Tui Mine: Post Remediation Ecological Monitoring 2013

Waikato Regional Council
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Ecological Monitoring 2013

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Limitations:

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**Executive Summary**

Waikato Regional Council (WRC) has commissioned Pattle Delamore Partners Ltd (PDP) to undertake environmental monitoring pre and post mine remediation of Tui Mine, Te Aroha in the Tui and Tunakohoia Streams. This report presents results from ecosystem health sampling in 2013, four years on from the baseline study conducted by Coffey (2009).

The lower portions of the Tui and Tunakohoia Streams below the mine discharge were once devoid of aquatic life. Remediation efforts focused on mitigating and reducing discharge to these streams have led to an increase in aquatic life, particularly macroinvertebrates.

Macroinvertebrate community results for the un-impacted (control) sites above the mine discharge (Tui Stream and Tunakohoia Stream south branch) were similar to those sites for the baseline 2009 survey. Both un-impacted sites scored in the representative macroinvertebrate community index category ‘excellent’, indicating a healthy aquatic macroinvertebrate community. A notable improvement was observed in macroinvertebrate health at the two impacted sites (Tui Stream and Tunakohoia Stream north branch downstream of discharge) compared to the previous baseline study (Coffey 2009). The macroinvertebrate community in 2009 was depauperate (virtually absent), whereas in 2013, the macroinvertebrate taxonomic richness and abundance have increased considerably, scoring in the “good” and “excellent” categories for macroinvertebrate community index.

Based upon the findings of ecological monitoring conducted in 2013, macroinvertebrate communities at the monitoring localities that receive mine discharges (Tui Stream and Tunakohoia Stream north branch) are still impacted by past and/or present activities at the Tui Mine, but to a lesser extent than recorded in 2009. There has been an overall improvement observed at both the impacted and un-impacted sites, represented by increased taxa richness (diversity), abundance and improved community composition.
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1.0 Overview

Pattle Delamore Partners Limited (PDP) were commissioned by Waikato Regional Council (WRC) to undertake progress monitoring of the Tui and Tunakohoia Streams in the vicinity of the Tui mine (Figure 1) post remediation.

Previous water quality (PDP 2010) and ecology reports (Coffey 2009) have noted:
- Good water quality and ecosystem health in the Tui stream and the southern branch of the Tunakohoia Stream above the discharge from the mine.
- Water highly contaminated with heavy metals below the mine discharge in Tui stream and in the northern branch of the Tunakohoia Stream. Very poor ecosystem health in these areas. Unable to support the hardiest macroinvertebrates.

The current work undertaken by PDP has included:
- The collection, analysis and interpretation of ecosystem health surveys: macroinvertebrates, periphyton and habitat assessment.

This report presents the results of the ecological monitoring carried out in October 2013.

2.0 Introduction

Freshwater macroinvertebrates are widely used to monitor the state and health of stream environments around New Zealand. Because of their sedentary habitats, relatively long life cycles (annual) and ease of sampling, macroinvertebrates are good indicators of the state of streams and rivers. Aquatic flora and fauna assemblages can be spatially complex and temporally variable depending on a wide range of environmental and biological factors. Such factors as light, nutrients, physio-chemical conditions (i.e. temperature and dissolved oxygen), current velocity, substrate, physical disturbance and competition can all influence diversity. However, in systems receiving Acid Mine Drainage (AMD; also known as acid rock drainage) such as from the Tui Mine, the chemical characteristics of the by-product are of overriding importance and can strongly influence community composition (Harding, 2005; Lefcort et al., 2010). Acid mine drainage, characterised by acidic metalliferous conditions in water, generate physical, chemical and biological degradation of stream habitat.

2.1 History of Tui Mine

Tui Mine was once dubbed New Zealand’s most contaminated site. But after more than five years of work and funding from government, the major risks to community health and safety and environmental damage have been removed by remedial works. The successful conclusion of the complex project to remediate Tui Mine was celebrated in May 2013.
2.1.1 History

Tui Mine was opened by Norpac Mining Ltd in 1967 to extract metals, including zinc, copper and lead (gold and silver were also extracted. The mine prospered until unacceptable concentrations of mercury were detected in the ore and the mine became uneconomic. Norpac went into liquidation in 1975 and Tui Mine was abandoned. Left behind were waste rock and ore dumps, a tailings dam and the ruins of the mine workings which were leaching heavy metals into Tui and Tunakohoia streams. Furthermore, there was a risk of mine tailings instability during an extreme event and flow down the mountain.

2.1.2 Risks from Tui Mine (prior remediation)

Waters of the Tui and Tunakohoia Stream have been reported to run ‘red’. This rusty red colour is caused when oxidised iron particles in the adits (entrance to underground mine) are disturbed. The iron mixes with water draining from the adits, discolouring water downstream. In sections of the streams below the discharge of Tui mine, there are still rusty-coloured water and sediment.

Three main issues arising as a result of the mining activity at this site:

1. The Tunakohoia stream, located on Crown land managed by the Department of Conservation (DOC), was affected by heavy metals leaching from the adits and from the tailings dam. These heavy metals, including lead and cadmium, were contaminating the Tunakohoia stream which flows through the centre of the Te Aroha township.

2. The Tui catchment is adjacent to but separate from the Tunakohoia catchment. The Tui catchment was also affected by heavy metals arising from the tailings dam.

3. The tailing dam is located in the Tui catchment, on land owned by the Matamata-Piako District Council. Technical reports found that this structure was at risk of collapse in a moderate seismic event or an extreme weather event (Aecom 2010). Such events could have resulted in over 90,000 m³ of mine waste liquefying and flowing down the Tui stream past the edge of Te Aroha.

2.1.3 Remediation

In February 2010 consents were lodged for remediation works, and Phase 1 remediation started in October 2010. Phase 2 remediation started 2011 and was completed in 2013.

Phase 1: Treatment of old underground mine workings: involved preparatory work (detailed design, site establishment, access road) and the treatment of the old underground mine workings. The old mine workings discharge contaminated water into the Tunakohoia Stream. The workings were partially plugged with engineered concrete bulkheads, and an alkaline solution (lime or cement) was injected into the ground to counter the strongly acidic conditions.
Phase 2: Stabilisation and rehabilitation of the tailings dam: involved remediating the tailings dam area. To contain the tailings, a one-metre cap of clean fill was placed over the newly shaped land. This cap has been grassed and is designed to stop oxygen and water entering the stabilised tailings in the short term until vegetation cover establishes. Initial planting of native plants at the site’s old processing plant was carried out in May 2013.

Ongoing monitoring and maintenance is now occurring and programmed until 2045.

2.1.4 Description of Current Local Biodiversity

The mountainous area surrounding Te Aroha and thus Tui Mine, is characterised by regenerating hardwood forest, including kanuaka, manuka, rewa rewa, tawa pūriri and kohekohe as well as some introduced weed species. The lush forest area is home to a range of native and introduced fauna. Several native bird species can be observed such as the gray warbler, North Island fantail, tui, bellbird, long tailed and shining cuckoo, New Zealand Pigeon, silvereye, morepork and New Zealand Kingfisher. Threatened Hochstetters frog, striped skink and Te Aroha stag beetle are also known to be higher up in the catchment (Aecom 2010). There are also many species of introduced birds commonly seen in the area including house sparrow, hedge sparrow, chaffinch, redpoll, goldfinch, greenfinch, yellowhammer, starling, song thrush, myna and magpie.

Both the Tui and Tunakohoia Streams are considered to be high quality, hard-bottom, mountain streams that support healthy macroinvertebrate communities in those sections of the stream not impacted by AMD. However, downstream of the mine, ongoing AMD with its associated heavy metal loading into these streams effectively precludes the establishment of any macroinvertebrates, not even pollution tolerant species (Coffey 2009).

Two records of fish surveys being undertaken in the Tui stream (1981 and 1997) are found in the New Zealand Freshwater Fish Database, however on both occasions no species were found. There were no records of fish surveys in the Tunakohoia stream. The lack of fish in the Tui stream (and presumably the Tunakohoia stream) was considered to be primarily related to the adverse effect of the heavy metals being discharged into these streams from the Tui mine (Aecom 2010) and possible barriers for fish passage. It is important to note however, that there have been recent reports of the presence of common bullies in the Tui and Tunakohoia Stream (Ross Hill, Kaimai Valley Services pers comms).
2.1.5 Summary of Baseline Ecological Report (Coffey 2009)

- Macroinvertebrate results indicated healthy aquatic macroinvertebrate communities in the control sites at Tui Stream and the Tunakohoia Stream south branch above any mine discharge. However, results indicated depauperate macroinvertebrate communities in the impacted sites, Tui Stream and Tunakohoia Stream north branch below the mine discharge (Coffey 2009).

- Physical habitats at all of the ecological monitoring sites were similar and there was no significant variation in the physico-chemical parameters (dissolved oxygen, pH and temperature) between the control sites and the sites downstream of the mine discharges.

- Macroinvertebrate communities at the monitoring localities that receive mine discharges (Tui Stream and Tunakohoia Stream north branch) were considered to have been impacted by past and/or present activities at the Tui Mine.

2.1.6 Summary of water quality report (PDP 2010)

The water sampling programme found that:

- The highest concentrations of metals were generally found in the discharges from the Tui tailings dam into the Tui Stream. However, the highest concentrations of zinc were found in the discharge from adit 5 (SW5 on Figure 1) of the Tui Mine.

- The discharges from the tailings dam and the Tui mine adits are elevated in dissolved arsenic, cadmium, copper, lead and zinc. However, concentrations of mercury at all monitoring sites were below analytical detection limit (<0.00008 g/m³).

- With the exception of the discharges from the tailings dam, the pH of the water was found to be generally between 6.5 and 7.5 pH units (circum-neutral pH) at all monitoring sites.

- The concentration of contaminants of concern decreased during high flow events; however, the total mass flux of contaminants increased during high flow events. This indicates that during storm events stormwater does dilute the discharge; however, it also washes out more contaminants as well.

- The concentration of contaminants of concern at the tailings dam discharge to the Tui Stream appeared to be elevated compared to historical monitoring undertaken in 1998-2001.

2.2 Acid Mine Drainage

Acid mine drainage occurs when sulfide ores are exposed to the atmosphere, often enhanced through mining and milling processes. Accelerated oxidation of iron pyrite (FeS₂) and other sulfuric minerals result from their exposure to both oxygen and water. Waters contaminated by AMD have low pH and alkalinity and high concentrations of heavy
metal and sulfates. Sulfide minerals are generally acid-generating during oxidation, but not all. Most have the capacity to release metals on exposure to acidic water. The most common acid-generating sulphide minerals include pyrite \((\text{FeS}_2)\), pyrrhotite \((\text{FeS})\), marcasite \((\text{FeS}_2)\), chalcopyrite \((\text{CuFeS}_2)\) and arsenopyrite \((\text{FeAsS})\) (DITR, 2007). To avoid any significant environmental impacts, AMD must be collected and treated before being discharged into the environment and/or recycled back into the water table.

Typical chemical characteristics of AMD:

- Low pH (values range from 0.5 – 4);
- High soluble metal concentrations (e.g. iron, aluminium, cadmium, copper, lead, zinc, arsenic and mercury);
- High (sulphate) salinity (typical sulphate concentrations range from 500 - 10,000 mg/L; typical salinities range from 1000-20,000 \(\mu\)S/cm); and
- Low dissolved oxygen concentrations (e.g. < 6 mg/L).

Key indicators of AMD presence:

- Red-orange rust like layer on substrate (iron oxide precipitate);
- Red-coloured or unnaturally clear;
- Death of fish or aquatic organisms;
- Vegetation dieback or soil scalds;
- Poor productivity of revegetated areas; and
- Corrosion of concrete or steel structures.

2.2.1 Effects on Aquatic Resources

Healthy, unpolluted streams generally support a high taxa diversity and abundance, whereas AMD impacted streams are generally taxa depauperate, with fewer dominate species (Harding, 2005; Mulvihill et al., 2008; Gunn et al., 2010).

Macroinvertebrate Community Index (MCI) is a commonly used metric, however in waterways affected by AMD, the MCI can give highly variable and unrealistic results primarily because of AMD tolerance in otherwise clean water taxa (Hickey and Clements 1998; Harding et al. 2000; Gray and Harding 2012). The Acid Mine Drainage Index (AMDI) has been developed and has the advantage in specific sensitivity to the invertebrate communities and environmental stressors found in streams affected by AMD (Gray and Harding 2012).

The AMDI is defined by 3 categories:

- \(<20 = \text{impacted by AMD};
- \quad 20-40 = \text{moderately impacted by AMD}; \text{and}
- \quad >40 = \text{un-impacted by AMD}.\)
Alterations in water chemistry, particularly release of metals and increased acidity can have profound effects on invertebrate communities. Unlike other types of pollution such as organic pollution, stoneflies (Plecoptera) and caddisflies (Tricoptera) are not necessarily a good indicator of mine impacts due to their tolerances with low pH, high and heavy metal concentrations (Harding 2002; Gray and Harding 2012). In contrast, some mayfly (Ephemeroptera) taxa are sensitive to heavy metal concentrations, such as Ichthybotus and are generally absent from sites with heavy metal contamination.

Aquatic flora and fauna assemblages can be spatially complex and temporally variable depending on a wide range of environmental and biological factors. Such factors as light, nutrients, physio-chemical conditions (i.e. temperature and dissolved oxygen), current velocity, substrate, physical disturbance and competition can all influence diversity. However, in systems receiving AMD, the chemical characteristics of the by-product are of overriding importance and can strongly influence community composition (Harding, 2005; Lefcort et al., 2010). AMD, characterised by acidic metalliferous conditions in water, generate physical, chemical and biological degradation of stream habitat.

Concentrations of common elements such as copper, zinc, iron, aluminium, and mercury all dramatically increase in waters with low pH and become readily available to biological organisms. Exposure to low pH and elevated metal concentrations may cause a number of physiological and stresses to benthic invertebrates. For example, chronic and acute toxicity may result when fish are directly exposed to metals and H⁺ ions through their gills, impairing respiration (Jennings et al., 2008). Fish, are also indirectly exposed to metals through ingestion of contaminated sediments and food resources (Jennings et al., 2008).

Elevated concentrations of metals in water can be toxic to aquatic organisms, algae and macrophytes, leaving receiving streams biologically devoid (Kimmel, 1983; Bray et al., 2008). Furthermore, the common weathering product of sulfide oxidation is the formation of a red/orange coloured precipitate, iron hydroxide (Fe(OH)₃). The precipitation can physically coat the streambed, destroying habitat, reducing availability of gravels for spawning, and reducing food resources for fish and benthic macroinvertebrates (Barry et al., 2000; Farag et al., 2003; Boudou et al., 2005; Martin and Goldblatt, 2007; Jennings et al., 2008).

2.3 Methods

2.3.1 Ecological Sampling Procedures

Ecological monitoring was undertaken within the Tunakohoia and Tui Streams at four sampling locations: un-impacted Tui Stream (upstream of tailings discharge; SW12), impacted Tui Stream (downstream of discharge; SW13), un-impacted Tunakohoia Stream (south branch above north branch confluence; SW8) and impacted Tunakohoia Stream (north branch below discharge; SW7) (Table 1; Figure 1 Appendix A).
Table 1: Tui Baseline Monitoring Sites

<table>
<thead>
<tr>
<th>Site ID</th>
<th>State</th>
<th>Site Name</th>
<th>Site Description</th>
<th>Monitored For</th>
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<td>SW12</td>
<td>Un-impacted</td>
<td>Tui Stream</td>
<td>Tui Stream, upstream of tailings discharge.</td>
<td>Ecology &amp; Water Quality</td>
</tr>
<tr>
<td>SW13</td>
<td>Impacted</td>
<td>Tui Stream</td>
<td>Tui Stream, downstream of tailings discharge upstream of ford and culverts.</td>
<td>Ecology &amp; Water Quality</td>
</tr>
<tr>
<td>SW8</td>
<td>Un-impacted</td>
<td>Tunakohoia Stream</td>
<td>Tunakohoia Stream south branch, upstream of north branch confluence, town water supply inlet.</td>
<td>Ecology &amp; Water Quality</td>
</tr>
<tr>
<td>SW7</td>
<td>Impacted</td>
<td>Tunakohoia Stream</td>
<td>Tunakohoia Stream north branch, upstream of south branch confluence and downstream of tailings dam.</td>
<td>Ecology &amp; Water Quality</td>
</tr>
</tbody>
</table>

Ecological and water quality sampling was undertaken in October 2013. For consistency and comparison of results, ecosystem health samplings were carried out in accordance with sampling locations and methodologies used by Coffey (2009).

In brief, macroinvertebrates were collected semi-quantitatively using a long-handled D-net (kick net) with a 500 um mesh net. Sampling was conducted in accordance with established guidelines. An area of approximately 3 m² was sampled and the proportion of habitat types sampled was recorded on field assessment cover forms. Four replicates were collected at each site to allow for the detection of statistically significant differences in macroinvertebrates. The macroinvertebrate samples were preserved in the field for later processing and analysis.

Macroinvertebrate samples were sent to a suitably qualified and experienced consultant for identification, where a 200 individual fixed count with a scan for rare taxa for each macroinvertebrate sample was undertaken (Stark et al. 2001 and Kelly 2005). A representative sub-set of samples, consisting of two samples from the impacted sites (Impacted Tui and Tunakohoia Stream) and one sample from an un-impacted site (un-impacted Tui Stream) were sent to a third party consultant for quality assurance and control purposes.

Water quality parameters (temperature, conductivity, dissolved oxygen and pH) were measured at each ecological monitoring site using calibrated field meters. This information will be presented in an accompanying water quality report.

Habitat assessments were conducted at each of the four sites using field assessment forms and hard bottom forms (Collier and Kelly 2005). Habitat scores were very similar to that of 2009. Given there have been no notable changes, repetition of this information has not been presented in this report. For reference to habitat assessments see Coffey (2009).

Periphyton cover was also assessed, however other than iron precipitate observed at the impacted Tunakohoia Stream north branch (SW7), only one of the four sites had presence of a thin black algal film, the impacted Tui Stream below the discharge (SW13).
2.3.2 Statistical Analysis of the Data

A variety of individual metrics were used to assess the relative health of the macroinvertebrate communities at each site. The total number of invertebrates, taxonomic richness, Macroinvertebrate Community Index (MCI), Quantitative Macroinvertebrate Community Index (QMCI), and the percentage of Ephemeroptera, Plecoptera, Trichoptera (%EPT) were assessed for each site (Table 2).

A T-test was also performed on the indices data between un-impacted and impacted sites to test whether there were any significant differences (P<0.05) in the scores. Species were also reduced to broad taxonomic groups for the assessment of relative abundances of the taxa groups at each site (presented as % bar graph; Figure 4 Appendix C).

<table>
<thead>
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<th>Table 2: Macroinvertebrate Metrics</th>
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<tr>
<td>Metric</td>
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<td>-----------</td>
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<td>Taxa Richness</td>
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<td>QMCI</td>
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<td>%EPT</td>
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<td>AMDI</td>
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2.4 Results and Discussion

The presence and relative abundance of macroinvertebrates as measured at the sites, together with calculated metrics of macroinvertebrate community structure are provided in Appendix B.

2.4.1 Macroinvertebrate Health and Indices

Macroinvertebrate health results from both un-impacted sites, were similar to that of Coffey (2009), scoring “excellent” MCI and QMCI values (Table 2). This indicates very good instream habitat for aquatic macroinvertebrates (Figure 2 and 3 Appendix C).

MCI values were found to be significantly higher at the un-impacted sites compared to the impacted sites in Tui Stream ($p = 0.0068$, $r^2 = 0.73$) and the Tunakohoia Stream ($p = 0.0033$, $r^2 = 0.78$) in the 2013 sampling. A notable improvement was observed in macroinvertebrate health at the impacted sites on the Tui and Tunakohoia Streams in 2013, compared to surveys undertaken in 2009 (Coffey 2009) MCI health scores at the impacted site on Tui Stream improved from ‘poor’ in 2009 to ‘excellent’ in 2013 and the impacted site on the Tunakohoia Stream improved from ‘poor’ in 2009 to ‘good’ in 2013 (Table 2).

The improved MCI scores generally indicate very good instream habitat for aquatic macroinvertebrates, however mayflies (Ephemeroptera) were absent from the impacted sites (Appendix B). The likely reason for absence of mayflies at the impacted sites is not yet known.

Table 2. Summary Table: Average Macroinvertebrate Results

|----------|-----------------------------|---------------------------|-----------------------------|---------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|

Key: Stream Health Score Card
- MCI < 80 = Poor
- MCI 80-100 = Fair
- MCI 100-120 = Good
- MCI > 120 = Excellent
- QMCI < 4.00
- QMCI 4.00 - 5.00
- QMCI 5.00 - 6.00
- QMCI > 6.00

Key: Acid Mine Drainage Index
- AMDI < 20 = impacted by acid mine drainage
- AMDI 20 - 40 = moderately impact by AMD
- AMDI > 40 = unimpacted
The %EPT values obtained from the 2013 sampling were not significantly different between the impacted and un-impacted sites in Tui Stream. However, %EPT values were significantly different between the impacted and un-impacted sites on the Tunakohoia Stream (p = 0.0019, r² = 0.82).

2.4.1.1 Invertebrate Richness and Abundance

Macroinvertebrate community richness reflects the health of instream communities and generally increases with improving water quality, habitat diversity and/or habitat suitability.

Overall, taxonomic richness increased across all sampling locations from 24 in 2009 to 54 in 2013. Average taxonomic richness at the two un-impacted sites was similar between sampling rounds 2009 and 2013 (Table 2). Average taxonomic richness increased at both impacted sites from 2 to 7 taxa at the impacted site on Tui Stream and average taxa richness increased from 2 to 8 taxa at the impacted site on Tunakohoia Stream from 2009 to 2013. Taxonomic richness was significantly higher at the un-impacted sites compared to the impacted sites in the 2013 monitoring, in the Tui Stream (p = < 0.004, r² = 0.89) and the Tunakohoia Stream (p = <0.002, r² = 0.82).

Several species were recorded in 2013 that were not observed in 2009 at both the un-impacted and impacted sampling sites. For example at the un-impacted sites, mayflies *Ameletopsis perscitus* and *Austroclima sepia*, several stoneflies and diptera were recorded and at the impacted sites, stonefly *Acroperla trivacuata* and *Stenoperla spp* and the caddisfly *Hydropsyche* were recorded (Appendix B; Coffey 2009).

Average macroinvertebrate abundance at both un-impacted sites were similar to that observed in 2009, with the site on Tui Stream having generally higher abundances (Table 2) than the un-impacted site on the Tunakohoia Stream.

An increase in abundance at the two impacted sites was observed from the 2009 sampling (Table 2): 2 to 95 individuals at the impacted site on Tui Stream and 2 to 38 individuals at the impacted site on Tunakohoia Stream. Although an increase in abundance at the impacted sites was observed, numbers were still low (at <50 % of corresponding results from the un-impacted sites), particularly at the impacted site on the Tunakohoia Stream.

2.4.2 Acid Mine Drainage Index

Macroinvertebrate AMDI results from 2013 indicate that the two un-impacted sites are un-impacted by AMD (as expected) and the two impacted sites are moderately impacted by AMD (Table 2). AMDI values were significantly different at the un-impacted sites compared to the impacted sites in Tui Stream (p = <0.001, r² = 0.94) and in the Tunakohoia Stream (p = <0.0004, r² = 0.84).
2.4.3 Community Composition

When looking at the percent contribution of macroinvertebrate communities, Caddisfly (Trichoptera), family Hydropsyche (Orthopstche and Aoteapsyche) appear to be the dominant taxa at all four monitored sites (Figure 4, Appendix C). Mayfly (Ephemeroptera) and stoneflies (Plecoptera) were also dominant at the un-impacted sites and made up between 10-30 % of the community (Figure 4, Appendix C). Greater diversity was observed at the two un-impacted sites, represented by increased taxonomic richness and high abundances of each taxa. Freshwater Koura were present at the un-impacted site on Tui Stream, further suggesting good ecosystem health and aquatic diversity in the upper reaches above the mine discharge.

Although there have been improvements compared with the situation reported in Coffey (2009), the macroinvertebrate communities at the two impacted sites are generally dominated by 1 taxa, namely caddisflies (these make up 82% of the sample from the impacted site on Tui Stream and 67% of the sample at the impacted Tunakohoia Stream site) and secondary by Diptera (or true flies; Figure 4, Appendix C). When a community is dominated by few species it is generally indicative that they are under environmental stress.

2.5 Summary

Ecological monitoring was undertaken within the Tui and Tunakohoia Streams at four sampling locations, un-impacted Tui Stream (upstream of tailings discharge; SW12), impacted Tui Stream (downstream of discharge; SW13), un-impacted Tunakohoia Stream (south branch above north branch confluence; SW8) and impacted Tunakohoia Stream (north branch below discharge; SW7) (Table 1; Figure 1 Appendix A).

All four monitoring sites were physically similar, hard-bottomed habitats. Healthy aquatic macroinvertebrates were observed at the un-impacted control sites along the Tui Stream and the Tunakohoia Stream south branch. In previous sampling by Coffey (2009), healthy macroinvertebrate communities were not observed downstream of the tailings and mine discharges in the Tui Stream and the Tunakohoia Stream north branch, in fact they were virtually non-existent. However, this repeat survey four years on has demonstrated a notable improvement in the macroinvertebrate community.

Macroinvertebrate index scores and taxonomic richness increased at both impact sites:

Impacted Tui Stream (changes from 2009 -2013)

- MCI health scores improved from ‘poor’ to ‘excellent’
- Average taxonomic richness increased from 2 to 7 taxa
- AMDI scores indicate this sites is still “moderately’ impacted by AMD

Impacted Tunakohoia Stream (changes from 2009 -3013)

- MCI health scores improved from ‘poor’ to ‘good’
- Average taxonomic richness increased from 2 to 8 taxa
AMDI scores indicate this sites is still “moderately” impacted by AMD. The improved MCI scores generally indicate very good instream habitat for aquatic macroinvertebrates, however mayflies (Ephemeroptera) were absent from the impacted sites (Figure 2, Appendix B). The likely reason for absence of mayflies at the impacted sites is not yet known.

It is positive to see an improvement at the impacted sites, particularly with regards to the presence of the stonefly Acroperla trivacuata and Stenoperla spp and the caddisfly Hydropsyche. However, species of stoneflies and caddisflies are known to tolerate lower pH and higher heavy metal concentrations than some other aquatic taxa (Gray and Harding 2012). As the more sensitive taxa to heavy metal concentrations such as some mayfly species (Hickey and Golding 2002) are still absent from the impact sites, this potentially indicates some level of continued environmental stress.

The improvement in macroinvertebrate community health in the Tui and Tunakonoia Streams (below the Tui mine discharge) is likely attributed to remediation efforts and the associated improvement of instream water quality conditions. The findings in this report now need to be correlated with results of water quality sampling conducted by PDP to further explore causations / likely reasons for the observed improvement in macroinvertebrate health.

3.0 Recommendations

- Given the notable improvement in macroinvertebrate health at the two impacted sites, it is recommended that ecological monitoring of macroinvertebrate health be continued to track remediation progress. Although improvements in aquatic health have been observed, abundance and taxonomic richness are still significantly lower when compared to the un-impacted control sites. This indicates that the community has not yet returned to its likely pre mine discharge state.
- Seasonal changes (climatic condition) and stages of macroinvertebrate life cycles can have a significant influence on presence/absence of taxa. It is therefore recommended that a summer sampling survey be conducted to monitor seasonal changes.
- Additionally, common bullies have recently been observed in the Tui and Tunakohoia Streams. Given that no fish have been reported in these streams before, a fish survey or investigation is also recommended.
4.0 References


Figure 1: TUI MINE BASELINE MONITORING LOCATIONS MAP
## Appendix B: Stream Survey Sheet: Macroinvertebrate Identification and summary statistics

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## Appendix B

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Figure 2. Average Macroinvertebrate Community Index (MCI) scores at un-impacted and impacted sites on Tui Stream and Tunakohoia Stream (Appendix B) from 2009 and 2013, error bars are ± S.E (where n =4).

Figure 3. Average Quantitative Macroinvertebrate Community Index (QMCI) scores at un-impacted and impacted sites on Tui Stream and Tunakohoia Stream (Appendix B) from 2009 and 2013, error bars are ± S.E (where n =4).
Figure 4. Macroinvertebrate community composition represented by percent abundance of dominant categorised taxa at un-impacted and impacted sites on Tui Stream and Tunakohoia Stream. Taxa grouped into the category ‘Other’, include Crustacea, Mites, Oligochaetes and Snails.