Todd Energy Limited Mangahewa-E Hydraulic Fracturing Monitoring Programme Annual Report 2014-2015

Technical Report 2015-53

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Executive summary

Todd Energy Limited (Todd) operates the Mangahewa-E wellsite, located at 371 Tikorangi Road East, Waitara. The wellsite lies within the Waiau catchment and contains a hydrocarbon producing well and associated infrastructure.

During the 2014-2015 monitoring period, Todd held resource consent 9457-1, authorising the discharge of contaminants associated with hydraulic fracturing activities into land at depths greater than 3,200 m TVDss beneath the Mangahewa-E wellsite. The consent was issued by Taranaki Regional Council (the Council) on 26 February 2013 and contained 16 special conditions which set out the requirements that Todd had to satisfy.

The following report for the period July 2014 to June 2015 outlines and discusses the results of the monitoring programme implemented by the Council in relation to the programme of hydraulic fracturing undertaken by GPL, within their Mangahewa-E 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, Todd demonstrated an overall high level of environmental performance.

The programme of hydraulic fracturing undertaken by Todd at Mangahewa-E included the fracturing of four wells; Mangahewa-17, Mangahewa-18, Mangahewa-19 and Mangahewa-20. The hydraulic fracturing of these wells took place between 21 November and 20 December 2014.

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

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

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

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

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

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

This report includes recommendations for the 2015-2016 year.

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1. Introduction

1.1 Compliance monitoring programme reports and the Resource Management Act 1991

1.1.1 Introduction

The following report outlines and discusses the results of the monitoring programme implemented by the Taranaki Regional Council (the Council) in relation to the programme of hydraulic fracturing undertaken by Todd Energy Limited (Todd) at their Mangahewa-E wellsite, 371 Tikorangi Road East, Waitara over the period November – December 2014. The wellsite is located in the Waiau catchment. The report also assesses Todd's level of environmental performance and compliance with the resource consents held in relation to the activity.

The programme of hydraulic fracturing undertaken by Todd at the Mangahewa-E wellsite included the fracturing of four wells; Mangahewa-17, Mangahewa-18, Mangahewa-19 and Mangahewa-20. The monitoring programme implemented by the Council commenced during the 2014-2015 period. The programme consisted of groundwater, surface water and discharge monitoring components.

This is the first monitoring report produced by the Council in relation to the hydraulic fracturing activities at the Mangahewa-E 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 consent held by Todd for discharges into land associated with hydraulic fracturing in the Waiau catchment, a description of the activities undertaken under this consent, 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 2015-2016 monitoring year.

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

1.1.3 The Resource Management Act 1991 and monitoring

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

(a) the neighbourhood or the wider community around an activity, and may include cultural and social-economic effects;
(b) physical effects on the locality, including landscape, amenity and visual effects;
(c) ecosystems, including effects on plants, animals, or habitats, whether aquatic or terrestrial;
(d) natural and physical resources having special significance (eg, 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 Todd'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 issues 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 consent were met, or any failure to do this had trivial consequences and was addressed promptly and co-operatively.

- **Good** Perhaps some administrative requirements of the resource consent were not met at a particular time, however these are 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 consent 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 consent. Significant intervention by the Council was required. Typically there were grounds for an infringement notice.

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

1.2 Process description

1.2.1 Hydraulic fracturing

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

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

1.2.2 Mangahewa-E wellsite history

The Mangahewa-E wellsite has been in operation since March 2014. It lies in an active petrochemical exploration and production area, which operates alongside rural and farming operations. The area consists of predominantly low density housing due to its rural location. The topography of the site is flat countryside. The well site is located approximately 300 metres south of the Waiau Stream. The Mangahewa17 – Mangahewa-20 wells were drilled between April and October 2014.

A summary of all hydraulic fracturing activities carried out by Todd at the Mangahewa-C wellsite during the period being reported is provided below in Table 1. The location of the wellsite is illustrated in Figure 1.

Table 1 Summary of hydraulic fracturing activity at the Mangahewa-E wellsite (2014-2015)

Well	Wellsite	Consent	Date	Injection zone (mTVDBRT*)	Formation
Mangahewa-17	Mangahewa-E	9457-1	23/11/14 -26/11/14	3,676 – 4,117	Mangahewa
Mangahewa-18			13/12/14 – 20/12/14	3,410 – 4,085	Mangahewa
Mangahewa-19			28/11/14 – 7/12/14	3,571 – 4,168	Mangahewa
Mangahewa-20			21/11/14 – 23/11/14	3,637 – 4,135	Mangahewa

*mTVDBRT = metres true vertical depth below rotary table

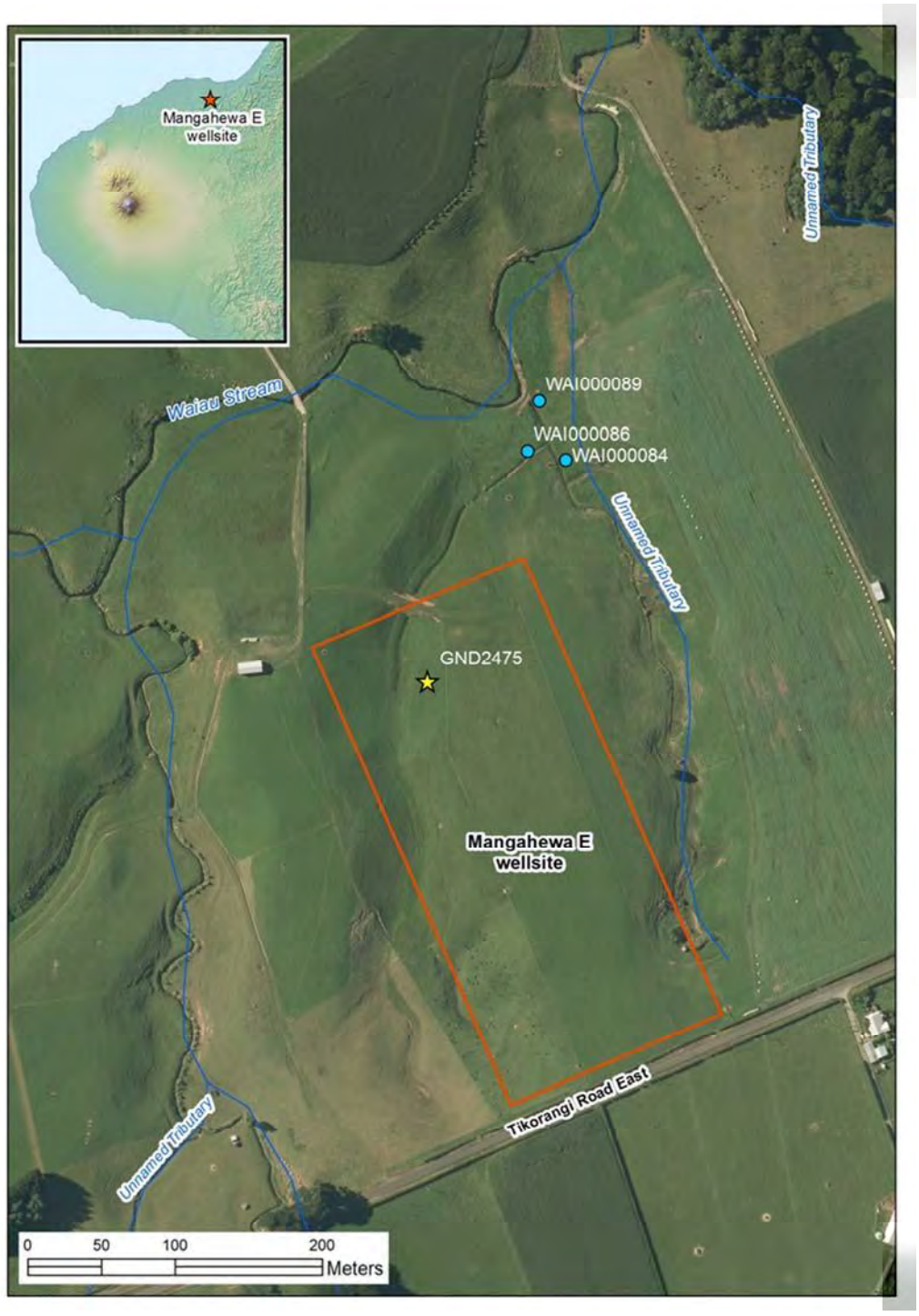

Figure 1 Location of groundwater (yellow star) and surface water (blue circles) sampling sites in relation to the Mangahewa-E wellsite

1.3 Resource consents

1.3.1 Discharges onto and into land

Sections 15(1)(b) of the RMA stipulate 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.

Todd holds resource consent 9457-2, authorising the discharge of water-based hydraulic fracturing fluids into land at the Mangahewa-E wellsite. Consent 9457-1 was granted to Todd Energy Limited on 26 February 2013. It is under this consent that Mangahewa-17, Mangahewa-18, Mangahewa-19 and Mangahewa-20 were hydraulically fractured. The consent was reviewed and four extra consent conditions were added and the consent became 9457--2 on 13 May 2015. Consent 9457-1 contains 16 special conditions which set out the requirements that Todd must satisfy. The special conditions attached to the consent are summarised below:

Consent 9457-1

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

Condition 2 stipulates the date after which no hydraulic fracturing discharge is to occur.

Condition 3 requires the consent holder to ensure that the exercising of the consent does not result in any contaminants reaching any useable freshwater.

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

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

Condition 9 requires the consent holder to submit a pre-fracturing discharge report at least 14 working days before the discharge commences.

Condition 10 is a notification requirement.

Condition 11 requires the consent holder to submit a post-fracturing discharge report within 90 days of the commencement date of hydraulic fracturing.

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

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

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

Condition 15 relates to the composition of the fracturing fluid.

Condition 16 is a review provision.

Copies of the resource consents are included in Appendix I.

1.4 Monitoring programme

1.4.1 Introduction

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

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

The monitoring programme implemented in relation to the hydraulic fracturing of the Mangahewa-E wells consisted of four primary components.

1.4.2 Programme liaison and management

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

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

1.4.3 Review of consent holder submitted data

As required by the conditions of consents 9457-1, Todd provided pre and post-fracturing discharge reports to the Council for the wells fractured during the period under review. Pre-fracturing discharge reports provide an outline of the proposed fracturing operations in relation to the well, while post-fracturing reports confirm details of the fracturing activities that actually occurred. The specific range of information required in the report is stipulated in the conditions of the resource consent.

1.4.4 Chemical sampling

The groundwater monitoring programme over the period in question included the sampling of one well, GND2475, and the analysis of the results.

The details of the well are included in Table 2 and their proximity to the Mangahewa-E wellsite is illustrated in Figure 2.

Table 2 Details of groundwater sites included in the monitoring programme

Hydraulically fractured wells	Monitoring site	Distance from wellsite (m)	Total depth (mbgl)	Screened interval (mbgl)	Aquifer
Mangahewa-17 Mangahewa-18 Mangahewa-19 Mangahewa-20	GND2475	At wellsite	34	13 – 23.4	Volcanics

Samples of groundwater were obtained before fracturing to provide a baseline reference of groundwater composition, with further rounds of sampling carried out post-fracturing (3 month and 1 year post-fracturing) for comparison with baseline results.

Samples were obtained using a peristaltic pump, using a low-flow sampling methodology. All samples were transported to Hill Laboratories Limited for analysis following standard chain of custody procedures.

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

1.4.5 Biomonitoring surveys

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

Biological surveys were performed pre and post-fracturing in the vicinity of the wellsite. Surveys were carried out in two unnamed tributaries of the Waiau Stream, as these are the nearest surface water bodies to the stormwater discharge locations of the Mangahewa-E wellsite. The surveys were undertaken to assess whether any discharges from the site during fracturing operations had resulted in any detrimental effects upon the biological communities in these waterways.

The details of each biomonitoring site included in the survey are presented in Table 3 and their proximity to the wellsite is illustrated in Figure2.

Table 3 Details of biomonitoring sites included in the monitoring programme

Site No.	Site code	Grid reference (NZTM)	Location	Sampling method		
				Pre Drill	Post-Drill Frac	Post-
1	WAI000084	1714201E-5678652N	10m upstream of minor tributary confluence	Sweep	Kick-sweep	Kick
2	WAI000086	1714175E-5678658N	15m upstream of confluence, 40m d/s of race	Sweep	Kick-sweep	Kick
3	WAI000089	1714183E-5678692N	15m downstream of confluence/ immediately upstream of culvert and confluence with Waiau Stream	Sweep	Kick-sweep	Kick

Figure 2 Biomonitoring sites in the two unnamed tributaries of the Waiau Stream in relation to the Mangahewa-E wellsite

2. Results

2.1 Consent holder submitted data

2.1.1 Mangahewa-17 post-fracturing discharge report

The conclusions from the Mangahewa-17 post-fracturing discharge report are summarised as follows:

- A total of four discrete zones were fractured over the period 23 November 2014 to 26 November 2014, at depths between 3,676 to 4,117 m TVDBRT.
- A total of 3,887 barrels (bbls) (618 m^3) of liquid was discharged across the four fractured zones. The total proppant weight was 46 tonnes.
- By volume, the fluid injected was comprised of 94.58% water, 2.55% proppant and 2.87% 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 Mangahewa-17 well was opened for flowback following the completion of fracturing. The zones were flowed back comingled post fracturing; hence a volume of fluid returned from each individual stage is not available. Additionally, the volume of fluid and the amount of proppant remaining in each individual stage is not available. At the completion of all flow-back operations, approximately 8,573 bbls (327 m^3) of fracture fluid and formation fluid were returned to the surface, leaving no fracture fluid remaining in the formation.
- All fluids produced during the stimulation and flowback period were trucked to Todd Well McKee-01 for disposal by deep well injection as per consent 4182-2.
- The Christmas tree, isolation tool, tubing and casings and wellhead have maintained full integrity throughout the treatment.
- It is considered that the mitigation measures implemented by Todd were effective in ensuring there were no adverse environmental effects associated with fracturing operations.

2.1.2 Mangahewa-18 post-fracturing discharge report

The conclusions from the Mangahewa-18 post-fracturing discharge report are summarised as follows:

- A total of six discrete zones were fractured over the period 13 December 2014 to 20 December 2014, at depths between 3,410 to 4,085 m TVDBRT.

- A total of 6824 bbls (1,085 m^3) of liquid was discharged across the four fractured zones. The total proppant weight was 136 tonnes.

- By volume, the fluid injected was comprised of 92.97% water, 3.71% proppant and 3.32% 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 Mangahewa-18 well was opened for flowback following the completion of fracturing. The zones were flowed back comingled post fracturing; hence a volume of fluid returned from each individual stage is not available. Additionally, the volume of fluid and the amount of proppant remaining in each individual stage is not available. At the completion of flow-back operations, approximately 3,041 bbls (484 m^3) of fracture fluid and formation fluid were returned to the surface, leaving 3,681 bbls (585m^3) remaining in the formation.

- All fluids produced during the stimulation and flowback period were trucked to Todd Well McKee-01 for disposal by deep well injection as per consent 4182-2.

- The Christmas tree, isolation tool, tubing and casings and wellhead have maintained full integrity throughout the treatment.

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

2.1.3 Mangahewa-19 post-fracturing discharge report

The conclusions from the Mangahewa-19 post-fracturing discharge report are summarised as follows:

- A total of four discrete zones were fractured over the period 28 November 2014 to 7 December 2014, at depths between 3,571 to 4,168 m TVDBRT.

- A total of 4,516bbls (718 m^3) of liquid was discharged across the four fractured zones. The total proppant weight was 85 tonnes.

- By volume, the fluid injected was comprised of 93.5% water, 2.93% proppant and 3.57% 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 Mangahewa-19 well was opened for flowback following the completion of fracturing. The zones were flowed back comingled post fracturing; hence a volume of fluid returned from each individual stage is not available.

Additionally, the volume of fluid and the amount of proppant remaining in each individual stage is not available. At the completion of flow-back operations, approximately 12,232 bbls (1,945 m^3) of fracture fluid and formation fluid were returned to the surface, leaving no fracture fluid remaining in the formation.

- All fluids produced during the stimulation and flowback period were trucked to Todd Well McKee-01 for disposal by deep well injection as per consent 4182-2.

- The Christmas tree, isolation tool, tubing and casings and wellhead have maintained full integrity throughout the treatment.

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

2.1.4 Mangahewa-20 post-fracturing discharge report

The conclusions from the Mangahewa-20 post-fracturing discharge report are summarised as follows:

- A total of four discrete zones were fractured over the period 21 November 2014 to 23 November 2014, at depths between 3,637 to 4,135 m TVDBRT.

- A total of 4,170 bbls (663m^3) of liquid was discharged across the four fractured zones. The total proppant weight was 53 tonnes.

- By volume, the fluid injected was comprised of 97.06% water, 0.88% proppant and 2.06% 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 Mangahewa-20 well was opened for flowback following the completion of fracturing. The zones were flowed back comingled post fracturing; hence a volume of fluid returned from each individual stage is not available. Additionally, the volume of fluid and the amount of proppant remaining in each individual stage is not available. At the completion of flow-back operations, approximately 3,518 bbls (559 m^3) of fracture fluid was returned to the surface, leaving 655 bbls (106 m^3) remaining in the formation.

- All fluids produced during the stimulation and flowback period were trucked to Todd Well McKee-01 for disposal by deep well injection as per consent 4182-2.

- The Christmas tree, isolation tool, tubing and casings and wellhead have maintained full integrity throughout the treatment.

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

2.2 Groundwater sampling

One site, GND2475, was sampled between November 2014 and December 2015 to monitor the effects of the hydraulic fracturing of the wells at the Mangahewa-E well site on local groundwater resources. Results are presented below in Table 4.

Key indicator parameters are pH, electrical conductivity, total dissolved solids, chloride and methane in groundwater. Changes in the concentration of these parameters may indicate the migration of deep formation water, which is highly saline in composition, via fractures or conduits created by the hydraulic fracturing process, leakage from the wellbore due to integrity issues, or the mishandling of fluids at the surface.

The results of the monitoring carried out indicate that the parameters remain consistent between pre and post-hydraulic fracturing groundwater sampling events. There was a small increase in chloride concentration but electrical conductivity, pH and total dissolved solids remained relatively stable. The fluctuations in the concentrations of these analytes are a result of natural variations in water composition and are unrelated to fracturing activities.

Methane was detected in both pre and post-hydraulic fracturing groundwater samples. Concentrations were generally low and within the expected ranges typically seen in shallow groundwater across Taranaki.

Very low concentrations of formaldehyde were detected in the pre-hydraulic fracturing sample, with none being detected in the post samples. Formaldehyde is known to occur naturally in groundwater across Taranaki. There were no traces of any substance associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities, in any of the post-fracturing samples obtained from the private water supply wells during the monitoring period.

Table 4 Results of groundwater sampling at GND2475

Parameter	Unit	GND2475		
Sample date		17 Nov 2014	27 May 2015	17 Dec 2015
Lab number		TRC1412087	TRC151837	TRC153967
Total alkalinity	g/m³ CaCO3	183	181	188
Barium	mg/kg	0.0172	0.0155	0.0184
Benzene	g/m³	<0.0010	<0.0010	<0.0010
Bromide	g/m³	0.26	0.30	0.29
Calcium	g/m³	6.2	6.5	7.6
Chloride	g/m³	68	72	75
Conductivity	mS/m@20C	57.2	56.5	58.6
Dissolved copper	g/m3	0.0020	0.0009	0.0010
Dissolved oxygen	g/m³	0.38	0.16	1.31
Ethylbenzene	g/m³	<0.0010	<0.0010	<0.0010
Ethane	g/m³	<0.003	<0.003	<0.003
Ethylene	g/m³	<0.003	<0.003	<0.003
Dissolved iron	g/m³	4.7	4.7	4.3
Formaldehyde	g/m³	0.03	<0.02	<0.02
Ethylene glycol	g/m³	<4	<4	<4
Total hydrocarbons	g/m³	<0.7	<0.7	<0.7
Bicarbonate	g/m³ HCO_3	220	220	230
Total hardness	g/m³ CaCO3	33	34	40
Mercury dissolved	g/m3	<0.00008	<0.00008	<0.00008
Potassium	g/m³	5.8	5.3	5.5
Methanol	g/m³	<2	<2	<2
Methane	g/m³	15.6	12.8	14.3
Magnesium	g/m³	4.2	4.4	5.2
Dissolved manganese	g/m³	0.128	0.142	0.131
Sodium	g/m³	123	118	111
Nickel	mg/kg	0.0007	0.0006	<0.0005
Nitrate & nitrite nitrogen	g/m³ N	<0.002	<0.02	<0.002
Nitrite	g/m³ N	<0.002	<0.02	<0.002
Nitrate	g/m³ N	<0.002	<0.02	<0.002
Dissolved oxygen saturation	%	3.8	1.6	13.2
pH	pH	7.8	7.5	7.7
Propylene glycol	g/m³	<4	<4	<4
Sulphate	g/m³	0.8	0.7	<0.5
Total dissolved solids	g/m³	340	340	340
Toluene	g/m³	<0.0010	<0.0010	<0.0010
o-Xylene	g/m³	<0.0010	<0.0010	<0.0010
m-Xylene	g/m³	<0.002	<0.002	<0.002
Dissolved zinc	g/m³	0.0063	0.0019	0.0010

Certificates of analysis for groundwater are included in Appendix II.

2.3 Carbon isotope analysis

As methane was detected in both pre and post-hydraulic fracturing groundwater samples The groundwater samples was sent to GNS Science for carbon isotope analysis in their National Isotope Centre The isotopic analysis is used to calculate a delta carbon13 ($\delta^{13}C$) value for a given sample, which is then used to determine the origin of the gas. Generally, a $\delta^{13}C$ value that exceeds -50‰ indicates biogenic methane, and a $\delta^{13}C$ value less than -50‰ indicates thermogenic methane. The higher or lower the $\delta^{13}C$ values, the stronger the isotopic signature. A $\delta^{13}C$ value in the vicinity of -50‰ can indicate a mixture of both biogenic and thermogenic methane. Results of analyses undertaken at Mangahewa E are presented below in Table 5.

Table 5 Results of carbon isotope analysis at private water supplies

Bore Name	GND2475	GND2475	GND2475
Date	17/11/14	27/05/15	17/12/2015
δ13C Value (‰)	-85.1	-79.7	-79.2

Table 5 shows that the methane gas present in GND2475 is strongly biogenic.

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

2.4 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 Mangahewa-17 and Mangahewa-20 wells for the November and December 2014 fracturing events are summarised below in Table 6. The hydraulic fracturing fluid analysed was a composite of fluid used in the Mangahwa-17 and Mangahewa-20 wells. The certificates of analysis are included in Appendix III.

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 samples taken were gel like in composition, as opposed to a liquid. While the fracturing fluid is predominantly comprised of water, specialised additives are used to increase the viscosity of the fluid in order to suspend the proppant prior to injection.

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

Table 6 Results of hydraulic fracturing fluid sampling

Parameter	Unit	Mangahewa 17 & 20 composite
Sample date	-	21 Nov 2014
Lab number	-	TRC1412300
Benzene	g/m^3	0.002
Ethylbenzene	g/m^3	0.0014
Ethylene glycol	g/m^3	380
Total hydrocarbons	g/m^3	5,200
Methane	g/m^3	<2
Propylene glycol	g/m^3	83

Parameter	Unit	Mangahewa 17 & 20 composite
Toluene	g/m³	0.0052
o-Xylene	g/m³	0.0022
m-Xylene	g/m³	0.005

Composite samples of return fluids from Mangahewa-17 and Mangahewa-19 were submitted for analysis. Return fluids are comprised of a mixture of hydraulic fracturing fluids and formation fluids produced from the target reservoir, following the completion of the hydraulic fracturing process. The relative concentrations of each contributing fluid type change as the volume of fluid produced from the well increases. Immediately following the opening of the well post-fracturing, a high proportion of the fluid returning to the wellhead is that injected during the hydraulic fracturing process. As the volume of fluid produced from the well increases, the proportion of hydraulic fracturing fluid reduces in relation to formation fluids.

The results of the analyses carried out on the return fluid sample obtained following the hydraulic fracturing of the Mangahewa-17, and Mangahewa-19 wells are summarised below in Table 6 and the certificates of analysis are included in Appendix III. The relatively high levels of salinity (sodium and chloride) in the samples indicate that the composite samples prepared contained a greater proportion of saline reservoir fluids than fluids introduced during fracturing activities. The presence of elevated levels of BTEX compounds are indicative of fluids being drawn from a hydrocarbon bearing reservoir.

Table 7 Results of hydraulic fracturing return fluid sampling

Parameter	Unit	Mangahewa-17	Mangahewa-19
Sample date		01-Dec-14	20-Dec-14
Lab number		TRC151151	TRC151152
Total alkalinity	g/m³ CaCO3	4100	2500
Barium	mg/kg	56	22
Benzene	g/m³	0.48	0.26
Bromide	g/m³	27	8.0
Calcium	g/m³	83	70
Chloride	g/m³	7400	3700
Conductivity	mS/m@20C	2660	1453
Dissolved copper	g/m³	<0.005	<0.005
Ethylbenzene	g/m³	0.026	0.045
Ethane	g/m³	0.004	0.067
Ethylene	g/m³	<0.003	<0.003
Dissolved iron	g/m³	0.91	3.0
Formaldehyde	g/m³	<0.02	0.70
Ethylene glycol	g/m³	<4	<4
Total hydrocarbons	g/m³	32	1050
Bicarbonate	g/m³ HCO_3	3560	1696
Total hardness	g/m³ CaCO3	260	210
Potassium	g/m³	270	400
Methanol	g/m³	<2	2
Methane	g/m³	0.065	1.02
Magnesium	g/m³	12	8
Dissolved manganese	g/m³	3.5	3.4
Sodium	g/m³	6500	3200
Nickel	mg/kg	<0.03	0.05
Nitrate & nitrite nitrogen	g/m³ N	<0.2	<0.2

Parameter	Unit	Mangahewa-17	Mangahewa-19
Nitrite	g/m³ N	<0.2	<0.2
Nitrate	g/m³ N	<0.2	<0.2
pH	pH	8.2	7.1
Propylene glycol	g/m³	<4	<4
Dissolved sulphur	g/m³	7	16
Sulphate	g/m³	21	48
Total dissolved solids	g/m³	18000	10400
Toluene	g/m³	0.21	0.168
o-Xylene	g/m³	0.134	0.21
m-Xylene	g/m³	0.160	0.31
Dissolved zinc	g/m³	0.04	0.04

2.5 Biomonitoring survey

The Council's standard 'kick-sampling', sweep-sampling' and 'kick-sweep sampling' techniques were used to collect streambed macroinvertebrates from two unnamed tributaries of the Waiau Stream in relation to fracturing at the Mangahewa-E wellsite. The intention of these surveys was to determine the health of the macroinvertebrate communities prior to fracturing, which then allowed a comparison with the health of macroinvertebrate communities once fracturing had been completed. Samples were processed to provide number of taxa (richness), MCI and SQMCIS scores for each site.

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

Taxa richness were similar among sites but varied between sampling occasions with a pattern of moderately low, moderate and low taxa richness observed indicating non wellsite related changes (e.g. water levels, temperature etc) except for the site 2 post-drill survey which had a moderately low taxa richness instead of the moderate taxa richness observed in sites 1 and 3. The taxa present at site 2 during the post-drill are characteristic of slow to very slow flowing streams that are organically rich but this does not explain the low taxa richness. Site 2 is situated on in a tributary of a different character to the tributary where sites 1 and 3 were located, which may have been a factor in the lower taxa richness observed. If site 2 was affected by a wellsite discharge then lower taxa richness would also be expected at site 3 which was not found.

MCI scores were similar for all three sites for the three surveys except for the post-hydraulic fracturing survey at site 2 which was significantly lower than scores at sites 1 and 3. It was noted during the site visit that there was a considerable amount of iron floc present on the bed of the stream and water levels were extremely low which could have caused the reduction in MCI score. If wellsite discharges had been a factor then it would be expected that MCI values at site 3 would show the same trend as site 2 which was not found.

The trends displayed by the $SQMCI_S$ values was the same as that of taxa richnesses with a pattern of moderately low, moderate and low $SQMCI_S$ values observed for the pre-drill, post-drill and post-hydraulic fracturing surveys respectively except for the site 2 post-drill survey which had a moderately low $SQMCI_S$ value. Higher $SQMCI_S$ values at site 1 for the post-drill survey as compared with the pre-drill survey can be solely attributed to the decrease in the abundance of the low scoring ostracod seed shrimps and oligochaete worms and for site 3 a decrease in ostracods and flatworms. Site 2 also had a decrease in the number of ostracods but it also had a decrease in higher scoring amphipods (*Paracalliope*) which was the main cause of the slight decrease in $SQMCI_S$ value from the pre-drill survey to the post-drill survey.

In general taxa richness, MCI and $SQMCI_S$ values were reasonably congruent which indicated that the two unnamed tributaries were of 'poor' health and that there were significant differences in taxa richnesses and $SQMCI_S$ values between surveys which were attributable to factors such as reduction in flows and loss of macrophytes and not wellsite discharges to nearby land. Sites 1 and 3 were also more similar in community composition to each other probably because they were in the same tributary as opposed to site 2 which was in a different unnamed tributary.

There was no evidence of wellsite discharges having had a significant impact on the macroinvertebrate communities with site 1, the 'control' site, having very similar macroinvertebrate indices compared with site 3, the 'second impacted' site.

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

2.6 Investigations, interventions, and incidents

The monitoring programme for the period under review was based on what was considered to be an appropriate level of monitoring, review of data, and liaison with the consent holder. During the 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 Todd's resource consent for hydraulic fracturing at the Mangahewa-E wellsite or provisions in Regional Plans.

3. Discussion

3.1 Environmental efects 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 Todd during the period being reported had resulted in any adverse effects on useable freshwater resources. As defined in the conditions of the relevant resource consent, useable freshwater includes both groundwater and surface water systems.

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

The results of post-fracturing groundwater sampling carried out at the Mangahewa-E wellsite showed only very minor variations in water composition in comparison to baseline results. The minor variations in some analytes are a result of natural variations in water composition and unrelated to fracturing activities. Methane was detected in low concentrations. Concentrations were within the expected range for shallow groundwater in Taranaki. The methane/ethane ratios for this well indicate that the methane gas is biogenic in origin and not derived from deep gas reservoirs. No traces of substances associated with hydraulic fracturing fluids, or hydrocarbons relating to fracturing activities were present in the groundwater during the post-fracturing sampling events.

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

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

3.2 Evaluation of performance

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

Table 8 Summary of performance for consent 9457-1

Purpose: *To discharge contaminants associated with hydraulic fracturing activities into land at depths greater than 3,200 mTVDss beneath the Mangahewa-E wellsite.*		
Condition requirement	Means of monitoring during period under review	Compliance achieved?
1. Any discharge shall occur below 3,200 mTVDss	Assessment of consent holder submitted data	Yes
2. No discharge shall occur after 1 June 2015	Assessment of consent holder submitted data	N/A
3. Exercise of consent shall not result in any contaminants reaching any useable freshwater	Results of groundwater monitoring	Yes
4. Consent holder shall undertake sampling programme	Development and certification of a monitoring programme	Yes
5. The monitoring programme shall include sampling of a groundwater bore installed in accordance with NZS 4411:2001	Inspection of bore	Yes
6. Sampling programme shall follow recognised field procedures and be analysed for a specified range of chemical parameters	Development and certification of a monitoring programme and assessment of results	Yes
7. All sampling to be carried out in accordance with a certified Sampling and Analysis Plan	Development and certification of a Sampling and Analysis Plan	Yes
8. Well and equipment pressure testing to be carried out prior to any hydraulic fracturing programme commencing	Assessment of consent holder submitted data	Yes
9. A pre-fracturing discharge report is to be provided to the Council 14 days prior to discharge	Pre-fracturing discharge report received	Yes
10. Consent holder shall notify the Council of hydraulic fracturing discharge	Notification received	Yes
11. A post-fracturing discharge report is to be provided to the Council within 90 days of any commencement	Post-fracturing discharge report received	Yes
12. The reports outlined in conditions 9 and 11 must be emailed to consents@trc.govt.nz	Reports received via email	Yes
13. The consent holder shall provide access to a location where samples of hydraulic fracturing fluids and return fluids can be obtained by the Council officers	Access provided	Yes
14. Consent holder to adopt best practicable option at all times	Site inspections, sampling and assessment of consent holder submitted data	Yes
15. No hydrocarbon based hydraulic fracturing fluid shall be discharged	Assessment of consent holder submitted data and sampling of fracturing fluid	Yes

Purpose: *To discharge contaminants associated with hydraulic fracturing activities into land at depths greater than 3,200 mTVDss beneath the Mangahewa-E wellsite.*		
Condition requirement	Means of monitoring during period under review	Compliance achieved?
16. 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 year, the Company demonstrated a high level of environmental and high level of administrative performance with the resource consents as defined in Section 1.1.4.

3.3 Alterations to monitoring programmes for 2015-2016

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

A one year post fracturing groundwater sampling round has already been carried out and the results have been included in this report. Therefore it is recommended that no further monitoring be carried out in relation to the hydraulic fracturing events at the Mangahewa-E wellsite. Monitoring should recommence however if any further fracturing is undertaken at the site.

3.4 Exercise of optional review of consent

Resource consent 9457-2 provides for an optional review of the consent an annual basis, with the next optional review date being June 2016. Condition 20 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.

Based on the results of monitoring in the year 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 for the forthcoming 2015-2016 monitoring period no further monitoring is required in relation to the hydraulic fracturing events at the Mangahewa-E wellsite. Monitoring should recommence however if any further fracturing is undertaken at the site.

2. THAT the option for a review of resource consent(s) in June 2016, as set out in condition 20 of consent 9457-2, 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).
Christmas tree	
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

Todd Energy Limited (2014) Technical Proposal – Hydraulic Fracturing Todd Mangahewa-E Wellsite Post-Fracturing Discharge Report – Mangahewa-17.

Todd Energy Limited (2014) Technical Proposal – Hydraulic Fracturing Todd Mangahewa-E Wellsite Post-Fracturing Discharge Report – Mangahewa-18.

Todd Energy Limited (2014) Technical Proposal – Hydraulic Fracturing Todd Mangahewa-E Wellsite Post-Fracturing Discharge Report – Mangahewa-19.

Todd Energy Limited (2014) Technical Proposal – Hydraulic Fracturing Todd Mangahewa-E Wellsite Post-Fracturing Discharge Report – Mangahewa-20.

Todd Energy Limited (2014) Technical Proposal – Hydraulic Fracturing Todd Mangahewa-E Wellsite Pre-Fracturing Discharge Report – Mangahewa-17.

Todd Energy Limited (2014) Technical Proposal – Hydraulic Fracturing Todd Mangahewa-E Wellsite Pre-Fracturing Discharge Report – Mangahewa-18.

Todd Energy Limited (2014) Technical Proposal – Hydraulic Fracturing Todd Mangahewa-E Wellsite Pre-Fracturing Discharge Report – Mangahewa-19.

Todd Energy Limited (2014) Technical Proposal – Hydraulic Fracturing Todd Mangahewa-E Wellsite Pre-Fracturing Discharge Report – Mangahewa-20.

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

Taranaki Regional Council (2015) Biomonitoring of two unnamed tributaries of the Waiau Stream in relation to drilling and hydraulic fracturing at the Mangahewa-E wellsite, May and November 2014 and January 2015. Report DS006.

Taranaki Regional Council (2014) Todd Energy Limited Hydraulic Fracturing – Mangahewa-E Wellsite Water Quality Monitoring Programme.

Appendix I

Resource consents held by Todd

(For a copy of the resource consent please contact the TRC consent department)

Discharge Permit

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

Name of Consent Holder:	Todd Energy Limited P O Box 802 NEW PLYMOUTH 4340
Decision Date:	26 February 2013
Commencement Date:	26 February 2013

Conditions of Consent

Consent Granted:	To discharge contaminants associated with hydraulic fracturing activities into land at depths greater than 3200 mTVDss beneath the Mangahewa-E wellsite
Expiry Date:	1 June 2020
Review Date(s):	June annually
Site Location:	Mangahewa-E wellsite, Tikorangi Road East, Waitara (Property owner: K & L Sarten)
Legal Description:	Lot 3 DP 18870 [Discharge source and site]
Grid Reference (NZTM)	1714172E-5678428N
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 to section 36 of the Resource Management Act.

Special conditions

1. The discharge point shall be deeper than 3200 mTVDss.

   Note: mTVDss = metres true vertical depth subsea, i.e. the true vertical depth in metres below mean sea level.

2. There shall be no discharge of hydraulic fracturing fluids into the reservoir after 1 June 2015.

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

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

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

5. The Monitoring Programme shall include sampling of groundwater from a bore installed in accordance with NZS 4411:2001. The bore shall be of a depth, location and design determined after consultation with the Chief Executive, Taranaki Regional Council.

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

   (a) pH;
   (b) conductivity;
   (c) total dissolved solids;
   (d) major ions (Ca, Mg, K, Na, total alkalinity, bromide, chloride, nitrate-nitrogen, and sulphate);
   (e) trace metals (barium, copper, iron, manganese, nickel, and zinc);
   (f) total petroleum hydrocarbons;
   (g) formaldehyde;
   (h) dissolved methane and ethane gas;
   (i) methanol;
   (j) glycols;

(k) benzene, toluene, ethylbenzene, and xylenes (BTEX); and
(l) carbon-13 composition of any dissolved methane gas discovered (^{13}C-CH_4).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Signed at Stratford on 15 November 2013

For and on behalf of
Taranaki Regional Council

_____

Director-Resource Management

Discharge Permit

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

Name of Consent Holder:	Todd Energy Limited PO Box 802 New Plymouth 4340
Decision Date:	13 May 2015
Commencement Date:	13 May 2015

Conditions of Consent

Consent Granted:	To discharge water-based hydraulic fracturing fluids into land at depths greater than 3,200 mTVDss beneath the Mangahewa-E wellsite
Expiry Date:	01 June 2027
Review Date(s):	June Annually
Site Location:	Mangahewa-E wellsite, 371 Tikorangi Road East, Waitara (Property owner: K & L Sarten)
Legal Description:	Lot 3 DP 18870
Grid Reference (NZTM)	1714165E-5678459N
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 points shall be deeper than 3,200 m TVDss.

   Note: mTVDss = metres true vertical depth subsea, i.e., the true vertical depth in metres below mean sea level

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

3. If the GeoNet seismic monitoring network records a seismic event higher than a Modified Mercalli intensity of magnitude 3.0 within 5 km of the geographical position (in 3 dimensions) of any hydraulic fracturing discharge, then:

   (a) if a hydraulic fracturing discharge is currently being undertaken, it shall cease immediately and not recommence; or
   (b) if a hydraulic fracturing discharge has occurred within the previous 72 hours no further hydraulic fracturing discharges shall occur.

4. Following the occurrence of any seismic event described in special condition 3 the consent holder shall investigate and report to the Chief Executive, Taranaki Regional Council on the likelihood of the seismic event being induced by the exercise of this consent. Hydraulic fracturing discharges may only then continue once the Chief Executive, Taranaki Regional Council has considered the report and concluded that the environmental risk of recommencing hydraulic fracturing is acceptable and has advised the consent holder accordingly.

5. The consent holder shall ensure that the exercise of this consent does not result in contaminants reaching any useable fresh water (groundwater or surface water). Usable fresh groundwater is defined as any groundwater having a Total Dissolved Solids concentration of less than 1,000 mg/l.

6. 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 5 (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.

7. The Monitoring Programme shall include sampling of groundwater from a bore installed in accordance with NZS 4411:2001. The bore shall be of a depth, location and design determined after consultation with the Chief Executive, Taranaki Regional Council.

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

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

   Note: *The samples required, under conditions 7 and 9 could be taken and analysed by the Council or other contracted party on behalf of the consent holder.*

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

   Note: *The Sampling and Analysis Plan may be combined with the Monitoring Programme required by* condition 6.

10. 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.

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

    (a) the specific well in which each discharge is to occur, the intended fracture interval(s) ('fracture interval' is the discrete subsurface zone to receive a hydraulic fracture treatment), and the duration of the hydraulic fracturing programme;
    (b) the number of discharges proposed and the geographical position (i.e. depth and lateral position) of each intended discharge point;

(c) the total volume of fracture fluid planned to be pumped down the well, including mini-fracture treatments, and their intended composition, including a list of all contaminants and Material Safety Data Sheets for all the chemicals to be used;
(d) the monitoring techniques to be used to determine the fate of discharged material;
(e) the results of the reviews required by condition 17;
(f) results of modelling showing an assessment of the likely extent and dimensions of the fractures that will be generated by the discharge;
(g) the preventative and mitigation measures to be in place to ensure the discharge does not cause adverse environmental effects and complies with condition 5;
(h) the extent and permeability characteristics of the geology above the discharge point to the surface;
(i) any identified faults within the modelled fracture length plus a margin of 50%, and the potential for adverse environmental effects due to the presence of the identified faults;
(j) the burst pressure of the well casing and the anticipated maximum well and discharge pressures and the duration of the pressures; and
(k) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal; and
(l) details why the contaminants in the discharge and the monitoring techniques used comply with condition 17.

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.*

12. The consent holder shall notify the Taranaki Regional Council of the date that each discharge is intended to commence by emailing worknotification@trc.govt.nz. Notification also shall identify the 'Pre-fracturing Discharge Report', required by condition 11, which details the discharge and be given no less than 3 days before the intended discharge date. If any discharge occurs more than 30 days after the notification date, additional notification as specified in this condition is required.

13. Subject to Condition 14, within 90 days of any commencement date as advised under condition 12, the consent holder shall submit a comprehensive 'Post-fracturing Discharge Report' to the Chief Executive. The report shall, as a minimum, contain:

(a) date and time of discharge;
(b) confirmation of the interval(s) where fracturing occurred for that programme, and the geographical position (i.e., depth and lateral position) of the discharge point for each fracture interval;
(c) the contaminant volumes and composition of fluid discharged into each fracture interval;
(d) the volume of return fluids from each fracture interval;
(e) an analysis for the constituents set out in conditions 8(a) to 8(k), in a return fluid sample taken within the first two hours of flow back, for each fracture interval if flowed back individually, or for the well if flowed back with all intervals comingled;
(f) an estimate of the volume of fluids (and proppant) remaining underground;

(g) the volume of water produced with the hydrocarbons (produced water) over the period beginning at the start of the hydraulic fracturing programme and ending 30 days after the programme is completed or after that period of production;
(h) an assessment of the extent and dimensions of the fractures that were generated by the discharge, based on modelling undertaken after the discharge has occurred and other diagnostic techniques, including production analysis, available to determine fracture length, height and containment;
(i) the results of pressure testing required by condition 10 and the top-hole pressure (psi), slurry rate (bpm), surface proppant concentration (lb/gal), bottom hole proppant concentration (lb/gal), and calculated bottom hole pressure (psi), as well as predicted values for each of these parameters; prior to, during and after each hydraulic fracture treatment;
(j) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal;
(k) details of any incidents where hydraulic fracture fluid is unable to pass through the well perforations (screen outs) that occurred, their likely cause and implications for compliance with conditions 1 and 5; and
(l) results of the monitoring referred to in condition 11 (d); and
(m) an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.

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

15. The reports described in conditions 11 and 13 shall be emailed to consents@trc.govt.nz with a reference to the number of this consent.

16. 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.

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

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

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

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

20. The Taranaki Regional Council may review any or all of the conditions of this consent by giving notice of review:
    a) during the month of June each year, and/or
    b) within 30 days of receiving any investigation and report in accordance with special condition 4 above;

    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 17; 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 13 May 2015

For and on behalf of
Taranaki Regional Council

_____

A D McLay
Director - Resource Management

Appendix II

Groundwater certificates of analysis

Hill Laboratories
BETTER TESTING BETTER RESULTS

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

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

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1432635 SPv1
Contact:	Regan Phipps	**Date Registered:**	29-May-2015
	C/- Taranaki Regional Council	**Date Reported:**	09-Jun-2015
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	Mangahewa E 3 Month Post HF
		Submitted By:	R McDonnell

Sample Type: Aqueous

Sample Name:		GND2475 27-May-2015 10:23 am				
Lab Number:		1432635.1				
Individual Tests						
Sum of Anions	meq/L	5.7	-	-	-	-
Sum of Cations	meq/L	6.1	-	-	-	-
pH	pH Units	7.5	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	181	-	-	-	-
Bicarbonate	g/m³ at 25°C	220	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	34	-	-	-	-
Electrical Conductivity (EC)	mS/m	56.5	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	340	-	-	-	-
Dissolved Barium	g/m³	0.0155	-	-	-	-
Dissolved Bromine*	g/m³	0.30	-	-	-	-
Dissolved Calcium	g/m³	6.5	-	-	-	-
Dissolved Copper	g/m³	0.0009	-	-	-	-
Dissolved Iron	g/m³	4.7	-	-	-	-
Dissolved Magnesium	g/m³	4.4	-	-	-	-
Dissolved Manganese	g/m³	0.142	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	0.0006	-	-	-	-
Dissolved Potassium	g/m³	5.3	-	-	-	-
Dissolved Sodium	g/m³	118	-	-	-	-
Dissolved Zinc	g/m³	0.0019	-	-	-	-
Chloride	g/m³	72	-	-	-	-
Nitrite-N	g/m³	< 0.02	-	-	-	-
Nitrate-N	g/m³	< 0.02	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	< 0.02 #1	-	-	-	-
Sulphate	g/m³	0.7	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	-	-	-	-
Toluene	g/m³	< 0.0010	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-

Sample Type: Aqueous						
Sample Name:	GND2475 27-May-2015 10:23 am					
Lab Number:	1432635.1					
BTEX in Water by Headspace GC-MS						
o-Xylene g/m³	< 0.0010	-	-	-	-	
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde g/m³	< 0.02	-	-	-	-	
Gases in groundwater						
Ethane g/m³	< 0.003	-	-	-	-	
Ethylene g/m³	< 0.003	-	-	-	-	
Methane g/m³	12.8	-	-	-	-	
Total Petroleum Hydrocarbons in Water						
C7 - C9 g/m³	< 0.10	-	-	-	-	
C10 - C14 g/m³	< 0.2	-	-	-	-	
C15 - C36 g/m³	< 0.4	-	-	-	-	
Total hydrocarbons (C7 - C36) g/m³	< 0.7	-	-	-	-	

Analyst's Comments

#1 Severe matrix interferences required that a dilution be performed prior to analysis, resulting in a detection limit higher than that normally achieved for the NOxN /NO2N analysis.

SUMMARY OF METHODS

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

Sample Type: Aqueous

Test	Method Description	Default Detection Limit	Sample No
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m³	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.07 meq/L	1
Total cations for anion/cation balance check	Sum of cations as mEquiv/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H^+) also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.05 meq/L	1
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 22nd ed. 2012.	1.0 g/m³ at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m³	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m³	1

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

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

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:**	1517579	SPv1
Contact:	Regan Phipps	**Date Registered:**	18-Dec-2015	
	C/- Taranaki Regional Council	**Date Reported:**	29-Dec-2015	
	Private Bag 713	**Quote No:**	47915	
	STRATFORD 4352	**Order No:**		
		Client Reference:	MHWE 1 Yr Past HF	
		Submitted By:	R McDonnell	

Sample Type: Aqueous

Sample Name:		GND2475 17-Dec-2015 9:51 am				
Lab Number:		1517579.1				
Individual Tests						
Sum of Anions	meq/L	5.9	-	-	-	-
Sum of Cations	meq/L	5.9	-	-	-	-
pH	pH Units	7.7	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	188	-	-	-	-
Bicarbonate	g/m³ at 25°C	230	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	40	-	-	-	-
Electrical Conductivity (EC)	mS/m	58.6	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	340	-	-	-	-
Dissolved Barium	g/m³	0.0184	-	-	-	-
Dissolved Bromine*	g/m³	0.29	-	-	-	-
Dissolved Calcium	g/m³	7.6	-	-	-	-
Dissolved Copper	g/m³	0.0010	-	-	-	-
Dissolved Iron	g/m³	4.3	-	-	-	-
Dissolved Magnesium	g/m³	5.2	-	-	-	-
Dissolved Manganese	g/m³	0.131	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	< 0.0005	-	-	-	-
Dissolved Potassium	g/m³	5.5	-	-	-	-
Dissolved Sodium	g/m³	111	-	-	-	-
Dissolved Zinc	g/m³	0.0010	-	-	-	-
Chloride	g/m³	75	-	-	-	-
Nitrite-N	g/m³	< 0.002	-	-	-	-
Nitrate-N	g/m³	< 0.002	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	< 0.002	-	-	-	-
Sulphate	g/m³	< 0.5	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	-	-	-	-
Toluene	g/m³	< 0.0010	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-

Sample Type: Aqueous						
Sample Name:	GND2475 17-Dec-2015 9:51 am					
Lab Number:	1517579.1					
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m³	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m³	< 0.003	-	-	-	-
Ethylene	g/m³	< 0.003	-	-	-	-
Methane	g/m³	14.3	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	-	-	-	-
C10 - C14	g/m³	< 0.2	-	-	-	-
C15 - C36	g/m³	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	-	-	-	-

SUMMARY OF METHODS

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

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m³	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L calculated from Alkalinity (bicarbonate), Chloride and Sulphate. Nitrate-N, Nitrite-N. Fluoride, Dissolved Reactive Phosphorus and Cyanide also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.07 meq/L	1
Total cations for anion/cation balance check	Sum of cations as mEquiv/L calculated from Sodium, Potassium, Calcium and Magnesium. Iron, Manganese, Aluminium, Zinc, Copper, Lithium, Total Ammoniacal-N and pH (H^+) also included in calculation if available. APHA 1030 E 22nd ed. 2012.	0.05 meq/L	1
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field.	0.1 pH Units	1
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
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
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m³	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m³	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m³	1

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

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

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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1352160 SPv1
Contact:	Regan Phipps	**Date Registered:**	18-Nov-2014
	C/- Taranaki Regional Council	**Date Reported:**	27-Nov-2014
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	Mangahewa E-Pre HF GW
		Submitted By:	R McDonnell

Sample Type: Aqueous

Sample Name:		GND2475 17-Nov-2014 1:10 pm				
Lab Number:		1352160.1				
Individual Tests						
Sum of Anions	meq/L	5.6	-	-	-	-
Sum of Cations	meq/L	6.3	-	-	-	-
pH	pH Units	7.8	-	-	-	-
Total Alkalinity	g/m³ as $CaCO_3$	183	-	-	-	-
Bicarbonate	g/m³ at 25°C	220	-	-	-	-
Total Hardness	g/m³ as $CaCO_3$	33	-	-	-	-
Electrical Conductivity (EC)	mS/m	57.2	-	-	-	-
Total Dissolved Solids (TDS)	g/m³	340	-	-	-	-
Dissolved Barium	g/m³	0.0172	-	-	-	-
Dissolved Bromine*	g/m³	0.26	-	-	-	-
Dissolved Calcium	g/m³	6.2	-	-	-	-
Dissolved Copper	g/m³	0.0020	-	-	-	-
Dissolved Iron	g/m³	4.7	-	-	-	-
Dissolved Magnesium	g/m³	4.2	-	-	-	-
Dissolved Manganese	g/m³	0.128	-	-	-	-
Dissolved Mercury	g/m³	< 0.00008	-	-	-	-
Dissolved Nickel	g/m³	0.0007	-	-	-	-
Dissolved Potassium	g/m³	5.8	-	-	-	-
Dissolved Sodium	g/m³	123	-	-	-	-
Dissolved Zinc	g/m³	0.0063	-	-	-	-
Chloride	g/m³	68	-	-	-	-
Nitrite-N	g/m³	< 0.002	-	-	-	-
Nitrate-N	g/m³	< 0.002	-	-	-	-
Nitrate-N + Nitrite-N	g/m³	< 0.002	-	-	-	-
Sulphate	g/m³	0.8	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	-	-	-	-
Toluene	g/m³	< 0.0010	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-

Sample Type: Aqueous						
Sample Name:		GND2475 17-Nov-2014 1:10 pm				
Lab Number:		1352160.1				
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m³	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m³	0.03	-	-	-	-
Gases in groundwater						
Ethane	g/m³	< 0.003	-	-	-	-
Ethylene	g/m³	< 0.003	-	-	-	-
Methane	g/m³	15.6	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	-	-	-	-
C10 - C14	g/m³	< 0.2	-	-	-	-
C15 - C36	g/m³	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	< 0.7	-	-	-	-

SUMMARY OF METHODS

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

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	1
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	1
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	1
Formaldehyde in Water by DNPH & LCMSMS	DNPH derivatisation, extraction, LCMSMS	0.02 g/m³	1
Gases in groundwater	Manual headspace creation and sub-sampling, GC-FID analysis.	0.002 - 0.003 g/m³	1
Total Petroleum Hydrocarbons in Water	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m³	1
Filtration, Unpreserved	Sample filtration through 0.45µm membrane filter.	-	1
Total anions for anion/cation balance check	Calculation: sum of anions as mEquiv/L.	0.07 meq/L	1
Total cations for anion/cation balance check	Calculation: sum of cations as mEquiv/L.	0.05 meq/L	1
pH	pH meter. APHA 4500-H^+ B 22nd ed. 2012.	0.1 pH Units	1
Total Alkalinity	Titration to pH 4.5 (M-alkalinity), autotitrator. APHA 2320 B (Modified for alk <20) 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1
Bicarbonate	Calculation: from alkalinity and pH, valid where TDS is not >500 mg/L and alkalinity is almost entirely due to hydroxides, carbonates or bicarbonates. APHA 4500-CO_2 D 22nd ed. 2012.	1.0 g/m³ at 25°C	1
Total Hardness	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m³ as $CaCO_3$	1
Electrical Conductivity (EC)	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	1
Total Dissolved Solids (TDS)	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	10 g/m³	1
Dissolved Barium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.00010 g/m³	1
Dissolved Bromine*	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.005 g/m³	1
Dissolved Calcium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m³	1
Dissolved Copper	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m³	1
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m³	1

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

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

Appendix III

Hydraulic fracturing and return fluids certificates of analysis

Hill Laboratories
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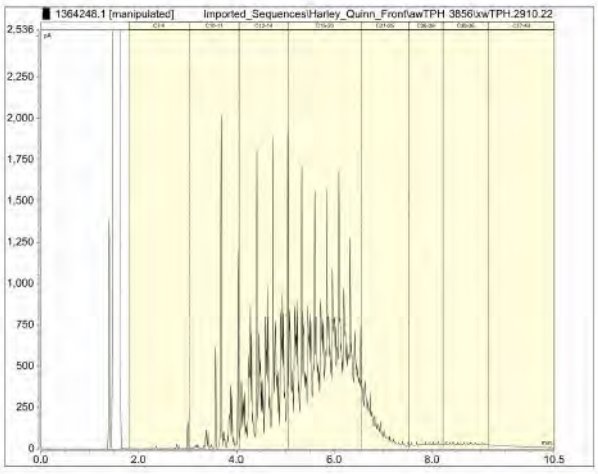
ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1364248	SPv1
Contact:	Regan Phipps	**Date Registered:**	13-Dec-2014	
	C/- Taranaki Regional Council	**Date Reported:**	29-Dec-2014	
	Private Bag 713	**Quote No:**	50522	
	STRATFORD 4352	**Order No:**		
		Client Reference:	Mangahewa E - HF Fluid	
		Submitted By:	Regan Phipps	

Sample Type: Aqueous

Sample Name:		GND2478				
Lab Number:		1364248.1				
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	380	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	83	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	0.0020	-	-	-	-
Toluene	g/m³	0.0052	-	-	-	-
Ethylbenzene	g/m³	0.0014	-	-	-	-
m&p-Xylene	g/m³	0.005	-	-	-	-
o-Xylene	g/m³	0.0022	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	19.1	-	-	-	-
C10 - C14	g/m³	1,880	-	-	-	-
C15 - C36	g/m³	3,300	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	5,200	-	-	-	-

1364248.1
GND2478
Client Chromatogram for TPH by FID



SUMMARY OF METHODS

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

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

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

Appendix IV

Biomonitoring report

To	Job Manager; Callum MacKenzie
From	Freshwater Biologists; Darin Sutherland and Bart Jansma
Report No	DS006
Document	1487382
Date	22 April 2015

Biomonitoring of two unnamed tributaries of the Waiau Stream in relation to drilling and hydraulic fracturing at the Mangahewa-E wellsite, May and November 2014 and January 2015

Introduction

Pre-drill, post-drill and post-frac macroinvertebrate surveys were performed at the Mangahewa-E wellsite to determine whether drilling and hydraulic fracturing ('fracking') discharges of treated stormwater, uncontaminated site water, and production water onto land had had any detrimental effects upon macroinvertebrate communities of the nearby unnamed tributary of the Waiau Stream. The pre-drill survey produced baseline results that allowed comparison with the post-drill and post-frac surveys enabling any changes in the condition of the macroinvertebrate communities to be determined. The Mangahewa-E wellsite stormwater and site production water were discharged from a skimmer pit on to land within the vicinity of two unnamed tributaries of the Waiau Stream (Figure 1).

Methods

The pre-drill survey was undertaken on 16 May 2014 at three sites (Table 1). Site 1 was the control site while site 2 was the primary impacted site and site 3 was the secondary impacted site. The subsequent post-drill survey was completed at the same three sites on 12 November 2014 and the post-frac survey was also completed at the same three sites on 13 January 2015. The altitude of the three sites was approximately 60 m asl.

Two different sampling techniques were used to collect macroinvertebrates in the unnamed tributaries of the Waiau Stream: the Council's standard 'kick-sampling' and a combination of 'kick-sampling' and a 'vegetation sweep' (Table 1). The 'kick-sampling' and 'vegetation sweep' techniques are very similar to Protocol C1 (hard-bottomed, semi-quantitative) and C2 (soft-bottomed, semi-quantitative) of the New Zealand Macroinvertebrate Working Group (NZMWG) protocols for macroinvertebrate samples in wadeable streams (Stark et al, 2001). The two techniques are used depending on the situation and a combination of techniques may be used when different conditions are encountered in the same reach of stream. Furthermore, vegetation sweeps may be used when the stream is not wadeable (e.g. due to water depth and/or speed) but vegetation on the bank edges can still be sampled.

Table 1 Biomonitoring sites and sampling methods used in the two unnamed tributaries of the Waiau Stream in relation to the Mangahewa-E wellsite.

Site No.	Site code	Grid reference (NZTM)	Location	Sampling method		
				Pre Drill	Post-Drill	Post-Frac
1	WAI000084	1714201E-5678652N	10m upstream of minor tributary confluence	Sweep	Kick-sweep	Kick
2	WAI000086	1714175E-5678658N	15m upstream of confluence, 40m d/s of race	Sweep	Kick-sweep	Kick
3	WAI000089	1714183E-5678692N	15m downstream of confluence/ immediately upstream of culvert and confluence with Waiau Stream	Sweep	Kick-sweep	Kick

Figure 1 Biomonitoring sites in the two unnamed tributaries of the Waiau Stream in relation to the Mangahewa-E wellsite

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

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

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

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

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

Results

Site habitat characteristics

The water temperatures were moderately cool during the pre-drill and post-drill sampling but were high for sites 1 and 3 and moderate for site 2 during the post-frac survey. Water colour and clarity were uncoloured and clear for all three survey dates (Table 2). Water velocity was slow for all three sites on all sampling occasions but the flow condition were progressively lower from the pre-dill to the post-frac (Table 3).

Substrate at site 1 during the pre-drill and post-drill survey was comprised entirely of silt while during the post-frac survey it was comprised mainly of silt but with some sand and fine and coarse gravel. Substrate at site 2 for the pre-drill, post-drill and post-frac was comprised nearly entirely of silt. Substrate at site 3 for the pre-drill and post-drill was comprised nearly entirely of silt and for the post-frac a mixture of silt and sand.

At site 1 there was patchy periphyton mats and macrophytes on the bed of the stream during the pre-survey, macrophytes on the bed but no periphyton during the post-survey and no periphyton or macrophytes during the post-frac. At site 2 there were macrophytes on the bed of the stream during the pre and post-survey and no periphyton or macrophytes during the post-frac. At site 3 there were slippery periphyton mats and macrophytes on the bed of the

stream during the pre-survey, macrophytes on the bed but no periphyton during the post-survey and no periphyton or macrophytes during the post-frac. All sites on all survey occasions did not have moss, leaves or wood present and all sites were unshaded.

Table 2 Summary of time of sampling and some water quality variables collected at each site for the pre and post-drill and post-frac monitoring (May and November 2014 and January 2015) at the Mangahewa-E wellsite.

	Time (NZST)			Temperature (°C)			Water Colour			Water Clarity		
	Pre	Post-Drill	Post-Frac	Pre	Post-Drill	Post-Frac	Pre	Post-Drill	Post-Frac	Pre	Post-Drill	Post-Frac
WAI000084	1225	1130	1215	15.1	15.2	29.0	Uncoloured	Uncoloured	Uncoloured	Clear	Clear	Clear
WAI000086	1240	1105	1155	15.3	14.8	18.9	Uncoloured	Uncoloured	Uncoloured	Clear	Clear	Clear
WAI000089	1205	1040	1140	15.1	15.6	24.1	Uncoloured	Uncoloured	Uncoloured	Clear	Clear	Clear

Table 3 Summary of some additional water variables collected at each site for the pre and post-drill and post-frac monitoring (May and November 2014 and January 2015) at the Mangahewa-E wellsite.

	Flow condition			Water speed			Days since 3x Fresh			Sampling habitat		
	Pre	Post-Drill	Post-Frac	Pre	Post-Drill	Post-Frac	Pre	Post-Drill	Post-Frac	Pre	Post-Drill	Post-Frac
WAI000084	Moderate	Low	Very low	Slow	Slow	Slow	9	9	12	Pool	Run	Run
WAI000086	Moderate	Low	Very low	Slow	Slow	Slow	9	9	12	Pool	Run	Run
WAI000089	Moderate	Low	Very low	Slow	Slow	Slow	9	9	12	Pool	Run	Run

Macroinvertebrate communities

Results of the pre-drill, post-drill and post-frac surveys are summarised in Table 4 and the macroinvertebrate faunal data are presented in Table 5.

Table 4 Summary of number of taxa, MCI values and $SQMCI_S$ for the pre and post-drill and post-frac monitoring (May and November 2014 and January 2015) at the Mangahewa-E wellsite.

	Numbers of taxa			MCI values			$SQMCI_S$		
	Pre	Post-Drill	Post-Frac	Pre	Post-Drill	Post-Frac	Pre	Post-Drill	Post-Frac
WAI000084	17	23	10	72	75	70	3.9	4.5	3.3
WAI000086	16	14	9	73	71	58	3.0	2.8	2.2
WAI000089	19	25	11	78	76	75	3.1	4.4	2.8

Table 5 Macroinvertebrate fauna of two unnamed tributaries of the Waiau Stream in relation to the pre and post-drill and post-frac monitoring (May and November 2014 and January 2015) at the Mangahewa-E wellsite.

Taxa List		MCI Score	Pre-drill			Post-drill			Post-frac		
	Site Code		WAI000084	WAI000086	WAI000089	WAI000084	WAI000086	WAI000089	WAI000084	WAI000086	WAI000089
PLATYHELMINTHES (FLATWORMS)	*Cura*	3	R	C	A	R	R	-	-	-	-
NEMERTEA	Nemertea	3	C	-	C	R	-	-	-	-	-
NEMATODA	Nematoda	3	-	-	-	R	R	R	-	-	-
ANNELIDA (WORMS)	Oligochaeta	1	VA	R	-	A	C	A	R	R	A
	Lumbricidae	5	C	R	-	-	-	R	-	-	-
HIRUDINEA (LEECHES)	Hirudinea	3	-	-	-	R	-	-	-	-	-
MOLLUSCA	Lymnaeidae	3	-	-	C	-	-	R	-	-	-
	Physa	3	-	-	R	R	VA	A	-	-	-
	Potamopyrgus	4	VA	-	A	VA	-	VA	A	-	C
	Sphaeriidae	3	R	-	-	-	-	-	R	-	R
CRUSTACEA	Copepoda	5	C	C	A	-	VA	-	-	R	-
	Ostracoda	1	VA	XA	XA	A	VA	A	C	C	A
	Paracalliope	5	XA	XA	XA	XA	R	XA	-	R	A
EPHEMEROPTERA (MAYFLIES)	*Zephlebia group*	7	-	-	-	R	-	-	-	-	-
ODONATA (DRAGONFLIES)	*Ischnura*	4	-	-	-	-	-	R	-	-	-
	Xanthocnemis	4	R	R	C	C	-	A	-	-	-
HEMIPTERA (BUGS)	*Microvelia*	3	-	-	-	R	-	R	-	-	-
	Sigara	3	-	-	-	-	-	R	-	-	-
COLEOPTERA (BEETLES)	Dytiscidae	5	-	C	-	R	R	R	-	-	R
	Hydrophilidae	5	-	R	R	-	-	-	R	-	-
TRICHOPTERA (CADDISFLIES)	*Polyplectropus*	6	-	-	-	R	-	R	-	-	-
	Psilochorema	6	-	R	-	R	-	R	-	-	-
	Oecetis	4	-	-	-	-	-	R	-	-	-
	Oxyethira	2	-	C	R	R	-	-	-	C	-
	Triplectides	5	-	-	-	R	-	-	-	-	-
DIPTERA (TRUE FLIES)	Hexatomini	5	-	-	R	-	-	-	R	-	R
	Paralimnophila	6	R	-	C	-	R	R	R	R	R
	Zelandotipula	6	-	-	R	-	-	R	-	-	-
	Chironomus	1	-	-	-	-	-	C	-	R	-
	Orthocladiinae	2	R	R	C	C	VA	A	C	A	-
	Polypedilum	3	-	-	-	-	A	-	-	-	-
	Tanypodinae	5	A	R	A	A	C	C	-	-	-
	Tanytarsini	3	-	XA	C	-	-	-	C	C	R
	Ceratopogonidae	3	R	R	-	-	-	-	-	-	-
	Paradixa	4	-	-	R	R	-	C	-	-	-
	Empididae	3	R	R	-	R	-	C	-	-	-
	Muscidae	3	-	-	-	-	R	-	-	-	R
	Austrosimulium	3	R	-	-	A	-	C	-	-	-
ACARINA (MITES)	Acarina	5	R	-	C	C	C	C	R	-	C
	No of taxa		17	16	19	23	23	25	10	9	11
	MCI		72	73	78	75	75	76	70	58	75
	SQMCIs		3.9	3.0	3.1	4.5	4.5	4.4	3.3	2.2	2.8
	EPT (taxa)		0	1	0	4	4	3	0	0	0
	%EPT (taxa)		0	6	0	17	17	12	0	0	0

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

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

Site 1. 10m upstream of minor tributary confluence

A moderately low macroinvertebrate community richness of 17 taxa was found at site 1 the 'control' site during the pre-drill survey. A higher richness of 23 taxa was found in the follow-up post-drill survey while a much lower taxa richness of 10 taxa was found in the post-frac survey (Results of the pre-drill, post-drill and post-frac surveys are summarised in Table 4 and the macroinvertebrate faunal data are presented in Table 5.

Table 4).

The MCI score for all three surveys was relatively consistent, 72, 75, and 70 units for the pre-drill, post-drill and post-frac surveys respectively, which indicated communities of 'poor' biological health. The $SQMCI_S$ scores of 3.9 units and 4.5 units for the pre and post-drill survey were similar but the post-frac $SQMCI_S$ score of 3.3 units was significantly lower than the post-drill survey score.

The community at the time of the pre-drill survey was characterised by three 'tolerant' taxa (oligochaete worms, snails (*Potamopyrgus*), and ostracod seed shrimps and two 'moderately sensitive' taxa, amphipods (*Paracalliope*) and midges (Tanypodinae). The community at the time of the post-drill survey was characterised by four 'tolerant' taxa (oligochaete worms, snails (*Potamopyrgus*), ostracod seed shrimps and sandflies (*Austrosimulium*), and two 'moderately sensitive' taxa, amphipods (*Paracalliope*) and midges (Tanypodinae). The community at the post-frac survey was characterised by one 'tolerant' taxon, snails (*Potamopyrgus*) (Table 5).

Site 2. 15m upstream of confluence, 40m d/s of race

A moderately low macroinvertebrate community richness of 16 taxa was found at site 2 the 'first impacted' site during the pre-drill survey. A slightly lower taxa richness of 14 taxa was found in the follow- up post-drill survey while a low taxa richness of 9 taxa was found in the post-frac survey (Results of the pre-drill, post-drill and post-frac surveys are summarised in Table 4 and the macroinvertebrate faunal data are presented in Table 5.

Table 4).

The pre and post-drill survey MCI scores of 73 and 71 respectively indicated 'poor' biological health. The post-frac survey MCI score of 58 units indicated 'very poor' biological health. The $SQMCI_S$ score of 3.0 units and 2.8 units for the pre and post-drill survey were similar to each other but the post-frac $SQMCI_S$ score of 2.2 units was marginally lower.

The community at the time of the pre-drill survey was characterised by one 'tolerant' taxon ostracod seed shrimps and two 'moderately sensitive' taxa, amphipods (*Paracalliope*) and midges (Tanypodinae). The community at the time of the post-drill survey was characterised by four 'tolerant' taxa ostracod seed shrimps, snails (*Physa*), midges (*Orthocladiinae*), and the true fly (*Polypedium*) and one 'moderately sensitive', taxon copepods. The community at the post-frac survey was characterised by one 'tolerant' taxon, midges (*Orthocladiinae*) (Table 5).

Site 3. 15m downstream of minor confluence/ immediately upstream of culvert & confluence with Waiau Stream

A moderately low macroinvertebrate community richness of 19 taxa was found at site 3 the 'second impacted' site during the pre-drill survey. A higher richness of 25 taxa was found in the follow- up post-drill survey while a low taxa richness of 11 taxa was found in the post-frac

survey (Results of the pre-drill, post-drill and post-frac surveys are summarised in Table 4 and the macroinvertebrate faunal data are presented in Table 5.

Table 4).

The MCI score for all three surveys was relatively consistent, 78, 76, and 75 units for the pre-drill, post-drill and post-frac surveys respectively, which indicated communities of 'poor' biological health. The $SQMCI_S$ scores of 3.1 units and 2.8 units for the pre-drill and post-frac surveys were similar but the post-drill $SQMCI_S$ score of 4.4 units was significantly higher.

The community at the time of the pre-drill survey was characterised by three 'tolerant' taxa, flatworms (Platyhelminth), snails (*Potamopyrgus*) and ostracod seed shrimps and three 'moderately sensitive' taxa, copepods, amphipods (*Paracalliope*) and midges (Tanypodinae). The community at the time of the post-drill survey was characterised by five 'tolerant' taxa, oligochaete worms, snails (*Physa*) and (*Potamopyrgus*), ostracod seed shrimps and damselflies (*Xanthocnemis*), and one 'moderately sensitive' taxon, amphipods (*Paracalliope*). The community at the time of the post-frac survey was characterised by two 'tolerant' taxa, oligochaete worms and ostracod seed shrimps and one 'moderately sensitive' taxon, amphipods (*Paracalliope*) (Table 5).

Discussion and Conclusions

The Councils 'kick-sampling' technique and a combination of 'vegetation sweep' and 'kick-sampling' techniques were used at three sites to collect streambed macroinvertebrates from two unnamed tributaries of the Waiau Stream. This has provided data to assess any ongoing impacts of skimmer pit discharges to nearby land from the Mangahewa-E wellsite on the macroinvertebrate communities of two unnamed tributaries of the Waiau Stream. Samples were processed to provide number of taxa (richness), MCI, and $SQMCI_S$ scores for each site.

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

The May 2014 pre-drill survey, the November 2014 post-drill survey and the January 2015 post-frac survey of three sites, upstream and downstream of the skimmer pit discharge point to land near an unnamed tributary of the Waiau stream was conducted as a result of drilling and fracking at the Mangahewa-E wellsite. Taxa richness were similar among sites but varied between sampling occasions with a pattern of moderately low, moderate and low taxa richness observed indicating non wellsite related changes (e.g. water levels, temperature etc) except for the site 2 post-drill survey which had a moderately low taxa richness instead of the moderate taxa richness observed in sites 1 and 3. The taxa present at site 2 during the post-drill are characteristic of slow to very slow flowing streams that are organically rich but this does not explain the low taxa richness. Site 2 is situated on in a tributary of a different character to the tributary where sites 1 and 3 were located, which may have been a factor in the lower taxa richness observed. If site 2 was affected by a wellsite discharge then lower taxa richness would also be expected at site 3 which was not found.

MCI scores were similar for all three sites for the three surveys except for the post-frac survey at site 2 which was significantly lower than scores at sites 1 and 3. It was noted during the site visit that there was a considerable amount of iron floc present on the bed of the stream and water levels were extremely low which could have caused the reduction in MCI score. If wellsite discharges had been a factor then it would be expected that MCI values at site 3 would show the same trend as site 2 which was not found.

The trends displayed by the $SQMCI_S$ values was the same as that of taxa richnesses with a pattern of moderately low, moderate and low $SQMCI_S$ values observed for the pre-drill, post-drill and post-frac surveys respectively except for the site 2 post-drill survey which had a moderately low $SQMCI_S$ value. Higher $SQMCI_S$ values at site 1 for the post-drill survey as compared with the pre-drill survey can be solely attributed to the decrease in the abundance of the low scoring ostracod seed shrimps and oligochaete worms and for site 3 a decrease in ostracods and flatworms. Site 2 also had a decrease in the number of ostracods but it also had a decrease in higher scoring amphipods (*Paracalliope*) which was the main cause of the slight decrease in $SQMCI_S$ value from the pre-drill survey to the post-drill survey.

In general taxa richness, MCI and $SQMCI_S$ values were reasonably congruent which indicated that the two unnamed tributaries were of 'poor' health and that there were significant differences in taxa richnesses and $SQMCI_S$ values between surveys which were attributable to factors such as reduction in flows and loss of macrophytes and not wellsite discharges to nearby land. Sites 1 and 3 were also more similar in community composition to each other probably because they were in the same tributary as opposed to site 2 which was in a different unnamed tributary.

Summary

- Pre-drill, post-drill and post-frac macroinvertebrate surveys were completed at three sites near the Mangahewa-E wellsite to determine if any wellsites discharges to nearby land had impacted on the health of the macroinvertebrate communities on two unnamed tributaries of the Waiau Stream.

- Taxa richness and $SQMCI_S$ values varied between sampling dates while MCI values remained relatively consistent.

- There were some differences between sites 1 and 3 and site 2 taxa richnesses, MCI and $SQMCI_S$ scores which were probably due to sites 1 and 3 being located in the same tributary while site 2 was located in an adjacent tributary.

- The primary influences on the macroinvertebrate communities appeared to be the reduction in flows and the loss of macrophyte habitat.

- There was no evidence of wellsite discharges having had a significant impact on the macroinvertebrate communities with site 1, the 'control' site, having very similar macroinvertebrate indices compared with site 3, the 'second impacted' site.

References

Stark JD, 1985: A macroinvertebrate community index of water quality for stony streams. *Water and Soil* Miscellaneous Publication No. 87.

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.

Stark JD, 1999: An evaluation of Taranaki Regional Council's SQMCI biomonitoring index. Cawthron Institute, Nelson. Cawthron Report No. 472.

Stark JD, Boothroyd IKG, Harding JS, Maxted JR, Scarsbrook MR, 2001: Protocols for sampling macroinvertebrates in wadeable streams. New Zealand Macroinvertebrate Working Group Report No. 1. Prepared for the Ministry for the Environment. Sustainable Management Fund Project No. 5103. 57p.

TRC, 2014: Fresh Water Macroinvertebrate Fauna Biological Monitoring Programme Annual State of the Environment Monitoring Report 2012-2013. TRC Technical Report 2012-13. 247p.

TRC, 2015: Some statistics from the Taranaki Regional Council database (Esam) of freshwater macroinvertebrate surveys performed during the period from January 1980 to 30 September 2014. Technical Report 2014-105.