Greymouth Petroleum Limited
Ohanga-A Hydraulic Fracturing Monitoring Programme
Annual Report
2014-2015

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Executive summary

Greymouth Petroleum Limited (GPL) operates the Ohanga-A wellsite, located at 324 Ohanga Road, Urenui. The wellsite lies within the Onaero catchment and contains two hydrocarbon producing wells and associated infrastructure.

GPL hold resource consent 10053-1, authorising the discharge of water based hydraulic fracturing fluids into land at depths greater than 2,700 m TVD beneath the Ohanga-A wellsite. The consent was issued by Taranaki Regional Council (the Council) on 21 January 2015 and contains 18 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 Ohanga-A 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, Greymouth demonstrated an overall high level of environmental performance.

The programme of hydraulic fracturing undertaken by GPL at Ohanga-A included the fracturing of two wells; Ngatoro-2St2 and Ohanga-1. The hydraulic fracturing of these wells took place between 2 February and 25 March 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, GPL demonstrated a high level of both 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 Ohanga-A wellsite, 324 Ohanga Road, Urenui over the period February to March 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 Ohanga-A wellsite included the fracturing of two wells; Ohanga-2St2 and Ohanga-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 Ohanga-A 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 RMA and the Council's obligations and general approach to monitoring sites though annual programmes, the resource consents held by GPL in the Onaero catchment, the nature of the monitoring programme in place for the period under review, and a description of the activities and operations conducted in GPL'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 GPL'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 GPL'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 Ohanga-A wellsite history

The Ohanga-A wellsite is located within the rural environment, surrounded by predominantly pastoral farming. A number of wellsites and pipelines associated with hydrocarbon exploration, production, and processing are located within a 10km radius of the site. Some of these sites include the Urenui A Wellsite, Kowhai A Wellsite, Epiha A Wellsite, the Turangi Production Station and Todd Energy's Mangahewa E and Mangahewa C wellsites.The surrounding topography of the Ohanga A Wellsite is flat to undulating with gully features.

Ohanga-2St2 is a side-track of the existing Ohanga-2St1. Sidetracking began on 5 December 2014 and was completed on 25 January 2015. Ohanga-1 was drilled from 29 September 1990 to 9 November 1990. The location of the wellsite is illustrated in Figure 1.

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

Table 1 Summary of hydraulic fracturing activity

Well	Wellsite	Consent	Date	Injection zone (m TVDss)	Formation
Ohanga-2St2	Ohanga-A	10053-1	02/02/2015	2,962-2,965	McKee1
			11/02/2015	2,981-2,984	McKee2
Ohanga-1			25/03/2015	3,000-3,071	McKee1

Figure 1 Location of groundwater and surface water sampling sites in relation to the Ohanga-A wellsite

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 10053-1, authorising the discharge of water based hydraulic fracturing fluids into land at the Ohanga-A wellsite. The consent was issued by the Council on 21 January 2015, under Section 87(e) of the RMA. This is the consent under which Ohanga-St2 and Ohanga-1 were fractured. Consent 10053-1 contains 18 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 that more than one post-fracturing discharge report may be required if multiple hydraulic fracturing discharges occur to meet the specified 90 day deadline from each commencement date.

Condition 13 stipulates how the reports required by conditions 9 and 11 are to be submitted.

Condition 14 requires the consent holder to allow the Council access to a location where samples of hydraulic fracturing and return fluids can be obtained.

Condition 15 requires the consent holder to use best practicable options.

Condition 16 relates to the composition of the fracturing fluid.

Condition 17 is a lapse clause.

Consent 18 is a review provision.

A copy of the consent is attached to this report in Appendix I.

1.4 Monitoring programme

1.4.1 Introduction

Section 35 of the RMA sets out 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 for the Ohanga-A site 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 10053-1, GPL submitted pre and post-fracturing discharge reports to the Council for the wells 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 Ohanga-A wellsite, and the analysis of the results.

In order to select suitable sites for sampling, the Council carried out a well survey in the vicinity of the Ohanga-A wellsite to identify existing groundwater abstractions. The survey was undertaken within a defined 'area of review' which extended 1 km radially from the wellsite. The survey did not result in any suitable sampling locations being identified. In the absence of any suitable existing sampling sites, condition 5 of consent 10053-1 required GPL to install a suitable monitoring bore 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. The details of the monitoring bore installed are included in Table 2 and its location at the wellsite is illustrated in Figure 1.

Table 2 Details of the groundwater site included in the monitoring programme

Hydraulically fractured wellS	Monitoring site	Location	Total depth (m)	Screened interval (m)	Aquifer
Ohanga-2St2 Ohanga-1	GND2487	In wellsite	30	21 - 30	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 Ohanga-A 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 the unnamed tributary of the Onaero River as this is the nearest surface water body to the stormwater discharge location of the Ohanga-A 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 No.	Site code	Grid reference (NZTM)	Location	Sampling method	
				Post-drill	Post-frac
1	ONR000390	1717211E-5679529N	5 m upstream of the discharge tributary confluence	Kick-sweep	Vegetation sweep
2	ONR000394	1717266E-5679610N	145 m downstream of the discharge tributary confluence	Vegetation sweep	Vegetation sweep
3	ONR000396	1717307E-5679665N	260 m downstream of the discharge tributary confluence	Vegetation sweep	Vegetation sweep

2. Results

2.1 Consent holder submitted data

2.1.1 Ohanga-2St2 post-fracturing dischrge report

The conclusions from the Ohanga-2St2 post-fracturing discharge report are summarised as follows:

- A total of two discrete zones were fractured between 2 February and 11 February 2015, at depths between 2,962 and 2,984 m TVDss.

- A total of 3,266 barrels (bbls) (519 m^3) of liquid was discharged across the two fractured zones. The total proppant weight was 119 tonnes.

- By volume, 79.72% of the fluid injected was water, 18.65% was proppant and 1.63% 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 Ohanga-2ST2 well was opened for flowback immediately after placement of the proppant. 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 clear from the composition and physical properties of the flowback fluid that it is dominantly hydraulic fracturing fluid during the initial stages of flowback, and from this a reasonable estimate of fluid remaining underground can be made. At the completion of all flow-back operations, approximately 1,557 bbls (248 m^3) of fracture fluids and formation fluid were returned to the surface, leaving 1,709 bbls (272 m^3) underground. It is estimated that all of the proppant injected (119 tonnes) 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 of the Ohanga-2St2 well 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.

2.1.2 Ohanga-1 post-fracturing dischrge report

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

- A total of seven discrete zones were fractured on 25 March 2015, at depths between 3,000 and 3,071 m TVDss.

- A total of 2,117 barrels (bbls) (337 m^3) of liquid was discharged across the seven fractured zones. The total proppant weight was 68 tonnes.

- By volume, 77.52% of the fluid injected was water, 20.26% was proppant and 2.22% 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 Ohanga-1 well was opened for flowback immediately after placement of the proppant. At the completion of all flow-back operations, approximately 1,130 bbls (180 m^3) of fracture fluids and formation fluid were returned to the surface, leaving 987 bbls (157 m^3) underground. It is estimated that all of the proppant injected (68 tonnes) 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 of the Ohanga-1 well 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 Groundwater sampling survey

One site was sampled to monitor the effects of the hydraulic fracturing of the Ohanga-2St2 and Ohanga-1 wells on local groundwater resources.

The results of the laboratory analysis of samples from site GND2487 show only minor variations in analyte concentration across all sampling events. The changes in concentrations of these analytes are a result of natural variations in water composition and are unrelated to hydraulic fracturing activities. Trace levels of formaldehyde was detected in the post-fracturing sample. Apart from this, no other traces of substances associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities in the post-fracturing sample obtained were detected. Formaldehyde can occur naturally in the environment and has been found in groundwater samples in Taranaki previously. It is not suspected that this formaldehyde is related to hydraulic fracturing activities at the Ohanga-A wellsite.

Dissolved methane was detected in both samples taken from GND2487. Concentrations were within the expected ranges for shallow groundwater across Taranaki. Carbon isotope analysis showed that the methane gas is biogenic in origin.

A full summary of results for all groundwater samples taken in relation to hydraulic fracturing of the Ohanga-2St2 and Ohanga-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 GND2487

Parameter	Unit	GND2487	
		Pre-frac	**Post-frac**
Sample date	-	28 Jan 2015	19 Jun 2015
Lab number	-	TRC150798	TRC152065
δ13C	‰	68.9	66.9
Total alkalinity	g/m^3 CaCO3	220	210
Barium	mg/kg	0.0170	0.0187
Benzene	g/m^3	<0.0010	<0.0010
Dissolved bromide	g/m^3	0.060	0.060
Calcium	g/m^3	45	46
Chloride	g/m^3	14.8	14.1
Electrical conductivity	mS/m@20C	44.1	43.0
Dissolved copper	g/m^3	0.0012	<0.0010
Dissolved Oxygen	g/m^3	0.62	0.58
Ethylbenzene	g/m^3	<0.0010	<0.0010
Ethane	g/m^3	<0.003	<0.003
Ethylene	g/m^3	<0.004	<0.003
Dissolved iron	g/m^3	1.70	11.1
Formaldehyde	g/m^3	<0.02	0.02
Ethylene glycol	g/m^3	<4	<4
Hydrocarbons	g/m^3	<0.7	<0.7
Bicarbonate	g/m^3 HCO3	260	260
Total hardness	g/m^3 CaCO3	191	185
Dissolved mercury	g/m^3	<0.00008	<0.00008
Potassium	g/m^3	5.6	5.3
Water Level	mbgl	8.167	7.828
Methanol	g/m^3	<2	<2
Methane	g/m^3	20	22
Magnesium	g/m^3	19.0	17.0
Dissolved manganese	g/m^3	0.29	0.38
Sodium	g/m^3	16.2	15.1
Nickel	mg/kg	0.0013	<0.0005
Nitrite + nitrate nitrogen	g/m^3 N	0.005	<0.002
Nitrite nitrogen	g/m^3 N	0.005	<0.002
Nitrate nitrogen	g/m^3 N	<0.002	<0.002
pH	pH	7.1	7.0
Propylene glycol	g/m^3	<4	<4
Sulphate	g/m^3	3.2	<0.5
Sum of Anions	meq/l	4.8	4.6
Sum of Cations	meq/l	4.7	4.9
Total Dissolved Solids	g/m^3	260	280
Temperature	Deg.C	16.0	14.3
Toluene	g/m^3	<0.0010	<0.0010

o-Xylene	g/m^3	<0.0010	<0.0010
m-Xylene	g/m^3	<0.002	<0.002
Dissolved zinc	g/m^3	0.0088	0.0050

2.2.2 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 Ohanga-1 well are summarised below in Table 5. No samples of hydraulic fracturing fluid were collected for Ohanga-2St2. 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 5 Results of hydraulic fracturing fluid sampling for Ohanga-1

Parameter	Unit	Ohanga-1
Sample date	-	25 March 2015
Lab number	-	TRC152893
Benzene	g/m^3	<0.010
Ethylbenzene	g/m^3	0.012
Ethylene glycol	g/m^3	40
Total hydrocarbons	g/m^3	700
Methanol	g/m^3	<2
Propylene glycol	g/m^3	<4
Toluene	g/m^3	<0.010
o-Xylene	g/m^3	<0.010
m-Xylene	g/m^3	<0.02

Composite samples of return fluids from Ohanga-2St2 and Ohanga-1 were 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 Ohanga-2St2 and Ohanga-1wells are summarised below in Table 6 and Table 7, respectively, and the certificates of analysis is included in Appendix III. Table 6 shows the results of two return fluid samples taken from

Ohanga-2St2. The higher levels of salinity (sodium and chloride), BTEX compounds and total hydrocarbons in the second sample (TRC151699) indicate that this sample was taken further into the flowback than the first sample.

Table 6 Results of hydraulic fracturing return fluid sampling for Ohanga-2St2

Parameter	**Unit**	**Ohanga-2st2**	
Sample Date	-	3 February 2015	
Lab number	-	TRC151050	TRC151699
Total alkalinity	g/m^3 CaCO3	3600	1830
Barium	mg/kg	0.045	0.57
Benzene	g/m^3	0.0011	9.0
Dissolved bromine	g/m^3	<0.5	6.4
Calcium	g/m^3	10	65
Chloride	g/m^3	230	1100
Electrical conductivity	mS/m@20°C	839	788
Dissolved copper	g/m^3	0.008	0.020
Ethylbenzene	g/m^3	<0.0010	2.2
Ethane	g/m^3	<0.003	0.20
Ethylene	g/m^3	<0.003	<0.003
Dissolved iron	g/m^3	0.09	5.5
Formaldehyde	g/m^3	8.9	0.21
Ethylene glycol	g/m^3	<4	41
Total hydrocarbons	g/m^3	187	1660
Bicarbonate	g/m^3 HCO3	2270	1873
Total hardness	g/m^3 CaCO3	58	210
Dissolved mercury	g/m^3	<0.0075	<0.011
Potassium	g/m^3	2300	620
Methanol	g/m^3	<2	<20
Methane	g/m^3	<0.002	0.52
Magnesium	g/m^3	8	11
Dissolved manganese	g/m^3	<0.005	3.8
Sodium	g/m^3	530	1220
Nickel	mg/kg	<0.03	0.04
Nitrate + nitrite nitrogen	g/m^3 N	0.39	<0.2
Nitrite	g/m^3 N	0.066	<0.2
Nitrate	g/m^3 N	0.33	<0.2
pH	pH	9.3	6.9
Propylene glycol	g/m^3	<4	<4
Dissolved sulphur	g/m^3	37	85
Sulphate	g/m^3	112	250
Total dissolved solids	g/m^3	8700	8000
Toluene	g/m^3	0.0036	14.5
o-Xylene	g/m^3	0.0013	4.1
m-Xylene	g/m^3	0.002	12.8
Dissolved zinc	g/m^3	0.07	0.56

Table 7 shows the return fluid analysis from Ohanga-1. 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 for Ohanga-1

Parameter	Unit	Ohanga-1
Sample Date	-	25 March 2015
Lab number	-	TRC152892
Total alkalinity	g/m^3 CaCO3	1190
Barium	mg/kg	7.6
Benzene	g/m^3	2.4
Total bromine	g/m^3	22
Calcium	g/m^3	1,980
Chloride	g/m^3	7,600
Electrical conductivity	mS/m@20^{o}C	2,430
Total copper	g/m^3	0.0156
Ethylbenzene	g/m^3	0.80
Ethane	g/m^3	-
Ethylene	g/m^3	-
Total iron	g/m^3	24
Formaldehyde	g/m^3	0.72
Ethylene glycol	g/m^3	<20
Total hydrocarbons	g/m^3	-
Bicarbonate	g/m^3 HCO3	939
Total hardness	g/m^3 CaCO3	5,200
Total mercury	g/m^3	<0.011
Potassium	g/m^3	980
Methanol	g/m^3	<20
Methane	g/m^3	-
Magnesium	g/m^3	63
Total manganese	g/m^3	4.3
Sodium	g/m^3	2,800
Nickel	mg/kg	0.03
Nitrate + nitrite nitrogen	g/m^3 N	<0.02
Nitrite	g/m^3 N	<0.02
Nitrate	g/m^3 N	<0.02
pH	pH	7.1
Propylene glycol	g/m^3	34
Total sulphur	g/m^3	33
Sulphate	g/m^3	99
Total dissolved solids	g/m^3	17,900
Toluene	g/m^3	3.5
o-Xylene	g/m^3	2.1

Parameter	Unit	Ohanga-1
m-Xylene	g/m^3	4.2
Total zinc	g/m^3	0.049

2.3 Biomonitoring survey

The Council's 'vegetation-sweep' technique and a combination of 'vegetation sweep' and 'kick-sampling' sampling techniques were used to collect streambed macroinvertebrates from the unnamed tributary of the Onaero River in relation to fracturing at the Ohanga-A 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. Post-fracturing surveys were carried out in April 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.

MCI scores did not significantly change between the pre-fracturing and post-fracturing surveys. There were some insignificant changes (Stark, 1998) but again there was no pattern evident with the 'primary impacted' site showing a decrease in MCI score but the 'secondary impacted' site showing an increase in MCI score. There was a significant decrease in $SQMCI_S$ scores (Stark, 1998) at all three sites between the pre-fracturing survey and post-fracturing survey which can be attributed to an increase in the number of very 'tolerant' oligochaete worms and ostracod seed shrimps at all three sites. These increases in abundance were probably due to the long period of relatively fine weather with very low flows and no flushing flows (the post-fracturing survey had 112 days without a 7 x median fresh) experienced prior to the post-fracturing survey as oligochaete worms and ostracod seed shrimp are typically found in high abundances in very slow flowing waterways with silt substrates and organic enrichment.

There was no evidence that wellsite discharges had had significant impacts 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.

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 a selected site on the Ohanga-A 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 Ohanga-2St2 and Ohanga-1 wells 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 and carbon isotope analysis indicates that the methane was biogenic in origin. Apart from trace levels of formaldehyde, no traces of substances associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities were present in the groundwater during the post-fracturing sampling event.

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 GPL's compliance record for the year under review is set out in Table 8.

Table 8 Summary of performance for consent 10053-1

Purpose: *To discharge water based hydraulic fracturing fluids into land at depths greater than 2,700 m TVD beneath the Ohanga-A wellsite*		
Condition requirement	Means of monitoring during period under review	Compliance achieved?
1. Any discharge shall occur below 2,700 mTVD	Assessment of consent holder submitted data	Yes
2. No discharge shall occur after 1 June 2022	Assessment of consent holder submitted data	N/A*
3. Exercise of consent shall not result in any contaminants reaching any useable freshwater aquifers	Results of groundwater monitoring	Yes
4. Consent holder shall undertake sampling programme	Development and certification of a monitoring programme	Yes
5. If no suitable well exists within 500 m of the wellsite, a monitoring well will have to be installed	Assessment of borehole log received	Yes
6. All sampling to be taken in accordance with recognised field procedures and analysed for a specific range of parameters	Assessment of sampling 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. Consent holder shall undertake well and equipment pressure testing prior to hydraulic fracturing	Assessment of post-hydraulic fracturing report	Yes
9. A pre-fracturing discharge report is to be provided to the Council 10 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 90 working days after the discharge commences	Post-fracturing discharge report received	Yes
12. More than one post-fracturing discharge report may be necessary if multiple discharges occur that can't meet the 90 day deadline	Post-fracturing discharge report received	Yes
13. The reports outlined in conditions 9 and 11 must be emailed to consents@trc.govt.nz	Reports received via email	Yes

14. 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
15. Consent holder to adopt best practicable option at all times	Site inspections, sampling and assessment of consent holder submitted data	Yes
16. No hydrocarbon based hydraulic fracturing fluid shall be discharged	Assessment of consent holder submitted data and sampling of fracturing fluid	Yes
17. Lapse clause	Receive notice of exercise of consent	Yes
18. 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

N/A = not applicable

During the year, GPL demonstrated both a high level of environmental and administrative performance with the resource consents 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 the 2015-2016 monitoring year a one year post fracturing groundwater sampling round be carried out. After that, it is recommended that no further monitoring be carried out in relation to the hydraulic fracturing events at the Ohanga-A wellsite. Monitoring should recommence if any further fracturing is undertaken at the site.

3.4 Exercise of optional review of consent

Resource consent 10053-1 provides for an optional review of the consent in June annually. Condition 18 allows the Council to review the consent, if there are grounds that.

Based on the results of monitoring in the year under review, and in previous years as set out in earlier annual compliance monitoring reports, 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 for the forthcoming 2015/2016 monitoring period, a one-year-post-fracturing groundwater sampling round is carried out. After that, it is recommended that no further monitoring be carried out in relation to the hydraulic fracturing events at the Ohanga-A wellsite. Monitoring should recommence, however, if any further fracturing is undertaken at the site.

2. THAT the option for a review of resource consent(s) in June 2016, as set out in condition 18 of consent 10053-1, 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 be 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

GPL Petroleum Limited (2015) Technical Proposal – Ohanga 2ST2

GPL Petroleum Limited (2015) Ohanga-1 Post-Fracturing Discharge Report

GPL Petroleum Limited (2015) Ohanga 2St2 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 (2014) Biomonitoring of an unnamed tributary of the Onaero River in relation to drilling and hydraulic fracturing by Greymouth Petroleum at the Ohanga-A wellsite, January and April 2015. Report DS009.

Taranaki Regional Council (2015) Greymouth Petroleum Limited Hydraulic Fracturing – Ohanga-A Wellsite Water Quality Monitoring Programme

Appendix I

Resource consent held by Greymouth Petroleum Limited

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 PO Box 3394 New Plymouth 4341
Decision Date:	21 January 2015
Commencement Date:	21 January 2015

Conditions of Consent

Consent Granted:	To discharge water based hydraulic fracturing fluids into land at depths greater than 2,700 mTVD beneath the Ohanga-A wellsite
Expiry Date:	1 June 2027
Review Date(s):	June annually
Site Location:	Ohanga-A wellsite, 324 Ohanga Road, Urenui (Property owner: PW & HL Blakelock)
Legal Description:	Secs 110 & 122 Blk VII Waitara SD (Discharge source & site)
Grid Reference (NZTM)	1717052E-5679360N
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 2,700 mTVD.

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

2. There shall be no discharge of hydraulic fracturing fluids after 1 June 2022.

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 1,000 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, at least one monitoring bore. The bore(s) 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 ($^{13}C\text{-}CH_4$).

   Note: The samples required, under conditions 4 and 6 could be taken and analysed by the Taranaki Regional 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. The 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 monitoring techniques to be used to determine the fate of discharged material;
   (e) the results of the reviews required by condition 15;
   (f) results of modelling showing an assessment of the likely extent and dimensions of the fractures that will be generated by the discharge;
   (g) the preventative and mitigation measures to be in place to ensure the discharge does not cause adverse environmental effects and complies with condition 3;
   (h) the extent and permeability characteristics of the geology above the discharge point to the surface;
   (i) any identified faults within the modelled fracture length plus a margin of 50%, and the potential for adverse environmental effects due to the presence of the identified faults;
   (j) the burst pressure of the well casing and the anticipated maximum well and discharge pressures and the duration of the pressures; and
   (k) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal; and
   (l) details why the contaminants in the discharge and the monitoring techniques used comply with condition 15.

   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 the date that each discharge is intended to commence by emailing worknotification@trc.govt.nz. Notification also shall identify the 'Pre-fracturing Discharge Report', required by condition 9, which details the discharge and be given no less than 3 days before the intended discharge date. If any discharge occurs more than 30 days after the notification date, additional notification as specified in this condition is required.

11. Subject to condition 12, within 90 days of any commencement date as advised under condition 10, the consent holder shall submit a comprehensive 'Post-fracturing Discharge Report' to the Chief Executive. The report shall, as a minimum, contain:

    (a) date and time of discharge;
    (b) 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;
    (c) the contaminant volumes and composition of fluid discharged into each fracture interval;
    (d) the volume of return fluids from each fracture interval;
    (e) 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;
    (f) an estimate of the volume of fluids (and proppant) remaining underground;
    (g) the volume of water produced with the hydrocarbons (produced water) over the period beginning at the start of the hydraulic fracturing programme and ending 30 days after the programme is completed or after that period of production;
    (h) 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;
    (i) 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;
    (j) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal;
    (k) 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
    (l) results of the monitoring referred to in condition 9(d);
    (m) an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.

12. For programs including multiple hydraulic fracturing discharges, more than one 'Post-fracturing Discharge Report' may be required in order to meet the specified 90 day deadline from each commencement date. In these situations the consent holder shall submit a subsequent 'Post-fracturing Discharge Report' to the Chief Executive within 90 days of the previous report submitted.

13. 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.

14. 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.

15. 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 of monitoring techniques used to ensure the discharge does not cause adverse environmental effects are undertaken;
    (c) regular reviews are undertaken of the preventative and mitigation measures adopted to ensure the discharge does not cause adverse environmental effects; and
    (d) regular reviews of the chemicals used are undertaken with a view to reducing the toxicity of the chemicals used.

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

17. This consent shall lapse on 1 June 2022, unless the consent is given effect to before the end of that period or the Taranaki Regional Council fixes a longer period pursuant to section 125(1)(b) of the Resource Management Act 1991.

18. 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 15; 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 21 January 2015

For and on behalf of
Taranaki Regional Council

A D McLay
Director - Resource Management

Appendix II Groundwater certificates of analysis

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:**	1441187 SPv1
Contact:	Regan Phipps	**Date Registered:**	20-Jun-2015
	C/- Taranaki Regional Council	**Date Reported:**	29-Jun-2015
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	Ohanga A 3 month Post HF
		Submitted By:	Regan Phipps

Sample Type: Aqueous

	Sample Name:	GND 2487 19-Jun-2015 9:24 am				
	Lab Number:	1441187.1				
Individual Tests						
Sum of Anions	meq/L	4.6	-	-	-	-
Sum of Cations	meq/L	4.9	-	-	-	-
pH	pH Units	7.0	-	-	-	-
Total Alkalinity	g/m^3 as CaCO$_3$	210	-	-	-	-
Bicarbonate	g/m^3 at 25°C	260	-	-	-	-
Total Hardness	g/m^3 as CaCO$_3$	185	-	-	-	-
Electrical Conductivity (EC)	mS/m	43.0	-	-	-	-
Total Dissolved Solids (TDS)	g/m^3	280	-	-	-	-
Dissolved Barium	g/m^3	0.0187	-	-	-	-
Dissolved Bromine*	g/m^3	0.060	-	-	-	-
Dissolved Calcium	g/m^3	46	-	-	-	-
Dissolved Copper	g/m^3	< 0.0010	-	-	-	-
Dissolved Iron	g/m^3	11.1	-	-	-	-
Dissolved Magnesium	g/m^3	17.0	-	-	-	-
Dissolved Manganese	g/m^3	0.38	-	-	-	-
Dissolved Mercury	g/m^3	< 0.00008	-	-	-	-
Dissolved Nickel	g/m^3	< 0.0005	-	-	-	-
Dissolved Potassium	g/m^3	5.3	-	-	-	-
Dissolved Sodium	g/m^3	15.1	-	-	-	-
Dissolved Zinc	g/m^3	0.0050	-	-	-	-
Chloride	g/m^3	14.1	-	-	-	-
Nitrite-N	g/m^3	< 0.002	-	-	-	-
Nitrate-N	g/m^3	< 0.002	-	-	-	-
Nitrate-N + Nitrite-N	g/m^3	< 0.002	-	-	-	-
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	0.0058	-	-	-	-
Toluene	g/m^3	0.0046	-	-	-	-
Ethylbenzene	g/m^3	< 0.0010	-	-	-	-
m&p-Xylene	g/m^3	< 0.002	-	-	-	-

ilac-MRA IANZ ACCREDITED LABORATORY

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:		GND 2487 19-Jun-2015 9:24 am				
Lab Number:		1441187.1				
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	22	-	-	-	-
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 (modified).	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 (modified).	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

Hill Laboratories
BETTER TESTING **BETTER RESULTS**

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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1378366 SPv1
Contact:	Regan Phipps	**Date Registered:**	29-Jan-2015
	C/- Taranaki Regional Council	**Date Reported:**	11-Feb-2015
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	Ohange A - Pre HF GW
		Submitted By:	R McDonnell

Sample Type: Aqueous

Sample Name:		GND2487 28-Jan-2015 9:39 am				
Lab Number:		1378366.1				
Individual Tests						
Sum of Anions	meq/L	4.8	-	-	-	-
Sum of Cations	meq/L	4.7	-	-	-	-
pH	pH Units	7.1	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	220	-	-	-	-
Bicarbonate	g/m³ at 25°C	260	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	191	-	-	-	-
Electrical Conductivity (EC)	mS/m	44.1	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	260	-	-	-	-
Dissolved Barium	g/m³	0.0170	-	-	-	-
Dissolved Bromine*	g/m³	0.060	-	-	-	-
Dissolved Calcium	g/m³	45	-	-	-	-
Dissolved Copper	g/m³	0.0012	-	-	-	-
Dissolved Iron	g/m³	1.70	-	-	-	-
Dissolved Magnesium	g/m³	19.0	-	-	-	-
Dissolved Manganese	g/m³	0.29	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	0.0013	-	-	-	-
Dissolved Potassium	g/m³	5.6	-	-	-	-
Dissolved Sodium	g/m³	16.2	-	-	-	-
Dissolved Zinc	g/m³	0.0088	-	-	-	-
Chloride	g/m³	14.8	-	-	-	-
Nitrite-N	g/m³	0.005	-	-	-	-
Nitrate-N	g/m³	< 0.002	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	0.005	-	-	-	-
Sulphate	g/m³	3.2	-	-	-	-
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	< 0.0010	-	-	-	-
Toluene	g/m³	< 0.0010	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-

Sample Type: Aqueous

Sample Name:		GND2487 28-Jan-2015 9:39 am				
Lab Number:		1378366.1				
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	20	-	-	-	-
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 III Hydraulic fracturing and return fluid certificates of analysis

Hill Laboratories
BETTER TESTING **BETTER RESULTS**

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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1392622 SPv1
Contact:	Regan Phipps	**Date Registered:**	04-Mar-2015
	C/- Taranaki Regional Council	**Date Reported:**	20-Mar-2015
	Private Bag 713	**Quote No:**	49265
	STRATFORD 4352	**Order No:**	
		Client Reference:	Ohanga A Return Fluid
		Submitted By:	Regan Phipps

Sample Type: Saline

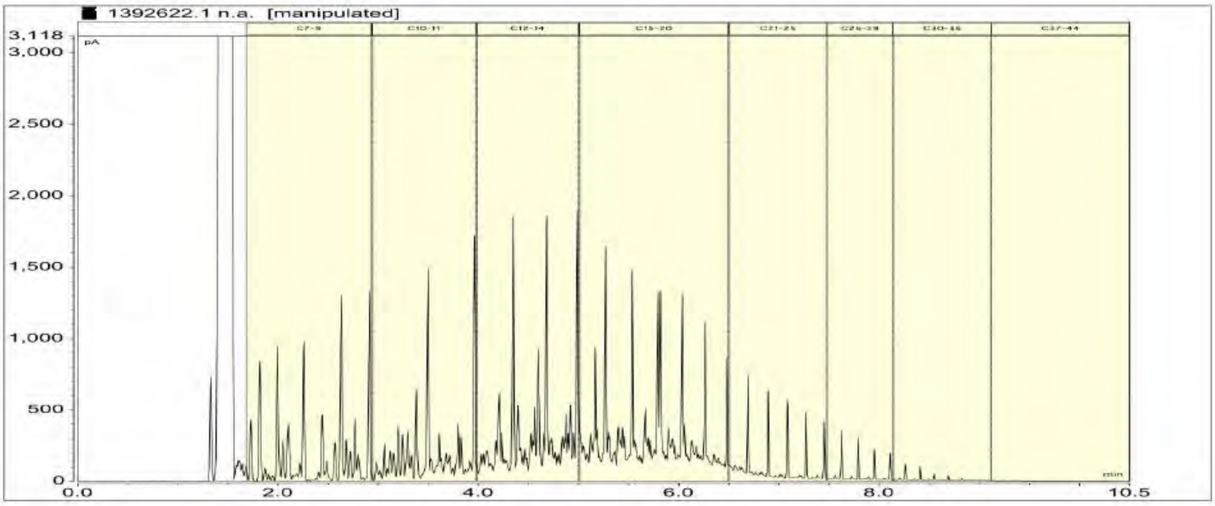
Sample Name:		GND1490 03-Feb-2015 5:30 pm				
Lab Number:		1392622.1				
Individual Tests						
pH*	pH Units	6.9	-	-	-	-
Total Alkalinity*	g/m^3 as $CaCO_3$	1,830	-	-	-	-
Analysis Temperature for Bicarbonate	°C	23	-	-	-	-
Bicarbonate	g/m^3 at Analysis Temperature	1,873	-	-	-	-
Total Hardness*	g/m^3 as $CaCO_3$	210	-	-	-	-
Electrical Conductivity (EC)*	mS/m	788	-	-	-	-
Total Dissolved Solids (TDS)*	g/m^3	8,000	-	-	-	-
Dissolved Barium*	g/m^3	0.57	-	-	-	-
Dissolved Bromine*	g/m^3	6.4	-	-	-	-
Dissolved Calcium*	g/m^3	65	-	-	-	-
Dissolved Copper*	g/m^3	0.020	-	-	-	-
Dissolved Iron*	g/m^3	5.5	-	-	-	-
Dissolved Magnesium*	g/m^3	11	-	-	-	-
Dissolved Manganese*	g/m^3	3.8	-	-	-	-
Total Mercury*	g/m^3	< 0.011	-	-	-	-
Dissolved Nickel*	g/m^3	0.04	-	-	-	-
Dissolved Potassium*	g/m^3	620	-	-	-	-
Dissolved Sodium*	g/m^3	1,220	-	-	-	-
Dissolved Sulphur*	g/m^3	85	-	-	-	-
Dissolved Zinc*	g/m^3	0.56	-	-	-	-
Chloride*	g/m^3	1,100	-	-	-	-
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	250	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m^3	41	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m^3	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m^3	< 20	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene*	g/m^3	9.0	-	-	-	-
Toluene*	g/m^3	14.5	-	-	-	-
Ethylbenzene*	g/m^3	2.2	-	-	-	-

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: Saline

Sample Name:		GND1490 03-Feb-2015 5:30 pm				
Lab Number:		1392622.1				
BTEX in Water by Headspace GC-MS						
m&p-Xylene*	g/m³	12.8	-	-	-	-
o-Xylene*	g/m³	4.1	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde*	g/m³	0.21	-	-	-	-
Gases in groundwater						
Ethane*	g/m³	0.20	-	-	-	-
Ethylene*	g/m³	< 0.003	-	-	-	-
Methane*	g/m³	0.52	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9*	g/m³	300	-	-	-	-
C10 - C14*	g/m³	650	-	-	-	-
C15 - C36*	g/m³	710	-	-	-	-
Total hydrocarbons (C7 - C36)*	g/m³	1,660	-	-	-	-

1392622.1
GND1490 03-Feb-2015 5:30 pm
Client Chromatogram for TPH by FID



Analyst's Comments

Due to the type of matrix found in sample 1392622.1, a dilution was required for the Methanol analysis. Hence the higher detection limit reported.

#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 / NOxNsal analysis.

Appendix No.1 - Bicarbonate - 1392622.1

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

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
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 Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	1
pH*	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)*	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.	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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Ara Heron BSc (Tech)
Client Services Manager - Environmental Division

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TE PŪ AO
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Private Bag 2000, Taupo
Phone: (07) 374 8211
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Email: w.labmanager@gns.cri.nz

CERTIFICATE OF ANALYSIS
SALINE FOR BICARBONATE ANALYSES

Report No: 2015030603

Customer Ref:142696

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

GNS Lot No: **2015030603**

GNS Sample No.	2015001142
Collection Date.	3/02/2015
Site ID:	1392622/1
Field ID	

pH		6.85	-	-	-
Bicarbonate (Total)	mg/l	1873	-	-	-
HCO_3 Analysis Temperature	ºC	23	-	-	-
HCO_3 Analysis Date		06/03/2015	-	-	-

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_3 Titration 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

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ANALYSIS REPORT

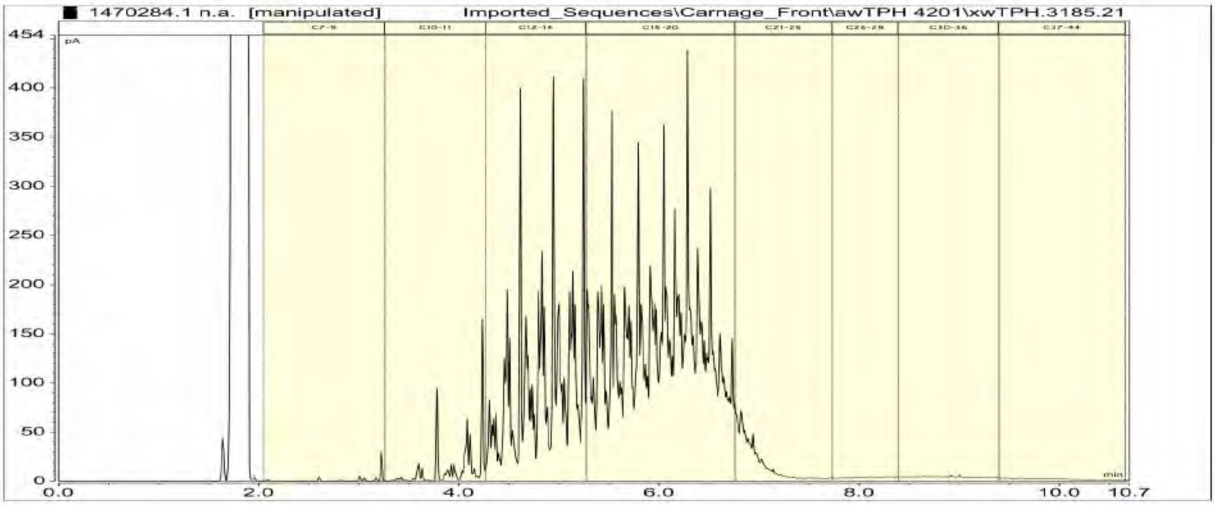
Client: Taranaki Regional Council
Contact: Regan Phipps
C/- Taranaki Regional Council
Private Bag 713
STRATFORD 4352

Lab No: 1470284 SPv1
Date Registered: 02-Sep-2015
Date Reported: 17-Sep-2015
Quote No: 50522
Order No:
Client Reference: Ohanga A - HF Fluid
Submitted By: Regan Phipps

Sample Type: Aqueous

Sample Name:		GND1489 25-Mar-2015 12:00 pm				
Lab Number:		1470284.1				
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	40	-	-	-	-
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	< 0.010	-	-	-	-
Toluene	g/m³	< 0.010	-	-	-	-
Ethylbenzene	g/m³	0.012	-	-	-	-
m&p-Xylene	g/m³	< 0.02	-	-	-	-
o-Xylene	g/m³	< 0.010	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	2.7	-	-	-	-
C10 - C14	g/m³	230	-	-	-	-
C15 - C36	g/m³	460	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	700	-	-	-	-

1470284.1
GND1489 25-Mar-2015 12:00 pm
Client Chromatogram for TPH by FID



Analyst's Comments

The sample was received in a plastic bottle that wasn't completely filled. Please note that glass bottles should be used (and completely filled) for hydrocarbon analysis to avoid loss of volatile compounds and possible plastic contamination.

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

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ANALYSIS REPORT

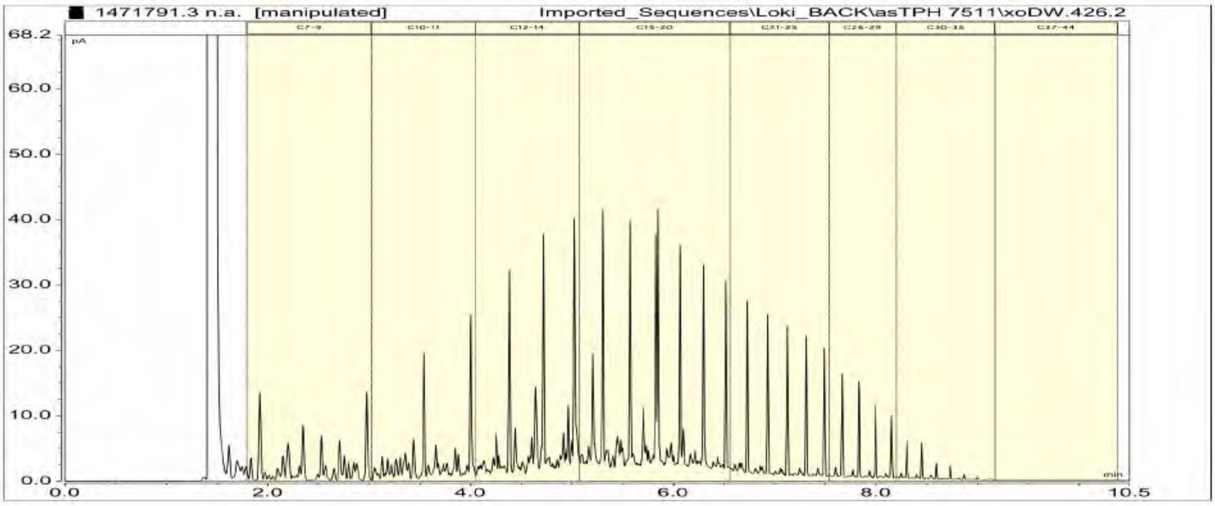
Client:	Taranaki Regional Council	**Lab No:**	1471791 SPv1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 STRATFORD 4352	**Date Registered:**	04-Sep-2015
		Date Reported:	16-Sep-2015
		Quote No:	71307
		Order No:	
		Client Reference:	Ohanga A - Return Fluid
		Submitted By:	R McDonnell

Sample Type: Saline

	Sample Name:	Composite of GND1489 1/2 & GND1489 2/2				
	Lab Number:	1471791.3				
Individual Tests						
pH*	pH Units	7.1	-	-	-	-
Total Alkalinity*	g/m^3 as $CaCO_3$	1,190	-	-	-	-
Analysis Temperature for Bicarbonate	°C	24	-	-	-	-
Bicarbonate	g/m^3 at Analysis Temperature	939	-	-	-	-
Total Hardness*	g/m^3 as $CaCO_3$	5,200	-	-	-	-
Electrical Conductivity (EC)*	mS/m	2,430	-	-	-	-
Total Dissolved Solids (TDS)*	g/m^3	17,900	-	-	-	-
Total Barium*	g/m^3	7.6	-	-	-	-
Total Bromine*	g/m^3	22	-	-	-	-
Total Calcium*	g/m^3	1,980	-	-	-	-
Total Copper*	g/m^3	0.0156	-	-	-	-
Total Iron*	g/m^3	24	-	-	-	-
Total Magnesium*	g/m^3	63	-	-	-	-
Total Manganese*	g/m^3	4.3	-	-	-	-
Total Mercury*	g/m^3	< 0.011	-	-	-	-
Total Nickel*	g/m^3	0.03	-	-	-	-
Total Potassium*	g/m^3	980	-	-	-	-
Total Sodium*	g/m^3	2,800	-	-	-	-
Total Sulphur*	g/m^3	33	-	-	-	-
Total Zinc*	g/m^3	0.049	-	-	-	-
Chloride*	g/m^3	7,600	-	-	-	-
Nitrite-N	g/m^3	< 0.02 [#1]	-	-	-	-
Nitrate-N	g/m^3	< 0.02	-	-	-	-
Nitrate*	g/m^3	< 0.09	-	-	-	-
Nitrate-N + Nitrite-N	g/m^3	< 0.02 [#1]	-	-	-	-
Sulphate*	g/m^3	99	-	-	-	-
Free Product GC Scan by FID						
Free Product*	mL/100mL	2.3	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m^3	< 20	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m^3	34	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m^3	< 20	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene*	g/m^3	2.4	-	-	-	-

Sample Type: Saline						
Sample Name:		Composite of GND1489 1/2 & GND1489 2/2				
Lab Number:		1471791.3				
BTEX in Water by Headspace GC-MS						
Toluene*	g/m³	3.5	-	-	-	-
Ethylbenzene*	g/m³	0.80	-	-	-	-
m&p-Xylene*	g/m³	4.2	-	-	-	-
o-Xylene*	g/m³	2.1	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde*	g/m³	0.72	-	-	-	-

1471791.3
Composite of GND1489 1/2 & GND1489 2/2
Client Chromatogram for GC Scan



Analyst's Comments

The sample was received in a plastic bottle that wasn't completely filled. Please note that glass bottles should be used (and completely filled) for hydrocarbon analysis to avoid loss of volatile compounds and possible plastic contamination.

Due to the type of matrix found in sample 1471791.3, a dilution was required for the Methanol and Glycol analysis. Hence the higher detection limits reported.

#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.

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
Client Chromatogram for GC Scan*	.	-	3
Free Product GC Scan by FID*	Dilution of free product in organic solvent	1.0 mL/100mL	3
Volume of Free Product present in TPH Water samples*	Volumes estimated using Measuring Cylinder.	1.0 mL/100mL	3
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	3
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	3
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	3
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	3
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	3
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	3
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	3

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Total Digestion*	Boiling nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	3
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	3
pH*	Saline water, pH meter. APHA 4500-H^+ B 22nd ed. 2012. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field.	0.1 pH Units	3
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m^3 as $CaCO_3$	3
Analysis Temperature for Bicarbonate	Temperature at which Bicarbonate titration was conducted as reported by Geological & Nuclear Sciences, Wairakei.	1.0 °C	3
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	3
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m^3 as $CaCO_3$	3
Electrical Conductivity (EC)*	Saline water, Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.10 mS/m	3
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	3
Total Barium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.00063 g/m^3	3
Total Bromine*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.11 g/m^3	3
Total Calcium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.1 g/m^3	3
Total Copper*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m^3	3
Total Iron*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0042 g/m^3	3
Total Magnesium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.42 g/m^3	3
Total Manganese*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m^3	3
Total Mercury*	Nitric acid digestion, ICP-MS, screen level. APHA 3125 B 22nd ed. 2012.	0.0021 g/m^3	3
Total Nickel*	Nitric acid digestion, ICP-MS with universal cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0011 g/m^3	3
Total Potassium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.1 g/m^3	3
Total Sodium*	Nitric acid digestion, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.42 g/m^3	3
Total Sulphur*	Nitric acid digestion, ICP-OES (method may not fully account for H_2S due to volatilisation during digestion). All forms of oxidised and organic sulphur will be determined by this method.	0.5 g/m^3	3
Total Zinc*	Nitric acid digestion, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0042 g/m^3	3
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	3
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m^3	3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	3
Nitrate*	Calculation from Nitrate-N.	0.010 g/m^3	3
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m^3	3
Total Sulphate*	Calculation: from total sulphur.	2 g/m^3	3

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

Appendix IV

Biomonitoring report

To	Job Manager; Callum MacKenzie
From	Freshwater Biologists; Darin Sutherland
Report No	DS009
Document	1509233
Date	28 May

Biomonitoring of an unnamed tributary of the Onaero River in relation to drilling and hydraulic fracturing by Greymouth Petroleum at the Ohanga-A wellsite, January and April 2015

Introduction

Macroinvertebrate surveys were performed at the Ohanga-A wellsite to determine whether hydraulic fracturing ('fracking') 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 onto land near an unnamed tributary of the Onaero River (Figure 1). There was no pre-drill survey and no other surveys were completed prior to drilling (e.g. for a previous drilling operation) making temporal assessments of the impact of drilling difficult.

Methods

The post-drill survey was undertaken on 21 January 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 subsequent post-frac survey was completed at the same three sites on 1 April 2015. The altitude of the three sites was approximately 60 m asl.

Two different sampling techniques were used to collect streambed macroinvertebrates in the unnamed tributary of the Onaero River, downstream of the various discharges from the Ohanga-A wellsite. The Council's standard 'vegetation sweep' technique was used at all sites for both surveys except for site 1 for the post-drill survey where a combination of the 'kick-sampling' and 'vegetation sweep' sampling techniques was used (Table 1, Figure 1). The 'kick-sampling' and 'vegetation sweep' techniques are very similar to Protocol C1 (hard-bottomed, semi-quantitative) and 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 Ohanga-A wellsite.

Site No.	Site code	Grid reference (NZTM)	Location	Sampling method	
				Post-drill	Post-frac
1	ONR000390	1717211E-5679529N	5 m upstream of the discharge tributary confluence	Kick-sweep	Vegetation sweep
2	ONR000394	1717266E-5679610N	145m downstream of the discharge tributary confluence	Vegetation sweep	Vegetation sweep
3	ONR000396	1717307E-5679665N	260m downstream of the discharge tributary confluence	Vegetation sweep	Vegetation sweep

Figure 1 Biomonitoring sites in an unnamed tributary of the Onaero River in relation to the Ohanga-A 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 warm (range 24.3-27.0 °C) but were substantially cooler during the post-frac survey (15.3-16.6 °C). Water levels were either low or very low and water speed was either slow or very slow. Water was uncoloured and clear apart from site 2 during the post frac survey when the water was grey and cloudy (Table 2). Substrate compositions during the post-drill and post-frac surveys for all three sites were either completely or nearly completely comprised of silt (Table 2).

No algal mats were present but filamentous algae were widespread at all sites during both surveys. Moss, leaves and wood were absent from all sites during both surveys except for site 1 during the post-drill survey which had patchy leaves present. Sites 1 and 3 had partial shading from overhanging vegetation during the post-drill survey while site 2 did not have any overhanging vegetation or shading and no sites had shading recorded during the post-frac survey.

Table 2 Summary of time of sampling and some water variables collected at each site.

	Time (NZST)		Temperature (°C)		Water Colour		Water Clarity		Flow Conditions		Water Speed	
	Post-drill	Post-frac	Post-drill	Post-frac	Post-drill	Post-frac	Post-drill	Post-frac	Post-drill	Post-frac	Post-drill	Post-frac
ONR000390	1415	1125	26.0	16.6	Uncoloured	Uncoloured	Clear	Clear	V. low	V. low	V. slow	Slow
ONR000394	1345	1105	26.0	15.3	Uncoloured	Grey	Clear	Cloudy	Low	V. low	Slow	Slow
ONR000396	1315	1045	24.3	15.8	Uncoloured	Uncoloured	Clear	Clear	Low	V. low	Slow	Slow

Macroinvertebrate communities

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

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

	No. of taxa	MCI value	SQMCI$_s$ value
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 Ohanga-A wellsite surveys of 26 January 2015 (post-drill) and 1 April, 2015 (post-frac).

Taxa List	Survey	MCI score	Post-drill			Post-frac		
	Site Code		ONR000390	ONR000394	ONR000396	ONR000390	ONR000394	ONR000396
	Site		1	2	3	1	2	3
PLATYHELMINTHES (FLATWORMS)	*Cura*	3	-	R	-	R	-	-
ANNELIDA (WORMS)	Oligochaeta	1	VA	R	C	VA	XA	A
HIRUDINEA (LEECHES)	Hirudinea	3	-	-	-	R	R	C
MOLLUSCA	Lymnaeidae	3	-	R	-	C	R	R
	Physa	3	-	C	R	R	-	C
	Potamopyrgus	4	VA	R	C	VA	R	VA
	Sphaeriidae	3	C	-	R	C	-	-
CRUSTACEA	Cladocera	5	-	R	-	-	-	-
	Ostracoda	1	A	VA	VA	VA	XA	XA
	Paracalliope	5	XA	XA	VA	VA	C	VA
	Paranephrops	5	-	-	-	R	-	R
EPHEMEROPTERA (MAYFLIES)	*Zephlebia group*	7	R	-	-	-	-	-
ODONATA (DRAGONFLIES)	*Xanthocnemis*	4	-	R	-	C	-	A
HEMIPTERA (BUGS)	*Anisops*	5	-	-	-	-	-	R
	Microvelia	3	-	R	R	-	-	-
	Sigara	3	-	C	C	-	-	VA
COLEOPTERA (BEETLES)	Dytiscidae	5	-	C	-	-	-	-
	Hydrophilidae	5	-	-	-	R	R	-
TRICHOPTERA (CADDISFLIES)	*Hydrobiosis*	5	R	-	-	-	-	-
	Psilochorema	6	R	-	-	-	-	-
	Oxyethira	2	R	R	R	C	-	A
	Paroxyethira	2	-	-	-	-	-	VA
	Triplectides	5	R	C	-	C	-	R
DIPTERA (TRUE FLIES)	*Zelandotipula*	6	R	-	-	-	-	-
	Corynoneura	3	-	R	-	-	-	-
	Orthocladiinae	2	R	R	R	-	R	C
	Polypedilum	3	C	R	-	-	-	-
	Tanypodinae	5	R	-	-	R	-	-
	Tanytarsini	3	-	R	-	-	-	-
	Paradixa	4	R	C	-	-	-	-
	Austrosimulium	3	-	R	-	-	-	-
No of taxa			15	20	10	15	8	15
MCI			79	65	54	69	60	64
SQMCIs			4.2	4.3	3.0	2.8	1.0	2.1
EPT (taxa)			4	1	0	1	0	1
%EPT (taxa)			27	5	0	7	0	7
'Tolerant' taxa	'Moderately sensitive' taxa	'Highly sensitive' taxa						

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

Site 1: 5 m upstream of the discharge tributary confluence

Moderately low macroinvertebrate community richnesses of 15 taxa were found at site 1 ('control' site) at the time of the post-drill and post-frac survey. Site 1 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 79 units indicated a community of 'poor' biological health. At the time of the post-frac survey the MCI score had decreased to 69 units which also indicated a community of 'poor' biological health. The post-drill and post-frac survey MCI scores were not significantly different (Stark, 1998) to the median MCI score calculated from 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 4.2 units was significantly higher than the post-frac score of 2.8 units and not significantly different (Stark, 1998) 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 and post-frac survey communities were characterised by three 'tolerant' taxa [oligochaete worms, snails (*Potamopygus*), and ostracod seed shrimps] and one 'moderate sensitively' taxon [amphipods (*Paracalliope*)] (Table 4).

Site 2: 145m downstream of the discharge tributary confluence

A moderate macroinvertebrate community richness of 20 taxa was found at site 2 ('primary impacted' site) at the time of the post-drill survey which was identical to the median value calculated from similar streams in the Taranaki region within the same altitudinal band (median taxa richness of 20 taxa; Table 3). A low taxa richness of only eight taxa was found at the time of the post-frac survey which was substantially lower than the median taxa richness 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 65 units indicated a community of 'poor' biological health. At the time of the post-frac survey the MCI score had decreased to 60 units which also indicated a community of 'poor' biological health. The post-drill and post-frac survey MCI scores were significantly lower (Stark, 1998) than the median MCI score calculated from 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 4.3 units was significantly higher than the post-frac score of 1.0 units and not significantly different (Stark, 1998) to the median value calculated from similar streams in the Taranaki region within the same altitudinal band (median $SQMCI_S$ score of 4.0 units; Table 3).

The post-drill community was characterised by one 'tolerant' taxon, (ostracod seed shrimps) and one 'moderately sensitive' taxon [amphipods (*Paracalliope*)]. The post-frac community was characterised by two 'tolerant' taxa, (oligochaete worms and ostracod seed shrimps; Table 4).

Site 3: 260m downstream of the discharge tributary confluence

A low macroinvertebrate community richness of 10 taxa was found at site 3 ('secondary impacted' site) at the time of the post-drill survey and a moderately low taxa richness of 15 taxa was found at the time of the post-frac survey. Site 3 also had a lower taxa richness than the median value calculated from 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 54 units indicated a community of 'very poor' biological health. At the time of the post-frac survey the MCI score had increased to 64 units which indicated a community of ‘poor’ biological health. The post-drill and post-frac survey MCI scores were significantly lower (Stark, 11998) than the median MCI score calculated from 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 3.0 units was significantly higher than the post-frac score of 2.1 units and both surveys were significantly lower (Stark, 1998) than the median value calculated from 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 community was characterised by one ‘tolerant’ taxon (ostracod seed shrimps) and one moderate taxon [amphipods (*Paracalliope*)]. The post-frac survey community was characterised by six ‘tolerant’ taxa, [oligochaete worms, snails (*Potamopygus*), true bug (*Sigara*), algal piercing caddisflies (*Oxyethira* and *Paroxyethira*), and ostracod seed shrimps] and one ‘moderately sensitive’ taxon [amphipods (*Paracalliope*)] (Table 4).

Discussion and Conclusions

The Council’s ‘vegetation sweep’ technique and a combination of ‘vegetation sweep’ and ‘kick-sampling’ techniques were used at three sites to collect streambed macroinvertebrates from an unnamed tributary of the Onaero River post drilling and post fracking at the Ohanga-A wellsite. This has provided data to assess impacts of skimmer pit discharge effects from the Ohanga-A 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 January 2015 post-drill survey and the April 2015 post-frac survey of three sites, upstream and downstream of the skimmer pit discharge point to an unnamed tributary of the Onaero River, were undertaken because of drilling and hydraulic fracturing at the Ohanga-A wellsite. Taxa richnesses at all three sites were generally lower than what was found at similar sites at the same altitudinal band and there was no obvious pattern between the post-drill and post-frac taxa richnesses. The ‘control’ site taxa richness remained constant, the ‘primary impacted’ site had a substantial decline in taxa richness but the ‘secondary impacted’ site had an increase in taxa richness which suggests that changes in taxa number between the post-drill and post-frac surveys were not the result of wellsite discharges and more likely due to temporal changes in combination with habitat variability among sites.

MCI scores did not significantly change between the post-drill and post-frac surveys. There were some insignificant changes (Stark, 1998) but again there was no pattern evident with the ‘primary impacted’ site showing a decrease in MCI score but the ‘secondary impacted’ site showing an increase in MCI score. There was a significant decrease in $SQMCI_S$ scores (Stark, 1998) at all three sites between the post-drill survey and post-frac survey which can be attributed to an increase in the number of very ‘tolerant’ oligochaete worms and ostracod seed shrimps at all three sites. These increases in abundance were probably due to the long period of relatively fine weather with very low flows and no flushing flows (the post-frac survey had

112 days without a 7 x median fresh) experienced prior to the post-frac survey as oligochaete worms and ostracod seed shrimp are typically found in high abundances in very slow flowing waterways with silt substrates and organic enrichment.

There was no evidence that wellsite discharges had had significant impacts on the health of the macroinvertebrate communities in the unnamed tributary of the Onaero River as shown by the post-drill and post-frac surveys.

Summary

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

- Taxa richnesses were generally low at the three sites surveyed and were less than numbers found at other similar sites within the Taranaki Region.

- MCI scores indicated that the macorinvertebrate communities surveyed were mostly of ‘poor’ health and had slightly lower values than those found at similar sites within the Taranaki Region. There were no significant decreases in MCI scores between the post-drill and post-frac surveys.

- There was a significant decrease in SQMCI_S scores at all three sites between the post-drill and post-frac surveys which was probably the caused by a long dry period of low flows and no flushing flows prior to the post-frac survey.

- There was no indication from any of the macroinvertebrate indices examined that Ohanga-A wellsite discharges had any significant impacts on the health of the macroinvertebrate communities present in the unnamed tributary of the Onaero River.

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