Todd Energy Limited
Mangahewa-D Hydraulic Fracturing Monitoring Programme Report
2014-2016

Technical Report 2016-106

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Executive summary

This report for the period July 2014 to June 2016 outlines and discusses the results of the monitoring programme implemented by the Taranaki Regional Council (the Council) in relation to hydraulic fracturing activities conducted by Todd Energy Limited (Todd) at their Mangahewa-D wellsite. The wellsite is located on Rimutauteka Road, Inglewood and lies within the Waitara Catchment. This report also assesses Todd's level of environmental performance and compliance with the resource consents held in relation to the activity.

Todd hold resource consent 7912-2.1, authorising the discharge of water based hydraulic fracturing fluids into land at depths greater than 3,325 metres true vertical depth subsea (TVDss) beneath the Mangahewa-D wellsite. This consent was issued by the Council on 10 November 2015 replacing consent 7912-2 which was issued on 30 June 2014. Consent 7912-2.1 contains a total of 17 special conditions which set out the requirements that Todd must satisfy.

The programme of hydraulic fracturing undertaken by Todd at Mangahewa-D between July 2014 and June 2016 included the fracturing of four wells. The wells targeted for stimulation were Mangahewa-21, Mangahewa-22, Mangahewa-23, and Mangahewa-24.The hydraulic fracturing of these wells took place between June 2015 and January 2016.

During the monitoring period, the Company demonstrated an overall high level of environmental performance.

The programme of monitoring implemented by the Council in relation to hydraulic fracturing activities at the Mangahewa-D wellsite was initiated in 2011. This report details the results of monitoring conducted during the 2014–2015 and the 2015-2016 monitoring years. A previous report published by the Council covers the results of monitoring undertaken over the period 2011-2014.

The programme of monitoring implemented by the Council during the period being reported included pre and post discharge groundwater sampling. Biomonitoring surveys were also carried out to assess the impact of any site discharges during the fracturing programme on unnamed tributaries of the Manganui River. Samples of hydraulic fracturing fluids, and fluids returning to the wellhead post-fracturing, were also obtained for physicochemical analysis in order to characterise the discharges and to determine compliance with consent conditions.

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

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

For reference, in the 2015-2016 year, 71% of consent holders achieved a high level of environmental performance and compliance with their consents, while another 24% demonstrated a good level of environmental performance and compliance.

This report includes recommendations for the future monitoring of any hydraulic fracturing activities at the Mangahewa-D wellsite.

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1.1 Compliance monitoring programme reports and the Resource Management Act 1991

1.1.1 Introduction

This 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–D wellsite, over the period July 2014 to June 2016. The report also assesses Todd's level of environmental performance and compliance with the resource consent held in relation to the activity.

The programme of hydraulic fracturing undertaken by Todd at their Mangahewa-D wellsite included the hydraulic fracturing of four wells. The wells targeted for stimulation were the Mangahewa-21, Mangahewa-22, Mangahewa-23 and Mangahewa-24 wells.

The programme of monitoring implemented by the Council in relation to these hydraulic fracturing activities spanned the 2014-2015 and 2015-2016 monitoring years. Monitoring included a mixture of groundwater, surface water and discharge monitoring components. This is the second monitoring report produced by the Council in relation to the hydraulic fracturing activities at the Mangahewa-D wellsite. The first report covered the reporting years spanning July 2011 to June 2014.

1.1.2 Structure of this report

Section 1 of this report is a background section. It sets out general information about:

- the nature of the monitoring programme in place for the period under review; and
- a description of the activities and operations conducted in the Company's site/catchment.

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

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

Section 4 presents recommendations to be implemented in the 2016 - onwards monitoring period.

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

1.1.3 The Resource Management Act 1991 and monitoring

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

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

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

1.1.4 Evaluation of environmental and administrative performance

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

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

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

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

Environmental Performance

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

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

  For example:

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

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

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

Administrative performance

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

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

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

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

For reference, in the 2015-2016 year, 71% of consent holders in Taranaki monitored through tailored compliance monitoring programmes achieved a high level of environmental performance and compliance with their consents, while another 24% 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 conventional production techniques.

The process of hydraulic fracturing involves the pumping of fluids 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 can be assisted by the use of cross-linked gels (gel fracking) or turbulent flow (slick-water fracking).

Gel fracturing

Gel fracturing utilises cross-linked gel solutions, which are liquid at the surface but, when mixed, form long-chain polymer bonds and thus become viscous gels. These gels are used to transport the proppant into the formation. Once in the formation they 'break' back with time, temperature and the aid of gel breaking chemicals into a liquid state and are flowed back to surface, without disturbing the proppant which remains in place and enhances the flow of hydrocarbons back to the surface.

Slick water fracturing

Slick water fracturing utilises water based fracturing fluids with friction-reducing additives. The addition of the friction reducers allows the fracturing fluids and proppant to be pumped to the target zone at higher rates and reduced pressures, than when using water alone. The higher rate creates turbulence within the fluid column holding the proppant and enabling its placement into the open fractures and enhancing the flow of hydrocarbons back to the surface. [1]

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[1] *http://geology.com/energy/hydraulic-fracturing-fluids/*

Nitrogen gas assisted fracturing

Nitrogen gas assisted fracturing involves replacing some of the fluid used in the fracturing process with nitrogen gas, which can fracture rock at high pressures much like water. While nitrogen (N^2) is a gas at room temperature, it can be maintained in a liquid state through cooling and pressurisation. Nitrogen assisted fracking is extremely beneficial from a production standpoint as inevitably during the fracturing process some of the water pumped down the well remains underground in the rock formation, which can block some of the small pores inhibiting hydrocarbon recovery. Nitrogen gas achieves the same purpose as water but returns more easily to the surface. [2] More indirectly, a reduction in the volume of water used also reduces the total concentration of chemical additives required and the volume of water returning to the surface that requires subsequent disposal[2].

1.2.2 The Mangahewa-D wellsite and hydraulic fracturing activities

The Mangahewa-D wellsite is located on Rimutauteka Road, Inglewood and lies within the Waitara catchment. The area surrounding the site is rural in nature and farming and forestry activities co-exist with active petroleum exploration and production operations. The location of the wellsite is illustrated in Figure 1.

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

Table 1 Summary of hydraulic fracturing activity (July 2014 - June 2016)

Well	Fracturing date		Range Mid Point Injection zones (m TVD)	Formation
	Start	End		
Mangahewa-21	28/10/15	03/01/16	3,423 to 4,125	Kapuni Group
Mangahewa-22	24/06/15	31/07/15	3,530 to 4,110	Kapuni Group
Mangahewa-23	9/07/15	14/09/15	3,530 to 4,686	Kapuni Group
Mangahewa-24	18/08/15	11/01/16	3,358 to 4,021	Kapuni Group

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 were granted consent 7912-1, authorising discharge of contaminants into land in relation to hydraulic fracturing at the Mangahewa-D wellsite, on 9 September 2011 under Section 87(e) of the RMA. The consent contained a total of 11 special conditions which set out the requirements that Todd must satisfy. The hydraulic fracturing of the Mangahewa-04 well was undertaken under this version of the consent.

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[2] *http://frackwire.com/nitrogen-gas-fracking*

Prior to the hydraulic fracturing of the Mangahewa-07 and Mangahewa-16 wells, Todd voluntarily chose to vary consent 7912-1 to align the special conditions of the consent with the standard set of conditions being applied to hydraulic fracturing consents by the Council at that time. The standard conditions being imposed by the Council had evolved significantly since the issuing of the original version of consent 7912-1, to reflect international best practice. The revised conditions included requirements for the sampling and analysis of groundwater in the vicinity of the wellsite. Todd applied to renew the consent on 29 November 2013 and consent 7912-2 was granted on 30 June 2014.

The consent was subsequently varied on 10 November 2015 (7912-2.1) to include a change in consent conditions, enabling the use of liquid nitrogen in the hydraulic fracturing process.

Figure 1 Location map

The current consent 7912-2.1 has seventeen special conditions, as summarised below:

- Condition 1 stipulates the minimum depth below which the injection of hydraulic fracturing fluids must occur;
- Condition 2 stipulates the date before which discharge of hydraulic fracturing fluids must 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 (ground or surface water);
- Conditions 4, 5, 6 and 7 relate to fresh water monitoring requirements, to allow compliance with condition 3 to be assessed;
- Condition 8 requires the consent holder to carry out pressure testing of equipment prior to discharging;
- Condition 9 requires the consent holder to submit a pre-fracturing discharge report prior to any discharge occurring;
- Condition 10 is a notification requirement;
- Condition 11 requires the consent holder to submit a post-fracturing discharge report after the completion of the hydraulic fracturing programme for each well;
- Condition 12 stipulates how the reports required by conditions 9 and 11 are to be submitted;
- Condition 13 requires the consent holder to allow the Council access to a location where samples of hydraulic fracturing and return fluids can be obtained;
- Condition 14 requires the consent holder to adopt best practicable options;
- Condition 15 relates to the composition of the fracturing fluid;
- Condition 16 is a lapse clause; and
- Condition 17 is a review provision.

Copies of the consents valid during the reporting period are included in Appendix I.

1.4 Monitoring programme

1.4.1 Introduction

Section 35 of the RMA sets obligations upon the Council to gather information, monitor and conduct research on the exercise of resource consents within the Taranaki region. The Council is also required to assess the effects arising from the exercising of these consents and report upon them.

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-D 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 Assessment of data submitted by consent holder

As required by the conditions of consents 7912-2.1, Todd submitted pre and post-fracturing discharge reports to the Council for each well fractured during the period under review. Pre-fracturing discharge reports provide an outline of the proposed fracturing operations in relation to each well, while post-fracturing reports confirm details of what actually occurred. The specific range of information required in each report is stipulated in the conditions of the consent.

1.4.4 Physicochemical sampling

1.4.4.1 Groundwater

In order to select suitable sites for sampling, the Council carried out a well survey in the vicinity of the Mangahewa-D wellsite to identify any existing groundwater abstractions in the area. The surveys were undertaken within a defined area which extended 1 km radially from the wellsite.

One shallow well (GND2305) was identified on the opposite side of the Manganui River to the wellsite, as were two springs, one on the opposite side of the Manganui River to the wellsite (GND2304) and one located on the true right bank of the Manganui River (GND2306).

Unfortunately, the spring discharge GND2306 was only found to flow intermittently and therefore samples could not always be obtained when required. Several visits were undertaken in an attempt to take samples from the spring, often unsuccessfully. In addition, following a review of sampling locations at the end of the 2013 year, it was decided that sampling from GND2304 and GND2305 would be discontinued as they were deemed to be hydraulically disconnected from shallow groundwater underlying the Mangahewa-D wellsite by the Manganui River.

Given the lack of suitable monitoring sites for groundwater sampling, a request was made to Todd to install a suitable monitoring well in the vicinity of the Mangahewa-D wellsite. The well (GND2459) was installed in April 2014 and is now the sole groundwater sampling location incorporated in the monitoring programme for this site.

The details of all groundwater sites that were sampled over the course of the 2014-2016 reporting period are included in Table 2. Their location and proximity to the Mangahewa-D wellsite is illustrated in Figure 2.

Figure 2 Current and historical groundwater monitoring sites at Mangahewa-D

Table 2 Details of groundwater sites included in the monitoring programme

Monitoring site	Distance from wellsite (m)	Total depth (m)	Screened interval (m)	Aquifer
GND2306*	265	N/A	N/A	Volcanics
GND2459	58	30.5	11.5 – 27.5	Volcanics

* Spring

Samples of groundwater were obtained pre-fracturing to provide a baseline reference of groundwater composition, with further rounds of sampling carried out three months and one year after the cessation of activities.

The monitoring bore is also used by Todd for water supply purposes. This is achieved by installing a temporary pump in the bore when needed. The method used for groundwater sampling is dictated by the presence or absence of this pump. Where downhole access to the bore was available, samples were obtained using a pneumatic bladder pump, using a low-flow sampling methodology. If direct access to the bore was not available the bore was purged and samples were taken from an outlet pipe using the installed pump. Samples taken from the spring were obtained directly from the spring discharge. All samples were transported to Hill Laboratories Limited for analysis following standard chain of custody procedures.

1.4.4.2 Hydraulic fracturing and return fluids

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

Samples of hydraulic fracturing fluid were obtained from storage tanks on-site. While the fracturing fluid is predominantly comprised of water, specialised additives are used to either increase the viscosity (gel fracking) or turbulence (slick-water fracking) of the fluid in order to suspend the proppant prior to injection.

Samples of return fluids for each well were collected at regular intervals during the flow-back period. 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 fluid 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 individual samples of return fluid are generally combined in a composite sample for laboratory analysis. Composites are designed to provide a representative sample of fluids returning to the wellhead over the entire flow-back period.

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

1.5 Surface water quality monitoring

1.5.1 Biomonitoring surveys

Macroinvertebrate surveys were carried out on 28 August 2014, 18 May 2015, 26 May 2015 and 18 April 2016 at the Mangahewa-D wellsite to determine whether discharges relating to hydraulic fracturing and/or drilling activities undertaken during the reporting period at the wellsite had caused a detrimental effect upon the macroinvertebrate communities of unnamed tributaries of the Manganui River. The wellsite treated stormwater, uncontaminated site water and production water were discharged from a skimmer pit into an unnamed tributary of the Manganui River (Figure 3). The latest survey undertaken in April 2016 is discussed in this report. The previous surveys undertaken in April and August 2014 are discussed in the 2011-2014 hydraulic fracturing report. The May 2015 survey was undertaken in relation to drilling activities rather than hydraulic fracturing activities.

Taxa richness is the most robust index when determining whether a macroinvertebrate community has been exposed to toxic discharges. When exposed to toxic discharges, macroinvertebrates may die and be swept downstream or may deliberately drift downstream as an avoidance mechanism (catastrophic drift). The Macroinvertebrate Index (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 Semi-quantitative Macroinvertebrate Index (SQMCI) 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 MCI or SQMCI between sites indicate the degree of adverse effects (if any) of the discharges being monitored.

The details of each biomonitoring site included in the surveys are presented in Table 3. Their location and proximity to the Mangahewa-D wellsite is illustrated in Figure 3.

Table 3 Details of biomonitoring sites included in the monitoring programme

Site number	Site code	Grid reference (NZTM)	Location	Altitude (masl)
1	MGN000489	1711359E 5673793N	55 m upstream of confluence from Mangahewa-D wellsite discharge	60
2	MGN000491	1711322E 5673832N	90 m downstream of Mangahewa-D wellsite discharge point and 10m upstream of tributary confluence	60
3	MGN000492	1711376E 5673894N	60 m downstream of confluence from Mangahewa-D wellsite	60
4	MGN000493	1711392E 5673936N	100 m downstream of confluence from Mangahewa-D wellsite	60

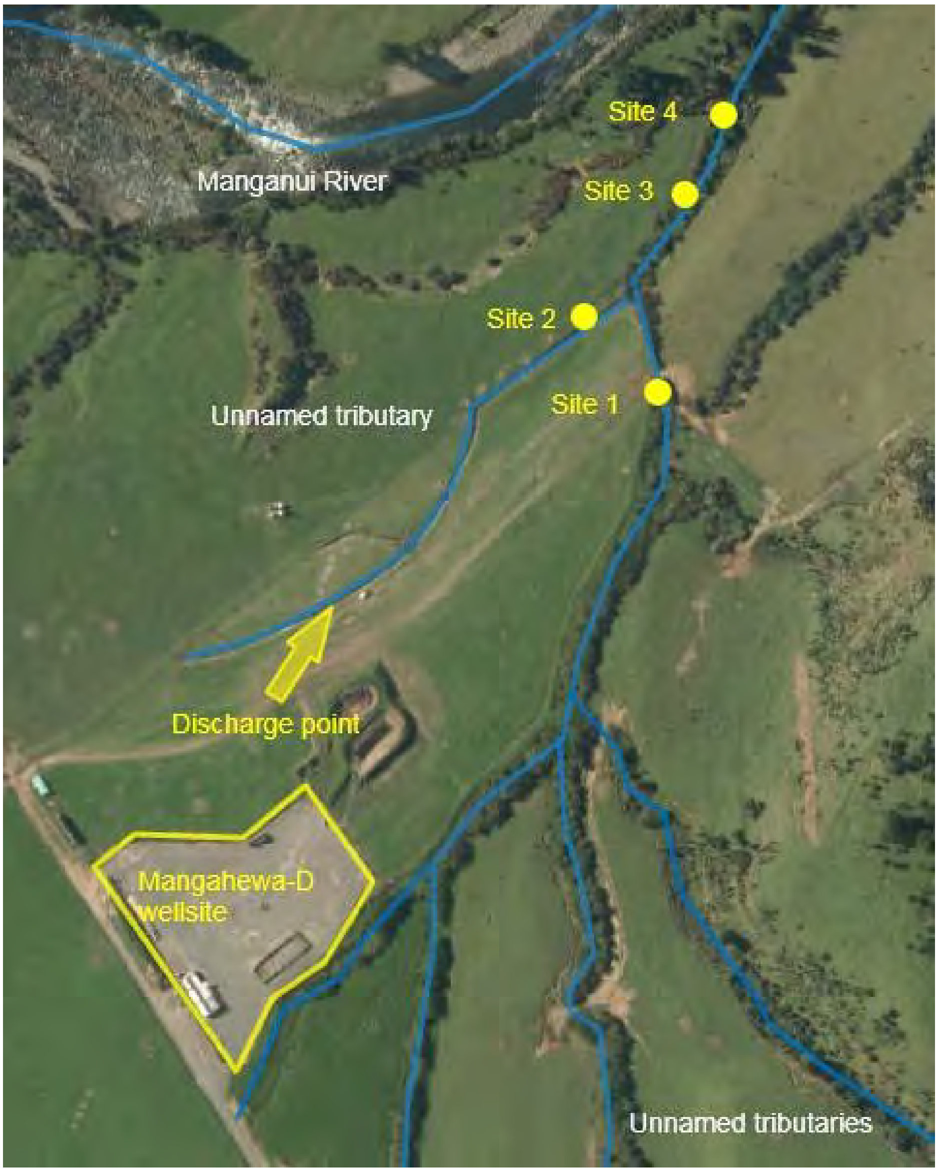

Figure 3 Location of biomonitoring sites in relation to the Mangahewa-D wellsite

2. Results

2.1 Consent holder submitted data

2.1.1 Mangahewa-21 post-fracturing discharge report

The conclusions from the Mangahewa-21 post-fracturing discharge report are summarised as follows:

- A total of ten discrete zones were fractured over the period 28 October 2015 to 3 January 2016 at depths between 3,423 to 4,125 m TVD.
- A total of 33,323 bbls (5,298 m^3) of liquid and 117,554 m^3 of nitrogen was discharged across the six fractured zones. The total proppant weight was 248 tonnes (542,168 lbs).
- By volume, 93.81% of the fluid injected was water, 1.31% was proppant, and 3.04% was nitrogen with the remaining 1.84% comprised of chemical additives.
- The Mangahewa-21 well was opened for flow-back following the completion of fracturing operations. In total, 23,719 bbls (3,771 m^3) of fluid was returned from the well over the initial flow-back period leaving approximately 9,604 bbls (1,527 m^3) or 29% of the fluids injected remaining in the formation. The remaining fluid is likely to be returned back to the surface as the well produces.
- Approximately 240.1 tonnes (529,311 lbs) or 98% of proppant remained within the formation after the completion of flow back.
- Nitrogen dissipates in to the formation and is returned over time as part of the gas produced.
- One screen out occurred while fracturing the MaB2u interval at 3,791 – 3,793 m TVD. Unexpected excessive fracture complexity was suspected as the primary cause of the change in pressure, which was relieved at the surface. A sweep/flush was undertaken to rectify the problem and no other remedial measures were required.
- All return fluid from the Mangahewa-21 fracturing operations was disposed of by deep well injection, via the McKee-A injection well under consent 4182-2, the McKee B injection well under consent 5052-2 and Tuhua-B injection well under consent 1315-1.
- The Christmas tree, tubing string, casing strings and wellhead maintained full integrity throughout the treatment.
- 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.

- 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-22 post-fracturing discharge report

The conclusions from the Mangahewa-22 post-fracturing discharge report are summarised as follows:

- A total of five discrete zones were fractured over the period 24 June to 31 July 2015, at depths between 3,676 to 4,089 m TVD.

- A total of 14,056 bbls (2,235 m^3) of liquid and 56,008 m^3 of nitrogen was discharged across the five fractured zones. The total proppant weight was 105 tonnes (231,809 lbs).

- By volume, 91.62% of the fluid injected was water, 1.17% was proppant, and 7.01% was nitrogen with the remaining 0.2% comprised of chemical additives.

- The Mangahewa-22 well was opened for flow-back following the completion of fracturing operations. In total, 12,243 bbls (1,946 m^3) of fluid was returned from the well over the initial flow-back period, leaving approximately 1,813 bbls (288 m^3) or 13% of the fluids injected remaining in the formation. Additional fluid is likely to be returned back to the surface as the well produces.

- Approximately 104.7 tonnes (230,852 lbs) or 99.6% of proppant remained within the formation after the completion of flow back.

- Nitrogen dissipates in to the formation and is returned over time as part of the gas produced.

- One screen out occurred while fracturing the MaA3l interval at a depth of 4,015 – 4,023 m TVD. Higher stress in the formation than initially modelled was the likely cause of the change in pressure, which was relieved at the surface. A reduction in nitrogen rate the use of a sweep stage and lower proppant loadings than those planned were used to rectify the problem.

- Another screen out occurred during the fracturing of MaA5l at a depth of 4,000 – 4,002 m TVD. Screen out occurred when the final proppant stage reached the perforations. Higher stress in the formation than initially modelled was the likely cause of the change in pressure. Pressure was maintained and at the end of the job was relieved at the surface. No other remediation measures were required.

- All return fluid from the Mangahewa-22 fracturing operations was disposed of by deep well injection, via the McKee-A injection well under consent 4182-2, the McKee B injection well under consent 5052-2 and Tuhua-B injection well under consent 1315-1.

- The Christmas tree, tubing string, casing strings and wellhead maintained full integrity throughout the treatment.

- 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.

- 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-23 post-fracturing discharge report

The conclusions from the Mangahewa-23 post-fracturing discharge report are summarised as follows:

- A total of nine discrete zones were fractured over the period 9 July to 14 September 2015, at depths between 3,530 to 4,110 m TVD.

- A total of 30,227 bbls (4,814 m^3) of liquid and 70,481 m^3 of nitrogen was discharged across the nine fractured zones. The total proppant weight was 272 tonnes (599,727 lbs).

- By volume, 90.63% of the fluid injected was water, 1.28% was proppant, and 6.30% was nitrogen with the remaining 1.8% comprised of chemical additives.

- The Mangahewa-23 well was opened for flow-back following the completion of fracturing operations. In total, greater than 13,868 bbls (2,205 m^3) of fluid was returned from the well over the initial flow-back period. A total flow-back volume cannot be determined as fluid returned after 14 August was comingled with fluid from other wells. Additional fluid after the initial flow-back is likely to be returned back to the surface as the well produces.

- Approximately 125.6 tonnes (276,981 lbs) or 99.1% of proppant remained within the formation after the completion of flow back.

- Nitrogen dissipates in to the formation and is returned over time as part of the gas produced.

- One screen out occurred while fracturing the MaA5u interval at a depth of 3,920 – 3,923 m TVD. Higher stress in the formation than initially modelled was the likely cause of the change in pressure, which was relieved at the surface. Screen out occurred towards the end of the proppant placement with proppant still being placed in the formation. No remediation measures were required.

- All return fluid from the Mangahewa-23 fracturing operations was disposed of by deep well injection, via the McKee-A injection well under consent 4182-2, the McKee B injection well under consent 5052-2 and Tuhua-B injection well under consent 1315-1.

- 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 Christmas tree, tubing string, casing strings and wellhead 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-24 post-fracturing discharge report

The conclusions from the Mangahewa-24 post-fracturing discharge report are summarised as follows:

- A total of seven discrete zones were fractured over the period 18 August 2015 to 11 January 2016, at depths between 3,358 to 4,021 m TVD.
- A total of 20,266 bbls (3,222 m^3) of liquid and 91,553 m^3 of nitrogen was discharged across the nine fractured zones. The total proppant weight was 187 tonnes (412,039 lbs).
- By volume, 92.73% of the fluid injected was water, 1.66% was proppant, and 3.78% was nitrogen with the remaining 1.8% comprised of chemical additives.
- The Mangahewa-24 well was opened for flow-back following the completion of fracturing operations. In total, 64,939 bbls (10,324 m^3) of fluid was returned from the well over the initial flow-back period. Additional fluid after the initial flow-back is likely to be returned back to the surface as the well produces.
- Approximately 181.6 tonnes (400,337 lbs) or 97.2% of proppant remained within the formation after the completion of flow back.
- Nitrogen dissipates in to the formation and is returned over time as part of the gas produced.
- One screen out occurred while fracturing the MaA4l interval at a depth of 3,984 – 3,986 m TVD. Higher stress in the formation than initially modelled was the likely cause of the change in pressure, which was relieved at the surface. Screen out occurred towards the end of the proppant placement with approximately 1,000 lbs of proppant remaining in the well. No remediation measures were required.
- All return fluid from the Mangahewa-23 fracturing operations was disposed of by deep well injection, via the McKee-A injection well under consent 4182-2, the McKee B injection well under consent 5052-2 and Tuhua-B injection well under consent 1315-1.
- 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 Christmas tree, tubing string, casing strings and wellhead 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 Physicochemical sampling

2.2.1 Groundwater

The recent hydraulic fracturing activities commenced at Mangahewa-D (wells MHW-21-24) in June 2015. Pre-fracturing sampling was undertaken on 27 May 2015 at two sites GND2459 and an alternate spring site close to GND2306, which was to dry to sample during the monitoring round. Hydraulic fracturing continued over several months until January 2016. A three month post-fracturing sample was undertaken on 14 April 2016 at GND2459. No sample was taken from GND2306 due to the on-going difficulties sampling this site, which was subsequently removed from the programme. The one year post-fracturing sampling was undertaken on 26 January 2017 (Table 4).

Table 4 Groundwater sampling undertaken for the 2014-2016 reporting period

Well	Fracturing date		Pre-fracturing sample date	3 month post-fracturing sample date	One year post-fracturing sample date
	Start	End			
Mangahewa-21	28/10/15	03/01/16	27/05/2015	14/04/2016	26/01/2017
Mangahewa-22	24/06/15	31/07/15	27/05/2015	14/04/2016	26/01/2017
Mangahewa-23	09/07/15	14/09/15	27/05/2015	14/04/2016	26/01/2017
Mangahewa-24	18/08/15	11/01/16	27/05/2015	14/04/2016	26/01/2017

The results of the laboratory analysis of samples from all sites sampled since activities began indicate there have been no significant changes in groundwater composition since monitoring commenced. This is demonstrated by the relatively narrow ranges between minimum and maximum analyte concentrations over time. The subtle variation in analyte concentrations at each site are a result of natural seasonal fluctuation and sampling variability.

A low level detection of toluene was recoded following sampling of site GND2459 during August 2014. It is important to note that the concentration was extremely low, at part per billion levels, well below the guideline value stipulated for toluene in the Drinking-water Standards for New Zealand (2008). No toluene was detected at this site during any previous or subsequent monitoring.

Low concentrations of methane were detected in the majority of samples taken at GND2459. Samples taken in August 2014 and July 2015 were sent to GNS for further analysis. Isotopic analysis of the dissolved methane within the samples analysed by GNS indicates the methane gas is neither strongly biogenic, nor strongly thermogenic, but potentially of mixed origin. The source of the methane contained in the sample taken in April 2016 could not be verified as the sample was damaged during storage. However isotopic analysis from this sample would be expected to be similar to those previously reported and concentrations from all samples were all within the expected ranges for shallow groundwater across Taranaki.

A full summary of results for all groundwater samples taken in relation to hydraulic fracturing of the Mangahewa-D wellsite is included below in Table 6. The certificates of analysis for the review period are included in Appendix II.

Table 5 Results of groundwater sampling carried out in relation to the Mangahewa-D fracturing events 2012-2016

Parameter	Unit	GND2305			GND2306		Unnamed Spring	GND2459				
		Baseline	Post-frac	Post-frac	Baseline	Post-frac	Pre-frac	Baseline	Post-frac Pre-frac	Pre-frac	Post-frac (3 month)	Post-frac (1 year)
Sample date		31/10/2012	13/05/2013	13/08/2013	31/10/2012	02/10/2013	27/05/2015	01/05/2014	26/08/2014	27/05/2015	14/04/2016	26/01/2017
Lab number	TRC	TRC123684	TRC136049	TRC136757	TRC123682	TRC137177	TRC151846	TRC149933	TRC1410894	TRC151847	TRC161447	TRC170590
Total alkalinity	g/m^3 CaCO3	21	19.2	18.8	37	34	31	99	112	93	95	98
Barium	mg/kg	0.05	0.049	0.053	0.027	0.028	0.025	0.024	0.0172	0.0085	0.0104	0.0147
Benzene	g/m^3	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0010	<0.001	<0.001	<0.0010	<0.0010	<0.0010
Dissolved bromine	g/m^3	-	-	0.067	-	0.035	0.034	0.059	0.05	0.054	0.123	0.136
Calcium	g/m^3	9.7	8.6	9	13.2	13	12.4	13	10.1	10.4	10.2	9.2
Chloride	g/m^3	18.5	19.8	20	8.3	8.6	9.9	12.8	12.7	12.9	14.2	15.9
Conductivity	mS/m@20ºC	14.3	14.1	14.8	12.1	12.6	12.6	23.1	25.2	21.7	23	24.2
Dissolved copper	g/m^3	0.0006	0.0013	0.0007	<0.0005	<0.0005	<0.0005	0.0023	0.0014	0.001	0.0017	0.0026
Ethylbenzene	g/m^3	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0010	<0.001	<0.001	<0.0010	<0.0010	<0.0010
Ethane	g/m^3	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.005	<0.003	<0.003	<0.003
Ethylene	g/m^3	<0.004	<0.004	<0.004	<0.004	<0.003	<0.003	<0.003	<0.003	<0.003	<0.004	<0.003
Dissolved iron	g/m^3	<0.02	<0.02	<0.02	<0.02	<0.02	0.13	2.5	2.5	3.2	1.4	1.78
Formaldehyde	g/m^3	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.03	<0.02	<0.02	<0.02
Ethylene glycol	g/m^3	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Hydrocarbons	g/m^3	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
Bicarbonate	g/m^3 HCO_3	26	23	23	45	42	37	121	137	113	115.9	118
Total hardness	g/m^3 $CaCO_3$	33	29	31	40	39	38	54	45	45	42	38
Dissolved mercury	g/m^3	-	-	<0.00008	-	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008
Potassium	g/m^3	18.9	5.2	5.6	2.7	2.4	2.1	5.5	5.3	4.9	5.4	5.0
Methanol	g/m^3	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2

Parameter	Unit	GND2305			GND2306		Unnamed Spring	GND2459				
		Baseline	Post-frac	Post-frac	Baseline	Post-frac	Pre-frac	Baseline	Post-frac Pre-frac	Pre-frac	Post-frac (3 month)	Post-frac (1 year)
Sample date		31/10/2012	13/05/2013	13/08/2013	31/10/2012	02/10/2013	27/05/2015	01/05/2014	26/08/2014	27/05/2015	14/04/2016	26/01/2017
Lab number	TRC	TRC123684	TRC136049	TRC136757	TRC123682	TRC137177	TRC151846	TRC149933	TRC1410894	TRC151847	TRC161447	TRC170590
Methane	g/m^3	<0.002	<0.002	<0.002	<0.002	<0.002	0.005	0.46	13.7	<4.6	3.5	0.45
δ13C value*	‰	-	-	-	-	-		-	-53	-58.6	-	_
Magnesium	g/m^3	2.1	1.73	2	1.6	1.6	1.58	5.2	4.7	4.5	4	3.7
Dissolved manganese	g/m^3	0.0013	0.0012	0.0016	<0.0006	0.0008	0.0188	0.2	0.24	0.25	0.22	0.43
Sodium	g/m^3	11.1	11.9	12.1	7.1	7.5	7.9	24	37	28	36	34
Nickel	mg/kg	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0008	0.0005	<0.0005	<0.0005	0.0044
Nitrate & nitrite nitrogen	g/m^3 N	2.6	2.4	3	0.69	1.47	2.2	0.044	<0.002	<0.002	0.26	0.088
Nitrite nitrogen	g/m^3 N	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.041	<0.002	<0.002	0.004	0.003
Nitrate nitrogen	g/m^3 N	2.6	2.4	3	<0.69	1.47	2.2	0.003	<0.002	<0.002	0.26	0.085
pH	pH	5.9	6.3	6.2	6.8	6.5	7.4	7.4	7.3	7.2	7.1	7.6
Propylene glycol	g/m^3	-	-	<4	-	<4	<4	<4	<4	<4	<4	<4
Sulphate	g/m^3	6.1	5.5	5.7	7.2	6.3	5.5	1.2	<0.5	1.6	1.1	0.7
Total dissolved solids	g/m^3	82	100	104	110	103	101	145	179	179	178	194
Toluene	g/m^3	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0010	<0.001	0.007	<0.0010	<0.0010	<0.0010
o-Xylene	g/m^3	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0010	<0.001	<0.001	<0.0010	<0.0010	<0.0010
m-Xylene	g/m^3	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Dissolved zinc	g/m^3	0.0061	0.0139	0.011	<0.001	<0.001	0.0013	0.04	1.98	0.46	0.05	0.053
Bromide	g/m^3	0.07	0.1	-	-	-	-	-	-	-	-	

* A value >-50‰ indicates thermogenic methane, a value <-50‰ indicates biogenic methane.

Note: Pre-fracturing and Post-fracturing groundwater monitoring results from the most recent HF activities are highlighted

2.2.2 Hydraulic fracturing and return fluids

The results of the analyses carried out on samples of the hydraulic fracturing fluid used in the treatment of the Mangahew-22 and Mangahewa-23 wells are shown below in Table 6. All hydraulic fracturing undertaken during the 2014–2016 reporting period utilised similar fluid. The certificates of analysis are included in Appendix III.

Table 6 Results of hydraulic fracturing fluid sampling

Parameter	Unit	Mangahewa-22	Mangahewa-23
		GND2523	GND2524
Sample date	-	27/07/2015	29/08/2015
Lab number	-	TRC152896	TRC153440
Benzene	g/m^3	<0.0010	<0.0010
Ethylbenzene	g/m^3	<0.0010	<0.0010
Ethylene glycol	g/m^3	<4	<4
Total hydrocarbons	g/m^3	74	13.3
Methanol	g/m^3	<2	<2
Propylene glycol	g/m^3	78	66
Toluene	g/m^3	0.0022	<0.0010
o-Xylene	g/m^3	0.0012	<0.0010
m-Xylene	g/m^3	<0.002	<0.002

The results of the analyses carried out on the return fluid samples obtained following the hydraulic fracturing of the Mangahewa-21, Manhgahewa-22, Mangahewa-23 and Mangahewa-24 wells are summarised below in Table 7 and certificates of analysis are included in Appendix III. Return fluid samples generally contain a composite of samples collected at different intervals during the flow back period. The relatively high levels of chloride, sodium and hydrocarbons in each sample indicate that the composite samples prepared contained a greater proportion of reservoir fluids than fluids introduced during fracturing activities (comprised predominantly of freshwater). A reduced number of parameters were analysed in the return fluid samples at the Mangahewa-21 well due to an administrative issue. However, both the range and concentrations of analytes in the reservoir at this location are expected to be within the range of those recorded during flow back of the other Mangahewa-D wells. The samples collected at the Mangahewa-21 well illustrate how the composition of the return fluid changes during flow back of the well. The samples show an increase in hydrocarbon concentrations as the fracturing fluid is removed and the samples become predominantly reservoir fluids.

Table 7 Results of hydraulic fracturing return fluid sampling

Parameter	Unit	Mangahewa-22	Mangahewa-22	Mangahewa-24	Mangahewa-23	Mangahewa-21	Mangahewa-21	Mangahewa-21	Mangahewa-21
		GND2523	GND2523	GND2525	GND2524	GND2522	GND2522	GND2522	GND2522
Sample date		27/06/2015	27/07/2015	18/08/2015	21/09/2015	28/10/2015	14/11/2015 06:55 am	14/11/2015 11:55 am	14/11/2015 05:40 pm
Lab number		TRC152897	TRC152915	TRC152899	TRC152898	TRC153968	TRC160442	TRC160443	TRC160444
Total alkalinity	g/m^3 CaCO$_3$	490	330	118	450				
Barium	mg/kg	112	25	0.5	8.1				
Benzene	g/m^3	2.1	3.5	<0.0010	10.9	<0.0010	0.24	0.073	0.083
Bromide	g/m^3	28	24	24	8.4				
Calcium	g/m^3	200	54	15	360				
Chloride	g/m^3	14,600	14,900	15,300	5,500				
Conductivity	mS/m@20C	4,240	4,940	5,420	1,798				
Dissolved copper	g/m^3	0.008	0.007	0.012	0.034				
Ethylbenzene	g/m^3	0.041	0.5	<0.0010	1.04	<0.0010	0.0119	0.0095	0.0097
Dissolved iron	g/m^3	0.7	1.09	0.12	38				
Formaldehyde	g/m^3	<0.15	0.4	0.85	<1.5				
Ethylene glycol	g/m^3	<4	<4	<4	124	<4	<4	50	42
Hydrocarbons	g/m^3	83	187	52	185	24	<4	46	35
Bicarbonate	g/m^3 HCO$_3$	432	348	117	350				
Total hardness	g/m^3 CaCO$_3$	590	230	84	950				
Dissolved mercury	g/m^3	<0.011	<0.011	<0.011	<0.011				
Potassium	g/m^3	8,900	13,700	16,800	2,500				
Methanol	g/m^3	2,100	<20	<2	,1840	<20	<2	3	<2
Magnesium	g/m^3	20	23	11	10				
Dissolved manganese	g/m^3	2.9	1.32	0.149	2.6				

Parameter	Unit	Mangahewa-22	Mangahewa-22	Mangahewa-24	Mangahewa-23	Mangahewa-21	Mangahewa-21	Mangahewa-21	Mangahewa-21
		GND2523	GND2523	GND2525	GND2524	GND2522	GND2522	GND2522	GND2522
Sample date		27/06/2015	27/07/2015	18/08/2015	21/09/2015	28/10/2015	14/11/2015 06:55 am	14/11/2015 11:55 am	14/11/2015 05:40 pm
Lab number		TRC152897	TRC152915	TRC152899	TRC152898	TRC153968	TRC160442	TRC160443	TRC160444
Sodium	g/m^3	3,700	1,670	320	1,650				
Nickel	mg/kg	0.11	0.07	<0.03	0.49				
Nitrate & nitrite nitrogen	g/m^3 N	<0.2	<0.02	0.09	0.02				
Nitrite nitrogen	g/m^3 N	<0.2	<0.02	<0.02	<0.02				
Nitrate nitrogen	g/m^3 N	<0.2	<0.02	0.08	0.02				
pH	pH	7.6	7	7.1	7				
Dissolved sulphur	g/m^3	147	78	330	210				
Sulphate	g/m^3	440	230	110	70				
Propylene glycol	g/m^3	6	14	62	1,410	<4	<4	126	77
Toluene	g/m^3	0.79	5.5	0.0011	11.6	0.0012	0.097	0.043	0.05
o-Xylene	g/m^3	0.172	1.44	<0.0010	2.1	<0.0010	0.058	0.057	0.063
m-Xylene	g/m^3	0.26	3.9	<0.002	4.9	<0.002	0.062	0.052	0.058
Dissolved zinc	g/m^3	0.25	0.15	0.09	0.3				
Temperature	^{o}C	22	23	23	22				
Total dissolved solids	g/m^3	28,000	31,000	33,000	13,400				

2.3 Biomonitoring surveys

A macroinvertebrate survey was carried out at the Mangahewa-D wellsite in April 2016 to determine whether discharges relating to hydraulic fracturing activities undertaken during January 2016 at the wellsite had caused a detrimental effect upon macroinvertebrate communities of two unnamed tributaries of the Manganui River. The wellsite treated stormwater, uncontaminated site water and production water were discharged from a skimmer pit into an unnamed tributary of the Manganui River.

A macroinvertebrate survey was undertaken on 18 April 2016, using the Council's 'kick sampling' and 'vegetation sweep' techniques to collect samples at three sites. A further site could not be sampled at this time due to low flow conditions. Taxa richnesses at site 21, 13 and 13 were recorded at sites 1, 3 and 4 respectively. The higher taxa richness at site 1 was in part due to a very high number of rare taxa recorded at this site.

MCI scores of 83, 71 and 68 units were recorded at sites 1, 3 and 4 respectively. Site 1 had a significantly higher score than either site 3 or site 4 (which were not significantly different from each other). $SQMCI_s$ scores of 3.6, 3.5 and 2.6 units were recorded at sites 1 and 3 (which were not significantly different from each other). The lower score at site 4 can be attributed directly to an increased abundance of ogliochete worms, which is associated with a higher proportion of silt substrate. These differences in invertebrate metrics are most likely related to habitat differences, rather than to discharges from Mangahewa-D wellsite.

There was no evidence that discharges from activity at the Mangahewa-D wellsite had caused any detrimental effects on two unnamed tributaries of the Manganui River. Observed differences in invertebrate metrics between sites are considered to be a result of habitat differences between sites and low flow conditions at the time of the survey.

A full report on the biomonitoring carried out in the vicinity of the wellsite and previous surveys undertaken in 2014 and 2015 are included in Appendix IV.

2.4 Investigations, interventions, and incidents

The monitoring programme for the 2014-2016 reporting period was based on what was considered to be an appropriate level of monitoring, review of data, and liaison with the consent holder. During the year matters may arise which require additional activity by the Council, for example provision of advice and information, or investigation of potential or actual causes 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, the Council was required to undertake additional investigations to assess Todd's compliance with consent conditions. Consultation was required in regard to the changes in fracturing fluid composition and the subsequent variation of the hydraulic fracturing consent.

Due to changes in fracturing fluid composition (the addition of nitrogen gas to fracturing fluids) and the limitations on fracture fluid composition imposed by consent condition 15, the condition was breached during some of the hydraulic fracturing activities at Mangahewa-22, Mangahewa-23 and Mangahewa-24 wells. The issues arising from the change in fracturing fluid composition were discussed with Todd and a consent variation was applied for and granted on 10 November 2015 to avoid any further issues.

No other action was deemed necessary as the addition of nitrogen to the hydraulic fracturing process is seen as a positive change, as discussed in Section 1.2.1, with no detrimental environmental effects expected.

3. Discussion

3.1 Environmental effects of hydraulic fracturing on useable freshwater resources

A total of four wells were stimulated by hydraulic fracturing at the Mangahewa-D wellsite between July 2014 and June 2016. As listed below in Table 8.

Table 8 Simulated wells hydraulic fracturing schedules

Well	Fracturing date	
	Start	End
Mangahewa-21	28/10/15	03/01/16
Mangahewa-22	24/06/15	31/07/15
Mangahewa-23	09/07/15	14/09/15
Mangahewa-24	18/08/15	11/01/16

Monitoring carried out by the Council in relation to the fracturing events undertaken since July 2014 included both groundwater and surface water monitoring components. Groundwater monitoring incorporated pre and post-fracturing sampling of a monitoring well installed by Todd and pre-sampling of an unnamed spring in the local vicinity of the Mangahewa-D wellsite.

The results of post-fracturing groundwater sampling carried out showed only very minor variations in water composition in comparison to baseline and historical results. The minor variations in most analytes are a result of natural variations in water composition.

A low level detection of toluene was detected during August 2014 and low concentrations of methane in all samples have been detected in GND2459. No toluene has been detected in this bore prior to or subsequent to the anomalous result.

The source of the methane was investigated after the August 2014 and May 2015 results and was found to be neither strongly biogenic or thermogenic.

The surface water monitoring component of the programme comprised of biomonitoring surveys of two unnamed tributaries of the Manganui River pre and post-fracturing of the wells during January 2016.

The results of the biomonitoring surveys undertaken in relation to the Mangahewa-D fracturing events during the 2014-2016 reporting period indicate that site activities had no adverse effects on local surface water resources.

In summary, the monitoring carried out by the Council during the period being reported indicates that the hydraulic fracturing activities undertaken by Todd at the Mangahewa-D wellsite has had no significant adverse effects on local groundwater or surface water resources.

3.2 Evaluation of performance

A tabular summary of the consent holder's compliance record for the period under review is set out in Tables 9.

Table 9 Summary of performance for Consent 7912-2.1

Purpose: ***To discharge water based hydraulic fracturing fluids into land at depths greater than 3,325 metres true vertical depth subsea (TVDss) beneath the Mangahewa-D wellsite***		
Condition requirement	**Means of monitoring during period under review**	**Compliance achieved?**
1. Any discharge shall occur below 3,325 mTVDss	Assessment of consent holder submitted data	yes
2. No discharge after 1 June 2019	Assessment of consent holder submitted data	yes
3. Exercise of consent shall not result in any contaminants reaching any useable freshwater (groundwater or surface water)	Results of groundwater and surface water monitoring	yes
4. Consent holder shall undertake sampling programme	Development and certification of a monitoring programme	yes
5. Installation of a suitable monitoring bore if required		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 after the hydraulic fracturing programme is completed	Post-fracturing discharge report received	yes
12. The reports outlined in conditions 9 and 11 must be emailed to consents@trc.govt.nz	Reports received via email	yes
13. The consent holder shall provide access to a location where samples of hydraulic fracturing fluids and return fluids can be obtained by the Council officers	Access provided	yes

Purpose: *To discharge water based hydraulic fracturing fluids into land at depths greater than 3,325 metres true vertical depth subsea (TVDss) beneath the Mangahewa-D wellsite*		
Condition requirement	**Means of monitoring during period under review**	**Compliance achieved?**
14. Consent holder to adopt best practicable option at all times	Site inspections, sampling and assessment of consent holder submitted data	yes
15. Fracture fluid composition by volume limits	Assessment of consent holder submitted data and sampling of fracturing fluid	partially
16. Lapse of consent		N/A
17. 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		**Good**

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 Recommendations from the 2011-2014 Annual Report

In the 2011-2014 Monitoring Report, it was recommended:

1. THAT during the 2014-2015 monitoring year, a further round of groundwater sampling be carried out to assess any delayed effects of hydraulic fracturing activities at the Mangahewa-D wellsite on local groundwater resources. The results of this sampling round will dictate whether any further sampling is required.

2. THAT the option for a review of consent 7912-2 in June 2015, as set out in conditions of the consent, is not exercised, on the grounds that the current conditions are adequate to ensure that any significant adverse effects on the environment are avoided.

These recommendations were implemented.

3.4 Alterations to monitoring of future hydraulic fracturing events

In designing and implementing the monitoring programmes for air/water discharges in the region, the Council has taken into account:

- the extent of information made available by previous authorities,
- its relevance under the RMA;
- its obligations to monitor emissions/discharges and effects under the RMA; and
- report to the regional community.

The Council also takes into account the scope of assessments required at the time of renewal of permits, and the need to maintain a sound understanding of industrial processes within Taranaki emitting to the atmosphere/discharging to the environment.

It is proposed that the range of monitoring carried out during the 2014-2016 period in relation to the Company's activities be replicated for any future fracturing events at the Mangahewa-D wellsite.

Recommendations to this effect are included in Section 4 of this report.

3.5 Exercise of optional review of consent

The next optional review dates for consents 7912-2.1 is provided for in June 2017.

The Council may serve notice of its intention to review, amend, delete or add to the conditions of this resource consent. A review may be required for the purpose of ensuring that the conditions are adequate to deal with any adverse effects on the environment arising from the exercise of this resource 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.

Based on the results of monitoring carried out in the period under review, and in previous years as set out in earlier compliance monitoring reports, it is considered that there are no grounds to require a consent review to be pursued or grounds to exercise the review options. A recommendation to this effect is presented in Section 4 of this report.

4. Recommendations

1. THAT the range of monitoring carried out during the 2014-2016 reporting period in relation to the Company's hydraulic fracturing activities be replicated for any future fracturing events at the Mangahewa-D wellsite.

2. THAT the Council notes there is no requirement at this time for a consent review to be pursued or grounds to exercise the review options.

Glossary of common terms and abbreviations

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

Biomonitoring	Assessing the health of the environment using aquatic organisms.
bbls	Barrel. Unit of measure used in the oil and gas industry (equivalent to approximately 159 litres).
Fresh	Elevated flow in a stream, such as after heavy rainfall.
g/m3	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.
Physicochemical	Measurement of both physical properties (e.g. temperature, clarity, density) and chemical determinants (e.g. metals and nutrients) to characterise the state of an environment.
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.
Screen Out	A condition that occurs when the solids carried in a treatment fluid, such as proppant in a fracture fluid, create a bridge across the perforations or similar restricted flow area. This creates a sudden and significant restriction to fluid flow that causes a rapid rise in pump pressure.
SQMCI	Semi quantitative macroinvertebrate community index.
TVDss	True vertical depth sub-sea
Workover	The repair or stimulation of an existing production well for the purpose of restoring, prolonging or enhancing the production of hydrocarbons.

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Thomas BT, 2014: Biomonitoring of an unnamed tributary of the Manganui River before and after hydraulic fracturing at Mangahewa D wellsite by Todd Energy Ltd, April 2014 & August 2014. (BT037).

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Taranaki Regional Council, (2016). Biomonitoring of two unnamed tributaries of the Manganui River in relation to hydraulic fracturing by Todd Energy Ltd at the Mangahewa-D wellsite, April 2016. Report KB010.

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Ministry of Health, (2008). *Drinking-water Standards for New Zealand* 2005 (Revised 2008). Wellington, Ministry of Health.

Appendix I
Resource consents held by Todd Company Limited

(For a copy of the signed 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 PO Box 802 New Plymouth 4340
Decision Date (Change):	10 November 2015
Commencement Date (Change):	10 November 2015 (Granted Date: 30 June 2014)

Conditions of Consent

Consent Granted:	To discharge water based hydraulic fracturing fluids into land at depths greater than 3325 mTVDss beneath the Mangahewa-D wellsite
Expiry Date:	1 June 2024
Review Date(s):	June Annually
Site Location:	Mangahewa-D wellsite, Rimutauteka Road, New Plymouth (Property owner: KV & SJ Collins)
Legal Description:	Rimutauteka 1A Blk X Waitara SD (Discharge source & site)
Grid Reference (NZTM)	1711150E-5673520N
Catchment:	Waitara
Tributary:	Manganui

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

General condition

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

Special conditions

1. The discharge point shall be deeper than 3325 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 after 1 June 2019.

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

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

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

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

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

   (a) pH;
   (b) conductivity;
   (c) total dissolved solids;
   (d) major ions (Ca, Mg, K, Na, total alkalinity, bromide, chloride, nitrate-nitrogen, and sulphate);
   (e) trace metals (barium, copper, iron, manganese, nickel, and zinc);
   (f) total petroleum hydrocarbons;
   (g) formaldehyde;
   (h) dissolved methane and ethane gas;
   (i) methanol;
   (j) glycols;
   (k) benzene, toluene, ethylbenzene, and xylenes (BTEX);
   (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. The plan shall specify the use of standard protocols recognised to constitute good professional practice including quality control and assurance. An International Accreditation New Zealand (IANZ) accredited laboratory shall be used for all sample analysis. Results shall be provided to the Chief Executive within 30 days of sampling and shall include supporting quality control and assurance information. These results will be used to assess compliance with condition 3.

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

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

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

   (a) the specific well in which each discharge is to occur, the intended fracture interval(s) ('fracture interval' is the discrete subsurface zone to receive a hydraulic fracture treatment), and the duration of the hydraulic fracturing programme;
   (b) the number of discharges proposed and the geographical position (i.e. depth and lateral position) of each intended discharge point;
   (c) the total volume of fracture fluid planned to be pumped down the well, including mini- fracture treatments, and their intended composition, including a list of all contaminants and Material Safety Data Sheets for all the chemicals to be used;
   (d) the monitoring techniques to be used to determine the fate of discharged material;
   (e) the results of the reviews required by condition 14;
   (f) results of modelling showing an assessment of the likely extent and dimensions of the fractures that will be generated by the discharge;
   (g) the preventative and mitigation measures to be in place to ensure the discharge does not cause adverse environmental effects and complies with condition 3;
   (h) the extent and permeability characteristics of the geology above the discharge point to the surface;
   (i) any identified faults within the modeled 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 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 14.

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

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

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

    (a) date and time of discharge;
    (b) confirmation of the interval(s) where fracturing occurred for that programme, and the geographical position (i.e. depth and lateral position) of the discharge point for each fracture interval;
    (c) the contaminant volumes and composition of fluid discharged into each fracture interval;
    (d) the volume of return fluids from each fracture interval;
    (e) an analysis for the constituents set out in conditions 6(a) to 6(k), in a return fluid sample taken within the first two hours of flow back, for each fracture interval if flowed back individually, or for the well if flowed back with all intervals comingled;
    (f) an estimate of the volume of fluids (and proppant) remaining underground;
    (g) the volume of water produced with the hydrocarbons (produced water) over the period beginning at the start of the hydraulic fracturing programme and ending 50 days after the programme is completed or after that period of production;
    (h) an assessment of the extent and dimensions of the fractures that were generated by the discharge, based on modelling undertaken after the discharge has occurred and other diagnostic techniques, including production analysis, available to determine fracture length, height and containment;
    (i) the results of pressure testing required by condition 8, and the top hole pressure (psi), slurry rate (bpm), surface proppant concentration (lb/gal), bottom hole proppant concentration (lb/gal), and calculated bottom hole pressure (psi), as well as predicted values for each of these parameters; prior to, during and after each hydraulic fracture treatment;
    (j) details of the disposal of any returned fluids, including any consents that are relied on to authorise the disposal;
    (k) details of any incidents where hydraulic fracture fluid is unable to pass through the well perforations (screen outs) that occurred, their likely cause and implications for compliance with conditions 1 and 3; and
    (l) results of the monitoring referred to in condition 9 (d);
    (m) an assessment of the effectiveness of the mitigation measures in place with specific reference to those described in the application for this consent.

    Note: *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.*

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 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.

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

16. This consent shall lapse on 30 June 2019, 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.

17. 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 10 November 2015

For and on behalf of
Taranaki Regional Council

A D McLay
Director – Resource Management

Appendix II

Please contact Todd Energy for details

Appendix III

Certificates of analysis (groundwater)

Hill Laboratories
BETTER TESTING BETTER RESULTS

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

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

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1316723 SPv1
Contact:	Regan Phipps	**Date Registered:**	27-Aug-2014
	C/- Taranaki Regional Council	**Date Reported:**	04-Sep-2014
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	Mangehewa D Post HF GW
		Submitted By:	Regan Phipps

Sample Type: Aqueous

Sample Name:		GND2459 26-Aug-2014 10:04 am				
Lab Number:		1316723.1				
Individual Tests						
Sum of Anions	meq/L	2.6	-	-	-	-
Sum of Cations	meq/L	2.8	-	-	-	-
pH	pH Units	7.3	-	-	-	-
Total Alkalinity	g/m^3 as $CaCO_3$	112	-	-	-	-
Bicarbonate	g/m^3 at 25°C	137	-	-	-	-
Total Hardness	g/m^3 as $CaCO_3$	45	-	-	-	-
Electrical Conductivity (EC)	mS/m	25.2	-	-	-	-
Total Dissolved Solids (TDS)	g/m^3	179	-	-	-	-
Dissolved Barium	g/m^3	0.0172	-	-	-	-
Dissolved Bromine*	g/m^3	0.050	-	-	-	-
Dissolved Calcium	g/m^3	10.1	-	-	-	-
Dissolved Copper	g/m^3	0.0014	-	-	-	-
Dissolved Iron	g/m^3	2.5	-	-	-	-
Dissolved Magnesium	g/m^3	4.7	-	-	-	-
Dissolved Manganese	g/m^3	0.24	-	-	-	-
Dissolved Mercury	g/m^3	< 0.00008	-	-	-	-
Dissolved Nickel	g/m^3	0.0005	-	-	-	-
Dissolved Potassium	g/m^3	5.3	-	-	-	-
Dissolved Sodium	g/m^3	37	-	-	-	-
Dissolved Zinc	g/m^3	1.98	-	-	-	-
Chloride	g/m^3	12.7	-	-	-	-
Nitrite-N	g/m^3	< 0.002	-	-	-	-
Nitrate-N	g/m^3	< 0.002	-	-	-	-
Nitrate-N + Nitrite-N	g/m^3	< 0.002	-	-	-	-
Sulphate	g/m^3	< 0.5	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m^3	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m^3	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m^3	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m^3	< 0.0010	-	-	-	-
Toluene	g/m^3	0.0070	-	-	-	-
Ethylbenzene	g/m^3	< 0.0010	-	-	-	-
m&p-Xylene	g/m^3	< 0.002	-	-	-	-

ilac-MRA 823 365 laboratory

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

Sample Type: Aqueous

Sample Name:		GND2459 26-Aug-2014 10:04 am				
Lab Number:		1316723.1				
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m^3	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m^3	0.03	-	-	-	-
Gases in groundwater						
Ethane	g/m^3	0.005	-	-	-	-
Ethylene	g/m^3	< 0.003	-	-	-	-
Methane	g/m^3	13.7	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m^3	< 0.10	-	-	-	-
C10 - C14	g/m^3	< 0.2	-	-	-	-
C15 - C36	g/m^3	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m^3	< 0.7	-	-	-	-

SUMMARY OF METHODS

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

Sample Type: Aqueous

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

Sample Type: Aqueous

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

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

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

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

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

Hill Laboratories
BETTER TESTING BETTER RESULTS

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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:**	1432634 SPv1
Contact:	Regan Phipps	**Date Registered:**	29-May-2015
	C/- Taranaki Regional Council	**Date Reported:**	08-Jun-2015
	Private Bag 713	**Quote No:**	47915
	STRATFORD 4352	**Order No:**	
		Client Reference:	Mangahewa D 1yr Post HF
		Submitted By:	Regan Phipps

Sample Type: Aqueous

Sample Name:		GND2459 27-May-2015 2:01 pm	GND2306 27-May-2015 2:55 pm			
Lab Number:		1432634.1	1432634.2			
Individual Tests						
Sum of Anions	meq/L	2.3	1.17	-	-	-
Sum of Cations	meq/L	2.4	1.15	-	-	-
pH	pH Units	7.2	7.4	-	-	-
Total Alkalinity	g/m^3 as CaCO$_3$	93	31	-	-	-
Bicarbonate	g/m^3 at 25°C	113	37	-	-	-
Total Hardness	g/m^3 as CaCO$_3$	45	38	-	-	-
Electrical Conductivity (EC)	mS/m	21.7	12.6	-	-	-
Total Dissolved Solids (TDS)	g/m^3	179	101	-	-	-
Dissolved Barium	g/m^3	0.0085	0.025	-	-	-
Dissolved Bromine*	g/m^3	0.054	0.034	-	-	-
Dissolved Calcium	g/m^3	10.4	12.4	-	-	-
Dissolved Copper	g/m^3	0.0010	< 0.0005	-	-	-
Dissolved Iron	g/m^3	3.2	0.13	-	-	-
Dissolved Magnesium	g/m^3	4.5	1.58	-	-	-
Dissolved Manganese	g/m^3	0.25	0.0188	-	-	-
Dissolved Mercury	g/m^3	< 0.00008	< 0.00008	-	-	-
Dissolved Nickel	g/m^3	< 0.0005	< 0.0005	-	-	-
Dissolved Potassium	g/m^3	4.9	2.1	-	-	-
Dissolved Sodium	g/m^3	28	7.9	-	-	-
Dissolved Zinc	g/m^3	0.46	0.0013	-	-	-
Chloride	g/m^3	12.9	9.9	-	-	-
Nitrite-N	g/m^3	< 0.002	< 0.002	-	-	-
Nitrate-N	g/m^3	< 0.002	2.2	-	-	-
Nitrate-N + Nitrite-N	g/m^3	< 0.002	2.2	-	-	-
Sulphate	g/m^3	1.6	5.5	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m^3	< 4	< 4	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m^3	< 4	< 4	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m^3	< 2	< 2	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m^3	< 0.0010	< 0.0010	-	-	-
Toluene	g/m^3	< 0.0010	< 0.0010	-	-	-
Ethylbenzene	g/m^3	< 0.0010	< 0.0010	-	-	-
m&p-Xylene	g/m^3	< 0.002	< 0.002	-	-	-

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Sample Type: Aqueous

Sample Name:		GND2459 27-May-2015 2:01 pm	GND2306 27-May-2015 2:55 pm			
Lab Number:		1432634.1	1432634.2			
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m^3	< 0.0010	< 0.0010	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m^3	< 0.02	< 0.02	-	-	-
Gases in groundwater						
Ethane	g/m^3	< 0.003	< 0.003	-	-	-
Ethylene	g/m^3	< 0.003	< 0.003	-	-	-
Methane	g/m^3	4.6	0.005	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m^3	< 0.10	< 0.10	-	-	-
C10 - C14	g/m^3	< 0.2	< 0.2	-	-	-
C15 - C36	g/m^3	< 0.4	< 0.4	-	-	-
Total hydrocarbons (C7 - C36)	g/m^3	< 0.7	< 0.7	-	-	-

SUMMARY OF METHODS

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

Sample Type: Aqueous

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

Sample Type: Aqueous			
Test	**Method Description**	**Default Detection Limit**	**Sample No**
Dissolved Iron	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1-2
Dissolved Magnesium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1-2
Dissolved Manganese	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1-2
Dissolved Mercury	0.45µm filtration, bromine oxidation followed by atomic fluorescence. US EPA Method 245.7, Feb 2005.	0.00008 g/m^3	1-2
Dissolved Nickel	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0005 g/m^3	1-2
Dissolved Potassium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.05 g/m^3	1-2
Dissolved Sodium	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.02 g/m^3	1-2
Dissolved Zinc	Filtered sample, ICP-MS, trace level. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	1-2
Chloride	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl^- E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m^3	1-2
Nitrite-N	Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m^3	1-2
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	1-2
Nitrate-N + Nitrite-N	Total oxidised nitrogen. Automated cadmium reduction, flow injection analyser. APHA 4500-NO_3^- I 22nd ed. 2012 (modified).	0.002 g/m^3	1-2
Sulphate	Filtered sample. Ion Chromatography. APHA 4110 B 22nd ed. 2012.	0.5 g/m^3	1-2

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

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

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Peter Robinson MSc (Hons), PhD, FNZIC
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BETTER TESTING **BETTER RESULTS**

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ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1568415 SPv1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 Stratford 4352	**Date Registered:**	15-Apr-2016
		Date Reported:	27-Apr-2016
		Quote No:	47915
		Order No:	
		Client Reference:	Mangahewa-D 21-24 3 Month Post-Frac
		Submitted By:	David Olson

Sample Type: Aqueous

Sample Name:		GND 2459 14-Apr-2016 1:45 pm				
Lab Number:		1568415.1				
Individual Tests						
Sum of Anions	meq/L	2.3	-	-	-	-
Sum of Cations	meq/L	2.6	-	-	-	-
pH	pH Units	7.1	-	-	-	-
Total Alkalinity	g/m^3 as $CaCO_3$	95	-	-	-	-
Bicarbonate	g/m^3 at 25°C	115	-	-	-	-
Total Hardness	g/m^3 as $CaCO_3$	42	-	-	-	-
Electrical Conductivity (EC)	mS/m	23.0	-	-	-	-
Total Dissolved Solids (TDS)	g/m^3	188	-	-	-	-
Dissolved Barium	g/m^3	0.0104	-	-	-	-
Dissolved Bromine*	g/m^3	0.123	-	-	-	-
Dissolved Calcium	g/m^3	10.2	-	-	-	-
Dissolved Copper	g/m^3	0.0017	-	-	-	-
Dissolved Iron	g/m^3	1.40	-	-	-	-
Dissolved Magnesium	g/m^3	4.0	-	-	-	-
Dissolved Manganese	g/m^3	0.22	-	-	-	-
Dissolved Mercury	g/m^3	< 0.00008	-	-	-	-
Dissolved Nickel	g/m^3	< 0.0005	-	-	-	-
Dissolved Potassium	g/m^3	5.4	-	-	-	-
Dissolved Sodium	g/m^3	36	-	-	-	-
Dissolved Zinc	g/m^3	0.050	-	-	-	-
Chloride	g/m^3	14.2	-	-	-	-
Nitrite-N	g/m^3	0.004	-	-	-	-
Nitrate-N	g/m^3	0.26	-	-	-	-
Nitrate-N + Nitrite-N	g/m^3	0.26	-	-	-	-
Sulphate	g/m^3	1.1	-	-	-	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m^3	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m^3	< 4	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m^3	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m^3	< 0.0010	-	-	-	-
Toluene	g/m^3	< 0.0010	-	-	-	-
Ethylbenzene	g/m^3	< 0.0010	-	-	-	-
m&p-Xylene	g/m^3	< 0.002	-	-	-	-

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The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

Sample Type: Aqueous

Sample Name:		GND 2459 14-Apr-2016 1:45 pm				
Lab Number:		1568415.1				
BTEX in Water by Headspace GC-MS						
o-Xylene	g/m^3	< 0.0010	-	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde	g/m^3	< 0.02	-	-	-	-
Gases in groundwater						
Ethane	g/m^3	< 0.003	-	-	-	-
Ethylene	g/m^3	< 0.004	-	-	-	-
Methane	g/m^3	3.5	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m^3	< 0.10	-	-	-	-
C10 - C14	g/m^3	< 0.2	-	-	-	-
C15 - C36	g/m^3	< 0.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m^3	< 0.7	-	-	-	-

SUMMARY OF METHODS

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

Sample Type: Aqueous

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

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

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

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

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

Appendix IV
Certificates of analysis
(hydraulic fracturing fluids and return flow fluids)

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Web www.hill-labs.co.nz

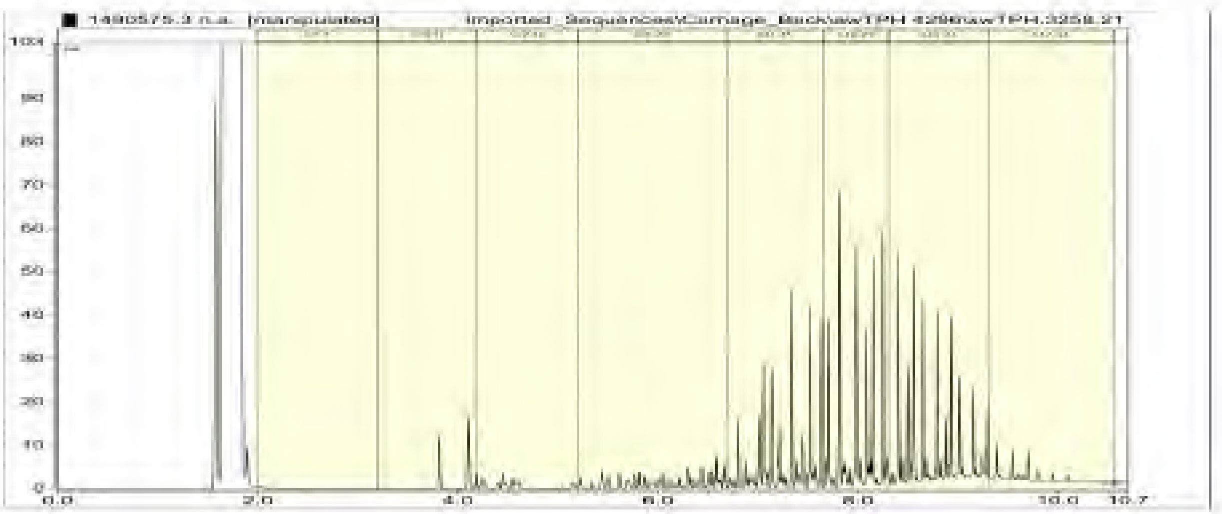
ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1490575	SPv1
Contact:	Regan Phipps	**Date Registered:**	20-Oct-2015	
	C/- Taranaki Regional Council	**Date Reported:**	04-Nov-2015	
	Private Bag 713	**Quote No:**	50522	
	STRATFORD 4352	**Order No:**		
		Client Reference:	MHW-23 Fracking Fluid	
		Submitted By:	R McDonnell	

Sample Type: Aqueous

	Sample Name:	Composite of MHW23 MaE3 & MHW23 MaA5				
	Lab Number:	1490575.3				
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	66	-	-	-	-
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	-	-	-	-
o-Xylene	g/m³	< 0.0010	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.10	-	-	-	-
C10 - C14	g/m³	0.9	-	-	-	-
C15 - C36	g/m³	12.4	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	13.3	-	-	-	-

1490575.3
Composite of MHW23 MaE3 & MHW23 MaA5
Client Chromatogram for TPH by FID



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Analyst's Comments

Only plastic containers were supplied for the samples 1490575/1,2. Please note that glass containers should be used for BTEX & hydrocarbon analysis to avoid loss of volatiles and possible plastic contamination.

SUMMARY OF METHODS

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

Sample Type: Aqueous

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

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

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

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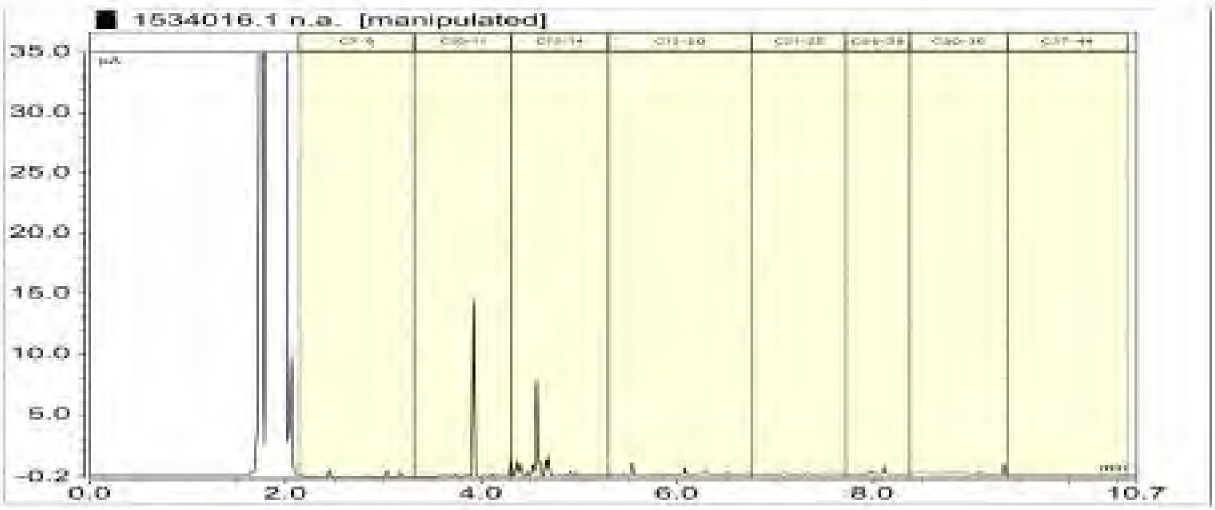
ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1534016 SPv1
Contact:	Regan Phipps C/- Taranaki Regional Council Private Bag 713 Stratford 4352	**Date Registered:**	05-Feb-2016
		Date Reported:	22-Feb-2016
		Quote No:	50522
		Order No:	
		Client Reference:	Manuahwewa - D 21 - HF Return Fluid
		Submitted By:	David Olson

Sample Type: Aqueous

Sample Name:		MHW21-030 14-Nov-2015 6:15 am	MHW21-032 14-Nov-2015 11:55 am	MHW21-034 14-Nov-2015 5:40 pm		
Lab Number:		1534016.1	1534016.2	1534016.3		
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	50	42	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	< 4	126	77	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	3	< 2	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	0.24	0.073	0.083	-	-
Toluene	g/m³	0.097	0.043	0.050	-	-
Ethylbenzene	g/m³	0.0119	0.0095	0.0097	-	-
m&p-Xylene	g/m³	0.062	0.052	0.058	-	-
o-Xylene	g/m³	0.058	0.057	0.063	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.4	1.2	0.7	-	-
C10 - C14	g/m³	3.3	12.3	10.2	-	-
C15 - C36	g/m³	< 2	33	24	-	-
Total hydrocarbons (C7 - C36)	g/m³	< 4	46	35	-	-

1534016.1
MHW21-030 14-Nov-2015 6:15 am
Client Chromatogram for TPH by FID



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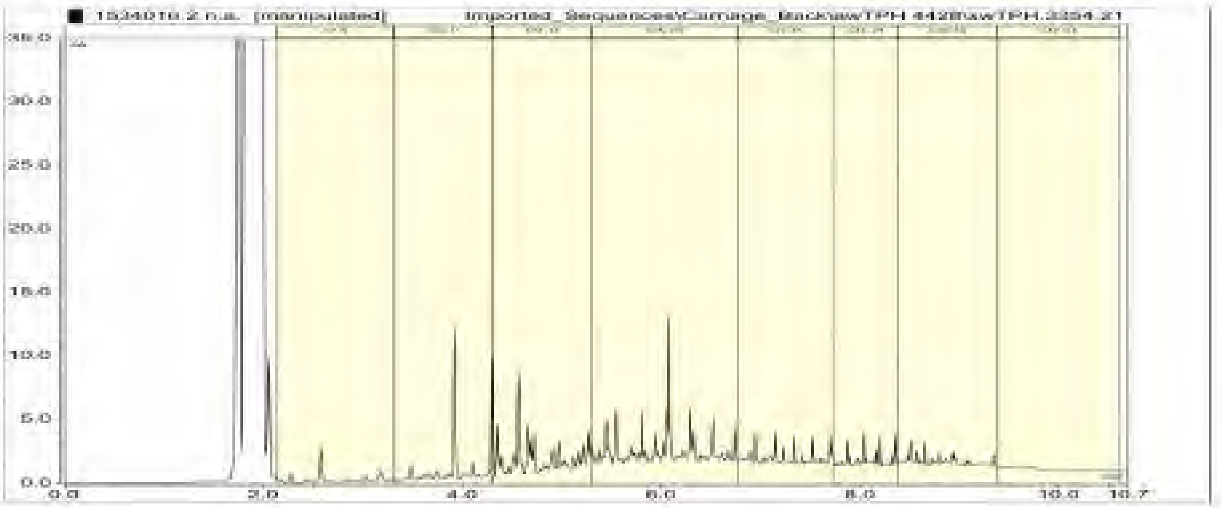
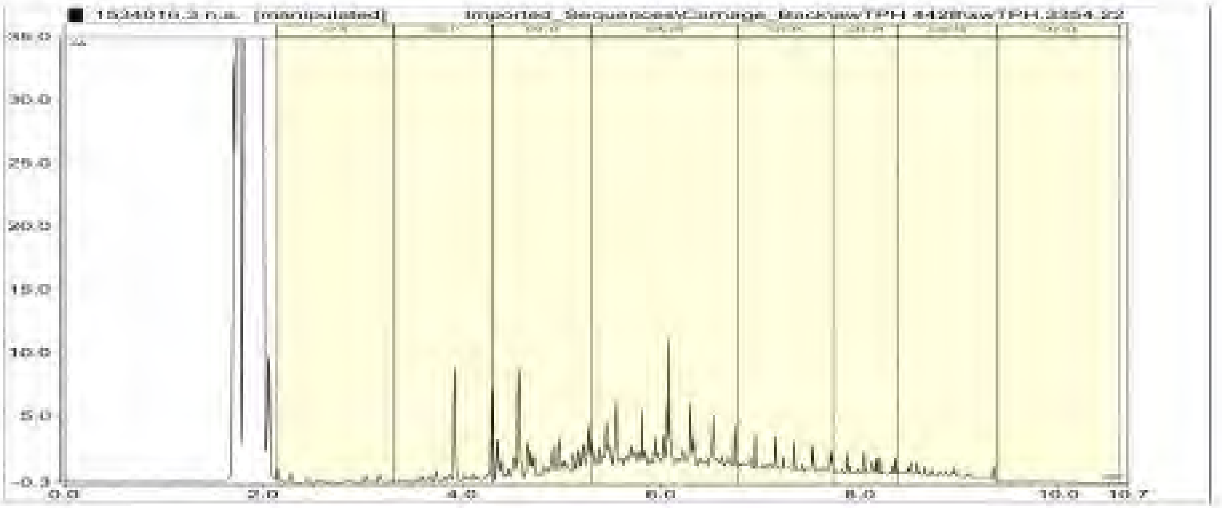
1534016.2
MHW21-032 14-Nov-2015 11:55 am
Client Chromatogram for TPH by FID



1534016.3
MHW21-034 14-Nov-2015 5:40 pm
Client Chromatogram for TPH by FID



SUMMARY OF METHODS

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

Sample Type: Aqueous

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

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

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

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

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BETTER TESTING **BETTER RESULTS**

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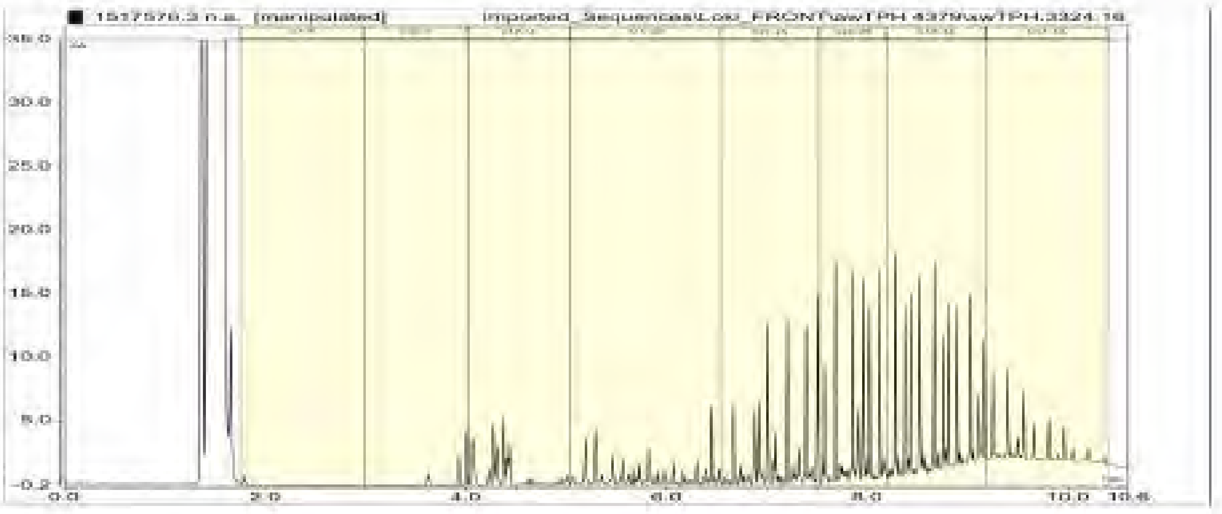
ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1517576 SPv1
Contact:	Regan Phipps	**Date Registered:**	18-Dec-2015
	C/- Taranaki Regional Council	**Date Reported:**	05-Jan-2016
	Private Bag 713	**Quote No:**	50522
	STRATFORD 4352	**Order No:**	
		Client Reference:	MHWD HHF Fluid
		Submitted By:	R McDonnell

Sample Type: Aqueous

Sample Name:		Composite of GND 2522 28.10.15 & GND 2522 8.11.15				
Lab Number:		1517576.3				
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	< 20	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	-	-	-	-
Toluene	g/m³	0.0012	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-
o-Xylene	g/m³	< 0.0010	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	< 0.4	-	-	-	-
C10 - C14	g/m³	2.0	-	-	-	-
C15 - C36	g/m³	22	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	24	-	-	-	-

1517576.3
Composite of GND 2522 28.10.15 & GND 2522 8.11.15
Client Chromatogram for TPH by FID



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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	3
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m³	3
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m³	3
BTEX in Water by Headspace GC-MS	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m³	3
Total Petroleum Hydrocarbons in Water*	Hexane extraction, GC-FID analysis US EPA 8015B/MfE Petroleum Industry Guidelines [KBIs:2803,10734]	0.10 - 0.7 g/m³	3

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

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

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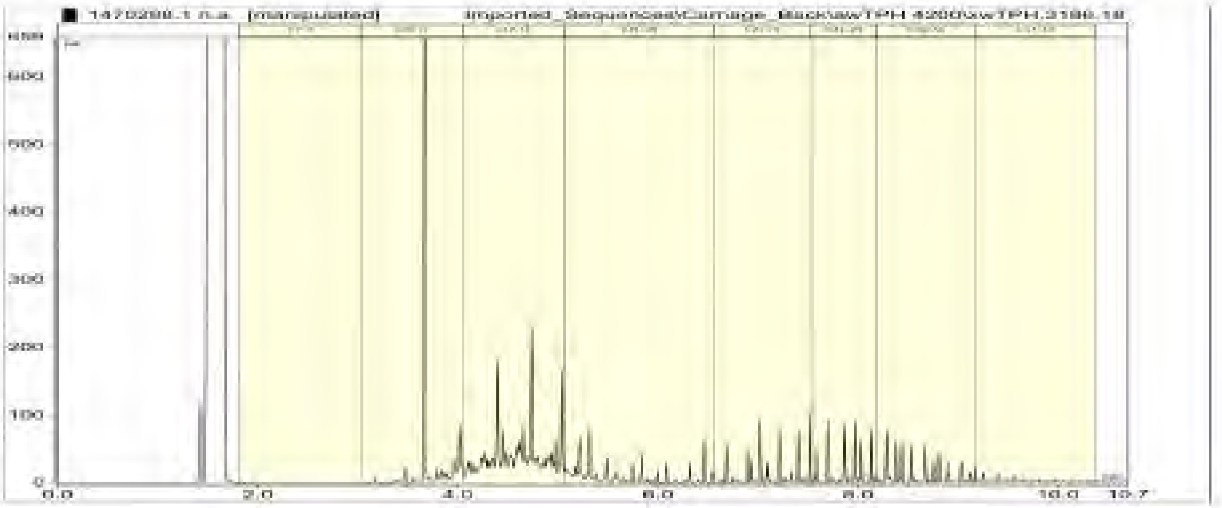
ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1470288	SPv1
Contact:	Regan Phipps	**Date Registered:**	02-Sep-2015	
	C/- Taranaki Regional Council	**Date Reported:**	17-Sep-2015	
	Private Bag 713	**Quote No:**	50522	
	STRATFORD 4352	**Order No:**		
		Client Reference:	Mangatawa D - HF Fluid	
		Submitted By:	Regan Phipps	

Sample Type: Aqueous

Sample Name:		GND 2523 27-Jul-2015 12:00 pm				
Lab Number:		1470288.1				
Ethylene Glycol in Water						
Ethylene glycol*	g/m³	< 4	-	-	-	-
Propylene Glycol in Water						
Propylene glycol*	g/m³	78	-	-	-	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m³	< 2	-	-	-	-
BTEX in Water by Headspace GC-MS						
Benzene	g/m³	< 0.0010	-	-	-	-
Toluene	g/m³	0.0022	-	-	-	-
Ethylbenzene	g/m³	< 0.0010	-	-	-	-
m&p-Xylene	g/m³	< 0.002	-	-	-	-
o-Xylene	g/m³	0.0012	-	-	-	-
Total Petroleum Hydrocarbons in Water						
C7 - C9	g/m³	0.10	-	-	-	-
C10 - C14	g/m³	48	-	-	-	-
C15 - C36	g/m³	26	-	-	-	-
Total hydrocarbons (C7 - C36)	g/m³	74	-	-	-	-

1470288.1
GND 2523 27-Jul-2015 12:00 pm
Client Chromatogram for TPH by FID



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Analyst's Comments

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

SUMMARY OF METHODS

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

Sample Type: Aqueous

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

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

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

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Web www.hill-labs.co.nz

ANALYSIS REPORT

Client:	Taranaki Regional Council	**Lab No:**	1471698 SPv1
Contact:	Regan Phipps	**Date Registered:**	04-Sep-2015
	C/- Taranaki Regional Council	**Date Reported:**	18-Sep-2015
	Private Bag 713	**Quote No:**	71307
	STRATFORD 4352	**Order No:**	
		Client Reference:	Mongahewe D - Return Fluid
		Submitted By:	R McDonnell

Sample Type: Saline

Sample Name:		Composite of GND2523 Return Fluid 1/3, GND2523 Return Fluid 2/3 & GND2523 Return Fluid 3/3	Composite of GND2524 Return Fluid 1/3, GND2524 Return Fluid 2/3 & GND2524 Return Fluid 3/3	Composite of GND2525 Return Fluid 1/3, GND2525 Return Fluid 2/3 & GND2525 Return Fluid 3/3	Composite of GND2523 Return Fluid 1/4, GND2523 Return Fluid 2/4, GND2523 Return Fluid 3/4 & GND2523 Return Fluid 4/4	
Lab Number:		1471698.14	1471698.15	1471698.16	1471698.17	
Individual Tests						
pH*	pH Units	7.6	7.0	7.1	7.0	-
Total Alkalinity*	g/m^3 as $CaCO_3$	490	450	118	330	-
Analysis Temperature for Bicarbonate	°C	22	22	23	23	-
Bicarbonate	g/m^3 at Analysis Temperature	432	350	117	348	-
Total Hardness*	g/m^3 as $CaCO_3$	590	950	84	230	-
Electrical Conductivity (EC)*	mS/m	4,240	1,798	5,420	4,940	-
Total Dissolved Solids (TDS)*	g/m^3	28,000	13,400	33,000	31,000	-
Dissolved Barium*	g/m^3	112	8.1	0.50	25	-
Dissolved Bromine*	g/m^3	28	8.4	24	24	-
Dissolved Calcium*	g/m^3	200	360	15	54	-
Dissolved Copper*	g/m^3	0.008	0.034	0.012	0.007	-
Dissolved Iron*	g/m^3	0.70	38	0.12	1.09	-
Dissolved Magnesium*	g/m^3	20	10	11	23	-
Dissolved Manganese*	g/m^3	2.9	2.6	0.149	1.32	-
Total Mercury*	g/m^3	< 0.011	< 0.011	< 0.011	< 0.011	-
Dissolved Nickel*	g/m^3	0.11	0.49	< 0.03	0.07	-
Dissolved Potassium*	g/m^3	8,900	2,500	16,800	13,700	-
Dissolved Sodium*	g/m^3	3,700	1,650	320	1,670	-
Dissolved Sulphur*	g/m^3	147	70	110	78	-
Dissolved Zinc*	g/m^3	0.25	0.30	0.09	0.15	-
Chloride*	g/m^3	14,600	5,500	15,300	14,900	-
Nitrite-N	g/m^3	< 0.2 [#2]	< 0.02 [#2]	< 0.02 [#2]	< 0.02 [#2]	-
Nitrate-N	g/m^3	< 0.2	0.02	0.08	< 0.02	-
Nitrate*	g/m^3	< 0.9	0.09	0.36	< 0.09	-
Nitrate-N + Nitrite-N	g/m^3	< 0.2 [#2]	0.02 [#2]	0.09 [#3]	< 0.02 [#2]	-
Sulphate*	g/m^3	440	210	330	230	-
Ethylene Glycol in Water						
Ethylene glycol*	g/m^3	< 4	124	< 4	< 4	-
Propylene Glycol in Water						
Propylene glycol*	g/m^3	6	1,410	62	14	-
Methanol in Water - Aqueous Solvents						
Methanol*	g/m^3	2,100	1,840	< 2	< 20 [#1]	-

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The tests reported herein have been performed in accordance with the terms of accreditation, with the exception of tests marked *, which are not accredited.

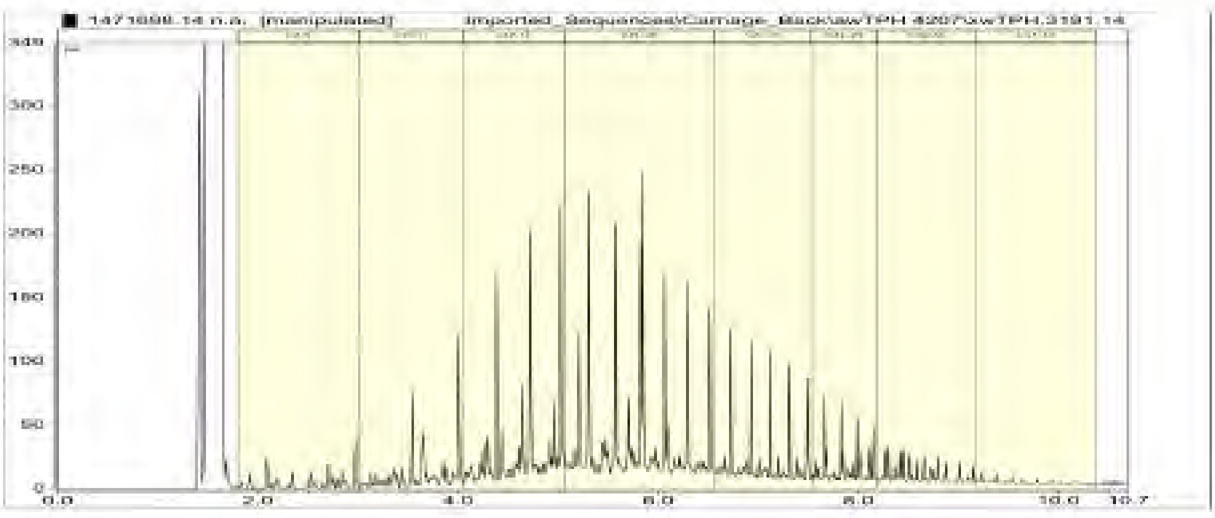
Sample Type: Saline

Sample Name:		Composite of GND2523 Return Fluid 1/3, GND2523 Return Fluid 2/3 & GND2523 Return Fluid 3/3	Composite of GND2524 Return Fluid 1/3, GND2524 Return Fluid 2/3 & GND2524 Return Fluid 3/3	Composite of GND2525 Return Fluid 1/3, GND2525 Return Fluid 2/3 & GND2525 Return Fluid 3/3	Composite of GND2523 Return Fluid 1/4, GND2523 Return Fluid 2/4, GND2523 Return Fluid 3/4 & GND2523 Return Fluid 4/4	
Lab Number:		1471698.14	1471698.15	1471698.16	1471698.17	
BTEX in Water by Headspace GC-MS						
Benzene*	g/m³	2.1	10.9	< 0.0010	3.5	-
Toluene*	g/m³	0.79	11.6	0.0011	5.5	-
Ethylbenzene*	g/m³	0.041	1.04	< 0.0010	0.50	-
m&p-Xylene*	g/m³	0.26	4.9	< 0.002	3.9	-
o-Xylene*	g/m³	0.172	2.1	< 0.0010	1.44	-
Acetaldehyde in Water by DNPH & LCMSMS						
Acetaldehyde*	g/m³	-	100	-	-	-
Formaldehyde in Water by DNPH & LCMSMS						
Formaldehyde*	g/m³	< 0.15	< 1.5	0.85	0.40	-
Total Petroleum Hydrocarbons in Water						
C7 - C9*	g/m³	3.3	82	< 0.15	28	-
C10 - C14*	g/m³	26	58	27	61	-
C15 - C36*	g/m³	54	46	25	97	-
Total hydrocarbons (C7 - C36)*	g/m³	83	185	52	187	-

1471698.14

Composite of GND2523 Return Fluid 1/3, GND2523 Return Fluid 2/3 & GND2523 Return Fluid 3/3

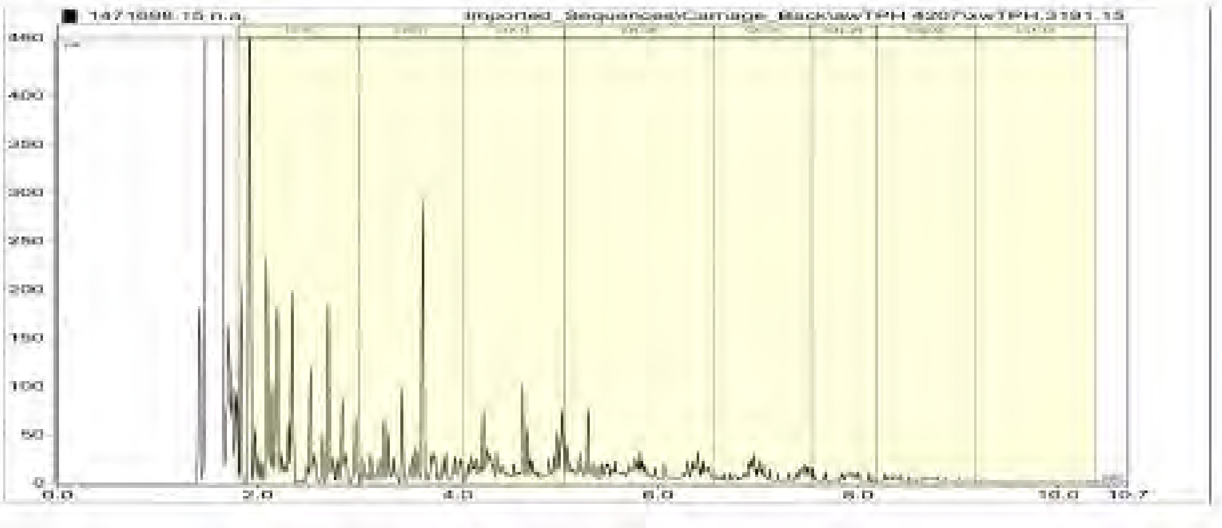
Client Chromatogram for TPH by FID



1471698.15

Composite of GND2524 Return Fluid 1/3, GND2524 Return Fluid 2/3 & GND2524 Return Fluid 3/3

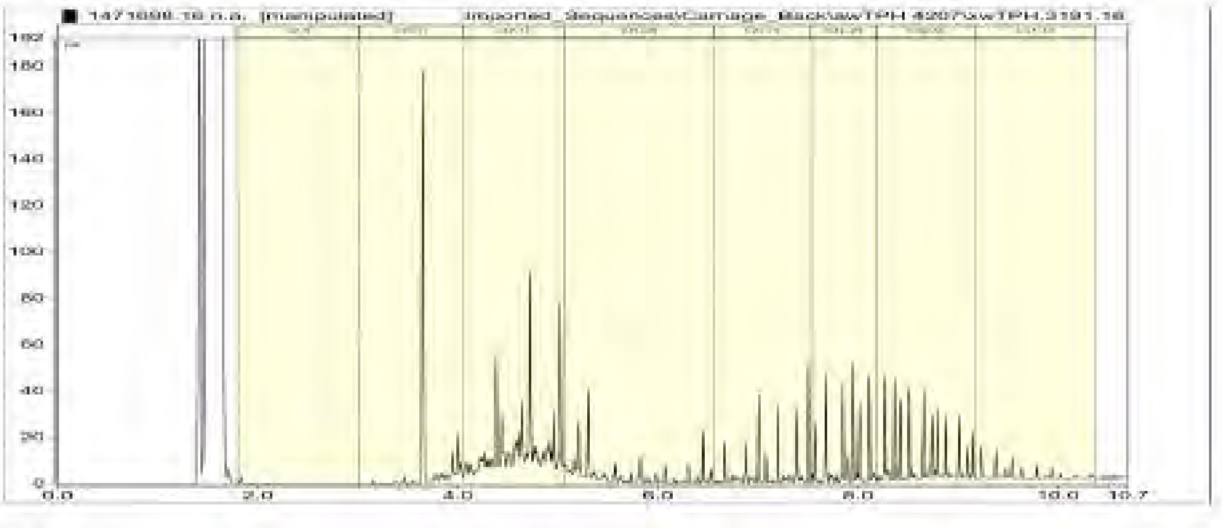
Client Chromatogram for TPH by FID



1471698.16

Composite of GND2525 Return Fluid 1/3, GND2525 Return Fluid 2/3 & GND2525 Return Fluid 3/3

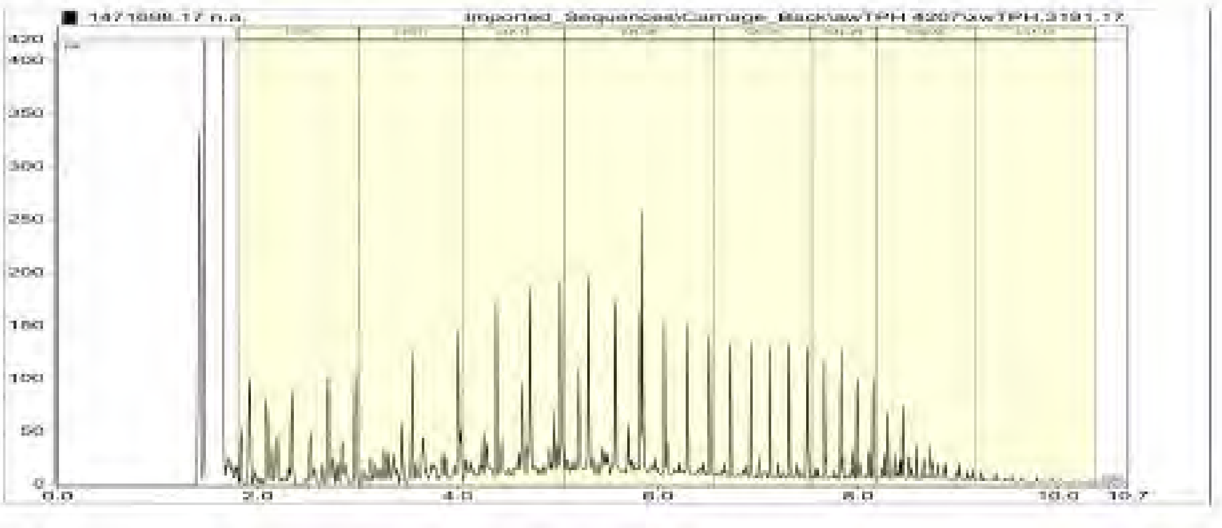
Client Chromatogram for TPH by FID



1471698.17

Composite of GND2523 Return Fluid 1/4, GND2523 Return Fluid 2/4, GND2523 Return Fluid 3/4 & GND2523 Return Fluid 4/4

Client Chromatogram for TPH by FID



Analyst's Comments

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

#1 Due to the type of matrix found in sample 1471698.17, a dilution was required for the Methanol analysis. Hence the higher detection limit reported.

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

#3

Appendix No.1 - Bicarbonate Report - 1471698

SUMMARY OF METHODS

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

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Acetaldehyde and Glutaraldehyde in Water extraction,Trace*	DNPH derivatisation, extraction, HPLC.	-	15
Ethylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	14-17
Propylene Glycol in Water*	Direct injection, dual column GC-FID	4 g/m^3	14-17
Methanol in Water - Aqueous Solvents*	Direct injection, dual column GC-FID	1.0 g/m^3	14-17
BTEX in Water by Headspace GC-MS*	Headspace GC-MS analysis, US EPA 8260B [KBIs:26687,3629]	0.0010 - 0.002 g/m^3	14-17
Acetaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m^3	15
Formaldehyde in Water by DNPH & LCMSMS*	DNPH derivatisation, extraction, LCMSMS	0.02 g/m^3	14-17
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	14-17
Filtration, Unpreserved*	Sample filtration through 0.45µm membrane filter.	-	14-17
Total Digestion of Saline Samples*	Nitric acid digestion. APHA 3030 E 22nd ed. 2012 (modified).	-	14-17
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	14
pH*	Saline water, pH meter. APHA 4500-H$^+$ B 22nd ed. 2012. Note: It is not possible to achieve the APHA Maximum Storage Recommendation for this test (15 min) when samples are analysed upon receipt at the laboratory, and not in the field.	0.1 pH Units	15-17
Total Alkalinity*	Saline water, Titration to pH 4.5.	1.0 g/m^3 as CaCO$_3$	14-17
Analysis Temperature for Bicarbonate	Temperature at which Bicarbonate titration was conducted as reported by Geological & Nuclear Sciences, Wairakei.	1.0 °C	14-17
Bicarbonate	Bicarbonate (HCO3) Titration Method conducted at reported temperature. Subcontracted to Geological & Nuclear Sciences, Wairakei. ASTM Standards D513-82 Vol.11.01 of 1988.	20 g/m^3 at Analysis Temperature	14-17
Total Hardness*	Calculation from Calcium and Magnesium. APHA 2340 B 22nd ed. 2012.	1.0 g/m^3 as CaCO$_3$	14-17
Electrical Conductivity (EC)*	Saline water, Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.10 mS/m	15-17
Electrical Conductivity (EC)*	Conductivity meter, 25°C. APHA 2510 B 22nd ed. 2012.	0.1 mS/m	14
Total Dissolved Solids (TDS)*	Filtration through GF/C (1.2 µm), gravimetric. APHA 2540 C (modified; drying temperature of 103 - 105°C used rather than 180 ± 2°C) 22nd ed. 2012.	50 g/m^3	14-17
Filtration for dissolved metals analysis*	Sample filtration through 0.45µm membrane filter and preservation with nitric acid. APHA 3030 B 22nd ed. 2012.	-	14-17
Dissolved Barium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.0006 g/m^3	14-17
Dissolved Bromine*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.10 g/m^3	14-17
Dissolved Calcium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.0 g/m^3	14-17
Dissolved Copper*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	14-17
Dissolved Iron*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.004 g/m^3	14-17

Sample Type: Saline

Test	Method Description	Default Detection Limit	Sample No
Dissolved Magnesium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.4 g/m^3	14-17
Dissolved Manganese*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	14-17
Total Mercury*	Nitric acid digestion, ICP-MS, screen level. APHA 3125 B 22nd ed. 2012.	0.0021 g/m^3	14-17
Dissolved Nickel*	Filtered sample, ICP-MS with universal cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.0010 g/m^3	14-17
Dissolved Potassium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	1.0 g/m^3	14-17
Dissolved Sodium*	Filtered sample, ICP-MS, ultratrace level. APHA 3125 B 22nd ed. 2012.	0.4 g/m^3	14-17
Dissolved Sulphur*	Filtered sample, ICP-OES.	0.10 g/m^3	14-17
Dissolved Zinc*	Filtered sample, ICP-MS with dynamic reaction cell, ultratrace. APHA 3125 B 22nd ed. 2012.	0.004 g/m^3	14-17
Chloride*	Filtered sample. Ferric thiocyanate colorimetry. Discrete Analyser. APHA 4500 Cl$^-$ E (modified from continuous flow analysis) 22nd ed. 2012.	0.5 g/m^3	14-17
Nitrite-N	Saline sample. Automated Azo dye colorimetry, Flow injection analyser. APHA 4500-NO$_3^-$ I 22nd ed. 2012 (modified).	0.002 g/m^3	14-17
Nitrate-N	Calculation: (Nitrate-N + Nitrite-N) - NO2N. In-House.	0.0010 g/m^3	14-17
Nitrate*	Calculation from Nitrate-N.	0.010 g/m^3	14-17
Nitrate-N + Nitrite-N	Saline sample. Total oxidised nitrogen. Automated cadmium reduction, Flow injection analyser. APHA 4500-NO$_3^-$ I 22nd ed. 2012 (modified).	0.002 g/m^3	14-17
Soluble Sulphate*	Calculation: from dissolved sulphur.	2 g/m^3	14-17

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

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

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CERTIFICATE OF ANALYSIS

JOB 1471698/14-/17 FOR BICARBONATE

Report No: 2015090807
Customer Ref:145130

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

GNS Sample No.		2015006306	2015006307	2015006308	2015006309
Collection Date:					
Site ID:		1471698/14	1471698/15	1471698/16	1471698/17
Field ID					
pH		7.09	6.89	6.71	6.84
Bicarbonate (Total)	mg/l	432	350	117	348
HCO_3 Analysis Temperature	ºC	22	22	23	23
HCO_3 Analysis Date		9/09/2015	9/09/2015	9/09/2015	9/09/2015

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

SUMMARY OF METHODS AND DETECTION LIMITS

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

Parameter	Method	*Detection Limit	
Bicarbonate (total)	HCO_3 Titration Method ASTM Standards D513-82 Vol.11.01 1988	20	mg/l
pH	Electrometric Method - APHA 4500-H+ B 22nd Edition 2012	-	-

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

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

A Noddings
Ann Noddings
Senior Technician

Appendix V
Biomonitoring report

To Job Manager, Jane Harvey
From Technical Officer, Katie Blakemore
Report No KB010
Document 1702970
Date 22 June 2016

Biomonitoring of two unnamed tributaries of the Manganui River in relation to hydraulic fracturing by Todd Energy Ltd at the Mangahewa-D wellsite, April 2016

Introduction

A macroinvertebrate survey was carried out at the Mangahewa-D wellsite to determine whether discharges relating to hydraulic fracturing (HF) activities undertaken during January 2016 at the wellsite had caused a detrimental effect upon macroinvertebrate communities of two unnamed tributaries of the Manganui River. At the wellsite treated stormwater, uncontaminated site water and production water were discharged from a skimmer pit into an unnamed tributary of the Manganui River (Figure 1). Previous surveys had been completed in relation to drilling activity at the site on 15 April 2014, 28 August 2014, 18 May 2015 and 26 May 2015. The results of these surveys are discussed in the reports listed in the references.

Methods

The post –HF survey was undertaken on 18 April 2016 at three previously established sites (Figure 1, Table 1). A fourth previously established site (site 2) was not sampled on this occasion because there was no flow in this tributary.

The standard '400 ml kick-sampling' technique was used to collect streambed macroinvertebrates at site 1. A combination of 'vegetation sweep' sampling and 'kick-sampling' was to collect streambed at sites 3 and 4. The 'kick-sampling' and 'vegetation sweep' techniques are very similar to Protocol C1 (hard-bottomed, semi-quantitative) and C2 (soft-bottomed, semi-quantitative) of the New Zealand Macroinvertebrate Working Group (NZMWG) protocols for macroinvertebrate samples in wadeable streams (Stark *et al*, 2001).

Table 1 Biomonitoring sites in two unnamed tributaries of the Manganui River in relation to the Mangahewa-D wellsite

Site number	Site code	Grid reference (NZTM)	Location	Altitude (masl)
1	MGN000489	1711359E 5673793N	55m upstream of confluence from Mangahewa-D wellsite discharge	60
2	MGN000491	1711322E 5673832N	90m downstream of Mangahewa-D wellsite discharge point and 10m upstream of tributary confluence	60
3	MGN000492	1711376E 5673894N	60m downstream of confluence from Mangahewa-D wellsite	60
4	MGN000493	1711392E 5673936N	100m downstream of confluence from Mangahewa-D wellsite	60

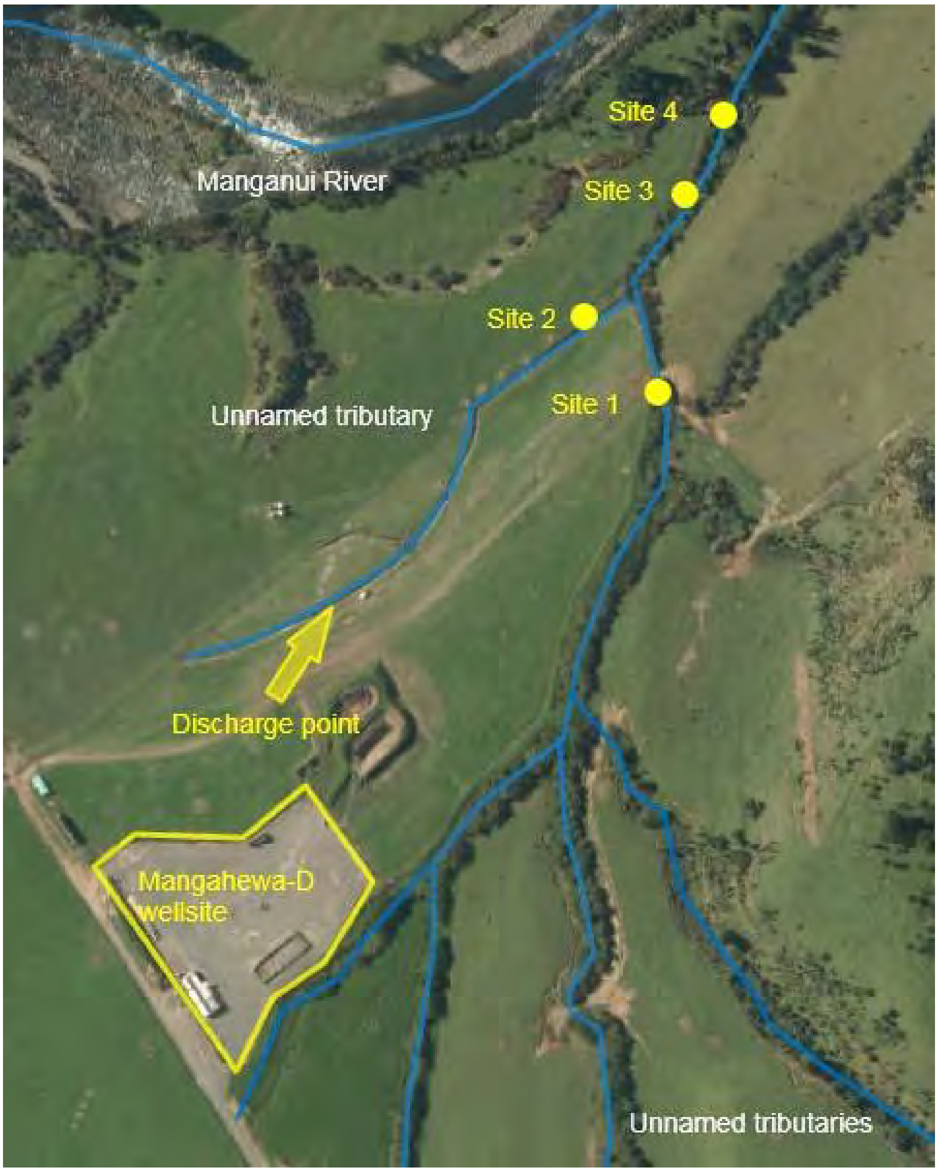

Figure 1 Biomonitoring sites in two unnamed tributaries of the Manganui River in relation to the Mangahewa-D wellsite

Samples were preserved with Kahle's Fluid for later sorting and identification under a stereomicroscope according to Taranaki Regional Council methodology using protocol P1 of NZMWG protocols for sampling macroinvertebrates in wadeable streams (Stark et al. 2001). Macroinvertebrate taxa found in each sample were recorded based on the abundance categories in Table 2.

Table 2 Macroinvertebrate abundance categories

Abundance category	Number of individuals
R (rare)	1-4
C (common)	5-19
A (abundant)	20-99
VA (very abundant)	100-499
XA (extremely abundant)	>499

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. However, other physical variables such as sedimentation, temperatures, water velocity, and dissolved oxygen levels may also affect the MCI values because the taxa that are able to tolerate extremes in these variables generally have lower sensitivity scores. More 'sensitive' communities inhabit less polluted waterways. A gradation of biological water quality conditions based upon MCI ranges which has been adapted for Taranaki streams and rivers (TRC, 2013) from Stark's classification (Stark, 1985; Boothroyd and Stark, 2000) (Table 3). A difference of eleven or more MCI units is considered significant (Stark 1998).

Table 3 Macroinvertebrate community health based on MCI ranges which has been adapted for Taranaki streams and rivers (TRC, 2013) from Stark's classification (Stark, 1985 and Boothroyd and Stark, 2000)

Grading	MCI
Excellent	>140
Very Good	120-140
Good	100-119
Fair	80-99
Poor	60-79
Very Poor	<60

A semi-quantitative MCI value (SQMCIs) 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 SQMCIs is not multiplied by a scaling factor of 20, so that its corresponding range of values is 20x lower.

Results

The post-HF survey was carried out six days after a fresh in excess of 3x median flow and 15 days after a fresh in excess of 7x median flow (based on the Manganui River at Everett Park). Flows were very low and steady at site 1, and low and slow at sites 3 and 4. Water was clear and uncoloured at all sites. Water temperatures at the time of the late afternoon survey ranged from 14.5 -14.7 °C at the three sites. Substrate at site 1 comprised cobble, concrete and bedrock with some coarse gravel and wood or root also present, while at site 3 substrate was predominantly sand and cobble, with some fine and coarse gravel and wood or root present. Site 4 had predominantly sand, silt and cobble, with some fine and coarse gravel, boulder and wood or root present. A silt coating was present at sites 3 and 4.

Periphyton was absent at sites 1 and 4, while site 3 had slippery periphyton mats but no filamentous periphyton. Patches of wood and widespread leaves were present on the streambed, while moss was absent from all three sites. Macrophytes were present on the stream edges at sites 3 and 4, but absent at site 1. Overhanging vegetation was present at all three sites and provided complete shading of the streambed at sites 1 and 3, and partial shading at site 4.

Macroinvertebrate communities

Comparative data from similar sites is provided in Table 4, while the results from previous surveys are summarised in Table 5. Results of the current survey are provided in Table 6.

Table 4 Summary of taxa richness, MCI values, SQMCI$_S$ values for ‘control’ sites in Taranaki lowland coastal streams at altitudes between 50 and 79 m asl (TRC 2015).

	Number of taxa	MCI	SQMCI$_S$
Number of Samples	111	111	82
Range	0-30	60-103	1.4-6.7
Median	20	79	4.0

Table 5 Range of previously recorded taxa richness, MCI and SQMCI$_S$ scores for the survey sites, together with results of the current survey

Site Number	Site Code	No. of surveys	Number of Taxa		MCI		SQMCIs	
			Range	Current Survey	Range	Current Survey	Range	Current Survey
1	MGN000489	5	19-21	21	66-74	83	2.5-3.8	3.6
3	MGN000492	5	4-16	13	55-80	71	2.5-4.0	3.5
4	MGN000493	5	6-27	13	70-85	68	3.5-3.9	2.6

Table 6 Macroinvertebrate fauna of an unnamed tributary of the Manganui River in relation to the Mangahewa-D wellsite survey undertaken on 18 April 2016

Taxa List	**Site Number**	**MCI score**	**1**	**3**	**4**
	Site Code		**MGN000489**	**MGN000492**	**MGN000493**
	Sample Number		**FWB16204**	**FWB16206**	**FWB16207**
COELENTERATA	Coelenterata	3	-	-	R
PLATYHELMINTHES (FLATWORMS)	*Cura*	3	C	C	R
NEMERTEA	Nemertea	3	R	R	R
ANNELIDA (WORMS)	Oligochaeta	1	A	A	VA
	Lumbricidae	5	R	-	-
HIRUDINEA (LEECHES)	Hirudinea	3	R	C	-
MOLLUSCA	*Physa*	3	R	R	R
	Potamopyrgus	4	VA	VA	VA
	Sphaeriidae	3	R	-	-
CRUSTACEA	Copepoda	5	R	-	-
	Ostracoda	1	R	-	C
	Isopoda	5	R	-	-
	Paracalliope	5	R	R	R
	Paratya	3	-	R	-
EPHEMEROPTERA (MAYFLIES)	*Coloburiscus*	7	R	-	-
	Deleatidium	8	R	-	-
	Zephlebia group	7	R	-	-
ODONATA (DRAGONFLIES)	*Xanthocnemis*	4	C	R	R
COLEOPTERA (BEETLES)	Hydrophilidae	5	R	-	-
TRICHOPTERA (CADDISFLIES)	*Hydrobiosis*	5	-	R	-
	Oxyethira	2	R	R	-
	Triplectides	5	R	C	C
DIPTERA (TRUE FLIES)	Orthocladiinae	2	-	-	R
	Tanypodinae	5	-	R	R
	Ceratopogonidae	3	R	-	-
ACARINA (MITES)	Acarina	5	C	-	R
		No of taxa	21	13	13
		MCI	83	71	68
		SQMCIs	3.6	3.5	2.6
		EPT (taxa)	4	2	1
		%EPT (taxa)	19	15	8
'Tolerant' taxa	'Moderately sensitive' taxa	'Highly sensitive' taxa			

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

Site 1: 55m upstream of confluence from Mangahewa-D wellsite discharge

Site 1 recorded a moderate taxa richness of 21 taxa, equal to the highest previously recorded taxa richness for this site (Table 5) and similar to the median taxa richness for similar sites (Table 4). The macroinvertebrate community was characterised by two 'tolerant' taxa, oligochaete worms and snail (*Potamopyrgus*). Sixteen of the taxa present were recorded as rare taxa (ie. less than 5 individuals) at this site.

A MCI score of 83 units was recorded at this site, categorizing the site as having 'fair' macroinvertebrate community health. This is the highest recorded MCI score for this site to date (Table 5), but is similar to the median score recorded for similar sites (Table 4). A SQMCI$_s$

score of 3.6 units was recorded in the current survey, within the range of previously recorded $SQMCI_s$ scores at this site (Table 5).

Site 2: 90m downstream of Mangahewa-D wellsite discharge point and 10m upstream of tributary confluence

Site 2 was dry at the time of sampling. Consequently no macroinvertebrate sample could be collected.

Site 3: 60m downstream of confluence from Mangahewa-D wellsite

Site 3 recorded a moderately low taxa richness of 13 taxa, within the range of previously recorded results for this site (Table 5). The macroinvertebrate community was characterised by two 'tolerant' taxa, oligochaete worms and snail (*Potamopyrgus*).

A MCI score of 71 units was recorded at this site, categorising it as having 'poor' macroinvertebrate community health. This is within the range of previously recorded scores for this site (Table 5) and is similar to the median score for similar sites (Table 4). However, it is significantly less than that recorded upstream. A $SQMCI_s$ score of 3.5 units was recorded, within the range of previously recorded scores for this site (Table 5).

Site 4: 100m downstream of confluence from Mangahewa-D wellsite

Site 4 recorded a moderately low taxa richness of 13 taxa, which is within the range of previously recorded results for this site (Table 5). The macroinvertebrate community was characterised by two 'tolerant' taxa, oligochaete worms and snail (*Potamopyrgus*).

The survey recorded a MCI score of 68 units at this site, categorising the site as having 'poor' macroinvertebrate community health. This is the lowest currently recorded score for this site, but is not significantly lower (Stark 1998) than the previous minimum score for this site (Table 5) or to the score recorded at site 3. It is a significant (Stark 1998) 11 units lower than the median MCI score for similar sites. A $SQMCI_s$ score of 2.6 units was recorded at this site; significantly lower (Stark 1998) than the previously recorded minimum score for this site and that recorded at sites 1 and 3.

Discussion and conclusions

The Council's 'kick-sampling' and 'vegetation sweep' techniques were used at three sites to collect streambed macroinvertebrates from two unnamed tributaries of the Manganui River in relation to hydraulic fracturing at the Mangahewa-D wellsite. This has provided data to assess any potential impacts the stormwater, uncontaminated site water and production water discharges have had on the macroinvertebrate communities of the stream. Samples were processed to provide number of taxa (richness), MCI, and $SQMCI_S$ scores for each site.

Taxa richness is the most robust index when determining whether a macroinvertebrate community has been exposed to toxic discharges. When exposed to toxic discharges, macroinvertebrates may die and be swept downstream or may deliberately drift downstream as an avoidance mechanism (catastrophic drift). 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. However, it is also influenced by the 'patchiness' of macroinvertebrates on the streambed, and as such must be considered in the context of all three metrics. Significant differences in either the MCI or the $SQMCI_S$ scores between sites may indicate the degree of adverse effects (if any) of the discharge being monitored.

The current survey was undertaken during a period of low flow conditions. Under these conditions, organisms are more likely to experience extremes of variables such as water temperature, conductivity and dissolved oxygen levels. There is also less dilution of any discharges that may occur. Therefore, organisms which cannot tolerate these conditions may die or deliberately drift downstream to avoid the unfavourable conditions (catastrophic drift), thus reducing taxa richness. The low flow conditions may also reduce the area of habitat available, directly impacting the organisms present. Taxa which are classed as 'tolerant' are less likely to be affected by the environmental conditions experienced under low flow conditions.

The current survey recorded moderate taxa richnesses, which were within the previously recorded range for all sites. However, the taxa richnesses recorded at sites 3 and 4 (the 'impact' sites) were substantially lower than that recorded at site 1. All three sites had a relatively high proportion of rare taxa recorded. This indicates that physical habitat limitation, most likely due to low flow conditions, was an important determinant of macroinvertebrate communities at the time of this survey. Physical habitat also differed significantly between sites, with deposited sediment present on the streambed at sites 3 and 4 but not site 1. Site 1 also had a much coarser substrate, with no silt or sand present. In contrast substrate at sites 3 and 4 was dominated by silt and sand, with more sand at site 3 and silt at site 4. Hard bottom substrate generally provides better habitat for a wider variety of macroinvertebrate taxa compared to sand and silt. This difference in substrate was reflected by the higher proportion of 'sensitive' taxa at site 1 (48%) compared to sites 3 and 4 (both 31%).

MCI scores of 83, 71 and 68 units were recorded at sites 1, 3 and 4 respectively. This is a significantly higher (Stark 1998) score at site 1 compared to either site 3 or site 4. The MCI score at site 1 was also the highest recorded score for this site, in contrast to site 4 which had the lowest recorded score for this site. The higher proportion of sensitive taxa at site 1 accounts for the higher MCI score at this site. $SQMCI_s$ scores of 3.6, 3.5 and 2.6 units were recorded at sites 1, 3 and 4 respectively. These scores are similar at sites 1 and 3, while site 4 had a significantly lower score (Stark 1998) than either site 1 or site 3. Site 4 also had a $SQMCI_s$ score significantly lower than any previously recorded score. This score was influenced by the 'very abundant' oligochaete worms at site 4, compared to sites 1 and 3. The increase from 'abundant' at sites 1 and 3 to 'very abundant' had a disproportionate affect on $SQMCI_s$ score. If oligochaete worms were only 'abundant' at site 4, the $SQMCI_s$ score would increase significantly (Stark 1998) to 3.5 units. This variability is partially related to the high proportion of 'rare' taxa at this site, and indicates that the significantly lower $SQMCI_s$ score at site 4 is not a significant concern. Further, this change in the abundance of oligochaete worms is likely to be due to the higher proportion of silt at site 4 compared to sites 1 and 3.This variability in MCI and $SQMCI_s$ scores may be in part a reflection of the limited historical data for these sites, as well as being influenced by the low flow conditions over the summer prior to the survey.

The lower invertebrate metric results recorded at sites 3 and 4 compared to site 1 are most likely a reflection of differing habitat conditions between the sites, rather than effects related to wellsite discharges. In particular, sites 3 and 4 had a relatively high proportion of sand and silt substrate, while these were not present at site 1. The observed results are reflective of both physical habitat limitation caused by low flow conditions, and increased fine sediment at the downstream sites.

At the time of the current survey, site 2, which is located in the unnamed tributary directly receiving the wellsite discharges, was dry. This provides further support for no significant detrimental impacts caused by wellsite discharges on the two unnamed tributaries of the Manganui River.

Summary

A macroinvertebrate survey was undertaken on 18 April 2016, using the Council's 'kick-sampling' and 'vegetation sweep' techniques to collect samples at three sites. A further site could not be sampled at this time due to low flow conditions. Taxa richnesses of 21, 13 and 13 were recorded at sites 1, 3 and 4 respectively. The higher taxa richness at site 1 was in part due to a very high number of rare taxa recorded at this site. MCI scores of 83, 71 and 68 units were recorded at site 1, 3 and 4 respectively. Site 1 had a significantly higher score than either site 3 or site 4 (which were not significantly different from each other). SQMCI$_s$ scores of 3.6, 3.5 and 2.6 were recorded at sites 1, 3 and 4 respectively. The score recorded at site 4 was significantly lower than those recorded at sites 1 and 3 (which were not significantly different from each other). The lower score at site 4 can be attributed directly to an increased abundance of oligochaete worms, which is associated with a higher proportion of silt substrate. These differences in invertebrate metrics are most likely related to habitat differences, rather than to discharges from the Mangahewa-D wellsite.

There was no evidence that discharges from activity at the Mangahewa-D wellsite had caused any detrimental effects on these two unnamed tributaries of the Manganui River. Observed differences in invertebrate metrics between sites are considered to be a result of habitat differences between sites and low flow conditions at the time of the survey.

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