Greymouth Petroleum Limited
Urenui-1 Hydraulic Fracturing Monitoring Programme Annual Report
2014-2015

Technical Report 2015-30

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Executive summary

Greymouth Petroleum Limited (GPL) operates the Urenui-1 wellsite, located at 229 Ohanga Road, Onaero. The wellsite lies within the Onaero catchment and contains a hydrocarbon producing well and associated infrastructure.

GPL hold resource consent 9632-1, authorising the discharge of contaminants associated with hydraulic fracturing activities into land at depths greater than 3,000 m TVD beneath the Urenui-1 wellsite. The consent was issued by Taranaki Regional Council (the Council) on 24 September 2013 and contains 16 special conditions which set out the requirements that GPL must satisfy.

The following report for the period July 2014 to June 2015 outlines and discusses the results of the monitoring programme implemented by the Council in relation to the programme of hydraulic fracturing undertaken by GPL within their Urenui-1 wellsite. The report also assesses GPL's level of environmental performance and compliance with the resource consent held in relation to the activity.

During the monitoring period being reported, GPL demonstrated a high level of environmental performance.

The programme of hydraulic fracturing undertaken by GPL at Urenui-1 included the fracturing of one well; Urenui-1. The hydraulic fracturing of this well took place on 12 January 2015.

The programme of monitoring implemented by the Council in relation to these activities spanned the 2014-2015 monitoring period. The programme included the analysis of samples taken from a groundwater site on the wellsite. Samples of groundwater were obtained prior to hydraulic fracturing being undertaken to provide a baseline reference of groundwater composition, with a further round of sampling carried out post hydraulic fracturing for comparison with baseline results.

In addition, samples of both the hydraulic fracturing fluid and the formation fluids produced back to the wellhead immediately following the fracturing event were obtained for analysis.

The monitoring programme also incorporated a surface water component, whereby biomonitoring surveys were undertaken in surface water bodies surrounding the wellsite. In order to provide a baseline reference for stream health, surveys were undertaken prior to hydraulic fracturing. Additional surveys were then carried out post hydraulic fracturing to determine whether the activity had resulted in any adverse effects on stream health.

The monitoring carried out by the Council indicates that the hydraulic fracturing activities undertaken by GPL had no adverse effects on local groundwater or surface water resources. There were no unauthorised incidents recording non-compliance in respect of the resource consent, or provisions in regional plans, during the period under review.

During the year, the Company demonstrated a high level of environmental and administrative performance with the resource consents.

For reference, in the 2014-2015 year, 75% of consent holders in Taranaki monitored through tailored compliance monitoring programmes achieved a high level of environmental performance and compliance with their consents, while another 22% demonstrated a good level of environmental performance and compliance with their consents.

This report includes recommendations for the 2015-2016 year.

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1. Introduction

1.1 Compliance monitoring programme reports and the Resource Management Act 1991

1.1.1 Introduction

The following report outlines and discusses the results of the monitoring programme implemented by the Taranaki Regional Council (the Council) in relation to the programme of hydraulic fracturing undertaken by Greymouth Petroleum Limited (GPL) at their Urenui-1 wellsite, 229 Ohanga Road, Onaero over the period November 2014 to July 2015. The wellsite is located in the Onaero catchment. The report also assesses GPL's level of environmental performance and compliance with the resource consent held in relation to the activity.

The programme of hydraulic fracturing undertaken by GPL at the Urenui-1 wellsite included the fracturing of one well; Urenui-1.

The programme of monitoring implemented by the Council in relation to this activity spanned the 2014-2015 monitoring period and included groundwater, surface water and discharge monitoring components. This is the first monitoring report produced by the Council in relation to the hydraulic fracturing activities at the Urenui-1 wellsite.

1.1.2 Structure of this report

Section 1 of this report is a background section. It sets out general information about compliance monitoring under the *Resource Management Act 1991* and the Council's obligations and general approach to monitoring sites though annual programmes, the resource consents held by the Company/companies in the Waitara catchment, the nature of the monitoring programme in place for the period under review, and a description of the activities and operations conducted in the Company's site/catchment.

Section 2 presents the results of monitoring during the period under review, including scientific and technical data.

Section 3 discusses the results, their interpretations, and their significance for the environment.

Section 4 presents recommendations to be implemented in the 2015-2016 monitoring year.

A glossary of common abbreviations and scientific terms, and a bibliography, are presented at the end of the report.

1.1.3 The Resource Management Act 1991 and monitoring

The RMA primarily addresses environmental 'effects' which are defined as positive or adverse, temporary or permanent, past, present or future, or cumulative. Effects may arise in relation to:

(a) the neighbourhood or the wider community around an activity, and may include cultural and social-economic effects;
(b) physical effects on the locality, including landscape, amenity and visual effects;
(c) ecosystems, including effects on plants, animals, or habitats, whether aquatic or terrestrial;
(d) natural and physical resources having special significance (for example recreational, cultural, or aesthetic);
(e) risks to the neighbourhood or environment.

In drafting and reviewing conditions on discharge permits, and in implementing monitoring programmes, the Council is recognising the comprehensive meaning of 'effects' inasmuch as is appropriate for each activity. Monitoring programmes are not only based on existing permit conditions, but also on the obligations of the RMA to assess the effects of the exercise of consents. In accordance with section 35 of the RMA, the Council undertakes compliance monitoring for consents and rules in regional plans, and maintains an overview of the performance of resource users and consent holders. Compliance monitoring, including both activity and impact monitoring, enables the Council to continually re-evaluate its approach and that of consent holders to resource management and, ultimately, through the refinement of methods and considered responsible resource utilisation, to move closer to achieving sustainable development of the region's resources.

1.1.4 Evaluation of environmental and administrative performance

Besides discussing the various details of the performance and extent of compliance by the consent holder/s during the period under review, this report also assigns a rating as to each Company's environmental and administrative performance.

Environmental performance is concerned with actual or likely effects on the receiving environment from the activities during the monitoring year. **Administrative performance** is concerned with the Company's approach to demonstrating consent compliance in site operations and management including the timely provision of information to Council (such as contingency plans and water take data) in accordance with consent conditions.

Events that were beyond the control of the consent holder and unforeseeable (that is a defence under the provisions of the *RMA* can be established) may be excluded with regard to the performance rating applied. For example loss of data due to a flood destroying deployed field equipment.

The categories used by the Council for this monitoring period, and their interpretation, are as follows:

Environmental Performance

- **High:** No or inconsequential (short-term duration, less than minor in severity) breaches of consent or regional plan parameters resulting from the activity; no adverse effects of significance noted or likely in the receiving environment .The Council did not record any verified unauthorised incidents involving significant environmental impacts and was not obliged to issue any abatement notices or infringement notices in relation to such impacts.

- **Good:** Likely or actual adverse effects of activities on the receiving environment were negligible or minor at most. There were some such issues noted during monitoring, from self reports, or in response to unauthorised incident reports, but these items were not critical, and follow-up inspections showed they have been dealt with. These minor issues were resolved positively, co-operatively, and quickly. The Council was not obliged to issue any abatement notices or infringement notices in relation to the minor non-compliant effects; however abatement notices may have been issued to mitigate an identified potential for an environmental effect to occur.

  For example:

  - High suspended solid values recorded in discharge samples, however the discharge was to land or to receiving waters that were in high flow at the time;
  - Strong odour beyond boundary but no residential properties or other recipient nearby.

- **Improvement required:** Likely or actual adverse effects of activities on the receiving environment were more than minor, but not substantial. There were some issues noted during monitoring, from self reports, or in response to unauthorised incident reports. Cumulative adverse effects of a persistent minor non-compliant activity could elevate a minor issue to this level. Abatement notices and infringement notices may have been issued in respect of effects.

- **Poor:** Likely or actual adverse effects of activities on the receiving environment were significant. There were some items noted during monitoring, from self reports, or in response to unauthorised incident reports. Cumulative adverse effects of a persistent moderate non-compliant activity could elevate an 'improvement required' issue to this level. Typically there were grounds for either a prosecution or an infringement notice in respect of effects.

Administrative performance

- **High:** The administrative requirements of the resource consents were met, or any failure to do this had trivial consequences and were addressed promptly and co-operatively.

- **Good:** Perhaps some administrative requirements of the resource consents were not met at a particular time, however this was addressed without repeated interventions from the Council staff. Alternatively adequate reason was provided for matters such as the no or late provision of information, interpretation of 'best practical option' for avoiding potential effects, etc.

- **Improvement required:** Repeated interventions to meet the administrative requirements of the resource consents were made by Council staff. These matters took some time to resolve, or remained unresolved at the end of the period under review. The Council may have issued an abatement notice to attain compliance.

- **Poor**: Material failings to meet the administrative requirements of the resource consents. Significant intervention by the Council was required. Typically there were grounds for an infringement notice.

For reference, in the 2014-2015 year, 75% of consent holders in Taranaki monitored through tailored compliance monitoring programmes achieved a high level of environmental performance and compliance with their consents, while another 22% demonstrated a good level of environmental performance and compliance with their consents.

1.2 Process description

1.2.1 Hydraulic fracturing

Hydraulic fracturing is a reservoir stimulation technique used to increase the flow of hydrocarbons to the surface. The primary objective of hydraulic fracturing is to increase the permeability of the target reservoir by creating numerous small, interconnected fractures, thus increasing the flow of hydrocarbons from the formation to a given well. The process of hydraulic fracturing has enabled companies to produce hydrocarbons at economically viable rates from extremely low permeability reservoirs and those that have become depleted using 'traditional' production techniques.

The process of hydraulic fracturing involves the pumping of fluids (consisting of freshwater and a small volume of chemicals) and a proppant (medium-grained sand or small ceramic pellets) down a well, through a perforated section of the well casing, and into the target reservoir. The fluid mixture is pumped at a pressure that exceeds the fracture strength of the reservoir rock in order to create fractures. Once fractures have been initiated, pumping continues in order to force the fluid and proppant into the fractures created. The proppant is designed to keep the fractures open when the pumping is stopped. The placement of proppant into the fractures is assisted by the use of cross-linked gels. These are solutions, which are liquid at the surface but, when mixed, form long-chain polymer bonds and thus become gels that transport the proppant into the formation. Once in the formation these gels 'break' back with time and temperature to a liquid state and are flowed back to surface without disturbing the proppant wedge. With continued flow, fluids pumped as part of hydraulic fracturing process, formation fluids and hydrocarbons are drawn to the surface.

1.2.2 Urenui-1 wellsite history

The Urenui-1 well was originally drilled in 1972. Greymouth Petroleum Limited re-established the wellsite and re-entered the well in 2014. The land on which the wellsite is located has historically been used for dairy farming. The area around the wellsite is rural with low population density. The closest residential community is Urenui, a small rural community which lies approximately 4 km to the northwest of the site. The site lies in an active petroleum exploration area. GPL and TODD have wellsites in the area.

The Urenui-1 well was drilled from 23 March to 5 June 1972. The location of the wellsite is illustrated in Figure 1.

An outline of the hydraulic fracturing activities carried out by GPL at the Urenui-1 wellsite during the period being reported is provided below in Table 1.

Table 1 Summary of hydraulic fracturing activity (2014-2015)

Well	Wellsite	Consent	Date	Injection zone (m TVDss)	Formation
Urenui-1	Urenui-1	9632-1	12/1/2015	3,093 – 3,096	McKee

Figure 1 Location of Urenui-1 wellsite where hydraulic fracturing occurred during the period under review

1.3 Resource consents

1.3.1 Discharges onto and into land

Section 15(1)(b) of the RMA stipulates that no person may discharge any contaminant onto or into land, which may result in that contaminant (or any other contaminant emanating as a result of natural processes from that contaminant) entering water, unless the activity is expressly allowed for by a resource consent, a rule in a regional plan, or by national regulations.

GPL holds resource consent 9632-1, authorising the discharge of water based hydraulic fracturing fluids into land at the Urenui-1 wellsite. The consent was issued by the Council on 11 December 2013, under Section 87(e) of the RMA. This is the consent under which Urenui-1 was fractured. Consent 9632-1 contains 16 special conditions which set out the requirements that GPL must satisfy.

Condition 1 stipulates the minimum depth below which the injection of hydraulic fracturing fluids must occur.

Condition 2 stipulates the date after which no hydraulic fracturing fluids shall be discharged into the reservoir.

Condition 3 requires the consent holder to ensure that the exercising of the consent does not result in any contaminants reaching any useable freshwater (ground or surface water).

Conditions 4, 5, 6 and 7 relate to fresh water monitoring requirements, to allow compliance with condition 3 to be assessed.

Condition 8 requires the consent holder to carry out pressure testing of equipment prior to discharging.

Condition 9 requires the consent holder to submit a pre-fracturing discharge report prior to any discharge occurring.

Condition 10 is a notification requirement.

Condition 11 requires the consent holder to submit a post-fracturing discharge report after the completion of the hydraulic fracturing programme for each well.

Condition 12 stipulates how the reports required by conditions 9 and 11 are to be submitted.

Condition 13 requires the consent holder to allow the Council access to a location where samples of hydraulic fracturing and return fluids can be obtained.

Condition 14 requires the consent holder to use best practicable options.

Condition 15 relates to the composition of the fracturing fluid.

Consent 16 is a review provision.

1.4 Monitoring programme

1.4.1 Introduction

Section 35 of the RMA sets obligations upon the Council to gather information, monitor, and conduct research on the exercise of resource consents, and the effects arising, within the Taranaki region and report upon these.

The Council may therefore make and record measurements of physical and chemical parameters, take samples for analysis, carry out surveys and inspections, conduct investigations, and seek information from consent holders.

The monitoring programme implemented in relation to the hydraulic fracturing of the Urenui-1 well consisted of four primary components.

1.4.2 Programme liaison and management

There is generally a significant investment of time and resources by the Council in:

- ongoing liaison with resource consent holders over consent conditions and their interpretation and application;
- in discussion over monitoring requirements;
- preparation for any reviews;
- renewals;
- new consents;
- advice on the Council's environmental management strategies and content of regional plans and;
- consultation on associated matters.

1.4.3 Review of consent holder submitted data

As required by the conditions of consent 9632-1, GPL submitted pre and post-fracturing discharge reports to the Council for the well fractured during the period under review. Pre-fracturing discharge reports provide an outline of the proposed fracturing operations in relation to the well, while post-fracturing reports confirm details of what actually occurred. The specific range of information required in each report is stipulated in the conditions of the resource consent.

1.4.4 Chemical sampling

The primary component of the monitoring programme implemented by the Council was the sampling of a groundwater monitoring bore on the Urenui-1 wellsite, and the analysis of the results.

A survey of existing groundwater abstractions in the vicinity (within 500 m) of the Urenui-1wellsite did not result in any suitable sampling locations being identified. In the absence of any suitable existing sampling sites, condition 5 of consent 9632-1 required GPL to install a suitable monitoring bore (GND2474) for the purposes of obtaining groundwater samples. The design and location of the monitoring bore was discussed and agreed with Council staff prior to installation. A further survey of wells within 1 km of the wellsite was conducted by the Council. One well suitable for the groundwater monitoring programme was identified (GND1179). The details of the monitoring bore installed and the additional well are included in Table 2 and their proximity to the wellsite is shown in Figure 1.

Table 2 Details of groundwater sites included in the monitoring programme

Hydraulically fractured well	Monitoring site	Distance from wellhead(m)	Total depth (m)	Screened interval (mbgl)	Aquifer
Urenui-1	GND2474	260	30	21 - 30	Volcanics
	GND1179	550	28.5	22 - 28	Volcanics

Samples of groundwater were obtained before fracturing to provide a baseline reference of groundwater composition, with further rounds of sampling carried out post-fracturing for comparison with baseline results.

All samples were transported to Hill Laboratories Limited for analysis following standard chain of custody procedures.

In addition to the sampling of local groundwater, samples of both the hydraulic fracturing fluid and the reservoir fluids produced back to the wellhead immediately following each fracturing event (return fluids) were obtained for analysis at Hill Laboratories Limited.

1.4.5 Biomonitoring surveys

Biomonitoring surveys are carried out to assess whether any stormwater discharges from the Urenui-1 wellsite during the course of fracturing operations resulted in any detrimental effects upon the biological communities within the receiving waters.

Biological surveys were performed pre and post-fracturing in the vicinity of the wellsite. Surveys were carried out in an unnamed tributary of the Onaero River as this is the nearest surface water body to the stormwater discharge location of the Urenui-1 wellsite.

The details of each biomonitoring site included in the survey are presented in Table 3 and their proximity to the wellsite is illustrated in Figure 1.

Table 3 Details of biomonitoring sites included in the monitoring programme

Site code	GPS reference (NZTM)	Location	Sampling method used
ONR000400	E 1717539 N 5679719	50 m upstream of stormwater discharge point	Vegetation sweep
ONR000403	E 1717628 N 5679773	60 m downstream of stormwater discharge point	Vegetation sweep
ONR000405	E 1717650 N 5679796	40 m downstream of ONR000403	Vegetation sweep

2. Results

2.1 Consent holder submitted data

2.1.1 Urenui-1 post-fracturing discharge report

The conclusions from the Urenui-1 post-fracturing discharge report are summarised as follows:

- One discrete zone was fractured on 12 January 2015 at a depth of between 3,093 and 3,096 m TVDss.

- A total of 1,708 barrels (bbls) (272m^3) of liquid was discharged across the eight fractured zones. The total proppant weight was 46 tonnes.

- By volume, 82.8% of the fluid injected was water, 15.6% was proppant and 1.6% was chemicals.

- Pressure testing of the tubing and well head equipment was carried out prior to fracturing commencing. The maximum pressure exerted during the fracturing programme remained below the successfully tested levels at all times.

- The Urenui-1 well was opened for flowback immediately following the placement of the proppant. At the completion of all flow-back operations, approximately 1,728.38 bbls (275 m^3) of fracture fluids and formation fluid were returned to the surface. Due to the fact that the flowback fluid from hydraulic fracturing operations consists of a mixture of the original fluid with native reservoir fluids, it is not feasible to calculate the exact quantity remaining underground. However, it is inferred that all (or most) of the hydraulic fracturing fluid has been returned to surface. It is estimated that nearly all the proppant injected remains in the formation, with small volumes expected to have settled inside the casing, where they may remain, unless circulated to the surface during later well interventions.

- All fluids that returned to the surface during flowback were disposed of by deep well injection at the Kaimiro-G wellsite, as authorised by consent 9470-1.

- It is considered that the mitigation measures implemented by GPL were effective in ensuring there were no adverse environmental effects associated with fracturing operations.

2.2 Chemical sampling

2.2.1 Urenui-1 groundwater sampling survey

Two sites were sampled to monitor the effects of the hydraulic fracturing of the Urenui-1 well on local groundwater resources.

The results of the laboratory analysis of samples from site GND2447 indicate a slight decrease in barium, electrical conductivity, dissolved iron and bicarbonate concentrations . The changes in concentrations of these analytes are a result of natural variations in water composition and are unrelated to hydraulic fracturing activities. There were no traces of substances associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities in any of the post-fracturing samples obtained.

Dissolved methane was detected in the April 2015 samples taken from GND2447. Concentrations were at trace level and were within the expected ranges for shallow groundwater across Taranaki.

The results of the laboratory analysis of samples from site GND1179 indicate a slight increase in calcium, electrical conductivity, magnesium and bicarbonate concentrations. The changes in concentrations of these analytes are a result of natural variations in water composition and are unrelated to hydraulic fracturing activities. There were no traces of substances associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities in any of the post-fracturing samples obtained.

Dissolved methane was detected in both the pre and post-fracturing samples taken from GND1179. Concentrations were at trace level in the pre-fracturing sample and were also within the expected ranges for shallow groundwater across Taranaki. Concentrations were higher in the post-fracturing sample, but the methane/ethane ratios indicate that the gas is biogenic in origin and not derived from deep gas reservoirs (See section 2.2.2).

A full summary of results for all groundwater samples taken in relation to hydraulic fracturing of the Urenui-1 well is included below in Table 4. The certificates of analysis are included in Appendix II.

Table 4 Results of groundwater sampling carried out in GND2469

Parameter	Unit	GND2447		GND1179	
		Pre-frac	Post-frac	Pre-frac	Post-frac
Sample date	-	06 Nov 2014	23 Apr 2015	14 Nov 2014	30 Apr 2015
Lab number	-	TRC1412027	TRC151702	TRC1412029	TRC151703
Total Alkalinity	g/m^3 $CaCO_3$	17.5	12.4	60	66
Barium	mg/kg	0.0076	0.022	0.0081	0.0129
Benzene	g/m^3	<0.0010	<0.0010	<0.0010	<0.0010
Dissolved bromine	g/m^3	0.064	0.067	0.046	0.095
Calcium	g/m^3	9.2	7.4	10.7	14.4
Chloride	g/m^3	22	20	12.9	24
Electrical conductivity	mS/m@20^{o}C	14.9	13.6	17.3	21.6
Dissolved copper	g/m^3	<0.0005	<0.0005	<0.0005	<0.0005
Dissolved oxygen	g/m^3	5.77	1.86	0.22	0.05
Ethylbenzene	g/m^3	<0.0010	<0.0010	<0.0010	<0.0010
Ethane	g/m^3	<0.003	<0.003	<0.003	<0.003
Ethylene	g/m^3	<0.003	<0.004	<0.003	<0.003
Dissolved iron	g/m^3	0.04	<0.02	1.68	6.0
Formaldehyde	g/m^3	<0.02	<0.02	<0.02	<0.02

Parameter	Unit	GND2447		GND1179	
		Pre-frac	Post-frac	Pre-frac	Post-frac
Ethylene glycol	g/m^3	<4	<4	<4	<4
Hydrocarbons	g/m^3	<0.7	<0.7	<0.7	<0.7
Bicarbonate	g/m^3 HCO_3	21.4	15.1	73.2	80
Total hardness	g/m^3 $CaCO_3$	37	33	34	47
Dissolved mercury	g/m^3	<0.00008	<0.00008	<0.00008	<0.00008
Potassium	g/m^3	2.5	2.6	12.2	9.7
Water Level	m	5.405	3.870	11.723	10.950
Methanol	g/m^3	<2	<2	<2	<2
Methane	g/m^3	<0.010	0.005	0.91	4.0
Magnesium	g/m^3	3.3	3.5	1.72	2.7
Manganese Dissolved	g/m^3	0.033	0.0120	0.064	0.166
Sodium	g/m^3	11.7	10.5	8.9	9.4
Nickel	mg/kg	0.0011	<0.0005	<0.0005	<0.0005
Nitrate + nitrite oxygen	g/m^3 N	3.4	3.5	0.011	0.034
Nitrite nitrogen	g/m^3 N	0.003	<0.002	0.007	0.013
Nitrate nitrogen	g/m^3 N	3.4	3.5	0.004	0.021
pH	pH Units	6.1	5.7	7.8	7.5
Propylene glycol	g/m^3	<4	<4	<4	<4
Sulphate	g/m^3	3.5	4.0	1.1	<0.5
Sum of Anions	meq/l	1.30	1.15	1.60	1.98
Sum of Cations	meq/l	1.31	1.18	1.44	1.82
Total Dissolved Solids	g/m^3	111	95	72	97
Temperature	^oC	14	17.0	15.4	15.0
Toluene	g/m^3	<0.0010	<0.0010	<0.0010	<0.0010
o-Xylene	g/m^3	<0.0010	<0.0010	<0.0010	<0.0010
m-Xylene	g/m^3	<0.002	<0.002	<0.002	<0.002
Dissolved zinc	g/m^3	0.0055	0.021	0.0015	0.0021
13C	‰	-	-	87.2	87

2.2.2 Carbon isotope analysis

During the period being reported, two groundwater samples from GND1179 were sent to GNS Science for carbon isotope analysis in their National Isotope Centre. The isotopic analysis is used to calculate a delta carbon13 (δ13C) value for a given sample, which is then used to determine the origin of the gas. Generally, a δ13C value that exceeds -50‰ indicates biogenic methane, and a δ13C value less than -50‰ indicates thermogenic methane. The higher or lower the δ13C values, the stronger the isotopic signature. A δ13C value in the vicinity of -50‰ can indicate a mixture of both biogenic and thermogenic methane. Results of analyses undertaken in the period being reported are compared with previous results in Table 5 below.

Table 5 Results of carbon isotope analysis at GND1179

	GND1179	
Date	14/11/2014	30/4/2015
δ13C value	-87.2‰	-87‰

Table 5 shows that the methane gas present in GND1179 is strongly biogenic and that there was no change in the source of methane gas between pre and post-fracturing sampling events.

It is important to note that the results were issued from the analysing laboratory with an uncertainty of measurement of ±10‰

2.2.3 Hydraulic fracturing and return fluids

The results of the analyses carried out on samples of the hydraulic fracturing fluid used in the treatment of the Urenui-1 well are summarised below in Table 6. The certificates of analysis are included in Appendix III.

Due to the viscosity of the sample of the fluid samples obtained, the range of analyses that were able to be performed on each sample were limited. The samples taken were gel like in composition, as opposed to a liquid. While the fracturing fluid is predominantly comprised of water, specialised additives are used to increase the viscosity of the fluid in order to suspend the proppant prior to injection.

Due to the volume of water used in the fracturing fluid mixture, all additives included in the mixture are highly dilute.

Table 6 Results of hydraulic fracturing fluid sampling

Parameter	Unit	Urenui-1
Sample date	-	12 Jan 2015
Lab number	-	TRC151150
Benzene	g/m^3	0.0026
Ethylbenzene	g/m^3	<0.0010
Ethylene glycol	g/m^3	<4
Hydrocarbons	g/m^3	230
Methanol	g/m^3	<2
Propylene glycol	g/m^3	<4
Toluene	g/m^3	0.0030
o-Xylene	g/m^3	<0.0010
m-Xylene	g/m^3	<0.002

A composite sample of return fluids from Urenui-1 was submitted for analysis. Return fluids are comprised of a mixture of hydraulic fracturing fluids and formation fluids produced from the target reservoir, following the completion of the hydraulic fracturing process. The relative concentrations of each contributing fluid type change as the volume of fluid produced from the well increases. Immediately following the opening of the well post-fracturing, a high proportion of the fluid returning to the wellhead is that injected during the hydraulic fracturing process. As the volume of fluid produced from the well increases, the proportion of hydraulic fracturing fluid reduces in relation to formation fluids.

The results of the analyses carried out on the return fluid sample obtained following the hydraulic fracturing of the Urenui-1 well are summarised below in Table 7 and the certificates of analysis is included in Appendix III. The relatively high levels of salinity (sodium and chloride) in the sample indicate that the composite samples prepared contained a greater proportion of saline reservoir fluids than fluids introduced during fracturing activities. The presence of BTEX compounds are indicative of fluids being drawn from a hydrocarbon bearing reservoir.

Table 7 Results of hydraulic fracturing return fluid sampling

Parameter	Unit	Urenui-1
Sample date	-	12 Jan 2015
Lab number	-	TRC151701
Benzene	g/m^3	4.2
Ethylbenzene	g/m^3	0.062
Ethylene glycol	g/m^3	<4
Hydrocarbons	g/m^3	3,500
Methanol	g/m^3	3
Propylene glycol	g/m^3	<4
Toluene	g/m^3	1.22
o-Xylene	g/m^3	0.155
m-Xylene	g/m^3	0.25
Total alkalinity	g/m^3 $CaCO_3$	1,160
Barium	mg/kg	1.39
Dissolved bromide	g/m^3	16.1
Calcium	g/m^3	31
Chloride	g/m^3	2,000
Electrical conductivity	mS/m@20°C	852
Dissolved copper	g/m^3	<0.005
Ethane	g/m^3	0.036
Ethylene	g/m^3	<0.003
Dissolved iron	g/m^3	3.9
Formaldehyde	g/m^3	0.30

Parameter	Unit	Urenui-1
Bicarbonate	g/m^3 HCO_3	973
Total hardness	g/m^3 $CaCO_3$	104
Dissolved mercury	g/m^3	<0.011
Potassium	g/m^3	310
Methane	g/m^3	0.161
Magnesium	g/m^3	7
Dissolved manganese	g/m^3	0.96
Sodium	g/m^3	1,760
Nickel	mg/kg	<0.03
Nitrate + nitrite oxygen	g/m^3 N	<0.2
Nitrite nitrogen	g/m^3 N	<0.2
Nitrate nitrogen	g/m^3 N	<0.2
pH	pH	6.7
Dissolved sulphur	g/m^3	8
Sulphate	g/m^3	25
Total dissolved solids	g/m^3	6,700
Dissolved zinc	g/m^3	0.02

2.3 Biomonitoring survey

The Council's standard 'vegetation sweep' techniques were used to collect streambed macroinvertebrates from an unnamed tributary of the Onaero River in relation to fracturing at the Urenui-1 wellsite. The intention of these surveys was to determine the health of the macroinvertebrate communities prior to fracturing, which then allowed a comparison with the health of macroinvertebrate communities once fracturing had been completed. A post-fracturing survey was carried out in February 2015. Samples were processed to provide number of taxa (richness), MCI and SQMCIS scores for each site.

The MCI is a measure of the overall sensitivity of the macroinvertebrate community to the effects of organic pollution in stony streams. It is based on the presence/absence of taxa with varying degrees of sensitivity to environmental conditions. The SQMCIS takes into account taxa abundances as well as sensitivity to pollution. It may indicate subtle changes in communities, and therefore be the more relevant index if non-organic impacts are occurring. Significant differences in either the MCI or the SQMCIS between sites indicate the degree of adverse effects (if any) of the discharges being monitored.

Taxa richnesses at all three sites were generally lower than previously found at similar sites at the same altitudinal band and there were no substantial differences between the pre-fracturing and post-fracturing taxa richnesses with a maximum difference of just two taxa.

MCI scores did not significantly change between the pre-fracturing and post-fracturing surveys (Stark, 1998) although the 'primary impacted' site had an increase in MCI score of eight units. The post-fracturing $SQMCI_S$ scores showed an improvement compared with the pre-fracturing survey results and there were no significant differences between the 'control' site and the 'primary impacted' and 'secondary impacted' sites. There was no evidence that wellsite discharges had had a significant impact on the health of the macroinvertebrate communities in the unnamed tributary of the Onaero River as shown by the pre-fracturing and post-fracturing surveys.

A copy of the biomonitoring report is included in Appendix IV.

2.4 Investigations, interventions, and incidents

The monitoring programme for the year was based on what was considered to be an appropriate level of monitoring, review of data, and liaison with the consent holder. During each period matters may arise which require additional activity by the Council, for example provision of advice and information, or investigation of potential or actual courses of non-compliance or failure to maintain good practices. A pro-active approach that in the first instance avoids issues occurring is favoured.

The Council operates and maintains a register of all complaints or reported and discovered excursions from acceptable limits and practices, including non-compliance with consents, which may damage the environment. The Incident Register includes events where the company concerned has itself notified the Council. The register contains details of any investigation and corrective action taken.

Complaints may be alleged to be associated with a particular site. If there is potentially an issue of legal liability, the Council must be able to prove by investigation that the identified company is indeed the source of the incident (or that the allegation cannot be proven).

During the period under review, there was no requirement for the Council to undertake any significant additional investigations and/or interventions, or record incidents, in association with the conditions in GPL's resource consent or provisions in Regional Plans relating to this site.

3. Discussion

3.1 Environmental effects of hydraulic fracturing on useable freshwater resources

The primary objective of the monitoring programme implemented by the Council was to assess whether the hydraulic fracturing activities undertaken by GPL during the period being reported had resulted in any adverse effects on useable freshwater resources. As defined in the conditions of the relevant resource consent, useable freshwater includes both groundwater and surface water systems.

To assess the level of environmental performance and compliance by GPL during the period being reported, the monitoring programme implemented by the Council included both groundwater and surface water monitoring components. The groundwater monitoring component of the programme included the sampling of groundwater at two selected sites near the Urenui-1 wellsite. The surface water monitoring component of the programme comprised biomonitoring surveys being carried out in surface water systems adjacent to the wellsite. Both groundwater and surface water systems were surveyed prior to any hydraulic fracturing occurring to determine baseline conditions, allowing comparisons to be made with post-fracturing results.

The results of post-fracturing groundwater sampling carried out in the vicinity of the Urenui-1 well showed only very minor variations in water composition in comparison to baseline results. The minor variations in some analytes are a result of natural variations in water composition and unrelated to fracturing activities. Methane was detected in low concentrations. Concentrations were within the expected range for shallow groundwater in Taranaki. No traces of substances associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities were present in the groundwater during any of the post-fracturing sampling events.

The result of the biomonitoring survey undertaken suggests that hydraulic fracturing operations did not result in adverse effects on local surface water resources, with community indices in line with reference sites of similar altitude.

In summary, the monitoring carried out by the Council during the 2014-2015 monitoring period indicates that the hydraulic fracturing activities undertaken by GPL over the period being reported had no adverse effects on local groundwater or surface water resources.

3.2 Evaluation of performance

A tabular summary of the consent holder's compliance record for the year under review is set out in Table 8.

Table 8 Summary of performance for Consent 9632-1

Purpose: *To discharge water contaminants associated with hydraulic fracturing activities into land at depths greater than 3,000 mTVD beneath the Urenui-1 wellsite.*		
Condition requirement	Means of monitoring during period under review	Compliance achieved?
1. Any discharge shall occur below 3,000 mTVD	Assessment of consent holder submitted data	Yes
2. No discharge of hydraulic fracturing fluids after 1 June 2016	Assessment of consent holder submitted data and site inspections	N/A
3. Exercise of consent shall not result in any contaminants reaching any useable freshwater (groundwater or surface water)	Results of groundwater and surface water monitoring	Yes
4. Consent holder shall undertake sampling programme	Development and certification of a monitoring programme	Yes
5. A dedicated groundwater monitoring well will need to be installed	Development and certification of a monitoring programme	Yes
6. Sampling programme shall follow recognised field procedures and be analysed for a specified range of chemical parameters	Development and certification of a monitoring programme and assessment of results	Yes
7. All sampling to be carried out in accordance with a certified sampling and analysis plan	Development and certification of a sampling and analysis plan	Yes
8. Well and equipment pressure testing to be carried out prior to any hydraulic fracturing programme commencing	Assessment of consent holder submitted data	Yes
9. A pre-fracturing discharge report is to be provided to the Council 14 days prior to discharge	Pre-fracturing discharge report received	Yes
10. Consent holder shall notify the Council of hydraulic fracturing discharge	Notification received	Yes
11. A post-fracturing discharge report is to be provided to the Council within 60 days after the hydraulic fracturing programme is completed	Post-fracturing discharge report received	Yes
12. The reports outlined in conditions 9 and 11 must be emailed to consents@trc.govt.nz	Reports received via email	Yes
13. The consent holder shall provide access to a location where samples of hydraulic fracturing fluids and return fluids can be obtained by the Council officers	Access provided	Yes

Purpose: *To discharge water contaminants associated with hydraulic fracturing activities into land at depths greater than 3,000 mTVD beneath the Urenui-1 wellsite.*		
Condition requirement	Means of monitoring during period under review	Compliance achieved?
14. Consent holder to adopt best practicable option at all times	Site inspections, sampling and assessment of consent holder submitted data	Yes
15. No hydrocarbon based hydraulic fracturing fluid shall be discharged	Assessment of consent holder submitted data and sampling of fracturing fluid	Yes
16. Notice of Council to review consent	No provision for review during period	N/A
Overall assessment of consent compliance and environmental performance in respect of this consent		High
Overall assessment of administrative performance in respect of this consent		High

During the 2014-2015 monitoring periods, GPL demonstrated a high level of environmental performance and a high level of administrative performance and compliance with its resource consent as defined in Section 1.1.4.

3.3 Alterations to monitoring programmes for 2015-2016

In designing and implementing the monitoring programmes for air/water discharges in the region, the Council has taken into account the extent of information made available by previous authorities, its relevance under the RMA, its obligations to monitor emissions/discharges and effects under the RMA, and report to the regional community. The Council also takes into account the scope of assessments required at the time of renewal of permits, and the need to maintain a sound understanding of industrial processes within Taranaki emitting to the atmosphere/discharging to the environment.

It is proposed that for 2015-2016 year, a one year post-fracturing groundwater sample is collected in January 2016. Following this, no further monitoring should be carried out in relation to the previous fracturing events at Ngatoro-E. Monitoring should recommence however if any further fracturing is undertaken at the site.

3.4 Exercise of optional review of consent

Resource consent 9632-1 provides for an optional review of the consent an annual basis, with the next optional review date being June 2016. Condition 16 of this consent allows the Council to review consent conditions to ensure they are adequate to deal with any significant adverse effects on the environment arising from the exercise of this consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time. The Council can also review the consent in order to further specify the best practicable option and/or to ensure that hydraulic fracturing operations appropriately take into account any best practice guidance published by a recognised industry association or environmental regulator.

Following an assessment of the current consent conditions and the results of monitoring undertaken over the period under review, it is considered that there are no grounds that require a review to be pursued or grounds to exercise the review option.

4. Recommendations

1. THAT a one year post-fracturing groundwater sample is collected from GND2469 in January 2016.

2. Following the post-fracturing sampling event in January 2016, the monitoring programme should be discontinued, unless further fracturing is undertaken at the site.

3. THAT the option for a review of resource consents in June 2016, as set out in condition 16 of consent 9632-1, is not exercised, on the grounds that the current conditions of the consent are adequate to ensure that any significant adverse effects on the environment are avoided.

Glossary of common terms and abbreviations

The following abbreviations and terms may be used within this report:

Biomonitoring	Assessing the health of the environment using aquatic organisms.
bbls	Barrel. Unit of measure used in the oil and gas industry (equivalent to approximately 159 litres).
Fresh	Elevated flow in a stream, such as after heavy rainfall.
g/m^3	Grams per cubic metre, and equivalent to milligrams per litre (mg/L). In water, this is also equivalent to parts per million (ppm), but the same does not apply to gaseous mixtures.
Incident	An event that is alleged or is found to have occurred that may have actual or potential environmental consequences or may involve non-compliance with a consent or rule in a regional plan. Registration of an incident by the Council does not automatically mean such an outcome had actually occurred.
Intervention	Action/s taken by Council to instruct or direct actions be taken to avoid or reduce the likelihood of an incident occurring.
Investigation	Action taken by Council to establish the circumstances/events surrounding an incident including any allegations of an incident.
Macroinvertebrate	An invertebrate that is large enough to be seen without the use of a microscope.
MCI	Macroinvertebrate community index; a numerical indication of the state of biological life in a stream that takes into account the sensitivity of the taxa present to organic pollution in stony habitats.
mS/m	Millisiemens per metre.
m^3	Cubic metre (1,000 litres).
pH	A numerical system for measuring acidity in solutions, with 7 as neutral. Numbers lower than 7 are increasingly acidic and higher than 7 are increasingly alkaline. The scale is logarithmic i.e. a change of 1 represents a ten-fold change in strength. For example, a pH of 4 is ten times more acidic than a pH of 5.
Resource consent	Refer Section 87 of the RMA. Resource consents include land use consents (refer Sections 9 and 13 of the RMA), coastal permits (Sections 12, 14 and 15), water permits (Section 14) and discharge permits (Section 15).
RMA	*Resource Management Act 1991* and including all subsequent amendments.
SQMCI	Semi quantitative macroinvertebrate community index.

Bibliography and references

Greymouth Petroleum Limited (2014) Technical Proposal – Urenui-1

Greymouth Petroleum Limited (2015) Urenui-1 Post-Fracturing Discharge Report

Stark JD, (1998) SQMCI: a biotic index for freshwater macroinvertebrate coded abundance data. *New Zealand Journal of Marine and Freshwater Research 32(1)*: 55-66

Taranaki Regional Council (2015) Biomonitoring of an unnamed tributary of the Onaero River following drilling by Greymouth Petroleum Ltd at the Urenui-1 wellsite, February 2015. Document # 1517080

Taranaki Regional Council (2014) Greymouth Petroleum Limited Hydraulic Fracturing - Urenui-1 Wellsite Water Quality Monitoring Program

Appendix II

Resource consent held by GPL

Discharge Permit

Pursuant to the Resource Management Act 1991 a resource consent is hereby granted by the Taranaki Regional Council

Name of Consent Holder:	Greymouth Petroleum Limited P O Box 3394 NEW PLYMOUTH 4341
Decision Date:	24 September 2013
Commencement Date:	24 September 2013

Conditions of Consent

Consent Granted:	To discharge contaminants associated with hydraulic fracturing activities into land at depths greater than 3000 mTVD beneath the Urenui-1 wellsite
Expiry Date:	1 June 2021
Review Date(s):	June Annually
Site Location:	Urenui-1 wellsite, 229 Ohanga Road, Onaero (Property owner: RB & SM Honeyfield)
Legal Description:	Lot 2 DP 390983 (Discharge source & site)
Grid Reference (NZTM)	1717433E-5679972N
Catchment:	Onaero

For General, Standard and Special conditions pertaining to this consent please see reverse side of this document

General condition

a. The consent holder shall pay to the Taranaki Regional Council all the administration, monitoring and supervision costs of this consent, fixed in accordance with section 36 of the Resource Management Act 1991.

Special Conditions

1. The discharge point shall be deeper than 3000 mTVD.

   Note: mTVD = metres true vertical depth, i.e. the true vertical depth in metres below mean ground level.

2. There shall be no discharge of hydraulic fracturing fluids into the reservoir after 1 June 2016.

3. The consent holder shall ensure that the exercise of this consent does not result in contaminants reaching any useable fresh water (groundwater or surface water). Usable fresh groundwater is defined as any groundwater having a Total Dissolved Solids concentration of less than 1000 mg/l.

4. The consent holder shall undertake a programme of sampling and testing that monitors the effects of the exercise of this consent on fresh water resources to assess compliance with condition 3 (the 'Monitoring Programme'). The Monitoring Programme shall be certified by the Chief Executive, Taranaki Regional Council ('the Chief Executive'), before this consent is exercised, and shall include:

   (a) the location of the discharge point(s);
   (b) the location of sampling sites; and
   (c) sampling frequency with reference to a hydraulic fracturing programme.

5. Depending on the suitability of existing bores within 500 m of the wellsite for obtaining a representative groundwater sample, it may be necessary for the Monitoring Programme to include installation of, and sampling from, a monitoring bore. The bore would be of a depth, location and design determined after consultation with the Chief Executive, Taranaki Regional Council and installed in accordance with NZS 4411:2001.

6. All water samples taken for monitoring purposes shall be taken in accordance with recognised field procedures and analysed for:

   (a) pH;
   (b) conductivity;
   (c) total dissolved solids;
   (d) major ions (Ca, Mg, K, Na, total alkalinity, bromide, chloride, nitrate-nitrogen, and sulphate);
   (e) trace metals (barium, copper, iron, manganese, nickel, and zinc);
   (f) total petroleum hydrocarbons;
   (g) formaldehyde;
   (h) dissolved methane and ethane gas;
   (i) methanol;
   (j) glycols;
   (k) benzene, toluene, ethylbenzene, and xylenes (BTEX); and
   (l) carbon-13 composition of any dissolved methane gas discovered ($^{13}C-CH_4$).

Note: *The samples required, under conditions 4 and 6 could be taken and analysed by the Council or other contracted party on behalf of the consent holder.*

7. All sampling and analysis shall be undertaken in accordance with a *Sampling and Analysis Plan*, which shall be submitted to the Chief Executive for review and certification before the first sampling is undertaken. This plan shall specify the use of standard protocols recognised to constitute good professional practice including quality control and assurance. An International Accreditation New Zealand (IANZ) accredited laboratory shall be used for all sample analysis. Results shall be provided to the Chief Executive within 30 days of sampling and shall include supporting quality control and assurance information. These results will be used to assess compliance with condition 3.

Note: *The Sampling and Analysis Plan may be combined with the Monitoring Programme required by condition 4.*

8. The consent holder shall undertake well and equipment pressure testing prior to any hydraulic fracture programme on a given well to ensure any discharge will not affect the integrity of the well and hydraulic fracturing equipment.

9. Any hydraulic fracture discharge shall only occur after the consent holder has provided a comprehensive 'Pre-fracturing discharge report' to the Chief Executive. The report shall be provided at least 14 days before the discharge is proposed to commence and shall detail the hydraulic fracturing programme proposed, including as a minimum:

   (a) the specific well in which each discharge is to occur, the intended fracture interval(s) ('fracture interval' is the discrete subsurface zone to receive a hydraulic fracture treatment), and the duration of the hydraulic fracturing programme;
   (b) the number of discharges proposed and the geographical position (i.e. depth and lateral position) of each intended discharge point;
   (c) the total volume of fracture fluid planned to be pumped down the well, including mini- fracture treatments, and their intended composition, including a list of all contaminants and Material Safety Data Sheets for all the chemicals to be used;
   (d) the results of the reviews required by condition 14;
   (e) results of modelling showing an assessment of the likely extent and dimensions of the fractures that will be generated by the discharge;
   (f) the preventative and mitigation measures to be in place to ensure the discharge does not cause adverse environmental effects and complies with condition 3;
   (g) the extent and permeability characteristics of the geology above the discharge point to the surface;
   (h) any identified faults within the modeled fracture length plus a margin of 50%, and the potential for adverse environmental effects due to the presence of the identified faults;
   (i) the burst pressure of the well and the anticipated maximum well and discharge pressures and the duration of the pressures; and
   (j) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal.

Note: *For the avoidance of doubt, the information provided with a resource consent application would usually be sufficient to constitute a 'Pre-fracturing discharge report' for any imminent hydraulic fracturing discharge. The Pre-fracturing discharge report provided for any later discharge may refer to the resource consent application or earlier Pre-fracturing discharge reports noting any differences.*

10. The consent holder shall notify the Taranaki Regional Council of each discharge by emailing worknotification@trc.govt.nz. Notification shall include the date that the discharge is to occur and identify the 'Pre-fracturing discharge report', required by condition 9, which details the discharge. Where practicable and reasonable notice shall be given between 3 days and 14 days before the discharge occurs, but in any event 24 hours notice shall be given.

11. At the conclusion of a hydraulic fracturing programme on a given well, the consent holder shall submit a comprehensive 'Post-fracturing discharge report' to the Chief Executive. The report shall be provided within 60 days after the programme is completed and, as a minimum, shall contain:

    (a) confirmation of the interval(s) where fracturing occurred for that programme, and the geographical position (i.e. depth and lateral position) of the discharge point for each fracture interval;
    (b) the contaminant volumes and compositions discharged into each fracture interval;
    (c) the volume of return fluids from each fracture interval;
    (d) an analysis for the constituents set out in conditions 6(a)to 6(k), in a return fluid sample taken within the first two hours of flow back, for each fracture interval, if flowed back individually, or for the well if flowed back with all intervals comingled;
    (e) an estimate of the volume of fluids (and proppant) remaining underground;
    (f) the volume of water produced with the hydrocarbons (produced water) over the period beginning at the start of the hydraulic fracturing programme and ending 50 days after the programme is completed or after that period of production;
    (g) an assessment of the extent and dimensions of the fractures that were generated by the discharge, based on modelling undertaken after the discharge has occurred and other diagnostic techniques, including production analysis, available to determine fracture length, height and containment;
    (h) the results of pressure testing required by condition 8, and the top hole pressure (psi), slurry rate (bpm), surface proppant concentration (lb/gal), bottom hole proppant concentration (lb/gal), and calculated bottom hole pressure (psi), as well as predicted values for each of these parameters; prior to, during and after each hydraulic fracture treatment;
    (i) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal;
    (j) details of any incidents where hydraulic fracture fluid is unable to pass through the well perforations (screen outs) that occurred, their likely cause and implications for compliance with conditions 1 and 3; and
    (k) an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.

12. The reports described in conditions 9 and 11 shall be emailed to consents@trc.govt.nz with a reference to the number of this consent.

13. The consent holder shall provide access to a location where the Taranaki Regional Council officers can obtain a sample of the hydraulic fracturing fluids and the return fluids.

14. The consent holder shall at all times adopt the best practicable option, as defined in section 2 of the Resource Management Act 1991, to prevent or minimize any actual or likely adverse effect of the activity on the environment by, as a minimum, ensuring that:

    (a) the discharge is contained within the fracture interval;
    (b) regular reviews are undertaken of the preventative and mitigation measures adopted to ensure the discharge does not cause adverse environmental effects; and
    (c) regular reviews of the chemicals used are undertaken with a view to reducing the toxicity of the chemicals used.

15. The fracture fluid shall be comprised of no less than 95% water and proppant by volume.

16. The Taranaki Regional Council may review any or all of the conditions of this consent by giving notice of review during the month of June each year, for the purposes of:

    (a) ensuring that the conditions are adequate to deal with any significant adverse effects on the environment arising from the exercise of this consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time; and/or

    (b) further specifying the best practicable option as required by condition 14; and/or

    (c) ensuring hydraulic fracturing operations appropriately take into account any best practice guidance published by a recognised industry association or environmental regulator.

Signed at Stratford on 24 September 2013

For and on behalf of
Taranaki Regional Council

Director-Resource Management

Appendix III

Certificates of analysis (Groundwater)

Hill Laboratories
BETTER TESTING **BETTER RESULTS**

R J Hill Laboratories Limited
1 Clyde Street
Private Bag 3205
Hamilton 3240, New Zealand

Tel +64 7 858 2000
Fax +64 7 858 2001
Email mail@hill-labs.co.nz
Web www.hill-labs.co.nz

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1351573 SPv1
Contact:	Regan Phipps	**Date Registered:**	15-Nov-2014
	C/- Taranaki Regional Council	**Date Reported:**	26-Nov-2014
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	Urenui 1 - Pre HF GW
		Submitted By:	R McDonnell

Sample Type: Aqueous

Sample Name:		GND1179 14-Nov-2014 9:13 am	GND0303 14-Nov-2014 11:31 am			
Lab Number:		1351573.1	1351573.2			
Individual Tests						
Sum of Anions	meq/L	1.60	1.52	-	-	-
Sum of Cations	meq/L	1.44	2.8 [#1]	-	-	-
pH	pH Units	7.8	6.6	-	-	-
Total Alkalinity	g/m^3 as $CaCO_3$	60	48	-	-	-
Bicarbonate	g/m^3 at 25°C	73	59	-	-	-
Total Hardness	g/m^3 as $CaCO_3$	34	27	-	-	-
Electrical Conductivity (EC)	mS/m	17.3	15.0	-	-	-
Total Dissolved Solids (TDS)	g/m^3	72	83	-	-	-
Dissolved Barium	g/m^3	0.0081	0.0179	-	-	-
Dissolved Bromine*	g/m^3	0.046	0.066	-	-	-
Dissolved Calcium	g/m^3	10.7	5.4	-	-	-
Dissolved Copper	g/m^3	< 0.0005	< 0.0005	-	-	-
Dissolved Iron	g/m^3	1.68	47	-	-	-
Dissolved Magnesium	g/m^3	1.72	3.4	-	-	-
Dissolved Manganese	g/m^3	0.064	0.42	-	-	-
Dissolved Mercury	g/m^3	< 0.00008	< 0.00008	-	-	-
Dissolved Nickel	g/m^3	< 0.0005	0.0010	-	-	-
Dissolved Potassium	g/m^3	12.2	1.60	-	-	-
Dissolved Sodium	g/m^3	8.9	11.9	-	-	-
Dissolved Zinc	g/m^3	0.0015	0.0032	-	-	-
Chloride	g/m^3	12.9	19.4	-	-	-
Nitrite-N	g/m^3	0.007	< 0.2 [#2]	-	-	-
Nitrate-N	g/m^3	0.004	< 0.2	-	-	-
Nitrate-N + Nitrite-N	g/m^3	0.011	< 0.2 [#2]	-	-	-
Sulphate	g/m^3	1.1	0.6	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m^3	< 4	< 4	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m^3	< 4	< 4	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m^3	< 2	< 2	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m^3	< 0.0010	< 0.0010	-	-	-
Toluene	g/m^3	< 0.0010	< 0.0010	-	-	-
Ethylbenzene	g/m^3	< 0.0010	< 0.0010	-	-	-
m&p-Xylene	g/m^3	< 0.002	< 0.002	-	-	-

Sample Type: Aqueous

Sample Name:		GND1179 14-Nov-2014 9:13 am	GND0303 14-Nov-2014 11:31 am			
Lab Number:		1351573.1	1351573.2			
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m^3	< 0.0010	< 0.0010	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m^3	< 0.02	< 0.02	-	-	-
Gases in groundwater						
Ethane	g/m^3	< 0.003	< 0.003	-	-	-
Ethylene	g/m^3	< 0.003	< 0.003	-	-	-
Methane	g/m^3	0.91	2.1	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m^3	< 0.10	< 0.10	-	-	-
C10 - C14	g/m^3	< 0.2	< 0.2	-	-	-
C15 - C36	g/m^3	< 0.4	< 0.4	-	-	-
Total hydrocarbons (C7 - C36)	g/m^3	< 0.7	< 0.7	-	-	-

Analyst's Comments

#1 It was noted that some of the anion / cation balances did not agree to within expected limits. This was largely attributed to the high levels of dissolved iron. We have included dissolved iron in the cation balance equations. However, the precipitation of large amounts of iron in the unpreserved containers (soon after sampling) will result in the loss of ions from solution and consumption of alkalinity. This may well result in the lower anions relative to the cations. The loss of iron and consequent loss in the cation balance would not be seen as the dissolved iron is sampled into an acid preserved container, stabilising the iron in solution.

#2 Severe matrix interferences required that a dilution be performed prior to analysis of this sample, resulting in a detection limit higher than that normally achieved for the NO2N, NO3N and NOxN analysis.

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	1-2
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	1-2
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m^3	1-2
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m^3	1-2
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m^3	1-2
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m^3	1-2
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m^3	1-2
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-2
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L.	0.07 meq/L	1-2
Total cations for anion/cation balance check	Calculation: sum of cations as mEquiv/L.	0.05 meq/L	1-2
pH	pH meter. APHA 4500-H$^+$ B 22nd ed. 2012.	0.1 pH Units	1-2
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m^3 as CaCO$_3$	1-2
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO$_2$ D 22nd ed. 2012.	1.0 g/m^3 at 25°C	1-2
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m^3 as CaCO$_3$	1-2
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1-2
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m^3	1-2

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m³	1-2
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m³	1-2
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-2
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-2
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-2
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-2
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-2
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1-2
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-2
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-2
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-2
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m³	1-2
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	1-2
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m³	1-2
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1-2
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m³	1-2
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m³	1-2

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Graham Corban MSc Tech (Hons)
Client Services Manager - Environmental Division

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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1348454 SPv1
Contact:	Regan Phipps	**Date Registered:**	07-Nov-2014
	C/- Taranaki Regional Council	**Date Reported:**	17-Nov-2014
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	Urenui 1 Pre HF GW
		Submitted By:	Regan Phipps

Sample Type: Aqueous

Sample Name:		GND2474 06-Nov-2014 8:44 am				
Lab Number:		1348454.1				
Individual Tests						
Sum of Anions	meq/L	1.30	-	-	-	-
Sum of Cations	meq/L	1.31	-	-	-	-
pH	pH Units	6.1	-	-	-	-
Total Alkalinity	g/m^3 as $CaCO_3$	17.5	-	-	-	-
Bicarbonate	g/m^3 at 25°C	21	-	-	-	-
Total Hardness	g/m^3 as $CaCO_3$	37	-	-	-	-
Electrical Conductivity (EC)	mS/m	14.9	-	-	-	-
Total Dissolved Solids (TDS)	g/m^3	111	-	-	-	-
Dissolved Barium	g/m^3	0.0076	-	-	-	-
Dissolved Bromine*	g/m^3	0.064	-	-	-	-
Dissolved Calcium	g/m^3	9.2	-	-	-	-
Dissolved Copper	g/m^3	< 0.0005	-	-	-	-
Dissolved Iron	g/m^3	0.04	-	-	-	-
Dissolved Magnesium	g/m^3	3.3	-	-	-	-
Dissolved Manganese	g/m^3	0.033	-	-	-	-
Dissolved Mercury	g/m^3	< 0.00008	-	-	-	-
Dissolved Nickel	g/m^3	0.0011	-	-	-	-
Dissolved Potassium	g/m^3	2.5	-	-	-	-
Dissolved Sodium	g/m^3	11.7	-	-	-	-
Dissolved Zinc	g/m^3	0.0055	-	-	-	-
Chloride	g/m^3	22	-	-	-	-
Nitrite-N	g/m^3	0.003	-	-	-	-
Nitrate-N	g/m^3	3.4	-	-	-	-
Nitrate-N + Nitrite-N	g/m^3	3.4	-	-	-	-
Sulphate	g/m^3	3.5	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m^3	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m^3	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m^3	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m^3	< 0.0010	-	-	-	-
Toluene	g/m^3	< 0.0010	-	-	-	-
Ethylbenzene	g/m^3	< 0.0010	-	-	-	-
m&p-Xylene	g/m^3	< 0.002	-	-	-	-

Sample Type: Aqueous

Sample Name:		GND2474 06-Nov-2014 8:44 am				
Lab Number:		1348454.1				
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m^3	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m^3	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m^3	< 0.003	-	-	-	-
Ethylene	g/m^3	< 0.003	-	-	-	-
Methane	g/m^3	0.010	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m^3	< 0.10	-	-	-	-
C10 - C14	g/m^3	< 0.2	-	-	-	-
C15 - C36	g/m^3	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m^3	< 0.7	-	-	-	-

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m^3	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m^3	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m^3	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m^3	1
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m^3	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L.	0.07 meq/L	1
Total cations for anion/cation balance check	Calculation: sum of cations as mEquiv/L.	0.05 meq/L	1
pH	pH meter. APHA 4500-H$^+$ B 22nd ed. 2012.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m^3 as $CaCO_3$	1
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 22nd ed. 2012.	1.0 g/m^3 at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m^3 as $CaCO_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m^3	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m^3	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m^3	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m^3	1
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	1
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m^3	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m^3	1

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1416941	SPv1
Contact:	Regan Phipps	**Date Registered:**	24-Apr-2015	
	C/- Taranaki Regional Council	**Date Reported:**	07-May-2015	
	Private Bag 713	**Quote No:**	47915	
	STRATFORD 4352	**Order No:**		
		Client Reference:		
		Submitted By:	Regan Phipps	

Sample Type: Aqueous

	Sample Name:	GND2474 23-Apr-2015 2:42 pm				
	Lab Number:	1416941.1				
Individual Tests						
Sum of Anions	meq/L	1.15	-	-	-	-
Sum of Cations	meq/L	1.18	-	-	-	-
pH	pH Units	5.7	-	-	-	-
Total Alkalinity	g/m^3 as $CaCO_3$	12.4	-	-	-	-
Bicarbonate	g/m^3 at 25°C	15.1	-	-	-	-
Total Hardness	g/m^3 as $CaCO_3$	33	-	-	-	-
Electrical Conductivity (EC)	mS/m	13.6	-	-	-	-
Total Dissolved Solids (TDS)	g/m^3	95	-	-	-	-
Dissolved Barium	g/m^3	0.022	-	-	-	-
Dissolved Bromine*	g/m^3	0.067	-	-	-	-
Dissolved Calcium	g/m^3	7.4	-	-	-	-
Dissolved Copper	g/m^3	< 0.0005	-	-	-	-
Dissolved Iron	g/m^3	< 0.02	-	-	-	-
Dissolved Magnesium	g/m^3	3.5	-	-	-	-
Dissolved Manganese	g/m^3	0.0120	-	-	-	-
Dissolved Mercury	g/m^3	< 0.00008	-	-	-	-
Dissolved Nickel	g/m^3	< 0.0005	-	-	-	-
Dissolved Potassium	g/m^3	2.6	-	-	-	-
Dissolved Sodium	g/m^3	10.5	-	-	-	-
Dissolved Zinc	g/m^3	0.021	-	-	-	-
Chloride	g/m^3	20	-	-	-	-
Nitrite-N	g/m^3	< 0.002	-	-	-	-
Nitrate-N	g/m^3	3.5	-	-	-	-
Nitrate-N + Nitrite-N	g/m^3	3.5	-	-	-	-
Sulphate	g/m^3	4.0	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m^3	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m^3	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m^3	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m^3	< 0.0010	-	-	-	-
Toluene	g/m^3	< 0.0010	-	-	-	-
Ethylbenzene	g/m^3	< 0.0010	-	-	-	-
m&p-Xylene	g/m^3	< 0.002	-	-	-	-

This Laboratory is accredited by International Accreditation New Zealand (IANZ), which represents New Zealand in the International Laboratory Accreditation Cooperation (ILAC). Through the ILAC Mutual Recognition Arrangement (ILAC-MRA) this accreditation is internationally recognised.
The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

Sample Type: Aqueous

Sample Name:		GND2474 23-Apr-2015 2:42 pm				
Lab Number:		1416941.1				
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m^3	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m^3	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m^3	< 0.003	-	-	-	-
Ethylene	g/m^3	< 0.004	-	-	-	-
Methane	g/m^3	0.005	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m^3	< 0.10	-	-	-	-
C10 - C14	g/m^3	< 0.2	-	-	-	-
C15 - C36	g/m^3	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m^3	< 0.7	-	-	-	-

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m^3	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m^3	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m^3	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m^3	1
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m^3	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.07 meq/L	1
Total cations for anion/cation balance check	Sum of cations as mEquiv/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H^+) also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.05 meq/L	1
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m^3 as $CaCO_3$	1
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 22nd ed. 2012.	1.0 g/m^3 at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m^3 as $CaCO_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m^3	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m^3	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m^3	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m^3	1
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	1
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m^3	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m^3	1

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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ANALYSIS REPORT

SPv1

Client:	Taranaki Regional Council	**Lab No:**	1420157
Contact:	Regan Phipps	**Date Registered:**	01-May-2015
	C/- Taranaki Regional Council	**Date Reported:**	11-May-2015
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	GND1179
		Submitted By:	R McDonnell

Sample Type: Aqueous

	Sample Name:	GND1179 30-Apr-2015 8:53 am				
	Lab Number:	1420157.1				
Individual Tests						
Sum of Anions	meq/L	1.98	-	-	-	-
Sum of Cations	meq/L	1.82	-	-	-	-
pH	pH Units	7.5	-	-	-	-
Total Alkalinity	g/m^3 as $CaCO_3$	66	-	-	-	-
Bicarbonate	g/m^3 at 25°C	80	-	-	-	-
Total Hardness	g/m^3 as $CaCO_3$	47	-	-	-	-
Electrical Conductivity (EC)	mS/m	21.6	-	-	-	-
Total Dissolved Solids (TDS)	g/m^3	97	-	-	-	-
Dissolved Barium	g/m^3	0.0129	-	-	-	-
Dissolved Bromine*	g/m^3	0.095	-	-	-	-
Dissolved Calcium	g/m^3	14.4	-	-	-	-
Dissolved Copper	g/m^3	< 0.0005	-	-	-	-
Dissolved Iron	g/m^3	6.0	-	-	-	-
Dissolved Magnesium	g/m^3	2.7	-	-	-	-
Dissolved Manganese	g/m^3	0.166	-	-	-	-
Dissolved Mercury	g/m^3	< 0.00008	-	-	-	-
Dissolved Nickel	g/m^3	< 0.0005	-	-	-	-
Dissolved Potassium	g/m^3	9.7	-	-	-	-
Dissolved Sodium	g/m^3	9.4	-	-	-	-
Dissolved Zinc	g/m^3	0.0021	-	-	-	-
Chloride	g/m^3	24	-	-	-	-
Nitrite-N	g/m^3	0.013	-	-	-	-
Nitrate-N	g/m^3	0.021	-	-	-	-
Nitrate-N + Nitrite-N	g/m^3	0.034	-	-	-	-
Sulphate	g/m^3	< 0.5	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m^3	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m^3	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m^3	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m^3	< 0.0010	-	-	-	-
Toluene	g/m^3	< 0.0010	-	-	-	-
Ethylbenzene	g/m^3	< 0.0010	-	-	-	-
m&p-Xylene	g/m^3	< 0.002	-	-	-	-

Sample Type: Aqueous

Sample Name:		GND1179 30-Apr-2015 8:53 am				
Lab Number:		1420157.1				
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m^3	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m^3	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m^3	< 0.003	-	-	-	-
Ethylene	g/m^3	< 0.003	-	-	-	-
Methane	g/m^3	4.0	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m^3	< 0.10	-	-	-	-
C10 - C14	g/m^3	< 0.2	-	-	-	-
C15 - C36	g/m^3	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m^3	< 0.7	-	-	-	-

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m^3	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m^3	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m^3	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m^3	1
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m^3	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.07 meq/L	1
Total cations for anion/cation balance check	Sum of cations as mEquiv/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H$^+$) also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.05 meq/L	1
pH	pH meter. APHA 4500-H$^+$ B 22nd ed. 2012.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m^3 as CaCO$_3$	1
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO$_2$ D 22nd ed. 2012.	1.0 g/m^3 at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m^3 as CaCO$_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m^3	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m^3	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m^3	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m^3	1
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	1
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m^3	1
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	1
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m^3	1

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Ara Heron BSc (Tech)
Client Services Manager - Environmental Division

Appendix IV

Certificates of analysis (Hydraulic fracturing and return fluid)

Hill Laboratories
BETTER TESTING **BETTER RESULTS**

R J Hill Laboratories Limited
1 Clyde Street
Private Bag 3205
Hamilton 3240, New Zealand

Tel +64 7 858 2000
Fax +64 7 858 2001
Email mail@hill-labs.co.nz
Web www.hill-labs.co.nz

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1388035 SPv1
Contact:	Regan Phipps	**Date Registered:**	21-Feb-2015
	C/- Taranaki Regional Council	**Date Reported:**	01-Apr-2015
	Private Bag 713	**Quote No:**	49265
	STRATFORD 4352	**Order No:**	
		Client Reference:	Urenui 1 Return Fluid
		Submitted By:	R McDonnell

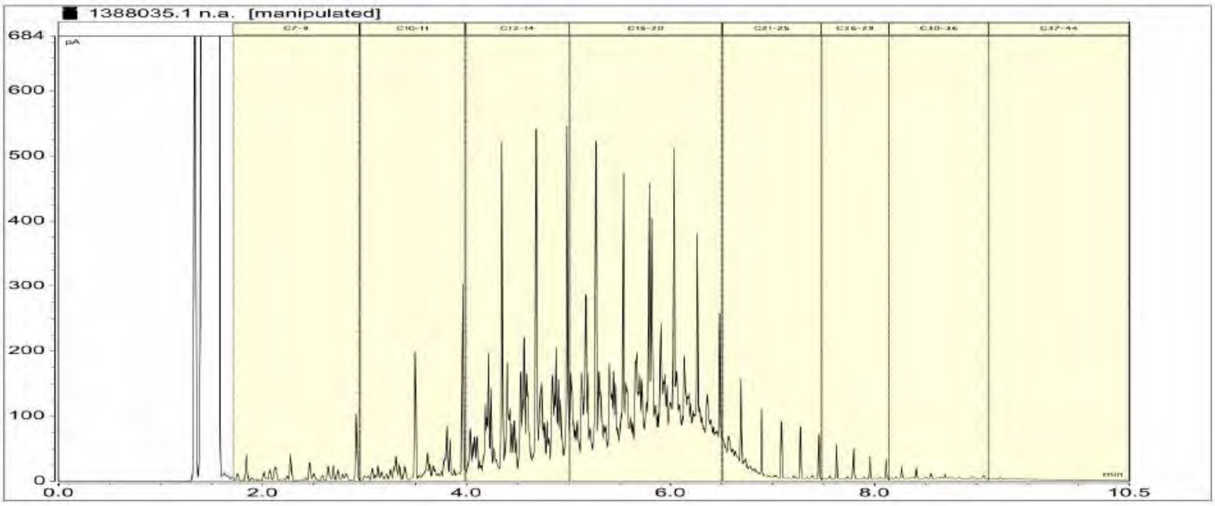
Sample Type: Saline

Sample Name:		GND2471 12-Jan-2015 12:00 pm				
Lab Number:		1388035.1				
Individual Tests						
pH*	pH Units	6.7	-	-	-	-
Total Alkalinity*	g/m^3 as $CaCO_3$	1,160	-	-	-	-
Analysis Temperature for Bicarbonate	°C	22	-	-	-	-
Bicarbonate	g/m^3 at Analysis Temperature	973	-	-	-	-
Total Hardness*	g/m^3 as $CaCO_3$	104	-	-	-	-
Electrical Conductivity (EC)*	mS/m	852	-	-	-	-
Total Dissolved Solids (TDS)*	g/m^3	6,700	-	-	-	-
Dissolved Barium*	g/m^3	1.39	-	-	-	-
Dissolved Bromine*	g/m^3	16.1	-	-	-	-
Dissolved Calcium*	g/m^3	31	-	-	-	-
Dissolved Copper*	g/m^3	< 0.005	-	-	-	-
Dissolved Iron*	g/m^3	3.9	-	-	-	-
Dissolved Magnesium*	g/m^3	7	-	-	-	-
Dissolved Manganese*	g/m^3	0.96	-	-	-	-
Total Mercury*	g/m^3	< 0.011	-	-	-	-
Dissolved Nickel*	g/m^3	< 0.03	-	-	-	-
Dissolved Potassium*	g/m^3	310	-	-	-	-
Dissolved Sodium*	g/m^3	1,760	-	-	-	-
Dissolved Sulphur*	g/m^3	8	-	-	-	-
Dissolved Zinc*	g/m^3	0.02	-	-	-	-
Chloride*	g/m^3	2,000	-	-	-	-
Nitrite-N	g/m^3	< 0.2 [#1]	-	-	-	-
Nitrate-N	g/m^3	< 0.2	-	-	-	-
Nitrate*	g/m^3	< 0.9	-	-	-	-
Nitrate-N + Nitrite-N	g/m^3	< 0.2 [#1]	-	-	-	-
Sulphate*	g/m^3	25	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m^3	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m^3	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m^3	3	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene*	g/m^3	4.2	-	-	-	-
Toluene*	g/m^3	1.22	-	-	-	-
Ethylbenzene*	g/m^3	0.062	-	-	-	-

Sample Type: Saline

Sample Name:		GND2471 12-Jan-2015 12:00 pm				
Lab Number:		1388035.1				
BTEX in Water by Headspace GC-MS						
m&p-Xylene*	g/m³	0.25	-	-	-	-
o-Xylene*	g/m³	0.155	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde*	g/m³	0.30	-	-	-	-
Gases in groundwater						
Ethane*	g/m³	0.036	-	-	-	-
Ethylene*	g/m³	< 0.003	-	-	-	-
Methane*	g/m³	0.161	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9*	g/m³	103	-	-	-	-
C10 - C14*	g/m³	1,230	-	-	-	-
C15 - C36*	g/m³	2,200	-	-	-	-
Total hydrocarbons (C7 - C36)*	g/m³	3,500	-	-	-	-

1388035.1
GND2471 12-Jan-2015 12:00 pm
Client Chromatogram for TPH by FID



Analyst's Comments

[#1] Severe matrix interferences required that a dilution be performed prior to analysis of this sample, resulting in a detection limit higher than that normally achieved for the NO2Nsal, NO3Nsal and NOxNsal analysis.

Appendix No.1 - Bicarbonate - 1388035.1

SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1
Gases in groundwater*	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1
Total Petroleum Hydrocarbons in Water*	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m³	1

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	1
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	1
pH*	Saline water, pH meter. APHA 4500-H^+ B 22nd ed. 2012.	0.1 pH Units	1
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m^3 as $CaCO_3$	1
Analysis Temperature for Bicarbonate	Temperature at which Bicarbonate titration was conducted as reported by Geological & Nuclear Sciences, Wairakei.	1.0 °C	1
Bicarbonate	Bicarbonate (HCO3) Titration Method conducted at reported temperature. Subcontracted to Geological & Nuclear Sciences, Wairakei. ASTM Standards D513-82 Vol.11.01 of 1988.	20 g/m^3 at Analysis Temperature	1
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m^3 as $CaCO_3$	1
Electrical Conductivity (EC)*	Saline water, Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.10 mS/m	1
Total Dissolved Solids (TDS)*	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	50 g/m^3	1
Filtration for dissolved metals analysis*	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22nd ed. 2012.	-	1
Dissolved Barium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.0006 g/m^3	1
Dissolved Bromine*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.10 g/m^3	1
Dissolved Calcium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.0 g/m^3	1
Dissolved Copper*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	1
Dissolved Iron*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.004 g/m^3	1
Dissolved Magnesium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.4 g/m^3	1
Dissolved Manganese*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	1
Total Mercury*	Nitric acid digestion, ICP-MS, screen level. APHA 3125 B 22nd ed. 2012.	0.0021 g/m^3	1
Dissolved Nickel*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.006 g/m^3	1
Dissolved Potassium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.0 g/m^3	1
Dissolved Sodium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.4 g/m^3	1
Dissolved Sulphur*	Filtered sample, ICP-OES.	0.10 g/m^3	1
Dissolved Zinc*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.004 g/m^3	1
Chloride*	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m^3	1
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	1
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1
Nitrate*	Calculation from Nitrate-N.	0.010 g/m^3	1
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m^3	1
Soluble Sulphate*	Calculation: from dissolved sulphur.	2 g/m^3	1

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Graham Corban MSc Tech (Hons)
Client Services Manager - Environmental Division

GNS SCIENCE
TE PŪ AO
ANALYTICAL LABORATORY
Private Bag 2000, Taupo
Phone: (07) 374 8211
Fax: (07) 374 8199
Email: w.labmanager@gns.cri.nz

CERTIFICATE OF ANALYSIS

SALINE FOR BICARBONATE ANALYSES

Report No: 2015030303

Customer Ref:142658

Ara Heron
RJ Hill Laboratories (Hamilton)
Environmental Reports Officers
Private Bag 3205
Hamilton

GNS Lot No: **2015030303**

GNS Sample No.	2015001078
Collection Date.	12/01/2015
Site ID:	1388035/1
Field ID	

pH		6.86	-	-	-
Bicarbonate (Total)	mg/l	973	-	-	-
HCO_3 Analysis Temperature	°C	22	-	-	-
HCO_3 Analysis Date		03/03/2015	-	-	-

IANZ
ACCREDITED LABORATORY
ACCREDITATION No 768

Tests marked with a † are not accredited and are outside the scope of the laboratory's accreditation.

SUMMARY OF METHODS AND DETECTION LIMITS

The following table gives a brief description of the methods used to conduct the analyses on this report.
The detection limits given below are those attainable in a relatively clean matrix.

Parameter	**Method**	***Detection Limit**	
Bicarbonate (total)	HCO_3Titration Method ASTM Standards D513-82 Vol.11.01 1988	20	mg/l
pH	Electrometric Method - APHA 4500-H+ B 22nd Edition 2012	-	-

*Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Notes: These samples were collected by yourselves (or your agent) and analysed as received at the laboratory. This report must not be reproduced, except in full, without the written consent of the signatory. Samples are held at the laboratory after reporting for a period of 2 to 6 months, dependent on sample type.

M. K. Appleby.
Moya Appleby
Senior Technician

Hill Laboratories
BETTER TESTING **BETTER RESULTS**

R J Hill Laboratories Limited
1 Clyde Street
Private Bag 3205
Hamilton 3240, New Zealand

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Fax +64 7 858 2001
Email mail@hill-labs.co.nz
Web www.hill-labs.co.nz

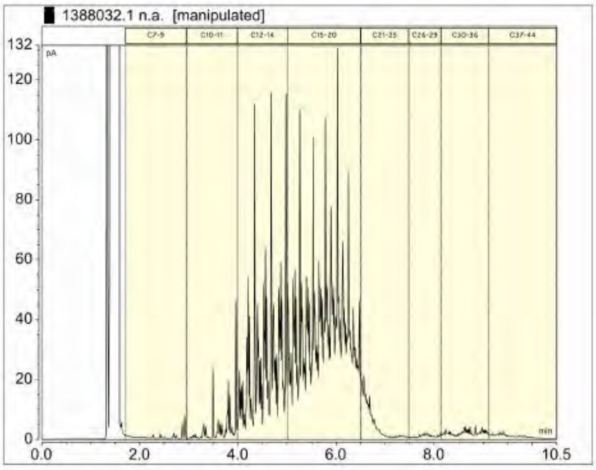
ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1388032 SPv1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	**Date Registered:**	21-Feb-2015
		Date Reported:	10-Mar-2015
		Quote No:	50522
		Order No:	
		Client Reference:	Hydraulic fracturing fluid testing
		Submitted By:	R McDonnell

Sample Type: Aqueous

Sample Name:		GND2471 12-Jan-2015 12:00 pm				
Lab Number:		1388032.1				
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	0.0026	-	-	-	-
Toluene	g/m³	0.0030	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-
o-Xylene	g/m³	< 0.0010	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	0.4	-	-	-	-
C10 - C14	g/m³	73	-	-	-	-
C15 - C36	g/m³	154	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	230	-	-	-	-

1388032.1
GND2471 12-Jan-2015 12:00 pm
Client Chromatogram for TPH by FID



SUMMARY OF METHODS

The following table(s) gives a brief description of the methods used to conduct the analyses for this job. The detection limits given below are those attainable in a relatively clean matrix. Detection limits may be higher for individual samples should insufficient sample be available, or if the matrix requires that dilutions be performed during analysis.

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m^3	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m^3	1
Total Petroleum Hydrocarbons in Water*	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m^3	1

These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

Samples are held at the laboratory after reporting for a length of time depending on the preservation used and the stability of the analytes being tested. Once the storage period is completed the samples are discarded unless otherwise advised by the client.

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Peter Robinson MSc (Hons), PhD, FNZIC
Client Services Manager - Environmental Division

Appendix V

Biomonitoring report

To	Job Manager; Callum MacKenzie
From	Freshwater Biologist; Darin Sutherland
Report No	DS010
Document	1517080
Date	29 May

Biomonitoring of an unnamed tributary of the Onaero River following drilling by Greymouth Petroleum Ltd at the Urenui-1 wellsite, February 2015.

Introduction

Macroinvertebrate surveys were performed at the Urenui-1 wellsite to determine whether drilling discharges had a detrimental effect upon macroinvertebrate communities of an unnamed tributary of the Onaero River. The wellsite treated stormwater, uncontaminated site water, and production water was discharged from a skimmer pit to land near the unnamed tributary (Figure 1). There was a pre-drill survey completed on the 19 August, 2014 (Thomas, 2014) to provide baseline data about the macroinvertebrate communities present in the unnamed tributary so that comparisons could be made between the pre-drill and post-drill surveys.

Methods

The post-drill survey was undertaken on 10 February 2015 at three sites (Table 1). Site 1 was the control site while site 2 was the primary impacted site and site 3 was the secondary impacted site. The altitude of the three sites was approximately 60 m asl.

The Council's standard 'vegetation sweep' technique was used to collect streambed macroinvertebrates in the unnamed tributary of the Onaero River Stream (Table 1; Figure 1). The 'vegetation sweep' technique is very similar to C2 (soft-bottomed, semi-quantitative) of the New Zealand Macroinvertebrate Working Group (NZMWG) protocols for macroinvertebrate samples in wadeable streams (Stark *et al*, 2001).

Table 1 Biomonitoring sites in an unnamed tributary of the Onaero River in relation to the Urenui-1 wellsite.

Site No.	Site code	Grid reference (NZTM)	Location
1	ONR000400	1717539E-5679719N	50m upstream Urenui-1 wellsite discharge
2	ONR000403	1717628E-5679773N	60m downstream of Urenui-1 wellsite discharge
3	ONR000405	1717650E-5679796N	100m downstream of Urenui-1 wellsite discharge

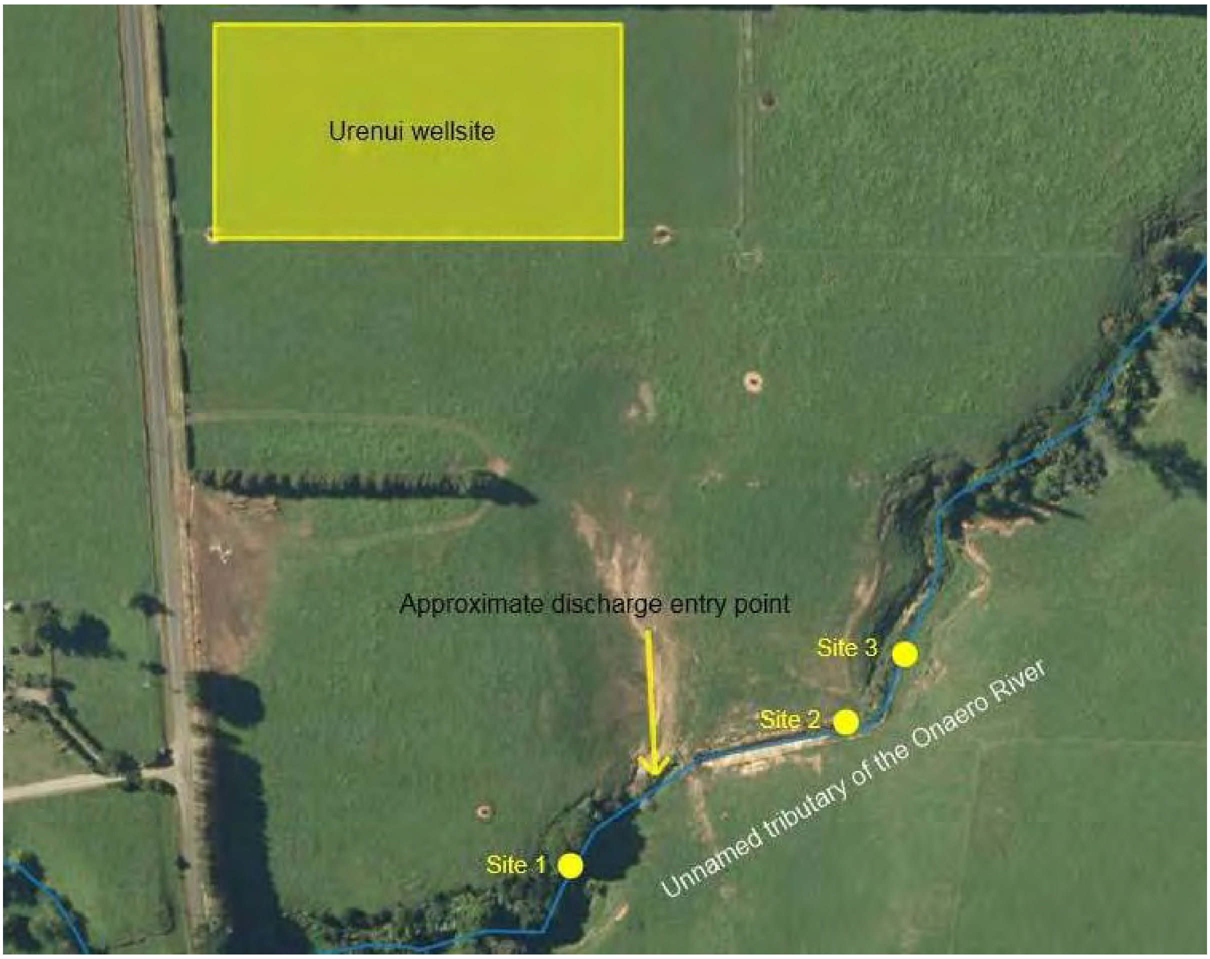

Figure 1 Biomonitoring sites in an unnamed tributary of the Onaero River in relation to the Urenui-1 wellsite

Samples were preserved with Kahle's Fluid for later sorting and identification under a stereomicroscope according to Taranaki Regional Council methodology which uses Protocol P1 of NZMWG protocols of sampling macroinvertebrates in wadeable streams (Stark et al, 2001). Macroinvertebrate taxa found in each sample were recorded as:

R (rare) = less than 5 individuals;
C (common) = 5-19 individuals;
A (abundant) = estimated 20-99 individuals;
VA (very abundant) = estimated 100-499 individuals;
XA (extremely abundant) = estimated 500 individuals or more.

Stark (1985) developed a scoring system for macroinvertebrate taxa according to their sensitivity to organic pollution in stony New Zealand streams. Highly 'sensitive' taxa were assigned the highest scores of 9 or 10, while the most 'tolerant' forms scored 1. Sensitivity scores for certain taxa have been modified in accordance with Taranaki experience.

By averaging the scores obtained from a list of taxa taken from one site and multiplying by a scaling factor of 20, a Macroinvertebrate Community Index (MCI) value was obtained. The MCI is a measure of the overall sensitivity of macroinvertebrate communities to the effects of organic pollution. More 'sensitive' communities inhabit less polluted waterways. A difference of 11 units or more in MCI values is considered significantly different (Stark 1998).

A semi-quantitative MCI value ($SQMCI_s$) has also been calculated for the taxa present at each site by multiplying each taxon score by a loading factor (related to its abundance), totalling these products, and dividing by the sum of the loading factors (Stark, 1998 and 1999). The loading factors were 1 for rare (R), 5 for common (C), 20 for abundant (A), 100 for very abundant (VA) and 500 for extremely abundant (XA). Unlike the MCI, the $SQMCI_s$ is not multiplied by a scaling factor of 20, so that its corresponding range of values is 20x lower. A difference of 0.9 units or more in $SQMCI_s$ is considered significantly different (Stark, 1998).

Results

Site habitat characteristics

The water temperatures during the post-drill survey were cool (range 16.6-18.0 °C). Water levels were low and water speed was very slow. Water was uncoloured and clear apart from (Table 2). Substrate compositions for all three sites were comprised of silt (Table 2).

No algal mats were present but filamentous algae were widespread at sites 1 and 2 but not 3. Moss, leaves and wood were absent from all sites during and macrophytes were present on the stream edges on site 1 and on the bed in sites 2 and 3. Site 1 had partial shading from overhanging vegetation but sites 2 and 3 had no shading.

Table 2 Summary of time of sampling and some water variables collected on 119 August 2014 (pre-drill) and 10 February, 2015 (post-drill) at each site.

	Time (NZST)		Temperature (°C)		Water Colour		Water Clarity		Flow Conditions		Water Speed	
	Pre-drill	Post-drill	Pre-drill	Post- drill	Pre-drill	Post- drill	Pre-drill	Post- drill	Pre-drill	Post- drill	Pre-drill	Post- drill
ONR000400	1040	1100	12.5	16.6	Uncoloured	Uncoloured	Clear	Clear	Moderate	Low	Slow	V. Slow
ONR000403	1015	1045	12.3	18.0	Uncoloured	Uncoloured	Clear	Clear	Moderate	Low	Steady	V. Slow
ONR000405	1000	1035	12.3	16.6	Uncoloured	Uncoloured	Clear	Clear	Moderate	Low	Steady	V. Slow

Macroinvertebrate communities

Comparative data for similar sites (TRC, 2015) are summarised in Table 3. Results of the pre-drill and post-drill survey macroinvertebrate faunal data are summarised in (Table 4).

Table 3 Range and median number of taxa, MCI and SQMCIs scores for 'control' sites (lowland coastal streams) at altitudes between 50 and 79 m asl (TRC, 2015).

	No. of taxa	MCI	$SQMCI_s$
No. Samples	98	98	69
Range	19-30	60-100	1.4-6.2
Median	20	78	4.0

Table 4 Macroinvertebrate fauna of an unnamed tributary of the Onaero River in relation to the Urenui-1 wellsite surveys sampled) August 19 2014 (pre-drill and post-drill 10 February 2015 (post-drill).

Taxa List	Site Code	MCI Score	Pre-drill			Post-drill		
	Sample Number		ONR000400	ONR000403	ONR000405	ONR000400	ONR000403	ONR000405
PLATYHELMINTHES (FLATWORMS)	*Cura*	3	C	C	C	-	-	-
NEMERTEA	Nemertea	3	-	R	R	-	-	-
ANNELIDA (WORMS)	Oligochaeta	1	XA	VA	XA	-	R	-
HIRUDINEA (LEECHES)	Hirudinea	3	-	R	C	-	-	-
MOLLUSCA	*Physa*	3	-	-	R	-	-	A
	Potamopyrgus	4	XA	XA	XA	VA	XA	XA
	Sphaeriidae	3	A	R	C	R	-	R
CRUSTACEA	Ostracoda	1	VA	A	VA	A	C	A
	Paracalliope	5	A	XA	VA	VA	XA	XA
EPHEMEROPTERA (MAYFLIES)	*Deleatidium*	8	-	-	-	R	-	-
	Zephlebia group	7	-	-	R	R	R	R
ODONATA (DRAGONFLIES)	*Austrolestes*	4	-	-	-	R	R	-
	Xanthocnemis	4	A	C	A	C	C	A
HEMIPTERA (BUGS)	*Microvelia*	3	R	-	-	R	-	-
	Sigara	3	R	-	-	R	-	C
TRICHOPTERA (CADDISFLIES)	*Plectrocnemia*	8	-	-	-	R	-	-
	Polyplectropus	6	R	-	-	-	R	-
	Psilochorema	6	-	-	-	-	R	R
	Oxyethira	2	R	-	-	A	-	R
	Paroxyethira	2	-	-	R	R	-	C
	Triplectides	5	C	C	C	C	R	C
DIPTERA (TRUE FLIES)	*Paralimnophila*	6	R	R	R	-	-	-
	Orthocladiinae	2	-	-	-	C	C	R
	Polypedilum	3	-	-	-	R	-	-
	Tanypodinae	5	R	R	-	R	-	-
	Paradixa	4	-	-	-	-	R	-
	Empididae	3	-	R	-	-	R	C
	Austrosimulium	3	R	A	C	-	-	R
ACARINA (MITES)	Acarina	5	C	R	R	-	-	-
No of taxa			16	15	16	17	13	15
MCI			74	72	73	81	80	71
SQMCIs			2.5	4.1	2.6	4.0	4.5	4.4
EPT (taxa)			2	1	2	4	4	3
%EPT (taxa)			13	7	13	24	31	20
'Tolerant' taxa	'Moderately sensitive' taxa	'Highly sensitive' taxa						

R = Rare C = Common A = Abundant VA = Very Abundant XA = Extremely Abundant

Site 1- 50m upstream of Urenui-1 wellsite discharge

A moderately low macroinvertebrate community richness of 17 taxa was found at site 1 ('control' site) at the time of the post-drill survey. Site 1 also had a lower taxa richness compared with the median found at other sites in similar streams in the Taranaki region within the same altitudinal band (median taxa richness of 20 taxa; Table 3).

The post-drill MCI score of 81 units indicated a community of 'fair' biological health and was not significantly different to the median MCI score found at other sites in similar streams in the Taranaki region within the same altitudinal band (median MCI score of 78; Table 3). The post-drill $SQMCI_S$ score of 4.0 units was not significantly different to other sites in similar streams in the Taranaki region within the same altitudinal band (median $SQMCI_S$ score of 4.0 units; Table 3).

The post-drill survey community was characterised by three 'tolerant' taxa [snail (*Potamopygus*), ostracod seed shrimps, and caddisfly (*Oxyethira*)] and one 'moderately sensitive' taxon, [amphipods (*Paracalliope*)] (Table 4).

Site 2- 60m downstream of Urenui-1 wellsite discharge

A moderately low macroinvertebrate community richness of 13 taxa was found at site 2 ('primary impacted' site) at the time of the post-drill survey which was lower than that found at other sites in similar streams in the Taranaki region within the same altitudinal band (median taxa richness of 20 taxa; Table 3).

The post-drill MCI score of 80 units indicated a community of 'fair' biological health and was not significantly different to the median MCI score found at other sites in similar streams in the Taranaki region within the same altitudinal band (median MCI score of 78; Table 3). The post-drill $SQMCI_S$ score of 4.5 units was not significantly different to other sites in similar streams in the Taranaki region within the same altitudinal band (median $SQMCI_S$ score of 4.0 units; Table 3).

The post-drill survey community was characterised by one 'tolerant' taxon, [snail (*Potamopygus*)], and one 'moderately sensitive' taxon, [amphipod (*Paracalliope*)] (Table 4).

Site 3- 100m downstream of Urenui-1 wellsite discharge

A moderately low macroinvertebrate community richness of 15 taxa was found at site 3 ('secondary impacted' site) at the time of the post-drill survey. Site 3 also had a lower taxa richness compared with numbers found at other sites in similar streams in the Taranaki region within the same altitudinal band (median taxa richness of 20 taxa; Table 3).

The post-drill MCI score of 71 units indicated a community of 'poor' biological health but was not significantly different to the median MCI score found at other sites in similar streams in the Taranaki region within the same altitudinal band (median MCI score of 78; Table 3). The post-drill $SQMCI_S$ score of 4.4 units was not significantly different to that found in similar streams in the Taranaki region within the same altitudinal band (median $SQMCI_S$ score of 4.0 units; Table 3).

The post-drill survey community was characterised by two 'tolerant' taxa [snail (*Potamopygus*) and damselfly (*Xanthocnemis*)] and one 'moderately sensitive' taxon, [amphipod (*Paracalliope*)] (Table 4).

Discussion and Conclusions

The Councils 'vegetation sweep' technique was used at three sites to collect streambed macroinvertebrates from an unnamed tributary of the Onaero River post-drilling at the Urenui-1 wellsite. This has provided data to assess impacts of skimmer pit discharge effects from the Urenui-1 wellsite on the macroinvertebrate communities of this stream. Samples were processed to provide number of taxa (richness), MCI, and $SQMCI_S$ scores for each site.

The MCI is a measure of the overall sensitivity of the macroinvertebrate community to the effects of organic pollution in stony streams. It is based on the presence/absence of taxa with varying degrees of sensitivity to environmental conditions. The $SQMCI_S$ takes into account taxa abundances as well as sensitivity to pollution. It may indicate subtle changes in communities, and therefore be the more relevant index if non-organic impacts are occurring. Significant differences in either the MCI or the $SQMCI_S$ between sites may indicate the degree of adverse effects (if any) of the discharge being monitored.

The February 2015 post-drill survey of three sites, upstream and downstream of the skimmer pit discharge point to an unnamed tributary of the Onaero River, was undertaken because of drilling at the Urenui-1 wellsite. Taxa richnesses at all three sites were generally lower than previously found at similar sites at the same altitudinal band and there were no substantial differences between the pre-drill and post-drill taxa richnesses with a maximum difference of just two taxa.

MCI scores did not significantly change between the pre-drill and post-drills surveys (Stark, 1998) although the 'primary impacted' site had an increase in MCI score of eight units. The post-drill $SQMCI_S$ scores showed an improvement compared with the pre-drill survey results and there were no significant differences between the 'control' site and the 'primary impacted' and 'secondary impacted' sites. There was no evidence that wellsite discharges had had a significant impact on the health of the macroinvertebrate communities in the unnamed tributary of the Onaero River as shown by the pre-drill and post-drill surveys.

Summary

- A post-drill macroinvertebrate survey was completed at three sites near the Urenui-1 wellsite to determine if any wellsite discharges to nearby land had impacted on the health of macroinvertebrate communities in the adjacent unnamed tributary of the Onaero River.

- Taxa richnesses were moderately low at the three sites surveyed and were lower than values found at other similar sites within the Taranaki Region.

- MCI scores indicated that the macorinvertebrate communities surveyed were mostly of 'fair' health and had similar values to those found at similar sites within the Taranaki Region. There were no significant decreases in MCI score between the pre-drill and post-drill surveys or between the 'control' site and the 'primary impacted' and 'secondary impacted' sites.

- $SQMCI_S$ scores at all three sites improved between the pre-drill and post-drill surveys and there were no significant decreases in scores between the 'control' site and the 'primary impacted' and 'secondary impacted' sites.

- There was no indication from any of the macroinvertebrate indices examined that Urenui-1 wellsite discharges adjacent to an unnamed tributary of the Onaero River had any adverse effects on the health of the macroinvertebrate communities present at sites downstream of the discharge area.

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