Greymouth Petroleum Limited Kowhai-B Hydraulic Fracturing Monitoring Programme Report 2012-2014

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Executive summary

Greymouth Petroleum Limited (GPL) operate the Kowhai-B wellsite, located at 451 Ngatimaru Road, Tikorangi. The wellsite lies within the Waiau catchment and contains a hydrocarbon producing well and associated infrastructure.

GPL hold resource consent 9207-1, authorising the discharge of water based hydraulic fracturing fluids into land at depths greater than 3,000 m TVD beneath the Kowhai-B wellsite. The consent was issued by Taranaki Regional Council (the Council) on 29 March 2012 and contains a total of 14 special conditions which set out the requirements that GPL must satisfy.

The following report for the period July 2012 to June 2014 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 Kowhai-B wellsite. The report also assesses GPL's level of environmental performance and compliance with the resource consent held in relation to the activity.

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

The programme of hydraulic fracturing undertaken by GPL at the Kowhai-B wellsite included the fracturing of one well; Kowhai-2. The hydraulic fracturing of this well took place between March and April 2013.

The programme of monitoring implemented by the Council in relation to this activity spanned the 2012-2013 and 2013-2014 monitoring periods. The programme included the analysis of samples taken from groundwater sites surrounding 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 fracturing were obtained for analysis.

The monitoring programme also incorporated a surface water component, whereby a biomonitoring survey was undertaken in surface water bodies surrounding the wellsite. A baseline survey was not carried out, but a post-fracturing survey was. Based on this, a comparison cannot be made between surface water quality before and after hydraulic fracturing, but the post fracturing sample can provide an insight into general surface water quality in the vicinity of the wellsite.

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 consents, or provisions in regional plans, during the period under review.

GPL demonstrated a high level of environmental and administrative performance and compliance with the resource consent over the reporting period.

For reference, in the 2012-2013 year, 35% 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 59% demonstrated a good level of environmental performance and compliance with their consents. In the 2013-2014 year, 60% of consent holders achieved a high level of environmental performance and compliance with their consents, while another 29% demonstrated a good level of environmental performance and compliance.

This report includes recommendations for the 2014-2015 year.

Note: This report relates specifically to the Council's monitoring of hydraulic fracturing activities at the Kowhai-B wellsite over the 2012-2014 period. A separate report covering the monitoring of all other general wellsite activities will be prepared by the Council in due course.

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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 Kowhai-B wellsite, 451 Ngatimaru Road, Tikorangi over the period July 2012 to June 2014. The wellsite is located in the Waiau 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 Kowhai-B wellsite included the fracturing of one well; Kowhai-2.

The programme of monitoring implemented by the Council in relation to these activities spanned the 2012-2013 and 2013-2014 monitoring periods and included groundwater, surface water and discharge monitoring components. This is the first monitoring report produced by the Council in relation to hydraulic fracturing at the Kowhai-B wellsite.

1.1.2 Structure of this report

Section 1 of this report is a background section. It sets out general information about compliance monitoring under the *Resource Management Act 1991* (RMA) and the Council's obligations and general approach to monitoring sites though annual programmes, the resource consents held by Greymouth for discharges into land associated with hydraulic fracturing in the Waiau catchment, a description of the activities undertaken under these consents, and the nature of the monitoring programme in place for the period under review.

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 2014-2015 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 consent 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 the Company's approach to demonstrating consent compliance in site operations and management including the timely provision of information to Council (such as contingency plans and water take data) in accordance with consent conditions.

Events that were beyond the control of the consent holder and unforeseeable (i.e. 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 compliance

- **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 2012-2013 year, 35% 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 59% demonstrated a good level of environmental performance and compliance with their consents. In the 2013-2014 year, 60% of consent holders achieved a high level of environmental performance and compliance with their consents, while another 29% demonstrated a good level of environmental performance and compliance.

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 Kowhai-B wellsite history

The Kowhai-B wellsite has been in operation since 2012. The area around the wellsite and Ngatimaru Road is rural with low population density. The site lies in an active petroleum exploration area, with the Kowhai-A wellsite, the Turangi-A wellsite, the Turangi production station and the Pohukura production station within a 10 km radius of the site. These operations function alongside pastoral farming and dairy runoff operations in the area.

The Kowhai-2 well was drilled between January and March 2013 and hydraulic fracturing occurred during March and April 2013. Monitoring continued for a year

beyond the end of fracturing activity. The location of the wellsite is illustrated in Figure 1. Well construction schematics for Kowhai-2 are included in Appendix I.

A summary of all hydraulic fracturing activities carried out by GPL at the Kowhai-B wellsite during the period being reported is provided below in Table 1.

Table 1 Summary of hydraulic fracturing activity (2012-2014)

Well	Wellsite	Consent	Date		Injection zone (m TVDss)	Formation
			Start	End		
Kowhai-2	Kowhai-B	9207-1	23/03/13	02/04/13	3,802 to 4,067	Kapuni

Figure 1 Location of Kowhai-B wellsite

1.3 Resource consent

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 **9207-1**, authorising the discharge of contaminants into land at the Kowhai-B wellsite. The consent was issued by the Council on 29 March 2012, under Section 87(e) of the RMA. This is the consent under which Kowhai-2 was fractured. Consent 9207-1 contains a total of 14 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 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 3, 4 and 5 relate to fresh water monitoring requirements, to allow compliance with condition 2 to be assessed.

Condition 6 requires the consent holder to carry out pressure testing of equipment prior to discharging.

Condition 7 requires the consent holder to submit a pre-fracturing discharge report prior to any discharge occurring.

Condition 8 is a notification requirement.

Condition 9 requires the consent holder to submit a post-fracturing discharge report after the completion of the hydraulic fracturing programme for each well.

Condition 10 stipulates how the reports required by conditions 7 and 9 are to be submitted.

Condition 11 requires the consent holder to allow the Council access to a location where samples of hydraulic fracturing and return fluids can be obtained.

Condition 12 requires the consent holder to adopt use best practicable options.

Condition 13 relates to the composition of the fracturing fluid.

Consent 14 is a review provision

1.4 Monitoring programme

1.4.1 Introduction

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

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

The monitoring programme implemented in relation to the hydraulic fracturing of the Kowhai-2 well consisted of four primary components.

1.4.2 Programme liaison and management

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

- ongoing liaison with resource consent holders over consent conditions and their interpretation and application;
- in discussion over monitoring requirements;
- preparation for any consent reviews or renewals;
- 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 consents 9207-1, GPL submitted pre and post-fracturing discharge reports to the Council for the well fractured during the period under review. Pre-fracturing discharge reports provide an outline of the proposed fracturing operations in relation to the well, while post-fracturing reports confirm details of what actually occurred. The specific range of information required in each report is stipulated in the conditions of the resource consent.

1.4.4 Chemical sampling

The primary component of the monitoring programme implemented by the Council was the sampling of existing groundwater supplies in the vicinity of the Kowhai-B wellsite and the analysis of the results.

In order to select suitable sites for sampling, the Council carried out a survey in the vicinity of the wellsite to identify existing groundwater abstractions. The surveys were undertaken within defined 'area of review' which extended 1 km radially from the Kowhai-B wellsite. In total, four existing groundwater sites were identified for inclusion in the monitoring programme, GND2318, GND2319, GND2320 and GND2324. However, during groundwater sampling, GND2320 was found to be dry and therefore it was removed from the monitoring programme. The details of each site are included in Table 2 and their proximity to the wellsite is illustrated in Figures 2.

Table 2 Details of groundwater sites included in the monitoring programme

Monitoring site	Distance from wellsite location (m)	Total depth (m)	Screened interval (m)	Aquifer
GND2318	1,485	NA*	NA*	Volcanics
GND2319	1,241	NA*	NA*	Volcanics
GND2324	1,056	NA*	NA*	Volcanics

* Spring

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

Samples taken from springs were obtained directly from the spring discharge. 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 were carried out to assess whether any stormwater discharges from the Kowhai-B wellsite during the course of fracturing operations had resulted in any detrimental effects upon the biological communities within the receiving waters.

At the time of this Kowhai-2 fracturing event, the Council was only in the process of implementing a standard requirement for biomonitoring of receiving waters as a means of assessing potential impacts on surface water systems. As such, no pre-fracturing biomonitoring survey was undertaken in relation to this fracturing event. A post-fracturing biomonitoring survey was however carried out in December 2013. The survey was carried out in the stream which receives stormwater discharges from the Kowhai-B wellsite. As no pre-fracturing survey was carried out, it cannot be assessed whether stormwater discharges from the site had resulted in any detrimental effects upon the biological communities within the receiving waters. The post-fracturing survey would provide an indication whether water quality in the stream may have been affected by activities at this site.

The details of each biomonitoring site included in the survey are presented in Table 3 and their proximity to the Kowhai-B wellsite is illustrated in Figure 4.

Table 3 Details of biomonitoring sites included in the monitoring programme

Site code	GPS reference (NZTM)	Location	Sampling method used
WAI000060	E 1711185 N 5677828	50m upstream of the stormwater discharge point	Vegetation sweep
WAI000062	E 1711231 N 5677797	50m downstream of the stormwater discharge point	Vegetation sweep
WAI000065	E 1711258 N 5677826	50m downstream of WAI000062	Vegetation sweep

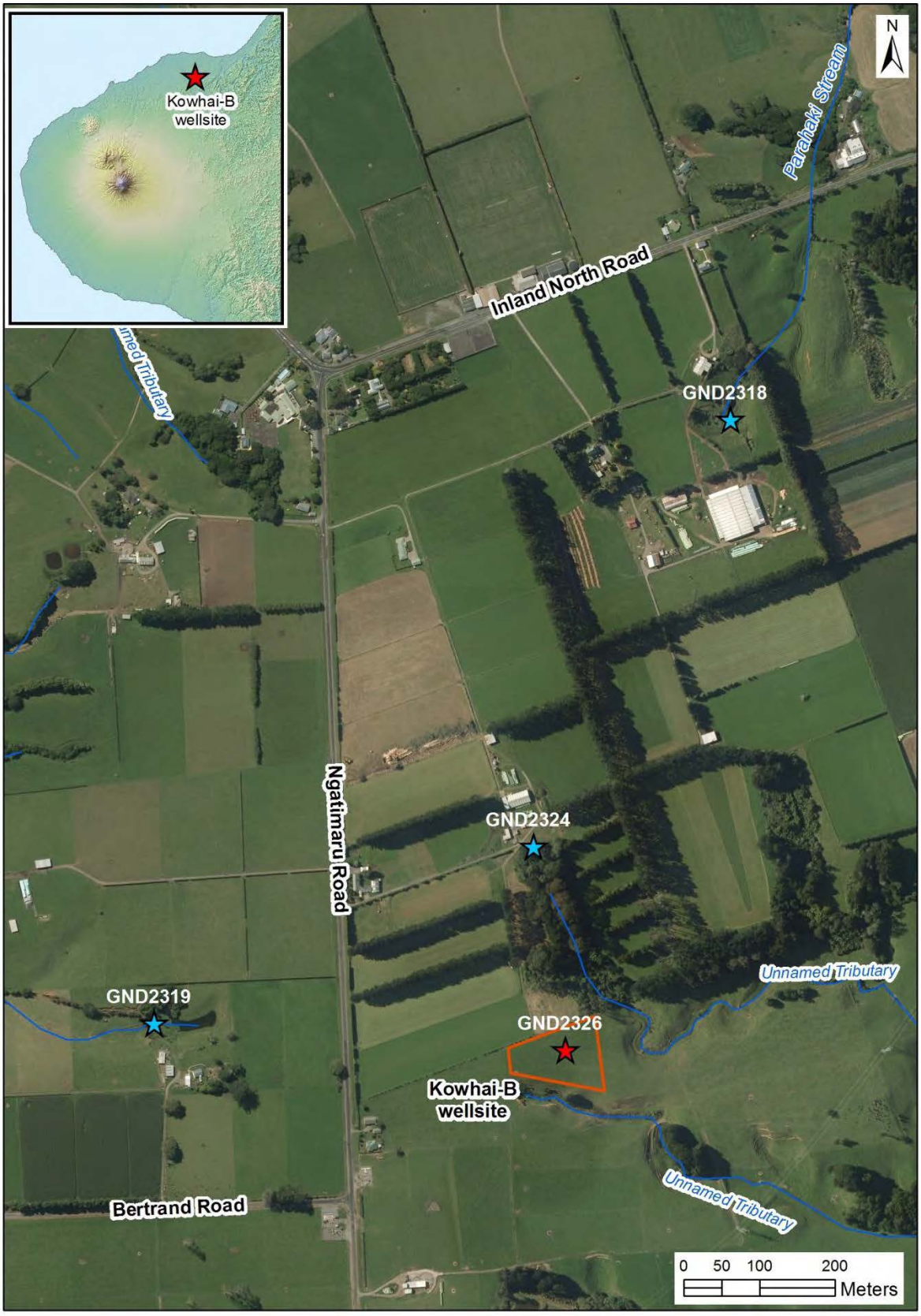


Figure 2 Location of groundwater sampling sites in relation to Kowhai-2 well (GND2326)

Figure 3 Location of biomonitoring sites in relation to Kowhai-B wellsite

2. Results

2.1 Consent holder submitted data

2.1.1 Kowhai-2 post-fracturing discharge report

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

- A total of three discrete zones were fractured over the period 23 March to 02 April 2013, at depths between 3,802 to 4,067m TVDss.
- A total of 7,161 barrels (bbls) (1,138 m^3) of liquid was discharged across the three fractured zones. The total proppant weight was 216 tonnes.
- By volume the fluid injected was comprised of 92.32% (1,051 m^3) water, 5.23% proppant and 2.45% 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 Kowhai-2 well was opened for flowback following the completion of fracturing of each individual zone. At the completion of all flow-back operations, approximately 4,341 bbls (690 m^3) of fracture fluids and formation fluid were returned to the surface, leaving approximately 2,820 bbls (448 m^3) of the fluids injected remaining in the formation. Additional fluid is likely to be returned back to the surface as the well produces.
- All fluids that returned to the surface during flowback of each hydraulic fracturing operation were disposed of by deep well injection at the Kaimiro-G wellsite as authorised by consent 9470-1.
- During the initial stages of the first hydraulic fracturing operation on Kowhai-2, an incident occurred in which a small quantity of linear gel leaked from the stringer assembly. The job was shut down immediately, and the leak was confined with hand-dug metal berms, then cleaned up with the vacuum truck and absorbent spill pads. Any wetted metal was also removed from the site. This leak did not result in any contaminants escaping into the environment.
- All fracturing treatments were placed successfully. 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 Kowhai-2 groundwater sampling survey

A total of three sites were sampled to monitor the effects of the hydraulic fracturing of the Kowhai-2 well on local groundwater resources.

The results of the laboratory analysis of samples from site GND2318 indicate a slight increase in calcium, sulphate and nitrate concentrations and conductivity in the post-fracturing samples. The results of the laboratory analysis of samples from site GND2319 indicate a slight increase in barium and sulphate concentrations, total dissolved solids and pH in the post-fracturing samples. The results of the laboratory analysis of samples from site GND2324 indicate a slight decrease in chloride and bicarbonate and a slight increase in sulphate and dissolved iron concentrations in the post-fracturing samples. The changes in the concentrations of these analytes are a result of natural variations in water composition and are unrelated to fracturing activities. There were no traces of substances associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities in any of the post-fracturing samples obtained.

Dissolved methane was detected in all samples taken from each well except one post-fracturing sample taken from GND2318. Concentrations were within the expected range for shallow groundwater in Taranaki.

A full summary of results for all groundwater samples taken in relation to hydraulic fracturing of the Kowhai-2 well is included below in Table 4. The certificates of analysis are included in Appendix III.

Table 4 Results of groundwater sampling carried out in the vicinity of the Kowhai-2 well

Parameter	unit	GND2318			GND2319			GND2324		
		Pre-frac	Post-frac		Pre-frac	Post-frac		Pre-frac	Post-frac	
Sample date		14 Mar 2013	09 Jul 2013	22 Apr 2014	14 Mar 2013	09 Jul 2013	22 Apr 2014	14 Mar 2013	09 Jul 2013	22 Apr 2014
Lab number		TRC135329	TRC136535	TRC149955	TRC135326	TRC136537	TRC149953	TRC135328	TRC136536	TRC149954
Alkalinity	g/m3 $CaCO_3$	55	29	34	46	29	34	44	32	39
Barium	mg/kg	0.069	0.053	0.069	0.0071	0.029	0.0196	0.079	0.043	0.051
Benzene	g/m^3	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Bromine	g/m^3	-	0.115	0.188	0.35	0.076	0.093	<0.05	0.074	0.127
Calcium	g/m^3	11.5	12.3	13.5	12.1	11.6	9.3	13.2	11.2	12.6
Chloride	g/m^3	28	21	34	22	14.8	16.7	32	7.5	12.9
Conductivity	mS/m@20C	22.9	17.7	25.7	16.7	13.8	13.6	22.7	12.9	17.1
Dissolved copper	g/m^3	0.0010	0.0005	0.0011	<0.0005	<0.0005	<0.0005	0.0008	<0.0005	<0.0005
Ethylbenzene	g/m^3	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
Ethane	g/m^3	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Ethylene	g/m^3	<0.003	<0.004	<0.003	<0.003	<0.004	<0.003	<0.003	<0.004	<0.003
Dissolved iron	g/m^3	2.0	<0.02	0.21	0.83	0.35	1.33	1.79	0.72	5.3
Formaldehyde	g/m^3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ethylene glycol	g/m^3	<4	<4	<4	<4	<4	<4	<4	<4	<4
Hydrocarbons	g/m^3	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
Bicarbonate	g/m3 HCO_3	67	35	41.5	56	35	41.5	54	39	47.6
Total hardness	g/m3 $CaCO_3$	44	41	47	45	39	33	47	37	45
Dissolved mercury	g/m^3	-	<0.00008	<0.00008	-	<0.00008	<0.00008	-	<0.00008	<0.00008
Potassium	g/m^3	15	10.4	17.7	5.7	3.0	5.2	12.4	6.2	7.1
Methanol	g/m^3	<2	<2	<2	<2	<2	<2	<2	<2	<2
Methane	g/m^3	0.090	<0.002	0.031	0.33	0.013	0.38	0.039	0.065	0.44
Magnesium	g/m^3	3.7	2.6	3.2	3.5	2.4	2.4	3.4	2.2	3.3
Manganese	g/m^3	0.147	0.0088	0.052	0.78	0.041	0.106	0.26	0.27	0.26
Sodium	g/m^3	14.1	11.5	17.2	12.3	8.3	9.7	15.8	6.1	9.1
Nickel	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	-	<0.0005	<0.0005	<0.0005	<0.0005
Nitrate & nitrite nitrogen	g/m^3 N	0.078	1.88	4.2	<0.002	0.36	<0.002	<0.002	0.194	0.047
Nitrite nitrogen	g/m^3 N	0.014	<0.002	0.012	<0.002	0.013	0.003	<0.002	0.003	0.002
Nitrate nitrogen	g/m^3 N	0.065	1.88	4.2	<0.002	0.35	<0.002	<0.002	0.192	0.044
pH	pH	7	6.2	6.2	6.8	6.4	7.6	6.0	6.1	6.7
Propylene glycol	g/m^3	-	<4	<4	-	<4	<4	-	<4	<4
Sulphate	g/m^3	7.8	13.4	12.2	<0.5	13.3	3.0	12.3	14.6	17.7
Sum of anions	meq/L	-	1.59	2.2	-	1.30	1.22	-	1.17	1.52
Sum of cations	meq/L	-	1.60	2.1	-	1.23	1.27	-	1.21	1.68
Total dissolved solids	g/m^3	126	118	162	80	88	99	136	90	115
Toluene	g/m^3	<0.0010	<0.0010	<0.0010	0.0066	<0.0010	<0.0010	<0.0063	<0.0010	<0.0010
o-Xylene	g/m^3	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
m-Xylene	g/m^3	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Dissolved zinc	g/m^3	0.0045	0.0132	0.0179	0.0021	0.0048	0.0032	0.026	0.067	0.0122

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 Kowhai-2 well are summarised below in Table 5. The certificates of analysis are included in Appendix IV.

Due to the viscosity of the fluid samples obtained, the range of analyses that were able to be performed on each sample were limited. The sample taken was 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

Parameter	Unit	Kowhai-2
Sample date		25/03/2013
Lab number		TRC135765
Benzene	g/m^3	<0.005
Ethylbenzene	g/m^3	0.006
Ethylene glycol	g/m^3	7
Total hydrocarbons	g/m^3	179
Methane	g/m^3	<1
Propylene glycol	g/m^3	<4
Toluene	g/m^3	<0.010
o-Xylene	g/m^3	<0.010
m-Xylene	g/m^3	0.006

A composite sample of return fluids from Kowhai-2 was submitted for analysis. Return fluids are comprised of a mixture of hydraulic fracturing fluids and formation fluids produced from the target reservoir, following the completion of the hydraulic fracturing process. The relative concentrations of each contributing fluid type change as the volume of fluid produced from the well increases. Immediately following the opening of the well post-fracturing, a high proportion of the fluid returning to the wellhead is that injected during the hydraulic fracturing process. As the volume of fluid produced from the well increases, the proportion of hydraulic fracturing fluid reduces in relation to formation fluids.

The results of the analyses carried out on the return fluid sample obtained following the hydraulic fracturing of the Kowhai-2 well are summarised below in Table 6 and the certificates of analysis are included in Appendix IV. The relatively low levels of salinity (sodium and chloride) in each sample indicate that the composite samples prepared contained a greater proportion of fluids introduced during fracturing activities (comprised predominantly of freshwater) than saline reservoir fluids. The presence of elevated levels of hydrocarbon and BTEX compounds are indicative of fluids being drawn from a hydrocarbon bearing reservoir.

Table 6 Results of hydraulic fracturing return fluid sampling

Parameter	Unit	Kowhai-2
Sample date	-	02-Apr-13
Lab number	-	TRC135570
Total alkalinity	g/m^3 $CaCO_3$	810
Barium	mg/kg	0.135
Benzene	g/m^3	0.21
Bromide	g/m^3	<5
Calcium	g/m^3	22
Chloride	g/m^3	230
Conductivity	mS/m@20C	213
Dissolved copper	g/m^3	0.005
Ethylbenzene	g/m^3	0.026
Ethane	g/m^3	<0.003
Ethylene	g/m^3	<0.003
Dissolved iron	g/m^3	0.47
Formaldehyde	g/m^3	<0.15
Ethylene glycol	g/m^3	<4
Hydrocarbons	g/m^3	780
Bicarbonate	g/m3 HCO_3	988.2
Total hardness	g/m3 $CaCO_3$	86
Potassium	g/m^3	220
Methanol	g/m^3	<2
Methane	g/m^3	0.004
Magnesium	g/m^3	8
Dissolved manganese	g/m^3	0.024
Sodium	g/m^3	240
Nickel	mg/kg	<0.03
Nitrate & nitrite nitrogen	g/m^3 N	0.009
Nitrite	g/m^3 N	<0.002
Nitrate	g/m^3 N	0.008
PH	pH units	6.8
Propylene glycol	g/m^3	<4
Dissolved sulphur	g/m^3	<5
Sulphate	g/m^3	<15
Toluene	g/m^3	0.23
o-Xylene	g/m^3	0.030
m-Xylene	g/m^3	0.081
Dissolved zinc	g/m^3	0.07

2.3 Biomonitoring survey

The Council's standard 'vegetation sweep' sampling techniques were used to collect streambed macroinvertebrates from the unnamed tributary of the Waiau Stream in relation to fracturing at the Kowhai B wellsite. No pre-fracturing survey was carried out to determine the health of the macroinvertebrate communities prior to fracturing, so a comparison with the health of the macroinvertebrate communities after fracturing cannot be completed. 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 indicate the degree of adverse effects (if any) of the discharges being monitored.

The macroinvertebrate community at the three sites sampled was typical of Taranaki lowland coastal streams at a similar altitude apart from the control site which had a below average SQMCI score which was due to high abundances of pollution tolerant mudsnails (*Potamopyrgus* sp), seed shrimps (Ostracoda) and one species of caddisfly (*Oxyethira* sp) while it lacked high abundances of any pollution sensitive taxa. The low score is likely due to the habitat at the control site rather than water quality as poor water quality would likely affect the two downstream sites as well.

Taxa numbers for all three sites were slightly above average compared with typical Taranaki lowland coastal streams at a similar altitude.

There were no significant negative differences in macroinvertebrate health (MCI and SQMCIs) between the control site and the two potentially impacted sites suggesting that there was no significant impact from the wellsite activities. As there was no pre-drill survey it cannot be categorically stated that there was no effect as the two potentially impacted sites may have had significantly different macroinvertebrate health prior to any wellsite activities commencing.

A full report on the biomonitoring carried out in the vicinity of the wellsite is included in Appendix V.

2.4 Investigations, interventions, and incidents

The monitoring programme for the two years 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 consents or provisions in Regional Plans in relation 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 consents, 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 selected sites in the vicinity of the Kowhai-B wellsite. The surface water monitoring component of the programme comprised of a biomonitoring survey being carried out in surface water systems adjacent to the wellsite. Groundwater was surveyed prior to any hydraulic fracturing occurring to determine baseline conditions, allowing comparisons to be made with post-fracturing results. Only one biomonitoring survey was carried out and this took place following the fracturing of the Kowhai-2 well.

The results of post-fracturing groundwater sampling carried out in the vicinity of the Kowhai-2 well showed only very minor variations in water composition in comparison to baseline results. The minor variations in some analytes are typical of natural variations in water composition and therefore considered unrelated to fracturing activities. Methane was detected in low concentrations in each well in pre and post fracturing samples. Concentrations were within the expected range for shallow groundwater in Taranaki. No traces of substances associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities were present in the groundwater.

The results 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 period under review indicates that the hydraulic fracturing activities undertaken by GPL during the period being reported had no adverse effects on local groundwater or surface water resources.

3.2 Evaluation of performance

A tabular summary of the consent holder's compliance record for the period under review is set out in Table 7.

Table 7 Summary of performance for Consent 9207-1
To discharge contaminants in association with hydraulic fracturing activities into land at depths greater than 3,000 mTVD beneath the Kowhai-B wellsite at or about (NZTM) 1711087E-5677788N

Condition requirement	Means of monitoring during period under review	Compliance achieved?
1. Any discharge shall occur below 3,000 mTVD	Assessment of consent holder submitted data	Yes
2. Exercise of consent shall not result in any contaminants reaching any useable freshwater (groundwater or surface water)	Results of groundwater and surface water monitoring	Yes
3. Consent holder shall undertake sampling programme	Development and certification of a monitoring programme	Yes
4. Sampling programme shall follow recognised field procedures and be analysed for a specified range of chemical parameters	Development and certification of a monitoring programme and assessment of results	Yes
5. 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
6. Well and equipment pressure testing to be carried out prior to any hydraulic fracturing programme commencing	Assessment of consent holder submitted data	Yes
7. A pre-fracturing discharge report is to be provided to the Council 14 days prior to discharge	Pre-fracturing discharge report received	Yes
8. Consent holder shall notify the Council of hydraulic fracturing discharge	Notification received	Yes
9. A post-fracturing discharge report is to be provided to the Council within 60 days after the hydraulic fracturing programme is completed	Post-fracturing discharge report received	Yes
10. The reports outlined in conditions 7 and 9 must be emailed to consents@trc.govt.nz	Reports received via email	Yes
11. 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
12. Consent holder to adopt best practicable option at all times	Site inspections, sampling and assessment of consent holder submitted data	Yes
13. No hydrocarbon based hydraulic fracturing fluid shall be discharged	Assessment of consent holder submitted data and sampling of fracturing fluid	Yes

Condition requirement	Means of monitoring during period under review	Compliance achieved?
14. Notice of Council to review consent	No provision for review during period	N/A
Overall assessment of environmental performance and compliance in respect of this consent		High
Overall assessment of administrative performance and compliance in respect of this consent		High

During the 2012-2014 monitoring period, GPL demonstrated a high level of environmental and a high level of administrative performance and compliance with its resource consent as defined in Section 1.1.4.

3.3 Alterations to monitoring programmes for 2014-2015

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 the obligations of the RMA in terms of monitoring emissions/discharges and effects, and subsequently reporting 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 2014-2015 year, no further monitoring be carried out in relation to previously undertaken hydraulic fracturing events at the Kowhai-B wellsite. Monitoring should recommence however if any further fracturing is undertaken at the site.

3.4 Exercise of optional review of consent

Resource consent 9207-1 provides for an optional review of the consent an annual basis, with the next optional review date being June 2015. Condition 14 of this consent allows the Council to review consent conditions to ensure they are adequate to deal with any significant adverse effects on the environment arising from the exercise of this consent, which were either not foreseen at the time the application was considered or which it was not appropriate to deal with at the time. The Council can also review the consent in order to further specify the best practicable option and/or to ensure that hydraulic fracturing operations appropriately take into account any best practice guidance published by a recognised industry association or environmental regulator.

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

4. Recommendations

1. THAT no further monitoring be carried out in relation to previously undertaken hydraulic fracturing events at the Kowhai-B wellsite. Monitoring should recommence however if any further fracturing is undertaken at the site.

2. THAT the option for a review of resource consent in June 2015, as set out in condition 14 of consent 9207-1, is not exercised, on the grounds that the current conditions of the consents are adequate to ensure that any significant adverse effects on the environment are avoided.

Glossary of common terms and abbreviations

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

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

Bibliography and references

Greymouth Petroleum Limited (2013) Technical Proposal- Kowhai 2.

Greymouth Petroleum Limited (2013) Kowhai-2 Post-Fracturing Discharge Report.

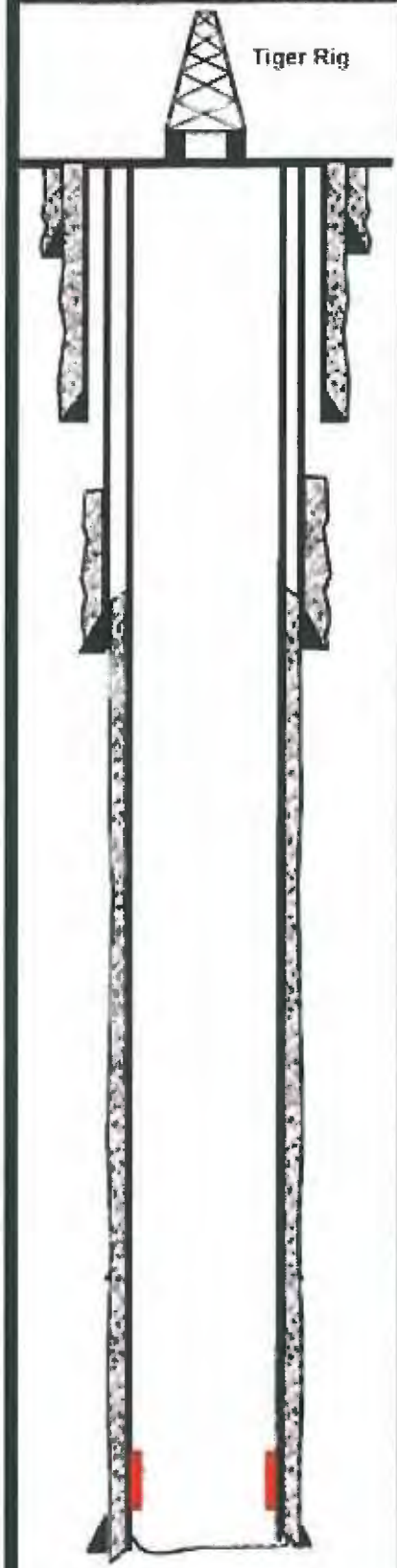
Stark JD, (1998) SQMCI: a biotic index for freshwater macroinvertebrate coded abundance data. *New Zealand Journal of Marine and Freshwater Research 32(1)*: 55-66.

Taranaki Regional Council (2014) Biomonitoring of an unnamed tributary of the Waiau Stream following drilling and hydraulic fracturing by Greymouth Petroleum Ltd at the Kowhai B wellsite, December 2013. Report BT013.

Taranaki Regional Council (2013) Greymouth Petroleum Kowhai-B Hydraulic Fracturing Groundwater Monitoring Programme.

Appendix I

Well construction geological stratigraphy schematics

SCHEMATIC	DESCRIPTION	DEPTH m AHBKB	DEPTH m SSTVD
	Tiger Rig Drill Floor (DF): 93.22m AMSL Ground Level (GL) 86.47m AMSL	0.0	
	20" Conductor Casing	106.0	
	13-3/8" Casing	903.0	
	9-5/8" CBL, Top of cement 1300m		
	Max Deviation: 22 degrees		
	9-5/8" Casing, 47ppf	3517.0	
	4299.00 - 430 [.00 Zone 15		
	4 ½" CASING TO SURFACE, 15.1ppf, foam cement job	4546	
	TD, 6-3/4" hole	4550	

Comments

Updated: MILLS, MARCH 2013

'S' Shaped well

LOCATION:

NZTM

5677788.68mN

1711087.40mE

PETROCHEM LIMITED

Kowhai-2

well status diagram

Appendix II

Resource consents held by GPL

Discharge Permit

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

Name of Consent Holder:	Greymouth Petroleum Limited P O Box 3394 NEW PLYMOUTH 4341
Decision Date:	29 March 2012
Commencement Date:	29 March 2012

Conditions of Consent

Consent Granted:	To discharge contaminants in association with hydraulic fracturing activities into land at depths greater than 3000 mTVD beneath the Kowhai-B wellsite at or about (NZTM) 1711087E-5677788N
Expiry Date:	1 June 2015
Review Date(s):	June 2012, June 2013, June 2014
Site Location:	Kowhai-B wellsite, 451 Ngatimaru Road, Tikorangi (Property owner: R & B Jupp)
Legal Description:	Lot 4 DP 378739 Blk VI Waitara SD (Discharge source & site)
Catchment:	Waiau

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

General condition

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

Special conditions

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

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

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

3. 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 2 (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.

4. 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 3 and 4, could be taken and analysed by the Council or other contracted party on behalf of the consent holder.*

5. All sampling and analysis shall be undertaken in accordance with a *Sampling and Analysis Plan*, which shall be submitted to the Chief Executive for review and certification before the first sampling is undertaken. This plan shall specify the use of standard protocols recognised to constitute good professional practice including quality control and assurance. An International Accreditation New Zealand (IANZ) accredited laboratory shall be used for all sample analysis. Results shall be provided to the Chief Executive within 30 days of sampling and shall include supporting quality control and assurance information. These results will be used to assess compliance with condition 2.

   Note: *The Sampling and Analysis Plan may be combined with the Monitoring Programme required by condition 2.*

6. 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.

7. 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 and the intended fracture interval(s) ('fracture interval' is the discrete subsurface zone to receive a hydraulic fracture treatment);
   (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 and its intended composition, including a list of all contaminants and Material Safety Data Sheets for all the chemicals to be used;
   (d) the results of the reviews required by condition 12;
   (e) results of modelling showing an assessment of the likely extent and dimensions of the fractures that will be generated by the discharge;
   (f) the preventative and mitigation measures to be in place to ensure the discharge does not cause adverse environmental effects and complies with condition 2;
   (g) the extent and permeability characteristics of the geology above the discharge point to the surface;
   (h) any identified faults within the modeled fracture length plus a margin of 50%, and the potential for adverse environmental effects due to the presence of the identified faults;
   (i) the burst pressure of the well and the anticipated maximum well and discharge pressures and the duration of the pressures; and
   (j) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal.

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

8. The consent holder shall notify the Taranaki Regional Council of each discharge by emailing worknotification@trc.govt.nz. Notification shall include the date that the discharge is to occur and identify the 'Pre-fracturing discharge report', required by condition 7, which details the discharge. Where practicable and reasonable notice shall be given between 3 days and 14 days before the discharge occurs, but in any event 24 hours notice shall be given.

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

   (a) confirmation of the interval(s) where fracturing occurred for that programme, and the geographical position (i.e. depth and lateral position) of the discharge point for each fracture interval;
   (b) the contaminant volumes and compositions discharged into each fracture interval;
   (c) the volume of return fluids from each fracture interval;
   (d) an analysis for the constituents set out in conditions 4(a) to 4(k), in a return fluid sample taken within the first two hours of flow back, for each fracture interval if flowed back individually, or for the well if flowed back with all intervals comingled;
   (e) an estimate of the volume of fluids (and proppant) remaining underground;
   (f) the volume of water produced with the hydrocarbons (produced water) over the period beginning at the start of the hydraulic fracturing programme and ending 50 days after the programme is completed;
   (g) an assessment of the extent and dimensions of the fractures that were generated by the discharge, based on modelling undertaken after the discharge has occurred and other diagnostic techniques, including production analysis, available to determine fracture length, height and containment;
   (h) the results of pressure testing required by condition 6, and the well and discharge pressure durations and the maximum pressure reached during the hydraulic fracture discharge;
   (i) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal;
   (j) details of any incidents where hydraulic fracture fluid is unable to pass through the well perforations (screen outs) that occurred, their likely cause and implications for compliance with conditions 1 and 2; and
   (k) an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.

10. The reports described in conditions 7 and 9 shall be emailed to consents@trc.govt.nz with a reference to the number of this consent.

11. 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.

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

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

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

14. 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 12; 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 29 March 2012

For and on behalf of
Taranaki Regional Council

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Director-Resource Management

Appendix III

Certifcates of analysis (Groundwater)

Hill Laboratories
BETTER TESTING BETTER RESULTS

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

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

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1111569	SPv3
Contact:	Regan Phipps	**Date Registered:**	15-Mar-2013	
	C/- Taranaki Regional Council	**Date Reported:**	25-Mar-2013	
	Private Bag 713	**Quote No:**	47915	
	STRATFORD 4352	**Order No:**		
		Client Reference:		
		Submitted By:	Regan Phipps	

Sample Type: Aqueous

Sample Name:		GND2318 14-Mar-2013 10:40 am	GND2319 14-Mar-2013 9:30 am	GND2324 14-Mar-2013 10:05 am		
Lab Number:		1111569.4	1111569.5	1111569.6		
Individual Tests						
Sum of Anions	meq/L	2.1	1.55	2.0	-	-
Sum of Cations	meq/L	1.95	1.63	2.0	-	-
pH	pH Units	7.0	6.8	6.0	-	-
Total Alkalinity	g/m³ as $CaCO_3$	55	46	44	-	-
Bicarbonate	g/m³ at 25°C	67	56	54	-	-
Total Hardness	g/m³ as $CaCO_3$	44	45	47	-	-
Electrical Conductivity (EC)	mS/m	22.9	16.7	22.7	-	-
Total Dissolved Solids (TDS)	g/m³	126	80 #1	136	-	-
Dissolved Barium	g/m³	0.069	0.0071	0.079	-	-
Dissolved Calcium	g/m³	11.5	12.1	13.2	-	-
Dissolved Copper	g/m³	0.0010	< 0.0005	0.0008	-	-
Dissolved Iron	g/m³	2.0	0.83	1.79	-	-
Dissolved Magnesium	g/m³	3.7	3.5	3.4	-	-
Dissolved Manganese	g/m³	0.147	0.78	0.26	-	-
Dissolved Mercury	g/m³	< 0.00008	< 0.00008	< 0.00008	-	-
Dissolved Nickel	g/m³	< 0.0005	< 0.0005	< 0.0005	-	-
Dissolved Potassium	g/m³	15.0	5.7	12.4	-	-
Dissolved Sodium	g/m³	14.1	12.3	15.8	-	-
Dissolved Zinc	g/m³	0.0045	0.0021	0.026	-	-
Bromide	g/m³	< 0.05	0.35	< 0.05	-	-
Chloride	g/m³	28	22	32	-	-
Nitrite-N	g/m³	0.014	< 0.002	< 0.002	-	-
Nitrate-N	g/m³	0.065	< 0.002	< 0.002	-	-
Nitrate-N + Nitrite-N	g/m³	0.078	< 0.002	< 0.002	-	-
Sulphate	g/m³	7.8	< 0.5	12.3	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	< 4	< 4	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	< 4	< 4	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	< 2	< 2	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
Toluene	g/m³	< 0.0010	0.0066	0.0063	-	-
Ethylbenzene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
m&p-Xylene	g/m³	< 0.002	< 0.002	< 0.002	-	-

Sample Type: Aqueous						
Sample Name:		GND2318 14-Mar-2013 10:40 am	GND2319 14-Mar-2013 9:30 am	GND2324 14-Mar-2013 10:05 am		
Lab Number:		1111569.4	1111569.5	1111569.6		
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	< 0.02	< 0.02	-	-
Gases in groundwater						
Ethane	g/m³	< 0.003	< 0.003	< 0.003	-	-
Ethylene	g/m³	< 0.003	< 0.003	< 0.003	-	-
Methane	g/m³	0.090	0.33	0.039	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	< 0.10	< 0.10	-	-
C10 - C14	g/m³	< 0.2	< 0.2	< 0.2	-	-
C15 - C36	g/m³	< 0.4	< 0.4	< 0.4	-	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	< 0.7	< 0.7	-	-

Analyst's Comments

Supplement to test report 1111569v1 issued on 22/3/13.

#1 Due to the nature of this sample it was found to be difficult to filter. A smaller volume of sample was used for the analysis resulting in a detection limit higher than that normally achieved for the Total Dissolved Solids analysis.

SUMMARY OF METHODS

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

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Samples**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	-	4-6
Propylene Glycol in Water*	Direct injection, dual column GC-FID	-	4-6
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	-	4-6
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B	-	4-6
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	-	4-6
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	-	4-6
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines	-	4-6
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	4-6
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L.	0.07 meq/L	4-6
Total cations for anion/cation balance check	Calculation: sum of cations as mEquiv/L.	0.05 meq/L	4-6
pH	pH meter. APHA 4500-H^+ B 21st ed. 2005.	0.1 pH Units	4-6
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 21st ed. 2005.	1.0 g/m³ as $CaCO_3$	4-6
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 21st ed. 2005.	1.0 g/m³ at 25°C	4-6
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 21st ed. 2005.	1.0 g/m³ as $CaCO_3$	4-6
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 21st ed. 2005.	0.1 mS/m	4-6
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) 21st ed. 2005.	10 g/m³	4-6
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.00010 g/m³	4-6
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.05 g/m³	4-6
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0005 g/m³	4-6
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.02 g/m³	4-6

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Samples**
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.02 g/m^3	4-6
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0005 g/m^3	4-6
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m^3	4-6
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0005 g/m^3	4-6
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.05 g/m^3	4-6
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.02 g/m^3	4-6
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0010 g/m^3	4-6
Bromide	Filtered sample. Ion Chromatography. APHA 4110 B 21st ed. 2005.	0.05 g/m^3	4-6
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 21st ed. 2005.	0.5 g/m^3	4-6
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3- I (Modified) 21st ed. 2005.	0.002 g/m^3	4-6
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N.	0.002 g/m^3	4-6
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I (Modified) 21st ed. 2005.	0.002 g/m^3	4-6
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 21st ed. 2005.	0.5 g/m^3	4-6

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

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

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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1154505 SPv1
Contact:	Regan Phipps	**Date Registered:**	10-Jul-2013
	C/- Taranaki Regional Council	**Date Reported:**	17-Jul-2013
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	Kowhai B - Post Frac GW Sa
		Submitted By:	Regan Phipps

Sample Type: Aqueous

Sample Name:		GND2318 09-Jul-2013 12:50 pm	GND2324 09-Jul-2013 1:20 pm	GND2319 09-Jul-2013 1:50 pm		
Lab Number:		1154505.1	1154505.2	1154505.3		
Individual Tests						
Sum of Anions	meq/L	1.59	1.17	1.30	-	-
Sum of Cations	meq/L	1.60	1.21	1.23	-	-
pH	pH Units	6.2	6.1	6.4	-	-
Total Alkalinity	g/m³ as $CaCO_3$	29	32	29	-	-
Bicarbonate	g/m³ at 25°C	35	39	35	-	-
Total Hardness	g/m³ as $CaCO_3$	41	37	39	-	-
Electrical Conductivity (EC)	mS/m	17.7	12.9	13.8	-	-
Total Dissolved Solids (TDS)	g/m³	118	90	88	-	-
Dissolved Barium	g/m³	0.043	0.043	0.029	-	-
Dissolved Bromine*	g/m³	0.115	0.074	0.076	-	-
Dissolved Calcium	g/m³	12.3	11.2	11.6	-	-
Dissolved Copper	g/m³	0.0005	< 0.0005	< 0.0005	-	-
Dissolved Iron	g/m³	< 0.02	0.72	0.35	-	-
Dissolved Magnesium	g/m³	2.6	2.2	2.4	-	-
Dissolved Manganese	g/m³	0.0088	0.27	0.041	-	-
Dissolved Mercury	g/m³	< 0.00008	< 0.00008	< 0.00008	-	-
Dissolved Nickel	g/m³	< 0.0005	< 0.0005	< 0.0005	-	-
Dissolved Potassium	g/m³	10.4	6.2	3.0	-	-
Dissolved Sodium	g/m³	11.5	6.1	8.3	-	-
Dissolved Zinc	g/m³	0.0132	0.067	0.0048	-	-
Chloride	g/m³	21	7.5	14.8	-	-
Nitrite-N	g/m³	< 0.002	0.003	0.013	-	-
Nitrate-N	g/m³	1.88	0.192	0.35	-	-
Nitrate-N + Nitrite-N	g/m³	1.88	0.194	0.36	-	-
Sulphate	g/m³	13.4	14.6	13.3	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	< 4	< 4	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	< 4	< 4	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	< 2	< 2	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
Toluene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
Ethylbenzene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
m&p-Xylene	g/m³	< 0.002	< 0.002	< 0.002	-	-

Sample Type: Aqueous						
Sample Name:		GND2318 09-Jul-2013 12:50 pm	GND2324 09-Jul-2013 1:20 pm	GND2319 09-Jul-2013 1:50 pm		
Lab Number:		1154505.1	1154505.2	1154505.3		
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	< 0.02	< 0.02	-	-
Gases in groundwater						
Ethane	g/m³	< 0.003	< 0.003	< 0.003	-	-
Ethylene	g/m³	< 0.004	< 0.004	< 0.004	-	-
Methane	g/m³	< 0.002	0.065	0.013	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	< 0.10	< 0.10	-	-
C10 - C14	g/m³	< 0.2	< 0.2	< 0.2	-	-
C15 - C36	g/m³	< 0.4	< 0.4	< 0.4	-	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	< 0.7	< 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**	**Samples**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	-	1-3
Propylene Glycol in Water*	Direct injection, dual column GC-FID	-	1-3
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	-	1-3
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	-	1-3
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	-	1-3
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	-	1-3
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	-	1-3
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-3
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L.	0.07 meq/L	1-3
Total cations for anion/cation balance check	Calculation: sum of cations as mEquiv/L.	0.05 meq/L	1-3
pH	pH meter. APHA 4500-H^+ B 21st ed. 2005.	0.1 pH Units	1-3
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 21st ed. 2005.	1.0 g/m³ as $CaCO_3$	1-3
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 21st ed. 2005.	1.0 g/m³ at 25°C	1-3
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 21st ed. 2005.	1.0 g/m³ as $CaCO_3$	1-3
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 21st ed. 2005.	0.1 mS/m	1-3
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) 21st ed. 2005.	10 g/m³	1-3
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.00010 g/m³	1-3
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.005 g/m³	1-3
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.05 g/m³	1-3
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0005 g/m³	1-3
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.02 g/m³	1-3
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.02 g/m³	1-3

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Samples**
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0005 g/m³	1-3
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1-3
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0005 g/m³	1-3
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.05 g/m³	1-3
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.02 g/m³	1-3
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 21st ed. 2005.	0.0010 g/m³	1-3
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 21st ed. 2005.	0.5 g/m³	1-3
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3- I 21st ed. 2005.	0.002 g/m³	1-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N.	0.002 g/m³	1-3
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 21st ed. 2005.	0.002 g/m³	1-3
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 21st ed. 2005.	0.5 g/m³	1-3

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

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

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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1265735	SPv1
Contact:	Regan Phipps	**Date Registered:**	23-Apr-2014	
	C/- Taranaki Regional Council	**Date Reported:**	02-May-2014	
	Private Bag 713	**Quote No:**	47915	
	STRATFORD 4352	**Order No:**		
		Client Reference:	Kowhai B - Post HF GW	
		Submitted By:	R McDonnell	

Sample Type: Aqueous

Sample Name:		GND2319 22-Apr-2014 1:45 pm	GND2324 22-Apr-2014 2:15 pm	GND2318 22-Apr-2014 2:45 pm		
Lab Number:		1265735.1	1265735.2	1265735.3		
Individual Tests						
Sum of Anions	meq/L	1.22	1.52	2.2	-	-
Sum of Cations	meq/L	1.27	1.68	2.1	-	-
pH	pH Units	7.6	6.7	6.2	-	-
Total Alkalinity	g/m³ as $CaCO_3$	34	39	34	-	-
Bicarbonate	g/m³ at 25°C	42	48	41	-	-
Total Hardness	g/m³ as $CaCO_3$	33	45	47	-	-
Electrical Conductivity (EC)	mS/m	13.6	17.1	25.7	-	-
Total Dissolved Solids (TDS)	g/m³	99	115	162	-	-
Dissolved Barium	g/m³	0.0196	0.051	0.069	-	-
Dissolved Bromine*	g/m³	0.093	0.127	0.188	-	-
Dissolved Calcium	g/m³	9.3	12.6	13.5	-	-
Dissolved Copper	g/m³	< 0.0005	< 0.0005	0.0011	-	-
Dissolved Iron	g/m³	1.33	5.3	0.21	-	-
Dissolved Magnesium	g/m³	2.4	3.3	3.2	-	-
Dissolved Manganese	g/m³	0.106	0.26	0.052	-	-
Dissolved Mercury	g/m³	< 0.00008	< 0.00008	< 0.00008	-	-
Dissolved Nickel	g/m³	< 0.0005	< 0.0005	< 0.0005	-	-
Dissolved Potassium	g/m³	5.2	7.1	17.7	-	-
Dissolved Sodium	g/m³	9.7	9.1	17.2	-	-
Dissolved Zinc	g/m³	0.0032	0.0122	0.0179	-	-
Chloride	g/m³	16.7	12.9	34	-	-
Nitrite-N	g/m³	0.003 #1	0.002	0.012	-	-
Nitrate-N	g/m³	< 0.002	0.044	4.2	-	-
Nitrate-N + Nitrite-N	g/m³	< 0.002 #1	0.047	4.2	-	-
Sulphate	g/m³	3.0	17.7	12.2	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	< 4	< 4	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	< 4	< 4	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	< 2	< 2	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
Toluene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
Ethylbenzene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
m&p-Xylene	g/m³	< 0.002	< 0.002	< 0.002	-	-

Sample Type: Aqueous						
Sample Name:		GND2319 22-Apr-2014 1:45 pm	GND2324 22-Apr-2014 2:15 pm	GND2318 22-Apr-2014 2:45 pm		
Lab Number:		1265735.1	1265735.2	1265735.3		
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m³	< 0.0010	< 0.0010	< 0.0010	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	< 0.02	< 0.02	-	-
Gases in groundwater						
Ethane	g/m³	< 0.003	< 0.003	< 0.003	-	-
Ethylene	g/m³	< 0.003	< 0.003	< 0.003	-	-
Methane	g/m³	0.38	0.44	0.031	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	< 0.10	< 0.10	-	-
C10 - C14	g/m³	< 0.2	< 0.2	< 0.2	-	-
C15 - C36	g/m³	< 0.4	< 0.4	< 0.4	-	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	< 0.7	< 0.7	-	-

Analyst's Comments

#1 It has been noted that the result for Nitrite-N was greater than that for Nitrate-N + Nitrite-N, but within the analytical variation of these methods.

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/m³	1-3
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1-3
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1-3
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1-3
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1-3
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1-3
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	1-3
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1-3
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L.	0.07 meq/L	1-3
Total cations for anion/cation balance check	Calculation: sum of cations as mEquiv/L.	0.05 meq/L	1-3
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012.	0.1 pH Units	1-3
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1-3
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/m³ at 25°C	1-3
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1-3
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1-3
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.	10 g/m³	1-3
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m³	1-3
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m³	1-3
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-3
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-3

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/m³	1-3
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-3
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-3
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m³	1-3
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1-3
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1-3
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1-3
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m³	1-3
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m³	1-3
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m³	1-3
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m³	1-3
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012.	0.002 g/m³	1-3
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m³	1-3

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.

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

Appendix IV

Certifcates of analysis (Hydrualic fracturing and return fluid)

Hill Laboratories
BETTER TESTING BETTER RESULTS

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

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

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1120364 SPv1
Contact:	Regan Phipps	**Date Registered:**	09-Apr-2013
	C/- Taranaki Regional Council	**Date Reported:**	26-Apr-2013
	Private Bag 713	**Quote No:**	49265
	STRATFORD 4352	**Order No:**	
		Client Reference:	High Salinity Produced Wate
		Submitted By:	Regan Phipps

Sample Type: Saline

		Sample Name:	GND2326 02-Apr-2013 5:40 pm				
		Lab Number:	1120364.1				
Individual Tests							
pH*	pH Units		6.8	-	-	-	-
Total Alkalinity*	g/m³ as $CaCO_3$		810	-	-	-	-
Total Hardness*	g/m³ as $CaCO_3$		86	-	-	-	-
Electrical Conductivity (EC)*	mS/m		213	-	-	-	-
Dissolved Barium*	g/m³		0.135	-	-	-	-
Dissolved Calcium*	g/m³		22	-	-	-	-
Dissolved Copper*	g/m³		0.005	-	-	-	-
Dissolved Iron*	g/m³		0.47	-	-	-	-
Dissolved Magnesium*	g/m³		8	-	-	-	-
Dissolved Manganese*	g/m³		0.024	-	-	-	-
Dissolved Nickel*	g/m³		< 0.03	-	-	-	-
Dissolved Potassium*	g/m³		220	-	-	-	-
Dissolved Sodium*	g/m³		240	-	-	-	-
Dissolved Sulphur*	g/m³		< 5	-	-	-	-
Dissolved Zinc*	g/m³		0.07	-	-	-	-
Bromide*	g/m³		< 5	-	-	-	-
Chloride*	g/m³		230	-	-	-	-
Nitrite-N	g/m³		< 0.002	-	-	-	-
Nitrate-N*	g/m³		0.008	-	-	-	-
Nitrate*	g/m³		0.036	-	-	-	-
Nitrate-N + Nitrite-N	g/m³		0.009	-	-	-	-
Sulphate*	g/m³		< 15	-	-	-	-
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		0.21	-	-	-	-
Toluene*	g/m³		0.23	-	-	-	-
Ethylbenzene*	g/m³		0.026	-	-	-	-
m&p-Xylene*	g/m³		0.081	-	-	-	-
o-Xylene*	g/m³		0.030	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS							
Formaldehyde*	g/m³		< 0.15	-	-	-	-

Sample Type: Saline						
Sample Name:		GND2326 02-Apr-2013 5:40 pm				
Lab Number:		1120364.1				
Gases in groundwater						
Ethane*	g/m³	< 0.003	-	-	-	-
Ethylene*	g/m³	< 0.003	-	-	-	-
Methane*	g/m³	0.004	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9*	g/m³	3.0	-	-	-	-
C10 - C14*	g/m³	300	-	-	-	-
C15 - C36*	g/m³	480	-	-	-	-
Total hydrocarbons (C7 - C36)*	g/m³	780	-	-	-	-

Analyst's Comments

Appendix No.1 - Total Petroleum Hydrocarbon Chromatograms

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	Samples
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	-	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	-	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	-	1
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis, US EPA 8260B	-	1
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	-	1
Gases in groundwater*	Manual headspace creation and sub-sampling, GC-FID analysis.	-	1
Total Petroleum Hydrocarbons in Water*	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines	-	1
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	1
pH*	Saline water, pH meter. APHA 4500-H^+ B 21st ed. 2005.	0.1 pH Units	1
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m³ as $CaCO_3$	1
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 21st ed. 2005.	1.0 g/m³ as $CaCO_3$	1
Electrical Conductivity (EC)*	Saline water, Conductivity meter, 25°C. APHA 2510 B 21st ed. 2005.	0.10 mS/m	1
Filtration for dissolved metals analysis*	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 21st ed. 2005.	-	1
Dissolved Barium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 21st ed. 2005.	0.0006 g/m³	1
Dissolved Calcium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 21st ed. 2005.	1.0 g/m³	1
Dissolved Copper*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 21st ed. 2005.	0.0010 g/m³	1
Dissolved Iron*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 21st ed. 2005.	0.004 g/m³	1
Dissolved Magnesium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 21st ed. 2005.	0.4 g/m³	1
Dissolved Manganese*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 21st ed. 2005.	0.0010 g/m³	1
Dissolved Nickel*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 21st ed. 2005.	0.006 g/m³	1
Dissolved Potassium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 21st ed. 2005.	1.0 g/m³	1
Dissolved Sodium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 21st ed. 2005.	0.4 g/m³	1
Dissolved Sulphur*	Filtered sample, ICP-OES.	0.10 g/m³	1
Dissolved Zinc*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 21st ed. 2005.	0.004 g/m³	1
Bromide*	Filtered sample. Ion Chromatography. APHA 4110 B 21st ed. 2005.	0.05 g/m³	1

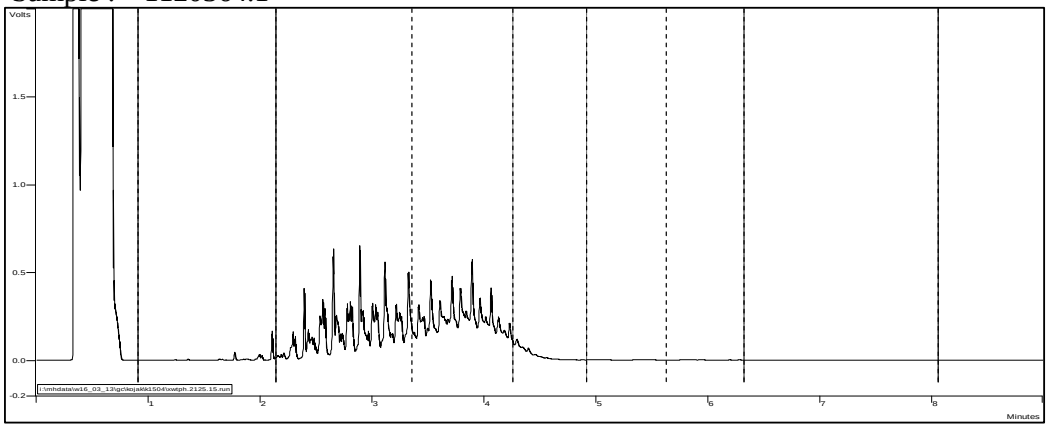
Sample Type: Saline			
Test	**Method Description**	**Default Detection Limit**	**Samples**
Chloride*	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 21st ed. 2005.	0.5 g/m³	1
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I (Modified) 21st ed. 2005.	0.002 g/m³	1
Nitrate-N*	Calculation: (Nitrate-N + Nitrite-N) - NO2N.	0.002 g/m³	1
Nitrate*	Calculation from Nitrate-N.	0.010 g/m³	1
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO_3^- I (Modified) 21st ed. 2005.	0.002 g/m³	1
Soluble Sulphate*	Calculation: from dissolved sulphur.	2 g/m³	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.

Martin Cowell - BSc (Chem)
Client Services Manager - Environmental Division

Sample : 1120364.1



C7 C10 C15 C20 C25 C30 C34 C44

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Web www.hill-labs.co.nz

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1115382 SPv1
Contact:	Regan Phipps	**Date Registered:**	26-Mar-2013
	C/- Taranaki Regional Council	**Date Reported:**	03-Apr-2013
	Private Bag 713	**Quote No:**	50522
	STRATFORD 4352	**Order No:**	
		Client Reference:	Hydraulic fracturing fluid testi
		Submitted By:	Regan Phipps

Sample Type: Aqueous

Sample Name:		GND2326 [Hydraulic Fracturing Fluid] 25-Mar-2013 9:37 am				
Lab Number:		1115382.1				
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	7	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	1.0	-	-	-	-
C10 - C14	g/m³	66	-	-	-	-
C15 - C36	g/m³	112	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	179	-	-	-	-
BTEX in VOC Water by Purge&Trap GC-MS						
Benzene	g/m³	< 0.005	-	-	-	-
Toluene	g/m³	< 0.010	-	-	-	-
Ethylbenzene	g/m³	0.006	-	-	-	-
m&p-Xylene	g/m³	0.006	-	-	-	-
o-Xylene	g/m³	< 0.005	-	-	-	-
Halogenated Aliphatics in VOC Water by Purge&Trap GC-MS						
Bromomethane (Methyl Bromide)	g/m³	< 0.02	-	-	-	-
Carbon tetrachloride	g/m³	< 0.005	-	-	-	-
Chloroethane	g/m³	< 0.005	-	-	-	-
Chloromethane	g/m³	< 0.005	-	-	-	-
1,2-Dibromo-3-chloropropane	g/m³	< 0.005	-	-	-	-
1,2-Dibromoethane (ethylene dibromide, EDB)	g/m³	< 0.005	-	-	-	-
Dibromomethane	g/m³	< 0.005	-	-	-	-
Dichlorodifluoromethane	g/m³	< 0.005	-	-	-	-
1,1-Dichloroethane	g/m³	< 0.005	-	-	-	-
1,2-Dichloroethane	g/m³	< 0.005	-	-	-	-
1,1-Dichloroethene	g/m³	< 0.005	-	-	-	-
cis-1,2-Dichloroethene	g/m³	< 0.005	-	-	-	-
trans-1,2-Dichloroethene	g/m³	< 0.005	-	-	-	-
Dichloromethane (methylene chloride)	g/m³	< 0.10	-	-	-	-
1,2-Dichloropropane	g/m³	< 0.005	-	-	-	-
1,3-Dichloropropane	g/m³	< 0.005	-	-	-	-
1,1-Dichloropropene	g/m³	< 0.005	-	-	-	-

Sample Type: Aqueous						
Sample Name:		GND2326 [Hydraulic Fracturing Fluid] 25-Mar-2013 9:37 am				
Lab Number:		1115382.1				
Halogenated Aliphatics in VOC Water by Purge&Trap GC-MS						
cis-1,3-Dichloropropene	g/m³	< 0.005	-	-	-	-
trans-1,3-Dichloropropene	g/m³	< 0.005	-	-	-	-
Hexachlorobutadiene	g/m³	< 0.005	-	-	-	-
1,1,1,2-Tetrachloroethane	g/m³	< 0.005	-	-	-	-
1,1,2,2-Tetrachloroethane	g/m³	< 0.005	-	-	-	-
Tetrachloroethene (tetrachloroethylene)	g/m³	< 0.005	-	-	-	-
1,1,1-Trichloroethane	g/m³	< 0.005	-	-	-	-
1,1,2-Trichloroethane	g/m³	< 0.005	-	-	-	-
Trichloroethene (trichloroethylene)	g/m³	< 0.005	-	-	-	-
Trichlorofluoromethane	g/m³	< 0.005	-	-	-	-
1,2,3-Trichloropropane	g/m³	< 0.005	-	-	-	-
1,1,2-Trichlorotrifluoroethane (Freon 113)	g/m³	< 0.05	-	-	-	-
Vinyl chloride	g/m³	< 0.005	-	-	-	-
Haloaromatics in VOC Water by Purge&Trap GC-MS						
Bromobenzene	g/m³	< 0.005	-	-	-	-
Chlorobenzene (monochlorobenzene)	g/m³	< 0.005	-	-	-	-
2-Chlorotoluene	g/m³	< 0.005	-	-	-	-
4-Chlorotoluene	g/m³	< 0.005	-	-	-	-
1,2-Dichlorobenzene	g/m³	< 0.005	-	-	-	-
1,3-Dichlorobenzene	g/m³	< 0.005	-	-	-	-
1,4-Dichlorobenzene	g/m³	< 0.005	-	-	-	-
1,2,3-Trichlorobenzene	g/m³	< 0.005	-	-	-	-
1,2,4-Trichlorobenzene	g/m³	< 0.005	-	-	-	-
1,3,5-Trichlorobenzene	g/m³	< 0.005	-	-	-	-
Monoaromatic Hydrocarbons in VOC Water by Purge&Trap GC-MS						
n-Butylbenzene	g/m³	< 0.005	-	-	-	-
tert-Butylbenzene	g/m³	< 0.005	-	-	-	-
Isopropylbenzene (Cumene)	g/m³	< 0.005	-	-	-	-
4-Isopropyltoluene (p-Cymene)	g/m³	< 0.005	-	-	-	-
n-Propylbenzene	g/m³	< 0.005	-	-	-	-
sec-Butylbenzene	g/m³	< 0.005	-	-	-	-
Styrene	g/m³	< 0.005	-	-	-	-
1,2,4-Trimethylbenzene	g/m³	0.006	-	-	-	-
1,3,5-Trimethylbenzene	g/m³	< 0.005	-	-	-	-
Ketones in VOC Water by Purge&Trap GC-MS						
Acetone	g/m³	< 0.5	-	-	-	-
2-Butanone (MEK)	g/m³	< 0.05	-	-	-	-
Methyl tert-butylether (MTBE)	g/m³	< 0.05	-	-	-	-
4-Methylpentan-2-one (MIBK)	g/m³	< 0.05	-	-	-	-
Trihalomethanes in VOC Water by Purge&Trap GC-MS						
Bromodichloromethane	g/m³	< 0.005	-	-	-	-
Bromoform (tribromomethane)	g/m³	< 0.005	-	-	-	-
Chloroform (Trichloromethane)	g/m³	0.019	-	-	-	-
Dibromochloromethane	g/m³	< 0.005	-	-	-	-
Other VOC in Water by Purge&Trap GC-MS						
Carbon disulphide	g/m³	< 0.05	-	-	-	-
Naphthalene	g/m³	0.016	-	-	-	-
System monitoring Compounds for VOC - % Recovery						
4-Bromofluorobenzene	%	101	-	-	-	-
Toluene-d8	%	98	-	-	-	-

Analyst's Comments

Appendix No.1 - Total Petroleum Hydrocarbon Chromatograms

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	Samples
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	-	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	-	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	-	1
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines	-	1
Volatile Organic Compounds Screening in Water by Purge&Trap	Purge & Trap, GC-MS FS analysis	-	1

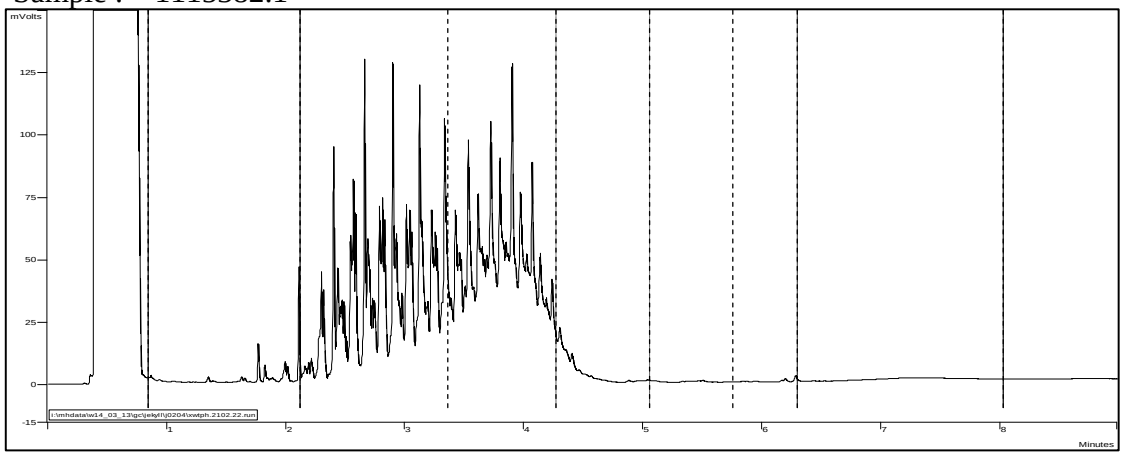
These samples were collected by yourselves (or your agent) and analysed as received at the laboratory.

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.

This report must not be reproduced, except in full, without the written consent of the signatory.

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

Sample : 1115382.1



C7 C10 C15 C20 C25 C30 C34 C44

Appendix V

Biomonitoring report

To Job Manager; Callum MacKenzie
From Freshwater Biologist; Brooke Thomas
Document 1324966
Date 19 March 2014

Biomonitoring of an unnamed tributary of the Waiau Stream following drilling and hydraulic fracturing by Greymouth Petroleum Ltd at the Kowhai B wellsite, December 2013

Introduction

This biological survey was performed following drilling and hydraulic fracturing activities at the Kowhai B wellsite to determine whether or not treated stormwater and uncontaminated site and production water discharges from the drilling site onto land, in the vicinity of the unnamed tributary of the Waiau Stream had any effects upon the communities of this stream. Although this survey was undertaken some time after drilling activities and hydraulic fracturing were completed, it will still provide a remnant indication as to whether or not consented discharges had an effect of the macroinvertebrate communities of this stream.

Methods

The Kowhai B wellsite stormwater and site production water was consented for discharge on to land within the vicinity of an unnamed tributary of the Waiau Stream (Figure 1). This survey was undertaken on 17 December 2013 at three newly established sites; 50 m upstream of the Kowhai B wellsite discharge (site 1), 50 m downstream of the Kowhai B wellsite discharge (site 2) and 100 m downstream of the Kowhai B wellsite discharge (site 3) (Table 1).

The 'vegetation sweep' sampling technique was used to collect streambed macroinvertebrates from the unnamed tributary of the Waiau Stream, upstream and downstream of the consented discharges from the Kowhai B wellsite. The 'vegetation sweep' sampling technique is very similar to Protocol 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 and sampling methods used in the unnamed tributary of the Waiau Stream related to the Kowhai B wellsite.

Site No.	Site code	Grid reference (NZTM)	Location	Sampling method	Altitude (m above sea level)
1	WAI000060	1711185E-5677828N	50m u/s of Kowhai B wellsite discharge	Vegetation sweep	80
2	WAI000062	1711231E-5677797N	50m d/s of Kowhai B wellsite discharge	Vegetation sweep	80
3	WAI000065	1711258E-5677826N	100m d/s of Kowhai B wellsite discharge	Vegetation sweep	80

Figure 1 Biomonitoring sites in the unnamed tributary of the Waiau Stream in relation to the Kowhai B wellsite.

Samples were preserved with Kahle's Fluid for later sorting and identification under a stereomicroscope according to Taranaki Regional Council methodology using 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 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 $SQMCI_s$ score is not multiplied by a scaling factor of 20, so that its corresponding range of values is 20x lower.

Results and discussion

At the time of this midday survey water temperatures in the stream ranged from 16.5 °C to 17.3°C. A very slow uncoloured, clear flow was noted at all three sites. Substrate comprised of silt at all three sites. No periphyton was recorded at site 2 or site 3, whereas long green filamentous algae was recorded as 'widespread' at site 1.Macrophytes were abundant at all three sites, growing on both the stream bed and at the edges of the stream.

Macroinvertebrate communities

Table 2 summarises the results of the current macroinvertebrate survey performed following drilling and hydraulic fracturing activities at the Kowhai B wellsite. Comparative data for sites in similar streams in the region are presented in Table 3. The macroinvertebrate fauna recorded by the current survey are presented in Table 4

Table 2: Number of taxa, MCI, and $SQMCI_s$ in the unnamed tributary of the Waiau Stream, sampled on 17 December 2013 after drilling and hydraulic fracturing at the Kowhai B wellsite.

Site No.	No taxa	MCI value	$SQMCI_s$ value
1	18	82	2.4
2	21	80	3.5
3	23	77	3.5

Table 3: Range and median number of taxa, MCI values and $SQMCI_s$ scores for lowland coastal streams at altitudes 50-79 m asl ((TRC, 1999 (updated 2013)).

	No. of taxa	MCI value	$SQMCI_s$ value
No. Samples	61	61	33
Range	0-27	60-90	1.4-5.0
Median	17	73	4

Table 4: Macroinvertebrate fauna of the unnamed tributary of the Waiau Stream in relation to the Kowhai B post drilling and post hydraulic fracturing survey sampled 17 December 2013

Taxa List	Site Number	MCI score	Site 1	Site 2	Site 3
	Site Code		WAI000060	WAI000062	WAI000065
	Sample Number		FWB13395	FWB13396	FWB13397
PLATYHELMINTHES (FLATWORMS)	*Cura*	3	R	R	R
NEMERTEA	Nemertea	3	C	-	R
NEMATODA	Nematoda	3	-	R	-
ANNELIDA (WORMS)	Oligochaeta	1	-	C	A
MOLLUSCA	Lymnaeidae	3	-	R	-
	Potamopyrgus	4	XA	XA	XA
CRUSTACEA	Ostracoda	1	XA	XA	XA
	Paracalliope	5	R	VA	XA
	Paraleptamphopidae	5	R	XA	VA
EPHEMEROPTERA (MAYFLIES)	*Zephlebia group*	7	A	A	C
ODONATA (DRAGONFLIES)	*Xanthocnemis*	4	-	R	-
HEMIPTERA (BUGS)	*Microvelia*	3	-	-	R
	Saldula	5	R	-	R
TRICHOPTERA (CADDISFLIES)	*Polyplectropus*	6	R	C	-
	Psilochorema	6	-	-	R
	Oxyethira	2	XA	-	-
	Triplectides	5	-	-	R
DIPTERA (TRUE FLIES)	*Paralimnophila*	6	-	R	-
	Zelandotipula	6	R	R	C
	Orthocladiinae	2	C	A	A
	Polypedilum	3	-	-	R
	Tanypodinae	5	C	A	A
	Dolichopodidae	3	-	-	R
	Paradixa	4	-	-	A
	Empididae	3	A	A	C
	Ephydridae	4	R	C	R
	Sciomyzidae	3	-	R	R
	Austrosimulium	3	R	R	C
	Stratiomyidae	5	R	R	-
ACARINA (MITES)	Acarina	5	R	C	A
		No of taxa	18	21	23
		MCI	82	80	77
		SQMCIs	2.4	3.5	3.5
		EPT (taxa)	2	2	3
		%EPT (taxa)	11	10	13

'Tolerant' taxa | 'Moderately sensitive' taxa | 'Highly sensitive' taxa

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

Site 1- 50m upstream of Kowhai B wellsite discharge

A moderate community richness of eighteen taxa was found at site 1 (Table 2 and Table 4), one taxa more than the median richness found at similar sites elsewhere in the region (Table 3). The macroinvertebrate community was comprised of equal proportions of 'tolerant' (50%), and 'moderately sensitive' taxa (50%),which was reflected in the MCI score of 82 units. This MCI score was an insignificant 9 units greater than the median MCI score for 'control' sites in similar streams at comparative altitudes (Stark, 1998) (Table 3).

The community at this site was characterised by one 'moderately sensitive' taxon, (mayfly (*Zephlebia* group)), and four 'tolerant' taxa; (snail (*Potamopyrgus*), caddisfly (*Oxyethira*), seed shrimp (*Ostracoda*) and Empidid fly larvae).

The numerical dominance of 'tolerant' taxa resulted in a $SQMCI_S$ score of 2.4 units, which was significantly lower (by 1.6 units) than the median score for 'control' sites in similar streams at this altitude (Table 3). However, this $SQMCI_S$ score was still within the range of $SQMCI_S$ scores found at 'control' sites in similar streams at comparable altitudes (Table 3).

Site 2- 50m downstream of Kowhai B wellsite discharge

A moderate community richness of twenty one taxa was found at site 2 (Table 2 and Table 4), three taxa more than what was found at site 1, and four taxa more than the median richness found at similar sites in the region (Table 3). The macroinvertebrate community was comprised of a significant proportion of 'tolerant' taxa (57%), which was reflected in the MCI score of 80 units. This was an insignificant 2 units fewer than what was recorded at site 1 and an insignificant 7 units greater than the median MCI score for 'control' sites in similar streams at comparative altitudes (Stark, 1998) (Table 3).

The community at this site was characterised by four 'moderately sensitive' taxa, (amphipods (*Paracalliope*) and (Paraleptamphopidae), mayfly (*Zephlebia* group), and true fly larvae (Tanypodinae)), and four 'tolerant' taxa; (snail (*Potamopyrgus*), seed shrimp (*Ostracoda*), Empidid fly larvae and orthoclad midges).

Two 'tolerant' taxa and one 'moderately sensitive' taxon were extremely abundant at this site (Table 4). The numerical dominance of 'tolerant' taxa resulted in a $SQMCI_S$ score of 3.5 units, which was an insignificant 0.5 unit fewer than the median score for 'control' sites in similar streams at this altitude (Table 3), and a significant 1.1 units higher than the upstream control site.

Site 3- 100m downstream of Kowhai B wellsite discharge

A moderate community richness of twenty three taxa was found at site 3 (Table 2 and Table 4), five taxa more than the upstream control site, and six taxa more than the median richness found at similar sites elsewhere in the region (Table 3). The macroinvertebrate community was comprised of a significant proportion of 'tolerant' taxa (57%), which was reflected in the MCI score of 77 units. This MCI score was 3 units less than what was found at site 2, and an insignificant (Stark, 1998) four units more than the median MCI score for 'control' sites in similar streams at comparative altitudes (Table 3).

The community at this site was characterised by four 'moderately sensitive' taxa, (amphipods (*Paracalliope*) and (Paraleptamphopidae), true fly larvae (Tanypodinae) and mite (Acarina)), and five 'tolerant' taxa; (snail (*Potamopyrgus*), seed shrimp (*Ostracoda*), orthoclad midges, oligochaete worms and true fly larvae (*Paradixa*)).

Two 'tolerant' taxa and one 'moderately sensitive' taxon were extremely abundant at this site (Table 4). A numerical dominance of 'tolerant' taxa resulted in the $SQMCI_S$ score of 3.5 units which was the same as site 2 and an insignificant 0.5 unit fewer than the median score for 'control' sites in similar streams at comparative altitudes elsewhere in the region (Stark, 1998) (Table 3). This $SQMCI_S$ score was significantly greater (by 1.1 units) than the upstream control site 1 (Table 2).

Summary and Conclusions

The Councils 'vegetation sweep' sampling technique was used at three sites to collect streambed macroinvertebrates from the unnamed tributary of the Waiau Stream. Comparative data for sites in similar streams in the region has been used with results from the current survey, for the assessment of possible consented discharge effects from the Kowhai B 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.

This December 2013 survey of three sites, upstream and downstream of the consented discharge point to land near the stream, was undertaken following drilling and hydraulic fracturing activities at the Kowhai B wellsite. Taxa richness's were moderate and within a narrow range for all sites and the macroinvertebrate communities of the stream contained relatively high proportions of 'tolerant' taxa. A total of 30 taxa was found through the reach of the stream surveyed, with 13 of these taxa (43%) found at all three sites and 6 taxa (20%), found at any two of these sites.

There was no significant difference in MCI scores from the current survey to 'control' sites in similar streams at comparative altitudes (Stark, 1998). In addition, $SQMCI_S$ scores at sites 2 and 3 were not significantly different to 'control' sites (TRC, 1999 (updated 2013)). Site 1 however, had a significantly lower $SQMCI_S$ score, to both site 2 and site 3 and to 'control' sites (TRC, 1999 (updated 2013)). This can be attributed to a slight difference in habitat, rather than to a change in water quality caused by the presence of widespread long green filamentous algae at site 1.

The MCI scores recorded in this survey indicated that the stream macroinvertebrate communities were of 'poor' (site 1) and 'fair' health (sites 2 and 3) (TRC, 2014). These results were within the range of what would be expected at comparable streams of a similar altitude elsewhere in the region. There was no remnant indication from the results of this survey that

the consented discharge from the Kowhai B wellsite has impacted on the biological communities of the unnamed tributary of the Waiau Stream.

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