Profile	Basic Soil BS	Sulphate Sulphur SO4	Organic Sulphur OS	Anion Storage Capacity ASC	Total Sulphur tS	Resin P RP	Organic Soil Profile OrgSP	Organic Matter OM	Pot Avail Nitrogen AN	Boron B	Trace Metals EDTA	Mehlich 3 M3	Other	Lab#
MPIPS 0011	Surface	Avona	Sludge		✓	✓							✓				Al	
MPIPS 0012	Surface	Takavaine	Sludge															
MPIPS 0013	Surface	Avatiu	Sludge															
MPIPS 0014	Surface	Taipara	Sludge															

*Soil Code: Ash (A), Pumice (Pu), Peat (Pt), Sedimentary (Sed) – applies for pasture only, Glasshouse (GH)

Recommended Soil Profiles: (see Crop Guides) *Pasture* (Basic Soil + SO4-S), *Arable Crops* (Basic Soil + SO4-S + Potentially Available N), *Vegetables* (Basic Soil + SO4 S + Pot Available N), *Avocado* (Basic Soil + M3), *Kiwifruit* (Basic Soil + Pot Available N)

PLANT SAMPLE DETAILS

Recommended Profiles are outlined below, and on the reverse of this sheet. *Please indicate your requested tests with a ✓*

Sample Identification	Dairy (D), Drystock (DS) OR Crop Type/Variety (Specify)	Crop Plant Part / Growth Stage	Rec. Profile	Basic Plant BP	Molybdenum MO	Cobalt CO	Selenium SE	Iodine I	Chloride CL	Nitrate NO3	Mixed Pasture Profile MPast	Complete Pasture Profile CPP	Combined Grape Profile CGP	Combined Potato Profile CPotP	Other	Lab#

Recommended Plant Profiles: (see Crop Guides) *Clover Only* (Basic Plant + Molybdenum), *Kiwifruit* (Basic Plant + Cl), *Avocado* (Basic Plant + Cl), *Brassica* (Basic Plant + Molybdenum), *Lucerne* (Basic Plant + Molybdenum), *Mixed Pasture* (Basic Plant, Mo, Co, Se + Cl + Crude Protein + ME), *Complete Pasture* (Mixed Pasture + Clover Only Profiles)

FEED SAMPLE DETAILS

Recommended Profiles are outlined below. *Please indicate your requested tests with a ✓*

Sample Identification	Crop Grown	Sample Source e.g. paddock, trucks, stack, bales	Weeks in stack/bales (silage/baleage only)	Dry Matter DM	Dry Matter, CP, ME DMME	Feed Feed	Extended Feed ExtFed	Silage Silage	Extended Silage ExtSil	Compound Feed CpdFeed NIR	Compound Feed CpdFeed Wet Chem	Other e.g. VFA, NO3-N, Starch, Cl	Lab#

Recommended Feed Profiles:

- *Feedstuff*: DM (Dry matter only), DMME (Dry Matter, Crude Protein, Digestibility, Metabolisable Energy), Feed (Dry Matter, Crude Protein, Crude Fat, Ash, Soluble Sugars, Starch, ADF, NDF, Lignin, Metabolisable Energy, Digestibility), ExtFed (Feed profile plus major & trace elements incl Cl), CpdFeed (Dry Matter, Crude Protein, Crude Fat, Ash, Soluble Sugars, Starch, ADF, NDF, Metabolisable Energy, Digestibility) - select between NIR analysis OR Wet Chemistry only (Price Impact).
- *Silage/Baleage*: Silage (pH, Dry Matter, Crude Protein, Crude Fat, Ash, Soluble Sugars, Starch, ADF, NDF, Lignin, Metabolisable Energy, Digestibility, Lactic Acid, Ammonium N/Total N), ExtSil (Silage profile plus major & trace elements incl Cl)

ADDITIONAL INSTRUCTIONS

NB. Please advise laboratory if hazardous substances possibly present in samples.

☐ Total Number of Samples Sent

NOTE: If more than one courier bag being sent for one farm, please indicate eg. 1 of 2, 2 of 2 etc on outside of courier bag so that all samples are reported in one job.

- pH
- EC
- Olsen Phosphorus
- Chloride
- Solube salts
- Extractable sulphur
- Calcium Chloride extractable Aluminium
- Total recoverable Sulphur

Please supply more of: (specify quantities required)

- Qty: ☐ Request Forms KB 2009
- Qty: ☐ Plant/Feed Bags (indiv)
- Qty: ☐ Soil & Plant DIY sampling kits
- Qty: ☐ Soil Bags (indiv)
- Qty: ☐ Courier Bags: ☐ NZ Courier ☐ Courier Post
- Qty: ☐ Other

PLEASE SIGN (refer to terms of trade overleaf) Signature ____ Date ____

KB Item: 2009 Version: 28

Job No: Date Recv: 05-May-21 13:04

260 4062

Received by: Rory Standen

3126040621

Hamilton, New Zealand | W www.hill-laboratories.com

Name Peter Free
Address GHD Ltd
134 Queens Street East, Hastings
Postcode 4122
Email Peter.Free@ghd.com
Phone 027 429 8232 **Fax**
Client Reference
Additional Client Ref PMU Services 12504023
Quote No **Order No**
Date Sampled ~~10/12/2020~~ 24-4-21

Charge To ☐ Client ☑ Submitter (Company) ☐ Other

Primary Contact Peter Free
Submitter (if different)
Company GHD Limited
Address 134 Queens Street East, Hastings
Email

Results To Reports will be emailed to Primary Contact by default. Additional Reports will be sent as specified below.

☑ Email Primary Contact ☐ Email Client ☐ Email Submitter
☐ Email Other
☐ Other

SOIL SAMPLE DETAILS

Recommended Profiles are outlined below, and on the reverse of this sheet. Please indicate your requested tests with a ✓

Sample Identification	Sample Depth (mm)	Dairy (D), Drystock (DS) OR Crop Type (Specify)	Soil Code*	Rec. Profile	Basic Soil BS	Sulphate Sulphur SO4	Organic Sulphur OS	Anion Storage Capacity ASC	Total Sulphur tS	Resin P RP	Organic Soil Profile OrgSP	Organic Matter OM	Pot Avail Nitrogen AN	Boron B	Trace Metals EDTA	Mehlich 3 M3	Other	Lab#
MPIPS 0015	Surface	Papua	Sludge		✓	✓							✓				Al	

*Soil Code: Ash (A), Pumice (Pu), Peat (Pt), Sedimentary (Sed) – applies for pasture only, Glasshouse (GH)

Recommended Soil Profiles: (see Crop Guides) Pasture (Basic Soil + SO4-S), Arable Crops (Basic Soil + SO4-S + Potentially Available N), Vegetables (Basic Soil + SO4 S + Pot Available N). Avocado (Basic Soil + M3), Kiwifruit (Basic Soil + Pot Available N)

PLANT SAMPLE DETAILS

Recommended Profiles are outlined below, and on the reverse of this sheet. Please indicate your requested tests with a ✓

Sample Identification	Dairy (D), Drystock (DS) OR Crop Type/Variety (Specify)	Crop Plant Part / Growth Stage	Rec. Profile	Basic Plant BP	Molybdenum MO	Cobalt CO	Selenium SE	Iodine I	Chloride CL	Nitrate NO3	Mixed Pasture Profile MPast	Complete Pasture Profile CPP	Combined Grape Profile CGP	Combined Potato Profile CPotP	Other	Lab#

Recommended Plant Profiles: (see Crop Guides) Clover Only (Basic Plant + Molybdenum). Kiwifruit (Basic Plant + Cl). Avocado (Basic Plant + Cl). Brassica (Basic Plant + Molybdenum). Lucerne (Basic Plant + Molybdenum). Mixed Pasture (Basic Plant, Mo, Co, Se + Cl + Crude Protein + ME). Complete Pasture (Mixed Pasture + Clover Only Profiles)

FEED SAMPLE DETAILS

Recommended Profiles are outlined below. Please indicate your requested tests with a ✓

Sample Identification	Crop Grown	Sample Source e.g. paddock, trucks, stack, bales	Weeks in stack/bales (silage/baleage only)	Dry Matter DM	Dry Matter, CP, ME DMME	Feed Feed	Extended Feed ExtFed	Silage Silage	Extended Silage ExtSil	Compound Feed CpdFeed NIR	Compound Feed CpdFeed Wet Chem	Other e.g. VFA, NO3-N, Starch, Cl	Lab#

Recommended Feed Profiles:

- **Feedstuff**: DM (Dry matter only), DMME (Dry Matter, Crude Protein, Digestibility, Metabolisable Energy), Feed (Dry Matter, Crude Protein, Crude Fat, Ash, Soluble Sugars, Starch, ADF, NDF, Lignin, Metabolisable Energy, Digestibility), ExtFed (Feed profile plus major & trace elements incl Cl), CpdFeed (Dry Matter, Crude Protein, Crude Fat, Ash, Soluble Sugars, Starch, ADF, NDF, Metabolisable Energy, Digestibility) - select between NIR analysis OR Wet Chemistry only (Price Impact).
- **Silage/Baleage**: Silage (pH, Dry Matter, Crude Protein, Crude Fat, Ash, Soluble Sugars, Starch, ADF, NDF, Lignin, Metabolisable Energy, Digestibility, Lactic Acid, Ammonium N/Total N). ExtSil (Silage profile plus major & trace elements incl Cl)

ADDITIONAL INSTRUCTIONS

NB. Please advise laboratory if hazardous substances possibly present in samples.

☐ Total Number of Samples Sent

NOTE: If more than one courier bag being sent for one farm, please indicate eg. 1 of 2, 2 of 2 etc on outside of courier bag so that all samples are reported in one job.

- pH
- Olsen Phosphorus
- Soluble salts
- EC
- Chloride
- Extractable sulphur
- Calcium Chloride extractable Aluminium
- Total recoverable sulpher

Please supply more of: (specify quantities required)

Qty: ☐ Request Forms KB 2009 ☐ Plant/Feed Bags (indiv)
Qty: ☐ Soil & Plant DIY sampling kits ☐ Soil Bags (indiv)
Qty: ☐ Courier Bags: ☐ NZ Courier ☐ Courier Post
Qty: ☐ Other

PLEASE SIGN (refer to terms of trade overleaf) Signature Date

KB Item: 2009 Version: 28

Soil

Hill Laboratories
TRIED, TESTED **AND TRUSTED**

ANALYSIS REQUEST

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Client

Name: Peter Free
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134 Queens Street East, Hastings
Postcode: 4122
Email: Peter.Free@ghd.com
Phone: 027 429 8232 Fax:
Client Reference:
Additional Client Ref: PMU Services 12504023
Quote No: Order No:
Date Sampled: ~~10/12/2020~~ 27-4-2021

Charge To ☐ Client ☑ Submitter (Company) ☐ Other

Primary Contact Peter Free
Submitter *(if different)*
Company: GHD Limited
Address: 134 Queens Street East, Hastings
Email:

Results To — *Reports will be emailed to Primary Contact by default. Additional Reports will be sent as specified below.*
☑ Email Primary Contact ☐ Email Client ☐ Email Submitter
☐ Email Other
☐ Other

SOIL SAMPLE DETAILS

Recommended Profiles are outlined below, and on the reverse of this sheet. *Please indicate your requested tests with a ✓*

Sample Identification	Sample Depth (mm)	Dairy (D), Drystock (DS) OR Crop Type (Specify)	Soil Code*	Rec. Profile	Basic Soil BS	Sulphate Sulphur SO4	Organic Sulphur OS	Anion Storage Capacity ASC	Total Sulphur tS	Resin P RP	Organic Soil Profile OrgSP	Organic Matter OM	Pot Avail Nitrogen AN	Boron B	Trace Metals EDTA	Mehlich 3 M3	Other	Lab#
MPIPS 0016	0.5m	Avana	Sed		✓	✓							✓				Al	
MPIPS 0017	0.5m	Takuvaine	Sed															
MPIPS 0018	0.5m	Avatiu	Sed															
MPIPS 0019	0.5m	Taipara	Sed															

*Soil Code: Ash (A), Pumice (Pu), Peat (Pt), Sedimentary (Sed) – applies for pasture only, Glasshouse (GH)

Recommended Soil Profiles: (see Crop Guides) Pasture (Basic Soil + SO4-S), Arable Crops (Basic Soil + SO4-S + Potentially Available N), Vegetables (Basic Soil + SO4 S + Pot Available N), Avocado (Basic Soil + M3), Kiwifruit (Basic Soil + Pot Available N)

PLANT SAMPLE DETAILS

Recommended Profiles are outlined below, and on the reverse of this sheet. *Please indicate your requested tests with a ✓*

Sample Identification	Dairy (D), Drystock (DS) OR Crop Type/Variety (Specify)	Crop Plant Part / Growth Stage	Rec. Profile	Basic Plant BP	Molybdenum MO	Cobalt CO	Selenium SE	Iodine I	Chloride CL	Nitrate NO3	Mixed Pasture Profile MPast	Complete Pasture Profile CPP	Combined Grape Profile CGP	Combined Potato Profile CPotP	Other	Lab#

Recommended Plant Profiles: (see Crop Guides) Clover Only (Basic Plant + Molybdenum), Kiwifruit (Basic Plant + Cl), Avocado (Basic Plant + Cl), Brassica (Basic Plant + Molybdenum), Lucerne (Basic Plant + Molybdenum), Mixed Pasture (Basic Plant, Mo, Co, Se + Cl + Crude Protein + ME), Complete Pasture (Mixed Pasture + Clover Only Profiles)

FEED SAMPLE DETAILS

Recommended Profiles are outlined below. *Please indicate your requested tests with a ✓*

Sample Identification	Crop Grown	Sample Source e.g. paddock, trucks, stack, bales	Weeks in stack/bales (silage/baleage only)	Dry Matter DM	Dry Matter, CP, ME DMME	Feed Feed	Extended Feed ExtFed	Silage Silage	Extended Silage ExtSil	Compound Feed CpdFeed NIR	Compound Feed CpdFeed Wet Chem	Other e.g. VFA, NO3-N, Starch, Cl	Lab#

Recommended Feed Profiles:
- **Feedstuff**: DM (Dry matter only), DMME (Dry Matter, Crude Protein, Digestibility, Metabolisable Energy), Feed (Dry Matter, Crude Protein, Crude Fat, Ash, Soluble Sugars, Starch, ADF, NDF, Lignin, Metabolisable Energy, Digestibility), ExtFed (Feed profile plus major & trace elements incl Cl), CpdFeed (Dry Matter, Crude Protein, Crude Fat, Ash, Soluble Sugars, Starch, ADF, NDF, Metabolisable Energy, Digestibility) - select between NIR analysis OR Wet Chemistry only (Price impact).
- **Silage/Baleage**: Silage (pH, Dry Matter, Crude Protein, Crude Fat, Ash, Soluble Sugars, Starch, ADF, NDF, Lignin, Metabolisable Energy, Digestibility, Lactic Acid, Ammonium N/Total N). ExtSil (Silage profile plus major & trace elements incl Cl)

ADDITIONAL INSTRUCTIONS

NB. Please advise laboratory if hazardous substances possibly present in samples

☐ Total Number of Samples Sent — **NOTE:** If more than one courier bag being sent for one farm, please indicate eg. 1 of 2, 2 of 2 etc on outside of courier bag so that all samples are reported in one job.

- pH
- Olsen Phosphorus
- Soluble salts
- EC
- Chloride
- Extractable sulphur
- Calcium Chloride extractable Aluminium
- Total recoverable Sulphur

Please supply more of: *(specify quantities required)*

Qty: [ ] Request Forms KB 2009 — [ ] Plant/Feed Bags (indiv)
Qty: [ ] Soil & Plant DIY sampling kits — [ ] Soil Bags (indiv)
Qty: [ ] Courier Bags: ☐ NZ Courier ☐ Courier Post
Qty: [ ] Other

PLEASE SIGN *(refer to terms of trade overleaf)* Signature [signature] Date 27-4-21

KB Item: 2009 Version: 28

Soil

Hill Laboratories
TRIED, TESTED AND TRUSTED

ANALYSIS REQUEST

R J Hill Laboratories Limited
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Hamilton, New Zealand

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W www.hill-laboratories.com

Client

Name: Peter Free
Address: GHD Ltd
134 Queens Street East, Hastings
Postcode: 4122
Email: Peter.Free@ghd.com
Phone: 027 429 8232 Fax:
Client Reference:
Additional Client Ref: PMU Services 12504023
Quote No: Order No:
Date Sampled: ~~10/12/2020~~ 27-4-21

Charge To ☐ Client ☑ Submitter (Company) ☐ Other

Primary Contact Peter Free

Submitter (if different)
Company: GHD Limited
Address: 134 Queens Street East, Hastings
Email:

Results To Reports will be emailed to Primary Contact by default. Additional Reports will be sent as specified below.

☑ Email Primary Contact ☐ Email Client ☐ Email Submitter
☐ Email Other
☐ Other

SOIL SAMPLE DETAILS

Recommended Profiles are outlined below, and on the reverse of this sheet. Please indicate your requested tests with a ✓

Sample Identification	Sample Depth (mm)	Dairy (D), Drystock (DS) OR Crop Type (Specify)	Soil Code*	Rec. Profile	BS (Basic Soil)	SO4 (Sulphate Sulphur)	OS (Organic Sulphur)	ASC (Anion Storage Capacity)	tS (Total Sulphur)	RP (Resin P)	OrgSP (Organic Soil Profile)	OM (Organic Matter)	AN (Pot Avail Nitrogen)	B (Boron)	EDTA (Trace Metals)	M3 (Mehlich 3)	Other	Lab#
MPIPS 0020	0.5m	Papua	Sed		✓	✓							✓				Al	

*Soil Code: Ash (A), Pumice (Pu), Peat (Pt), Sedimentary (Sed) – applies for pasture only, Glasshouse (GH)

Recommended Soil Profiles (see Crop Guides): Pasture (Basic Soil + SO4-S), Arable Crops (Basic Soil + SO4-S + Potentially Available N), Vegetables (Basic Soil + SO4 S + Pot Available N), Avocado (Basic Soil + M3), Kiwifruit (Basic Soil + Pot Available N)

PLANT SAMPLE DETAILS

Recommended Profiles are outlined below, and on the reverse of this sheet. Please indicate your requested tests with a ✓

Sample Identification	Dairy (D), Drystock (DS) OR Crop Type/Variety (Specify)	Crop Plant Part / Growth Stage	Rec. Profile	BP (Basic Plant)	MO (Molybdenum)	CO (Cobalt)	SE (Selenium)	I (Iodine)	CL (Chloride)	NO3 (Nitrate)	MPast (Mixed Pasture Profile)	CPP (Complete Pasture Profile)	CGP (Combined Grape Profile)	CPotP (Combined Potato Profile)	Other	Lab#
/																
/																

Recommended Plant Profiles (see Crop Guides): Clover Only (Basic Plant + Molybdenum), Kiwifruit (Basic Plant + Cl), Avocado (Basic Plant + Cl), Brassica (Basic Plant + Molybdenum), Lucerne (Basic Plant + Molybdenum), Mixed Pasture (Basic Plant, Mo, Co, Se + Cl + Crude Protein + ME), Complete Pasture (Mixed Pasture + Clover Only Profiles)

FEED SAMPLE DETAILS

Recommended Profiles are outlined below. Please indicate your requested tests with a ✓

Sample Identification	Crop Grown	Sample Source e.g. paddock, trucks, stack, bales	Weeks in stack/bales (silage/baleage only)	DM (Dry Matter)	DMME (Dry Matter, CP, ME)	Feed	ExtFed (Extended Feed)	Silage	ExtSil (Extended Silage)	CpdFeed (Compound Feed) NIR	CpdFeed Wet Chem	Other e.g. VFA, NO3-N, Starch, Cl	Lab#
/													
/													

Recommended Feed Profiles:
- Feedstuff: DM (Dry matter only), DMME (Dry Matter, Crude Protein, Digestibility, Metabolisable Energy), Feed (Dry Matter, Crude Protein, Crude Fat, Ash, Soluble Sugars, Starch, ADF, NDF, Lignin, Metabolisable Energy, Digestibility), ExtFed (Feed profile plus major & trace elements incl Cl), CpdFeed (Dry Matter, Crude Protein, Crude Fat, Ash, Soluble Sugars, Starch, ADF, NDF, Metabolisable Energy, Digestibility) - select between NIR analysis OR Wet Chemistry only (Price impact).
- Silage/Baleage: Silage (pH, Dry Matter, Crude Protein, Crude Fat, Ash, Soluble Sugars, Starch, ADF, NDF, Lignin, Metabolisable Energy, Digestibility, Lactic Acid, Ammonium N/Total N), ExtSil (Silage profile plus major & trace elements incl Cl)

ADDITIONAL INSTRUCTIONS

NB. Please advise laboratory if hazardous substances possibly present in samples.

☐ Total Number of Samples Sent

NOTE: If more than one courier bag being sent for one farm, please indicate eg. 1 of 2, 2 of 2 etc on outside of courier bag so that all samples are reported in one job.

• pH • Olsen Phosphorus • Solube salts
• EC
• calcium Chloride extractable • Extractable Sulphur
Aluminium

Please supply more of: (specify quantities required)
Qty: ☐ Request Forms KB 2009 ☐ Plant/Feed Bags (indiv)
Qty: ☐ Soil & Plant DIY sampling kits ☐ Soil Bags (indiv)
Qty: ☐ Courier Bags: ☐ NZ Courier ☐ Courier Post
Qty: ☐ Other

PLEASE SIGN (refer to terms of trade overleaf) Signature: P J Free Date: 27-4-21

• Total recoverable sulphur

KB Item: 2009 Version: 28

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Job Information Summary

Client:	GHD Limited	**Lab No:**	2604062
Contact:	Dr M Wallis	**Date Registered:**	14-May-2021 10:36 am
	C/- GHD Limited	**Priority:**	Normal
	PO Box 660	**Quote No:**	110915
	Waikato Mail Centre	**Order No:**	12504023
	Hamilton 3240	**Client Reference:**	PACL sludge
		Add. Client Ref:	PMU Services
		Submitted By:	Peter Free
		Charge To:	GHD Limited
		Target Date:	19-May-2021 4:30 pm

Samples

No	Sample Name	Sample Type	Containers	Tests Requested
1	MPIS 0011 Avana (Sludge)	Sludge	ClientsDryS	Metals extensive suite, trace level (33 metals)
2	MPIS 0012 Takuvaine (Sludge)	Sludge	ClientsDryS	Metals extensive suite, trace level (33 metals)
3	MPIS 0013 Avatiu (Sludge)	Sludge	ClientsDryS	Metals extensive suite, trace level (33 metals)
4	MPIS 0014 Taipara (Sludge)	Sludge	ClientsDryS	Metals extensive suite, trace level (33 metals)
5	MPIS 0015 Papua (Sludge)	Sludge	ClientsDryS	Metals extensive suite, trace level (33 metals)
6	MPIS 0016 Avana (Soil)	Sludge	ClientsDryS	Metals extensive suite, trace level (33 metals)
7	MPIS 0017 Takuvaine (Soil)	Sludge	ClientsDryS	Metals extensive suite, trace level (33 metals)
8	MPIS 0018 Avatiu (Soil)	Sludge	ClientsDryS	Metals extensive suite, trace level (33 metals)
9	MPIS 0019 Taipara (Soil)	Sludge	ClientsDryS	Metals extensive suite, trace level (33 metals)
10	MPIS 0020 Papua (Soil)	Sludge	ClientsDryS	Metals extensive suite, trace level (33 metals)

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Sludge

Test	Method Description	Default Detection Limit	Sample No
Metals extensive suite, trace level (33 metals)	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.008 - 100 mg/kg dry wt	1-10
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-10

Appendix B

Laboratory Reports (results)

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Certificate of Analysis

SPv1

Client:	GHD Limited	**Lab No:**	2604062
Contact:	Dr M Wallis	**Date Received:**	05-May-2021
	C/- GHD Limited	**Date Reported:**	18-May-2021
	PO Box 660	**Quote No:**	110915
	Waikato Mail Centre	**Order No:**	12504023
	Hamilton 3240	**Client Reference:**	PACL sludge
		Add. Client Ref:	PMU Services
		Submitted By:	Peter Free

Sample Type: Sludge

Sample Name:		MPIS 0011 Avana (Sludge)	MPIS 0012 Takuvaine (Sludge)	MPIS 0013 Avatiu (Sludge)	MPIS 0014 Taipara (Sludge)	MPIS 0015 Papua (Sludge)
Lab Number:		2604062.1	2604062.2	2604062.3	2604062.4	2604062.5
Metals extensive suite, trace level (33 metals)						
Total Recoverable Aluminium	mg/kg dry wt	168,000	170,000	147,000	189,000	181,000
Total Recoverable Antimony	mg/kg dry wt	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08
Total Recoverable Arsenic	mg/kg dry wt	0.9	1.4	1.5	1.2	1.4
Total Recoverable Barium	mg/kg dry wt	109	95	115	65	91
Total Recoverable Bismuth	mg/kg dry wt	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
Total Recoverable Boron	mg/kg dry wt	7	6	6	6	7
Total Recoverable Cadmium	mg/kg dry wt	0.20	0.137	0.134	0.128	0.146
Total Recoverable Caesium	mg/kg dry wt	0.14	0.19	0.18	0.05	0.14
Total Recoverable Calcium	mg/kg dry wt	3,100	4,800	5,700	2,100	4,900
Total Recoverable Chromium	mg/kg dry wt	63	35	30	28	33
Total Recoverable Cobalt	mg/kg dry wt	9.2	9.0	12.0	3.4	6.7
Total Recoverable Copper	mg/kg dry wt	16.5	19.5	23	8.2	15.8
Total Recoverable Iron	mg/kg dry wt	18,100	16,700	23,000	7,000	13,000
Total Recoverable Lanthanum	mg/kg dry wt	11.0	15.3	18.0	9.5	13.0
Total Recoverable Lead	mg/kg dry wt	1.85	2.1	2.2	1.34	1.73
Total Recoverable Lithium	mg/kg dry wt	1.1	1.3	1.2	0.4	1.2
Total Recoverable Magnesium	mg/kg dry wt	4,100	3,700	4,900	440	2,000
Total Recoverable Manganese	mg/kg dry wt	260	240	340	186	187
Total Recoverable Mercury	mg/kg dry wt	0.04	0.04	0.03	0.03	0.03
Total Recoverable Molybdenum	mg/kg dry wt	0.72	0.78	0.72	0.42	0.44
Total Recoverable Nickel	mg/kg dry wt	39	25	28	7.4	18.8
Total Recoverable Phosphorus	mg/kg dry wt	3,900	4,900	5,400	1,530	4,300
Total Recoverable Potassium	mg/kg dry wt	420	750	1,030	163	470
Total Recoverable Rubidium	mg/kg dry wt	3.4	8.1	10.3	1.15	5.0
Total Recoverable Selenium	mg/kg dry wt	< 2	< 2	< 2	< 2	< 2
Total Recoverable Silver	mg/kg dry wt	0.10	0.08	0.09	0.05	0.08
Total Recoverable Sodium	mg/kg dry wt	210	155	175	160	161
Total Recoverable Strontium	mg/kg dry wt	70	89	107	46	99
Total Recoverable Thallium	mg/kg dry wt	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
Total Recoverable Tin	mg/kg dry wt	1.24	1.27	1.26	0.98	1.22
Total Recoverable Uranium	mg/kg dry wt	0.66	0.80	0.74	0.75	0.84
Total Recoverable Vanadium	mg/kg dry wt	76	73	74	53	74
Total Recoverable Zinc	mg/kg dry wt	56	27	36	17.7	26

Sample Type: Sludge						
Sample Name:		MPIS 0016 Avana (Soil)	MPIS 0017 Takuvaine (Soil)	MPIS 0018 Avatiu (Soil)	MPIS 0019 Taipara (Soil)	MPIS 0020 Papua (Soil)
Lab Number:		2604062.6	2604062.7	2604062.8	2604062.9	2604062.10
Metals extensive suite, trace level (33 metals)						
Total Recoverable Aluminium	mg/kg dry wt	31,000	35,000	38,000	40,000	29,000
Total Recoverable Antimony	mg/kg dry wt	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08
Total Recoverable Arsenic	mg/kg dry wt	0.5	1.1	1.1	0.6	0.5
Total Recoverable Barium	mg/kg dry wt	300	290	370	480	300
Total Recoverable Bismuth	mg/kg dry wt	< 0.04	< 0.04	< 0.04	< 0.04	< 0.04
Total Recoverable Boron	mg/kg dry wt	< 2	< 2	3	< 2	< 2
Total Recoverable Cadmium	mg/kg dry wt	0.32	0.26	0.32	0.83	0.20
Total Recoverable Caesium	mg/kg dry wt	0.41	0.54	0.59	0.47	0.43
Total Recoverable Calcium	mg/kg dry wt	7,100	8,000	11,900	15,600	7,200
Total Recoverable Chromium	mg/kg dry wt	132	93	84	173	93
Total Recoverable Cobalt	mg/kg dry wt	34	46	48	42	32
Total Recoverable Copper	mg/kg dry wt	32	55	56	37	36
Total Recoverable Iron	mg/kg dry wt	63,000	77,000	85,000	77,000	60,000
Total Recoverable Lanthanum	mg/kg dry wt	30	43	44	42	44
Total Recoverable Lead	mg/kg dry wt	3.9	4.6	5.7	9.3	4.3
Total Recoverable Lithium	mg/kg dry wt	4.1	4.3	3.8	4.8	4.2
Total Recoverable Magnesium	mg/kg dry wt	21,000	17,000	11,900	9,100	13,200
Total Recoverable Manganese	mg/kg dry wt	650	1,450	1,750	900	850
Total Recoverable Mercury	mg/kg dry wt	0.02	0.03	0.04	0.02	< 0.02
Total Recoverable Molybdenum	mg/kg dry wt	0.56	0.64	0.57	0.64	0.41
Total Recoverable Nickel	mg/kg dry wt	141	99	92	120	108
Total Recoverable Phosphorus	mg/kg dry wt	1,440	1,700	1,870	3,600	1,080
Total Recoverable Potassium	mg/kg dry wt	1,170	2,800	2,900	1,780	1,270
Total Recoverable Rubidium	mg/kg dry wt	11.0	30	35	10.5	13.7
Total Recoverable Selenium	mg/kg dry wt	< 2	< 2	< 2	< 2	< 2
Total Recoverable Silver	mg/kg dry wt	0.07	0.07	0.08	0.07	0.05
Total Recoverable Sodium	mg/kg dry wt	270	300	280	340	300
Total Recoverable Strontium	mg/kg dry wt	175	170	260	172	200
Total Recoverable Thallium	mg/kg dry wt	< 0.04	0.08	0.10	0.04	0.05
Total Recoverable Tin	mg/kg dry wt	1.28	1.43	1.69	1.88	1.39
Total Recoverable Uranium	mg/kg dry wt	0.90	1.13	1.28	2.8	1.06
Total Recoverable Vanadium	mg/kg dry wt	126	155	162	143	112
Total Recoverable Zinc	mg/kg dry wt	94	90	104	101	88

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Sludge			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Metals extensive suite, trace level (33 metals)	Dried sample, <2mm fraction. Nitric/Hydrochloric acid digestion, ICP-MS, trace level.	0.008 - 100 mg/kg dry wt	1-10
Total Recoverable digestion	Nitric / hydrochloric acid digestion. US EPA 200.2.	-	1-10

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 17-May-2021 and 18-May-2021. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

Ara Heron BSc (Tech)
Client Services Manager - Environmental

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W www.hill-laboratories.com

Certificate of Analysis

Client:	GHD Limited	**Lab No:**	2602738 shvpv2
Address:	PO Box 660 Waikato Mail Centre Hamilton 3240	**Date Received:**	04-May-2021
		Date Reported:	20-May-2021
		Quote No:	110915
		Order No:	12504023
		Client Reference:	PACL sludge
		Add. Client Ref:	PMU Services
Phone:	07 834 7900	**Submitted By:**	Peter Free

Sample Name: MPIS 0011 Avana (Sludge) **Lab Number:** 2602738.1
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range	Low	Medium	High
pH	pH Units	6.9	5.8 - 6.3			
Olsen Phosphorus	mg/L	10	20 - 30			
Volume Weight	g/mL	0.84	0.60 - 1.00			
Sulphate Sulphur	mg/kg	140	7 - 15			
Extractable Organic Sulphur	mg/kg	< 2	10 - 20			
Soluble Salts (Field)	%	< 0.05	0.05 - 0.30			
EC (in 1:5 Extract)	mS/cm	0.13				
Aluminium ($CaCl_2$ Extractable)	mg/kg	< 0.2	0.0 - 3.0			
Chloride*	mg/kg	165				
'Total' Sulphur	mg/kg	2,740				

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Client:	GHD Limited	**Lab No:**	2602738 shvpv2
Address:	PO Box 660 Waikato Mail Centre Hamilton 3240	**Date Received:**	04-May-2021
		Date Reported:	20-May-2021
		Quote No:	110915
		Order No:	12504023
		Client Reference:	PACL sludge
		Add. Client Ref:	PMU Services
Phone:	07 834 7900	**Submitted By:**	Peter Free

Sample Name: MPIS 0012 Takuvaine (Sludge) **Lab Number:** 2602738.2
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range	Low	Medium	High
pH	pH Units	7.0	5.8 - 6.3			
Olsen Phosphorus	mg/L	13	20 - 30			
Volume Weight	g/mL	0.68	0.60 - 1.00			
Sulphate Sulphur	mg/kg	576	7 - 15			
Extractable Organic Sulphur	mg/kg	< 2	10 - 20			
Soluble Salts (Field)	%	0.07	0.05 - 0.30			
EC (in 1:5 Extract)	mS/cm	0.21				
Aluminium ($CaCl_2$ Extractable)	mg/kg	< 0.2	0.0 - 3.0			
Chloride*	mg/kg	135				
'Total' Sulphur	mg/kg	3,650				

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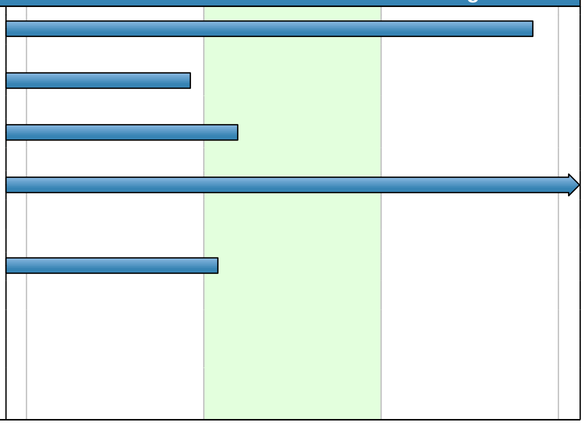
Certificate of Analysis

Client:	GHD Limited	**Lab No:**	2602738 shvpv2
Address:	PO Box 660 Waikato Mail Centre Hamilton 3240	**Date Received:**	04-May-2021
		Date Reported:	20-May-2021
		Quote No:	110915
		Order No:	12504023
		Client Reference:	PACL sludge
		Add. Client Ref:	PMU Services
Phone:	07 834 7900	**Submitted By:**	Peter Free

Sample Name: MPIS 0013 Avatiu (Sludge) **Lab Number:** 2602738.3
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range	Low	Medium	High
pH	pH Units	7.1	5.8 - 6.3			
Olsen Phosphorus	mg/L	19	20 - 30			
Volume Weight	g/mL	0.68	0.60 - 1.00			
Sulphate Sulphur	mg/kg	441	7 - 15			
Extractable Organic Sulphur	mg/kg	< 2	10 - 20			
Soluble Salts (Field)	%	0.07	0.05 - 0.30			
EC (in 1:5 Extract)	mS/cm	0.20				
Aluminium ($CaCl_2$ Extractable)	mg/kg	< 0.2	0.0 - 3.0			
Chloride*	mg/kg	125				
'Total' Sulphur	mg/kg	2,750				



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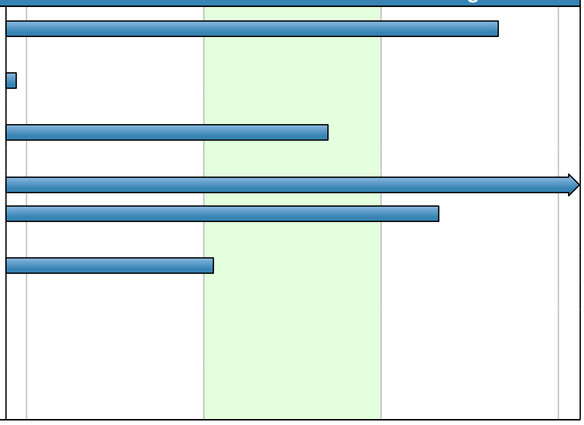
Certificate of Analysis

Client:	GHD Limited	**Lab No:**	2602738 shvpv2
Address:	PO Box 660 Waikato Mail Centre Hamilton 3240	**Date Received:**	04-May-2021
		Date Reported:	20-May-2021
		Quote No:	110915
		Order No:	12504023
		Client Reference:	PACL sludge
		Add. Client Ref:	PMU Services
Phone:	07 834 7900	**Submitted By:**	Peter Free

Sample Name: MPIS 0014 Taipara (Sludge) **Lab Number:** 2602738.4
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range	Low	Medium	High
pH	pH Units	6.9	5.8 - 6.3			
Olsen Phosphorus	mg/L	3	20 - 30			
Volume Weight	g/mL	0.88	0.60 - 1.00			
Sulphate Sulphur	mg/kg	242	7 - 15			
Extractable Organic Sulphur	mg/kg	27	10 - 20			
Soluble Salts (Field)	%	0.06	0.05 - 0.30			
EC (in 1:5 Extract)	mS/cm	0.18				
Aluminium ($CaCl_2$ Extractable)	mg/kg	< 0.2	0.0 - 3.0			
Chloride*	mg/kg	227				
'Total' Sulphur	mg/kg	4,520				



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Address:	PO Box 660 Waikato Mail Centre Hamilton 3240	**Date Received:**	04-May-2021	
		Date Reported:	20-May-2021	
		Quote No:	110915	
		Order No:	12504023	
		Client Reference:	PACL sludge	
		Add. Client Ref:	PMU Services	
Phone:	07 834 7900	**Submitted By:**	Peter Free	

Sample Name: MPIS 0015 Papua (Sludge) **Lab Number:** 2602738.5
Sample Type: SOIL General, Outdoor (S10)

Analysis		Level Found	Medium Range	Low	Medium	High
pH	pH Units	7.2	5.8 - 6.3			
Olsen Phosphorus	mg/L	13	20 - 30			
Volume Weight	g/mL	0.76	0.60 - 1.00			
Sulphate Sulphur	mg/kg	248	7 - 15			
Extractable Organic Sulphur	mg/kg	< 2	10 - 20			
Soluble Salts (Field)	%	0.06	0.05 - 0.30			
EC (in 1:5 Extract)	mS/cm	0.16				
Aluminium ($CaCl_2$ Extractable)	mg/kg	< 0.2	0.0 - 3.0			
Chloride*	mg/kg	136				
'Total' Sulphur	mg/kg	2,690				

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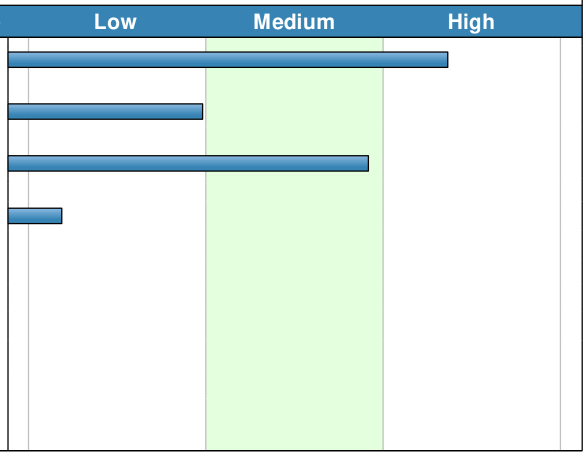
Certificate of Analysis

Client:	GHD Limited	**Lab No:**	2602738	shvpv2
Address:	PO Box 660 Waikato Mail Centre Hamilton 3240	**Date Received:**	04-May-2021	
		Date Reported:	20-May-2021	
		Quote No:	110915	
		Order No:	12504023	
		Client Reference:	PACL sludge	
		Add. Client Ref:	PMU Services	
Phone:	07 834 7900	**Submitted By:**	Peter Free	

Sample Name: MPIS 0016 Avana (Soil) **Lab Number:** 2602738.6
Sample Type: SOIL General, Overseas (S74)

Analysis		Level Found	Medium Range
pH	pH Units	6.7	5.8 - 6.5
Olsen Phosphorus	mg/L	20	20 - 30
Volume Weight	g/mL	0.97	0.60 - 1.00
Sulphate Sulphur	mg/kg	5	10 - 20
Extractable Organic Sulphur	mg/kg	< 2	12 - 20
Soluble Salts (Field)	%	< 0.05	0.05 - 0.30
EC (in 1:5 Extract)	mS/cm	0.01	
Aluminium ($CaCl_2$ Extractable)	mg/kg	< 0.2	0.0 - 3.0
Chloride*	mg/kg	15	
'Total' Sulphur	mg/kg	491	



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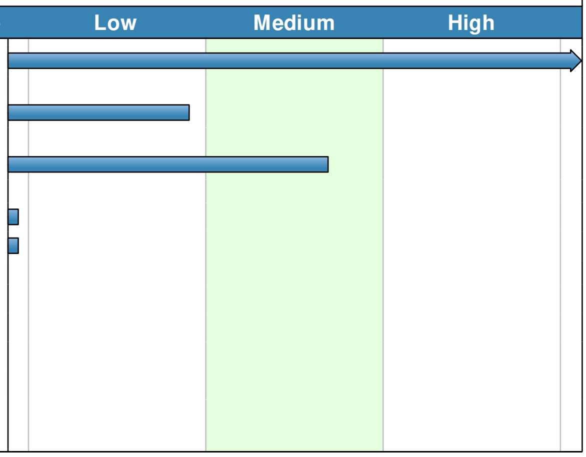
		Date Reported:	20-May-2021
		Quote No:	110915
		Order No:	12504023
		Client Reference:	PACL sludge
		Add. Client Ref:	PMU Services
Phone:	07 834 7900	**Submitted By:**	Peter Free

Sample Name: MPIS 0017 Takuvaine (Soil) **Lab Number:** 2602738.7
Sample Type: SOIL General, Overseas (S74)

Analysis		Level Found	Medium Range
pH	pH Units	7.1	5.8 - 6.5
Olsen Phosphorus	mg/L	19	20 - 30
Volume Weight	g/mL	0.88	0.60 - 1.00
Sulphate Sulphur	mg/kg	2	10 - 20
Extractable Organic Sulphur	mg/kg	2	12 - 20
Soluble Salts (Field)	%	< 0.05	0.05 - 0.30
EC (in 1:5 Extract)	mS/cm	< 0.01	
Aluminium ($CaCl_2$ Extractable)	mg/kg	< 0.2	0.0 - 3.0
Chloride*	mg/kg	< 10	
'Total' Sulphur	mg/kg	288	



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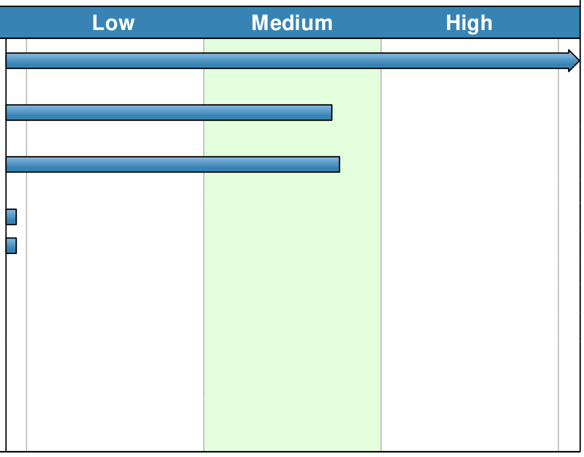
Address:	PO Box 660 Waikato Mail Centre Hamilton 3240	**Date Received:**	04-May-2021
		Date Reported:	20-May-2021
		Quote No:	110915
		Order No:	12504023
		Client Reference:	PACL sludge
		Add. Client Ref:	PMU Services
Phone:	07 834 7900	**Submitted By:**	Peter Free

Sample Name: MPIS 0018 Avatiu (Soil) **Lab Number:** 2602738.8
Sample Type: SOIL General, Overseas (S74)

Analysis		Level Found	Medium Range
pH	pH Units	7.5	5.8 - 6.5
Olsen Phosphorus	mg/L	27	20 - 30
Volume Weight	g/mL	0.91	0.60 - 1.00
Sulphate Sulphur	mg/kg	4	10 - 20
Extractable Organic Sulphur	mg/kg	2	12 - 20
Soluble Salts (Field)	%	< 0.05	0.05 - 0.30
EC (in 1:5 Extract)	mS/cm	0.03	
Aluminium ($CaCl_2$ Extractable)	mg/kg	< 0.2	0.0 - 3.0
Chloride*	mg/kg	< 10	
'Total' Sulphur	mg/kg	368	



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Private Bag 3205
Hamilton 3240 New Zealand

T **0508 HILL LAB** (44 555 22)
T +64 7 858 2000
E mail@hill-labs.co.nz
W www.hill-laboratories.com

Certificate of Analysis

Client:	GHD Limited	**Lab No:**	2602738 shvpv2
Address:	PO Box 660 Waikato Mail Centre Hamilton 3240	**Date Received:**	04-May-2021
		Date Reported:	20-May-2021
		Quote No:	110915
		Order No:	12504023
		Client Reference:	PACL sludge
		Add. Client Ref:	PMU Services
Phone:	07 834 7900	**Submitted By:**	Peter Free

Sample Name: MPIS 0019 Taipara (Soil) **Lab Number:** 2602738.9
Sample Type: SOIL General, Overseas (S74)

Analysis		Level Found	Medium Range	Low	Medium	High
pH	pH Units	6.8	5.8 - 6.5			
Olsen Phosphorus	mg/L	20	20 - 30			
Volume Weight	g/mL	0.91	0.60 - 1.00			
Sulphate Sulphur	mg/kg	33	10 - 20			
Extractable Organic Sulphur	mg/kg	< 2	12 - 20			
Soluble Salts (Field)	%	< 0.05	0.05 - 0.30			
EC (in 1:5 Extract)	mS/cm	0.05				
Aluminium ($CaCl_2$ Extractable)	mg/kg	< 0.2	0.0 - 3.0			
Chloride*	mg/kg	< 10				
'Total' Sulphur	mg/kg	436				

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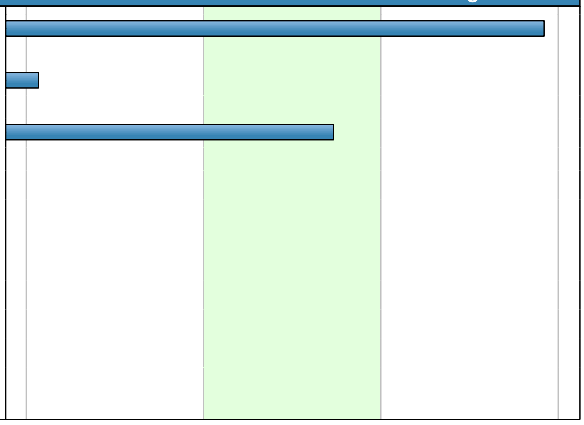
Certificate of Analysis

Client:	GHD Limited	**Lab No:**	2602738 shvpv2
Address:	PO Box 660 Waikato Mail Centre Hamilton 3240	**Date Received:**	04-May-2021
		Date Reported:	20-May-2021
		Quote No:	110915
		Order No:	12504023
		Client Reference:	PACL sludge
		Add. Client Ref:	PMU Services
Phone:	07 834 7900	**Submitted By:**	Peter Free

Sample Name: MPIS 0020 Papua (Soil) **Lab Number:** 2602738.10
Sample Type: SOIL General, Overseas (S74)

Analysis		Level Found	Medium Range	Low	Medium	High
pH	pH Units	7.0	5.8 - 6.5			
Olsen Phosphorus	mg/L	6	20 - 30			
Volume Weight	g/mL	0.89	0.60 - 1.00			
Sulphate Sulphur	mg/kg	< 1	10 - 20			
Extractable Organic Sulphur	mg/kg	< 2	12 - 20			
Soluble Salts (Field)	%	< 0.05	0.05 - 0.30			
EC (in 1:5 Extract)	mS/cm	< 0.01				
Aluminium ($CaCl_2$ Extractable)	mg/kg	< 0.2	0.0 - 3.0			
Chloride*	mg/kg	< 10				
'Total' Sulphur	mg/kg	142				



The above nutrient graphs compare the levels found with reference interpretation levels. NOTE: It is important that the correct sample type be assigned, and that the recommended sampling procedure has been followed. R J Hill Laboratories Limited does not accept any responsibility for the resulting use of this information.
IANZ Accreditation does not apply to comments and interpretations, i.e. the 'Range Levels' and subsequent graphs.

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Certificate of Analysis

Client:	GHD Limited	**Lab No:**	2602738 shvpv2
Address:	PO Box 660 Waikato Mail Centre Hamilton 3240	**Date Received:**	04-May-2021
		Date Reported:	20-May-2021
		Quote No:	110915
		Order No:	12504023
		Client Reference:	PACL sludge
		Add. Client Ref:	PMU Services
Phone:	07 834 7900	**Submitted By:**	Peter Free

Soil Analysis Results

Sample Name:	MPIS 0011 Avana (Sludge)	MPIS 0012 Takuvaine (Sludge)	MPIS 0013 Avatiu (Sludge)	MPIS 0014 Taipara (Sludge)	MPIS 0015 Papua (Sludge)	MPIS 0016 Avana (Soil)
Lab Number:	2602738.1	2602738.2	2602738.3	2602738.4	2602738.5	2602738.6
Sample Type:	SOIL General, Outdoor	SOIL General, Outdoor	SOIL General, Outdoor	SOIL General, Outdoor	SOIL General, Outdoor	SOIL General, Overseas
Sample Type Code:	S10	S10	S10	S10	S10	S74
pH pH Units	6.9	7.0	7.1	6.9	7.2	6.7
Olsen Phosphorus mg/L	10	13	19	3	13	20
Volume Weight g/mL	0.84	0.68	0.68	0.88	0.76	0.97
Sulphate Sulphur mg/kg	140	576	441	242	248	5
Extractable Organic Sulphur mg/kg	< 2	< 2	< 2	27	< 2	< 2
Soluble Salts (Field) %	< 0.05	0.07	0.07	0.06	0.06	< 0.05
EC (in 1:5 Extract) mS/cm	0.13	0.21	0.20	0.18	0.16	0.01
Aluminium ($CaCl_2$ Extractable) mg/kg	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Chloride* mg/kg	165	135	125	227	136	15
'Total' Sulphur mg/kg	2,740	3,650	2,750	4,520	2,690	491

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Certificate of Analysis

Client:	GHD Limited	**Lab No:**	2602738	shvpv2
Address:	PO Box 660 Waikato Mail Centre Hamilton 3240	**Date Received:**	04-May-2021	
		Date Reported:	20-May-2021	
		Quote No:	110915	
		Order No:	12504023	
		Client Reference:	PACL sludge	
		Add. Client Ref:	PMU Services	
Phone:	07 834 7900	**Submitted By:**	Peter Free	

Soil Analysis Results

Sample Name:		MPIS 0017 Takuvaine (Soil)	MPIS 0018 Avatiu (Soil)	MPIS 0019 Taipara (Soil)	MPIS 0020 Papua (Soil)		
Lab Number:		2602738.7	2602738.8	2602738.9	2602738.10		
Sample Type:		SOIL General, Overseas	SOIL General, Overseas	SOIL General, Overseas	SOIL General, Overseas		
Sample Type Code:		S74	S74	S74	S74		
pH	pH Units	7.1	7.5	6.8	7.0	-	-
Olsen Phosphorus	mg/L	19	27	20	6	-	-
Volume Weight	g/mL	0.88	0.91	0.91	0.89	-	-
Sulphate Sulphur	mg/kg	2	4	33	< 1	-	-
Extractable Organic Sulphur	mg/kg	2	2	< 2	< 2	-	-
Soluble Salts (Field)	%	< 0.05	< 0.05	< 0.05	< 0.05	-	-
EC (in 1:5 Extract)	mS/cm	< 0.01	0.03	0.05	< 0.01	-	-
Aluminium ($CaCl_2$ Extractable)	mg/kg	< 0.2	< 0.2	< 0.2	< 0.2	-	-
Chloride*	mg/kg	< 10	< 10	< 10	< 10	-	-
'Total' Sulphur	mg/kg	288	368	436	142	-	-

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		Order No:	12504023
		Client Reference:	PACL sludge
		Add. Client Ref:	PMU Services
Phone:	07 834 7900	**Submitted By:**	Peter Free

Analyst's Comments

Samples 1-10 Comment:
The guidelines for interpretation of 0.02M CaCl2 Extractable Aluminium are: Less than 3 mg/kg unlikely to be toxic to plants; 3-10 mg/kg may be toxic to plants in soils with low Organic Matter; greater than 10 mg/kg toxic to plants. Interpretive levels for raw peat soils are not well known so other observations should be taken into consideration.

Summary of Methods

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively simple matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis. A detection limit range indicates the lowest and highest detection limits in the associated suite of analytes. A full listing of compounds and detection limits are available from the laboratory upon request. Unless otherwise indicated, analyses were performed at Hill Laboratories, 28 Duke Street, Frankton, Hamilton 3204.

Sample Type: Soil

Test	Method Description	Default Detection Limit	Sample No
Sample Registration*	Samples were registered according to instructions received.	-	1-10
Soil Prep (Dry & Grind)*	Air dried at 35 - 40°C overnight (residual moisture typically 4%) and crushed to pass through a 2mm screen.	-	1-10
pH	1:2 (v/v) soil:water slurry followed by potentiometric determination of pH. In-house.	0.1 pH Units	1-10
Olsen Phosphorus	Olsen extraction followed by Molybdenum Blue colorimetry. In-house method.	1 mg/L	1-10
Sulphate Sulphur	0.02M Potassium phosphate extraction followed by Ion Chromatography. In-house.	1 mg/kg	1-10
Extractable Organic Sulphur	0.02M Potassium phosphate extraction. Total extractable S is determined by ICP-OES from which the Sulphate-S is subtracted. In-house.	2 mg/kg	1-10
'Total' Sulphur	Nitric/hydrochloric digestion (based on US EPA 200.2) followed by ICP-OES. (Total recoverable nutrients reported on a dry weight basis) The levels from this method are referred to as 'Totals' in quotation marks, as they will be a slight under-estimation of the true Totals for some elements. In-house.	45 mg/kg	1-10
Aluminium ($CaCl_2$ Extractable)	0.02M Calcium Chloride extraction followed by ICP-OES. In-house.	0.2 mg/kg	1-10
Soluble Salts (Field)	1:5 soil:water extraction followed by potentiometric determination of conductivity. Calculated by EC (mS/cm) x 0.35. In-house.	0.05 %	1-10
EC (in 1:5 Extract)	Electrical Conductivity measured in 1:5 Soil:Water extract.	0.01 mS/cm	1-10
Chloride*	1:5 Soil:Saturated Calcium Sulphate extraction followed by Potentiometric Titration.	10 mg/kg	1-10
Volume Weight	The weight/volume ratio of dried, ground soil. In-house.	0.01 g/mL	1-10

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Testing was completed between 14-May-2021 and 20-May-2021. For completion dates of individual analyses please contact the laboratory.

Samples are held at the laboratory after reporting for a length of time based on the stability of the samples and analytes being tested (considering any preservation used), and the storage space available. Once the storage period is completed, the samples are discarded unless otherwise agreed with the customer. Extended storage times may incur additional charges.

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Shelley Edhouse
Quality Assurance Coordinator - Agriculture

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→ The Power of Commitment

Appendix G: Sludge disposal facility plans

TO TATOU VAI LIMITED
TO TATOU VAI SLUDGE EIA
RAROTONGA SLUDGE MONOFILL
For Information Only

DRAWING	Rev	Title
GENERAL		
● 1013086.0000-001	1	DRAWING LIST AND LOCATION PLAN
PLAN		
● 1013086.0000-011	1	SITE LAYOUT PLAN
SLUDGE FIRST LIFT		
● 1013086.0000-021	1	TYPICAL PLAN AND SECTION
● 1013086.0000-022	1	CONSTRUCTION & FILLING SEQUENCE
SLUDGE SECOND LIFT		
● 1013086.0000-023	1	CONSTRUCTION & FILLING SEQUENCE
DETAILS		
● 1013086.0000-031	1	TYPICAL LEACHATE DRAIN DETAILS

TOPOMAP SOURCED FROM LINZ DATA SERVICE <https://data.linz.govt.nz/layer/52315-cook-islands-topo25-zone4-maps/> , LICENSED BY LINZ FOR RE-USE UNDER THE CREATIVE COMMONS ATTRIBUTION 4.0 NEW ZEALAND LICENCE (CC BY 4.0). ACCESSED 18/06/2021.

LOCATION PLAN
SCALE 1:25000

● Denotes drawing this issue: 06/07/2021

A3 SCALE 1:25000
0 0.5 1.0 1.5 (km)

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REV	DESCRIPTION	CAD	CHK	DATE	APPROVED	DATE
1	INFORMATION ISSUE	LIWA				

DESIGNED	DSMT	Jun.21
DRAWN	LIWA	Jun.21
DESIGN CHECKED	DSMT	06.07.21
DRAWING CHECKED		

DRAWING STATUS: FOR INFORMATION ONLY
PROJECT PHASE: CONCEPT DESIGN

NOT FOR CONSTRUCTION
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CLIENT: TO TATOU VAI LIMITED
PROJECT: TO TATOU VAI SLUDGE EIA
TITLE: GENERAL DRAWING LIST AND LOCATION PLAN
SCALE (A3): 1:25000 DWG No. 1013086.0000-001 REV 1

C:\12dSynergy\data\ALBTCAD\To Tatou Vai Sludge EIA_772\CAD\DWG\1013086.0000-011.dwg 2021-Jul-06 10:24:11 am Plotted By: LIXIA WANG

LEGEND

- PROPOSED SLUDGE DISPOSAL SITE BOUNDARY
- 40 — EXISTING CONTOUR (1m INTERVAL)
- PROPERTY BOUNDARY
- EXISTING FORMED ROAD
- CENTER OF STREAM

NOTES:
1. ALL DIMENSIONS IN METRES UNLESS NOTED OTHERWISE.
2. AERIAL PHOTO SOURCED FROM TT MapViewer. ACCESSED 21/06/2021.
3. EXISTING SURVEY PROVIDED BY THE EAGLE LAND SURVEY LIMITED, DATED 03/02/2021. RECEIVED 07/05/2021.
4. DATUM IS MEAN SEA LEVEL.

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1	INFORMATION ISSUE	LIWA				

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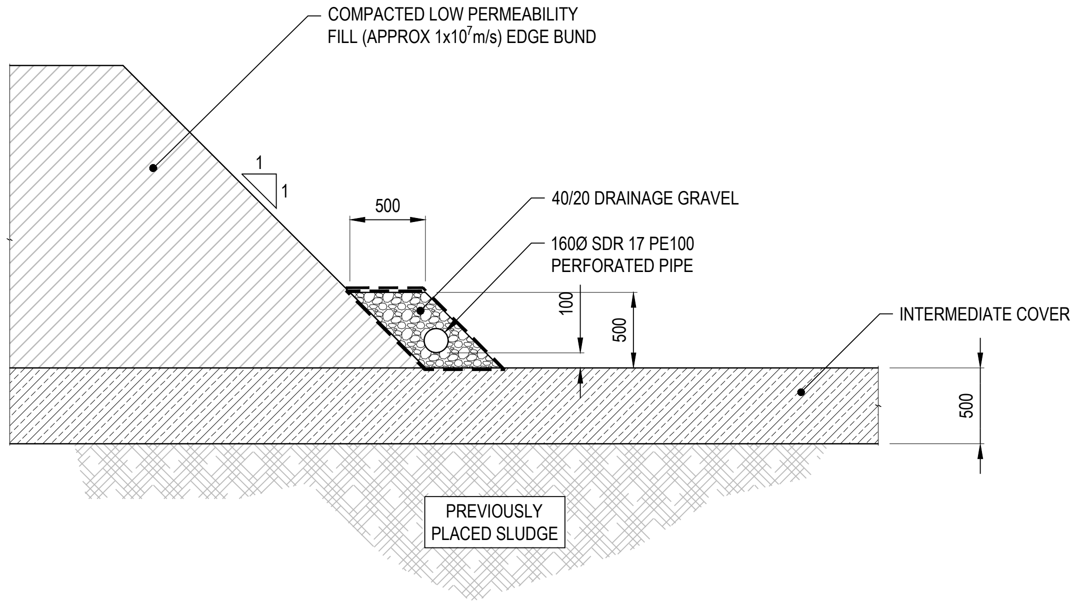
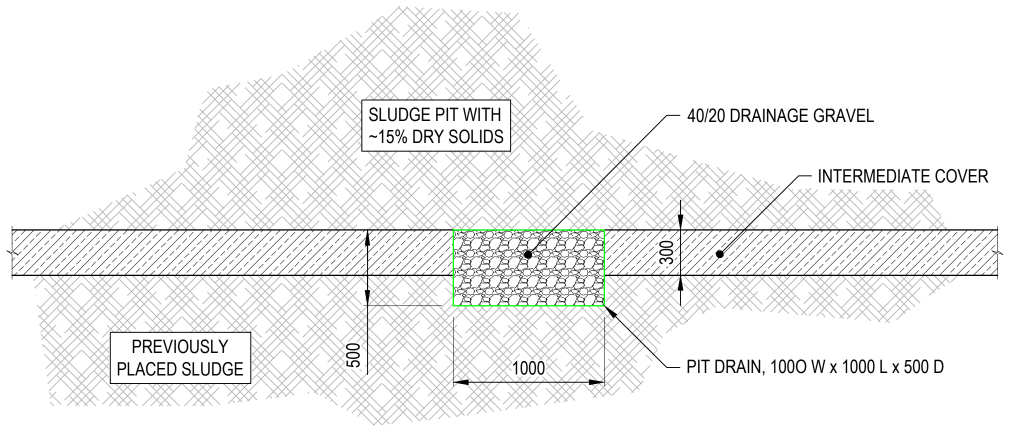
CLIENT: TO TATOU VAI LIMITED
PROJECT: TO TATOU VAI SLUDGE EIA
TITLE: PLAN
SITE LAYOUT PLAN

SCALE (A3): 1:1000 DWG No. 1013086.0000-011 REV 1

NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE.



DETAIL B / 022 PERIMETER PIPED DRAIN
SCALE 1: 50



DETAIL C / 023 PIT DRAIN
SCALE 1: 50

A3 SCALE 1:50
0 0.5 1.0 1.5 2.0 2.5 (m)
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1	INFORMATION ISSUE	LIWA				

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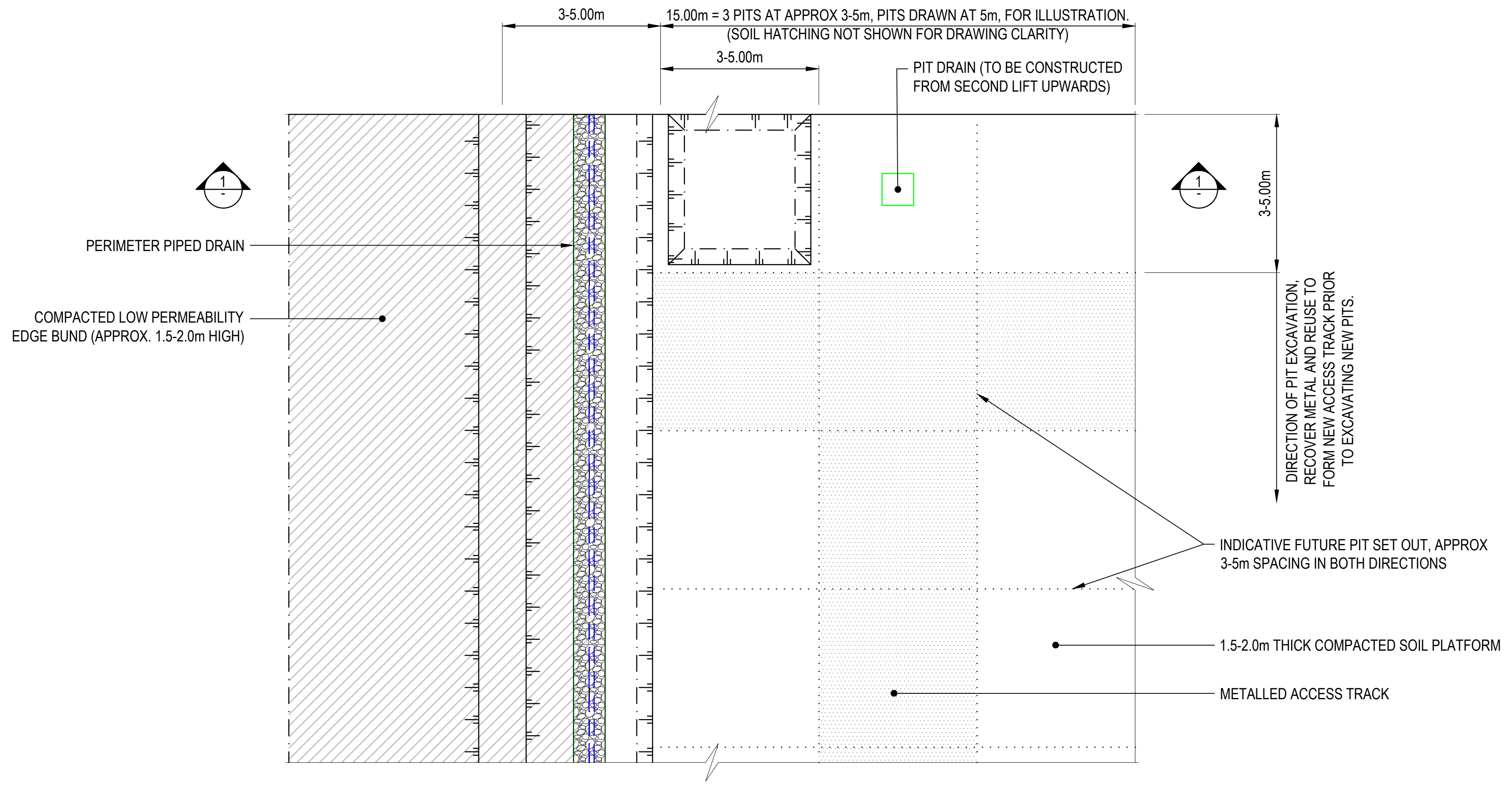
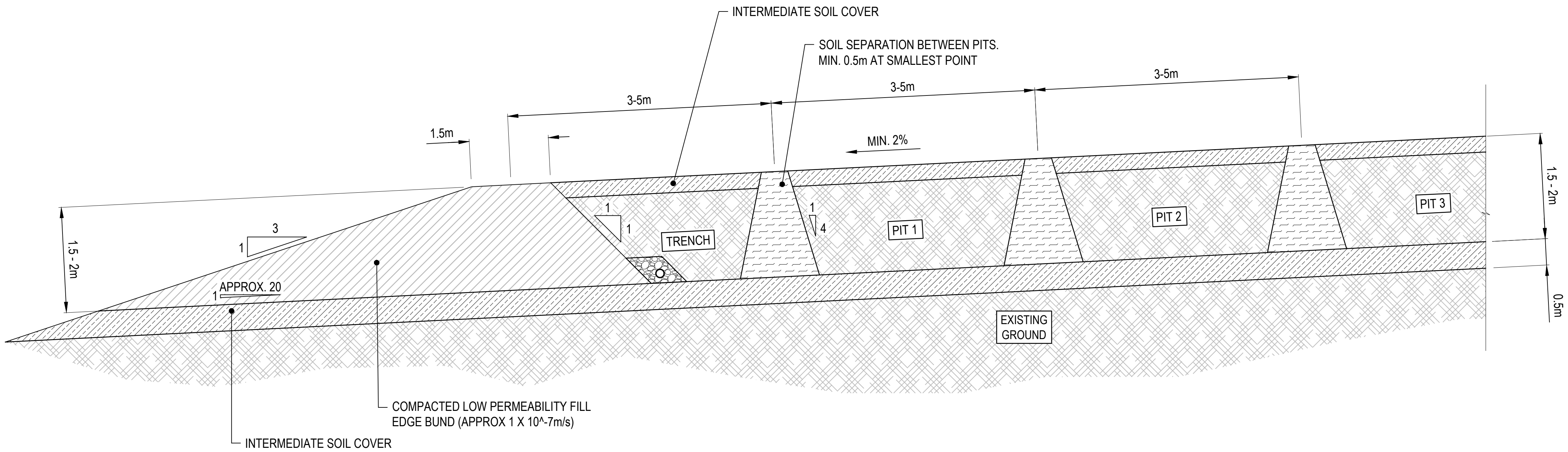
CLIENT: TO TATOU VAI LIMITED
PROJECT: TO TATOU VAI SLUDGE EIA
TITLE: DETAILS
TYPICAL LEACHATE DRAIN DETAILS
SCALE (A3): 1:50 DWG No. 1013086.0000-031 REV 1

NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE.
2. ALL EXPOSED AND UNSEALED SOIL SURFACE SHALL BE GRASSED FOR SOIL EROSION AND SEDIMENT CONTROL.



DETAIL A/011 FIRST LIFT TYPICAL LAYOUT PLAN
SCALE 1: 200



SECTION 1/- 1/011 FIRST LIFT TYPICAL SECTION ONCE SLUDGE PLACED
SCALE 1: 100

A3 SCALE 1:200
0 2 4 6 8 10 (m)

ORIGINAL IN COLOUR

REV	DESCRIPTION	CAD	CHK	DATE	APPROVED	DATE
1	INFORMATION ISSUE	LIWA				

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DRAWN	LIWA	Jun.21
DESIGN CHECKED	DSMT	06.07.21
DRAWING CHECKED		

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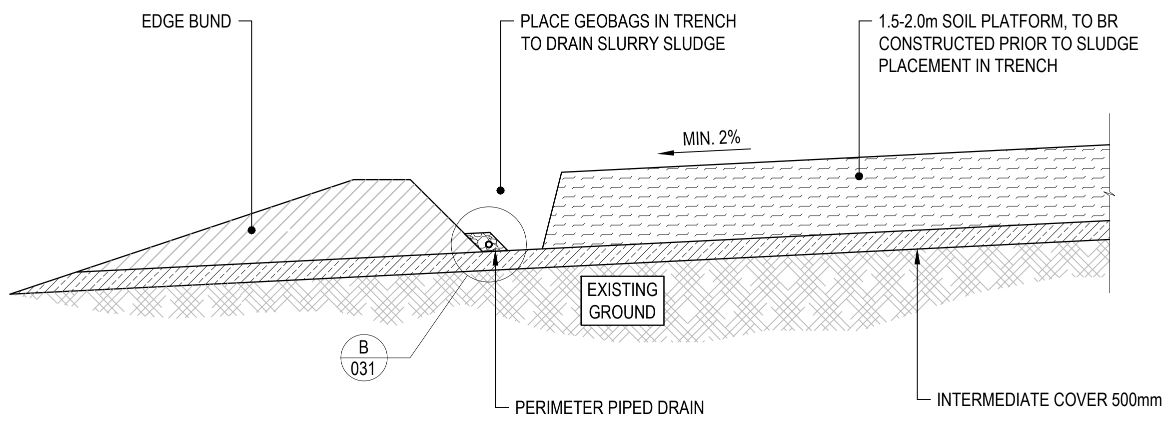
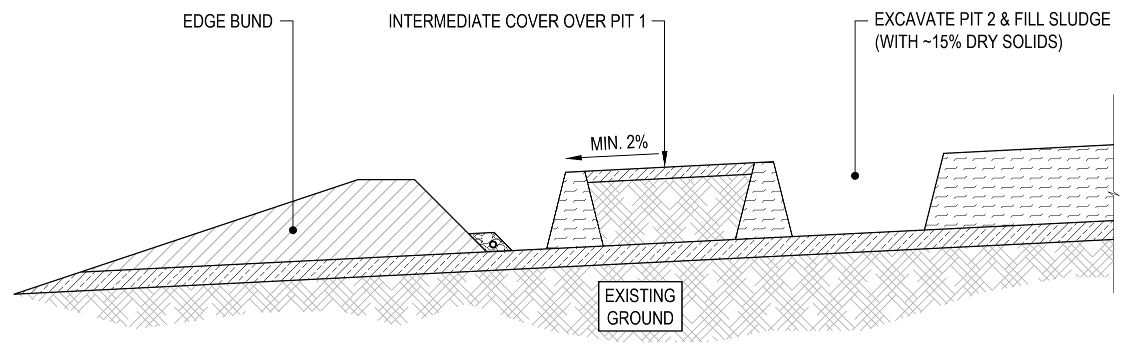
CLIENT: TO TATOU VAI LIMITED
PROJECT: TO TATOU VAI SLUDGE EIA
TITLE: SLUDGE FIRST LIFT TYPICAL PLAN AND SECTION
SCALE (A3): AS SHOWN
DWG No. 1013086.0000-021
REV 1

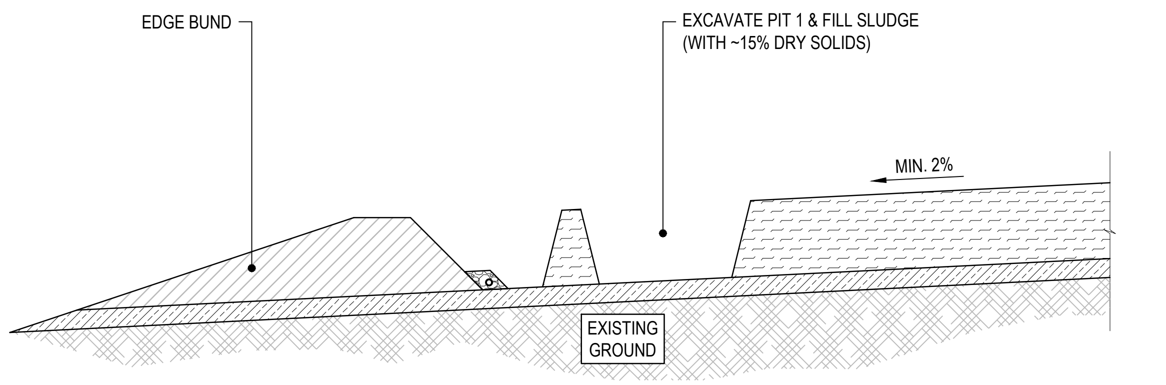
NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE.



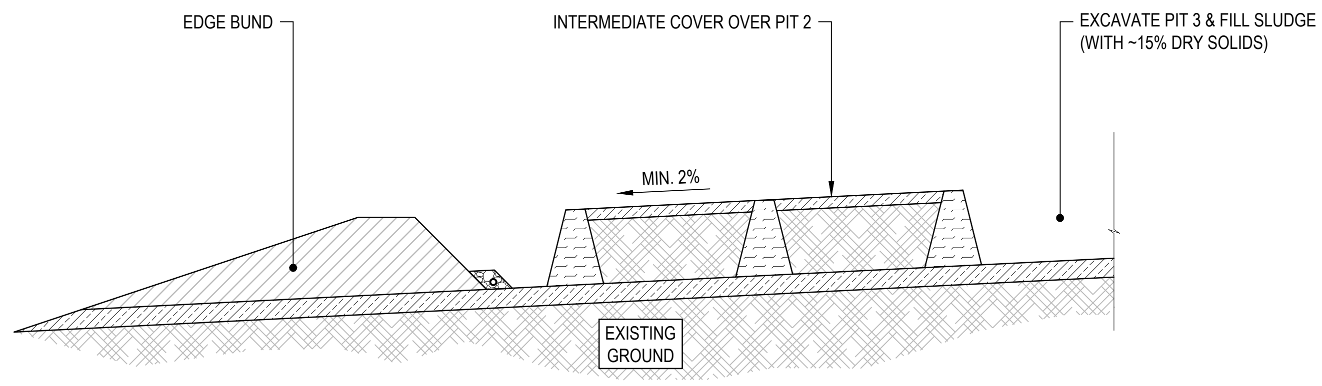
FIRST LIFT - STEP 1



FIRST LIFT - STEP 3



FIRST LIFT - STEP 2



FIRST LIFT - STEP 4

SLUDGE FIRST LIFT - CONSTRUCTION & FILLING SEQUENCE
SCALE 1:200

A3 SCALE 1:200
0 2 4 6 8 10 (m)
ORIGINAL IN COLOUR

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1	INFORMATION ISSUE	LIWA		

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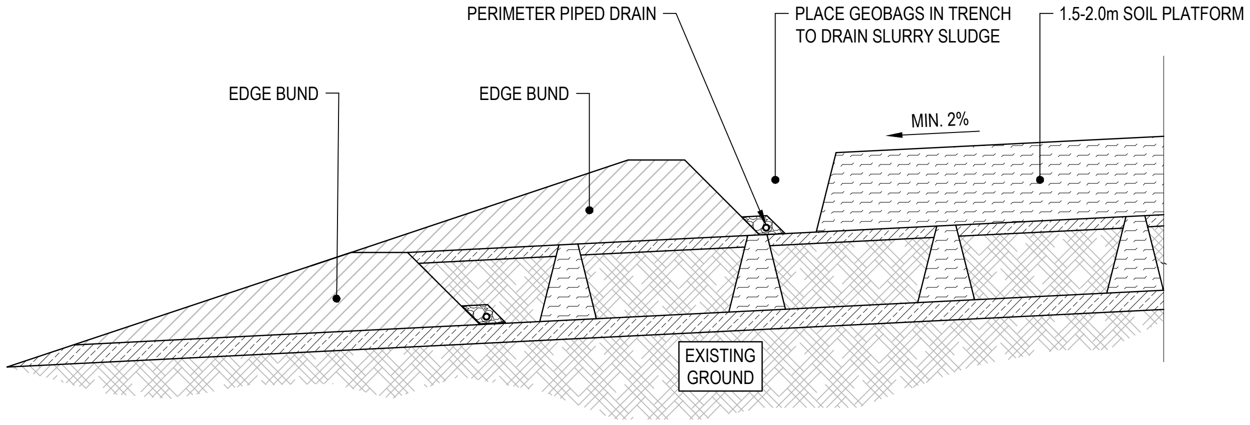
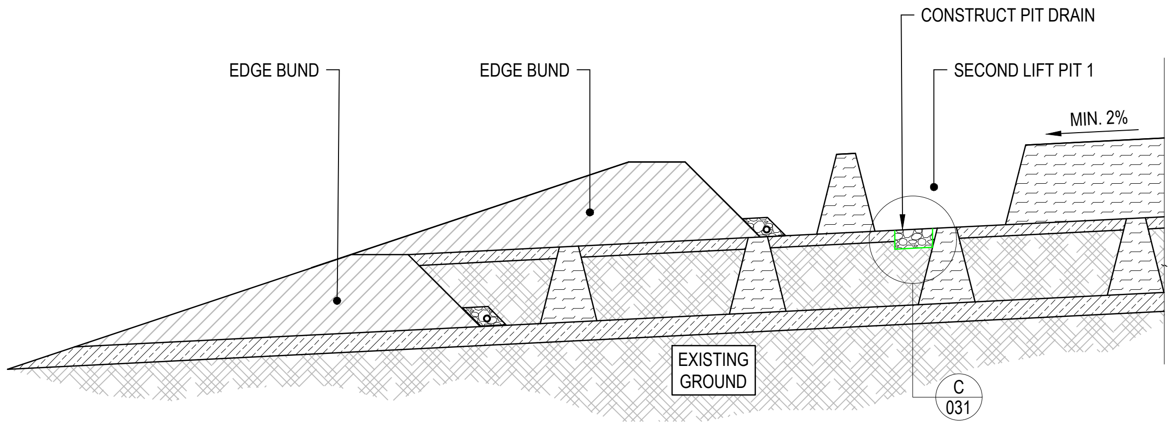
PROJECT: TO TATOU VAI SLUDGE EIA
TITLE: SLUDGE FIRST LIFT CONSTRUCTION & FILLING SEQUENCE
SCALE (A3): 1:200 DWG No. 1013086.0000-022 REV 1

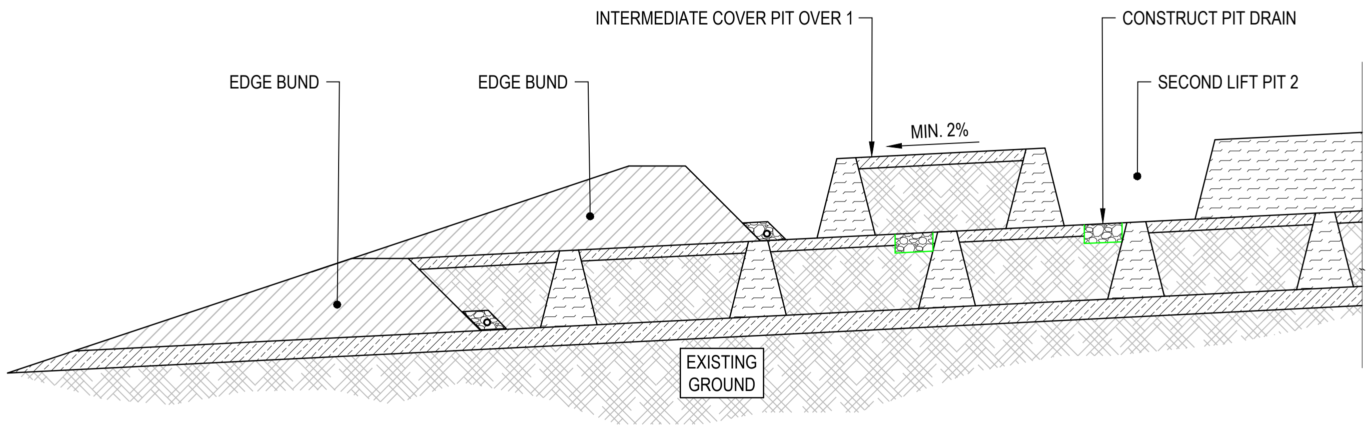
NOTES:
1. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE.



SECOND LIFT - STEP 1



SECOND LIFT - STEP 2



SECOND LIFT - STEP 3

SLUDGE SECOND AND SUBSEQUENT LIFT - CONSTRUCTION & FILLING SEQUENCE
SCALE 1:200

A3 SCALE 1:200
0 2 4 6 8 10 (m)

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1	INFORMATION ISSUE	LIWA				

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DESIGN CHECKED	DSMT	06.07.21
DRAWING CHECKED		

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PROJECT: TO TATOU VAI SLUDGE EIA
TITLE: SLUDGE SECOND LIFT CONSTRUCTION & FILLING SEQUENCE
SCALE (A3): 1:200 DWG No. 1013086.0000-023 REV 1

Appendix H: TTV environmental mitigation/management commitments

Appendix I: Consultation records