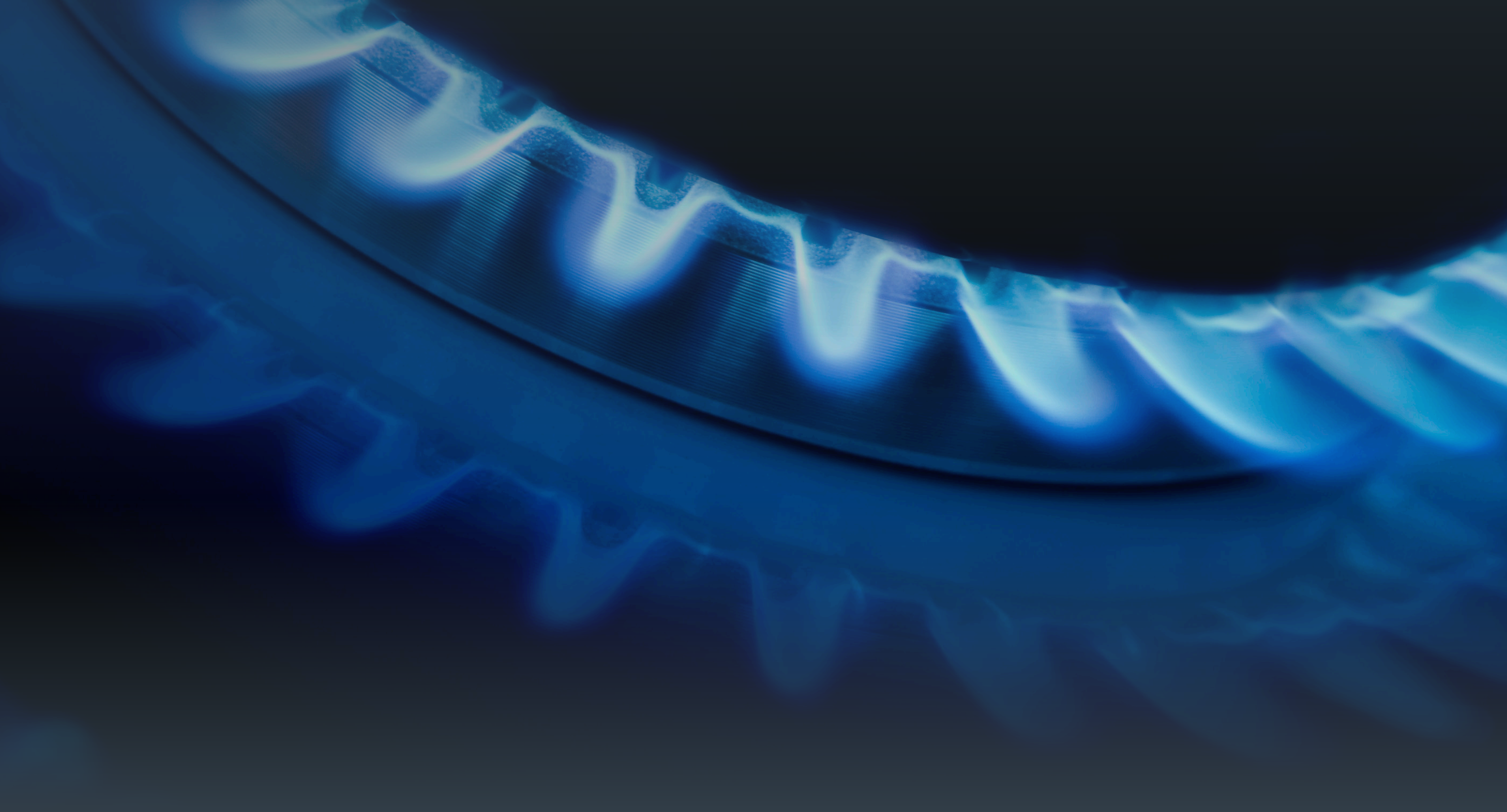
AECOM

GEOTECHNICAL RISK MANAGEMENT REVIEW
FIRST GAS TRANSMISSION PIPELINES

New Zealand Commerce Commission | Sept 2019



Geotechnical Risk Management Review

First Gas Transmission Pipelines

Client: Commerce Commission

Co No.: N/A

Prepared by

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0	31-May-2019	For Client Review	Ian Martin Area Manager, Wellington	
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Executive Summary

Buried gas pipelines are susceptible to accumulated strain, bending and possible rupture effects from soil movements and other geohazards, which in turn may lead to loss of containment with associated health and safety, loss of supply, environmental, reputational and cost impacts. Common geohazards that affect pipelines include: landslides/slope instability, settlement, erosion (stream and/or coastal) and fault movement.

AECOM was retained by the NZ Commerce Commission to undertake a review of the risk management practices of the gas pipeline businesses that are subject to economic regulation in New Zealand. The review was to include assessment First Gas's management of the geotechnical risks associated with the gas transmission network pipelines, all of which have been owned by First Gas since 2016.

The purpose of the review presented in this report was to determine how well First Gas has assessed, documented and managed geotechnical risk and geohazards affecting the gas transmission pipelines; it does not consider the distribution networks.

First Gas recognises that the risk natural land movement poses to its gas pipelines can be managed or mitigated but cannot be entirely eliminated. Management processes and systems are in place to identify and assess geohazards and determine whether and how to monitor or remediate, and to prioritise remediation works. The procedures are regularly reviewed in accordance with AS/NZS 2885 and First Gas is currently undertaking a programme of work to capture historical information within a GIS system that will provide a much-improved and much more accessible record of identified geohazards and their management.

First Gas support their dedicated (and personally committed) pipeline integrity (geohazards) specialist with other field technicians and experienced engineering consultants, some of whom have a long history of geohazard assessment and management on the pipelines.

The main conclusions from our review and assessment of the geohazard risk management methodology followed by First Gas for the transmission pipelines are:

1. First Gas have good, well documented processes in place to identify geohazards and to evaluate and manage the risks associated with the identified hazards.
2. These procedures are consistent with the requirements of AS/NZS 2885.
3. First Gas currently has a high level of knowledge of the geohazards affecting transmission pipelines and makes good use of external expertise when appropriate.
4. Recognising that the natural geohazards that may affect First Gas transmission pipelines are a function of the New Zealand geology, topography and climate, and that these differ from Australian conditions, First Gas are developing additional procedures and guidelines to complement AS/NZS 2885 requirements in relation to geohazards.
5. The processes and procedures which continue to be developed and followed by First Gas in compliance with AS/NZS 2885 in relation to geohazards appear to be aligned with national and international good industry practice.
6. The draft *Pipeline Geohazard Management Plan* and associated documents are, however, focussed on the geohazards that have historically affected the pipelines most frequently, or are considered the most likely to affect them (landslide movement, shallow slumping, erosion, coastal erosion). Low likelihood events could be captured better.
7. Historical information relating to geohazards is currently difficult to locate and staff interviewed were unable to tell us how many geohazard sites have been identified and assessed in total.
8. The high level 'big picture' view of relative geohazard risks (the *Geohazard Risk Zones Map*) is a very useful document but is not supported by explanatory information and does not define the High, Medium and Low risk classes depicted.

In accordance with the Brief, the following comments confirm that, in the opinion of the reviewer, First Gas, in assessing their exposure to geotechnical risks, has:

- made appropriate enquiries to understand and manage the risks;
- sought adequate expert advice where required;
- received advice that has adequately responded to the questions asked; and
- appropriate processes in place for monitoring identified risks.

Recommendations

In the opinion of the reviewer, two areas for improvement in the management of geohazards that would help First Gas to better monitor and manage the geotechnical risks are:

1. Understanding of low probability, high impact events

Recommendation 1: FGL should better document the areas potentially at risk from earthquake and volcanic events as a matter of priority.

Recommendation 2: This information should be used to assess both risk and potential consequences so that appropriate emergency action plans (which could include ‘react when necessary’ at remote locations) can be developed.

2. Capture of historical events

Recommendation 3: Capture of all available information in the GIS *Geohazard Web Viewer* should be given priority.

Recommendation 4: Consider adding the following information to the new system as separate GIS layers:

1. Regional geological maps, specifically the GNS QMAP series which is available in electronic format.
2. Regional information available through GeoNet, GNS and Regional Councils that identifies areas of potential hazards such as liquefiable soils, streams at risk from lahars.
3. The GeoNet active faults database, also available in electronic format. GNS have defined classes of active fault on the basis of recurrence interval (Class 1 less than 2000 years, etc) which should be adopted to help identify the faults most likely to affect one or more of the pipelines. This should be undertaken in conjunction with an assessment of the implications of the NZ Seismic Hazard Model and NZS 1170.5.
4. Topographic maps (LINZ), as this information assists with risk zoning based on or taking account of topography (eg. slope angle maps).

Recommendation 5: The criteria for high level risk classifications (High, Medium and Low) used on overview maps in initial assessments of new geohazards be clearly defined and documented within the *Pipeline Geohazard Management Plan*. When combined with the GIS-based geohazards management system that is being developed and introduced, this additional information will give First Gas a very powerful geohazard management tool.

Recommendation 6: To make the best use of this geohazard management tool in future, it is important that First Gas instigate a succession plan for the incumbent Pipeline Integrity Specialist.

1.0 Introduction

1.1 Background

Since April 2016, First Gas - Transmission has owned all of the gas transmission assets in New Zealand[1], comprising more than 2,500 kms of high-pressure pipelines and stations that supply natural gas from Taranaki to consumers throughout the North Island. In addition, there are four gas distribution businesses: First Gas–Distribution, Vector, Powerco and Gasnet, also operating only in the North Island. There are no gas transmission lines in the South Island.

The gas transmission network is subject to known geotechnical hazards. First Gas (and its predecessor companies) have identified a number of geohazard[2] areas on the transmission network that are actively monitored and/or have plans for remediation. In addition, there is a history of previous remediation works that continue to be monitored.

Gas pipeline businesses (GPBs) in New Zealand are subject to information disclosure and price-quality regulation under Part 4 of the Commerce Act 1986[3]. Under the information disclosure requirements, the GPBs are required to publicly disclose an Asset Management Plan (AMP) or an AMP update each year. The AMP provides information on how the business intends to manage its network assets. The purpose of information disclosure requirements is to ensure that sufficient information is readily available to interested persons to assess whether the Part 4 purpose is being met.

The Commerce Commission (NZCC), which is New Zealand’s competition, consumer and regulatory agency, has commissioned AECOM New Zealand Ltd to review the risk management practices of the gas pipeline businesses that are subject to economic regulation in New Zealand. This report relates only to the geotechnical hazards and risks related to First Gas Ltd’s gas transmission network.

1.2 Scope of Report

The RFP dated 11 January 2019 states that this review is to assess First Gas’s management of the geotechnical risks. Specifically, the assessment is required to ascertain whether First Gas, in assessing their exposure to geotechnical risks, has in the opinion of the reviewer:

- Made appropriate enquiries to understand and manage the risks;
- Where required, has sought adequate expert advice to understand risks;
- Where expert advice has been sought, the advice adequately responds to the questions asked;
- Whether First Gas has appropriate processes in place for monitoring identified risks; and
- Whether there is any other analysis that would be required in the monitoring and management of the geotechnical risks.

1.3 Reviewers Expectations

The key aspects we expect to see in a thorough geotechnical risk assessment and management programme for the gas transmission network include:

- Evidence that the network has been mapped geospatially to identify soil and rock types and geohazards (such as active faults, landslides, erodible materials) affecting the network;

[1] On 20 April 2016, Vector Gas Limited, owner of the Vector transmission system, was acquired by First State Funds and was renamed First Gas Limited (First Gas). Then, on 15 June 2016, First Gas purchased the Maui pipeline from Shell, Todd and OMV (collectively known as the Maui Mining Companies).

[2] Geohazard is the term used for land instability events, such as landslides, erosion or movement of rocks or debris, that have the potential to affect the integrity of the gas transmission pipelines.

[3] Gas pipelines businesses do not face direct competition for their services and are therefore regulated under Part 4 of the Commerce Act.

- Good understanding of geohazards and geotechnical conditions impacting the network – active faulting, corrosivity, shrink/swell potential, erosion risk, slope stability (slumping, slippage), flooding, etc – and of historical events affecting the pipelines since construction[4];
- Condition of pipes known (particularly regarding corrosivity), statistical extrapolation of condition data recognises pipe coating/protection as well as varying soil conditions;
- Critical pipes are specifically identified (those ones which have the highest consequence of failure) and there is greater certainty in the understanding of geotechnical conditions affecting them;
- Risks[5] of location-specific damage to the pipes affecting supply are assessed in a systematic manner considering:
  - Consequence of the event (seismic, slippage, corrosion etc) - considering impacts on both the network itself and on the users and other stakeholders, environment, and associated costs;
  - Likelihood of that stated event (e.g. likelihood of the seismic event leading to the impacts described by the consequences, or likelihood of corrosion failure which would be a function of both ground conditions and current pipe condition/protection);
- This systematic manner is consistent with the FGL's risk management policy, framework and ISO 31000;
- Options for mitigating location-specific risks are identified, systematically evaluated and implemented (or scheduled) in accordance with a soundly prioritised plan;
- The outputs of the risk management studies feed directly into the operations, inspection, maintenance, renewal and development strategies. So, for instance, critical assets are inspected more frequently, have a greater maintenance focus and are renewed earlier, and maybe with better materials; and
- Confirmation that Residual risks have been assessed by First Gas as acceptable.

1.4 Exclusions

Our proposal dated 13 February 2019 specifically noted that

1. we would not reassess the actual risk assessment itself, but would specifically note any significant anomalies observed in the assessments and evaluations.
2. although some reference may be made to the overall risk management assessment framework, the geotechnical risk management assessment would be more of a technical review.

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[4] While First Gas has only had control of the gas transmission network since mid-2016, it is expected that historical information on geohazards and geotechnical issues was transferred along with ownership of the assets

[5] For asset managers we generally consider risks in the following 3 classes:

- Infrastructure – essentially the cost of repair or replacement of the infrastructure subsequent to an event
- Functionality – impact on the performance of the infrastructure or network availability
- Safety – impact on infrastructure users and the public. This needs to consider the impact of mitigation measures as well (eg reduction in service level leading to unsafe situations)

The highest risk level for these classes is the risk level for that location specific event. This caters for variations in appetite for different types of risk, and allows a more focussed consideration of mitigation measures.

2.0 Methodology

2.1 Process Followed

The process we followed in undertaking this review was:

1. Determine the types of geotechnical and geohazard information (documents) that we would expect to be available for the transmission network.
2. Request that the appropriate documents be provided for review.
3. Review and evaluate the documents provided.
4. Request additional documentation as appropriate.
5. Summarise our review of the documentation.
6. Meet with First Gas and the Commerce Commission representatives to discuss geohazard issue identification, management and mitigation.
7. Submit the draft report for client review.
8. Submit the final report addressing client comments.

2.2 Information Reviewed

The information reviewed for this assessment was obtained from First Gas via Commerce Commission, and supplemented with information (such as Asset Management Plans[6]) downloaded from the internet.

The supplied information that we reviewed is listed and key points summarised in **Appendix A**. This information included:

- 3209319 Asset Risk Management Guide (September 2018);
- 3207768 Standard Threat Assessment (STA), Rev 6 (2018);
- 3205330 Pipeline Surveillance Guidelines;
- 3208656 Seismic Fault Crossing Guideline;
- 3208429 Geotechnical Feature Risk Ranking Tool;
- 3207969 Pipeline Safety Management Study Procedure, Rev 3 (Oct 2015);
- 3208332 Pipeline Integrity Management Plan (PIMP); and
- (Draft) Pipeline Geo-Hazard Management Plan.

FGL's AMP is updated annually and is publicly available. It sets out how First Gas intends to manage the transmission network to meet customer gas demands over the next ten years. As part of our geotechnical risk management review we accessed the following documents from FGL's website:

- Gas Transmission Asset Management Plan 2018 – Summary;
- Gas Transmission Asset Management Plan 2018 – Appendices;
- Gas Transmission Asset Management Plan Update 2017;
- Gas Asset Management Plan 2016;
- Maui Transitional Asset Management Plan 2015;
- Maui Asset Management Plan 2014; and

[6] Including AMP's published by previous owners of the pipelines (Vector, Maui Developments)

- Maui Asset Management Plan 2013.

In addition, we were provided with (or separately located) a number of technical reports and papers pertaining to geotechnical conditions and hazards associated with the Maui and/or Kapuni pipeline(s), including:

- Failure of the Kapuni-Auckland high-pressure gas pipeline (Thompson 1978);
- Maui Pipeline Project: Evaluation of as-built slope stability (Riddolls 1978);
- Assessment of landslide and other erosion hazards along the Kapuni and Maui Pipeline alignments: Urenui to Otorohanga. GNS report 2009/157;
- Geotechnical Assessment of the Site of the October 2011 Maui Gas Pipeline Failure near Pukearuhe, Northern Taranaki. GNS Science;
- Review of the Maui Pipeline Outage of October 2011. MBIE Report dated October 2012;
- Gilbert Stream Coastal Erosion Assessment (GNS 2016);
- Saxton Property, Glen Murray (PDP, 2017); and
- Turners Retirement Landslide, Mokau (PDP, 2019).

2.3 Meeting with FGL

AECOM and Commerce Commission representatives met with First Gas representatives in New Plymouth on 17 May 2019 to discuss and clarify geohazard identification and management procedures.

This very informative and highly interactive meeting was structured as a presentation of their hazard identification and assessment process (see Figure 2 below) by FGL, supported by several case histories. In addition, the GIS geohazards database that is currently under development was explained and demonstrated.

3.0 Outcomes from Data Review

As outlined in Section 1, First Gas now own and operate New Zealand's high pressure gas transmission system consisting of underground pipelines, compressor facilities and above ground stations in the North Island.

The purpose of the data review was to determine how well First Gas have assessed, documented and manage geotechnical risk and geohazards[7] affecting the transmission pipelines that carry gas to the main destinations shown in Figure 1. This section presents our findings from the review of the available information, including our discussions with First Gas. These findings are evaluated in Section 4.0 of this report.

3.1 Historical Background

Natural gas accounts for 21% of total primary energy supply and 14% of total consumer energy use in New Zealand (NZ Gas Story, 2016), and is currently supplied from 15 fields.

The first commercial discovery of gas in NZ was at Kapuni in 1959 and led to increased exploration activity and further major gas finds, notably the much larger offshore Maui gas/condensate field in 1969. With development of the onshore Kapuni field in 1970, gas was initially distributed through local gas networks in nine communities serviced by a transmission pipeline running north from Kapuni to Auckland, and south to Wellington. Following development of the Maui field and construction of a 309km pipeline from Oaonui to the Huntly power station, Maui gas deliveries began in 1979, and the high-pressure gas transmission system was extended to Northland, the Bay of Plenty and Hawke's Bay during the 1980s. This provided piped natural gas supply into all the major populated centres of the North Island.

No significant transmission pipeline extensions have been built since the 1980s, and none are currently planned.

Historical records maintained by previous owners of the transmission network transferred to First Gas in 2016.

The gas transmission network is subject to known geotechnical hazards. There have been only two significant pipeline failures attributed to geotechnical issues since construction in the 1970's and 1980's:

- the Kapuni pipeline failed and caught fire near Gilbert Stream (Pukearuhe Road, north Taranaki) in July 1977 where the pipeline crossed the corner of a landslide. Compressional loading caused the pipe to buckle and split along a weld.
- in October 2011 a gas leak on the Maui pipeline occurred at Pukearuhe (North Taranaki) as a result of pipe damage caused by land movement.

Riddolls (1978) described 19 locations where the Maui pipeline crosses areas with evidence of slope instability in Tertiary-age fine grained sedimentary rocks. Four of these sites were between Ngaruawahia and the Huntly offtake, the remainder between Pukearuhe and Te Kuiti.

A further high-level geotechnical assessment of the section of pipeline from Urenui (on the northern Taranaki coast) to Otorohanga (in southern Waikato) was undertaken for Vector Gas by GNS in 2009 and 2012. The 2009 assessment identified 59 landslide or erosion hazards along the route of this section of the pipeline. Eleven of these were classified as High risk.

The most recent significant geohazard affecting the Maui pipeline was identified by an in-line inspection in 2018 that identified a buckle in the pipeline at Pariroa, about 9.3 km south from the Mokau Compressor Station and close to a previously identified pipeline strain site at an active

[7] Geo-hazard is the term First Gas use for land instability events (such as landslides, erosion or movement of rocks or debris) that have the potential to affect the integrity of transmission pipelines.

landslide. An 800m long bypass around the site was completed in December 2018 to allow repairs to be undertaken at a later date while keeping the pipeline operational.

3.2 Characteristics of the Gas Transmission Network

Transmission pipeline systems transport gas at high pressure from production stations to delivery points supplying end-users and lower pressure local area gas distribution networks. The two open access pipeline systems in New Zealand, both now owned by First Gas, are:

- the 309km Maui pipeline (mostly 750mm diameter), extending from Oaonui, in southwest Taranaki, to Huntly.
- the 2,211km system (mostly from 155mm to 220mm diameter), generally radiating from the Maui pipeline and delivering gas throughout the North Island.

Of this, approximately 103km is installed in urban areas and the remainder in rural areas.

Gas produced in the Taranaki region is received into the gas transmission system, direct from gas producers, at a number of receipt points. The system transmits gas to most of the major towns and cities of the North Island (see Figure 1), where the pressure is reduced at delivery points before entering connected downstream gas distribution networks. Some large industrial gas consumers are supplied directly from the system at dedicated delivery points.

The gas transmission pipelines are all steel pipes, mostly installed below ground, and the nominal bore ranges from 50mm to 850mm diameter. At some locations, necessitated by geographical features, pipelines are installed above ground in a variety of methods including freely supported spans, attached to road bridges/dams and bespoke supporting structures. Buried pipelines are both externally coated and protected by cathodic protection systems. The pipelines are constructed to recognised standards in accordance with appropriate legislation.

The underground pipelines are coated with various non-conductive materials intended to isolate the pipe metal from the soil and groundwater to prevent corrosion. In the 1960s/1970s coal-tar enamel or Polyken tape wrap coatings were used. Pipelines constructed in the 1980s and later have extruded polyethylene coatings (‘yellow jacket’) and in some cases fusion-bonded epoxy coatings.

The transmission pipelines must be operated and maintained in accordance with the appropriate parts of the AS/NZS 2885 standard, and must have a current certificate of fitness to operate.

First Gas hold construction records for all the pipelines. Documentation is held in 4 formats:

- Electronic - the alignment drawings have been scanned and held in Meridian (Engineering document management system)
- Original Films - held off site by document management organisation
- Paper copies - held in archive
- Microfiche – held on site.

Documentation will be converted to digital format utilising external services as required.

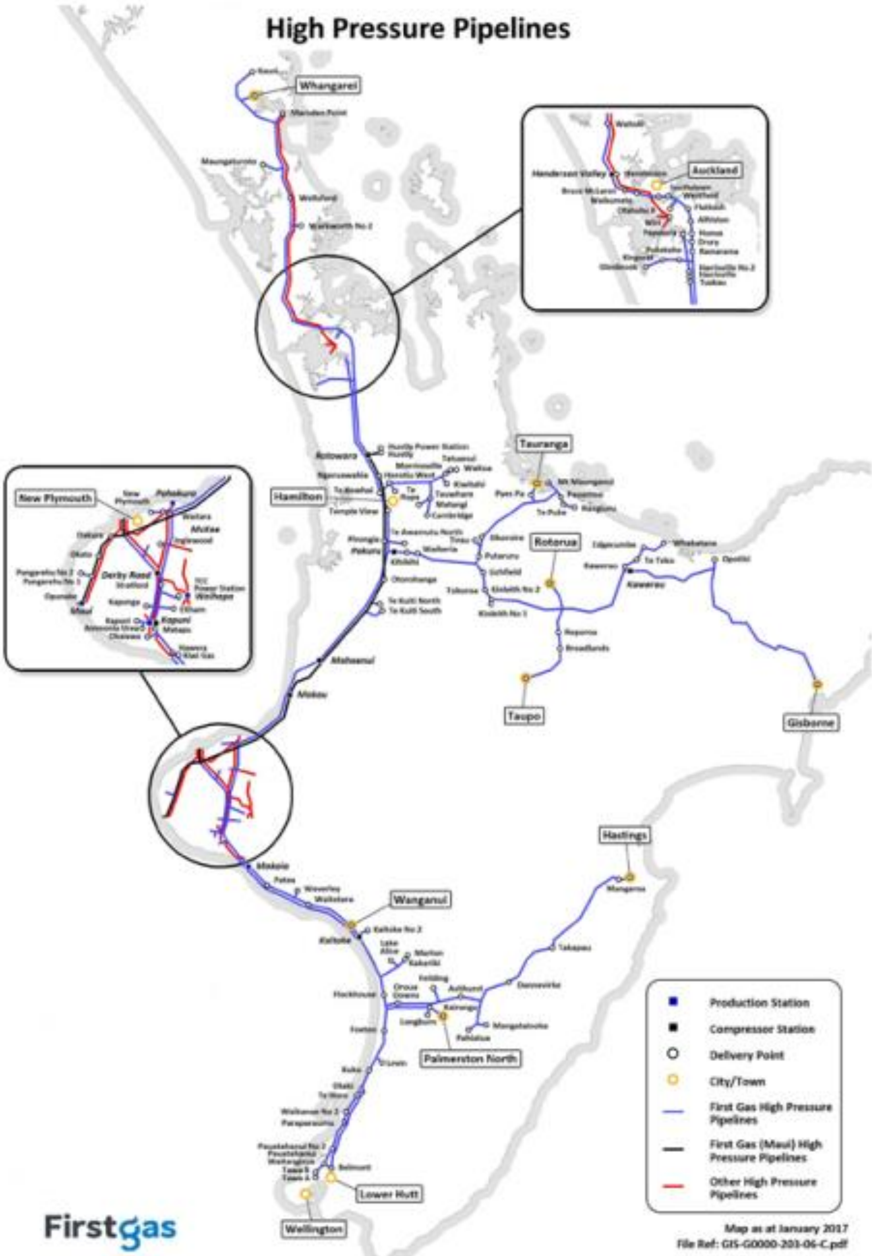

Figure 1 Map of high pressure gas transmission lines owned and operated by First Gas (blue and black lines). From FGL's 2017 AMP

3.3 Hazard Identification and Risk Management Practices

AS/NZS ISO 31000:2009 provides agencies with principles and general guidelines to be considered when developing risk management frameworks and programs. The two primary components of the ISO 31000 risk management process are the **Framework**, which guides the overall structure and operation of risk management across an organization, and the **Process**, which describes the actual method of identifying, analysing, and treating risks. This review of geotechnical risk is focussed on the **Process** as it applies to geohazards.

For a gas pipeline, the highest risk to the business is a pipeline rupture leading to loss of supply, loss of life, environmental damage, property damage or a combination of these outcomes.

Hence, for this review, we define a **geohazard** as any natural circumstance or condition that creates the risk of an unplanned and unwanted event, with a potential for harm in terms of loss of supply, human injury or ill health, damage to property, the workplace environment, or a combination of these. **Risk** is a combination of the likelihood and consequence(s) of a specified loss event occurring. It includes the possibility of economic or financial loss, harm to people, processes, property, the environment or relations with external stakeholders.

The ultimate goal in pipeline risk assessment and management in the context of this review is to understand the risks involved and establish actions to limit the likelihood of failure of the pipeline, and/or limit the consequences should failure occur to within specified acceptable risk levels. To achieve this goal, it is necessary to identify sites that may represent a geohazard, to visually inspect these sites, to understand how the geohazard impacts on the pipeline network and to create a cycle of site assessment and management practices based on the site inspections that deal with the risks identified.

The five risk management process steps that combine to deliver a simple and effective risk management process are:

- Step 1: Identify the Risk
- Step 2: Analyse the Risk
- Step 3: Evaluate or Rank the Risk
- Step 4: Treat the Risk
- Step 5: Monitor and Review the Risk.

Figure 2 outlines the process followed by First Gas once a possible geohazard feature is identified and their Draft *Pipeline Geo-Hazard Management Plan* and the *Pipeline Geohazard Management Flow Chart* provide more detail of the process followed to identify, characterise, assess and mitigate or monitor the hazard and its associated risk.

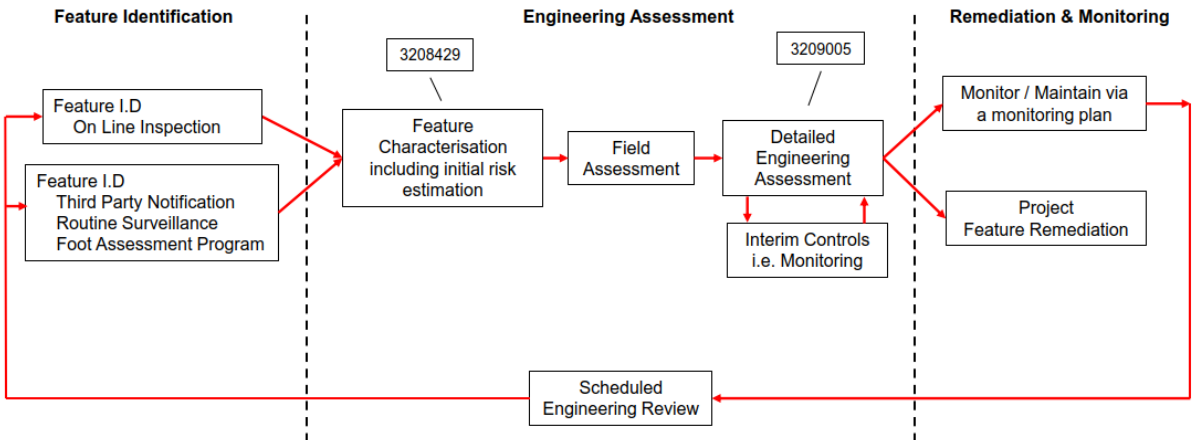

Figure 2 Outline of hazard identification and assessment process (from First Gas Power Point Presentation, 5 Oct 2016)

3.3.1 Hazard Identification

Hazard Identification is the process of recognising that a hazard exists and defining its characteristics.

The first step in evaluating the potential threats for a pipeline system or segment is to define and gather the necessary data and information that characterise the segments and the potential threats to each segment. As the Owner, First Gas needs to identify the location-specific threats to the integrity of the pipeline(s), and understand the public, environmental, and operational consequences of an incident.

As shown by Figure 2, current (new) hazards (features) are recognised by First Gas either through routine surveillance procedures (flyovers, walkovers, etc), in-line inspections and/or third party notifications (such as landowner, contractor or public advice). So far as we can ascertain, similar procedures were put in place by previous owners and provide the historical records of geohazards affecting the pipelines.

3.3.1.1 Recognised Geohazards

First Gas have identified a number of standard geo-hazards as part of their risk assessment process (Document 3207768 Standard Threat Assessment (STA), Rev 6, September 2018). These standard geo-hazards and the risk profiles associated with them are listed below and are used where no location specific information is available. Where location specific information in relation to geo-hazards is available, the information is used to establish the risk profile for that location.

- **Frost heave** – the STA assesses this as 'not credible' as the depth of burial of the pipelines is well below ground freeze depths in the North Island (or anywhere else in NZ - except high alpine areas).
- **Lightning** – this is a natural hazard but is not a geotechnical issue.
- **Erosion (loss of cover)** – in general, this is not a direct threat but could expose a pipeline to increased risk (e.g. from ploughing). The STA excludes locations such as stream crossings which are assessed as location-specific features.
- **Tomo's** (sinkholes formed by the action of water on limestone or volcanic rock). The STA assesses these as 'not a direct threat'.
- **Landslip** – The STA recognises that landslide risk in NZ is higher than in many other countries due to our topography, geology and rainfall patterns. Known landslips are subject to geotechnical monitoring and review. New failures are seen as the greatest risk to pipeline integrity. The STA recognises that the consequences of a landslide could be severe (rupture, loss of supply) for prolonged periods but judges this to be a low risk.
- **Mine subsidence** – only a threat where mining has occurred. As there is a low probability that a pipeline has been constructed over unknown mining areas, this risk is judged to be negligible.
- **Earthquake ground movement** (liquefaction, lateral spread, settlement). Considered low risk largely due to nature of the pipes.
- **Earthquake rupture** (fault crossing rupture). Standard assessment excludes known faults (specific locations). Indicates a low risk of rupture due to movement on an unknown (active) fault[8].
- **Volcanic/lahar activity** – rated as not credible in the standard assessment but addressed as a location-specific issue (for example, lahars at river crossings).
- **River/stream crossings** – buried or aerial. These are assessed on a location-specific basis.
- **Corrosion** (due to soil chemistry or hot ground) is not considered in the STA but is addressed as part of the pipeline management process.

3.3.1.2 Risk Classification

Risk management includes identifying hazards, establishing the associated risks and evaluating strategies to eliminate or reduce the risk(s). These processes provide an inventory for action and forms the basis for implementing control measures and establishing inspection schedules. There are two generic methods:

1. **Qualitative Risk Assessment** in which the probability and consequences are estimated in a subjective manner in terms of High, Medium and Low, and
2. **Quantified Risk Assessment** in which the probability and consequences are determined by quantitative methods that provide a precise numerical measure of the risk.

First Gas and its predecessors have used **Qualitative Risk Assessment** for geohazards.

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[8] We note that there is on-going potential for GNS to add new faults to active faults database. In our experience, the AFDB does not always match the seismic sources GNS (and others) consider in seismic hazard analysis

First Gas classify geohazard risk at two levels:

1. High level classification such as the *Geohazard Risk Zones Map* uses three risk categories: High, Medium and Low. These categories are not defined on the map or in the (draft) *Pipeline Geohazard Management Plan* and are not defined consistently in other documents reviewed.

In two examples (shown in Table 1 below), GNS (Perrin 2009) classified 'Threat Risk' into High, Intermediate and Low Risk categories, and GNS (Massey et al 2007) defined High, Medium and Low 'Impact Scenario' Classes.

It is not known which, if either, of these was used to determine the Risk Categories shown on the *Geohazard Risk Zones Map*.

2. At the location-specific level, use of the *Geohazard Risk Ranking Tool* assigns each assessed feature a pipeline-specific score based on five classes[9] each of severity and probability (frequency). This generates an overall site-specific assessment in one of five categories of 'Pipeline Integrity Response' which is used to prioritise integrity reviews.

   This is a preliminary assessment based solely on surface evidence and may be amended on the basis of additional information (detailed mapping, subsurface investigations).

The *Pipeline Safety Management Study Procedure* (3207969) indicates that AS2885.1 (2012) recognises three levels of risk:

- Intolerable (High and Extreme). Equates to score of 18-25. Must be reduced.
- Tolerable (Intermediate). Score of 13-17; must be reduced to ALARP.
- Acceptable (Low and Negligible). Score less than 13. No action required.

Table 1 Geohazard Risk Classifications used in two previous reports

Class	Perrin (2009) 'Threat Risk'	GNS (2007) 'Impact Scenario Class'
High	Risk to pipeline: rupture or deformation. Event is expected to occur often (< 30 years)	High risk to the pipeline. The pipeline has been exposed at the ground surface or the hazard is highly active and could lead to failure of the pipe
Intermediate (Medium)	Risk to pipeline: rupture or deformation. Event is expected to occur infrequently (30 to 3,000 years) Risk to pipeline: exposure without deformation or rupture. Event is expected to occur frequently (< 30 years)	No immediate risk to the pipeline. However ongoing development of the hazard could impact the pipeline in future (months); hazard assessed as active
Low	Little risk to the pipeline OR Risk to pipeline: exposure without deformation or rupture. Event is expected to occur infrequently (30 to 3000 years) OR Risk to pipeline: rupture or deformation. Event is very unlikely to occur (>3,000 years)	No risk to the pipeline at present or in the future (years); hazard assessed as inactive

3.3.1.3 Identification Methods

In the STA, it is stated that since the 2011 Pukearuhe incident, the Geo-Hazard Management system has been a proactive program that actively identifies relic, active and potential landslip areas.

The geohazards may be identified in a number of ways, including:

- Construction records;
- Historical records;

[9] These classes match the AS2885.1 Appendix F matrix but use different terminology.

and for new features:

- Flyovers (line flights);
- In-line inspection surveys;
- Walkovers (visual inspection); and
- Landowner/other advice.

The typical frequency for **In-line Inspection surveys (ILI)** of the pipelines is 10 years in rural locations and five years in urban locations, reflecting the greater safety-related consequences expected in urban areas. ILI vehicles can be fitted with geospatial mapping tool units that gather very accurate, three-dimensional positioning of pipelines. This data can be used to calculate pipe bending strain that is commonly associated with land movement around pipelines. An overview of the timing for ILI surveys on the transmission system is defined in the Pipeline Integrity Management Plan (PIMP) and is shown in Table 7 of Appendix C of the 2018 AMP.

Visual inspections are conducted at varying intervals. For example, the following table (Table 2), taken from the 2018 Asset Management Plan, shows more frequent inspections in populated areas, reflecting the greater safety-related consequences expected.

Table 2 Routine Inspection Frequencies

FREQUENCY	ACTIVITY
Daily	Road patrols in Auckland urban area
Monthly	Road patrols in the Whitby area.
Monthly	Road patrols Line flights Surveillance of special areas of interest
Three Monthly	Line flights Surveillance of special areas of interest
Ad Hoc	Post storm, flood or seismic event pipeline route inspections

3.3.1.4 Significant Hazards

The two most common natural hazards affecting buried pipelines are ground movements and erosion.

Potential ground movement hazards include landslides (debris flows, earth and rock slides, rock fall, or soil creep) along with surface water and groundwater erosion hazards on slopes. The surface water and ground water erosion may lead to pipeline exposure, while ground movements may result in pipeline loading.

Potential stream erosion issues are scour, bank erosion, encroachment, channel degradation, and avulsion (rapid abandonment and development of a new channel), any of which could lead to pipeline exposure.

Any of these hazards may be triggered by an extreme weather event. In New Zealand, other hazards that need to be considered are earthquake effects (ground shaking and ground displacement), coastal erosion and active volcanism (including lahars, hot ground and soil chemistry effects).

3.3.1.4.1 Landslides

Landslides are a significant hazard for the gas network because the pipelines are buried at relatively shallow depth and so can be affected by both deep-seated and shallow instability. Such ground movement could result in complete failure or significant leaks with in major environmental impacts and long periods of service disruption.

3.3.1.4.2 Stream Crossings

Stream crossings are a recognised problem area, particularly in relation to erosion. The reviewed AMP's and other reports recognise/address identified problem areas and remediation examples were presented at the meeting with First Gas on 17 May.

3.3.1.4.3 Coastal Erosion

The reviewed reports and AMP's contain references to coastal erosion threats, particularly in the Whitecliffs to Tongaporutu area on the northern Taranaki coast. The main risk sites are well documented, well understood, and effectively managed.

3.3.1.4.4 Earthquake Shaking

New Zealand is located on the boundary between the Indo-Australian and Pacific Plates, and is subject to frequent strong earthquakes. The documents reviewed show some recognition that earthquake shaking may cause (slope) instability but there is no mention in the documents reviewed of the NZ Seismic Hazard Model, NZS 1170.5 or geological susceptibility maps.

3.3.1.4.5 Fault Displacement

Most of the main transmission pipelines cross mapped active faults (as shown in the GNS Active Faults Database). We were advised that this has been considered when developing the *Geohazards Risk Map* but we have not seen any maps showing the locations of faults that cross the pipeline routes. The *Seismic Fault Crossing Guideline* (document 3208656) requires the risk to existing pipelines at all fault crossings to be re-assessed as part of the 5 yearly SMS.

3.3.1.4.6 Other Hazards

The documents reviewed make no mention of hot ground[10] (Rotorua), soil chemistry implications for corrosion or the potential implications of active volcanism, lahars in particular.

3.3.2 Risk Management

Risks to gas infrastructure presented by low-probability, high-impact events can be planned for, and good planning can help minimise the effects if these risks eventuate.

Management of risk to pipeline integrity includes management of external threats (third party interference, natural hazards), management of inherent threats (e.g. corrosion) and maintenance and operating strategies to monitor and prevent such threats. The overarching management of these risks is carried out via the ***Pipeline Integrity Management Plan*** (PIMP) which details the pipeline operation and maintenance activities to be undertaken to support the safe and reliable operation of the high-pressure pipeline system.

The PIMP is reviewed at least 5 yearly or immediately after a pipeline failure event. Reviews consider monitoring data and pipeline activities from the previous period and identify any change in risks associated with the pipelines from a wide range of threats, which are broadly categorised as:

- third party interference;
- corrosion; and
- nature (flooding, earthquakes, slips etc).

First Gas have several risk management systems and processes to capture and assess risks and subsequently manage any associated actions which minimise the potential for occurrence or reoccurrence. These include

1. A draft ***Risk Management Manual*** that applies to all First Gas Group companies and to all risks, including corporate risk, asset risk and transient project risk. The aim is to achieve consistency across all areas of the business and ensure that best practice in risk management is being applied.
2. The ***Asset Risk Management Guide*** (ARMG) dated September 2018 deals with asset risks that are managed via the risk item register (RIR) and includes a process flow to map the management of asset risk items to Maximo (see Figure A-1 of the ARMG).

[10] There are a number of issues with hot ground: Increases in pressure, temperature related strains, liner performance. We understand that First Gas consider these separately from geo-hazards.

3.3.2.1 Relevant Procedures

Management of landslide and erosion risks identified in First Gas' risk management documentation as a key risk, and monitoring and mitigation plans are in place in respect of these risks. As described in Appendix C of the 2018 AMP, First Gas has a hierarchy of risk management which is outlined below.

Remaining life reviews are conducted ten yearly on individual pipelines. The review comprises technical workshops facilitated by an independent party. The remaining life review takes into account the design standard, construction quality, material quality, operational stresses, maintenance history, asset working environment and external stresses to evaluate current condition and determine a remaining life. Geohazards are not a specific focus of these reviews.

In addition to remaining life reviews, **Safety Management Study (SMS) reviews** are conducted at a minimum of every five years, or when there is a signification change to the transmission system design or operations. The SMS and subsequent reviews are conducted in accordance with pipeline standard AS/NZS 2885 and address any issues (including geohazards) that could impact on pipeline condition. The SMS produces a list of actions for monitoring or mitigating threats that may include site monitoring, specific studies to provide better knowledge in areas of uncertainty and/or enhancements and repairs to improve pipeline integrity.

The SMS process uses a **Standard Threat Assessment (STA)** to assess threats (including geohazards) to the transmission system and apply them to hypothetical base case pipelines in typical rural and urban areas. Any areas of the pipeline that differ from the base case are reviewed, and appropriate mitigating measures determined on a location-specific basis.

Any actions identified as part of the SMS are implemented to change or improve maintenance routines or renewal programmes.

Annual **Asset Management Plans** set out how First Gas intends to manage the transmission network to meet customer gas demands over the next ten years. These plans provide information on the current identified geohazard risks along the transmission system and work underway to address these risks, and specify, among other things, the assessed risk rating and any changes from the rating in the previous AMP. These work programmes, which are updated for each AMP, to systematically address the high level risks to bring them down to medium or ALARP level.

3.3.2.2 High Level Reviews

The small scale *Geohazard Risk Zones Map* (dated 2015) provides an overview of the entire transmission network with sections of pipeline classified as High, Medium or Low Risk. The basis of the map and the indicated risk zones is not clearly stated. From discussions with First Gas, we believe that the map is based on a desktop review of geological maps, topography, aerial imagery and historical performance records. The lack of supporting information limits the value of this map.

Two high level assessments of geotechnical hazards are known to have been undertaken on parts of the gas transmission system. These are:

1. Riddolls (1978) report *Maui Pipeline Project: Evaluation of as-built slope stability* gives brief descriptions of 19 sites (identified by chainage) with evidence of slope instability in fine grained Tertiary-age sedimentary rocks between Pukearuhe (north Taranaki) and Huntly.
2. A geotechnical assessment of the section of pipeline from Urenui (on the northern Taranaki coast) to Otorohanga (in southern Waikato) for Vector Gas by GNS in 2009 identified 59 landslide or erosion hazards along this section of the pipeline. Following the October 2011 pipeline outage at the Pukearuhe site, the pipeline threats along the Urenui to Otorohanga route were reassessed by GNS (2012) based on a helicopter flyover with detailed examination at the previously identified sites. No new threat locations were identified and none of the previous threat levels had changed.

3.3.2.3 Current Geohazards Programme

In the 2018 AMP, First Gas state that the impact of geohazards and how this translates to pipeline integrity risk is a current focus for FGL. It is further stated that *analysis has identified a number of high geo-hazard risk areas and a dedicated programme is currently identifying the individual risks on these sections. The resultant risk will then be assessed by the Pipeline Integrity Team*.

The new programme that has been implemented to better understand and manage geohazards which represent a pipeline integrity risk on the gas transmission system is expected to be a 10 year project. This significant programme of work involves:

- initial reporting of each of the identified geohazards and assessing each feature for its likely impact to the pipeline; and
- conducting more detailed field assessments, geotechnical assessments, and pipeline integrity impact assessments.

The assessment process involves an initial desktop review and helicopter flight overview. From this, the system risk is assessed based upon observations, known local conditions and specific features into high, medium and low risks. This work is aligned with intelligent pigging reports to gain a more detailed understanding of the specific feature, how active it is and the impact it has on the pipeline. This implies a focus on landslides and erosion features rather than all potential geohazards.

3.3.2.4 Remedial Works

A number of key projects have been identified over the planning period 2018-2019 and previous AMPs viewed have included similar lists. Older (completed) projects drop off the list and it is not clear how and where are they documented.

Table 8 of Appendix C of the 2018 AMP (included as **Appendix B**) identifies current High Risk geohazards and actions planned or undertaken. Remediation is planned where required, alongside routine monitoring on the feature. Appendix C of the AMP provides greater detail on the status of current risks and planned activities for each site.

This process enables First Gas to ensure that the geohazard management activities undertaken follow a risk-based approach.

3.4 Monitoring Methods

Monitoring, in the context of First Gas pipeline operations, is the periodic inspection of a pipeline or pipeline segment to determine its condition and detect changes before they cause an outage. The period between succeeding inspections varies from daily to possibly many years depending on the assessed risk, as determined by the location and the type of issue (not just geohazards) that the monitoring is helping to manage.

Effective monitoring of long linear structures requires a relatively cheap, reproducible inspection. First Gas has well-established pipeline monitoring procedures and requirements which are detailed in the *Pipeline Surveillance Guidelines* (Doc 3205330).

3.4.1 Routine Surveillance

Regular inspections of the pipelines undertaken in accordance with the Pipeline Surveillance Guidelines may include:

- flyover (observation by helicopter following the route of the pipeline);
- walkover; and
- in-line inspections.

The typical frequency for in-line inspections is 10 year intervals in rural areas, and 5 year intervals in urban areas. Aerial inspections may be undertaken at monthly to yearly intervals and ‘foot inspections’ are scheduled to provide coverage of the pipelines every 5 years. These ‘foot inspections’ are additional to routine pipeline patrols undertaken by pipeline technicians who inspect the pipeline routes and assets on a regular basis and prepare a ‘Patrol Report’ after each patrol. The Pipeline Surveillance Guidelines indicate that *the technicians have GNS training in recognising land movement issues and carry a GNS aide memoire*. We understand that their observations are seen as complementary to the functions of the Pipeline Integrity Specialist ‘foot inspections’ and aerial inspections.

The *Pipeline Management System Manual* states (Table 14.1) that records from routine inspections (patrols) are to be kept for a minimum of five years. Details of design, construction and commissioning, engineering drawings, corrosion details and details of leaks/damage (among other information) are required to be retained for the life of the asset.

3.4.2 Enhanced Monitoring

Additional patrols are initiated after extreme rainfall, storms or earthquakes. These are to identify (among other things) erosion or seismic-related ground conditions, changes to watercourses, terrain and/or stream crossings.

Sites that have been subjected to remedial works are also subsequently subject to enhanced monitoring. For example, in the MBIE (2012) report following the Pukearuhe incident, the following is stated:

The sites assessed as high risk are actively and regularly monitored. Monitoring activities typically undertaken at the high-risk landslide sites are:

- monthly flyover (observation by helicopter following the route of the pipeline);
- monthly walkover;
- remote onsite monitors providing monthly data download (rainfall, ground water depth, and GPS landslide points)
- snapshot measurement of drain flow rates;
- six-monthly vegetation control, drain clearing, and weed spraying; and
- annual check on electronic equipment, walkover accompanied by a geotechnical engineer and subsequent report from geotechnical engineer, full survey of manual survey points (these are generally pegs placed over a much wider area than the identified boundaries of the landslide).

3.4.3 Geohazard Features Monitored

Extreme weather events or earthquakes can cause impacts (such as erosion or ground movements) on parts of the transmission system. These events may trigger reactive work to remediate an issue, or may require additional monitoring. The *Pipeline Geohazard Management Process* flowchart (3209005) outlines First Gas' process for determining the appropriate response(s).

Currently, the routinely monitored geohazard features are mostly associated with landslides, coastal erosion or stream crossings, in addition to the monitoring of corrosion protection. Monitoring of threats to the pipeline from ground instability slips and/or erosion is detailed in the PIMP and remedial works (where required) are scheduled in the planned maintenance system or completed as capital work.

We have found no suggestion that there is specific scheduled surveillance monitoring of faults or other low likelihood potential hazards; instead, such events will be responded to when and if they occur.

3.5 Data Management

Pipeline monitoring means that a record of the current condition and the history of the pipeline is available, which is useful in planning and prioritising maintenance and remedial works associated with geohazards. The results of succeeding measurements or observations must be stored in a format that can easily be accessed and compared over time with newly obtained data.

The 2018 AMP reports that GIS[11] is used for the master asset register for below ground pipeline assets and includes geospatial, technical, hierarchical, spatial, contextual, connectivity, cathodic protection and land management data.

While the primary purposes of GIS are to prepare and provide accurate pipeline information and plans to any party proposing to carry out work in the vicinity of assets and to support (PIMS) and demand

[11] First Gas are using ArcGIS by Esri.

modelling systems, First Gas have developed a GIS *Geohazard Web Viewer* that is now set up for all the pipelines and have a programme to backfill the relevant historical geohazard information.

In this system, among other information, the locations of geohazards and the pipeline assets are captured with GPS or with geospatial mapping tool units fitted to ILI vehicles that gather very accurate, three-dimensional positioning of pipelines. The viewer allows the user to see identified geohazard features in relation to pipelines and other features.

All maintenance activities, including inspections of and works on geohazards, are planned through Maximo CMMS, Corrective Maintenance and Planned maintenance. Document 3208372 *Pipeline Management System Manual* Section 8 covers the utilisation and prioritisation of maintenance activities while Document 3208332 *Pipeline Integrity Management Plan* Section 6.7 refers to actions output from SMS being controlled and prioritised through Maximo.

The **Pipeline Management System Manual** describes First Gas' approach to records management and data acquisition and states (page 37) that a*ccurate and targeted records management is recognised by the GTB as a critical activity, preserving historical information to contribute to the safe operation and maintenance of the pipeline covering the pipelines' lifecycle. This section sets out the GTB approach to Records Management, which is designed to ensure the right information is maintained and that it is accessible when required.*

3.6 May 17 Meeting with First Gas

As part of the review, we met with First Gas representatives at their New Plymouth office to discuss their geohazard identification and management practices. At the meeting, FGL openly and freely provided clarifications to questions raised. In addition, they described hazards identified and actions taken at several recent sites. The examples described confirmed that FGL have appropriate processes and procedures for identifying and addressing the types of geohazards (such as stream erosion, coastal erosion and landslides) with which they have previous experience.

FGL also presented on the GIS *Geohazard Web Viewer* that is currently being introduced (see Section 4.2 below). This is an excellent initiative and will greatly improve geohazard understanding and management, help knowledge transfer and collate all information in one place. A key input will be the capture of historical information.

4.0 Evaluation of Findings

In Section 1.3 we outlined the key components we would expect to see in a thorough geotechnical risk assessment and management programme for the gas transmission network. In this section, we provide our evaluation of these factors in relation to the First Gas transmission network.

We acknowledge that we have seen only a selection of the available information and that our assessment may be affected by that.

We also note that the 2018 AMP prepared by First Gas indicates that the business is working on improving the understanding and management of geohazards and sees this as a 10 year project.

4.1 Understanding of Geohazards

The review undertaken suggests that there is good localised understanding of the geohazards and geotechnical conditions impacting the network. It appears that while some historical events affecting the pipelines since construction are well documented, there is poor documentation of other incidents/events. We understand that First Gas is working through the historical information to capture all available information in the GIS *Geohazard Web Viewer*.

First Gas retain a Pipeline Integrity Specialist whose role is specifically focussed on the identification and management of geohazards affecting the transmission network. The incumbent has been in this role since 2011 and has a long history of involvement with the pipeline network in various roles and a good knowledge of the geohazards affecting the pipelines.

The focus in geohazards management is on those hazards that are most likely to (or have) impact(ed) the pipelines – ground movements (landslides, slumping), erosion (runoff, stream erosion, coastal erosion) and third party activities (excavations, farming activities). Events that can be expected to occur much less frequently (damage due to fault movement or ground shaking, volcanic activity including lahars) are recognised and will to be reacted to when appropriate.

From our review of a range of literature relating to Australia, North America, South America and European practices, this approach is consistent with international practice[12]. We understand that FGL have critical spares (those items that are of high importance and/or unusual and have a long lead-time) in stock, so that rapid response can be achieved in the event of these HI/LP events.

4.2 Network Mapping of Geohazards

The data review did not find evidence that the gas transmission network has been systematically mapped geospatially to identify soil and rock types and geohazards (such as active faults, landslides, erodible materials) affecting the network. We did find an overview (small scale) map showing geohazard risk zones, but no supporting documentation to clearly explain how the risk zones were determined or how they are used in risk management.

Discussions with First Gas on 17 May showed that the map is largely based on a desktop review of geological maps, topography, aerial imagery and historical data.

First Gas have initiated a project with the objective of completing a full geohazard assessment of the transmission network in the next ten years (AMP 2018, p15). A key component of this is the capture of geohazards data in a new *Geohazard Feature Database* interfaced with ArcGIS. This work in progress was demonstrated to us at the meeting on 17 May and captures summary information at identified geohazard sites that can be accessed by point-and-click on colour coded points on aerial imagery.

Currently, the Geohazard Features Database does not interface with GIS layers that identify varying soil conditions or other regional information (geology, faults, etc).

[12] The specific hazards that receive the highest focus vary between countries depending on their geological and climatic conditions

4.3 Knowledge of Pipeline Condition

The Geohazard Features Database does not capture pipe condition information (particularly regarding corrosivity) or pipe coating/protection information. This information is managed elsewhere in First Gas' systems. FGL are aware of differences in pipe coatings used at the time of construction but it is not clear (from the information reviewed) whether the different pipe coatings are related to varying soil conditions.

From our review of FGL procedures, AMP's and other provided documents, such as consultant's reports, we believe that FGL maintains a high level of knowledge of the condition of the pipelines through regular in line inspections (pigging) and has a systematic approach to inspecting and evaluating the condition of the pipes (particularly regarding corrosivity).

4.4 High Consequence Locations

Critical pipeline sections (those which have the highest consequences in the event of failure) are those that would pose a threat to the greatest number of individuals (for example within Auckland and other built up areas). In such areas, gas leaks can result in environmental destruction, demolition of infrastructure assets and can impact human life.

We understand that a High Consequence Area (HCA) is a buffer that usually extends 200 m to either side of a section of pipeline that passes through developed areas where people live in an urban or suburban setting, or where people frequently gather (a school, for example). High Consequence Areas (HCA's) are defined in some jurisdictions[13] as "impact zones which contain 20 or more structures intended for human occupancy".

We did not find any suggestion that greater certainty in the understanding of geotechnical conditions affecting HCA pipelines is a requirement of AS/NZS 2885; typically the risk is managed through the design of the pipeline and regular inspections. First Gas manage this risk by undertaking much more frequent patrols of designated HCA's (for example, daily patrols within Auckland).

4.5 Assessment of Location-Specific Geohazards

First Gas' geo-hazard management processes consider the events or activities that can result in a geo-hazard event as dominated by:

- earthquake (with consequences such as landslides or ground displacement);
- heavy rainfall (leading to erosion); and
- human activity (including accidental damage and sabotage).

Once a geohazard is identified from routine surveillance or by advice from a third party, the risks of location-specific damage to the pipelines affecting supply are assessed in accordance with the *Pipeline Geohazard Management Process* flow chart (3209005). This includes a pipeline integrity assessment and ensures the assessment is carried out in a systematic manner that is consistent with the FGL's risk management policy framework and AS/NZS 2885. FGL commonly use external consultants in assessing location specific hazards[14].

As specified in the draft *Pipeline Geohazard Management Plan*, a geohazard risk assessment is conducted for each identified feature to determine the relevant severity (consequence) and frequency (likelihood) class in relation to the pipeline using the *Geohazard Feature Risk Ranking Tool* (document 3208429) taking into account likely trigger events, such as rainfall or earthquake.

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[13] For example, the US Department of Transportation Pipeline and Hazardous Materials Safety Administration https://primis.phmsa.dot.gov/comm/FactSheets/FSHCA.htm

[14] Several of the reports listed in Appendix A-2 were prepared by consultants retained to assess specific sites or sections of pipelines.

As noted above, First Gas and its predecessors have recognised that

1. landslides that penetrate to burial depths (typically 0.9m to 2.5m), or induce damaging stresses at those depths, pose a hazard to a pipeline.
2. Deeper landslides can induce enough stress or strain to a pipeline to result in deformation, or potentially loss of pipeline integrity and containment.
3. Surface erosion may result in a loss of pipeline cover leaving the pipeline exposed and at risk to operating outside minimum code requirements, or damage from being struck by debris or machinery.

However, in the opinion of the reviewer, current assessment procedures are very light on other (lower likelihood) hazards – areas at risk from earthquake shaking, ground (pipeline) displacement due to faulting, or volcanic activity (particularly lahars) are not specifically identified, while soil chemistry and hot ground effects on corrosion protection are not treated as geohazards.

4.6 Mitigation of Location-Specific Geohazards

This review has confirmed that First Gas has robust procedures to identify options for mitigating location-specific geohazard risks once they have been identified. In the examples seen, such options have been systematically evaluated, preferred options identified and implemented (or scheduled) in accordance with a prioritised plan. The AMP summarises the intended works for the coming year.

4.7 Risk Management

Options for mitigating location-specific High and Intermediate/Medium risks are identified, systematically evaluated and implemented (or scheduled) in accordance with a prioritised plan to reduce risk to ALARP, or better. For example, the assessment of coastal erosion risks at Whitecliffs included a risk assessment and an options assessment from which a preferred solution was identified and is being progressed.

First Gas' procedures are consistent with industry standards (such as AS/NZS2885 and ISO 31000) where the focus is on frequent events – erosion due to floods, rainstorms, slope instability (debris flows, landslides) – and local effects (such as acid soils, hot ground) and low frequency events such as fault rupture, liquefaction or volcanic activity are not afforded the same levels of attention. The current management philosophy appears to be to respond when/if these hazards eventuate. This is consistent with accepted industry practice for low likelihood events.

However, First Gas do see the management of geohazards as an integral part of the risk management process and have increased the focus/visibility of geohazard issues and are putting processes/tools and systems in place to support this. Examples of this include the update of the GIS and relevant support tools, and the change to ensure that all geohazards will now go through the RIR process with Work Orders generated via Maximo. These processes illustrate how FGL's risk management studies feed directly into the operations, inspection, maintenance, renewal and development strategies. As noted above, walkovers and flyovers are scheduled such that critical assets are inspected more frequently, indicating that these have a greater maintenance focus.

Risk assessments carried out under the SMA and STA procedures include assessments of residual risk. Any geohazard identified to have a residual risk that is higher than the acceptability threshold is specifically reported up through the organisation, and further mitigation options evaluated for implementation. The actions implemented may include physical works, improved maintenance routines or changes to renewal programmes to reduce the risk to ALARP or lower.

As noted above, the current management philosophy appears to be to respond when/if low frequency/high consequence hazard events occur (such as earthquakes causing ground displacement or liquefaction or volcanic activity resulting in lahars). The sites where such events may occur and/or have unacceptable outcomes are not currently well documented which does expose FGL to a very low level of risk while the knowledge base is brought up to date and better documented.

4.8 Information Gaps

Two gaps in the management of geohazards that First Gas are actively addressing to help better monitor and manage the geotechnical risks are briefly discussed below.

4.8.1 Low Probability, High Impact Events

The draft *Pipeline Geohazard Management Plan* and associated documents are focussed on the geohazards that have historically affected the pipelines most frequently or are considered the most likely to affect them (landslide movement, shallow slumping, erosion, coastal erosion).

FGL's existing processes place less emphasis on those parts of the pipelines that may be at (much lower) risk from earthquake-related ground movements (fault displacement, liquefaction) or volcanic activity (lahars, hot ground, thin crust, acid groundwater) – see AS/NZS 2885.1 Appendix K. While there is some understanding of these areas (*Geohazard Map*) there is no clear documentation of them.

4.8.2 Capture of Historical Events

The current geohazard risk management approach includes development of a GIS-based system to capture all known location-specific geohazards and details of their assessment and treatment. This is an excellent initiative that will provide an easily accessible tool for future use.

Historical information relating to geohazards is currently difficult to locate and staff interviewed were unable to tell us how many geohazard sites have been identified and assessed in total. This is partly due to the historical changes in ownership of the pipelines. First Gas is working through the historical information to capture all available information in the GIS *Geohazard Web Viewer*.

5.0 Comparison with International Standards and Experience

Other standards and published papers reviewed for this study are summarised in **Appendix A**.

5.1 International Standards

We had great difficulty locating international standards equivalent to AS/NZS 2885 in the public domain, particularly in relation to managing natural and geo hazards.

The American Society of Mechanical Engineers (ASME) has published Standard ASME B31.8-2003 which sets out the engineering requirements deemed necessary for the safe design and construction of pressure pipelines but is very general on natural hazards.

ISO 13623:2009 *Petroleum and natural gas industries -- Pipeline transportation systems* specifies requirements and gives recommendations for the design, materials, construction, testing, operation, maintenance and abandonment of pipeline systems used for transportation in the petroleum and natural gas industries. This has now been superseded by ISO 13623:2017.

The European standard for pipelines is *EN 14161 Petroleum and Natural Gas Industries - Pipeline Transportation Systems*. In the UK the regulations and the HSE accept EN14161.

5.2 Published Papers

Published papers proved more useful for evaluating how others manage natural hazards. In particular, a paper by Baumgard et al (2014) describes US and Canadian experience and procedures similar to those of First Gas, including development of a database to manage site-specific geohazard information.

Baumgard et al (2014) state that the challenges in implementing and maintaining a geohazard integrity management system can be generally divided into three broad categories: spatial, temporal, and procedural. The first two are technical in nature, while the latter relates to the manner in which the program is implemented and operated. The challenges described include understanding the influence of physiography, recognizing the episodic nature of some events, and determining appropriate failure criteria for the program. Specific issues they mention include (1) the challenge of scheduling the inspection of multiple sites on a regular but variable basis (depending on nature and character of the hazard) and (2) prescriptive (regulatory) requirements that appear to be based on arbitrary values or rules-of-thumb, and do not account for variations in geology, geometry or engineered protective measures.

An analysis of European and US pipeline geohazard data[15] found that landslides accounted for 46% of the geological incidents, while earthquakes represented 9% (Girgin & Krausmann 2014). Mostly this related to US experience as, generally, for Europe only overview data could be found, and the level of detail was not sufficient to allow an in-depth analysis of incident causes, dynamics and consequences.

5.3 Assessment

The processes and procedures which continue to be developed and followed by First Gas in compliance with AS/NZS 2885 in relation to geohazards appear to be aligned with national and international good industry practice.

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[15] The data set includes transmission, distribution and service pipelines both onshore and offshore.

6.0 Conclusions and Recommendations

6.1 Conclusions

The process for identifying and analysing geohazards and associated risks is well covered in the 2018 AMP and other documents reviewed. Identifying and evaluating risks, and relative ranking of the risks, is a key part of the First Gas risk management methodology.

The main conclusions from our review and assessment of the geohazard risk management methodology followed by First Gas for the transmission pipelines are:

1. First Gas have good, well documented processes in place to identify geohazards and to evaluate and manage the risks associated with the identified hazards
2. These procedures are consistent with the requirements of AS/NZS 2885
3. First Gas currently have a high level of knowledge of the geohazards affecting transmission pipelines and do not hesitate to retain specialist advice where appropriate to fully understand the hazards and associated risks
4. The reports by specialist advisors that we saw as part of this review were almost all of a very high standard.
5. Recognising that the natural geohazards that may affect First Gas transmission pipelines are a function of the New Zealand geology, topography and climate, and that these differ from Australian conditions, First Gas are developing additional procedures and guidelines to complement AS/NZS 2885 requirements in relation to geohazards.
6. The processes and procedures which continue to be developed and followed by First Gas in compliance with AS/NZS 2885 in relation to geohazards appear to be aligned with national and international good industry practice.
7. The draft *Pipeline Geohazard Management Plan* and associated documents are, however, focussed on the geohazards that have historically affected the pipelines most frequently, or are considered the most likely to affect them (landslide movement, shallow slumping, erosion, coastal erosion). While this is consistent with international practice, we believe there are opportunities for improvement (see Recommendations below)
8. The processes put in place for monitoring identified risks are dominantly visual or involve simple instrumentation (survey, piezometers, drainage flows). The data is internally reviewed and verified by consultants at High Risk sites. We consider this to be an appropriate approach.
9. Historical information relating to geohazards is currently difficult to locate and staff interviewed were unable to tell us how many geohazard sites have been identified and assessed in total.
10. The high level 'big picture' view of relative geohazard risks (the *Geohazard Risk Zones Map*) is a very useful document but is not supported by explanatory information and does not define the High, Medium and Low risk classes depicted.
11. It is possible that due to the amalgamation of a number of companies into FGL, there is some lack of consistency in the definition of risk levels. While these are not significant they could lead to uncertainties or ambiguities in the assessment of risk levels.

In accordance with the Brief, the following comments confirm that, in the opinion of the reviewer, First Gas, in assessing their exposure to geotechnical risks, has:

- made appropriate enquiries to understand and manage the risks (see Conclusions 1 and 2);
- sought adequate expert advice where required (see Conclusion 3);
- received advice that has adequately responded to the questions asked (see Conclusions 3 and 4); and
- appropriate processes in place for monitoring identified risks (see Conclusions 5, 6 and 7).

6.2 Recommendations

In the opinion of the reviewer, two areas for improvement in the management of geohazards that would help First Gas to better monitor and manage the geotechnical risks are, as outlined in Section 4.8 above:

1. Understanding of low probability, high impact events

Recommendation 1: FGL should better document the areas potentially at risk from earthquake and volcanic events as a matter of priority

Recommendation 2: This information should be used to assess both risk and potential consequences so that appropriate emergency action plans (which could include 'react when necessary' at remote locations) can be developed

2. Capture of historical events

Recommendation 3: Capture of all available information in the GIS *Geohazard Web Viewer* should be given priority.

Recommendation 4: Consider adding the following information to the new system as separate GIS layers:

1. Regional geological maps, specifically the GNS QMAP series which is available in electronic format.
2. Regional information available through GeoNet, GNS and Regional Councils that identifies areas of potential hazards such as liquefiable soils, streams at risk from lahars.
3. The GeoNet active faults database, also available in electronic format. GNS have defined classes of active fault on the basis of recurrence interval (Class 1 less than 2000 years, etc) which should be adopted to help identify the faults most likely to affect one or more of the pipelines. This should be undertaken in conjunction with an assessment of the implications of the NZ Seismic Hazard Model and NZS 1170.5.
4. Topographic maps (LINZ), as this information assists with risk zoning based on or taking account of topography (eg. slope angle maps).

Recommendation 5: The criteria for high level risk classifications (High, Medium and Low) used on overview maps in initial assessments of new geohazards be clearly defined and documented within the *Pipeline Geohazard Management Plan*. When combined with the GIS-based geohazards management system that is being developed and introduced, this additional information will give First Gas a very powerful geohazard management tool.

Recommendation 6: To make the best use of this geohazard management tool in future, it is important that First Gas instigate a succession plan for the incumbent Pipeline Integrity Specialist.

7.0 Standard Limitations

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Appendix A

Documents Reviewed

A-1: First Gas Documents Reviewed

Document Number	Title	Content	Comment
3208372	Pipeline Management System Manual	The purpose of the PMS Manual is to demonstrate that the management system fulfils the requirements of AS2885.3:2012. This is achieved by a combination of commentary on the various required activities and reference to the relevant procedures, instructions or other documents that control those activities.	The manual serves provides an overview of the key systems and processes. It outlines the important components of safe operation including the Pipeline Integrity Management Plan, Safety Management Study (SMS) and Document Control procedures.
3209319	Asset Risk Management Guide (Sept 2018)	This document deals with asset risks that are managed via the risk item register (RIR). The RIR contains process, safety and integrity risks (which include geohazards). Doc describes process for confirming a risk then managing it.	Outlines a robust process for documenting and managing asset risks in Maximo. Each risk item is regularly reviewed to ensure progress is being made on implementing any interim actions and the proposed solution. The geotechnical risks are assessed by the Pipeline Integrity Specialist and geotechnical consultants retained by FGL.
	RIR Work Plan FY2020	List of risks with summary info including risk scores. Includes geotechnical.	The risk cited in the RIR FY2020 work plan is the current or interim assessment depending on the status of any works started.
Draft document *(received 24 May)*	Pipeline Geohazard Management Plan	Purpose is to provide guidance and process to ensure quality of identification, risk evaluation, analysis, mitigation and monitoring of geo-hazards related to the pipeline and/or easement. Also applicable to off easement (or off pipeline) assets	Details the process to identify, assess, remediate and monitor natural hazards (Geo-Hazards) that have a significant effect on a transmission pipeline system. Outlines the typical geo-hazard events (erosion, landsliding, coastal erosion) and triggers (human activity, rainfall, earthquake) that are associated with these geo-hazard(s).

G0000-357-01-B	Geohazard Risk Zones Map	Overview map of network identifying High, Medium and Low risk zones. Dated 04/15.	FGL have advised that the H, M, L classes were based on field observations, areas that are known to have features, and historical knowledge of known geohazards areas. The heat map was used as a prioritisation tool to develop the 10-year assessment program, and not used elsewhere, hence it is not referenced in any of the documentation.
3209005	Geohazard Management Flow Chart, Rev 1 (2017)	Identifies process to be followed when a geohazard is identified	Reactive. Different paths for known v new features. Leads to decision to monitor or undertake remedial works.
3207768	Standard Threat Assessment (STA), Rev 6 (2018)	Comprehensive assessment of generic threats to pipeline. STA provides a consistent basis for assessing individual pipelines and is a starting point but is not location-specific.	Considers the following events: frost heave, lightning, erosion, tomo's, landslip, mine subsidence, earthquake (ground movements and rupture), volcanic activity, river/stream crossings. Section 3 of the STA includes Corrosion and Wear as a threat category.
3205330	Pipeline Surveillance Guidelines	Standard forms; not geohazard-specific	Lists features to check for, including geohazards and indicators
3208656	Seismic Fault Crossing Guideline	Provides guidance for risk, design, construction and maintenance	Mostly a design guideline. Also requires risk to existing pipelines at all fault crossings to be assessed at 5 yearly SMS; residual risk must be Low or ALARP. Recognises that existing pipelines may not have been designed in accordance with guidance and requires retrospective implementation of mitigation measures if residual risk is greater than Low. BUT document mentions 'active' and 'non active' faults, not defined. No mention of Active Faults database. No mention of construction records.

3209239	Guidelines for Geohazard Foot Assessment (Version 0, 2017)	Provides guidelines for identifying and assessing geohazard features associated with the transmission pipeline easement and surrounding area where there is potential for land instability to cause an integrity issue with the pipeline, pipeline above ground assets and/or associated easement.	Considers ground instability and erosion, post-construction effects including human activity. Appropriate for routine inspections or post-event inspections. Does not specifically address low probability events (earthquakes, volcanic activity)
3208429	Geotechnical Feature Risk Ranking Tool	Provides risk matrix and basis for it. Defines Severity and Frequency classes.	Relies on judgement. Pretty standard stuff except for terminology (which is a mixture of industry-specific (as per AS 2885) and company-specific – the geohazard feature evaluation and ranking severity categories use common geotechnical terms.
	Remaining Life Review Report (2017)	400 Line, Oaonui to Southdown (Maui pipeline) Provided as an example	Reports loss of containment (LOC) in 400 line at White Cliffs (Pukearuhe) in Oct 2011 when land movement caused pipeline to buckle at a weld. Notes similar incident in 200 line in July 1977. Also mentions a realignment of the 400 line (Westfield-Southdown section, 2009). Table 8 lists threats with a residual risk of High or Intermediate (2016 SMS review). These include a number of location-specific threats.
	Maui Pipeline Geohazard Features	Lists 841 sites (co-ordinates, severity, risk, rank, geology, length)	The Maui Geohazard Features document is an example of the information that has been uploaded into the GIS system. The information is available to all FGL personnel through the Geohazard Web viewer portal on the intranet. The Maui pipeline was the first significant section of pipeline completed; the whole network will eventually be included (part of the 10 year plan).

3207969	Pipeline Safety Management Study Procedure, Rev 3 (Oct 2015)	Describes systematic process to identify/assess threats.	Procedure to determine whether the pipeline's safety and security are within acceptable limits by assessing compliance and risk levels in accordance with AS2885.1 (2012). Links to Standard Threat Assessment (STA). Appears robust. Not specific to Geotech/hazards
3208583	Pipeline Project Safety Management Process (SMS)	Flow chart showing process (2016 version)	Shows FGL safety management process from Preliminary Design through Construction to Handover. Not Geotech specific.
Draft Doc	Risk Management Manual	This manual applies to all First Gas Group companies and to all risks, including corporate risk, asset risk and transient project risk.	Aims to achieve consistency across all areas of the business and ensure that best practice in risk management is being applied. Not Geotech specific.
Draft Doc	Risk Governance Guide	High level draft	Not directly relevant to geotech
3208332	Pipeline Integrity Management Plan (PIMP)	PIMP recognises 3 main categories of Threat: Third Party, Corrosion, Nature (flood, landslip, EQ etc). Section 7.4.2 (p 21) Patrol of Pipeline refers to 3205330 – Pipeline Surveillance Guidelines	Patrol report after each patrol. *Technicians have GNS training in recognising land movement issues and carry a GNS aide memoire.* Training is delivered by the Pipeline Integrity Specialist and is conducted at Field Technician team meetings. Additional patrols after extreme rainfall, storms, earthquakes. Identify (among other things) erosion or seismic-related ground conditions, changes to watercourses, terrain and crossings. Discussions on 17 May indicated that technicians have much wider range of responsibilities during field inspections and that currently there is only one dedicated geohazards inspection person (who undertakes the annual scheduled foot inspections – see below)
	FY18-19 Foot assessment plan	Details proposed site inspections on Lines 100, 400, 430, 432-435, 437 and 606.	Confirms that have inspection procedures on pipelines other than Maui. Discussions confirmed that similar plan is developed each year.

3207968	As Low as Reasonably Practicable (ALARP) Guidelines	Guideline setting out how risk assessments are carried out within the SMS process and how cost benefit analysis is used to support the quantitative assessments of ALARP.	Good outline of process and gives list of information required for an assessment. Not geotech specific.
	500 Pipeline SMS (2016)	Pipeline commissioned 1983. Supplies gas to BoP and Gisborne regions, linking Pokuru Compressor Station and Kawerau Delivery Point (182 km).	Five yearly review, Executive Summary only. States that majority of credible threats have Low or Negligible residual risk and that 'a few' credible threats have Intermediate risk that require further assessment to demonstrate ALARP. No details provided
	ILI-16 Desktop Review Workshop (July 2018)	Review of site info and scope of detailed site assessment (DSA) at Tongaporutu, 10 km south of Mokau Compressor Station. Area of known instability with previous report ID's. **Good example of good practice!!!**	Reviewed published geology, field observations by FGL Pipeline Integrity Team in June 2018, historical imagery. Described proposed DSA scope. References confirm previous work/obs 1978, 2009, 2012, 2014, 2016 See also Pariroa Land Feature (ILI-16) Initial Assessment Report that reports a buckle identified in the pipe in April 2018 following geohazard assessments in 2012, 2014 and 2016 that identified a landslide at Waikarora Stream. Report dated Sep 2018 details the nature of the buckle, mode of possible failure, recommends an ERP and permanent remediation works. Complementary Options Assessment Review (Oct 2018). PM activities are controlled through Maximo. Maintenance Plan for Waikorora area includes: PM 61029 (1/6/12 Month intervals), recording of data and monitoring equipment checks onsite. PM62632 (2 yearly) Geologist Line Flight PM 82339 (6 Monthly) Land Instability line flight PM 62004 (2 monthly) Taranaki Area aerial surveillance

A-2: External and Location-specific Documents Reviewed

Prepared by	Title	Content	Comment
Riddolls (1977)	Engineering geological assessment of gas pipeline routes at site of failure of Kapuni Pipeline, North Taranaki	NZGS Report EG289 on failure (and fire) of 200mm Kapuni pipeline at Pukearuhe 2 Jul 1977.	Failure attributed to land movement as pipeline crossed corner of landslide at an angle that created compressional loading causing the pipe to buckle and split along a weld.
Thompson (1978)	Failure of the Kapuni-Auckland high-pressure gas pipeline	Published paper describing the pipeline failure at Gilbert Stream (abstract only)	Abstract reports that the pipeline was restored to full operation within 24 hours with no interruption of supply due to in-line storage
Riddolls (1978)	Maui Pipeline Project: Evaluation of as-built slope stability	NZGS Report EG298. Assessment of potentially unstable sites along Maui pipeline. Based on air photo interpretation, with some ground inspection.	Report gives brief description of 19 sites (identified by chainage) with evidence of slope instability in fine grained Tertiary-age sedimentary rocks. Also notes the previous (1977) failure of Kapuni pipeline at Gilbert Stream.
GNS (2006)	Waikorora Landslide	Just north and inland from Pukearuhe. Approx 400m of the Maui pipeline traverses the head and lateral margins of this active landslide. Landslide is monitored. Rate of movement significantly reduced by remedial works in 1996.	Refers to 15 previous reports dated between 1987 and 2006; but first report of instability was in 1981.
GNS (2009)	Assessment of hazards Urenui to Otorohanga (Perrin)	Flyover survey to identify landslide and other geohazard threats along a part of the pipelines with known problem areas	Identifies 59 landslide and other erosion hazards along 140 km section of Maui and Kapuni pipelines. Notes that these are mostly in Tertiary-age mudstone.

GNS (2012)	Urenui to Otorohanga Threat Assessment Site Visits (Dellow)	Reassessment of the 59 (2009 report) sites based on ground inspections.	Identified eight hazard types, four of which included "High Risk" sites. Recommended quantitative baseline measurements using LiDAR and pigging that could be used to develop future change models.
GNS (2012)	Geotech assessment of Pukearuhe Landslide (Dellow et al)	Not seen/provided. Referenced in Gilbert Stream report. Also several media reports.	Reactive – but landslide had been recognised previously. See MBIE review dated Oct 2012 (found on internet)
MBIE (2012)	Review of the Maui Pipeline Outage of October 2011	Summarises information obtained on the Pukearuhe Landslide and evaluates wider regulatory, environmental and management implications of the outage. Investigations concluded that the pipeline failed due to overload caused by movement of a large, slow-moving landslide, that the pipeline is within the edge of the landslide, and that the landslide will continue to move.	States that (1) this was the first significant outage since construction in 1977 (2) the repaired section of the pipeline remains within the landslide, improved mitigation measures have been implemented (aimed at preventing failure in the short- to medium-term), and (3) a long-term solution is being developed
GNS (2016)	Gilbert Stream Coastal Erosion Assessment	Area north of Pukearuhe assesses cliff erosion retreat rates and potential to expose Maui pipeline. Updated in 2017.	This work has been used in planning remedial works/realignment – see PowerPoint First Gas to CC workshop 31 Aug 2018
OSD (2017)	Whitecliffs Options Screening Report	Known area of coastal erosion (see TVNZ 28 April 2018 as well). OSD cite a number of previous reports by engineering consultants and GNS. Good example of robust assessment	Report type = Reactive/Planning This work has been used in planning remedial works/realignment – see PowerPoint First Gas to CC workshop 31 Aug 2018
PDP (2017)	Saxton Property, Glen Murray	Huntly-Mill Road Pipeline (400B line). Shallow instability following heavy rain in April 2017. Assigns 'geohazard feature risk score' to each feature – this is based in First Gas' *Geohazard Feature Risk Ranking Tool* (Doc 3208429).	Excellent Report. Reactive FG subsequently determined remedial actions required
Construction Services (2017)	Ngapouri Stream, Waiotapu	Very basic investigations report for proposed retaining wall for pipeline protection.	Prepared for other consultants (Cardno).

Cardno (2019)	Ngapouri Stream, Waiotapu	Described as a follow-up report to review outline designs for managing erosion risks around three stream crossings in the Waiotapu area, Rotorua district	Pipeline not identified
PDP (2019)	Turners Retirement Landslide, Mokau	Maui Pipeline, approx distance 127.30 km. Remediated landslide feature showing in-line strain. Detailed report by PDP.	Excellent report. Includes (as does Saxton report) a useful summary table at front of document. First instability at site was in June 1990. Several previous reports on site dated 1992, 2016, 2018.

A-3: International Documents Reviewed

Prepared by	Title	Content	Comment
American Society of Mechanical Engineers	Gas transmission and distribution piping systems	Standard ASME B31.8-2003. Sets out the engineering requirements deemed necessary for the safe design and construction of pressure pipelines.	Clause 841.13 relates to the protection of pipelines from natural hazards. Very general in nature.
Wijewickreme, D. and Weerasekara, L.	Pipeline Geotechnical Engineering. In *Encyclopedia of Life Support Systems* (EOLSS)	Covers the role of geotechnical engineering in ensuring satisfactory performance of buried pipelines during all phases of their design life including construction and installation, operations, and under extreme field loading conditions.	Emphasises that adequate knowledge of site-specific soil and groundwater conditions is critical to the success of the design and installation of pipelines, as well as in predicting their performance under field conditions. Chapter 6 specific to geo hazards.
Ferris G,; Severin, J.	Pipeline integrity risk assessment and management	Paper discussing the risk that landslides pose to pipelines	Emphasises the need to identify geohazard sites and create inspection and management processes that allow the ability to react to a failure prior to rupture.
Oliveira, H.R. (2013)	A Proposed Geotechnical Risks Management Plan for Pipeline Integrity	American Society of Mechanical Engineers 2013 International Pipeline Geotechnical Conference paper (Abstract only)	Presents information about geotechnical risks in transmission pipelines and tools applied in identification, prevention and correction of geotechnical problems in pipelines
Baumgard et al (2014) In *Proceedings of the 10th International Pipeline Conference*	Implementing a geohazard integrity management programme	Describes experiences over a 15 year period to develop and implement a geohazards Integrity Management Program (IMP) with 12 major pipeline operators for approximately 13,500 individual geohazard sites spanning approximately 63,000 km of operating pipelines in Canada and the USA.	Found that most geohazards were associated with streams (erosion at crossings) or landslides. Describes a database called Cambio developed to store the data from site inspections. Described challenges associated with implementing and operating a successful geohazard management program in three broad categories: spatial, temporal, and procedural.
Girgin, S.; Krausmann, E. (2014). *JRC Technical Report*	Analysis of pipeline accidents induced by natural hazards	Reports on a study of European and U.S. pipeline incident data sources to identify the main accident triggers, system strengths and	Found that that natural hazards are a non-negligible threat to pipelines transporting hazardous materials. The analysis of the U.S.

		weaknesses, consequences and lessons learned.	data set showed that geological hazards triggered 37% of the onshore pipeline incidents analysed. Landslides accounted for 46% of the geological incidents, while earthquakes represented 9%.
Jamie Kereliuk, Director of Emergency Management at Kinder Morgan Canada.	5 facts about pipelines and natural disasters	Interview report discussing how much of a danger is posed by oil and gas operations, including pipelines, in the midst of natural disasters. Key message: There are multiple hazards that might affect a pipeline on any given day and the important thing is to have different plans in place to deal with each of these hazards.	All pipeline companies must have a comprehensive and up-to-date emergency management plan for each pipeline they operate. In any given area, potential hazards might include such natural events as fire, flood, tornadoes or earthquakes – and emergency management plans must include measures to protect against such natural disasters. Pipelines are also designed and built to very detailed specifications and standards, taking into account the types of natural events they may be subject to.
US Department of Transportation	Hazard Mitigation Planning for Pipelines	In January 2015, PHMSA and FEMA released a new hazard mitigation guidance document. “Hazard Mitigation Planning: Practices for Land Use Planning and Development near Pipelines” outlines best practices for communities to reduce risks from pipeline incidents, including those caused by natural hazards.	Notes that while pipelines are often thought of as presenting risks to communities, natural hazards can impact the integrity of pipelines. Although natural hazards are cited as the cause in fewer than ten percent (10%) of pipeline incidents, the failure of a large-diameter, high-pressure natural gas or hazardous liquid transmission pipeline during an earthquake or hurricane event can significantly complicate a communities’ ability to respond and recover from the event.

Appendix B

Major Identified Geohazards 2018

Table 8: Significant Geohazard Status Table

LOCATION	HAZARD	NOTABLE POINTS TO HIGHLIGHT	ACTIONS	ASSESSED RISK[2]	CHANGE IN RATING	STATUS
Gilbert Stream	Loss of pipeline integrity due to the erosion of cliff face.	Assessment of the erosion mechanism is due to slabbing of the 50m vertical cliff face. Coastal monitoring indicates that minor erosion is ongoing and that the clifftop is within 10m from the pipeline.	Relocation project released to detailed design and materials ordering.	High	No change	The project to mitigate risk has been initiated, with execution planned for FY2019. Geohazard feature monitoring has been implemented and managed by Pipeline Integrity team.
White Cliffs	Loss of pipeline integrity due to the erosion of cliff face.	Coastal monitoring indicates that erosion is ongoing and that the clifftop is within 25m from the pipeline. There are areas of additional interest noted.	Coastal erosion assessment review being completed by GNS Jan 2017. Routine monitoring ongoing.	High	No Change	The project execution has been planned for FY2022/FY2023. Geohazard feature monitoring has been implemented and managed by Pipeline Integrity team.
Turakina River Crossing	Pipeline exposed on bank side of river.	Pipeline needs to be protected and not realigned. Bank needs to be reinstated.	Project initiated, and scope of works completed and handed to project delivery for execution.	High	No Change	The project has been initiated and Scope of work has been reviewed, a more cost-effective solution has bene selected. Execution is planned to occur FY2019.
Pukearuhe Strain Site	Pipeline intersects a large active land feature; ongoing land movement has the potential for pipeline deformation from land induced stress.	The pipeline crosses through an active land feature. Previous Intelligent pigging results identified pipeline strain, associated with surface features.	Project plan resulted in the excavation and destressing of the section of pipeline.	Low	Changed from High to Low	Reports relating to the 400line intelligent pigging conducted in FY2018 have been reviewed, no pipeline movement change was identified. The risk remains at Low.
Waikokowai Road	Pipeline crosses through the head of an active lobe associated with a larger relic landslide.	Potential for pipeline deformation from the land movement induced strain. Recent events and continued monitoring confirms that this feature is active.	Project scoped to remediate and passed to project delivery team. Routine monitoring ongoing.	Low	Changed from High to Low	The land movement remediation work was completed in FY2018. The risk on 403line reduced to Low.

LOCATION	HAZARD	NOTABLE POINTS TO HIGHLIGHT	ACTIONS	ASSESSED RISK[2]	CHANGE IN RATING	STATUS
Troopers Road	Pipeline ascends through an area of active landslide slope; ongoing land movement has the potential for pipeline deformation from land movement induced stress.	The pipeline crosses through an active land feature, there is suspected pipeline deflection. Monitoring indicated some sub-surface deflection.	Scope of work include drainage to be installed and overburden removed. Routine monitoring ongoing.	Low	Changed from High to Low	The land movement remediation project was completed in FY2017. Reports relating to the 400line intelligent pigging conducted in FY2018 have been reviewed, no pipeline movement was identified.
Wall Road (South)	Pipeline descends through a portion of an active landslide slope associated with a large relic landslide, ongoing land movement has the potential for pipeline deformation from land movement induced stress.	The pipeline crosses through an active land feature with visible land surface features, previous ILI results identified pipeline strain associated with the identified surface features.	Project plan resulted in the excavation and destressing of the section of pipeline. Routine monitoring ongoing.	Low	Changed from High to Low	Project remediation completed. Reports relating to the 400line intelligent pigging conducted in FY2018 have been reviewed, no pipeline strain was identified, indicating that the remediation project was successful.
Mangatea Rd Te Kuiti	Pipeline ascends through an active landslide; ongoing land movement has the potential for pipeline deformation from land movement induced stress.	Recent project investigation excavations and reformation of open surface water contour drainage was to be completed.	Project plan completed FY2017. Routine monitoring ongoing.	Low	Changed from High to Low	The pipeline de-stress project was completed in FY2017. No land movement signs have been observed since. Site monitoring will continue.
Pipeline Awakau Road No.1	Pipeline traverses near the crest of a ridge.	Pipeline within 0.7m from the crest of the steep sided ridge.	Pipeline integrity review required. Routine monitoring ongoing	Intermediate	Changed from High to Intermediate	The option study will be finalised FY18 for the project scope of works. This site has been identified in FY2019 Geohazard remediation works list.
Mokau Land Movement	Slope Stability.	Pipelines ascend a steep slope from State Highway 3.	Ongoing monitoring monthly Pipeline Integrity review required.	Intermediate	Changed from High to Intermediate	The initial site investigation has been completed. A detailed site assessment will be conducted in FY2019.

LOCATION	HAZARD	NOTABLE POINTS TO HIGHLIGHT	ACTIONS	ASSESSED RISK[2]	CHANGE IN RATING	STATUS
Awakau Rd No.2	Slope Stability.	Pipeline Integrity review and Field Assessment required.	Pipeline Integrity review and Field Assessment required.	Intermediate	Changed from High to Intermediate	Field Assessments completed during Dec 2016, Geotech report completed 2017. The option study will be finalised in FY2018. This site has been identified in FY2019 Geohazard remediation works plan.
Bexley Station	Slope Stability.	Pipeline traverse, and area identified historically.	Pipeline Integrity review and Field Assessment required.	Low	Changed from High to Low	Field Assessments completed during 2016. Geotech report completed in 2017. Reports relating to the 400line intelligent pigging conducted in FY2018 have been reviewed and no pipeline movement change is reported in this section.
Mathers Rd, Te Kuiti	Landslide.		Geotech report and investigation completed.	Low	Changed from High to Low	Reports relating to the 400line intelligent pigging conducted in FY2018 have been reviewed and no pipeline movement change is reported in this section.

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