Report 2: A Quantitative Assessment of Sludge in the Lower North Island

Prepared by

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Regional Biosolids Strategy – Lower North Island

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1 EXECUTIVE SUMMARY

1.1 Background

Ten lower North Island councils are working in partnership to develop a biosolids strategy that includes a potential collective approach for sludge management and beneficial use programmes. The strategy is led and co-ordinated by Lowe Environmental Impact (LEI) and The Institute of Environmental Science and Research Ltd (ESR).

The first step in the project is to undertake a stock take and gaps analysis to determine the scale of the current sludge problem for each district. The project partners will then work together to determine potential collective solutions including processing, end-uses, consenting and stakeholder engagement processes. Some of the potential solutions will be trialled (e.g. field trials of composting). The outcome will be a 'tool box' of different scenarios that provides a model of operation that can be applied in other regions around New Zealand.

This report follows on from an earlier survey of the partner councils, which identified that information held by the councils regarding sludge volumes and quality in oxidation pond systems was limited (Stage 1 Gap analysis, Task 1a Desk top study, June 2017).

The purpose of this report is to provide more information on quantity and quality of sludge in oxidation ponds in the Lower North Island. Site investigations and sludge analyses were undertaken at two WWTPs where there are ponds likely to require de-sludging in the next 5 years (Foxton and Marton); and sludge in geobags at Shannon and Tokomaru WWTPs.

Information Collection
Investigations were undertaken to assess the sludge levels within ponds at Foxton and Marton; samples of sludge were collected from the pond areas at both sites and analysed for a range of variables in order to determine sludge quality. At Tokomaru and Shannon, sludge was stored on site in geobags. The geobags were opened and representative sludge samples taken and analysed for a range of variables in order to determine sludge quality.

Key Findings
The main findings from the site visits and field study are that:

- WWTP's that receive trade or industrial wastes are likely to have significantly higher sludge concentrations of metal contaminants. In this case, zinc was elevated in Foxton and all metals were elevated in Marton compared to Tokomaru and Shannon. For pond sludges in Marton and Foxton, zinc levels may limit beneficial re-use options without further treatment of the sludge (e.g. composting with green waste or blending with other WWTP sludge to dilute the metals).
- Differences in sludge quality were found between oxidation ponds depending where the pond was in the treatment sequence. Ponds at the beginning of the treatment train had higher organic matter, ammonia and heavy metals.
- Wastewater inputs into Tokomaru and Shannon ponds are mainly residential. Sludge from these ponds contained levels of heavy metals that meet current Biosolids guideline limits for Grade B biosolids and could be beneficially used with resource consents (e.g. land application).
- Levels of copper are similar between oxidation pond sludges suggesting that copper inputs are mainly domestically sourced.
- Pond sludges that have been geobagged are more stable than sludges accumulated and stored in oxidation ponds.

- Sludges in geobags contain less water than oxidation pond sludges indicating that the use of geobags to de-water oxidation pond sludge is successful.
- Large volumes of sludge are currently stored in the oxidation ponds at Foxton and Marton (25,500 tonnes and 47,500 tonnes wet weight, respectively).
- There are significant difficulties in measuring sludge volumes in oxidation ponds, mainly due to uneven pond floors and water levels in the ponds.

Regional statement on oxidation pond sludge and characteristics

Qualitative data was obtained from surveys and interviews with partner council members to collate information on oxidation ponds in the region.

A summary of the information obtained is as follows:

- There are approximately 62 oxidation ponds in the study region.
- Approximately 11 of these oxidation ponds require de-sludging in the next five years.
- Of the 11 pond systems needing de-sludging at least two have significant trade waste inputs and it is likely the sludge will require further treatment/blending before beneficial use to manage the contaminants.

National statement on oxidation pond sludge and characteristics

Sludge residing in oxidation ponds is not included in national waste management surveys. This Gaps Analysis can start to provide more information (qualitative and quantitative) about sludge volumes and quality in oxidation ponds nationwide. The key findings are:

- The 200 waste treatment pond systems in New Zealand are likely to contain over 4,000,000 tonnes of sludge (at 8 % dry solids). While this does not require management immediately, it will need to be managed over time.
- If WWTP's have minimal trade waste inputs, pond sludge is likely to meet Grade B levels for the presence of heavy metals and can be potentially beneficially re-used with no or minimal further processing.
- Sludge quality is dependent on where the sludge is in the treatment train; with sludges at the beginning of the treatment system having a lower quality and requiring further treatment before beneficial re-use. Sludges at the end of the treatment train are of a higher quality and could be beneficially used without further treatment.
- Geobags (or similar) may be a cost-effective sludge management option as they appear to dewater and further stabilise pond sludge to a point where it could be beneficially re-used after 18 months in bags.
- Sludge surveys have a high degree of error due to the uneven pond base, variable water levels, detection of the sludge interface and uneven sludge build up. This makes it very difficult for Council's to plan, and allocate budget to sludge management plans.
- There are real options for beneficial re-use if the sludge is further stabilised by composting with green-waste, or by blending sludges of different quality to obtain high value products.

2 INTRODUCTION

In the lower North Island, there is an estimated 80,000 tonnes of sludge (at 20% solids) produced from oxidation ponds (every 30-50 years)[1] and additional sludge from 5 high rate treatment plants. Most of this sludge which is removed from the treatment plants ends up in landfills. Landfilling is not a long-term management option and is becoming more difficult due to increased levies, space required and transportation distances. There is an increasing community expectation to develop sustainable use options where the material can be considered a resource. Management of solids can be especially difficult for smaller communities where limitations due to lesser economies of scale can stifle the development and creation of workable solutions. All territorial authorities are facing the same problem – what to do with their biosolids.

This project aims to develop a collective biosolids strategy and use programme in the lower North Island. The strategy will consider economies of scale and alternatives for discharge and beneficial use of biosolids which are affordable, sustainable and provide targeted solutions that are consistent with national waste minimisation strategies.

The Lowe Environmental Impact (LEI) / Institute of Environmental Science and Research Ltd (ESR) team (**Project Team**) is working with 10 councils in the Lower North Island to determine pathways to work together that will form the basis of a regional strategy. Firstly, a stocktake and gaps analysis is determining the scale of the current sludge problem for each district; then a collective approach will be used to determine potential collective solutions including processing, end-uses, consenting and stakeholder engagement processes. Some of the potential solutions will be trialled such as further processing to produce a higher quality product (e.g. field trials of composting). The outcome will be a 'tool box' of different scenarios that provides a model of operation that can be applied in other regions around New Zealand.

An initial Gaps Analysis was undertaken (Stage 1 Gap analysis Task 1a Desktop Study, June 2017) with the main finding being information on sludge volumes and quality is simply not available, mainly because it has never been investigated. The largest knowledge gaps relate to oxidation ponds and very little data exists on the sludge volumes and quality in oxidation ponds across the region. The next phase of this project (Task 1b Site visits and field investigations) focuses on this issue and takes a quantitative approach. The purpose of this task and report is to:

1. Collect quantitative information by undertaking field work to assess sludge levels within a representative number of ponds and analysis of sludge to determine composition for a range of variables (e.g. Organic Matter, Dry Matter, Volatile Solids, Copper, Phosphorus, Zinc, pH, Total Nitrogen, Ammoniacal-N, Nitrite-N, Nitrate-N, Total Oxidised Nitrogen, Total Carbon and *Escherichia coli*). The field work was focussed on examples of ponds likely to require de-sludging in the next 5 years (Foxton and Marton) as these locations will have more urgent requirements for the information gained. The field work also focussed on two recently de-sludged ponds to characterise the sludge while it was de-watering on-site in geobags. This data can then be used as a baseline for understanding the varying compositions of sludge and for planning further stages of this project.
2. Collect qualitative information to try on sludge volumes and quality using data such as age of the pond, if it has been emptied before, population and pond size to enable the site investigation data to be extrapolated to the Regional and National level.

[1] Data extrapolated from sludge surveys at Carterton, K Beecroft, 2017

3 STUDY METHODOLOGY

3.1 Background

To fill the knowledge gaps identified in Stage 1 (Task 1a Desktop Study) it was determined that investigations should be undertaken to more accurately assess both the volume and quality of sludge for a selection of representative WWTP's, with a focus on oxidation pond sludges.

3.2 Investigation Sites

Four treatment plants were chosen to be representative of the pond systems managed by the partner councils. The sampling locations were limited to two likely to require de-sludging in the next five years and two where pond sludge has recently been extracted and is currently stored on-site in geobags to de-water (mature sludge). The four WWTP's chosen for quantitative analysis were Foxton (in pond), Marton (in pond), Shannon (geobag) and Tokomaru (geobag).

3.3 Sampling Procedures

Sludge sampling procedures followed for each WWTP site are described below.

3.3.1 Sampling of Foxton WWTP Oxidation Ponds

Foxton WWTP is situated at Matakarapa, a few km south-west of Foxton, and serves a population of around 2,500 with some trade waste contribution. There are three naturally aerated (i.e. no mechanical aeration assistance) oxidation ponds in series that have been accumulating sludge since their construction (1975 for the main pond and 1997 for the two smaller maturation ponds) and are scheduled for de-sludging in the next 12-18 months.

The layout of the Foxton WWTP oxidation ponds is shown in Figure 3.1.

Figure 3.1: Aerial Image of Foxton WWTP Oxidation Ponds

There is information available on approximate sludge quantity (Horowhenua District Council, 2013) however, no data on sludge quality exists. The characteristics of the sludge in the ponds is likely to be highly variable with depth and distance from the inlet as well as between ponds, given that they run in succession. Inconsistent changes in the nature and volume of trade waste production over the years (particularly expansions and closures of industries) also contribute to the highly variable nature of the sludge. Sampling of the Foxton oxidation ponds was carried out on 22nd June 2017 by an environmental scientist from LEI.

Sludge Volume Estimation Procedure

Depth to sludge was measured at each sampling point using a flapped pole with measurements along its length. The base of the pole had a 20 cm long moving flap that sat on the top of the sludge in order to determine sludge depth. The pole was pushed into the water until a solid layer was felt and the depth from pond water surface to firm sludge was recorded. Sludge depth across the ponds was compared to estimated pond depth and used to determine the approximate sludge volume.

Sludge Quality Sampling

The locations of the sludge samples taken are shown in Figure 3.2. Five composite samples of sludge were collected for analysis to serve as representative samples for the ponds. These were obtained by taking sub samples using a tube sampling device as follows (Figure 3.2). Pond one (Facultative) was divided into three sections representing distance from inflow. Three sub-samples were taken from each section to combine as one composite for each; Foxton 1, 2 and 3. Five subsamples were taken from each of the two smaller ponds (maturation ponds 2 and 3) and combined for each pond to give samples Foxton 4 and 5.

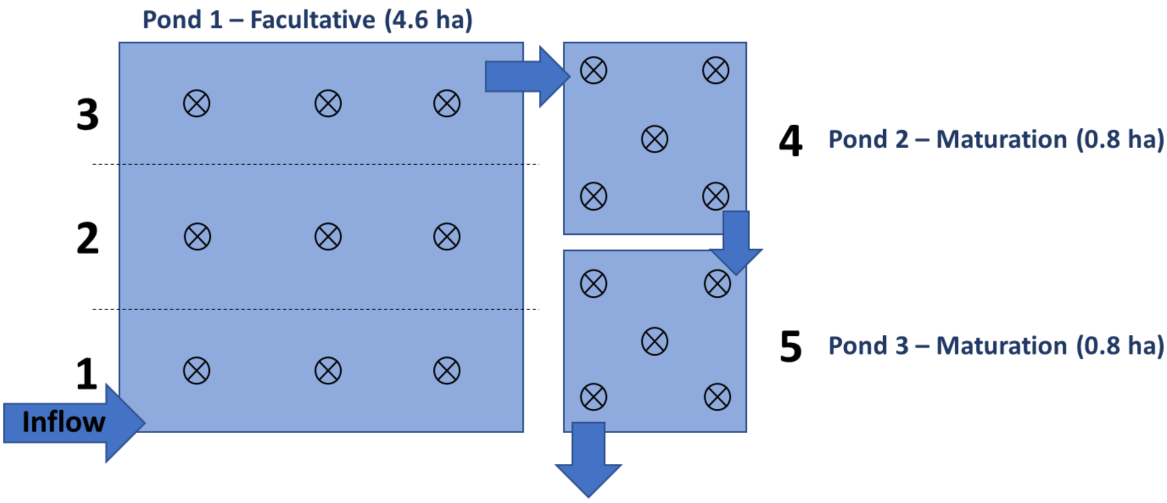

Figure 3.2: Diagram of Foxton oxidation ponds showing the locations of composite samples taken

3.3.2 Sampling of Marton Oxidation Ponds

The Marton wastewater treatment system serves a population of around 4,000, but due to trade waste inputs the population equivalent is 20,000 people (Chris Pepper, pers. comm), including leachate from the Bonny Glen landfill. The system has three ponds in sequence: an anaerobic lagoon covered with interlocked floating wetland, a large facultative oxidation pond with three aerators near its inlet and another aerator at the southern side, and a smaller maturation pond with a single aerator near its outlet. The treated wastewater then passes through a sand filter and UV disinfection system as a final treatment step.

The layout of the oxidation ponds at Marton WWTP can be seen in Figure 3.4 (the anaerobic lagoon occupies the vegetated oval area at the top of this image).

Figure 3.4: Aerial Image of Marton WWTP

The oxidation ponds have never been emptied since they were constructed in the 1970's and there is no information available on sludge quantity or quality. The characteristics of the sludge in the ponds is likely to be highly variable with depth and distance from the inlet. Variations of trade waste production will also contribute to the highly variable nature of the sludge. Based on this, a multiple grab sample and subsequent composite sample schedule of sampling was determined to be most appropriate to obtain representative sludge samples from the ponds.

Sampling of the Marton oxidation ponds was carried out on 4th July 2017 by an environmental scientist from LEI.

Sludge Volume Estimation Procedure

The depth from the base of the pond to sludge surface was measured using a flapped pole as for the Foxton ponds.

Sludge Quality Sampling

The locations of the sludge samples taken are shown in Figure 3.5. Six composite samples of sludge were taken for analysis to serve as representative samples for the ponds, these were obtained by taking sub samples using a tube sampling device inserted into the sludge (Figure 3.5). Pond 1 (aerobic lagoon) was divided into four sections representing potential movement of waste from inflow. Three samples were taken from each section to combine as one composite for each; Marton 1, 2, 3 and 4. Pond two (maturation) was divided into two sections and three subsamples taken from each and combined to give two composite samples; Marton 5 and 6.

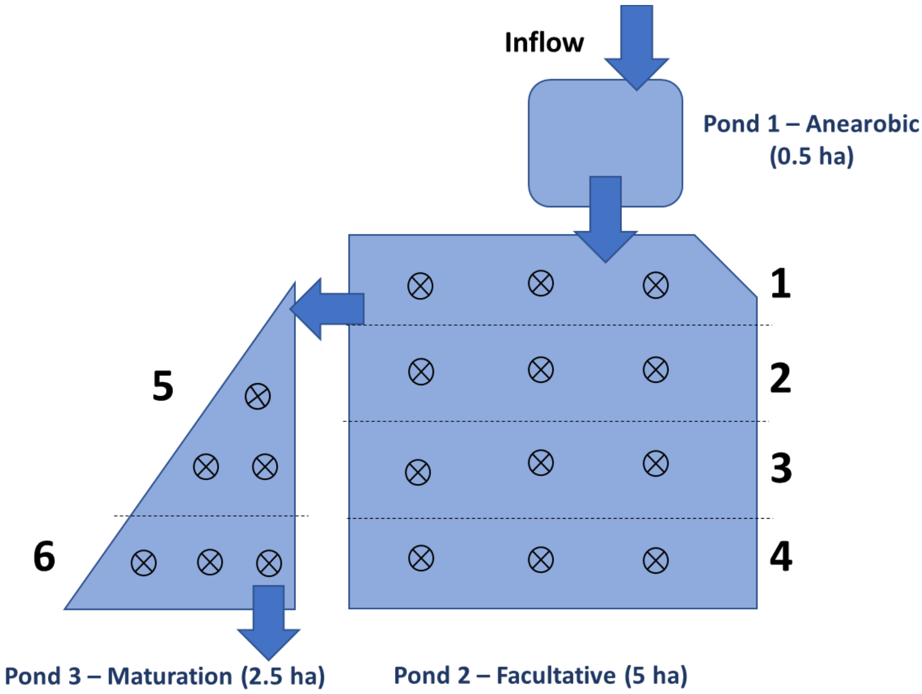

Figure 3.5. Diagram of Marton oxidation ponds showing the locations of composite samples taken

The anaerobic pond's sludge was not sampled because it is not readily accessible for sampling and the majority of participating councils do not have anaerobic ponds in their WWTP designs.

3.3.3 Sampling of Tokomaru and Shannon Geobags

The Shannon WWTP serves a population of around 1,500 and has one oxidation pond with a floating wetland. The oxidation pond was de-sludged in November 2015 when sludge was transferred to three geo-bags on site for dewatering/storage. Sludge remains in geobags and is due for transfer to landfill. The WWTP and full geobags are shown in Figure 3.6.

Figure 3.6: Shannon WWTP and geobags of sludge (upper left)

Tokomaru WWTP serves a population of 552 and has one oxidation pond which discharges wastewater to onsite wetlands. The oxidation pond was de-sludged in April 2016 when sludge was transferred to one geo-bag for dewatering until eventual disposal at landfill. The WWTP and geobag (prior to de-sludging commencing) are shown in Figure 3.7.

Figure 3.7: Tokomaru WWTP and geobag for sludge (top left)

There is no information available on the quantity or quality of sludge transferred into geobags at Shannon or Tokomaru (Stage 1 Gap analysis, Task 1a Desk top study, June 2017)

The current volumes of sludge stored at Shannon and Tokomaru were estimated from the approximate dimensions of the geobags. Their heights were estimated based on photos and sampling staff observations, while their lengths and widths were measured from recent aerial photography that is publicly available via internet on Google Earth and Horowhenua District Council's on-line maps (as shown in Figures 3.6 and 3.7 above).

Sampling of sludge in the Shannon and Tokomaru geobags was carried out on 22nd June 2017 by an environmental scientist from LEI. Sampling of geobags was limited to the location of access ports. One sample of each of the three geobags at Shannon was taken and combined to produce one composite sample. The geobag at Tokomaru was sampled at three port locations and combined. Sampling was by the use of 50 mm diameter pipe/corer. The top 10 mm of sludge was removed and corer pushed into sludge at an angle to a depth of approximately 1.5 m.

3.4 Sludge Analyses

All samples were transferred to clean, appropriate bottles/jars. Samples were subsequently sent to Hill Laboratories in Hamilton on the day of collection and were received within the timeframe for accredited analysis. The following parameters were measured:

- Organic matter

- 5-day Carbonaceous Biochemical Oxygen Demand ($cBOD_5$)
- Dry matter
- Ash
- pH
- Total Recoverable Metals: Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel and Zinc
- Nitrogen species: Total nitrogen, Ammoniacal-N, Nitrite-N, and Nitrate-N
- Total carbon
- Total phosphorus
- *Escherichia coli*

4 RESULTS

4.1 Sampling of Sludge

The oxidation ponds at Foxton and Marton and geobags at Shannon and Tokomaru were sampled as described in Section 3. The analytical results from these composite samples are summarised below and a full table of results can be found in Appendix A.

4.2 Sludge Results

Determination of the volume of sludge at each of the investigation sites has been undertaken. A summary of the analysis results and evaluation of the sludge quality is as follows.

4.2.1 Foxton WWTP – Treatment Ponds

Results of the sludge survey of the Foxton ponds are given in Table 4.1 and 4.2.

Table 4.1: Foxton WWTP Sludge Volumes in Pond

Sample Name	Age of pond	Dimensions	Last de-sludged	Calculated volume of sludge based on depth analysis
Pond 1 - Foxton 1 Foxton 2 Foxton 3	1974	4.6 ha x 1.5 m** deep	Never de-sludged	Average depth to the top of the sludge is 1.044 m. Estimated volume of sludge 20,976 m^3 at 8% DM (**1,678 t wt. dry solids***)
Pond 2 – Foxton 4	1997	0.8 ha x 2 m** deep	Never de-sludged	Average depth to top of sludge 1.62m Estimated volume of sludge 3,040 m^3 at 8% DM (**243 t wt. dry solids***)
Pond 3 – Foxton 5	1997	0.8 ha x 2 m** deep	Never de-sludged	Average depth to top of sludge 1.79 m Estimated volume of sludge 1,680 m^3 at 8% DM (**134 t wt. dry solids***)

*Calculations assume a weight to volume (density) ratio when wet of 1, percent DM based on Foxton averages excluding samples C and D as describes below.

**NB the depth used is the depth to the top of the water, not the depth to the pond top (i.e. not including the free-board height), as measured during the site investigation 22nd June 2017.

It should be noted that sludge surveys using the methodology applied here have a high degree of variability due to the uneven pond floors, water levels and uneven sludge build up. Also, different sludges within a pond can result is differing sludge interface detection. During the LEI site visit the sludge levels were measured to be higher than the previous survey that was undertaken by Chapman White in 2013. Sludge volumes have been calculated based on the LEI survey undertaken on the 22nd June 2017 and are given in Table 4.1. The estimated sludge volumes in this LEI survey are 25,696 m^3, higher than that estimated in 2013 which was 14,345 m^3. These discrepancies illustrate the difficulties in accurately mearing sludge volumes present in oxidation ponds.

Results of the sample analysis are given in Table 4.2.

Table 4.2: Foxton WWTP Sludge Quality Analysis Results

Parameter	Foxton 1	Foxton 2	Foxton 3	Foxton 4	Foxton 5
pH	7.11	7.11	7.19	7.17	7.14
Organic matter (g/100g dry wt)	12.6	44	64	72	12.6
Dry Matter (g/100g as rcvd)	31	9.8	6.8	7.4	28
Ash (g/100g dry wt)	87	56	36	28	87
Total Phosphorus (g/100g dry wt)	0.095	0.22	0.26	0.22	0.12
Total Nitrogen (g/100g dry wt)	0.32	1.92	1.59	2.1	1.34
Ammoniacal-N (mg/kg dry wt)	420	1,230	1,720	1,820	240
Nitrite-N (mg/kg dry wt)	<1.6	<5	<8	<7	<1.7
Nitrate-N (mg/kg dry wt)	<2.2	<7.1	<11	<9.5	<2.4
Nitrate-N + Nitrite-N (mg/kg dry wt)	<1.6	<5	<8	<7	<1.7
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$) (mg O_2/kg as rcvd)	980	750	730	650	730
Total Carbon (g/100g dry wt)	5.8	35	42	51	28
C:N ratio	18	18	26	24	21
Escherichia coli (MPN/g)	920**	5400**	540**	23	33
Total recoverable metals (mg/kg dry wt)					
Arsenic (As)	4	20	19	18	8
Cadmium (Cd)	0.12	1.21**	1.37**	1.39**	0.33
Chromium (Ch)	9	36	28	24	12
Copper (Cu)	28	220**	250**	260**	69
Lead (Pb)	8.4	54	58	47	15.6
Mercury (Hg)	<0.10	0.52	0.85	0.59	0.14
Nickel (Ni)	8	11	10	11	9
Zinc (Zn)	155	970**	1540*	1580*	430**

** indicates value exceeds the limits as determined by the Biosolids Guidelines (2003) for Grade A biosolids
* indicates value exceeds the limit as determined by the Biosolids Guidelines (2003) for Grade B biosoldis.

Notes:

- The total estimated volume of sludge in the three oxidation ponds at the Foxton WWTP is 25,696 m^3 at approximately 8% DM (2,055 dry tonnes, DM results from Foxton 1 and 5 are excluded as described below).
- pH measurements from the Foxton oxidation pond sludge were near neutral and within the range for both Grade A biosolids and NZ composting standards (pH 5.0-8.5). pH readings of this level pose no immediate risk to the receiving environment, or to plant health should the biosolids be used as a soil conditioner.
- The dry matter (DM) content for samples Foxton 2, Foxton 3 and Foxton 4 average 8% DM which is typical for a settled sludge within a pond. The dry matter content for Foxton 1 and Foxton 5 are high at 31% and 28% DM respectively. When considered with the ash contents of 87% for these two samples, it appears that the sample includes a high proportion of pond wall/base material or, in the case of Foxton 1 which is near the raw

wastewater inlet to the WWTP, additional contributions of inert material (sand and silt) from stormwater sources within the community's reticulation.

- Organic matter content of the samples was high for three out of five samples (Foxton 2, 3, and 4), and these were well above the minimum levels recommended in the NZ compost standards (>25 %).
- Total P levels are low, thus, there is limited risk of leaching and ground/surface water contamination from P.
- Total N was low in all samples and towards the bottom of what is often considered the 'normal' range for sludge (1-6%, Brett Robinson Pers. Comm.). This potentially reflects the age of the sludge (being older and more mature) and indicates that it is partly digested, posing less risk of vector attraction or odour.
- Low levels of nitrate-N (the most mobile form of nitrogen) were observed, combined with high C:N ratios which indicate low risk for leaching of N. The anoxic environment of sludge at the base of oxidation ponds is not expected to result in any oxidised forms of nitrogen being present in the sludge.
- Ammoniacal-N levels are high for three of the samples taken (Foxton 2, 3 and 4), and well above that expected for a mature compost (200-500 mg/kg), whilst the remaining two are within the expected range. Ammoniacal-N is the form of nitrogen used by plants so the high levels of ammonia in Foxton 2, 3 and 4 are an advantage if the sludge is to be used as a plant amendment. However, if the excess ammonia is not used by plants there is a risk it will be converted to more mobile forms of N (such as nitrate-N) through nitrification and subsequently leached to groundwater and/or surface water bodies.
- Overall the combination of low total N and nitrate-N and the high C:N ratio indicate that Foxton sludge is stabilised and poses little potential for leaching of nutrients if land applied, but the high levels of ammoniacal-N may require more intensive monitoring to assess whether the rate of conversion to nitrate is acceptable.
- Whilst cadmium and copper were above the recommended levels of metal contaminants for Grade A biosolids (NZWWA Biosolids Guidelines, 2003) in three samples (Foxton 2, 3 and 4), only two samples (Foxton 1 and 5) were over limits recommended for Grade B biosolids. If sludge from all five zones of the three oxidation ponds was combined, the dilution would bring the average cadmium and copper levels below the limits for Grade B biosolids so the biosolids would be classed as Grade B.
- The Foxton 3 and Foxton 4 samples had elevated Zn concentrations above 1,500 mg/kg dry wt (1,540 and 1,580 respectively). These levels are considered too high for land application; however, should all five zones from the three oxidation ponds be combined, the dilution factor would be sufficient to reduce the risk posed by Zn and levels would be below Zn limits for Grade B so the biosolids would be classed as Grade B.
- The inclusion of inorganic material in the Foxton 1 and Foxton 5 samples are likely to dilute the metals in the sludge and so should not be included in mass load calculations.
- Tests were not carried out on the bioavailability of these contaminant heavy metals, hence their potential uptake and concentration in plants and fate in the environment is unknown. However, previous research suggests that the pH of the Foxton sludges will not mobilise metals.
- Foxton 1, 2, and 3 showed relatively high levels of *E. coli*. These three samples were above the limits set for *E. coli* in Grade A biosolids so the biosolids would be classed as Grade B.
- The Foxton 4 sludge sample was collected from the second oxidation pond in the series where it has been observed that there is sludge carry over from the first pond. This may have contributed to the elevated organic matter, ammonia and metal concentrations.

4.2.2 Marton WWTP – Treatment Ponds

Results of the sludge survey of the Marton ponds are given in Table 4.3 and 4.4.

Table 4.3: Marton WWTP Sludge Volumes in Pond

Sample Name	Age of pond	Dimensions	Last de-sludged	Calculated volume of sludge based on LEI depth survey
Pond 1 - Marton 1 Marton 2 Marton 3 Marton 4	1974	5 ha x 2.7 m (approx.)**	Never de-sludged	Average depth to top of sludge 1.77 m Estimated volume of sludge 46,500 m^3 at 8% DM. **(3,720 t wt. dry solids*)**
Pond 2 – Marton 5 Marton 6	1974	2.5 ha x 1.6m	Never de-sludged	Average depth to top of sludge 1.56 m Estimated volume of sludge 1,050 m^3 at 8% DM **(84 t wt. dry solids*)**

*NB Calculations assume a weight to volume (density) ratio of 1, percent DM based on Marton averages excluding samples 6 as described below.
** measurements based on survey undertaken on 4th July 2017

The total volume of sludge in the Marton pond system is around 47,550 tonnes (3,840 dry tonnes). This is a large quantity which is a reflection of the age of the ponds, the size of the ponds and nature of the community, and the fact that these ponds have never been de-sludged.

Results of the sample analysis are given in Table 4.4

Table 4.4: Marton WWTP Sludge Quality Analysis Results

Parameter	Marton 1	Marton 2	Marton 3	Marton 4	Marton 5	Marton 6
pH	7.07	6.92	6.94	7.04	6.92	7.26
Organic matter (g/100g dry wt)	45	47	47	49	35	9.4
Dry Matter (g/100g as rcvd)	6.1	9.6	9.3	8.4	8.0	15.5
Ash (g/100g dry wt)	55	53	53	51	65	91
Total Phosphorus (g/100g dry wt)	0.69	0.57	0.87	0.94	0.37	0.21
Total Nitrogen (g/100g/dry wt)	2.7	2.9	2.9	2.7	2.6	1.43
Ammoniacal-N (mg/kg dry wt)	4700	2200	3600	4700	2300	440
Nitrite-N (mg/kg dry wt)	<9	<6	<6	<6	<7	<4
Nitrate-N (mg/kg dry wt)	<12	<7.2	<7.4	<8.3	<8.7	<4.4
Nitrate-N + Nitrite-N (mg/kg dry wt)	<9	<6	<6	<6	<7	<4
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$) (mg O_2/kg as rcvd)	760	630	690	690	570	1150
Total Carbon (g/100g dry wt)	23	28	26	25	21	10.8
C:N ratio	8.5	10	9	9	8	7.5
Escherichia coli (MPN/g)	17	33	23	70	11	2
Total recoverable metals (mg/kg dry wt)						
Arsenic (As)	63*	98*	27**	29**	52*	26**
Cadmium (Cd)	2.8**	3.9**	2.4**	2.4**	1.80**	1.04**
Chromium (Ch)	460	260	510	440	158	78
Copper (Cu)	580**	760**	570**	560**	380**	181**
Lead (Pb)	124	170	113	115	71	46
Mercury (Hg)	2.1**	3.1**	2.0**	2.3**	1.0	0.72
Nickel (Ni)	23	21	19	18	18	15
Zinc (Zn)	2100*	2500*	2100*	2100*	1030**	620**

** indicates value exceeds the limits as determined by the Biosolids Guidelines (2003) for Grade A biosolids
* indicates value exceeds the limit as determined by the Biosolids Guidelines (2003) for Grade B biosolids.

Notes:

- The total estimated wet volume of sludge in the two oxidation ponds at Marton is 47,550 tonnes at approximately 8 % DM (**3,804** dry tonnes, DM results from 6 is excluded as described below).
- pH measurements from the Marton oxidation ponds were near neutral and within the range for both Grade A biosolids and NZ composting standards (pH 5.0-8.5). pH readings of this level pose no immediate risk to the receiving environment, or to plant health should the biosolids be used as a soil conditioner.
- The dry matter (DM) content for Marton 1, 2, 3, 4 and 5 averaged 8 % DM which is typical for a settled sludge within a pond. The dry matter content for Marton 6 was slightly elevated at 15.5 %. It was noted that little sludge and some sand/stone was present in Sample 6, when considered with the ash contents of 91 % it appears that the sample included a high proportion of pond wall/base material or inert material (sand and silt) from

storm water sources and was therefore excluded from calculations for average DM of Martons pond sludge.

- Organic matter content of the samples was high in all except one sample (Marton 6), and above the minimum levels recommended in the NZ compost standards (>25 %). The low organic matter and high ash content of the Marton 6 sample is likely to be related to it having visibly more sand/stones rather than sludge in the sample.
- Nitrate, the mobile form of nitrogen, was low in all the samples, which is to be expected for the anoxic environment of sludge at the base of oxidation ponds.
- Ammoniacal-N levels are high for five of the samples taken (Marton 1, 2, 3, 4 and 5), well above that expected for a mature compost (200-500 mg/kg), whilst Marton 6 is within the expected range. Ammoniacal-N is the form of nitrogen used by plants so the high levels of ammonia is an advantage if the sludge is to be used as a plant amendment. However, if the excess ammonia is not used by plants there is a risk it will be converted to more mobile forms of N (such as nitrate-N) through nitrification and subsequently leached to groundwater and/or surface water bodies.
- Total N was low in all samples and towards the bottom of the 'normal' range for sludge (1-6 %). This reflects the age of the sludge (being older and more mature) and indicates that it is highly digested, posing less risk of vector attraction or odour.
- Total P levels are low, thus, there is limited risk of leaching and ground/surface water contamination from P.
- Low C:N ratios indicate that the nitrogen may be mobile with a risk of leaching. While the low C:N may indicate that mineralisation of N will occur, the actual levels of N (which are very low) do not suggest an adverse effect on the environment should it be applied to land or used as a soil conditioner.
- The levels of metal contaminants were variable between samples and are outlined below:
    - Elevated arsenic levels above Grade B limits for three out of six samples (Marton 1, 2 and 5) and the remaining three were above the limits for Grade A biosolids.
    - Cadmium and copper levels were above Grade A limits for all six samples (1 mg/kg and 100 mg/kg respectively) but remain below Grade B limits.
    - Mercury levels are above Grade A limits for four out of six samples (1 mg/kg) but do not reach Grade B limits for any samples.
    - Zinc levels in all six samples are elevated, with Marton 1, 2, 3 and 4 far exceeding levels recommended for Grade B biosolids (1,500 mg/kg). These samples all relate to Marton pond 1, indicating that the 46,500 tonnes of sludge in this pond is not suitable for re-use in its present form.
    - Tests were not carried out on the bioavailability of these contaminant heavy metals, hence their potential uptake and concentration in plants and fate in the environment is unknown. However, previous research suggests that the pH of the Marton sludges will not mobilise metals.
    - The levels of metal contaminants could be brought within Grade B or even Grade A limits by composting with green wastes or blending with sludge from other WWTP's.
- High metal levels in the sludge from Marton are likely indicative of the inclusion of leachate from Bonny Glen landfill into the treatment system as well as other trade waste contributions.
- All samples taken from the Marton oxidation ponds are below limits set for *E. coli* in biosolids (Grade A) and therefore suitable for land application.
- It is noted that a number of the parameters measured were different in Marton sample 6 compared to the other five samples. It is likely this is due to sampling zone 6 being the furthest from the WWTP inlet. The scientist sampling this pond noted that there was little sludge in this zoneand samples consisted of some sediment from the pond base.

4.2.3 Shannon and Tokomaru Geobags

Results of the sludge survey of the geobags are given in Tables 4.5 and 4.6. The dimensions of the geobags were estimated based on online mapping and aerial photography of the Tokomaru and Shannon WWTP sites. These values were used to approximate total sludge volumes. It should be noted that due to sloping sides and potential errors in dimensions, actual volumes may vary from that reported.

Table 4.5: Shannon and Tokomaru sludge volumes in geobags

Sample Name	Age of sludge	Dimensions	Calculated volume of sludge based aerial mapping analysis
Shannon geobags	1970-72 construction Removed from pond 2015	Three geobags 1 – 50m x 14m x 1m high 2 - 50m x 14m x 1m high 3 – 30m x 14m x 1m high	Estimated total volume of sludge 1,820 m^3 at 17.3 % DM (**315 t wt. dry solids***)
Tokomaru geobag	1970's construction Removed from pond in 2016	50m x 14m x 1m high	Estimated total volume of sludge 700 m^3 at 40 % DM (**280 t wt. dry solids***)

*NB Calculations assume a weight to volume (density) ratio of 1, percent DM based on Marton averages excluding samples 6 as described below.

The total volume of sludge stored in geobags is estimated to be 2,520 m^3. Results of the sample analyses are given in Table 4.6.

Table 4.6: Shannon and Tokomaru Sludge Quality Analysis Results

Parameter	Tokomaru composite	Shannon composite
pH	5.76	5.26
Organic matter (g/100g dry wt)	12.2	34
Dry Matter (g/100g as rcvd)	40	17.3
Ash (g/100g dry wt)	88	66
Total Phosphorus (g/100g dry wt)	0.12	0.20
Total Nitrogen (g/100g/dry wt)	0.47	1.21
Ammoniacal-N (mg/kg dry wt)	310	370
Nitrite-N (mg/kg dry wt)	<1.2	<3
Nitrate-N (mg/kg dry wt)	<1.7	<4
Nitrate-N + Nitrite-N (mg/kg dry wt)	<1.2	3
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$) (mg O_2/kg as rcvd)	570	1,390
Total Carbon (g/100g dry wt)	4.5	11.8
C:N ratio	10	10
Escherichia coli (MPN/g)	5	2
Total recoverable metals (mg/kg dry wt)		
Arsenic (As)	5	6
Cadmium (Cd)	0.42	0.71
Chromium (Ch)	22	38
Copper (Cu)	186**	460**
Lead (Pb)	28	93
Mercury (Hg)	0.21	0.47
Nickel (Ni)	15	18
Zinc (Zn)	220	510**

** indicates value exceeds the limits as determined by the Biosolids Guidelines (2003) for Grade A biosolids
* indicates value exceeds the limit as determined by the Biosolids Guidelines (2003) for Grade B biosolids.

Notes:

- The total estimated wet volume of sludge at the two geobag sites is 2,520 m^3 and when DM is taken into account the total volume of dry sludge is 595 tonnes.
- pH measurements from the Tokomaru and Shannon geobags were slightly acidic but still within the range for both Grade A biosolids and NZ composting standards (pH 5.0-8.5). pH readings of this level are considered safe for the receiving environment and plant health.
- Organic matter content of the Tokomaru geobag was low whilst Shannon was above the minimum levels recommended in the NZ compost standards (>25).
- The elevated dry matter (DM) for the geobag samples is indicative of the water removing capacity of geobagging. However, when combined with the elevated ash contents of these samples it suggests that the sludges include a high proportion of pond wall/base material and/or contributions of sand and silt from stormwater sources

within the community's reticulation. It should be noted that while 40 % DM of the tokomaru geobag sludge is surprisingly high, it is unlikely to have resulted from sampling error given it was based on three separate samples from the same geobag.

- Total N was very low in both Tokomaru and Shannon sludge samples, with Tokomaru having an N content below the 'normal' range for sludge (1-6 %). This reflects the age of the sludge (being older and more mature), its elevated inorganic (silt) content, and indicates that it is highly digested (stabilised), posing less risk of vector attraction or odour.
- Low levels of nitrate (the most mobile form of nitrogen) were observed indicating low risk for leaching of N.
- Ammonia levels are within the range expected for a mature compost (200-500 mg/kg), indicating the sludges are stable.
- Total P levels are very low, thus, there is limited risk of leaching and ground/surface water contamination from P.
- Low C:N ratios indicate that the nitrogen may be mobile with a risk of leaching. While the low C:N may indicate that mineralisation of N will occur, the actual levels of N (which are very low) do not suggest an adverse effect on the environment should it be applied to land or used as a soil conditioner.
- Metal contaminants measured in the Tokomaru and Shannon sludge samples were below limits for Grade B biosolids (NZWWA, Biosolids Guidelines, 2003) although Cu and Ni were found to exceed that required to meet Grade A.
- Both Tokomaru and Shannon sludge samples are below limits set for *E. coli* in biosolids (Grade A).

4.3 Evaluation of Sludge Volume and Quality

Total dry mass of sludge was calculated using the total estimated sludge volume and percent dry matter (Table 4.7.). These values were subsequently used to estimate total mass of N, P, As and Zn at each site.

Table 4.7: Nutrient and Contaminant Mass Loads

	Dry mass of sludge (t wt.)	N mass (kg)	P mass (kg)	As mass (kg)	Zn mass (kg)
FWWTP	**2,055**	**28,377**	**3,434**	**28**	**1,935**
Pond 1	1,678	21,478	2,738	23	1,493
Pond 2	243	5,103	535	4	384
Pond 3	134	1,796	161	1	58
MWWTP	**3,804**	**105,853**	**28,795**	**204**	**8,253**
Pond 1	3,720	104,160	28,551	201	8,184
Pond 2	84	1,693	247	3	69
Shannon	**315**	**3,812**	**630**	**2**	**161**
Tokomaru	**280**	**1,316**	**336**	**1**	**62**

Only As and Zn mass has been included in this table since these are the only heavy metal contaminants which were measured above (exceeding) the biosolids Grade "b" guideline limit. In this situation, the mass load of these metals may be limiting for a discharge to land, however for any metal which is below the "b" guideline limit the nitrogen content of the material will be the most limiting parameter for a discharge to land.

4.4 Accumulation of Sludge in Ponds

An attempt was made to extrapolate the data obtained from the quantitative results to determine an accumulation rate for sludge. Total pond sludge volumes from Foxton and Marton were combined with population and age since the last de-sludging to approximate accumulation rates. Sludge solids (8 % DM) were found to accumulate at the rate of 289 (Foxton) and 276 (Marton) kg per person per year with 81 and 98 % of this sludge located in the first pond in the treatment system (Foxton and Marton respectively). Sludge accumulation rates are variable and appear to be influenced by:

- Whether a pond has ever been desludged – the per hectare volume of accumulated sludge in a pond which has never been desludged is lower than a recently (last 15 years) desludged pond, most likely due to mass wasting;
- Where the pond comes in the treatment train – the first pond typically has a higher accumulation of sludge than subsequent ponds (81 and 98 % of the sludge at Foxton and Marton (respectively) was found in the first pond of the treatment system), and the contents are potentially more inert closer to the inlet;
- The total population the oxidation pond system services;
- The amount of trade waste received to the pond. High levels of trade waste may elevate sludge accumulation rates. This is likely due to many factors including inhibition of microbial breakdown by contaminants. The same relationship may not be present where the origin of the trade waste is more organic based e.g. meatworks waste.

4.5 Conclusions

The sludges collected from Foxton, Marton, Tokomaru and Shannon were low in total N, P and nitrate-N. There were higher levels of ammoniacal-N in the Foxton and Marton pond sludges compared to the lower levels from the Tokomaru and Shannon geobags, potentially indicating that the geobag sludges have been stabilised to a greater degree. All of the sludges offer nutrient value in the form of ammoniacal-N at levels adequate for a plant amendment. However, the excess ammoniacal-N in the Foxton and Marton sludges may pose a risk of being converted to more mobile forms of N through nitrification if not utilised by plants.

None of the sludge samples tested met criteria for Grade A biosolids because of elevated metal levels. All of the samples tested from pond one at Foxton also did not meet criteria for Grade B biosolids based on elevated zinc. The same applied to Marton A and E sludges, due to elevated concentrations of various metals. However, the levels of metal contaminants could be brought within Grade B, or even Grade A limits, by mixing with sludges from the whole pond system, composting with green wastes or blending with material with lower contaminant concentrations, including sludge from other WWTP's.

Where pond systems are in a series, (Foxton and Marton), there is clearly a difference in sludge quality between the different ponds, as well as different areas of the pond (points in the treatment train). In most cases, the sludge quality close to the inlet is poorer compared to sludge further along the system. This is due to more rapid deposition of contaminants in the initial sections of a pond system where much of the contaminants settle into sludge. Sediment from stormwater sources within the community's reticulation appears to be a factor in elevating ash and dry matter concentrations of sludge.

There is also a marked difference between sites, with higher overall metal contaminants in the Marton sludges. This is most likely attributable to the inclusion of leachate from Bonny Glen landfill into the Marton treatment system. Contaminants at Foxton, Shannon and Tokomaru are likely to be from domestic and agroindustrial sources.

Tokomaru and Shannon geobag sludges were within guideline limits for Grade B biosolids and could be used under restrictions for Grade B in its current state (e.g. land application). Foxton and Marton pond sludges require further treatment and stabilisation (e.g. composting) to dilute contaminants such as metals and reduce ammonium levels before beneficial re-use (e.g. land application or use as a soil amendment).

The notable difference between sites with respect to contaminant loads highlights the importance of considering the source of wastewater when assessing sludge quality. Proper assessment of trade waste contribution, and consideration of its influence over sludge quality is essential and should be taken into account when considering re-use or any potential biosolids strategy. It is likely that the risks presented by these factors could be minimised by composting sludge with green wastes or combining sludge from multiple sites or blending.

5 REGIONAL NATIONAL STATEMENT ON OXIDATION POND SLUDGE AND CHARACTERISTICS

5.1 Regional Data on Sludge Volumes in New Zealand

To be able to extrapolate the information gathered from the site investigations and field visits at Foxton, Marton, Tokomaru and Shannon, to give a picture of the sludge quality and quantity in the whole region, information on pond age and size in the other districts is required.

A questionnaire (Appendix B) was developed by the Project Team to collect the required information, Members of the Technical Group were contacted via email with follow-up phone calls if required. The members of the Technical Group and their contact information are given in Appendix C.

Where necessary, further information was gathered from external parties such as consultancies.

Detailed summary tables of the information is given in Appendix C.

A brief summary of the information obtained is as follows:

- For many councils, information on pond size, pond age and when (if) the pond has been emptied was difficult to obtain.
- There are approximately 62 oxidation ponds identified in the region, most of which are over 30 years old and have never been de-sludged.
- Approximately 11 of these oxidation ponds require de-sludging in the next five years.
- Of the 11 pond systems needing de-sludging at least two have significant trade waste inputs and it is likely the sludge will require further treatment/blending before beneficial use to manage the contaminants.

5.2 National Statement on Sludge Volumes in New Zealand

A stocktake of sludge volumes residing in oxidation ponds is not included in national waste management surveys prepared by WaterNZ. This Gaps Analysis aimed to provide more information about sludge volumes and quality in oxidation ponds within the region surveyed, this information can then be extrapolated to a nationwide scale.

There are up to 200 waste treatment pond systems in New Zealand. Many likely contain large quantities of sludge, have never been desludged and will require sludge management within five years. A lack of information available makes predicting total quantities of sludge difficult, however, based on the results from our quantitative surveys at Foxton, Marton, Tokomaru and Shannon there may be upwards of 4,000,000 tonnes of sludge (at 8 % DM) residing in these ponds. While this does not require management at one time, it will need to be managed over time.

The quality of the sludge in these oxidation ponds is likely to be highly variable. If the WWTP's have minimal trade waste inputs, pond sludge is likely to meet Grade B levels for the presence of heavy metals and can be potentially beneficially re-used with no or minimal further processing. Sludge quality is also dependent on where the sludge is in the treatment train; with sludges at the beginning of the treatment system having a lower quality and requiring further treatment before beneficial re-use. Sludges at the end of the treatment train are of a higher quality and could be beneficially used without further treatment.

There are real options for beneficial re-use of sludge in oxidation ponds. For those lower grades sludges, further stabilised through composting with green-waste and blending sludges of different quality has the potential to produce higher value products that can be used as soil conditioners.

6 CONCLUSIONS

This report undertook a quantitative study to collect information on volumes and characteristics of sludge in the oxidation ponds in the study region. Site investigations were carried out at four sites: Foxton, Marton, Tokomaru and Shannon where sludge was collected and analysed for a variety of physical, chemical and biological characteristics.

A summary of the information obtained from these investigations is as follows:

- WWTP's that receive trade or industrial wastes are likely to have significantly higher sludge concentrations of metal contaminants, in this case zinc was elevated in Foxton and all metals were elevated in Marton when compared to Tokomaru and Shannon. For pond sludges in Marton and Foxton, zinc levels may limit beneficial re-use options without further treatment of the sludge (e.g. composting with green waste or blending with other WWTP sludge to dilute the metals).
- Differences in sludge quality were found between oxidation ponds depending where the pond was in the treatment sequence. Ponds at the beginning of the treatment train had higher organic matter, ammonia and heavy metals.
- Wastewater inputs into Tokomaru and Shannon ponds are mainly residential; with sludge from these ponds having levels of heavy metals that meet current Biosolids guideline limits for grade Grade B biosolids and could be used in their current form with resource consents (e.g. land application).
- Levels of copper are similar between oxidation pond sludges suggesting that copper inputs are mainly domestically sourced.
- Ponds sludges that have been geobagged are more stable than sludges accumulated and stored in oxidation ponds.
- Ponds in geobags contain less water than oxidation pond sludges indicating that the use of geobags to de-water oxidation pond sludge is successful.

This study indicates that if WWTPs have minimal trade waste inputs, sludge is likely to meet Grade B levels for the presence of heavy metals. In addition, geobags may be cost-effective sludge management option as they appear to be able to dewater **and** further stabilise pond sludge to a point where it could be beneficially re-used after 18 months in bags.

Sludge quality is dependent on where the sludge is located in the treatment train. Sludges at the beginning of the treatment system have a lower quality and will require further treatment before beneficial re-use. Sludges at the end of the treatment train (e.g. Pond 3 at Foxton) are of a higher quality and could be beneficially used without further treatment.

Further qualitative information gathered through surveys and interviews with partner council members indicated that many oxidation pond systems in the region are old (more than 30 years) and have never been de-sludged. Approximately 11 oxidation ponds in the region require management in the next five years, and at least two of these have significant trade waste inputs, likely to require further sludge treatment/blending before beneficial use would be possible.

The WaterNZ national waste management survey estimates there is approximately 320,000 tonnes of sludge (at 20% dry solids) produced annually in New Zealand. This does not include sludge currently residing in oxidation ponds. Our estimates show that there may be up to 4,000,000 tonnes of sludge stored in oxidation ponds throughout New Zealand, with a large proportion requiring management within five years, in particular that located in smaller communities WWTP.

Identify the next steps:
Collation of background information in Stage 1: Gaps analysis has determined that the scale of the sludge problem in the region is significant with a large volume of sludge to be managed over the next five years. Although there are similarities between districts there are also some key differences. For example, most districts have oxidation pond sludge to manage, but some have recently de-sludged their ponds, whereas for others de-sludging is an urgent issue. Based on the information collated in the Stage 1.1 Gaps analysis, we will work with the partner councils to determine the feasibility of them working together to manage biosolids and develop a collective strategy.

7 APPENDICES

Appendix A: Chemical, physical, and biological analyses of sludge samples
Appendix B: Contact details for Project Technical Group
Appendix C: Qualitative data collected on pond size, volume and age

APPENDIX A

Chemical, physical, and biological analyses of sludge samples

TABLE A.1: Chemical, physical, and biological analyses of sludge samples

Parameter	Foxton A	Foxton B	Foxton C	Foxton D	Foxton E	Marton A	Marton B	Marton C	Marton D	Marton E	Marton F	Tokomaru	Shannon
pH	7.19	7.11	7.11	7.14	7.17	7.07	6.92	6.94	7.04	6.92	7.26	5.76	5.26
Organic matter (g/100g dry wt)	64	44	12.6	12.6	72	45	47	47	49	35	9.4	12.2	34
Dry Matter (g/100g as rcvd)	6.8	9.8	31	28	7.4	6.1	9.6	9.3	8.4	8.0	15.5	40	17.3
Ash (g/100g dry wt)	36	56	87	87	28	55	53	53	51	65	91	88	66
Total Phosphorus (g/100g dry wt)	0.26	0.22	0.095	0.12	0.22	0.69	0.57	0.87	0.94	0.37	0.21	0.12	0.20
Total Nitrogen (g/100g dry wt)	1.59	1.92	0.32	1.34	2.1	2.7	2.9	2.9	2.7	2.6	1.43	0.47	1.21
Ammonium-N (mg/kg dry wt)	1,720	1,230	420	240	1,820	4700	2200	3600	4700	2300	440	310	370
Nitrite-N (mg/kg dry wt)	<8	<5	<1.6	<1.7	<7	<9	<6	<6	<6	<7	<4	<1.2	<3
Nitrate-N (mg/kg dry wt)	<11	<7.1	<2.2	<2.4	<9.5	<12	<7.2	<7.4	<8.3	<8.7	<4.4	<1.7	<4
Nitrate-N + Nitrite-N (mg/kg dry wt)	<8	<5	<1.6	<1.7	<7	<9	<6	<6	<6	<7	<4	<1.2	3
Carbonaceous Biochemical Oxygen Demand ($cBOD_5$) (mg O_2/kg as rcvd)	730	750	980	730	650	760	630	690	690	570	1150	570	1390
Total Carbon (g/100g dry wt)	42	35	5.8	28	51	23	28	26	25	21	10.8	4.5	11.8
C:N ratio	26	18	18	21	24	8.5	10	9	9	8	7.5	10	10
Escherichia coli (MPN/g)	540	5400	920	33	23	17	33	23	70	11	2	5	2
Total recoverable metals (mg/kg dry wt)													
Arsenic (As)	19	20	4	8	18	63	98	27	29	52	26	5	6
Cadmium (Cd)	1.37	1.21	0.12	0.33	1.39	2.8	3.9	2.4	2.4	1.80	1.04	0.42	0.71
Chromium (Ch)	28	36	9	12	24	460	260	510	440	158	78	22	38
Copper (Cu)	250	220	28	69	260	580	760	570	560	380	181	186	460
Lead (Pb)	58	54	8.4	15.6	47	124	170	113	115	71	46	28	93
Mercury (Hg)	0.85	0.52	<0.10	0.14	0.59	2.1	3.1	2.0	2.3	1.0	0.72	0.21	0.47
Nickel (Ni)	10	11	8	9	11	23	21	19	18	18	15	15	18
Zinc (Zn)	1540	970	155	430	1580	2100	2500	2100	2100	1030	620	220	510
Sampling Procedures													
Date sampled	22/06/17	22/06/17	22/06/17	22/06/17	22/06/17	04/07/17	04/07/17	04/07/17	04/07/17	04/07/17	04/07/17	22/06/17	22/06/17
Depth – surface water to sludge (mm)	1200, 1250, 900	1250, 900, 900	1200, 900, 900	1750, 1800, 1800, 1800, 1800	1500, 1600, 1600, 1700, 1700	2700, 1500, 1600	1500, 1500, 1800	1500, 1600, 1850	2200, 2000, 1500	1900, 1500, 1700,	1550, 1600, 1500	n/a	n/a
Age of pond/sludge	1974			1997	1997	1974				1997		1972	1970's
Dimensions	4.6 ha x 1.5 m deep			0.8 ha x 1.8 m^1 deep	0.8 ha x 1.8 m^1 deep	5 ha x 2.7 m^1 deep				2.5 ha x 1.6m^1 deep		14m x 50m x 1m^1	1 – 14m x 50m x 1m^1 2 - 14m x 50m x 1m^1 3 – 14m x 30m x 1m^1
Comments		Sample looked watery	More solids than B	Most solid, sand content indicates pond base.		30cm core of mostly soft sludge					Little sludge, sand and silt indicate pond base	Three sampling ports, one with sock two open	Three geobags. Sampled one port per bag.

APPENDIX B

Contact details for Project Technical Group

Table B.1: Contact details for Project Technical Group

Affiliation	Name	Title	Email	Landline	Mobile
Manawatu District Council/ Rangitikei District Council	Chris Pepper	Senior Project Engineer	Chris.Pepper@mdc.govt.nz	06 323 0000	029 2014836
Tararua District Council	Dave Watson	Utilities Manager	dave.watson@tararuadc.govt.nz	06 374 4099	027 451 8639
Whanganui District Council	Arno Benadie	Senior Wastewater Engineer	arno.benadie@whanganui.govt.nz	06 349 0001	027 2896484
Masterton District Council	Phil Evans	Senior Advisor Waste Water Strategy and Compliance	philipe@mstn.govt.nz	06 3706284	0276720211
Kapiti Coast District Council	Glen O'Conner	Solid Waste Services Manager	glen.Oconnor@kapiticoast.govt.nz	04 2964 739	0275555739
Horowhenua District Council	Ryan Hughes	Engineering Officer	RyanH@horowhenua.govt.nz	06 366 0999	
Ruapehu District Council	Anne-Marie Westcott	Environmental Manager	annem@ruapehu.govt.nz	07 895 8188	
Horizons Regional Council	Robert Rose	Consents Monitoring Officer	robert.rose@horizons.govt.nz	06 9522862	0212477341
Palmerston North City Council	Phil Burt	Waste Asset Engineer	Phil.burt@pncc.govt.nz	06 356 8199	0264 837 082

APPENDIX C

Qualitative data collected on pond size, volume and age

Table C.1: Manawatu and Rangitikei District Pond Systems

Name	Population	Age of pond	Dimensions of pond	Volume of pond	Last de-sludged
Rongotea	600	2 ponds 1978 - 39 years	55m x 55m x 1.5 m 30m x 30m x 1.5m	4,537 m^3 1,350 m^3	2015
Kimbolton	200	1984 - 33 years	40m x 40m x 1.5m	2,400 m^3	never
Cheltenham	90	1984 - 33 years	22m x 22m x 1.5m	726 m^3	never
Awahuri	35	1985 - 32 years	36m x 12m x 1.5m	648 m^3	never
Sanson	540	2 ponds 1973 - 44 years	55m x 55m x 1.5m 55m x 20m x 1.5m	4,537 m^3 1,650 m^3	Never - needs de-sludging.
Ohakea	249 residents and up to 950 non-residents		Pasveer Ditch – 62m x 17m wide oval, 5m wide ditch Clarifier – 6 m diameter	Pasveer Ditch – 390 m^3 Clarifier volume unknown	Removed on regular basis to landfill
Halcombe	534	2 ponds 1977 - 40 years	40m x 40m x 1.5 m 40m x 20m x 1.5 m	2,400 m^3 1,200 m^3	2015
Duddings Lake	No permanent population				
Bulls	1,500	2 ponds 1974 – 43 years	Pond 1 – 1.98 ha x 1.5 m Pond 2 – 1.65 ha x 1.9 m	Pond 1 – 35,400 m^3 Pond 2 – 29,000 m^3	2016
Marton	4,000 but due to trade waste pop eqv. 20,000	Pond 1 1974 – 43 years Pond 2 - 1974	Pond 1 - 5 ha x 2.7 m Pond 2 - 2.5 ha x 1.6 m	Pond 1 – 135,000 m^3 Pond 2 - 40,000 m^3	Never
Koitiata	105, seasonally over 250	1986 – 31 years	0.0625ha, unknown depth	813 m^3	Never
Ratana	327	2 ponds 1979 – 38 years	Combined pond area 0.0853ha , unknown depth		Never
Hunterville	450	2 ponds 1977 – 40 years	Combined pond area 0.0853ha, unknown depth		Never
Taihape	1,670	1 pond 1976 – 41 years	3.2ha, unknown depth		Never

Notes: Of the 13 plants in the Rangitikei-Manawatu districts five likely have minimal sludge accumulated in ponds (Kimbolton, Cheltenham, Awahuri, Duddings Lake and Koitiata), and one has sludge removed offsite on a regular basis (Ohakea). Two of the remaining ponds were de-sludged two years ago (Halcombe and Rongotea) and one in 2016 (Bulls), whilst the remaining four have never been de-sludged (Sanson, Marton, Ratana and Taihape). All four are likely to require de-sludging within five years.

Table C.2: Tararua District Pond Systems

Name	Population	Age of pond	Dimensions of pond	Volume of pond	Last de-sludged
Dannevirke	5043	1976 – 41 years	Six ponds- 4.58ha, 2.42ha, 1.9ha, 0.64ha The ponds have been de-sludged, reshaped & lined in the last two years.		2014,2015,2016,2017
Pahiatua	2,500	1974- 43 years	Pond 1- 1.3ha Pond 2- 1.3ha Pond 3- 1.5ha	25659m^3 22267m^3 25169m^3	2002--2003. In sludge cells on site.
Woodville	1,401	1971- 40 years	Pond 1- 1.74ha Pond 2- 1.15ha Maturation pond 1- 0.214ha Maturation pond 2- 0.1183ha Unknown depths	35821m^3 18307m^3 3216m^3 1774m^3	Pond 1 desludged - 2008-2009
Norsewood	330	unknown	2 ponds Only grey water goes into these ponds, properties all have individual septic tanks.	4262m^3 1981m^3	n/a
Ormondville	422	unknown	2 ponds Only grey water goes into these ponds, properties all have individual septic tanks.	2836m^3 1364m^3	n/a
Eketahuna	441	unknown	Pond 1- 0.3352ha Pond 2- 0.1133ha Unknown depth	6033m^3 2039m^3	2016
Pongaroa	300	unknown	2 ponds Only grey water goes into these ponds, properties all have individual septic tanks. Pond 1- 0.2414ha Pond 2- 0.1033ha Unknown depth	4345m^3 1859m^3	n/a

Notes:

Only two ponds in the Tararua District are likely to contain sludge (Woodville and Pahiatua). Three of the other locations are primarily on septic tank systems with ponds only receiving grey water (Norsewood, Ormondville, Pongaroa) and two sites have recently been de-sludged (Eketahuna and Dannevirke).

Table C.3: Horowhenua Oxidation Pond Systems

Name	Population	Age of pond	Dimensions of pond	Volume of pond	Last de-sludged
Foxton Beach	1,641	1981 – 36 years	100m x 92m, 1.49m	13,708m^3	2013
Foxton	2,500	1974			Never
Shannon	1,500	1972	2.67ha, 0.9m deep	24,030m^3	2015 – in geobags
Tokomaru	552	1970's	80m x 40m, Unknown depth	Unknown at this stage	2016 – in geobag onsite
Waitarere Beach	585 permanent but summer population 2,000	1987	27m x 27m (at the top, 20m x 20m at the bottom), 1.5m depth	Roughly 750m^3	2013-2014

Notes:
Only the Foxton WWTP oxidation ponds in this District are in need of de-sludging, and this is programmed to occur in the next year or two. Levin WWTP generates sludge which is landfilled on a weekly basis. The Shannon and Tokomaru WWTP's have removed sludge currently being stored and de-watered in geobags onsite at the Tokomaru and Shannon WWTP's.

Table C.4: Masterton District Sludge Volumes

Name	Population	Age of pond	Dimensions of pond	Volume of pond	Last de-sludged
Homebush (Masterton)	25,000	2013 – 4 years	26.14ha	766,000m^3	Never
Riversdale	seasonal	2010 – 7 years	2ha	35,000m^3	Never
Castlepoint	197 (seasonal)	2005 (?)	0.16ha	2,800m^3	Unknown
Tinui	150	2007 – 10 years	0.20ha	3,000m^3	Unknown

Notes:
Relatively young ponds in the District. Most have never been de-sludged or it is unknown whether they have been. It is unlikely that Riversdale, Castlepoint or Tinui will need de-sludging in the next five years due to small populations and ponds less than 10 years old. The newer, recently built ponds at Homebush are not likely to require de-sludging soon.

Table C.5: Ruapehu District Sludge Volumes

Name	Population	Age of pond	Dimensions of pond	Volume of pond	Last de-sludged
National Park	240	No data	Pond 1 – 9,727 m^2 Pond 2 – 6,019 m^2		Never
Ohakune	1,500	No data	Pond 1 – Approximately 30,716 m^2 Pond 2 – Approximately 3,126 m^2		Never
Raetihi	749	No data	Pond 1 – Approximately 11,664 m^2 Pond 2 – Approximately 8,109 m^2 Pond 3 – Approximately 450 m^2		Never
Rangataua	1,344 (2006 data)	No data	Approximately 15,791 m^2		Never
Taumarunui	4,870	No data	Pond 1 – Approximately 4,723 m^2 Pond 2 – Approximately 4,783 m^2		Never

Notes:

These results are estimations only, due to the lack of information provided, and as such are unlikely to be accurate but do provide an indication of the size of ponds in the region. We have no data on the age of the ponds, but none have ever been desludged. Most of the locations have small population sizes and are likely to accumulate sludge at a low rate and are unlikely to require desludging within 5 years.

Table C.6: Kapiti Coast District Sludge Volumes

Name	Population	Age of pond	Dimensions of pond	Volume of pond	Last de-sludged
Ōtaki	6,000	n/a	n/a	n/a	2014
Paraparaumu	49,000	15-24 years old	Six ponds at Paraparaumu WWTP contain historical storage of sludge Ponds - S2 and P1-P5	unknown	Never

Notes:

The ponds at Otaki WWTP were de-sludged 3 years ago, Otaki ponds are used for processing the liquid content only, as the primary sludge is now processed by clarifier and then centrifuged to 6% DS. This is transported by tanker to the Paraparaumu WWTP and processed with the inlet flow. Sludge at Paraparaumu WWTP is currently transported to Silverstream landfill on a regular basis, however, historical storage of sludge from 1993-2002 is remaining in six oxidation ponds on site. These ponds contain a total of 7,300 m^3 (wet) in need of disposal. In 2012 these sludges were determined to be mature and suitable for removal with an average 61% solids and 16% volatile solids. All heavy metals were well below biosolids guideline limits.

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