# Appendix 19: Kinleith Discharge

## 1. Introduction

The Kinleith pulp and paper mill, south of Tokoroa, is operated by Carter Holt Harvey Ltd (CHH). The mill is consented to discharge treated wastewaters into Lake Maraetai. The discharge causes a discernable change in water colour of the lake and for some distance downstream and this discolouration has been identified by river iwi and the wider community as being a cause for concern (NIWA et al., 2009).

As part of their resource consent, CHH Kinleith is required to monitor the mill's wastewater discharge into the Waikato River and report the results to Environment Waikato (EW). They are also required to investigate and report on the feasibility and costs associated with improving the quality of the discharge (Environment Waikato, 2006).

Colour is a property of the effluent and is defined as the absorption of light at a specific wavelength in a filtered effluent sample. It is commonly expressed as platinum cobalt units (PCU) either as a concentration or a mass load (kg/d).

The colour of pulp and paper mill effluents originate in the wood handling, chemical pulping and bleaching, and papermaking processes and is due to tannin and lignin compounds in the wood. The majority of colour is produced in the chemical pulping and bleaching stages where the lignin in the wood is separated from the cellulose fibre. In the kraft pulping process, under alkaline conditions at high temperature and pressure, the lignin is solubilised and removed from the wood chips. These dissolved solids form highly coloured spent liquor called black liquor. This black liquor is washed from the pulp in subsequent washing stages and is collected and returned to the recovery cycle. The majority of the black liquor is typically recovered and reused in the process and does not enter the effluent system, although a small quantity is lost routinely. In addition, intermittent discharges and spills can occur.

Some residual black liquor remains with the pulp entering the bleach plant along with residual lignin inside the fibres that has not been removed in pulping. In the bleach plant the pulp is treated in a series of stages, called a bleach sequence. The dominant colour discharged from the bleach plant is the caustic extraction stage. Because of the chloride content of the caustic extraction and its corrosive nature this stream is generally not recovered.

Table 1 summarises the trends in the quality of the discharge from the Kinleith Mill from 2001 to 2008 and planned future improvements for discharge quality.

CHH state that a 50 percent reduction in colour discharged from Kinleith was achieved in the late 1990s prior to the granting of their current consent.  Much of the improvement was achieved by the introduction of oxygen delignification and improved post-oxygen washing.

**Table 1:** Summary of Kinleith wastewater discharge characteristics from 2001–2008, based on CHH (2009).

| Parameter | Monitoring Results | Consent Conditions | Consent compliance | Improvements During 2001-2008 | Planned Improvements |
|---|---|---|---|---|---|
| Flow ($m^3$/day) | Mean - 87,600<br>Max - 151,000 | Mean - None<br>Max - 165,000 | Consent conditions have never been exceeded. Very slight downward trend in discharge over the period. | A 20% reduction in discharge flow has been achieved when compared to production of the plant. A 50% reduction in discharge flow volume (not linked to production) has been achieved since 1990. These improvements have been achieved through reclaiming various process waters and other process improvements. This has increased the hydraulic retention time of the treatment and led to improvements in the levels of BOD, TSS and nutrients discharged. | Investigating future projects which would further decrease wastewater volumes by approx 5million L/day (involve reuse of water). The more feasible gains have already been achieved. |
| Biological Oxygen Demand (BOD) (tonnes/day) | Mean - 2.8<br>Max - 12.1 | Mean - 2.5<br>Max - 6.0 | The mean BOD reading exceeds the consent limit. Significant improvements have been made to BOD discharge over the period and BOD has reduced accordingly. Latest rolling mean shows consent compliance. | Addition of phosphorus and oxygen to the treatment process has addressed the nutrient imbalance and improved removal of BOD. CHH identified BOD as one area where significant improvements could be made easily. Process changes are aimed at directing flows with high organic loads to the recovery circuit. CHH has undertaken a number of process changes and improvements to the treatment process to improve BOD removal. | Future projects will focus on improving mill discharge to the treatment process. |
| Total Suspended Solids (TSS)<br>(tonnes/day) | Mean - 5.9<br>Max - 16.6 | Mean - 7.0<br>Max - 14.0 | The mean consent limit has not been exceeded since 2004. The extreme limit has been exceeded 4 times, but not since 2003 and the consent conditions have never actually been violated. | Addition of phosphorus and oxygen to the treatment process has addressed the nutrient imbalance and improved removal of TSS. Process changes and improvements have been made to improve TSS removal. | Ongoing improvements to hydraulic retention time and monitoring are expected to yield some improvements. |

**Table 1 (cont):**

| Parameter | Monitoring Results | Consent Conditions | Consent compliance | Improvements During 2001-2008 | Planned Improvements |
|---|---|---|---|---|---|
| Colour<br>(tonnes/day) | Mean - 35<br>Max - 75 | Mean - 75<br>Max - 140 | Consent conditions have never been exceeded. No significant improvement has been made in the period, however CHH state that they have managed to reduce colour significantly prior to 2001. | No improvement has been made in the monitoring period, but between 1996 and 2001 an approx 50% reduction of colour load was achieved (while mill output increased significantly). Projects undertaken to reduce colour load relate to the mill processes and include pulp washing improvements, black liquor improvements and improvements to bleaching. | CHH is keeping abreast of emerging technologies to reduce colour loads. It is also expected that improvements could be achieved through reducing black liquor discharge to the treatment process. |
| Total Nitrogen (TN)<br>(kg/day) | Mean - 431<br>Max - 728 | Mean - 600<br>Max - 750 | Consent conditions have never been exceeded. There has been a downward trend in TN discharged over the period. | No significant improvements to total nitrogen have been achieved, due to the need to maintain a nutrient balance in the treatment process. | Ongoing improvements to hydraulic retention time and monitoring are expected to yield some improvements. |
| Total Phosphorus (TP)<br>(kg/day) | Mean - 52<br>Max - 97 | Mean - 62<br>Max - 75 | The mean consent limit has never been exceeded. The extreme limit has been exceeded three times, most recently in 2005. There has been a steady increase in the discharge of TP since 2004. | The amount of phosphorus has increased. This is due to the addition of phosphorus to the treatment process that has brought about improvements in the removal of BOD and TSS. | Ongoing improvements to hydraulic retention time and monitoring are expected to yield some improvements. |

The composition and concentration of colour in the effluent stream of a pulp and paper mill is affected by differences in raw materials, wood type, process water characteristics, process lines, and operating regimes. The colour of effluent produced by a particular mill will be specific to their production line or processing technology, or an interaction of several processes. The exact nature of the discharge and cause of the colour is therefore likely to be unique to a particular mill and one treatment process is unlikely to provide a solution for all mill discharges.

Recently the CHH and Norkse Skog Tasman mills[1] at Kawerau renewed their wastewater discharge consents. As part of that process extensive reviews of colour removal technologies, costs and feasibility were undertaken. The capital and operating costs were calculated as was the likely colour reduction that would be achieved.

In assessing the probable cost to reduce Kinleith's colour load to the river reference has been made to reports and evidence presented in the Environment Court relating to the appeal against the CHH and Norske Skog Tasman mill discharges. Key references included Beca AMEC (2008), Beca AMEC (2009), and Johnson (2009 and 2010).

The Kinleith mill will have differences in the process configuration, the raw material inputs and the nature of the colour and the volume of wastewater compared to the Tasman mills (e.g., see Table 2 comparing flow and colour). However the costs generated for Tasman may be used to give an approximate order of magnitude of costs to treat Kinleith's colour (assuming similarities in production and mill age). More accurate cost estimates for the Kinleith plant would require a highly detailed study, undertaken in collaboration with CHH.

**Table 2:** Comparison of Kinleith and Tasman discharges.

| Item | Tasman | Kinleith |
|---|---|---|
| Flow (million L/day) | Typical 127 – 137 | Mean 87.6<br>Max 151 |
| Colour (t/day) | Typical 20 – 27 | Mean 35<br>Max 75 |

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[1] Norske Skog operate the paper mill while Carter Holt Harvey operate the pulp mill.

Effluent colour reduction technologies that are not currently used by Tasman were investigated and then ranked to identify the best viable technologies for implementation. The top-five technologies are summarised in the Table 3. CHH provided commentary as to which treatment technologies identified for Tasman may or may not be applicable to Kinleith. Capital cost estimates are indicative only.

**Table 3:** Tasman colour reduction options and suitability for adoption at Kinleith.

| Treatment | Description and Comment | Expected Colour Reduction (t/d) | % of Tasman Colour Load[1] | Estimated Capital Cost $Million | Suitability for Kinleith[2] |
|---|---|---|---|---|---|
| Spill collection | Reducing spills by monitoring, prevention and recycle within the liquor system is proven technology widely implemented in all major jurisdictions as well as an integral part of all new kraft pulp mill designs. Tasman monitors spills and recovers evaporator washings, but does not have a spill recovery system in place for all areas. | 1–2 | 4–9% | 0.5–1.5 | Spill control systems at Kinleith are already advanced and do not provide significant scope for enhancement. |
| Improved brownstock washing | Good brown stock washing is a fundamental requirement in any fibreline. Washing should remove most of the organics from the pulp in the fibreline so that they can be sent to the chemical recovery cycle. Any improvement that can be made in washing efficiency will reduce the organic loading in the effluent stream. This option has high capital costs and has implications for the quality of specialty pulps. | 0.3–1.6 | 1–7% | 4–7 | The opportunities for improved washing are less at Kinleith than at Tasman, because the washing efficiency of the Kinleith washers is already high and because the plant configuration does not give a ready upgrade path. |
| EOP filtrate recycle | Filtrate from the caustic extraction stage (termed EOP filtrate) of the bleach plant is the largest contributor to effluent colour. The recycling of this filtrate is a proven technology although it has limited acceptance by the pulp and paper industry, but can be limited by evaporator capacity. Tasman does not currently have the evaporator capacity to recycle more than a small portion of the EOP filtrate. | 0.9–1.4 | 4–6% | 5–8 | Filtrate recycling faces the same barriers at Kinleith as at Tasman. |

**Table 3 (cont):**

| Treatment | Description and Comment | Expected Colour Reduction (t/d) | % of Tasman Colour Load[1] | Estimated Capital Cost $Million | Suitability for Kinleith[2] |
|---|---|---|---|---|---|
| Advanced oxidation processes | Recent research has focused on use of advanced oxidation processes to treat various mill effluents. Although there are several processes in an experimental stage, the current viable oxidation processes use hydrogen peroxide, ozone or chlorine. Hydrogen peroxide treatment requires minimal capital investment but has been shown in some cases to exhibit a colour reversion in subsequent ASB treatment. The ozone treatment involves large capital investment and a large operating cost. Both peroxide and ozone have large chemical operating costs. Reducing effluent colour with chlorine has shown to be very effective, but chloroform generation can occur under certain conditions. The downside of this option is the increased generation of other contaminants. | 0.7–1.6 | 3–7% | 0.3–4 | The options for advanced oxidative treatment at Kinleith are similar to those at Kawerau. |
| End-of-pipe treatment | A broad category that includes tertiary clarification activated sludge treatment (AST), membrane filtration and chemically enhanced primary clarification. Each is a proven technology with the exception of membrane filtration. The use of membranes for effluent treatment is still under development. Chemically enhanced primary clarification is not favoured because it is expensive to operate and sludge characteristics make it very difficult to handle. Activated sludge plants have high operating costs due to the aeration demand and the costs associated with sludge dewatering and disposal. The chemicals in the sludge make disposal particularly problematic. This option has very high capital and operating costs. | 7–12 | 30–50% | 25–50 | The end-of-pipe options for Kinleith are similar to those at Kawerau. |

[1] Based on 23.5 t/d which is the midpoint of the typical Tasman colour range of 20–27 t/d.

[2] Comment provided by CHH Kinleith mill.

No viable colour reduction technologies were identified for the Norske Skog Tasman Mill. Of the options considered for CHH Tasman, spill recovery and brownstock washing measures were the most reasonable methods of reducing the mill effluent discharge colour, however neither of these are considered to be suitable options for Kinleith. The Kinleith mill already has spill recovery systems and the brownstock washing already has a high washing efficiency. Also, the Kinleith mill has limited evaporator capacity so that implementation of any treatment process which increases evaporator loading will require either significant capital investment to increase capacity or will impact on total plant throughput.

## 2. Goals

The colour change in the Waikato River produced by the mill discharge at Kinleith is regarded by river iwi and the wider community as being an issue which needs to be addressed. While the goal can be simply stated as wanting to reduce the colour load to the mill discharge, the challenge is to ensure that the mill remains economically viable.

## 3. Actions

Only three treatment options emerge as being suitable for adoption at Kinleith (see Table 3). Although based on options for Tasman, it has been assumed that implementation of any one of these processes could produce the same order of magnitude in colour reduction at Kinleith and would have similar capital and operational costs. Implementation of a combination of processes would not necessarily have an additive effect on colour reduction but some further reduction is likely.

The three actions, their potential costs (capital and operational), and the possible benefit in terms of colour reduction are summarised in Table 4.

**Table 4:** Colour reduction and indicative costs for the three Kinleith options.

| Action | Scenario | % Colour Reduction | Capital Cost ($ million) | Annual Operating Cost ($100,000) |
|---|---|---|---|---|
| A | End-of-pipe activated sludge treatment | 30–50% | 25–50 | 20–50 |
| B | Advanced oxidation processes - Chlorine, peroxide or ozone | 3–7% | 0.3–4.0 | 2–40[1] |
| C | EOP filtrate recycle (partial recycle of bleach plant effluent) | 4–6% | 5–8 | 5–7 |

[1] Chlorine has a relatively low to neutral supply cost. Peroxide has a high chemical supply cost and ozone has an extremely high chemical supply cost.

## 4. Outcomes

Action A involving end-of-pipe treatment could possibly achieve up to 50 percent colour reduction. However it would require significant capital expenditure and has a high associated operating cost. Implementation of any these three options would result in some reduction of colour load to the Waikato River, with increase in water clarity and light transmissivity in the vicinity of the discharge. Environment benefits would however have to be considered against the higher costs of production to cover the associated capital investment and operating costs (associated with process chemicals, energy, labour). There would also be flow-on regional social and economic effects as a consequence of lower nett revenues if these higher costs cannot be recovered from mill product sales.

## 5. Risks and probability of success

To achieve even a modest colour load reduction at the Kinleith mill would require significant capital investment and depending on the process may also have significant ongoing operating costs. For significant colour load reductions, end of pipe activated sludge treatment is required, which requires large capital expenditure and has high on-going operating costs. Advanced oxidation with chlorine has the lowest capital and operating cost but only achieves a modest colour reduction. It also has the potential disadvantage of forming chloroform. Bleach plant EOP filtrate recycling only achieves a modest colour reduction for a relatively high capital cost. This cost could be even higher if evaporator capacity has to be increased.

Implementing large capital works for effluent treatment may impact on the commercial viability of the mill. The mill produces commodity products that are subject to global supply and demand forces. This dictates the returns the mill receives. Although the Kinleith mill is the largest of its type in New Zealand it is relatively small by modern international standards and so it is important that any investment decision is economically sound.

## 6. References

CHH (2009). Kinleith pulp and paper mill wastewater discharge monitoring report – Conditions 22B and 23, Resource Consent 961348, January 2009.

Beca AMEC (2008). Literature review of colour reduction technologies for kraft pulp mill effluent. Prepared for Norske Skog Tasman & Carter Holt Harvey Tasman by Beca AMEC Ltd, September 2008.

Beca AMEC (2009). Colour reduction technology report. Prepared for Norske Skog Tasman & Carter Holt Harvey Tasman by Beca AMEC Ltd, June 2009.

Environment Waikato (2006). Review of science relating to discharges from the Kinleith pulp and paper mill. Environment Waikato Technical Report 2005/58.

Johnson, A.P. (2009). Statement of evidence of Anthony Peter Johnson (Beca AMEC Ltd). Presented to the Environment Court, 3 August 2009.

Johnson, A.P. (2010). Statement of evidence of Anthony Peter Johnson (Beca AMEC Ltd). Presented to the Environment Court, 5 March 2010.

# Appendix 20: Cyanotoxin Treatment

## 1. Introduction and methods

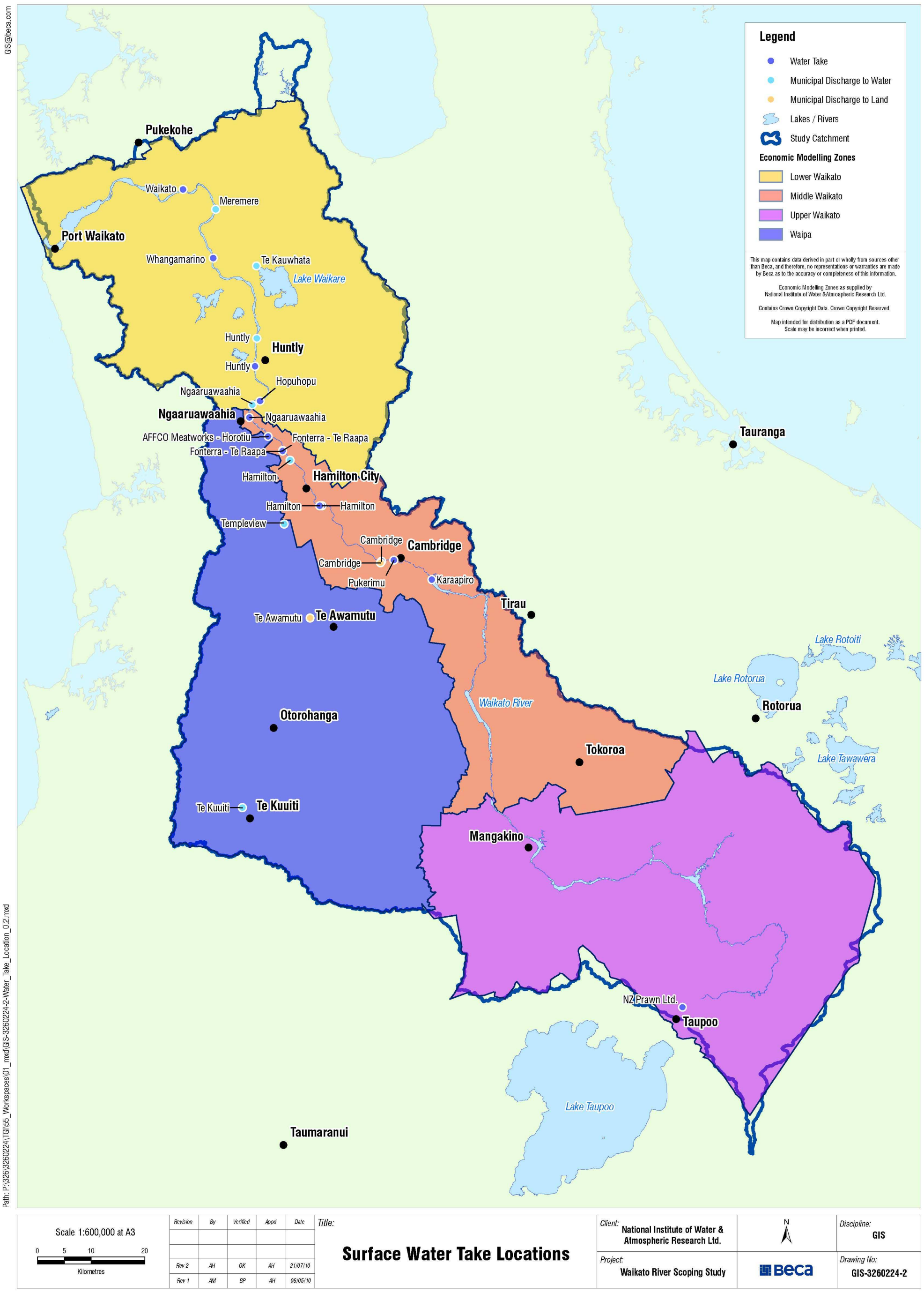
Some reaches of the Waikato River downstream of Lake Karaapiro are susceptible to blue-green algal blooms. If the nutrient load (nitrogen and phosphorus) to the river continues to rise, it is likely that these blooms will occur more frequently. The blooms pose a risk to public (human and animal health) as the chemicals (cyanotoxins) released into the water when the cyanobacteria (blue-green algae) die are toxic. If nothing is done to improve the nutrient loading of the Waikato River, community water treatment plants (WTPs) may need to upgrade their treatment processes to deal with the increased frequency and intensity of algal blooms.

This Study has considered the possibility of cyanotoxin treatment at any location where water is taken from the Waikato River (or an inline lake) and the water is used for drinking or food processing purposes. There is no historic evidence of algal blooms occurring in the Waipa River - therefore this Study has not considered water takes from this river. Water extracted from tributaries for drinking water has also not been evaluated.

WTPs and other businesses that draw water from the Waikato River have been identified from the Register of Community Drinking Water Supplies and the Resource Consents for the Waikato area. A total of 14 water takes from the Waikato River have been identified. Two of these water takes, Wairakei Resort and NZ Prawns Ltd, are located just downstream of Huka Falls. Blue-green algae levels very occasionally exceed ‘trigger’ levels in Lake Taupoo but this is thought to occur as a result of wind concentration. The risk to these water intakes is considered small and, as such, they have been excluded from the cost estimate.

Of the remaining 12 water takes, 10 are for community drinking water supplies and two, Fonterra Te Raapa and the AFFCO Meatworks, are industrial. Both are primary processing industries and the water may be used in the production of food. Although both these operations have treatment systems, neither have processes suitable for the removal of cyanotoxins.

**Figure 1:** Locations of water takes from the Waikato River which are used for drinking water supply or food processing.



## 2. Goals

The purpose of this paper is to generate an estimated cost for the increased level of treatment that may be required at community and industrial WTPs at risk from more frequent and severe algal blooms in the Waikato River should nutrient levels in the river continue to rise.

## 3. Actions

Algal blooms have a number of effects on drinking water. The cyanotoxins released by the algae are toxic to human and animal life, and also impart an unpalatable taste and odour to the water. Treatment for algal blooms should include processes to remove the entire cells, and treat the water for removal of cyanotoxins, taste and odour.

Under the Drinking Water Standards for New Zealand 2005 (revised 2008) (DWSNZ), water suppliers do not currently need to provide treatment to remove cyanobacteria but they do need to comply with the Chemical MAV (Maximum Acceptable Value) limits for cyanobacteria.

Regardless of whether a water source is able to treat for cyanotoxins or not, in areas where source water has previously experienced algal blooms the water supplier must implement a monitoring programme for cyanotoxins and develop a management protocol that specifies the actions to be taken should cyanotoxin levels reach a potentially hazardous level. The protocol will be site specific and will outline what steps are to be taken to provide safe drinking water in the event of an algal bloom. It will take into consideration factors such as whether the water supply is the sole supply for the community, the size of the community and whether alternative source water can be used. For some supplies it may be possible to stand down the WTP until the bloom is over. For others, installation of either a temporary or permanent treatment process may be the only solution.

If the cyanotoxin levels exceed 50 percent of the maximum acceptable value (MAV), more frequent monitoring must be implemented and the Drinking Water Assessor (DWA) informed. If the MAV is exceeded, the DWA and consumers must be informed. An alternative source of water must be used until levels drop below 50 percent of the MAV.

In conjunction with monitoring cyanotoxin levels, cyanobacterial cell counts may also be routinely monitored by authorities with water takes in water bodies at risk from blue-green algae blooms. The following table outlines some of the cyanobacterial cell count trigger levels, and the recommended actions (by the Ministry of Health) to be taken by local authorities in the event the trigger level is exceeded.

**Table 1:** Guideline values for a drinking water source and recommended actions (Kouzminov et al., 2007).

| Guideline Value | Threshold Level | Actions by Local Authorities |
|---|---|---|
| Vigilance Level | 2,000 cells/mL, or 0.2 mm3/L biovolume, or 10 µg/L chlorophyll a. | Continue regular monitoring of raw and treated water to ensure adequate system performance and consider analysis (bioassay test) of the treated water to confirm the absence of toxins. |
| Alert Level 1 | 20,000 cells/mL, or 2 mm3/L biovolume, or 10 µg/L chlorophyll a. | Prepare to implement water supply contingency plan, use an alternative source of water, or use water treatment processes capable of removing cells or toxin, or provide drinking water by tanker or bottles. |
| Alert Level 2 | 50,000 cells/mL, or 5 mm3/L bio-volume, or 25 µg/L chlorophyll or toxin concentrations exceeds MAV. | Monitoring frequency should be increased to at least twice weekly (preferably daily), the water body should be closed temporarily and a contingency plant should be activated, including advanced treatment process. |

It is important to note that cyanobacterial cell counts in excess of vigilance or alert levels do not necessarily mean that cyanotoxin levels will also exceed MAV values. Routine monitoring of cell counts is not part of DWSNZ, but is a best practice measure that provides an early warning of bloom conditions.

This Study’s review found that the two largest water supplies extracting from the Waikato River have some degree of permanently installed treatment for cyanotoxins.

Three upgrade options have been reviewed.

Option 1 assumes that the river nutrient levels stay the same or decrease from the current situation. Option 2 would apply if algal bloom frequency showed a moderate increase i.e., an event every 1–3 years. Option 3 would apply if the algal bloom frequency increased to say an annual basis.

**Table 2:** Options for the treatment of algal blooms (cyanotoxins).

| Upgrading Option | Upgade Required | Description |
|---|---|---|
| Option 1 | No new treatment. | Blooms are managed under the existing Public Health Risk Management Plan and there is no additional cost. |
| Option 2 | For plants with existing conventional filters, convert to Biological Activated Carbon (BAC).<br>Where no existing filters install new BAC filters. | The filters remove algae cells while the biological media is able to adsorb toxins, taste and odour. The bacteria are grown on granulated activated carbon (GAC) media and will take some time to adjust to bloom conditions.<br>Conversion of existing filters includes:<br>• Replacement of sand media with GAC.<br>• Combined air/water scour for backwash.<br>• Non-chlorinated backwash, including new tanks.<br>• Modifications to filters to increase bed depth.<br>• Automation of backwash procedure. |
| Option 3 | Option 2 plus:<br>• Powdered activated carbon (PAC) dosing for small plants.<br>• Ozone or UV-peroxide oxidation for large plants. | For the case where blooming is very frequent and additional treatment is required.<br>Large plants are those with population greater than 10,000.<br>PAC is able to adsorb the toxins.<br>Ozone and UV-peroxide oxidation work by degrading the chemical structure of the toxins. |

Suppliers were approached for costs for both Option 2 and Option 3. Due to the increased complexity of the treatment process for Option 3 this Study has not been able to provide a reasonable cost estimate, however they are anticipated to be significantly more than Option 2. The economic modelling scenarios are therefore based on the treatment plants upgrading to Option 2. The following three options have been selected for modelling:

| | |
|---|---|
| Option 1: | No changes to installed treatment. |
| Option 2: | Supplies greater than 10 MLD install Option 2 level of treatment permanently. |
| Option 3: | All suppliers install Option 2 treatment. |

Three of the WTPs already had BAC treatment in place (Waikato, Waiora Tce, Hamilton and Whangamarino). Hence these WTPs were excluded from possibly requiring upgrades under Option 2.

The following table summarises the water takes identified as being at risk of being affected by algal blooms.

**Table 3:** Water takes considered at risk of algal blooms.

| Water Take | Design Flow (ML/day) | Population [1] | Upgrading Options | |
|---|---|---|---|---|
| | | | Option 2 | Option 3 |
| Waikato (serves Auckland city) | 75 | 956,800 | Nothing required | Add ozone/UV-oxidation |
| Mercer Country Stop | 0.06 | 200 | Add BAC filter | Add PAC dosing |
| Alpha St. Cambridge | 16.8 | 13,400 | Replace filter with BAC | Add ozone/UV-oxidation |
| Karaapiro | 20.5 | 13,500 | Convert to BAC filter | Add ozone/UV-oxidation |
| Parallel Rd, Pukerimu | 7.8 | 3,700 | Convert to BAC filter | Add PAC dosing |
| Waiora Tce, Hamilton | 94 | 132,200 | Nothing required | Add ozone/UV-oxidation |
| Ngaaruawaahia | 7 | 5,700 | Convert to BAC filter | Add PAC dosing |
| Hopu Hopu | 0.8 | 660 | Convert to BAC filter | Add PAC dosing |
| Huntly | 7 | 7,410 | Convert to BAC filter | Add PAC dosing |
| Whangamarino | 3.1 | 1,700 | Nothing required | Add ozone/UV-oxidation |
| Fonterra Te Raapa | 28 | NA - Industrial | Convert to BAC filter | Add ozone/UV-oxidation |
| AFFCO Meatworks | 29 | NA - Industrial | Convert to BAC filter | Add ozone/UV-oxidation |

## 4. Desired outcome

The risk of illness caused by accidental consumption of cyanobacteria from drinking water is reduced.

## 5. Risks and probability of success

The biological media in BAC filters takes some time to adjust to algal bloom conditions. There is, therefore, a lapse in time before the bloom starts and treatment begins. Process such as PAC, ozone and UV-oxidation are effective as soon as they are started.

If nothing is done to prevent the increased nutrient levels in the river, the frequency and intensity of algal blooms will continue to increase. This will mean that the

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[1] Source: Water Information New Zealand, as extracted from the National WINZ database on 3 May 2010 and rounded to the nearest 100.

treatment process may not be adequate in the future, or under unanticipated bloom conditions.

At present, the cyanobacterial monitoring data collected by the various local authorities in the Waikato region is collected and collated by Environment Waikato. This information is publicly available. This is an important source of information and could be used as a tool for identifying and tracking the development and extent of algal blooms conditions.

## 6. Costs and timelines

The following table summarises the upgrade costs necessary to install treatment for cyanotoxins under Option 2. Costs for Option 3 have not been determined at this time. They are anticipated to be significantly more than Option 2.

The upgrade works would be implemented by the water suppliers and the costs ultimately passed on to the communities in the form of increased property or water rates.

It will take 3 to 6 months to design and tender the WTP upgrade. A further 6 months to 2 years should be allowed for procurement, construction and commissioning. This may seem like a long timeframe, but for some WTPs the construction and commissioning may need to be staged or sequenced in such a way to ensure that there is a sufficient quantity and quality of water supplied at all times.

Projects would be implemented on a case by case basis and potentially could have programme overlaps.

**Table 4:** Cost estimates for cyanotoxin treatment – Option 2.

| **Water Take** | **River Reach** | **Capital Cost $** | **Annual Operating Cost $** | **Preliminary & General (12%) $** | **Consenting and Investigations (10%) $** | **Design and supervision (10%) $** | **Contingency (30%) $** | **Capital Cost Total $** |
|---|---|---|---|---|---|---|---|---|
| Waikato | Lower | - | - | - | - | - | - | - |
| Mercer Country Stop | Lower | 19,000 | 10,500 | 2,280 | 2,128 | 2,341 | 7,725 | 30,000 |
| Hopuhopu | Lower | 201,000 | 600 | 24,120 | 22,512 | 24,763 | 81,719 | 350,000 |
| Huntly | Lower | 470,000 | 5,600 | 56,400 | 52,640 | 57,904 | 191,083 | 830,000 |
| Whangamarino | Lower | - | - | - | - | - | - | - |
| Alpha St. Cambridge | Middle | 1,774,000 | 34,300 | 212,880 | 198,688 | 218,557 | 721,237 | 3,130,000 |
| Karapiro | Middle | 982,000 | 16,500 | 117,840 | 109,984 | 120,982 | 399,242 | 1,730,000 |
| Parallel Rd, Pukerimu | Middle | 498,000 | 6,300 | 59,760 | 55,776 | 61,354 | 202,467 | 880,000 |
| Waiora Tce, Hamilton | Middle | - | - | - | - | - | - | - |
| Ngaaruawaahia | Middle | 470,000 | 5,600 | 56,400 | 52,640 | 57,904 | 191,083 | 830,000 |
| Fonterra Te Raapa | Middle | 1,127,000 | 22,600 | 135,240 | 126,224 | 138,846 | 458,193 | 1,990,000 |
| AFFCO Meatworks | Middle | 1,145,000 | 23,400 | 137,400 | 128,240 | 141,064 | 465,511 | 2,020,000 |
| **Total** | | **$6,686,000** | **$125,400** | **$800,000** | **$750,000** | **$820,000** | **$2,720,000** | **$11,790,000** |

# 7. Abatement costs

Based on the engineering data, total and unit discounted cost per person for the nine water takes considered at risk of algal blooms have been calculated. Total costs are made of capital and operational costs. Capital costs are assumed to occur in year 2, whereas operational costs are spread over 30 years. Costs have been discounted at 8 percent. Net present values are summarised in the table below.

**Table 5:** Net present values of total and unit costs.

| | Total costs ($millions) | Population Served | Cost per person ($thousands) |
|---|---|---|---|
| Alpha St. Cambridge | 3.07 | 13,368 | 0.23 |
| AFFCO Meatworks | 2.00 | | - |
| Fonterra Te Raapa | 1.96 | | - |
| Karaapiro | 1.67 | 13,500 | 0.12 |
| Parallel Rd, Pukerimu | 0.83 | 3,746 | 0.22 |
| Huntly | 0.77 | 7,410 | 0.10 |
| Ngaaruawaahia | 0.77 | 5,695 | 0.14 |
| Hopuhopu | 0.31 | 660 | 0.46 |
| Mercer Country Stop | 0.14 | 200 | 0.72 |

Both AFFCO Meatworks and Fonterra Te Raapa are industrial sites and therefore do not serve a population as such – no unit costs per person have been established. The graph below gives a representation of total and unit cost for the nine sites.

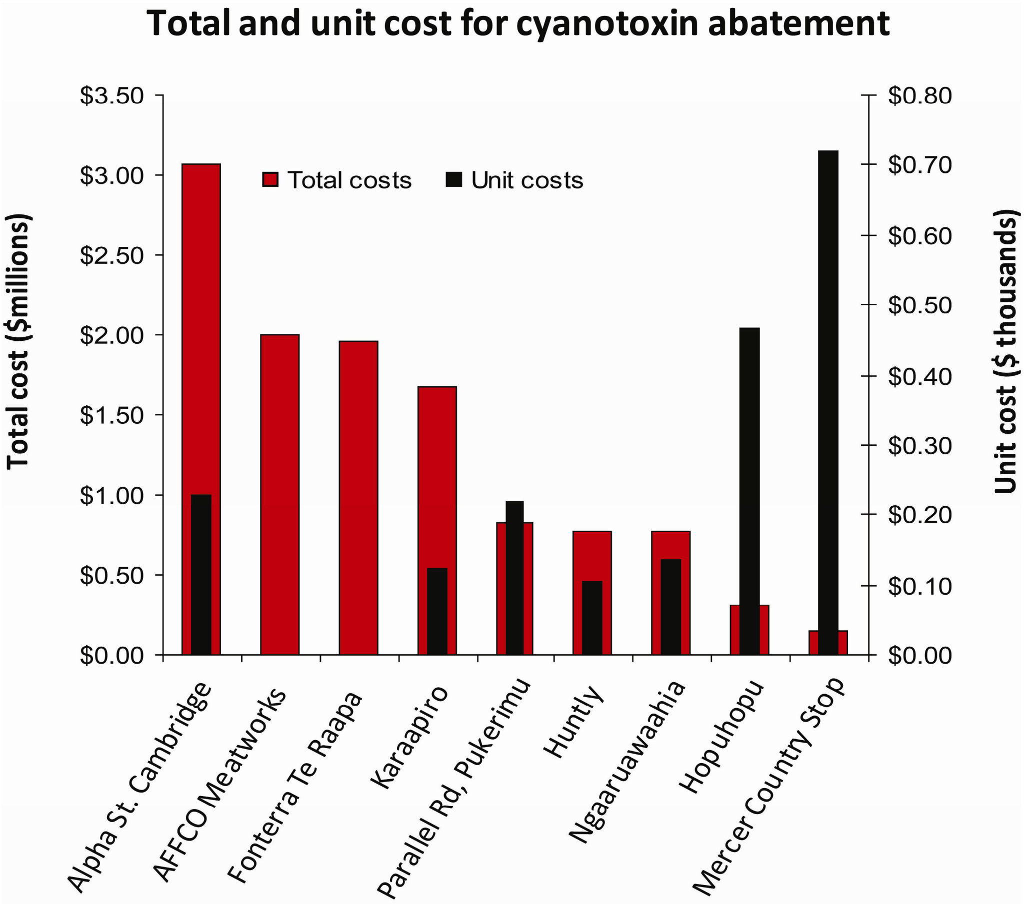

**Figure 2:** Cyanotoxin abatement costs.

The most expensive option is to treat cyanotoxin is at Alpha St. Cambridge where the net present value of total costs is $3.07m. Unit cost per person amount to $230 and rank as the third most expensive action. Hopuhopu and Mercer Country Stop have the lowest total discounted costs, but in contrast exhibit the highest per unit discounted costs, showing that these two options require extensive spending in a low population area, i.e., only a small number of people would benefit.

## 8. Glossary

| | |
|---|---|
| WTPs | Water treatment plants |
| DWSNZ | Drinking Water Standards for New Zealand 2005 (revised 2008) |
| MAV | Maximum acceptable value |
| DWA | Drinking water assessor |
| BMP | Best management practice |

| | |
|---|---|
| EBMP | Enhanced best management practice |
| BAC | Biological activated carbon |
| GAC | Granulated activated carbon |
| PAC | Powdered activated carbon |

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# Appendix 21: Toxic Contaminants

## 1. Introduction

A range of potentially toxic chemical contaminants enter the Waikato River from natural geothermal activity, wastewater discharges, and indirect diffuse source inputs. Geothermal sources result in high concentrations of mercury, arsenic and boron. The river receives background geothermal contaminants from Lake Taupoo with additional natural inputs downstream. A major input of geothermal contaminants enters the river from the Wairaakei Geothermal Power Station. As a result of these upstream inputs geothermally-contaminated sediment has accumulated in the bottom of Lake Ohakurii. At certain times of the year conditions in the lake lead to re-release of these contaminants into the overlying water.

A major point-source discharge of pulp and paper wastewaters occurs in the mid-river section at Maraetai. Historically this had significant concentrations of both mercury and dioxin in addition to resin acids and other organic material. However, improved treatment systems have markedly reduced contaminant concentrations.

The most significant urban contaminant inputs are from Cambridge, Hamilton and Huntly, with associated industrial inputs along this lower river reach. The Waipa River drains a wide agricultural area and receives the run-off and wastewater discharges from Te Kuuiti, Otorohanga and Te Awamutu. Numerous discharges of stormwater runoff occur from agricultural and urban areas. The Hamilton City discharges are elevated in contaminants (particularly metals) particularly during storms.

Run-off results in input of DDT, and other insecticides, as a legacy of past agricultural practices. Increases in zinc inputs are occurring because of the high usage for facial eczema control. The cumulative inputs of dairy processing wastewaters may result in toxic conditions in tributary streams (largely from ammonia) but not in the Waikato River.

A number of other significant point source discharges occur to the river, including municipal wastewaters, power station cooling tower discharges and various industrial wastewater and stormwater discharges. The individual and cumulative effect of contaminants derived from these discharges has not been assessed.

The contaminants in the river are of concern for two reasons; they can reach levels at which there will be an ecological effect with toxicity affecting some organisms and plants, and there can be human health risks associated with drinking untreated river water and consuming fish and invertebrates from the river.

## 2. Ohakurii sediment toxicity

Geothermally-derived arsenic (As) and mercury (Hg) accumulate in the sediments of Lake Ohakurii. It is estimated that more than 380 tonnes of arsenic and 0.5 tonne of Hg may have accumulated in the lake sediments since its formation in 1961 (N. Kim, Environment Waikato, pers. comm.). Ohakurii has the highest sediment concentrations of any of the Waikato River lakes, with arsenic and mercury concentrations exceeding sediment quality guidelines for ecological protection (Rumbsy and Coombes, 2008; ANZECC, 2000). (Other downstream lakes also have elevated concentrations which exceed sediment quality guidelines.)

A preliminary toxic risk assessment for these sediments could be made by comparing the sediment concentrations with the sediment quality guideline value (ANZECC, 2000). Exceedance would trigger the need for further investigation. In Lake Ohakurii, the average exceedance is about eight times the guideline value (with a maximum exceedance of 31 times). Sediment pore-water concentrations of the most toxic form of arsenic (AsIII) are known to be elevated and released to the overlying water when dissolved oxygen conditions in the lake drop (Aggett and Kriegman, 1988). This can potentially result in toxic conditions for both sediment-dwelling organisms and those living in the lake waters. Similarly, mercury concentrations will be elevated in pore waters and release to the overlying waters. These elevated in situ concentrations of geothermal contaminants pose a significant toxic hazard to key native species inhabiting sediments (particularly kooura and kaaeo/kaakahi), and the overlying waters.

Previous studies have shown marked accumulation of geothermal contaminants in Waikato River kaaeo/kaakahi (Hickey et al., 1995). The highest flesh and shell concentrations were in the upper Waikato River associated with geothermal inputs. The sensitivity of the larval glochidial life-stage or juvenile mussels to geothermal contaminants has not been determined. However, the field observations have shown marked declines in kaaeo/kaakahi at river sites downstream of upper Ohakurii (Roper and Hickey, 1994).

On the basis of the above summary, it is apparent that there is a major information gap around the toxicity of arsenic (and to a lesser extent mercury) in the Upper Waikato River. This gap could be most addressed by undertaking sediment toxicity tests, including multi-species sediment toxicity tests (e.g., with amphipods, fingernail clams, oligochaetes and juvenile kooura) and short- and long-term water toxicity tests with arsenic (e.g., with cladocerans, amphipods, iinanga and bullies). Additional information on chemical contamination, sediment physical characteristic and benthic community structure would be required to properly interpret test findings. Some studies on benthic macroinvertebrates have shown that animals in Lake Ohakurii appear to be affected by both chemical contaminants and the nature of the sediment (i.e., organic/muddy enrichment) (Hickey and Martin, 1996). Further investigations would be needed to provide a comprehensive assessment of the level of toxicological impacts, together with a characterisation of the sensitivity of a range of key species to arsenic exposure.

Such a study would cost (including report documentation and communication of study objectives and findings) about $220,000.

## 3. Health risks

Elevated concentrations of arsenic (As) in the river mean that untreated river water exceeds the water quality guidelines for drinking water at all river sites downstream of Aratiatia. However, arsenic is substantially removed by most conventional drinking water treatment systems (e.g., 90 percent reduction of arsenic is achieved after treatment of Hamilton drinking water; N. Kim, Environment Waikato, pers. comm.).

The risk from consuming food collected from the river is only poorly understood for a few contaminants and food species. Mercury is of particular concern because it can biomagnify through the food-chain. This can result in concentrations that could adversely affecting people eating kai from the river. Surveys of trout in 1998 found that mercury concentrations exceeded health regulations in only 11 of the 285 fish sampled, however, comparison with accepted daily intake values indicated that some sites "could conceivably pose some threat to human health" (Mills, 1995). Arsenic levels in fish were low and below health regulation limits at all sites. Previous studies have shown marked accumulation of geothermal contaminants in Waikato River kaaeo/kaakahi (Hickey et al., 1995). The highest flesh and shell concentrations were in the Upper Waikato River associated with geothermal inputs.

Since 1996–97 an estimated 4,200 elvers (juvenile tuna) have been transferred to Lake Ohakurii (Boubée, NIWA, pers. comm.). The introduction of tuna to Lake Ohakurii poses a significant risk for accumulation of high mercury concentrations from the contaminated sediments. This in term poses a risk to people who eat large quantities of tuna from the lake. No information is available on the contaminant concentrations in Ohakurii tuna.

Some species of aquatic plants are ‘hyper-accumulators’ of water and sediment-derived arsenic. Watercress is among the species which strongly accumulates arsenic (Robinson et al., 2006). A health assessment of watercress from Lake Ohakurii has indicated that regular consumption of 16 g of fresh watercress a week from Lake Ohakurii would be sufficient to exceed the tolerable daily intake (Robinson et al., 2006). While watercress occurs in some locations in the upper Waikato River main stem, its distribution is limited in extent and collection would largely occur from the less contaminated tributary streams. Health risk is therefore probably minimised by the low availability and suitability of river sites for regular collection. Watercress is an accumulator of a number of other metal contaminants (especially copper).

Previous fish and mussel monitoring studies have measured DDT, PCB, dioxin and other pulp and paper related contaminants at low tissue concentrations (Hickey et al., 1997; Burggraaf, 1996). While the use or discharge of many of these contaminants would be far less now than it has been in the past, some legacy areas of sediment contamination may still contain these persistent chemicals. DDT and PCBs have had multiple potential sources throughout the river. The dioxins have historically been associated with the pulp and paper mill discharge to Lake Whakamaru.

Different species of fish are harvested for consumption from the Lower Waikato River. The major harvested fisheries would be for mullet and whitebait. The whitebait would generally be considered of low risk to human health as their short time in the river does not provide sufficient time for chemical contaminant accumulation. There is no contaminant information available for mullet.

Kooura occur throughout the river system but currently there is no information is available on their distribution or abundance, nor on contaminant concentrations in their tissue.

To assess the health risk associated with a ‘food basket’ of the most commonly eaten species it is necessary to have robust data on the concentrations of contaminants in a range of species. From the above, contaminants of most interest are heavy metals (especially copper, arsenic and mercury), methyl mercury, PCB, DDT and dioxin. Species of most relevance are tuna, mullet, kaaeo/kaakahi, trout, whitebait and kooura. Information to help understand factors controlling contaminant uptake into these food species is also needed (e.g., animal size, age and condition, lipid content, and stable isotope analysis to understand food-chain routes).

A health risk assessment for food consumption would also need to be undertaken for different risk categories (e.g., river iwi, the general population, women of child-bearing age, and children) and for realistic levels of consumption which reflect actual amounts consumed (e.g., moderate and high consumers). Such analysis would help to show if there are health risks associated with ‘normal’ consumption levels or if guidance needs to be provided to limit consumption.

If significantly elevated concentrations of multiple chemical contaminants were found to occur, a cumulative health risk approach could be used to assess the risk for all of the contaminants present (Barnes and Dourson, 1988). Such a study would cost in the vicinity of $290,000.

# 4. Restoration

There are legitimate concerns for arsenic and mercury contamination occurring in the water and kai of the Waikato River, although there are many unknowns and further study is needed before specific restoration actions can be confirmed. There are also initiatives underway that will address some of the existing problems. For example geothermal contaminant inputs from the Wairakei Geothermal Power Station discharge will be managed through their resource consents. Similarly, although untreated river water is high in arsenic this can be substantially removed by most conventional large-scale drinking water treatment systems. The most likely restoration action that could be undertaken would involve capping or fixing arsenic and mercury in the sediments of Lake Ohakurii. This would have the benefit of limiting arsenic and mercury release from the lake sediments into the overlying water. While this action is not being recommended at this time it has been costed for future reference.

There is considerable uncertainty regarding other contaminants in the river and it is presently impossible to assess if or when a problem might arise. This is clearly a significant information gap, but of major interest to river iwi.

There are other discharges to the river that may have an ecological impact. These include stormwater discharges and dairy wastewater discharges to streams. While it is recognised that these effects may be occurring, they are of limited extent and are of low priority in the scheme of restoration actions.

Abatement costs have been developed for three options for restoration in Lake Ohakurii: Core cost, Anticipated Treatment and Whole-lake Treatment (see Table 1).

Figure 1 shows total abatement costs of reducing arsenic and mercury, and improving sediment ecology for each of three actions: Core cost, Anticipated Treatment and Whole-lake Treatment. Abatement potentials differ amongst actions, e.g., The Whole-lake treatment action is most costly for improving sediment ecology, but at the same time generates maximum benefits for sediment ecology (e.g., 100 percent). If the objective is to reduce both mercury and arsenic, and improve sediment ecology at the same time, then the Whole-lake action has to be implemented. Improving sediment ecology is positively correlated to costs; the higher the improvement the higher the cost. The most cost-effective way to reduce arsenic is by implementing the Core cost action, at a total cost of $1,505,000. Mercury can only be reduced by implementing the Whole-lake Treatment action.

**Table 1**: Benefits and costs of action components for reducing toxic contaminants.

| Components | Description | Details | Benefit | Cost | Options | | |
|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 |
| 1 | Laboratory testing of Ohakurii sediments and calibration of dosage. | Validation of various product options ranging from alum (binding only phosphorus and As) to Aqua-P (binding P, As, and Hg). | Capping dose and product selection established. Proof of As (and Hg) binding efficiency. | $110,000 | ▨ | 🟩 | 🟦 |
| | | | | | | | |
| 2 | Field efficacy trial in Whirinaki arm. | Field trial of Aqua-P applied to 74 ha of arm at 200g/m$^2$ (148 tonnes). Application cost estimate at 30% product cost. Monitoring allowance for As and P in and out of arm ($50k). Contingency of $75k for higher dosing rate if required. | Field efficacy established for arm of lake known to deoxygenate. Can be used to validate suitability of application method. | $585,000 | ▨ | 🟩 | 🟦 |
| | | | | | | | |
| 3 | Alum lake dose for As removal | Base alum dose calculation (480 tonnes). Contingency of 50% for possible higher dose requirement. | Peak As (and phosphorus) removed from export to downstream lakes and water supplies. | $660,000 | ▨ | | |
| | | | | | | | |
| 4 | Aqua-P lake dose for As removal | Base Aqua-P dose calculation (960 tonnes). Contingency of 50% for possible higher dose requirement. | Peak As (and phosphorus and mercury) removed from export to downstream lakes and water supplies. | $4,110,000 | | 🟩 | |
| | | | | | | | |
| 5 | Whole lake treatment for As and Hg removal | Base Aqua-P dose calculation (1600 tonnes). Contingency of 50% for possible higher dose requirement. | Peak As (and phosphorus and mercury) removed from export to downstream lakes and water supplies. | $6,900,000 | | | 🟦 |

**Table 1:** (cont.)

| Components | Description | Details | Benefit | Cost | Options | | |
|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 |
| 6 | Lake monitoring programme, public presentations and reports. | Lake biota and chemical monitoring associated with treatments. Report documentation and presentations. | Monitoring to show no adverse effects of treatments. Full documentation of remediation process. Long-term monitoring will show whole-lake benefits. | $150,000 | ◼ | 🟩 | 🟦 |
| | | | | | | | |
| | | | **1 Core cost** | $1,505,000 | ◼ | | |
| | | | **2 Anticipated treatment** | $4,955,000 | | 🟩 | |
| | | | **3 Whole-lake treatment** | $7,745,000 | | | 🟦 |

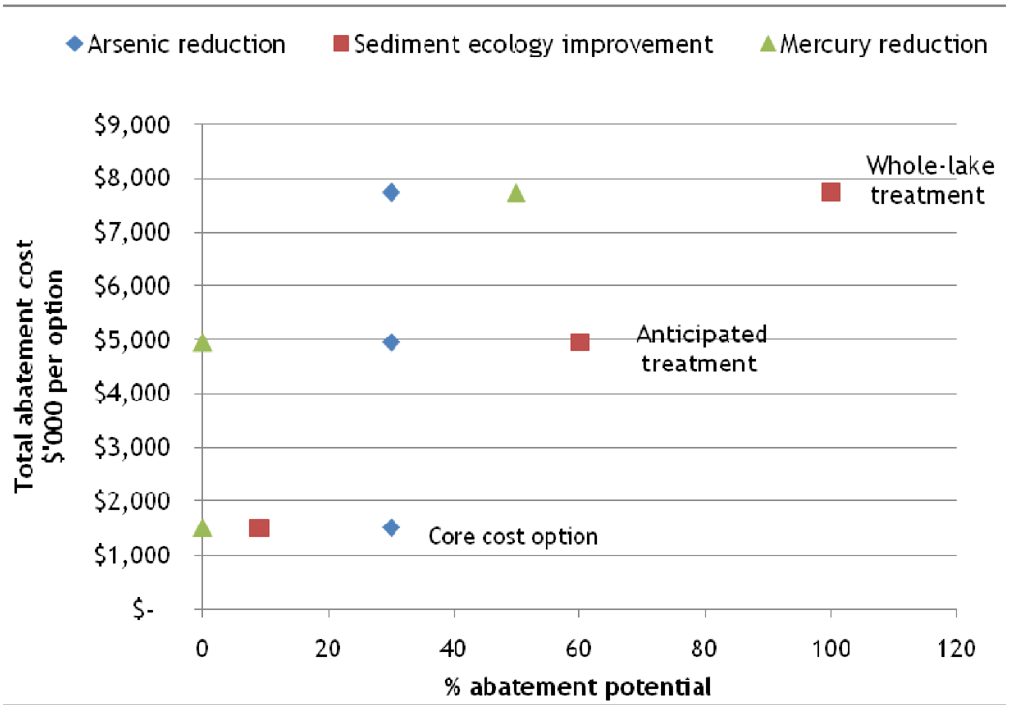

**Figure 1:** Abatement costs for three toxic contaminants reduction actions.

Each action has co-benefits, for example if the objective is to reduce arsenic, the core Cost option is most cost-effective and also has the additional benefits of improving sediment ecology (although at a higher cost than the other two options). Abatement potentials differ for each action. Therefore it is useful to construct another graph analysing unit costs (see other graph), which shows that the Whole-lake option is most the most cost-effective way to improve sediment ecology. Figure 2 shows the unit abatement cost per unit of reduction in arsenic and mercury, and per unit of improvement for sediment ecology for each action.

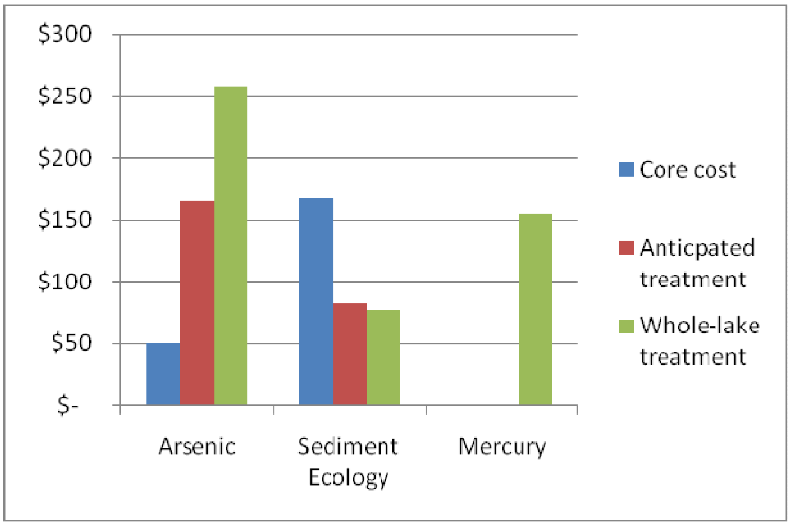

**Figure 2:** Unit costs for reducing toxic contaminants for all three actions.

The core cost option is the most cost effective at reducing arsenic, whereas the Whole-lake action is most cost-effective at improving sediment ecology and also has the added benefit of reducing mercury. The costs of reducing mercury for the first two actions are effectively zero as they do not have the ability to reduce mercury.

## 5. Information gaps

This review has highlighted many information gaps which need to be addressed before restoration recommendations can be developed further. Specific studies that are recommended include:

1. Monitor arsenic and mercury levels in tuna, kooura, and kaakahi throughout river to assess contaminant levels and monitor arsenic levels in water and watercress.
2. Undertake a full Health Risk Assessment (HRA) for mercury including food chain accumulation and species/amount consumed to gauge the seriousness of the problem and identify priorities and where effort needs to be focused.
3. Investigate arsenic mobilization mechanisms in Lake Ohakurii may to determine how big an issue it would be if the "worst case" scenario occurred of lake deoxygenation.
4. Investigate sediment arsenic toxicity to establish how big an issue it is and

determine the sensitivity of key native species (including juvenile kooura and kaaeo/kaakahi).

5. Undertake trials on sediment capping in Lake Ohakurii and assess its effectiveness at immobilisation of arsenic and mercury.
6. Investigate DDT, PCB, arsenic, zinc and copper levels in potential food organisms.
7. Undertake monitoring (at 5-yearly intervals) for emerging contaminants which may affect the river.
8. Monitor seasonal anoxia (oxygen depletion) in the hydro-lakes, especially Lake Ohakurii. (This is a fundamental measure of both the input of organic run-off, internal lake productivity and the potential of generation of sediment-associated arsenic.)

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# Appendix 22: Landfills

## 1. Overview

Contamination of waterways from landfills is an issue in the Waikato River catchment. Concerns raised during consultation for this Study ranged from municipal and industrial landfills through to small farm dumps used to dispose of farm animals. In the past there have been environmental issues linked to old landfills, controversy around siting new landfills and inappropriate dumping of highly toxic chemicals (such as organochlorine agricultural chemicals) in the Waikato River catchment.

If rain or groundwater infiltrates landfills, then leachate can contain very high concentrations of dissolved organic matter, toxic ammonia and heavy metals (especially iron and zinc), which can leach to, and contaminate groundwater or surface waters. Environmental impacts very much depend on the volume flow of leachate and the flow in the receiving waters. For example, despite highly contaminated leachate, and operating conditions that would not meet modern standards, it was not possible to discern an impact of the Horotiu landfill on the adjacent Waikato River. Impacts also depend on chemical, physical and biological processes that can occur as leachate travels through soils and other geological media, just as septic tanks rely on soil attenuation processes to treat highly contaminated leachate.

In the past, there have been problems in the Waikato River catchment with old, poorly managed landfills contaminating waterways and producing dangerous landfill gases. According to Environment Waikato's website unsatisfactory disposal sites in the region have now been closed or upgraded.[1] The website states that new landfills must use modern technology and management techniques to protect the environment. All open and most closed landfills must have resource consents from Environment Waikato. These consents set management standards including discharge controls, requirements for sealing and rehabilitation of closed sites and monitoring of ground and surface water, leachate and types of waste.

The Study team assumes that all currently used municipal land fills are adequately managed and monitored to ensure no environmental damage. The Study team was unable to identify any other specific issues around landfills and their impacts in the Waikato River catchment that were not under management by Environment Waikato. Consequently there are no recommended remediation actions around landfills.

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[1] http://www.ew.govt.nz/environmental-information/Solid-waste/What-happens-to-our-waste/

The Study team acknowledges that unconsented landfills can be a potential hazard to waters, but there is a mechanism for dealing with any that are identified. Landfills are acknowledged as potential contaminated sites by Environment Waikato. They are one of 52 land uses identified in the Ministry for Environment's Hazardous Activities and Industries List (HAIL) which defines industries and activities that typically use or store hazardous substances. Contaminated sites within the Waikato Region are in the process of being registered and tested for contamination.[2] Any suspected landfill sites can brought to Enviornment Waikato's attention for registration and assessment.

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[2] http://www.ew.govt.nz/environmental-information/Hazardous-substances-and-contaminated-sites/Contaminated-sites/Managing-contaminated-sites/