Te Mato Vai Stage 2 - Desktop Review of PACI Trial

Prepared for Ministry of Justice Cook Islands
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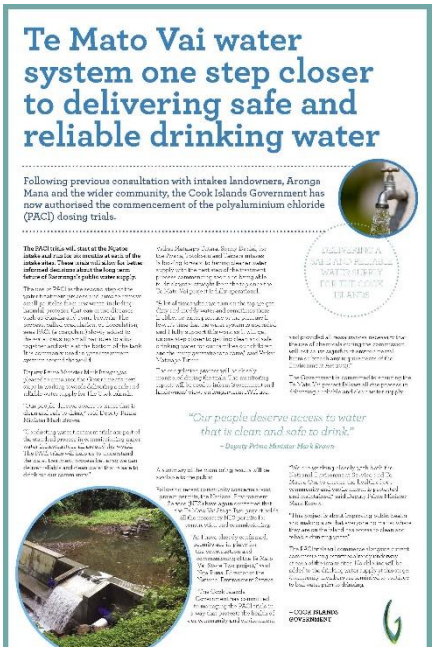

Te Mato Vai water system one step closer to delivering safe and reliable drinking water

Following previous consultation with intakes landowners, Aronga Mana and the wider community, the Cook Islands Government has now authorised the commencement of the polyaluminium chloride (PACI) dosing trials.

"Our people deserve access to water that is clean and safe to drink."

Revision History

Revision Nº	Prepared By	Description	Date
A	Andrew Watson	For client	3 September 2021

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Contents

1 Introduction

The Te Mato Vai project has replaced Rarotonga's water supply reticulation, added increased water storage, and provided treatment of the water for the first time. Stage 1 of Te Mato Vai covered the reticulation, and Stage 2 covered the storage and treatment.

The scope of this report is to provide a desktop review of the coagulant (polyaluminium chloride – PACl) trials carried out at the ten water treatment plants that have been constructed as part of Stage 2 of Te Mato Vai.

The High Court of the Cook Islands appointed me as a court expert early in 2020, and in March 2020 I submitted an expert independent report on Stage 2 of Te Mato Vai.

The court has now tasked me with preparing a report under Minute No. 18 of the Honourable Justice Patrick Keane (Misc. Nos. 41/2016 – 50/2016).

Paragraph [1] of that minute sets out the task: "….. to make a desktop review of the following:

> (a) the finalised PACL trial report, dated June 2021, containing the data from the PACL trials in respect of all the water intakes;
>
> (b) the memorandum of counsel for the landowners, dated 11 December 2020, setting out their concerns and issues relating to the PACL trials;
>
> (c) the Crown/PMU response (undated) to the landowners' memorandum;
>
> (d) a PACL sludge analysis by GHD, 'Characteristics of PACL Sludge Samples' (undated).

The four documents (a) to (d) were included in *Memorandum of Counsel for the Crown*, dated 25 June 2021, which was emailed to me on 18 August 2021.

Because the PACl trial report is the principal document for review, my report tackles this document first (as well as the appended sludge analysis report). It then turns to the two memoranda (items (b) and (c) above), which are reviewed in the context of the preceding trial report review.

2 PACl Trial Report

The following sections replicate the headings of the *PACl Trial Report*, and under each heading I review the corresponding section of the report.

1. Introduction

Figure 1 (Summary of the water treatment process in the new treatment plants) is a useful illustration of how the plants work, but I recommend two changes. Firstly, because the coagulation/flocculation step occurs at the start of the sedimentation tank, it should precede that step in the figure (i.e., step 2 should become step 1, and vice versa). Secondly, the filtration step: it does not "further filter", it just "filters"; and because it removes more than just protozoa it would be better to refer to "pathogens" or "microorganisms" rather than "protozoa".

I was surprised not to see any reference to the McConnell Dowell *Construction Execution Procedure: Poly Aluminium Chloride Dosing Trial* (CEP). Considerable time and effort was put into the CEP, and hopefully it was actually used during the trial, but this is not recorded. I last reviewed the CEP (Rev 3) in July 2020, but I don't have a copy of the final version.

Section 1.3 explains the offline and online trial process, and includes the following paragraph:

> "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."

The treated water quality data presented later on in the report clearly shows that there were times when the water was not safe for human consumption (*E. coli* ≥ 1/100mL). Until disinfection is implemented this will remain the case. This paragraph needs to be revised to make it clear that the water was not safe. Implementing chlorine dosing is necessary to consistently achieve a potable quality treated water, measured by the absence of *E.coli*.

Table 1 (Key dates for all plants) – the column showing the dates of the end of the trial for each plant don't match with the dates shown in the individual plant reports in Appendix C.

Table 2 (Rainfall data (mm/month) during the trial compared to the historical average for that month) is a little misleading in that it includes rainfall data for August and September, whereas the earliest trial started on 28 September, four plants were started in October and the remaining 5 were in November. If August and September are excluded, the October to May total during the trial was 1545 mm, compared with the 122-year average of 1530 mm. The dry months that are noted (November, December, January, and March) are of particular significance when looking at the sludge results (refer 5. below)

Between Section 1 and Section 2 of the report I would have expected some commentary on the PACl optimisation work that was scoped in the CEP to be undertaken during the offline trial. The CEP recorded that the expected optimum was a PACl dose of 10 mg/L based on the jar testing previously undertaken, but included trialling of as low as 5 mg/L. Was this work done? If it was, this should be captured in the report.

2. Treated Water Quality

Section 2.1 (The treated water quality requirements) – presumably these requirements were agreed with TTV and Te Marae Ora (CIMoH)? If so, this should be included in the report, so it is on the record.

The turbidity data presented in Table 3 (Turbidity summary statistics in NTU for all plants, when plants were treating water) has been aggregated from all 10 plants. A quick review of the individual plant reports in Appendix C reveals that the aggregated raw water data masks a lot of variability between the ten plants.

Although turbidity was typically only measured once per day, it is striking how the source streams can peak to high turbidity values in a single day and be back to less than 5 NTU the next day. If we take readings of raw water turbidity being ≥ 5 NTU as being indicative of rain events (as the report does in Section 2.7), the number of days of rain events varied from 2.5% of the trial period for Avana, to 7.5% for Matavera. This is important when I come to consider the performance of the sludge systems (refer 5. below).

The filtered turbidity results are good, although once again they are typically only taken daily, and any process upsets would be missed. Excluding the taking of turbidity readings during the filter ripening period after backwash is not ideal, so some means of measuring the turbidity of this water and diverting it to waste would be the preferred outcome, although I acknowledge this is not realistic with the current level of automation.

While the filtered water turbidity data presented in Table 4 (Filtered turbidity results above 1 NTU when plants were producing water) has been aggregated across all ten plants, Figure 2 (Statistical plots for the post AVG turbidity for each plant, when plants were treating water) graphically presents the data for each plant. A quick review of this figure against the individual plant reports in Appendix C shows some inconsistencies – for example, the figure shows 13 outliers (> 1.0 NTU) for Ngatoe but the data in the plant report only records 8, one of which at 4.80 NTU is beyond the range of the figure. These inconsistencies are probably not material to the outcome of the trial – that there are occasions when filtered water turbidity exceeds 1.0 NTU.

I am concerned that the report is suggesting that the results of the trials "…. are considered when setting the upper treated water turbidity compliance value" in the finalised CIDWS. Accepted practice is for water treatment plants to be designed and operated to meet a standard. The treatment goals of Te Mato Vai were to meet the draft CIDWS, which requires < 1.0 NTU leaving the treatment plant (with continuous turbidity monitoring).

The report does not address, or even consider, the gap between the original treatment goals and the results of the trial. While I could accept the occasional excursion up to 5 NTU (including in the post-backwash periods) there are several data points from the trial that indicate the loss of control of the treatment process. There is no attempt to understand these better and propose mitigation measures. For example,

- Should the raw water be diverted to waste when the stream turbidity is high? Various options for achieving this were considered in my March 2020 report.
- Is the half-hour delay between the plant starting up and the commencement of coagulant dosing a factor in the turbidity spikes, and if it is what can be done to resolve the issue?
- What is the treated water turbidity profile during filter ripening? Is there a build-up of solids occurring in the filter, suggesting that more frequent backwashing is required?
- Could the AVG filter backwashing be disabled, so it would then be manually initiated during the daily site visit and run to waste if necessary?

While the report is correct in that it does make sense for the CIDWS to "align the short-term maximum allowable turbidity to the turbidity requirements of the disinfection method that will be chosen", gross excursions must not be allowed.

Section 2.3 (PACl dose rates) states "The PACl dose rates are set between 10 and 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." Based on the results of the trial I would expect more detailed guidance on how to set optimal dose rates, both in terms of stream flow and each catchment's water quality characteristics.

The dissolved aluminium concentrations in the treated water that are reported in section 2.4 are good results. Because the sampling was typically only done weekly, none of these samples coincided with process upsets, so such events would have been missed. However, if these process upsets can be prevented, then I would not expect dissolved aluminium peaks either.

The reference to a target value for dissolved aluminium of 0.1 mg/L above Figure 3 is confusing – the treated water quality requirement set in section 2.1 is for 0.2 mg/L not 0.1 mg/L.

Section 2.5 (Escherichia coli (*E. coli*)) presents both aggregated and disaggregated data for E. coli in the raw water, post the settling tank, and post the AVG filters. Although the median for most plants is reasonable, a quick review of the plant data in Appendix C shows many instances of E. coli being greater than 10 /100 mL even when the treated water turbidity is less than 1.0 NTU. This emphasises the importance of disinfection being necessary to produce a safe water. Note that E. coli being present at 10 /100 mL or greater in the reticulation is the trigger in DWSNZ for a number of immediate interventions, including considering a boil water notice (but any positive results require corrective actions).

The report states that "…. the reason why the treated water concentrations in Takuvaine are higher is because there are long periods (weeks or longer) where it is often run only for a few hours per day, and then shut down again. It has to do with the storage tank being often full. This disrupts the normal operation with PACl, and results in the suboptimal E. coli measurements." A quick review of the plant data in Appendix C shows that there were 9 samples taken with very high E. coli results when treated water samples were < 1.0 NTU. Although this suggests that the coagulation process was working satisfactorily, the corresponding raw water samples all have a turbidity of ≤ 1.2 NTU. From the box plots presented in Figure 3 Takuvaine has the highest median E. coli count in its raw water (~500/100mL), and the plant data in Appendix C shows that high counts often occur during fine weather. This suggests faecal contamination in its catchment is directly entering the stream (i.e., it doesn't need rainfall conditions), warranting an investigation of the catchment to determine if the source(s) can be identified and actions taken to improve the quality of this raw water. Once the problems with the full storage tank/ network management have been resolved and the plant is operating normally, more E. coli sampling should be undertaken. The need for disinfection is high at all plants, however the priority here may be higher than the other plants.

For pH (section 2.6), the number of samples taken suggest that samples were taken about twice weekly, which is not frequent enough to pick up diurnal and flood fluctuations but does give a general indication of typical pH values. PACl normally gives good performance in water with pH values ranging from 6.0 to preferably less than 7 but may be adequate at up to 7.5. The results presented in the boxplots in Figure 6 indicate that for at least 75% of the time the raw water at the Avana, Avatiu, Taipara, Totokoitu and Takuvaine plants is within this range. However, for the other plants the raw water pH values go above 7.5 for between 25% and 50% of the time. Using the data from the trial to develop correlations between pH and dissolved aluminium, as well as pH and treated water turbidity, should be done to see if there is an issue, and to consider options for improvement.

While the higher pH values are not ideal for PACl, the trial has demonstrated that good, treated water quality is generally able to be achieved.

Section 2.7 (Operation during dry weather and rain weather) presents aggregated turbidity data for rain events (raw water > 5 NTU) and does indeed show good turbidity removal for most of the time. The comments I have made above in the context of Tables 3 & 4, and Figure 2, are also relevant to section 2.7 of the report. The boxplots of E. coli and dissolved aluminium in Figure 8 do not state how many data points these are based on, but I suspect it is not many unless there is more data than has not been included in Appendix C.

The data from the 18 February rainfall event at the Totokoitu plant is interesting and illustrates the importance of maintaining control of the coagulation process because of the nearly 4 hour delay before treated water quality is restored.

The conclusions (section 2.8) are reasonable, but I would like to reiterate some of the key points I have made on Section 2:

- There are occasions when filtered water turbidity exceeds 1.0 NTU. While occasional excursions up to 5 NTU (including in the post-backwash periods) are probably acceptable, there were several times during the trial where control of the treatment process was lost. There is no attempt to understand these better and propose mitigation measures.
- The treatment goals of Te Mato Vai were to meet the draft CIDWS, which requires < 1.0 NTU leaving the treatment plant (with continuous turbidity monitoring). The gap between the original treatment goals of TMV and the results of the trial is not addressed, or even considered. It is concerning that the report suggests the results of the trials are considered when setting the upper treated water turbidity compliance value in the finalised CIDWS - accepted practice is for water treatment plants to be designed and operated to meet a standard, not the other way round.
- There is no detailed guidance, that draws on the results of the trial, on how to set optimal PACl dose rates, both in terms of stream flow and each catchment's water quality characteristics.
- The many instances of E. coli being greater than 10 /100 mL in the treated water emphasises the importance of disinfection being necessary to produce a safe water.

3. Treated water quantity

The data presented in Table 8 (Average flow taken from streams between 29 October 2020 and 30 May 2021) provides some assurance that TMV as an overall scheme is able to deliver the design flows. However, it would be interesting to see the measured daily flow rates against treatment performance. For example, was Taipara's performance, which averaged 129% of its design flow, affected by high peak flow rates during flood events? As I noted in my letter to Judge Keane of 9 March 2020, there is no flow control on the pipeline from the intake to the settling tank, and the pipelines were oversized during the design. This means that for those plants with a large height difference between the intake and the settling tank, actual flows can be twice as large as the design flow – Taipara is one of those plants.

4. Discharges to the environment

I have no comments to make on sections 4.1 (Introduction) to 4.4 (Measurements in the streams), apart from an observation on Table 11 (Pond summary statistics for all plants from start of the trial until 30 May 2021). The CEP specified that testing for turbidity, pH and temperature was to be done every time a dissolved aluminium test was done – this means that the number of test results for turbidity and pH should be the same as the number of dissolved aluminium tests. This is a minor point, and in my opinion does not detract from the findings.

Section 4.5 (Settling tank overflow test results) is reassuring, but it would have been good to know the date of the two overflow tests, and how long prior to the tests had it been since PACl had been dosed into the water.

The five conclusions presented in section 4.6 are all reasonable.

5. Water treatment residuals (sludge)

Section 5.3 (Residual's production): The idea expressed in the first sub-section (Settling tank de-sludging frequency) of reducing the PACl solution strength, as a way of promoting a more even distribution of solids along the base of the settling tank, is unusual, and I am unsure of the basis for this proposal. However, I don't see this as an issue that needs further attention – sludge accumulation at the head of the tank is to be expected and increasing the time between cleaning out of the settling tank is not necessarily desirable, as anoxic conditions in the sludge will occur, as has already been experienced.

I endorse the advice to de-sludge the settling tanks every four to six weeks – this is more-or-less aligned with my March 2020 report of "…. on average, every 33 days", and much more frequent than the earlier GHD estimate of every 3 to 6 months. I would expect the lower end of this range (i.e. 4 weekly) may be more

appropriate – over time the operators will determine what is appropriate, and how long sludge can be left before anoxic conditions (i.e. smelly sludge) are observed to occur.

The second sub-section (Residual's production in the settling tanks) presents sludge production data for Ngatoe and Tupapa. By back calculation the estimates of total dried solids in the settling tanks look to have been based on about 0.2% concentration for the fluff and about 0.4% for the sludge. These are presumably based on the output from the Cerlic instrument, but although they do appear low (0.2 - 0.5% for the fluff and 1 - 2% for the settled sludge seem more reasonable). For completeness, it would have been useful to include this information in the report. The second to last column in Table 17 has been mistakenly copied over from the previous column and needs to be corrected.

The scaling up of the data from the October and November results to produce an estimated annual sludge volume total is flawed in my view as it takes no account of the specific conditions in those two months. It is correct that more sludge will be produced during the wetter months of the year, but it is not clear how the figure of 80% has been arrived at in the statement that "For a rough estimate, if residuals production were proportional to rainfall amount, we would expect those volumes to increase by approximately 80%". By my rough calculations, if the total dried solids at the end of 56 days at Ngatoe was 160.4 kg, and the rainfall over that period was 181 mm, then this would need to be scaled by the total annual historical rainfall divided by 181 mm. Table 2 does not present data for the full year, but based on say 2,000 mm/year at the coast, this would then scale up the 160.4 kg of solids by a factor of 11.05, bringing the yearly total to about 1770 kg, or 11.8 m^3 at 15% DS.

However, none of this takes account of the actual raw water conditions prevailing at Ngatoe and Tupapa during October and November 2020. From the individual plant reports in Appendix C, there were:

- Five days of floods at Ngatoe during October and November (5.58, 5.44, 12.2, 5.55, and 19.4 NTU in raw water)
- Two days of floods at Tupapa during October and November (5.03 and 7.02 NTU in raw water).

Using the industry-recognised procedure for estimating sludge volumes, and the available raw water quality data, I cannot even roughly approximate the measured sludge volume/mass presented in Tables 16 and 17. This suggests that the PACl dose rates and/or plant flows during October/November must have been much less than the averages reported over the whole trial period. Or perhaps the sludge volume and/or concentration measurements are not reliable?

The report includes photos of the Ngatoe scour pond following desludging of the plant's settling tank in December 2020. Using the dimensions from the construction drawings (that I roughly checked when on site in February 2020), I estimate that the sludge is about 0.5 m deep in the 10 December photo, which calculates out to a volume of 21 m3 of sludge. Assuming the pond was empty before the desludging took place (it was the first time that the settling tank had been desludged), and if we conservatively assume that the average solids concentration over the full depth was 5% DS (it was measured at 14% just below the crust), then this equates to about 1000 kg of dried solids. This is well in excess of the figure of 160.4 kg presented in Table 16 but aligns better with the estimates derived from the industry-recognised procedure.

This suggests to me that the sludge volume and/or concentration measurements made using the Cerlic instrument are not reliable.

However, offsetting my concerns that sludge volumes are understated, the evidence shows that sludge drying is occurring reasonably rapidly at many sites.

Section 5.4 (Drying performance of the ponds) initially looks at the performance of dedicated scour ponds. The photos of Ngatoe are impressive. Presumably the decanting arm was used to drop the water level by what looks like more than 0.5 m in 8 days (from 2 to 10 December)? Or is there some leakage through its base and perhaps walls? As I discussed in my March 2020 report, one of the benefits of unlined ponds is the

promotion of dewatering, and as long as there is no short-circuit to the stream (which seems unlikely as it is holding water), then I do not see any issues with the leakage.

In my March 2020 report I stated that "….. a dry solids content of 4% was achievable relatively quickly, and could increase to 6% or higher, but given the frequency of desludging that is required, 4% is more realistic." However, the report shows that the testing that was done on the dried sludge showed an average of about 14% just below the crust. The fact that it is a dedicated scour pond, the leakage, and the very low rainfall in December and January (meaning increased evaporation from hotter and sunnier days than normal), all contributed to achieving that performance. It is also good to see that the heavy rain on 12 December did not re-mobilise the dried solids significantly. The photo of Takuvaine (Figure 22) suggests that this pond is also performing well.

In terms of the combined ponds, the Matavera and Tupapa photos and solids testing results clearly show the advantages of operating the ponds in a duty/standby mode, compared with those for Taipara when operating both ponds in a duty mode.

The spadeablity and stickiness tests conducted at Matavera and Tupapa were good practical work which will help inform the long-term management of the sludge solids.

The sub-section on longer term drying performance of the ponds presents a good summary of the ponds at each plant (Table 21), but apart from the short commentary in the "Drying in a combined pond" sub-section on switching from duty/standby mode to duty/duty mode and the photo of Taipara, there is no other evidence that explains why some ponds are designated as "OK" (yellow) rather than "good" (green) in the summary table. The paragraph following the table gives an explanation for the sub-optimal performance of the Totokoitu and Turangi ponds. The obvious next step for the Totokoitu ponds is to construct an interceptor drain to divert the incoming runoff away. The footnote explains that for the Turangi ponds that efforts are underway to cut back the surrounding trees to let more sunlight in. While I expect that increased sunlight will aid drying, drainage by leakage is likely to have a similar if not greater impact – in the longer term moving the ponds to an area with improved drainage or implementing some other means of improving drainage could be of significant benefit, thereby avoiding the need to cart liquid sludge.

Section 5.6 (Recommended way of operating the ponds) is an excellent wrap-up of the trial work on drying performance. It is no doubt already being used in the day-to-day operation of the ponds.

Section 5.7 (Characterisation of residuals and possible disposal or reuse options) is a summary of the appended report *Characterisation of PACl Sludge Samples*. This work looks sound and reasonable to me. My only comment is that it would have been good to include some preliminary advice on the soil amendment rate (tonnes per hectare ploughed into the root zone) for PACl sludge rather than just saying it "could be high".

As I said in my March 2020 report, a win-win use for the sludge would seem to be building up low-lying flood-prone land, and the characterisation work supports its use in this type of application.

6. Operation without PACl

I totally endorse the content and conclusions of this section.

7. Summary and recommendations

I concur with the summary, although I think it downplays the ongoing need for a suction truck to remove sludge from the poorer performing ponds until hopefully their performance can be improved.

The recommendations are fine, apart from my already expressed concerns about:

- That until disinfection is implemented the water is not safe for human consumption
- Using the results of the trial to set the final turbidity standard in CIDWS
- The lack of recommended mitigation measures to prevent the loss of control of the treatment process.

3 Memoranda

This section of my report considers the two memoranda in the context of the *PACl Trial Report*:

- the memorandum of counsel for the landowners, dated 11 December 2020, setting out their concerns and issues relating to the PACL trials
- the Crown/PMU response (undated) to the landowners' memorandum.

To help the reader I have used the headings (and heading numbers) in the Crown/PMU response, and then given my opinion on whether the Crown/PMU response, and the PACl Trial results, have adequately answered the concerns and issues raised in the memorandum of counsel for the landowners.

3 List of concerns

1 Overflow of sediment tank

I am now satisfied that the risks of PACl contaminating the streams as a result of overflow at the inlet to the sedimentation tank is very low, as long as the ballcock is regularly checked. Note, however, that measuring dissolved aluminium in the discharge does not necessarily mean that no coagulant has been added.

I have some residual concerns that for the high energy plants, that flows well in excess of the design flows may be compromising the performance of those plants especially in flood conditions. This can be resolved with more operational experience, and if it is a problem then installing an orifice plate in the inlet pipeline.

2 High concentration of PACl in sediment tank if water flow is stopped

Refer my response to point 1 above. Ongoing operator vigilance will be important.

3 Whether diversion of water, if flooding occurs, to ensure PACl is right dose, especially overnight, if needed

The trial has shown that gross excursions of treated water turbidity can occur under flood conditions. These are not consistent with the project's objectives. Various mitigation measures need to be considered (including raw water diversion) and the best one(s) implemented.

I agree that raw water diversion could waste water under drought conditions. But because diversions would only occur in floods, if there was a flood during drought conditions more operational input may simply be necessary during the actual flood to minimise waste.

4 How to calculate a manual backwash as close as possible to automatic backwash

The fact that the PACl Trial occasionally found high filtered water turbidity, and that the report recommends that filtered water turbidity results should not be taken during the ripening stage (designated as the first 15 minutes after the backwash is complete), are of concern. I note that the Crown/PMU response states that "Currently we are seeing backwashes between one day and half a week between backwashes", but there is nothing in the report on the backwash frequency observed over the complete trial period – this would be useful information.

In my review of the PACl Trial report in Section 2 of this report I suggested that the treated water turbidity profile during filter ripening needed to be investigated, and that a possible mitigation measure could be a manually-initiated backwash (with the automatic one disabled), with running to waste if necessary to prevent turbidity spikes going into supply. The manual backwash could be initiated in response to a filtered water turbidity trigger, and/or head loss across the filter.

I do consider that being able to observe the filter head loss is a useful tool for the operators, and should be considered for implementation. This could be as simple as two clear hoses on the side of the filter, on one

the filter outlet side, and one inlet side, with the head loss being the difference in hight of water in the two pipes. If the cost of retrofitting a device to measure head loss is too difficult and/or expensive in the short term, then a backwashing frequency could simply be set based on the experience gleaned from the trial.

5 Effects of environmental factors on the scour ponds

Runoff into the ponds – the PACl Trial report acknowledges the issue with runoff into the Totokoitu ponds. I pointed this out in my March 2020 report, and it has not been rectified - to the detriment of the TMV project.

I agree that there is no evidence of geotechnical instability.

My March 2020 report pointed to a number of locations where I thought inundation was possible, and recommended checks be made. If the experience over the last year or so has shown no inundation has occurred, despite what appears to have been a significant flood on 18 February, then it may well not be an issue.

6 Spillage from PACl tank will go straight on to the concrete and down into the river. Tank not double skinned and no bunding.

PACl liquid has the following hazard classifications under NZ HSNO regulations:

- 6.1D (acute toxicity): harmful if swallowed, in contact with skin, or if inhaled
- 6.3A (skin irritancy): causes skin irritation
- 6.4A (eye irritancy): causes serious eye irritation

In terms of ecotoxicity, whist less toxic than other water treatment chemicals, it should not be released into waterways. Similarly, contact with skin and eyes in particular should be avoided.

PACl is corrosive to metals.

While I agree that catastrophic failure of one of the PACl tanks is extremely unlikely, it is possible to imagine a scenario where the tank pipework and/or its dosing pipeline broke – either by an accident or by a failure at a joint or of the pipe itself. If such a scenario happened when no one was on site, the chemical could find its way to the stream, especially at those sites where the tank is very near to the stream. Some simple bunding using soil/fill material would be a low-cost way of mitigating this risk in the short term, although a concrete or plastic bund would be preferred to enable the spillage to be recovered.

Hopefully the tree overhanging the Tupapa PACl tank has now been removed!

I note that the Crown/PMU response states the intention to revisit the bunding issue at the completion of the project, and I endorse this.

7 Overflow PACl pipe has nothing to stop insects and vermin getting into the tank

The Crown/PMU response satisfactorily addresses this concern.

8 Jar testing must precede river testing

Although this was added into the CEP, the CEP was not referenced in the PACl Trial report. Refer my comments on this in Section 2 of this report.

9 Will backwash lack the density to sink and therefore overflow if scour pond is full?

The trial has not identified this possibility as being of concern. For the combined ponds the trial did show better performance when the ponds are operated in a duty/standby mode.

10 Will sludge be too liquid to remove by digger?

The trial has shown that under the right conditions some of the ponds achieve a high solids content. It now seems that a couple of ponds will not be able to be cleaned out with a digger, and that several others will be dependent on a preceding period of generally fine weather and only minor floods in order for a digger to be feasible.

11 Will roads cope with a 30-35 ton suction truck?

My estimates of sludge quantities in the March 2020 report were based on the limited water quality data available at that time. The data collected during the trial has shown that the turbidity is better than expected during non-flood conditions, and that the periods of high turbidity during floods have a lower turbidity and are of a shorter duration than assumed. If treatment of water during floods can be avoided/minimised, this will reduce the volume of sludge produced significantly.

Refer to Section 2 of this report for my concerns about the estimates in the PACl Trial report of sludge weight. Because some of the ponds are able to achieve a high dry solids content, the volumes of sludge for disposal will be significantly less than I estimated in March 2020.

However, I believe that a suction truck will be needed at least in the short term for the poorly performing ponds and some of the other ponds in prolonged wet periods. So, the question posed by the landowners remains to be answered.

12 Will the sludge need its water centrifugally removed or put in another sludge pond

I endorse the approach of TTV to prepare for the worst case in terms of the EIA.

13 Can the 'dry' sludge be placed in the landfill and if so for how long can this continue given landfill is past its 'life'?

I can see no need to use the current landfill given the characterisation of the sludge as reported in the PACl Trial report, unless the landfill can beneficially use the material such as a daily cover material.

14 Is any of the agricultural land on Rarotonga suitable for sludge supplement?

This issue is well covered in the sludge characterisation report.

15 Specific remedial work identified in the report needs to be undertaken at some intakes

This question is beyond the scope of what I have been commissioned to do.

16 Naturally based alginate as a possible alternative (see p.16 of the Expert's report)

I agree that PACl should be retained for now, but if landowners still feel strongly about its use in say another year, TTV could commence investigations into alternatives. This should start at a desktop level looking at what is commercially available, their performance, and the costs of the products themselves and the modifications that would be necessary at each plant to implement. Subject to a favourable outcome of that study, bench scale testing of one or two products could be undertaken. Again, subject to a favourable outcome, full scale trials could take place at say one or two plants. The costs and benefits of implementing the preferred alternative coagulant could then be investigated. It is possible that naturally based products such as alginate will not perform as well as PACl, and are more likely to be suitable to supplement rather than replace the use of PACl.

5. Landowners believe that there are a number of events …..

5a The lack of data being communicated …..

This was obviously perceived as being an issue at the end of 2020, but the current monthly reports appended in the PACl Trial report indicate to me that this issue was well addressed as the trial advanced.

5b Issues and questions around the data that has been collected

It appears from the Crown/PMU response that this has been addressed.

5c The lack of notice given to landowners …..

I don't have sufficient information to comment on this.

5d The request for further information from the Crown ….

It appears from the Crown/PMU response that this has been addressed.

5e Anecdotal evidence that wildlife, in particular freshwater prawns which are usually abundant, are not present in the streams

The ecology report supports the Crown/PMU response on this issue.

5f Higher levels (than expected) of PACl sludge have accumulated in the settling tanks ….

Refer to my discussion on PACl sludge quantities in Section 2 of this report.

5g Fear by the landowners that this toxic PACl sludge will be removed off site in breach of their Environmental Permit and the relevant legislation

I can't comment on the legal side of this question, but it is a fair response to state that the sludge is non-toxic.

5h Observation that design flaws in the works (like scour ponds position and construction) have not been remedied as per the Watson report

The extent to which design flaws have been remedied is not within the scope of my commission. For the specific trial of PACl overflowing at the inlet to the settling tank, refer my comments in Section 2 of this report.

5i Whether the discharge of near clear water and supernatant water that discharges to the streams is environmentally friendly

I agree with the Crown/PMU response. Refer to my comments on the discharges to the environment in Section 2 of this report

5j During heavy rain surface flooding can result in scour pond washout directly into the stream

Refer to my response to item 5 in section 3 (List of concerns) above.

4 Concluding Comments

My review has made a number of comments on, and suggested changes to, the interpretation and reporting of the PACl trial, and areas where improvements might be possible. Despite this, I consider that the trial has demonstrated that coagulation with PACl is generally able to achieve a good level of treated water quality in terms of turbidity and dissolved aluminium. The trial has also provided a sound basis for management of sludge into the future and shown that the discharges to the environment can be managed acceptably.

The report, together with my review commentary, includes some areas where improvements are, or may be, needed. I expect that with some of these improvements, together with ongoing optimisation of the operation of the plants, are something that To Tatou Vai could well manage from this point onwards. A colleague, Philip La Roche, visited To Tatou Vai recently whist on holiday in the Cook Islands - he was impressed with how well the TTV operations team were progressing, including learning how to get the best out of the treatment plants.

Longer term, improvements should be considered to provide the operators the tools to best operate the plants. This could include making tank levels and flows available remotely, ability to start/stop the plants remotely (also removing the current lag between plant start and coagulant start), on-line water quality data, and improved coagulant dosing control.

I hope that the trial work that has been completed addresses the landowners' concerns, and that this gives all parties the confidence to move forward and let the water treatment plant assets move closer to delivering on the overarching goal of the Te Mato Vai project – "to contribute to the enhancement of public health".

In order to complete the delivery of that goal, however, the next priority needs to be implementing disinfection. This will provide substantial benefits in terms of improved public health for the community, and without this being implemented the value of the investment that has been made in installing water treatment will not be realised.