AN ECOLOGICAL OVERVIEW OF THE PUARENGA STREAM WITH PARTICULAR EMPHASIS ON CULTURAL VALUES

PREPARED FOR:

ROTORUA DISTRICT COUNCIL AND ENVIRONMENT BAY OF PLENTY

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TABLE OF CONTENTS

LIST OF TABLES

Cover plate. The Puarenga Stream at Whakarewarewa Village.

EXECUTIVE SUMMARY

This report provides an ecological overview of the Puarenga Stream system with particular emphasis on issues affecting Māori, incorporating the principles of a Cultural Health Index, to facilitate the participation of iwi in resource management processes and to assist in the prioritisation of remedial actions once issues of concern to iwi have been identified. The report also assesses the potential effects of two current resource consent applications, from Rotorua District Council - ongoing water abstraction from the Waipa Stream - and Environment Bay of Plenty for the addition of Alum to the lower Puarenga Stream.

The Puarenga Stream has significant cultural values, with three marae - Te Pakira, Hinemihi, and Hurunga O Te Rangi - situated along its banks, as well as the internationally-known tourist attractions of Whakarewarewa Village and Te Puia. The Puarenga Stream at Whakarewarewa is used extensively for swimming and bathing and is an integral part of the tourist experience.

Main land uses in the upper Puarenga catchment are plantation forestry and farming with industrial activities at the Waipa/Red Stag mill, Rotorua Landfill, and other industrial land uses adjacent to the State Highway 30 turnoff. Spray irrigation of treated sewage effluent has been underway in Whakarewarewa Forest since 1991. Most of these land uses are monitored and are well understood, in terms of effects on water quality, with the exception of pastoral farming effects in the catchment. Since the early 1990's extensive remedial works and management improvements have been made to reduce the impacts of industrial and municipal land uses in the Puarenga Stream catchment with recent monitoring showing a marked improvement in stream water quality. Water abstraction has been a long-term use of the Waipa Stream, and renewal of the existing resource consent will maintain the existing status quo with respect to water quality and volume in the Puarenga Stream.

The ecology of the Puarenga changes significantly at Whakarewarewa Village due to large scale natural geothermal inputs and, from this point downstream, the Puarenga is considered a thermal stream. Given, its thermal character in the lower reaches - low acidity and enriched heavy metal levels - the addition of Alum at such low concentrations is unlikely to adversely affect mahinga kai, recreational or ecological values in the lower Puarenga.

Remedial actions

- Regular hui should be held between tangata whenua and Environment Bay of Plenty to inform iwi of environmental issues in the catchment, to facilitate the participation of iwi in resource management processes, and to assist in the prioritisation of remedial actions of concern to iwi.

- Environment Bay of Plenty should consider monitoring and research into the following issues that are of concern to iwi; the "old" landfill in Sulphur Bay, livestock farming in the catchment (particularly in regard to faecal coliform levels), discharges from industry in the Ngapuna area, and the current state of PCP contamination in the Puarenga Stream.

- Resource management and research agencies should consider using iwi representatives i.e. kaitiaki, scientists and environmental students, to assist in monitoring and research projects in the Puarenga Stream system.

- Environment Bay of Plenty, Rotorua District Council and tangata whenua should consider the development of a management plan for the Puarenga Stream, with the primary aims of restoration of the riparian margins and wetlands and to enhance walking and cycling access between Rotorua City and Whakarewarewa Forest.

1 INTRODUCTION

Healthy waterways have always been prized by Māori. Ensuring that the mauri of a waterway is not diminished; gathering mahinga kai for sustenance and maintaining the mana of the tangata whenua are all fundamental cultural values. The right of tangata whenua to take part in managing freshwater resources is formally recognised and legislated in the Resource Management Act (1991), in Sections 5, 6(e), 7(a), and 8.

This report was instigated by the Tuhourangi Tribal Authority (TTA), which requested that a Cultural Health Assessment of the Puarenga Stream be prepared to assist them to determine the effects of two current (and future) resource consent applications on tangata whenua values in the Puarenga Stream system.

Aspects of this report are based on the principles outlined in the Cultural Health Index or CHI (Tipa and Tierney 2006) that was developed to help Māori participate meaningfully in the management of freshwater - specifically in relation to waterway health - and aims to achieve two main goals:

1. **To provide a way for Māori to take an active role in managing freshwater resources**.

2. **To provide an opportunity for resource management agencies to discuss and incorporate Māori perspectives and values for stream health in management decisions**.

The following sections include an overview of issues of concern to Māori, a description of the Puarenga catchment, results from field survey work, an assessment of land use issues in the catchment, and an overview of the state of the environment in the catchment. A set of remedial actions is also provided.

2 PROJECT OBJECTIVES

The objectives of this project were to:

- *Identify issues of concern to Māori.*

- *Collate and evaluate existing information on ecological and water quality values with special emphasis on mahinga kai species and recreational bathing in the Puarenga catchment.*
- *Discuss the potential effects of two proposed resource consent applications on the Puarenga Stream system.*
- *Prioritise remedial actions for issues of concern to Māori.*

3 ISSUES OF CONCERN TO MĀORI

Hui were held with the Tuhourangi Tribal Authority and Ngati Tarawhai (at Hinemihi Marae) on 26 April and 22 June 2008 respectively. A strong message from these hui was that a holistic view - "ki uta ki tai" (mountains to the sea) approach - was required to determine the potential effects of the two current (and future) resource consent applications in the Puarenga Stream system. Concerns were also raised at both hui in regard to water quality, and in particular the effects of Red Stag (previously Waipa) Timber Mill, the Rotorua District Council's (RDC) municipal landfill, and the RDC Land Treatment System (LTS), for sewage disposal, on the suitability of the Puarenga for swimming and the gathering of mahinga kai (wild food) resources. Access to the true right bank of the lower Puarenga and the effects of the 'old' rubbish dump, were additional issues raised at the hui at Hinemihi Marae.

After much consideration it was decided that the Cultural Health Index approach of Tipa and Tierney (2006) would not suit the goals of the Tuhourangi Tribal Authority for the following reasons: (1) the Puarenga has a considerable geothermal influence at Whakarewarewa which has a significant effect on the ecology and use of the lower stream, (2) the presence of large scale operations such as the timber mill, land treatment and disposal of domestic sewage, and municipal landfill in the catchment, and (3) the assessment needed to consider the potential effects of the two current resource consent applications on the Puarenga Stream. In addition, there was already considerable scientific and cultural information available on the Puarenga Stream and its catchment.

It was therefore decided that a better approach would be to compile an ecological overview of the Puarenga Stream system with particular emphasis on issues affecting Māori while incorporating the principles of the Cultural Health Index, namely, to facilitate the participation of iwi in resource management processes, and to assist in the prioritisation of remedial actions once issues of concern to iwi are identified. Once the ecological overview had been completed then the potential effects could then be assessed of two current resource

consent applications, from the Rotorua District Council for water abstraction from the Waipa Stream and Environment Bay of Plenty for the addition of Alum to the lower Puarenga Stream.

4 PUARENGA CATCHMENT

The Puarenga Stream is a major catchment on the southern side of Lake Rotorua, with a mean annual base flow of about 1.89m^3/s (Environment Bay of Plenty in Rutherford 2003). It flows through Whakarewarewa Village and Ngapuna before entering the lake at Te Arikiroa or Sulphur Bay (Figure 1).

The Puarenga Stream and its tributaries form a corridor of 'wild' habitat linking adjacent hills with the geothermal margins of Lake Rotorua. The western side of the Puarenga headwaters, adjacent to State Highway (SH30) - the Rotorua-Atiamuri Road - drains farmland and local areas of indigenous forest (in the headwaters of the Tureporepo tributary). The headwaters of the Waikaruru tributary, between SH30 and SH5 (the Rotorua - Taupo State Highway), adjoin a tributary of the Waikato catchment in the vicinity of the Kapenga wetland. The Kauaka tributary is in the small valley along SH5, and drains farmland to the west of the road and exotic plantation forest on the eastern side of this sub-catchment.

The Tureporepo and Waihuahuakakahi Streams arise in the western and southern areas of the catchment where the predominant land use is pastoral farming. Of note, however, is the Rotorua District Council municipal landfill which is situated approximately 2 km south of the SH 30 and SH 5 intersection (Figure 1).

The Waipa Stream and its tributaries, some of which are relatively large streams, mainly drain exotic plantation in Whakarewarewa Forest, although one headwater tributary (The Wash) drains farmland adjacent to Tarawera Road and Okareka Loop Road. The forested catchment and underlying pumice soils result in a stable flow regime typical of pumice streams. Whakarewarewa Forest also includes small pockets of indigenous forest and local wetlands. Whakarewarewa Forest is used for the spray irrigation of treated sewage effluent from Rotorua, and this is now an important component of this system. Red Stag timber mill, one of New Zealand's largest sawmills, occupies a 120 ha site alongside the Waipa Stream.

The Kauaka, Tureporepo, and Waipa Streams merge adjacent to the Waipa Mill turnoff to become the Puarenga Stream (Figure 1). The Puarenga then flows in a northerly direction through Whakarewarewa Village.

Upstream of Te Puia, the stream is in the floor of the Hemo Gorge, the main southern entrance to Rotorua City. The road is on the western side, while the eastern side is clothed with secondary indigenous forest on the flanks of Pohaturoa, a significant landscape feature and viewpoint above the geothermal area. This area is developing, through natural succession; into a locally important natural feature (control of large wilding pines has already been undertaken here and there is scope for further control of pines and other exotic trees). This section of the Puarenga Stream has long been recognised as a significant site for a colony of little shag (*Phalacrocorax melanoleucos*) (Rasch 1989). Black shag (*P. carbo*) also use this section of stream.

Upstream of the Whakarewarewa Village, the stream has a more natural environment dominated by geothermal vegetation and habitats and associated terrestrial indigenous vegetation, although there are some significant weed infestations adjacent to the stream channel. The Whakarewarewa thermal area is a large and ecologically significant site and the focus of a major tourism operation (Whakarewarewa Village and Te Puia). The Puarenga Stream is heavily influenced by natural geothermal inputs at Whakarewarewa thermal area (and at Ngapuna) and from this point downstream it is considered a thermal stream with acidic, warm water, ranging in temperature from 14 -22^{o}C.

The strip of riparian indigenous vegetation continues downstream of Whakarewarewa Village to around the main entrance to Scion Research (the former Forest Research Institute). Below this, the riparian margin is predominantly large exotic trees, with the exceptions of indigenous plantings at the Whakarewarewa School and adjacent to the Department of Conservation office in Sala Street. The section adjacent to Te Ngae Road and Ngapuna is relatively open and the stream then enters Lake Rotorua at Sulphur Bay. Sulphur Bay has very high values for indigenous vegetation and habitats and fauna. There are extensive geothermal flats which are used by large numbers of indigenous birds, including a breeding colony of black-billed gull (ranked as 'Chronically Threatened - Serious Decline'; Hitchmough *et al*. 2007). The bay is also used by large numbers of water birds, including shags, over-wintering dabchick (ranked as 'At Risk - Sparse'; Hitchmough *et al*. 2007), and scaup.

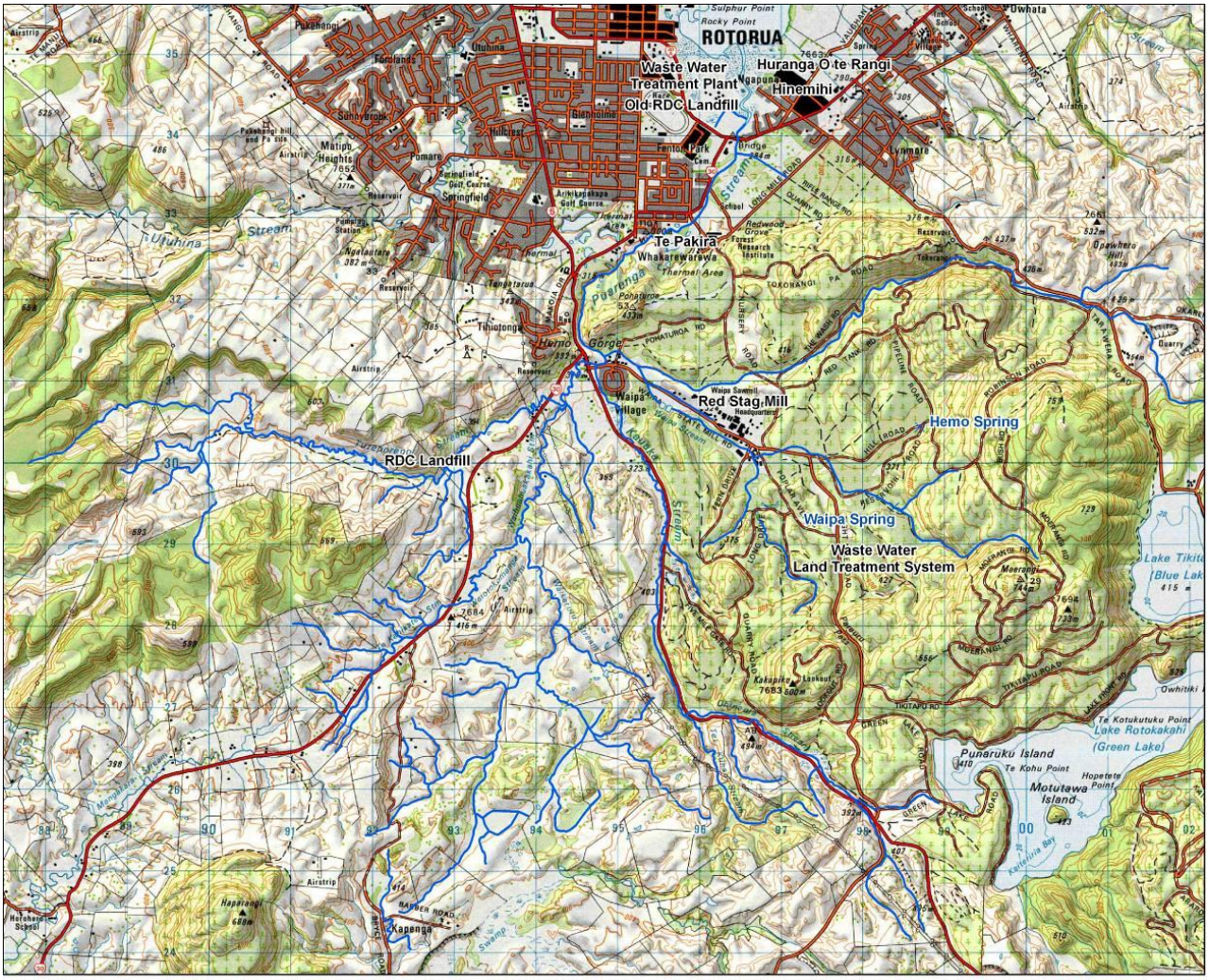

Figure 1. Puarenga Stream Catchment

5 STREAM AND SITE STATUS

The Puarenga has significant cultural values. Three marae are situated along its banks: Te Pakira, Hinemihi and Hurunga O Te Rangi. In addition, the Puarenga flows through the internationally renowned tourist attractions of Whakarewarewa Village and Te Puia.

The Puarenga Stream rises from springs and tributaries south of Te Hemo-a-Kuiwai (Hemo Gorge). The Puarenga flows through Te Whakarewarewa thermal reserve and rahui, flowing into the southernmost point of Lake Rotorua, at the eastern end of Te Arikiroa or Sulphur Bay. The name, Puarenga, is said to derive from sulphur particles which form into patterns resembling flowers due to the swirling currents (Stafford 1994). The Waipa and Hemo springs were used as a source of drinking water by villagers from Whakarewarewa when travelling to their gardens south of Rotorua such as Parekarangi (Makereti 1938; R. Mihinui, pers. comm.) or for collecting mahinga kai resources in the surrounding forest. During the Maori Land Court hearings of 1887, Mita Taupopoki of Ngati Wahiao and Hamuera Pango of Ngati Whakaue spoke of the Moerangi block (now in and adjacent to Whakarewarewa Forest) as having significant cultural bearing for gathering of raupo (*Typha orientalis*) and ochre (pigmented clay) and harvesting of tawa (*Beilschmiedia tawa*) berries during the season.

Te Whakarewarewa (Te Whakarewarewatanga-o-te-ope-taua-a-Wahiao "the uprising of the war party of Wahiao") was the site of Te Puia pa, which was built during the times of Taupopoki and Huarere, and occupied until the mid-1800's. Once abandoned as a pa, Te Whakarewarewa became a cemetery. Today the thermal village of Te Whakarewarewa is home to Tuhourangi/ Ngati Wahiao who have been guiding and hosting visitors there since the 1800s. A notable aspect of this experience is the "penny divers" who dive for coins tossed into the Puarenga Stream from the bridge at Whakarewarewa. Te Puia, formerly the New Zealand Māori Arts and Crafts Institute), a Māori cultural and geothermal visitor experience, is also sited adjacent to the Puarenga Stream.

Ngapuna Village is located to the east of the lower Puarenga Stream. Ngapuna was named after the 'many springs' present in the Owhata area. Much of the area was gifted by Ngati Hurunga-te-rangi to those Tuhourangi displaced by the eruption of Mount Tarawera in 1886 (Stafford 1994). Up until the mid- 1960's, the lower Puarenga was used extensively for swimming (Hinemihi Marae hui, 22 June 2008). Historically, raupo was harvested for weaving, while koura (*Paranephrops planifrons*) and watercress (*Rorrippa*

nasturtium-aquaticum) were present (V. Butterworth, secretary Huranga o Te Rangi marae, pers. comm.).

6 ECOLOGICAL CONTEXT AND HISTORY

Most of this section is from Beadel *et al*. (1998).

Before human arrival

From the time of the Rotorua tepha eruption until *c*.800 years ago, five major dome building lava flows and accompanying violent pyroclastic eruptions occurred within the Okataina Volcanic Centre, at average intervals of 2,000 years. Large areas of forest in that quarter of the district were undoubtedly obliterated or severely damaged on those occasions, but recovery and colonisation were probably well-advanced within a few decades after each event.

Indigenous forest is likely to have covered the project area when Māori first arrived. Forest composition is likely to have been rimu-northern rata/tawa-rewarewa-mangeao (*Litsea calicaris*)-kamahi forest on the hill slopes, with occasional hinau (*Elaeocarpus dentata*), pukatea, and tawari (*Ixerba brexioides*), with maybe small stands of kahikatea (*Dacrycarpus dacrydioides*) and a few pukatea (*Laurelia novaezelandiae*) on poorly-drained areas. Well-drained flats alongside streams may have supported rimu-miro (*Prumnopitys ferruginea*)-matai-totara (*Podocarpus totara*) forest with local kahikatea, tanekaha (*Phyllocladus trichomanoides*), hinau, rewarewa (*Knightia excelsa*), maire (*Nestegis* sp.), and kamahi (*Weinmannia racemosa*).

Human Influences Pre-1840

Reliable traditions indicate permanent occupation of the Rotorua district by Te Arawa began about 600-700 years ago. Very full accounts of Te Arawa history and areas used are provided in Stafford (1967; 1994).

Pollen studies (McGlone in Kennedy *et al*. 1978) show that *c*.700 years ago there began a marked reduction in the representation of large trees and a related increase in the proportion of pollen from shrubs characteristic of forest clearings, followed by an increasing preponderance of rārahu (bracken; *Pteridium esculentum*) fern spores. Fire was the principal means of forest clearance, and the writings of missionaries and European travellers in the early 1800s contain frequent references to customary Māori summer fires.

Forest was cleared for kainga (small settlements), pa (fortified villages), cultivations (kumara, taro, gourds), and for creating permanent rārahu fernland because the starchy rhizomes (aruhe) were a staple food. Fire was uncontrollable, so in dry, windy weather it often spread afar. In time, nearly all the Rotorua Caldera became open land up to about the highest terrace levels, with villages, kumara gardens, and rārahu fields scattered among low scrub of manuka, tutu (*Coriaria arborea*) and other indigenous shrubs, and rare pockets of surviving forest.

This vegetation became very extensive along the Tarawera River valley and southwards from about Whakarewarewa and Mt Tarawera, beyond which it graded into tussock and heathland. Only a few scattered sizeable stands of forest remained in this southernmost quarter of the Rotorua Lakes Ecological District, significantly on the highest ground or in shaded gullies.

A very detailed account of Māori former use of the natural resources of the district is provided in Makereti (1938), and further information is presented by Shaw *et al*. (1991). Resources taken from the forests were birds (e.g. tui, kereru), fruits (e.g. of tawa, hinau, kahikatea), small wood and other plant materials for a multitude of purposes, and occasionally large trees for waka (canoes) and major buildings. Many small clearings were made for encampments.

The vegetation history map of Beadel *et al*. (1998) shows that the vegetation of this area in 1840 was probably a mosaic of scrub, shrubland, and fernland, but there will have been tall forest remnants present. There was also a much larger area of wetland that is currently present to the east of Ngapuna (Beadel *et al*. 1998).

Post-1840 land use

Much of the catchment was cleared and developed for farming sometime in the first half of the 20th century. Whakarewarewa Forest was planted from 1900 onwards.

7 ECOLOGICAL ASSESSMENT METHODS

General

The upper Puarenga Stream system (Waipa, Kauaka, and Tureporepo Streams) have been visited by the authors for more than 20 years, so are very well known. Further site visits were undertaken in May 2008. Observations on vegetation and habitats were recorded during the field visits, along with habitat photographs. All species of avifauna (birds) heard and seen during the site visits were recorded.

Fisheries

Site visits were made to the Waipa and Hemo Springs on 2 May 2008 and in the lower Puarenga Stream on 8 May 2008, during sunny, clear calm weather. Water clarity at all sites was good and allowed excellent visibility while sampling. Electric fishing was used to assess fish populations at the two sites. Electric fishing is effective in estimating fish densities in sections of small streams and it is one of the least selective fish sampling methods. The study streams were sampled using a battery-powered 230 volt pulsed DC backpack set electric fishing machine. The study sections were fished in an upstream direction with the use of a handheld stop net (3mm mesh size) and a dip net. All fish captured were identified, counted and fish density was categorised subjectively, as 'Abundant', 'Common', 'Occasional', or 'Present'.

Notes were compiled on the fish and koura (freshwater crayfish) present, and observations made of stream width, depth, fish cover, substrate, riparian vegetation, and benthic invertebrates. This information was recorded on NIWA freshwater fish database forms (Appendix 1). All fisheries data has been submitted to NIWA for inclusion in the nationwide freshwater fish database. Site photographs were taken.

8 ECOLOGICAL VALUES AND MAHINGA KAI

Fisheries values

The Waipa Stream is a tributary of the Puarenga Stream, which flows through Whakarewarewa into Lake Rotorua. The Waipa Mill is situated alongside the Waipa Stream and most of the catchment is in exotic plantation pine forest. The forested catchment and underlying pumice soils result in a stable flow regime.

Waipa Spring

The stream channel immediately downstream of the Waipa spring is incised into a shallow gully with exotic trees on both sides of the gully. The stream channel is about 2m wide with a mean depth of 0.3m and a bed substrate comprised mainly of gravel and sand (Plate 1). The gully floor has been subject to earthworks to form small drainage channels in addition to the main stream channel. The alluvial flat in the gully floor has a thick cover of rank grass dominated by tall fescue (*Schedonorus phonix*), creeping buttercup (*Ranunculus repens*), and lotus (*Lotus pedunculatus*).

The gully sides include Himalayan honeysuckle (*Leycesteria formosa*), wheki (*Dicksonia squarrosa*), wheki-ponga (*D. fibrosa*), and kiokio (*Blechnum novae-zealandiae*). The stream channel has local patches of *Potamogeton chesmanii* and *Azolla rubra*. Channel margins include local purei (*Carex secta*), toetoe (*Cortaderia fulvida*), and *Carex geminata*.

Plate 1. Waipa Stream below the Rotorua District Council water intake, 30 June 2008.

Hemo Spring

This is a large spring (*c.* 20 m across) in a small valley floor at the levee of a valley surrounded by Douglas fir (*Pseudotsuga menziesii*) forest. The stream channel includes duckwood (*Lemna minor*) and watercress (*Rorrippa nasturtium-aquaticum*), the latter of which is locally common. Purei (*Carex secta*) and toetoe (*Cortaderia fulvida*) are common along stream margins, with patches of *Baumea* species. Yorkshire fog (*Holcus lantus*) is abundant, with local *Eleochoaris acuta*.

Lower Puarenga

Fisheries values in the Puarenga Stream are heavily affected by natural geothermal inflows from the Whakarewarewa and Ngapuna areas. The water is warm, acidic and enriched with heavy metals. The stream has been subject to earthworks to form stopbanks and a main stream channel. The streambed in this section is comprised mainly of mud, sand and fine gravel and is approximately 8m wide with a mean depth of 1m.

Riparian vegetation is comprised of manuka (*Leptospermum scoparium*), kanuka (*Kunzea ericoides*), mingimingi (*Leucopogon fasciculatus*), and prostrate kanuka (*Kunzea ericoides* var. *microflora*). Turutu (blueberry; *Dianella nigra*) is present along the edges of tracks and raupo and rushes occur in the water along the edges of parts of Sulphur Bay. Exotic plants such as blackberry (*Rubus fruticosus*), black wattle (*Acacia mearnsii*), gorse (*Ulex europaeus*), and Scotch broom (*Cytisus scoparious*) are also abundant.

Streambed substrates and habitat types at the three sampling sites are summarised in Table 2. Land uses and riparian vegetation at the four sampling sites are summarised in Table 1. Full descriptions of fisheries values at the study sites are outlined in Appendix 1.

Table 1 Sampling site names, descriptions, section lengths and predominant riparian vegetation in the study area, Puarenga Stream, 2 May and 8 May 2008.

Site name	NZMS 260 U16	Site description	Site length (m)	Riparian vegetation
1. Hemo Spring	98698 30439	Up & downstream of Hemo Spring dam	70	Mixture of native and exotic forest
2. Waipa Spring	98385 29460	Up & downstream of Waipa intake	70	Mixture of native and exotic forest
3. Lower Puarenga	96472 33978	Downstream of Te Ngae Road Bridge	70	Manuka, grasses

Distribution and abundance of fish and koura in the Puarenga system

The Puarenga Stream system is relatively well studied (Table 2) and the New Zealand Freshwater Fish database has 13 records for the catchment. In addition, fisheries and ecological surveys have been carried out in the Waipa Stream (Wildland Consultants 2003), Tureporepo Stream (Kusabs 1996), and the Kauaka Stream (C. Mitchell pers. comm.).

The Puarenga Stream has low fisheries values. Only three species of fish have been recorded in the 16 known fisheries surveys: brook char (*Salvelinus fontinalis*), rainbow trout (*Oncorhynchus mykiss*), and shortfin eel (*Anguilla australis*) (see Table 1). Koura or freshwater crayfish (*Paranephrops planifrons*) have also been recorded. Rainbow trout were the only fish species captured in our 2008 survey of the Waipa and Hemo springs and short sections of stream downstream of the springs. Eight rainbow trout ranging in size from 60 to 200mm were caught in the Hemo Spring stream whereas, 20 rainbow trout ranging in size from 60-330mm were captured in the Waipa Stream (Appendix 1). The rainbow trout population at both sites was a mixture of stunted adults and juvenile fish. A few small koura were also captured in both streams.

Small, stunted rainbow trout are the only fish species present in the upper Puarenga system (Kusabs 1996). Rainbow trout support important recreational fisheries throughout New Zealand. However, the rainbow trout population in the upper Puarenga system does not support angling due to the small, stunted nature of the fish present. Moreover, there is little angling activity in the lower section of the main Puarenga Stream due to large geothermal inputs at Whakarewarewa. No fish or koura were recorded in our 2008 this survey of the lower Puarenga Stream, although koura have been captured in a previous survey of the Puarenga in the vicinity of the Scion Research campus (NZFFD). The geothermal barrier also prevents the upstream migration of diadromous trout from Lake Rotorua to the upper catchment.

Cultural use

Koura were once harvested throughout the Puarenga system (Hinemihi Marae hui, 22 June 2008) but harvesting has not occurred since the establishment of industries at Waipa and Ngapuna and subsequent industrial discharges. Koaro (*Galaxias brevipinnis*; known locally as inanga) may have been harvested from the Puarenga prior to the introduction of trout to the Lake Rotorua catchment in the late 1800s, although there are no records of fishing grounds at the mouth of the Puarenga (Stafford 1994). Local harvesting of small trout from the upper Puarenga tributaries also occurred from time to time (R Mihinui, pers. comm.).

Table 2 Distribution and abundance of fish species recorded in the Puarenga Stream catchment.

Site name	Number of records	Fish and crustacean species present	Abundance	Size range (mm)
1. Waipa Stream	7	Rainbow trout Koura	Common Common	60 – 200
Hemo Spring	This study	Rainbow trout, Koura	Common Common	60 – 200
Waipa Spring	This study	Rainbow trout Koura	Common Common	60 – 350
2. Tureporepo Stream	2	Rainbow trout Brook char Koura	Abundant Rare (1) Common	60 – 210 30
Te Kahikatea	1	Koura	Common	
3. Kauaka Stream	3	Rainbow trout Shortfin eel Koura	Abundant Rare (1) Common	60 – 210 n/r
Ohineuia Stream	1	Rainbow trout	Abundant	60 - 300
4. Puarenga Stream	1	Koura	Common (5)	
Lower Puarenga	This study	No fish or koura recorded	-	-

Vegetation and Flora

Upper Puarenga catchment

The ecological value of much of the vegetation within the upper Puarenga catchment including the Hemo and Waipa springs is limited because it is dominated by exotic species, many of them invasive. Despite this, the vegetation does provide physical protection to the riparian margins (reducing erosion and direct run-off into the stream) and also provides shade to the in-stream habitat, which is important in reducing temperature fluctuations and potential algal or other unwanted aquatic growth. Removal or disturbance of riparian vegetation could release sediment into the waterway and reduce shading, thereby having an adverse effect.

A list of indigenous and exotic vascular plant species recorded during the field visits is provided in Appendix 1, with naturalised and planted exotic species also included in the list, although it should be noted that this list is not comprehensive.

Te Whakarewarewa, Lower Puarenga and Sulphur Bay

These thermal areas are harsh environments for plants, so there is not a great diversity of plant species as not many can tolerate the heat, acidity, poor soil and toxic gases. Indigenous vegetation consists of plants with needle-like leaves, slow growth, and irregular flowering habits. These include manuka, kanuka, mingimingi, and prostrate kanuka. In geothermally-heated soils, roots can only grow to a shallow depth which causes a wide flattened root system.

Whakarewarewa thermal area is a regionally-significant example of geothermal features and vegetation, with extensive areas of prostrate kanuka and other geothermal biota. It is a diverse place, with more than 20 vegetation and habitat types present (Wildland Consultants 2005), including very good examples of geothermal vegetation and other habitats such as mud pools and geysers. Six 'at risk' plant species occur at Whakarewarewa and the site has a 'national' ranking for ecological values (Wildland Consultants 2005).

At Te Arikiroa (Sulphur Bay), there is a large area of geothermal vegetation from Ngapuna, on the eastern side of Sulphur Bay, to Motutara Point on the western side of the bay. There is an extensive area of non-vegetated open habitat, which is heavily used by indigenous birds. Kanuka- and manuka-dominant vegetation covers reasonably large areas, with small areas only of prostate kanuka. This site has also been ranked as being 'nationally' significant for ecological values (Wildland Consultants 2005). Sulphur Bay has undergone considerable modification and the vegetation there reflects that history, with many weeds and modified areas.

Cultural use

A very detailed account of Māori former use of the natural resources of the district is provided in Makereti (1938), and further information is presented by Shaw *et al*. (1991). Plant resources obtained from the forests included fruits (e.g. of tawa, hinau, kahikatea, kawakawa, kiekie, konini, makomako, rohutu, tutu), ferns (rārahu, mamaku, pikopiko; *Polystichum richardii*), harakeke (flax), raupo, ti kouka (cabbage tree), small wood and other plant materials for a multitude of purposes, and occasionally large trees for waka (canoes) and major buildings. Moerangi was a favoured place for gathering tawa berries, which were cooked in the boiling and steam holes of Whakarewarewa (Makereti 1938). Today, plant species of cultural significance in the catchment include, harakeke, pikopiko, pūhā (sow thistle; *Sonchus spp.*), and watercress. The latter is an important food plant but can

accumulate arsenic and other contaminants particularly in geothermally-influenced waters (Robinson *et al*. 2006). Harakeke, raupo, mamaku, ti kouka and bracken (rārahu) occur in the general vicinity of the Waipa and Hemo Springs.

Pest plants

There are invasive weed species elsewhere in the catchment, downstream of the springs, all of which require control, including yellow flag (*Iris pseudacorus*), ivy (*Hedera helix*), male fern (*Dryopteris fillixmas*), and Chinese privet (*Ligustrum sinense*). Privet is also present adjacent to the Hemo Spring.

Avifauna (birds)

Upper catchment

Indigenous species recorded during the site visits included: riroriro (grey warbler; *Gerygone igata*), piwakawaka (fantail: *Rhipidura fuliginosa placabilis*), and korimako (bellbird; *Anthornis melanura*). Other indigenous species known to utilise forest habitats in Whakarewarewa Forest include toutouwai (North Island robin; *Petroica australis* subsp. *longipes*), tui (*Prosthemadera novaeseelandiae*), kereru (NZ pigeon; *Hemiphaga novaeseelandiae*), karearea (NZ falcon; *Falco novaeseelandiae*), and ruru (morepork; *Ninox novaeseelandiae*). Black shag (*Phalacrocorax carbo*), little shag (*Phalacrocorax melanoleucos brevirostris*), and grey duck (*Anas superciliosa superciliosa*) are likely to utilise aquatic habitats, along with mallard duck (*Anas platyrhynchos*) and paradise shelduck (*Tadorna variegata*).

Introduced species recording during the site visits included chaffinch (*Fringilla coelebs*), pheasant (*Phasianus colchicus*), goldfinch (*Carduelis carduelis*), blackbird (*Turdus merula*), song thrush (*T. philomelos*), dunnock (*Prunella modularis*), and eastern rosella (*Platycercus eximius*).

These are mostly common species, typical of the habitats present, and only three (kereru, falcon, and black shag) are classified as threatened (as per Hitchmough *et al*. 2007). The avifauna is dominated, numerically, by small insectivorous birds such as tauhou (silvereye), riroriro (grey warbler), piwakawaka (fantail), house sparrow, and goldfinch. Black shag (classified as 'At Risk – Sparse', Hitchmough *et al*. 2007) have been seen in the stream, downstream of Red Stag mill. Magpies are also common in the general area. There are most likely other common indigenous and exotic bird species using the site which were not noted during the brief site visits.

Sulphur Bay

The Puarenga Stream discharges into Lake Rotorua at Te Arikiroa or Sulphur Bay. The Sulphur Bay Wildlife Refuge covers 145 hectares and is administered by the Department of Conservation. There are 63 bird species found in the area – 45 indigenous and 24 water-dependent. Sulphur Bay is generally used for roosting and breeding but not often for feeding. Birds present include gulls, shags, ducks, banded dotterel, black swan, Caspian tern, grey teal, New Zealand dabchick, scaup, N.Z. shoveler, pukeko, stilts, spur-winged plover, welcome swallow, and white-faced heron. The banded dotterel is a threatened species and dabchick is classified as 'At Risk – Sparse' (Hitchmough *et al.* 2007).

Cultural use

Traditionally, kereru, kaka, pukeko, ducks, weka, tui, korimako would have been an important resource prior to habitat destruction, over-hunting, and predation by introduced pests. Kereru were captured with mahanga (snares) and tāhere (spears). Makereti (1938) notes that nga hapü ō Tuhourangi had many bird snaring areas, including Te Whakarewarewa and Moerangi. Ducks, pukeko, and shags would have been harvested from the lower Puarenga and at Sulphur Bay, and in the upper catchment. In recent times, there has been only limited cultural harvesting of birds from the Puarenga catchment including hunting of ducks from the Puarenga Stream (including its tributaries and wetlands) and upland game species (pheasant and quail) from the surrounding forest. Sulphur Bay has been protected as a Wildlife Refuge for many years, where hunting is prohibited.

Photo 2. Scaup in the lower Puarenga Stream, 1 July 2008.

9 CULTURAL STREAM HEALTH

Water quality in the Puarenga Stream system is relatively well studied due to extensive investigations into the fate of PCP at the Waipa sawmill complex and monitoring of the Rotorua District Council's sewage land treatment system and the Municipal Landfill. Environment Bay of Plenty also monitors recreational bathing water quality at Whakarewarewa Village. The history, descriptions and impacts of these activities are described in further detail below.

Red Stag (formerly Waipa) Mill Site

Red Stag Timber Limited is a large sawmill complex located approximately 5 km south of Rotorua. The mill is located in the Waipa Stream catchment, with the Waipa Stream on the southern boundary, the Puarenga on the northern boundary and the Kauaka Stream on the southwest boundary. Since its establishment the mill has used various chemicals to act as antisapstain preservative as well as to preserve the sawn timber against rot and insect attack. These chemicals have resulted in contamination of both land and groundwater.

Between 1956 and 1989, the mill used up to 1000 tonnes of PCP (Pentachlorophenol) an organoclorine pesticide which preserves timber by killing fungi and insects that cause decay. The PCP formulations used in New Zealand were contaminated with significant quantities of dioxins, which are known to be toxic and carcinogenic (Gifford *et al*. 1993). These chemicals also persist in the environment, enter the food chain, and accumulate in aquatic organisms.

In 1991, the full extent of PCP contamination was investigated in a study commissioned by the Ministry of the Environment and the Department of Health (Gifford *et al*. 1991). This study found significant contamination of soil, however the greatest concern was contamination of groundwater as it was mobile and moving off-site into the Waipa Stream and wider environment. To mitigate these effects, a groundwater remediation system was commissioned in 1994. This treatment involves abstraction of groundwater from interception trenches (700m in total), and then breaking down the PCP and dioxin in a Rayox Plant whereby hydrogen peroxide is added to the groundwater before irradiation with Ultra Violet light, resulting in the breakdown of PCP into carbon dioxide, water, and hydrochloric acid. The treated groundwater is then discharged into the RDC effluent treatment ponds for further breakdown before spray discharge to the forest.

Since implementation of the remediation system in 1994, PCP levels in the Waipa Stream have fallen from approximately 40 ppb (parts per billion) to about 0.2 ppb, which is significantly less than the ANZECC 2000 guidelines for 99% protection of species set at 3.6ppb. Overall compliance at the mill is high, although there were significant issues with stormwater compliance at the site in 2007. However, subsequent monitoring has shown that sealing works have shown improvements in the management of the site (Pickles and Collins, 2007).

Rotorua District Council Sewage Land Treatment System

The Rotorua Land Treatment System commenced in 1991 and is managed by Wastewater Treatment Plant Manager of the Rotorua District Council, with the objective of reducing nutrient loading to Lake Rotorua. Water quality in Lake Rotorua had been declining since the 1960's because of excessive phytoplankton (algae) growths caused by increased inputs of phosphorous (P) and nitrogen (N).

Sewage from Rotorua City is reticulated to the Rotorua Waste Water Treatment Plant. The treated final effluent is pumped to holding ponds in Whakarewarewa Forest prior to discharge by spray irrigation to forest stands. The irrigation area is divided into 16 blocks, of which 14

are operated on a daily rotational basis, with a net irrigation area of 220 ha (Park 2006). Spray areas have 15-30m wide vegetated buffer zone bordering forestry roads and public walking tracks to reduce spray drift and to provide a visual and physical barrier to the irrigation areas (Lowe *et al.* 2007). Irrigation is scheduled to minimize environmental impact, to meet forest operational and harvesting requirements, and to comply with the resource consent requirements.

An average of 19,000 m^3 of treated wastewater is irrigated into the forest, from a population of 59,000. The resource consent allows for a 'sewage-derived' load of 30 tonnes/year N and 3 tonnes/year P to Lake Rotorua.

After 16 years of operation, irrigated soils continue to retain phosphorous and are now saturated with nitrogen, storing about half of the N that has been applied (Lowe *et al.* 2007). The RDC continues to improve treatment processes and the irrigation schedule. Changes in irrigation frequency and an upgrade at the treatment plant have reduced the amount of N and P being exported from the forest. In 2006, the treatment plant received 900 t N and discharged 36 t N to the forest, of which 32t was exported to Lake Rotorua. In 2006 the treatment plant received 162 t P and discharged 28 t P to the LTS, of which only 1 t was exported to Lake Rotorua (Lowe *et al.* 2007). Moreover, since 2002, similar levels of faecal coliform/*E. coli* levels have been recorded upstream and downstream of the effluent disposal sites on the Waipa Stream (Park 2006).

Rotorua District Council Municipal Landfill

The RDC municipal landfill on State Highway 30 is situated on the banks of the Tureporepo Stream a tributary of the upper Puarenga. The landfill has been in use for approximately 33 years. A fully lined extension to the site was developed on the northern side of the Tureporepo Stream in the late 1990's. Leachate is pumped from the site to the RDC waste water treatment plant for disposal.

Surface water, groundwater, and leachate are monitored on a regular basis. In addition, Environment Bay of Plenty carry out annual inspections of the RDC landfill (Pickles & Gordon, 2000, Weiss 2004). Earlier monitoring reported that bore samples exceeded the allowable limits for conductivity, ammonium and chloride with some occasional problems with windblown rubbish (Pickles & Gordon, 2000). However, recent monitoring shows that samples are in compliance with the resource consent conditions with no evidence of leachate contamination affecting the Tureporepo Stream from the old landfill site or the extension (Weiss 2004). Moreover, similar levels of faecal coliform/*E. coli* levels have been recorded

upstream and downstream of the RDC Municipal landfill on the Tureporepo Stream (J McIntosh, Environment Bay of Plenty, pers. comm.).

Recreational bathing

The Puarenga Stream at Whakarewarewa is monitored regularly for recreational bathing quality by Environment Bay of Plenty. The bacterium *Escherichia coli* (commonly referred to as *E. coli*), is used as an indicator organism to assess the risk to health for swimmers/bathers. Environment Bay of Plenty also has a site on the Puarenga near the Scion Research campus which is used to monitor the effect of land use in the catchment upstream of this point. The upper limit for bathing quality is 550 *E coli*/100ml. Over the summers of 2004/5 and 2005/6 all samples complied with the Ministry of Health guidelines. However, in the summer of 2006/7 this bathing water guideline was exceeded for six out of 17 samples and four out of 13 sampling occasions in 2007/8. The source of *E coli* contamination is most probably from pastoral farming in the upper catchment.

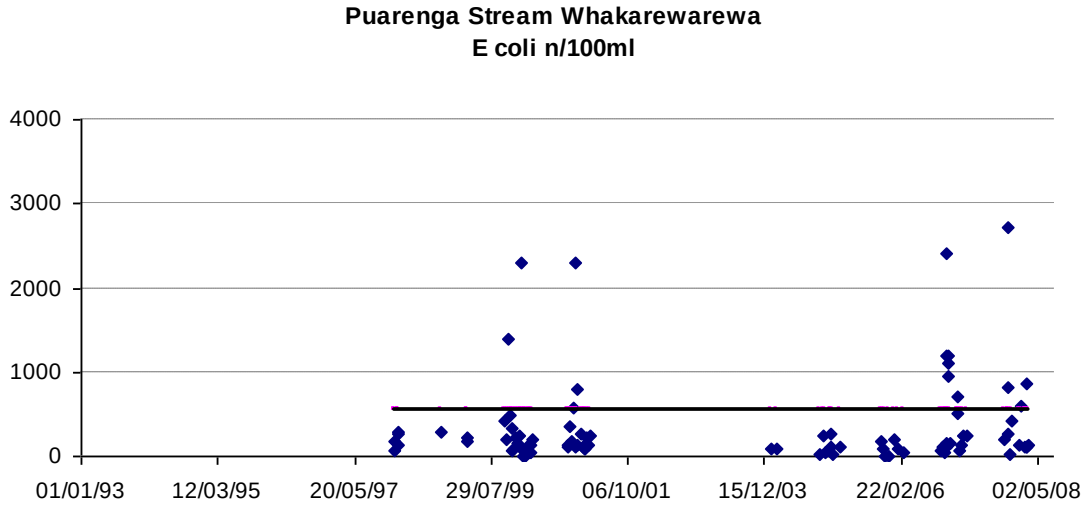

Figure 2: E. coli monitoring in the Puarenga Stream at Whakarewarewa, 1997-2008. (Source: Environment Bay of Plenty).

Summary

Water quality in the upper Puarenga (above Whakarewarewa) has improved significantly since the early 1990's when extensive remedial works and management improvements were made to reduce the impacts of industrial and municipal land uses in the upper catchment. However, faecal coliform levels regularly exceed Ministry of Health guidelines, particularly, following floods. The Puarenga Stream changes very significantly at Whakarewarewa due to

large scale geothermal inflows, and from this point downstream, it is considered a thermal stream, with acidic, warm water enriched with heavy metals.

10 POTENTIAL EFFECTS OF CURRENT RESOURCE APPLICATIONS

There are currently two proposed resource consent applications for the Puarenga Stream. The first, from RDC, is for the renewal of a resource consent for the abstraction of water from the Waipa and Hemo Springs, which are tributaries of the Waipa Stream. The second, from Environment Bay of Plenty, is for the addition of Alum (Aluminium sulphate) to the lower Puarenga Stream. The details and potential effects of these applications are outlined further below.

RDC Water Abstraction application

Abstraction of water for town supply from the Waipa Stream began in 1909. RDC abstracts up to 4,500 cubic metres per day (0.052 m^3/s) from the Hemo Spring to supply the Waipa Mill with an average rate of 1,800 cubic metres per day (ranging from 1,070 to 3,040 cubic metres per day depending on mill production) (Jowett 2008). RDC also abstracts up to 9,504 cubic metres per day (0.11 m^3/s) from the Waipa Spring, with an average take of 3,500 cubic metres per day varying seasonally from 3,000 to 7,000 cubic metres per day, with maximum abstraction in summer (November to February) (Jowett 2008). The combined Hemo/Waipa allocation is 1400 cubic metres per day or 0.162 m^3/s.

Abstraction of water from the springs has a significant effect on the flow of the Waipa Stream, with the combined Hemo/Waipa allocation of 1,400 cubic metres per day (0.162 m^3/s) equating to 20-25% of the approximate mean flow of the Waipa Stream (0.72 m^3/s = 0.61 + 0.12) at the Red Stag (Waipa) retail yard. However, it should be noted that the average summer water abstraction is about 0.12 m^3/s, compared to the allocated water take of 0.162 m^3/s.

Although, the abstraction of water has a significant effect on the flow of the Waipa Stream, it does not significantly affect mahinga kai values because the stream only supports a population of small stunted rainbow trout and limited numbers of small koura, while watercress growth under the current abstraction rates is prolific. There are also healthy stands of raupo downstream from the abstraction sites.

A significant issue raised by the Tuhourangi Tribal Authority was whether the reinstatement of high quality spring water inflows from the Hemo and Waipa Springs would improve water quality downstream at Whakarewarewa, i.e. that dilution of the 'paru' (unclean) water originating from significant point sources upstream i.e. Red Stag Mill, and RDC's Municipal Landfill and Land Treatment System.

The RDC water abstractions are unlikely to significantly affect water quality at Whakarewarewa for two main reasons. Firstly, considerable improvements have been made in surface and groundwater water quality at the point sources outlined above. For example, *E. coli* levels are now similar upstream and downstream of these sources. Secondly, the combined Hemo/Waipa abstractions comprise a relatively minor proportion of the flow at Whakarewarewa. The combined Hemo/Waipa allocation equates to approximately 8 % of the mean annual base flow of the Puarenga Stream (1.9 m^3/s), although this reduces to approximately 6% if the average summer water abstraction rate of about 0.12 m^3/s is used.

Summary

The RDC water abstractions are unlikely to significantly affect water quality at Whakarewarewa because water quality in the upper catchment has improved significantly since the early 1990's and the combined Hemo/Waipa allocations comprise only a small proportion of the flow of the Puarenga at Whakarewarewa.

Environment Bay of Plenty Alum dosing application

Water quality in Lake Rotorua has deteriorated since the 1960's because of excessive phytoplankton (algae) growths due to increasing phosphorous and nitrogen in the lake waters. Environment Bay of Plenty is proposing to dose the lower Puarenga Stream with Aluminium sulphate, commonly referred to as Alum. Alum is a colourless and non-evaporative dilute acidic substance used widely throughout the water treatment industry as a coagulant to remove pollutants from drinking water.

It is proposed to store the Alum in a secure and fully bunded facility (to mitigate potential storage failure) at the Rotorua District Council wastewater treatment plant north of Te Ngae Road. It is proposed to add the Alum to the Lower Puarenga Stream in small concentrations to assist with restoring Lake Rotorua water quality by adsorbing phosphorus that naturally occurs in the stream water.

Effects on Fish

The lower Puarenga has low fisheries values due to large scale natural geothermal inflows at Whakarewarewa. Nevertheless, aluminium can be very toxic to fish, particularly trout. The mechanism of aluminium toxicity has been attributed to maintenance of osmoregularity balance and respiratory problems associated with coagulation of mucus on the gills.

Effects on Humans

Human exposure to aluminium in the environment can occur through the ingestion of food and water. No acute pathogenic effects in the general population have been described after exposure to aluminium. However, there are only two mahinga kai species of cultural significance in the lower Puarenga: watercress and koura. Watercress and koura are known to accumulate arsenic and mercury, particularly in geothermally-influenced waters (Robinson *et al*. 2006). These mahinga kai species should not be harvested for human consumption from the lower Puarenga.

Effects on Recreational users

There is no direct evidence that aluminium is absorbed through the intact skin of humans and causes any adverse effects to humans in contact recreational waters. There is no ANZECC guideline values for aluminium in waters used for recreational purposes. Guideline values for aluminium in recreational waters have not been established by the World Health Organisation (WHO), Environment Canada, or USEPA. British Columbia water quality guidelines (1998) suggest a guideline value of 0.2mg/l for aluminium in recreational waters. It should be noted that the background level of aluminium in the lower Puarenga Stream is greater than 0.2mg/l. The British Columbia water quality standard may be an aquatic ecosystems standard rather than a recreational standard (J McIntosh pers. comm.) and may refer to free aluminium which is difficult to measure. Within the mixing zone in the lower Puarenga, the concentration of Alum is predicted to be 2mg/l and less than 2mg/l further downstream, due to dilution and precipitation of Gibbsite.

Summary

Given, significant large scale natural geothermal inflows (and heavy metal contamination) at Whakarewarewa, the addition of Alum at low concentrations is unlikely to adversely affect mahinga kai, recreational, or ecological values in the Puarenga Stream.

11 OVERVIEW OF STATE OF CATCHMENT ENVIRONMENT

The Puarenga has significant cultural values, with three marae - Te Pakira, Hinemihi, and Hurunga O Te Rangi - situated along its banks, as well as the internationally known tourist attractions of Whakarewarewa Village and Te Puia.

Main land uses in the upper Puarenga catchment are plantation forestry and farming with industrial uses at the Waipa/Red Stag mill, Rotorua Landfill, and other industrial land uses adjacent to the Tokoroa turnoff. Water abstraction has been a long-term use of the Waipa Stream, since 1909. Spray irrigation of treated sewage effluent has been underway since 1991. Most of these land uses are monitored and are well understood, in terms of effects on water quality, with the exception of pastoral farming effects in the catchment. Whakarewarewa Forest is heavily used for active recreation.

Downstream of the junctions of the Waipa, Kauaka, and Tureporepo Streams the main stem of the Puarenga becomes a relatively large stream with a more intact riparian corridor with a significant native component and important values for water birds (primarily kawau/shags). The Whakarewarewa thermal area has very significant ecological values and is a major tourism attraction. The character of the in-stream habitat changes very significantly at Whakarewarewa due to large scale natural geothermal inputs, although the indigenous riparian corridor continues downstream to the Scion Research campus. Downstream of the campus entrance the riparian character is primarily large exotic trees. Sulphur Bay has very significant ecological values for geothermal vegetation and avifauna habitat. There is an unresolved issue with the old landfill at Sulphur Bay.

12 REMEDIAL ACTIONS

1. Communication

Since the early 1990's extensive remedial works and management improvements have been made to reduce the impacts of industrial and municipal land uses in the Puarenga Stream catchment. Recent monitoring results show that there have been marked improvements in stream water quality. Unfortunately, this information has not been communicated effectively to the tangata whenua or the general public. It is hoped that the commissioning of this "overview" report is the beginning of more effective engagement between resource managers and tangata whenua. For example, it is recommended that results from the summer

recreational bathing water quality surveys at Whakarewarewa be communicated (as soon as practicable) to a designated resident (kaitiaki) at Whakarewarewa Village.

- ***Regular hui should be held between tangata whenua and Environment Bay of Plenty to inform iwi of environmental issues in the catchment, to facilitate the participation of iwi in resource management processes, and to assist in the prioritisation of remedial actions of concern to iwi.***

2. Monitoring and research

This overview has also identified some gaps in the current monitoring programme, namely, the effects of:

- the "old" landfill in Sulphur Bay;
- livestock farming in the catchment (particularly in regard to faecal coliform levels);
- discharges from industrial activities in the Ngapuna area;
- the current state of PCP contamination in the Puarenga Stream (particularly in sediments).

- ***Monitoring and research into these issues is required and should be considered by Environment Bay of Plenty.***

Iwi participation

Resource management and research agencies, such as, Environment Bay of Plenty, Rotorua District Council, Scion and NIWA regularly undertake monitoring and research projects in the Puarenga catchment. It is recommended that these agencies consider use kaitiaki, scientists and environmental students from the iwi, to assist in monitoring and research projects. This will enable iwi to actively participate in the resource management process and in research, and will help to build environmental capacity within iwi. Moreover, iwi participants are also an important medium for the communication of scientific monitoring information, from Environment Bay of Plenty, Scion Research, and NIWA, back to iwi.

The use of students (those studying environmental related sciences) and contracting them (on a part-time basis) to assist in such projects has a number of benefits. It not only gives students valuable work experience and financial assistance but ultimately it is hoped that on

completion of their studies that these students will be able to advise iwi, hapu, and whanau on environmental issues in the future.

- Resource management and research agencies should consider using iwi representatives i.e. kaitiaki, scientists and environmental students, to assist in monitoring and research projects in the Puarenga Stream system.

3. Integration into the wider environment

The Puarenga Stream, between the Red Stag Mill and Lake Rotorua, provides a significant opportunity for ecological restoration and enhanced walking and cycling access between Rotorua City and Whakarewarewa Forest. Sulphur Bay, on the margins of Lake Rotorua, has very significant ecological values for geothermal vegetation and bird habitat and has already been subject to active management and track development. Rotorua District Council has developed a walking/cycling track along the Puarenga Stream between Sulphur Bay and Whakarewarewa to provide access to Whakarewarewa thermal village and Te Puia (the former Māori Arts and Crafts Institute). Much of the riparian margin in this section comprises exotic trees and weed species, and it will require a long-term commitment to restore a more natural ecological corridor through this part of the city. It is notable, however, that only about 1 km of the stream margins (on both sides) are dominated by exotic trees. Local riparian restoration work has already been undertaken adjacent to the Department of Conservation office in Sala Street and there are indigenous plantings at the Whakarewarewa School. Māori landowners at Ngapuna have apparently also considered options for restoration works in the lower catchment, upstream of Sulphur Bay. Sulphur Bay has very significant values for indigenous birds and geothermal habitats.

- ***Environment Bay of Plenty, Rotorua District Council and tangata whenua should consider the development of a management plan for the Puarenga Stream, with the primary aims of restoration of the riparian margins and wetlands and to enhance walking and cycling access between Rotorua City and Whakarewarewa Forest.***

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14 REFERENCES

Beadel S.M.; Shaw W.B. and Nicholls J.L. 1998: Rotorua Lakes Ecological District - natural area survey. Wildland Consultants Ltd Contract Report No. 175. Prepared for Rotorua District Council and Environment Bay of Plenty. 551 pp.

Gifford J.S., Hannus I.M., Judd M. C., McFarlane P.N., Anderson S.M., Amoamo D.H. 1993: Assessment of chemical contaminants in the Lake Rotorua catchment. Unpublished report for the Bay of Plenty Regional Council. New Zealand Forest Research Institute. 93 p.

Hitchmough R.; Bull L.; Cromarty P. (comp.) 2007: New Zealand Threat Classification System lists - 2005. *Science and Technical Publishing*. Department of Conservation, Wellington. 194 pp.

Jowett I. 2008: Instream habitat and minimum flow requirements for the Waipa Stream. Ian Jowett Consulting Client report: IJ0703. Report prepared for Rotorua District Council. 31 pp.

Kennedy N.M., Pullar W.A. and Pain C.F. 1978: Late Quaternary land surfaces and geomorphic changes in the Rotorua Basin, North Island, New Zealand. *New Zealand Journal of Science 21*: 249-64. Appendix 1. Pollen analysis, Waingaehe Stream overflow channel, Holden's Bay, Rotorua. B y M.S. McGlone.

Kusabs I.A. 1996: Fish population survey of Tureporepo Stream. Report prepared for Rotorua District Council. September 1996. 11 pp.

Lowe A., Gielen G., Bainbridge A., Jones K. 2007: The Rotorua Land Treatment System after 16 Years. Pp 66-73. In: *New Zealand Land Treatment Collective - Proceedings for the 2007 Annual Conference, Rotorua, 14-16 March 2007*.

Makereti 1938: The old-time Maori. Victor. Gollancz Ltd, 1938. London. 352 pp.

National Environmental Health Forum (1998). *National Environmental Health Monographs. Metal Series 1*. Report of an international meeting, Brisbane.

Park S. 2006: Rotorua District Council Spray Irrigation Compliance Report. *Environment Bay of Plenty Environmental Publication 2006/17 October 2006*. 41pp.

Pickles S. H., Gordon D. A., 2000: Landfill compliance report. *Environment Bay of Plenty Environmental Report 2000/02 January 2000*. 38 pp.

Pickles S. H., Collins M., 2007: Red Stag Timber Limited: Waipa Mill Site Compliance Report. *Environment Bay of Plenty Environmental Report 2007/09 April 2007*. 21 pp.

Robinson B.; During G.; Bolan N.; Kanathasan M.; & Saravanau A. 2003: Uptake of arsenic by New Zealand watercress (*Lepidium sativum*). The *Science of the Total Environment*. 301: 67-73.

Rasch G. 1989: Wildlife and Wildlife Habitat in the Bay of Plenty Region. *Regional Report Series No. 11*. Department of Conservation, Rotorua. 136 pp.

Rutherford K. 2003: Lake Rotorua nutrient targets. Report to Environment Bay of Plenty. *NIWA Client Report: HAM2003-155. October 2003*. 58pp.

Shaw W.B., Schuster E., and Nicholls J.L. 1991: Traditional uses of wild plants. pp 109-113 in Clarkson B.D., Smale M.C. and Ecroyd C.E. (Compilers). Botany of Rotorua, Forest Research Institute, Rotorua. 132 pp.

Stafford D. M. 1994: Landmarks of Te Arawa. Volume 1: Rotorua. Reed Books. Auckland. 197 pp.

Stafford D.M. 1967: Te Arawa: A history of the Arawa People. Reed Publishing, Auckland (reprinted 1994). 573 pp.

Stafford D.M. 1986: The founding years in Rotorua: A history of events to 1990. Ray Richards Publisher, Auckland, and Rotorua District Council, Rotorua. 448 pp.

Stafford D.M. 1988: "The new century in Rotorua". Ray Richards Publisher, Auckland, and Rotorua District Council, Rotorua.

Tipa G., Teirney L. 2006: Using the cultural health index: How to assess the health of streams and waterways. Ministry for the Environment, Wellington, New Zealand. ISBN: 0-478-25949-2. Reference number 711. 54pp.

Weiss S. 2004: Landfill compliance report. *Environment Bay of Plenty Environmental Publication 2004/01 January 2004*. ISSN 1175 – 9372. 43 pp.

Wildlands Consultants Ltd 1996: Geothermal vegetation of the Bay of Plenty Region. *Wildland Consultants Ltd Contract Report No 155*. 234 pp.

Wildland Consultants Ltd 1997: Wetland and streamside survey of eight Bay of Plenty, Rotorua, and Taupo plantation forests. *Wildland Consultants Ltd Contract Report No. 156*. 169 pp.

Wildland Consultants 2003: Ecological effects of proposed earthworks at the Waiariki Institute of Technology mill site. Prepared for Martin McCauley Morton Ltd, Rotorua.

Wildland Consultants 2005: Geothermal vegetation of the Bay of Plenty Region based on the 2003 digital aerial photograph. *Wildland Consultants Ltd Contract Report No. 1072*. Prepared for Environment Bay of Plenty. 297 pp.

Wright S.D., Nugent G., and Parata H.G. 1995: Customary management of indigenous species - a Māori perspective. *New Zealand Journal of Ecology 19*(1): 83-86.

15 Appendix

NZ FRESHWATER FISH DATABASE
FORMS COMPLETED FOR THE
PUARENGA STREAM

FRESHWATER FISH DATABASE FORM

1

Date	**2/5/2008**	River/Lake system	**Puarenga Stream**					Catchment number	**146.070**
Time	**1300**	Sampling locality	**Waipa Spring**						
Observer	**iak**	Access						Altitude (m)	
Organisation	**indk**	NZMS 260 Map no.	**u16**	Coord.	**2798385 6329460**			Distance inland (km)	
Fishing method	**efm**	Area fished (m2) or no. nets used		Number of electric fishing passes	**1**			Tidal water	**n**

HABITAT DATA

Water	Colour	**u**			Clarity	**c**			Temp.	**11**	pH	**7**	
	Average width (m)	**2.0**	Average depth (m)	**0.3**	Maximum depth (m)	**0.6**			Conductivity				
Habitat type (%)	Still	**0**	Back-water	**0**	Pool	**5**	Run	**95**	Riffle	**0**	Rapid	**0**	Casc.	**0**
Substrate type (%)	Mud	**0**	Sand	**60**	Fine gravel	**40**	Coarse gravel	**0**	Cobble	**0**	Boulder	**0**	Bed-rock	**0**
Fish cover (y/n)	Macrophyte	**n**	Instream debris	**y**	Undercut bank	**y**	Bank veg.	**y**						
Catchment vegetation(%)	Native forest	**0**	Exotic forest	**100**	Farm	**0**	Urban zone	**0**	Scrub	**0**	Swamp land	**0**	Other	**0**
Riparian vegetation(%)	Native forest	**10**	Exotic forest	**30**	Grass tussock	**40**	Exposed bed	**0**	Scrub willow	**20**	Raupo flax	**0**	Other	**0**

Type of river/stream/lake **ftlssn**

Water level	**l**	Downstream barrier	**n**	Pollution	**n**		
Large invertebrate fauna	Koura	**y**	Paratya	**n**	Freshwater mussel	**n**	
Bottom fauna abundance	**l**	Predominant species group		Permanent water	**y**		

FISH DATA

Species		Abundance	Length	Habitat/Comments
Oncorhynchus mykiss	**Rainbow trout**	**20 (a)**	**60-330**	**gen**

Comments **Survey immediately above and below Waipa water intake**

FRESHWATER FISH DATABASE FORM

2

Date **2/5/2008**	River/Lake system **Puarenga Stream**		Catchment number **146.070**
Time **1500**	Sampling locality **Hemo Spring**		
Observer **iak**	Access		Altitude (m)
Organisation **indk**	NZMS 260 Map no. **u16**	Coord. **2798698 6330439**	Distance inland (km)
Fishing method **efm**	Area fished (m2) or no. nets used	Number of electric fishing passes **1**	Tidal water **n**

HABITAT DATA

Water	Colour				**u**	Clarity		**c**	Temp. **11**		pH **7**
	Average width (m) **2.0**		Average depth (m) **0.3**			Maximum depth (m)		**0.6**	Conductivity		
Habitat type (%)	Still **5**	Back-water **0**	Pool **0**			Run **95**	Riffle **0**		Rapid **0**		Casc. **0**
Substrate type (%)	Mud **0**	Sand **40**	Fine gravel **40**			Coarse gravel **20**	Cobble **0**		Boulder **0**		Bed-rock **0**
Fish cover (y/n)	Macrophyte **n**	Instream debris **y**	Undercut bank **y**			Bank veg. **y**					
Catchment vegetation(%)	Native forest **0**	Exotic forest **100**	Farm **0**			Urban zone **0**	Scrub **0**		Swamp land **0**		Other **0**
Riparian vegetation(%)	Native forest **20**	Exotic forest **80**	Grass tussock **0**			Exposed bed **0**	Scrub willow **0**		Raupo flax **0**		Other **0**

Type of river/stream/lake **ftlssn**

Water level **l**	Downstream barrier **n**		Pollution **n**
Large invertebrate fauna	Koura **y**	Paratya **n**	Freshwater mussel **n**
Bottom fauna abundance **l**	Predominant species group **k**		Permanent water **y**

FISH DATA

Species	Abundance	Length	Habitat/Comments
Oncorhynchus mykiss **Rainbow trout**	**8 (a)**	**60-200**	**gen**

Comments **Survey carried out below Hemo Spring**

FRESHWATER FISH DATABASE FORM

1

Date	**8/5/2008**	River/Lake system	**Puarenga Stream**	Catchment number	**146.070**
Time	**930**	Sampling locality	**Downstream Te Ngae Road Bridge**		
Observer	**iak**	Access		Altitude (m)	
Organisation	**indk**	NZMS 260 Map no.	**u16**	Coord. **2796472 6333978**	Distance inland (km)
Fishing method	**efm**	Area fished (m2) or no. nets used		Number of electric fishing passes **1**	Tidal water **n**

HABITAT DATA

Water	Colour	**u**			Clarity	**c**			Temp.		pH **3**
	Average width (m)	**8.0**	Average depth (m)	**0.5**	Maximum depth (m)	**2.5**			Conductivity		
Habitat type (%)	Still **0**	Back-water **0**	Pool **10**		Run **80**	Riffle **10**			Rapid **0**		Casc. **0**
Substrate type (%)	Mud **10**	Sand **50**	Fine gravel **40**		Coarse gravel **0**	Cobble **0**			Boulder **0**		Bed-rock **0**
Fish cover (y/n)	Macrophyte **n**	Instream debris **y**	Undercut bank **y**		Bank veg. **y**						
Catchment vegetation(%)	Native forest **0**	Exotic forest **0**	Farm **0**		Urban zone **25**	Scrub **25**			Swamp land **0**		Other **50**
Riparian vegetation(%)	Native forest **0**	Exotic forest **0**	Grass tussock **20**		Exposed bed **0**	Scrub willow **50**			Raupo flax **0**		Other **30**

Type of river/stream/lake **ftmssn**

Water level **n**	Downstream barrier **n**	Pollution **h**	
Large invertebrate fauna	Koura **n**	Paratya **n**	Freshwater mussel **n**
Bottom fauna abundance **l**	Predominant species group **o**	Permanent water **y**	

FISH DATA

Species	Abundance	Length	Habitat/Comments

Comments **No fish captured or seen. High geothermal influence.**

VASCULAR PLANT SPECIES RECORDED DURING THE SITE VISITS

Indigenous

Monocot. trees and shrubs

Cordyline australis	cabbage tree; ti kouka

Dicot. trees and shrubs

Coprosma robusta	karamu mingimingi
Pittosporum tenuifolium subsp. *tenuifolium*	kohuhu
Pseudopanax arboreus var. *arboreus*	whauwhaupaku, five finger

Dicot. lianes

Clematis sp. (*C. paniculata*)	puawananga

Ferns

Asplenium polyodon	petako
Blechnum chambersii	rereti
Blechnum novae-zelandiae s.s.	kiokio
Blechnum vulcanicum	korokio
Dicksonia fibrosa	wheki-ponga
Dicksonia squarrosa	wheki
Microsorum pustulatum	kowaowao, hounds tongue fern
Polystichum vestitum	puniu, shield fern
Pteridium esculentum	bracken, rarahu

Grasses

Cortaderia fulvida	toetoe

Sedges

Carex dissita	
Carex geminata	
Carex secta	purei
Carex virgata	purei
Schoenus maschalinus	
Uncinia uncinata	matau

Monocot. herbs (other than orchids, grasses, sedges and rushes)

Dianella nigra	turutu

Dicot. herbs (other than composites)

Acaena anserinifolia	piripiri
Epilobium pedunculare	
Gonocarpus micranthus subsp. *micranthus*	
Hydrocotyle heteromeria	

Introduced

Gymnosperms

Chamaecyparis pisifera	Sawara cypress
Larix decidua	larch
Pinus nigra	black pine
Pinus radiata	radiata pine
Pseudotsuga menziesii	Douglas fir
Sequoia sempervirens	redwood

Dicot. trees and shrubs

Alnus glutinosa	alder
Berberis glaucocarpa	barberry
Betula pendula	silver birch
Buddleja davidii	buddleia
Cotoneaster glaucophyllus	cotoneaster
Cytisus scoparius	broom
Leycesteria formosa	Himalayan honeysuckle
Ligustrum sinense	Chinese privet
Populus sp.	poplar
Rubus sp. (*R. fruticosus* agg.)	blackberry
Salix fragilis	crack willow
Ulex europaeus	gorse

Dicot. lianes

Lonicera japonica	Japanese honeysuckle
Vinca major	periwinkle

Grasses

Agrostis capillaris	browntop
Agrostis stolonifera	creeping bent
Anthoxanthum odoratum	sweet vernal
Axonopus fissifolius	narrow-leaved carpet grass
Holcus lanatus	Yorkshire fog
Poa annua	annual poa
Paspalum dilatatum	paspalum

Sedges

Carex ovalis

Rushes

Juncus articulatus	
Juncus effusus	soft rush
Juncus tenuis	track rush

Composite herbs

Bellis perennis	daisy
Cirsium vulgare	Scotch thistle
Conyza albida	fleabane
Hypochoeris radicata	catsear
Leontodon taraxacoides	hawkbit
Taraxacum officinale	dandelion

Dicot. herbs (other than composites)

Aphanes arvensis	parsley piert
Callitriche stagnalis	starwort
Cardamine sp.	
Cerastium fontanum	mouse-ear chickweed
Digitalis purpurea	foxglove
Galium aparine	cleavers
Plantago lanceolatum	narrow-leaved plantain
Ranunculus flammula	spearwort
Ranunculus repens	creeping buttercup
Rumex acetosella	sheep's sorrel
Rumex obtusifolius	broad-leaved dock
Stellaria media	chickweed
Trifolium repens	white clover
Vicia sativa	vetch

AVIFAUNA RECORDED DURING THE SITE VISITS

Indigenous Species

Circus approximans	kahu; Australasian harrier
Gerygone igata	riroriro; grey warbler
Phalacrocorax carbo	kawau; black shag
Rhipidura fuliginosa placabilis	piwakawaka; North Island fantail
Tadorna variegata	paradise shelduck[1]
Vanellus miles	spur-winged plover
Zosterops lateralis	silvereye; tauhou

Exotic Species

Anas platyrhynchos	mallard
Carduelis carduelis	goldfinch
Gymnorhina tibicen	Australian magpie
Passer domesticus	house sparrow
Turdus merula	blackbird

[1] Seen 31 July 2007.