

Engineering/Technical Investigation Report

Well Failure at Terra Wilder

December 2014



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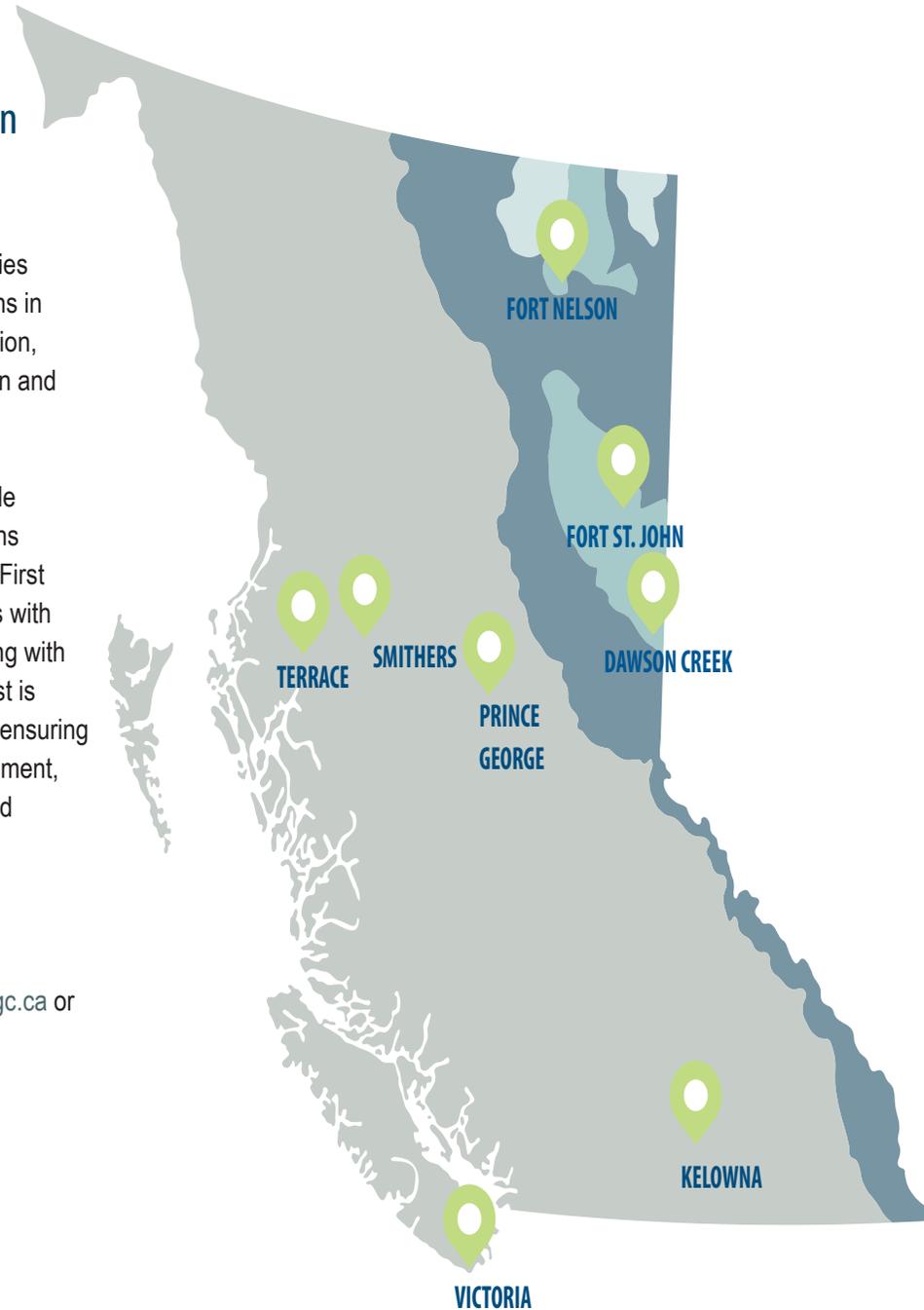
About the

BC Oil and Gas Commission

The BC Oil and Gas Commission (Commission) is the single-window regulatory agency with responsibilities for overseeing oil and gas operations in British Columbia, including exploration, development, pipeline transportation and reclamation.

The Commission's core roles include reviewing and assessing applications for industry activity, consulting with First Nations, ensuring industry complies with provincial legislation and cooperating with partner agencies. The public interest is protected through the objectives of ensuring public safety, protecting the environment, conserving petroleum resources and ensuring equitable participation in production.

For general information about the Commission, please visit www.bcogc.ca or phone 250-794-5200.



1. Incident Summary

On Dec. 11, 2014 at 09:30 hours, the Commission received a complaint of hydrogen sulphide odours at a residence on the Old Hope Road, approximately 12 km west of Fort St. John, British Columbia. Commission inspectors were dispatched to investigate.

On arrival, Commission inspectors noted that odour was present in the area and the complainant was not home. The inspectors searched the area, but were unable to pinpoint the source of the odour and the odour dissipated over time until it was faint to non-existent. The Commission inspectors believed the odour may have resulted from mercaptans¹ and Pacific Northern Gas was contacted to investigate whether or not the odour was related to their operations.

At 14:00 hrs, Terra Energy received a complaint of odours on the Old Hope Road. At 14:30 hrs, the Commission discussed the status of the odour investigation with Terra and a decision was made to establish access to the 07-02-84-20 wellsite as all other potential sources in the area had been investigated.

At 15:30 hrs, a Terra responder approached the 07-02-84-20 wellsite (the site) and determined there was a gas release at the site. The Terra responder called for backup and once backup arrived, the Terra responder entered the site with a SCBA (self-contained breathing apparatus) to investigate. The Terra responder determined there was a gas release coming from the surface casing vent on the wellhead and the concentration of hydrogen sulphide (H₂S) in the immediate vicinity of the wellhead exceeded 200 ppm.

¹ Mercaptans are sulphur compounds added to natural gas distribution systems that assist with leak detection as their odour is detectable at extremely low concentrations.

Terra activated its emergency response plan and dispatched response personnel to the site. The Commission was notified of the incident at 17:35 hrs.

Terra responders secured the site and conducted door to door notifications of area residents. Evacuation was not required, however, Terra offered hotel accommodations for those residents who chose to voluntarily leave.

Terra responders began monitoring for off-site H₂S using their personal monitors. Commission personnel were dispatched to the site to oversee the emergency response and to conduct independent air quality monitoring until a dedicated air monitoring unit arrived. During the night of Dec. 11, maximum off-lease concentrations of H₂S decreased significantly and ranged from 1 to 2 ppm.

On Dec. 12, Terra began work to open an access road to the site. Difficulties were encountered as wind was blowing gas and H₂S across the access road. At 16:25, a dedicated air monitoring unit arrived and was deployed in the vicinity of the site.

The Commission received complaints from area residents who claimed they were not notified of the incident. On investigation, the Commission determined Terra had not left messages or information packages for those residents who were not contacted when the initial notification was attempted. The Commission instructed Terra to ensure that all local residents were contacted and to leave information packages if residents were not home.

On Dec. 13, a flare stack was installed. Gas from the well was directed to the flare stack and ignited, eliminating the release of H₂S. At 16:35, high density fluid was injected into the well, eliminating the gas flow and bringing the well

under control.

From Dec. 14 to 16, a service rig was mobilized to the site and well abandonment operations were completed. The perforated zone in the well was permanently plugged with a mechanical plug and cement, and the production casing was tested. It was determined the production casing had failed between 6.7 m depth and the ground surface.

On Dec. 17, Terra excavated around the wellhead and identified that the casing failure had occurred at a depth of 0.9 m. The failed section of casing was removed and the well was capped, completing abandonment operations.



Figure 1: Location of Terra Wilder 07-02-84-20 wellsite.

2. Investigation Procedures

All companies engaged in oil and gas activities in British Columbia are required to report incidents where the safety of persons or the quality of the environment has been placed at risk. The Commission receives and reviews these reports and provides regulatory oversight of the follow-up responses and mitigation by the company.

Certain incidents may prompt a more detailed investigation by the Commission. As a general rule, the Commission may launch an Engineering/Technical Investigation into an incident when the incident:

- Results in significant impacts to the public or other stakeholders.
- May stem from a systemic issue within the company's management systems.
- May identify deficiencies in current practices and procedures within industry.
- May identify opportunities for improvement of processes and procedures within the Commission or within industry.
- Results or may have resulted in serious injury or death.
- Is in the public interest.

The Commission's goals in conducting an Engineering/Technical Investigation are to identify the incident cause and contributing factors. The results of these investigations are summarized in a publicly accessible report available from the Commission website. By sharing the results and findings of these investigations, the Commission reduces the likelihood of similar events occurring. Enforcement actions may arise during the course of a technical investigation but are not the primary purpose.

3. Relevant Information

3.1 Incident Chronology

The following observations and statements have been made following a review of the incident logs and the response to the information requests made by the Commission. The timing of the events and the emergency response to the incident are provided in Table 1.

Table 1: Incident Time Log (in Mountain Standard Time)

Time	Detail
1966	Well is drilled and completed in the Baldonnel formation. Well is tested but not placed on production.
1970	Well is abandoned.
2005	Well is re-entered and re-completed in the Baldonnel formation. Well is tested but not placed on production.
May 27, 2011	Terra Energy completes report stating well is suspended in accordance with Commission requirements.
Nov. 28, 2014	Commission receives and investigates an odour complaint in the area, but is unable to determine the source.
Dec. 11, 2014	

09:30	Commission receives complaint regarding sour gas odours on the Old Hope Road. Commission investigates and notifies Pacific Northern Gas and Terra of the odour complaint.
14:00	Terra receives complaint regarding sour gas odours on the Old Hope Road.
14:30	Commission discusses status of odour complaint investigation with Terra. Plan to establish access to 07-02-84-20 wellsite and investigate as a potential source.
15:30	Terra determines that there is a gas release from an inactive well located at 07-02-84-20.
16:30	Backup arrives, Terra personnel enters wellsite and determines there is a gas release from the surface casing vent. H ₂ S concentration exceeds 200 ppm at the wellhead.
17:27	Incident reported to Emergency Management BC (EMBC).
17:35	EMBC reports incident to Commission.
18:00	Commission inspector dispatched to site. Terra secures site, conducts door-to-door notification of area residents and conducts air quality monitoring.
23:36	No measurable H ₂ S at the lease access, but odours are evident. Terra and Commission personnel continue to monitor air quality until a dedicated air monitoring unit arrives.
Dec. 12, 2014	
07:00	Commission receives complaint from area resident who says they were not notified of the incident.
08:30	Air monitoring continues. Maximum H ₂ S reading of 2 ppm. Terra begins work to open an access road to the wellsite.
11:51	H ₂ S readings of 5 ppm, 30 metres from the road.
12:36	Work continues to establish access to the site. Difficulties are encountered as wind is blowing gas across the access road.
16:25	Dedicated air monitoring unit arrives and is deployed at the site.
Dec. 13, 2014	
13:00	Flare stack ignited. Gas flow from the well is directed to the flare stack.
16:35	Kill fluid is pumped into the well. Gas flow from the well is eliminated.
Dec. 14, 2014	Service rig is mobilized to the site. Well abandonment operations commence.
Dec. 15, 2014	Baldonnel perforations are permanently plugged. Determine that there is a leak in the well casing between 6.7 metres depth and surface.
Dec. 16, 2014	Begin to rig out service rig.
Dec. 17, 2014	Complete rig out service rig. Excavate around wellhead and identify casing failure on weld at 0.9 metres depth. Complete well abandonment.

3.2 Information Requests

On Jan. 6, 2015, a formal request for information (information request, or IR) was issued to Terra to provide a post incident report outlining the incident cause, contributing factors and measures taken to manage and respond to the incident.

3.3 Failure Analysis

The Commission visited the site immediately following the incident in order to assist with the incident response and to gather evidence. In addition, the Commission attended the site when the failed portion of well casing was excavated in order to examine the casing.

Following examination, the failed portion of casing was transported to Rae Engineering and Inspection Ltd. in Edmonton, Alberta (Rae) for metallurgical analysis.

The well was originally drilled in 1966 and completed for production from the Baldonnel formation. The well was tested, but was not placed on production and was abandoned in 1970. In 2005, the abandoned well was re-entered, re-completed in the Baldonnel formation and tested again. The well was not placed on production and was maintained in an inactive state until the time of the incident.

During the well abandonment in 1970, the well casing was cut and capped approximately 1 m below ground level. During the subsequent re-entry, the casing stub was exposed and a threaded collar was welded onto the casing to allow it to be extended back to ground level. The casing failure occurred where the collar was welded to the casing stub.

Rae determined the failure originated at the interface of the internal seal weld where the collar was welded onto the production casing and was caused by fatigue. The heat affected zones of the internal and external welds were found to have excessive hardness, making them susceptible to cracking. While there was no evidence of significant internal corrosion, Rae noted that the corrosive environment in the well likely accelerated crack propagation and the subsequent failure.

Excessive hardness of the weld and heat affected zones can result from rapid cooling of the weld. Pre-heating the metal prior to welding and controlling cooling after welding can prevent excessive hardness from developing.



Figure 2: Photograph showing the failed casing section.

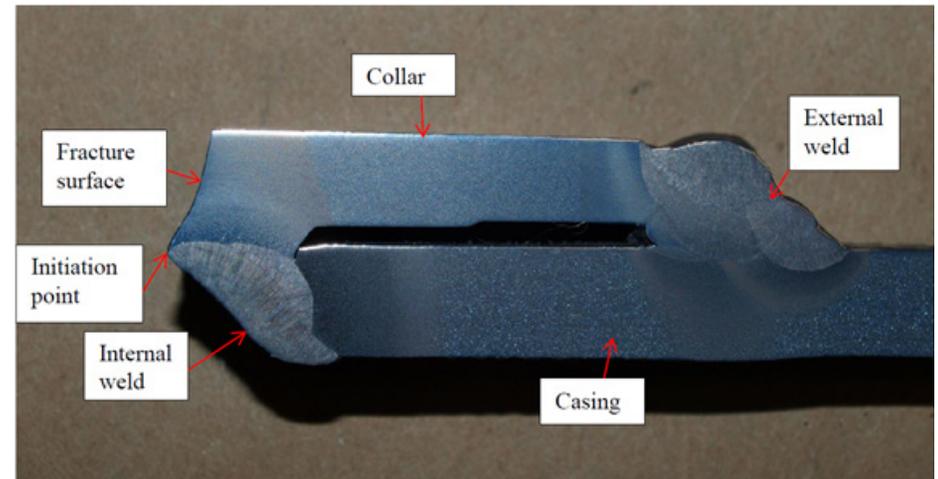


Figure 3: Photograph showing the cross section of failure location.

4. Analysis

4.1 Failure Cause and Contributing Factors

The following observations and statements are based on a review of the evidence:

- In 1966 the well was drilled as a horizontal well and completed in the Baldonnel formation. The well was tested, but not placed on production.
- In 1970, the well was abandoned. The abandonment included cutting and capping the well casing approximately 1 m below ground level.
- In 2005 the well was re-entered, re-completed in the Baldonnel formation and tested, but not put on production.
- During the 2005 re-entry, a casing collar was welded onto the casing stub in order to extend the casing back up to the ground surface.
- The Commission was unable to locate any information regarding the welding procedure, or post-welding QA/QC.
- On May 27, 2011, Terra completed a well suspension form indicating the well was suspended with a packer and tubing plug. In addition, the form indicated both production casing and tubing had passed a pressure test.
- Based on the location and type of well, the Commission's well suspension requirements indicated the well was to be inspected yearly and pressure tested every 3 years as a minimum. In addition, results are required to be documented and kept on file.
- Terra was unable to produce records to indicate the required inspections or pressure tests were completed on the well.
- A review of the Commission well file indicated there was no evidence that a packer and tubing plug had ever been installed in the well.
- During abandonment operations, it was determined the

well did not have a packer and tubing installed in the well.

- Failure of a casing collar weld at 0.9 m depth resulted in an uncontrolled release of natural gas containing H₂S from the well. The failure was discovered on Dec. 11, 2014.

Based on the preceding observations and statements, the Commission determined the cause of the Terra Wilder 07-02-84-20 well failure and gas release was the failure of a casing collar weld due to fatigue. Excessive hardness in the heat-affected zones of the welds resulted in a microstructure that was susceptible to cracking. The Commission was unable to determine whether the failure resulted from an inadequate welding procedure or a failure to follow the welding procedure.

Factors that contributed to the incident include:

1. Failure to suspend the well in accordance with Commission requirements. Had the well been adequately suspended, the failed portion of casing would have been isolated from wellbore fluids.
2. Failure to inspect and pressure test the casing according to Commission requirements. An adequate inspection would have identified excessive pressure between the production casing and the tubing. Further investigation would have identified the well was not adequately suspended.

Figure 4a illustrates the actual well configuration at the time of the incident. Figure 4b illustrates the well configuration Terra provided to the Commission when

reporting the well was suspended and shows how the casing failure location would have been isolated from reservoir fluids.

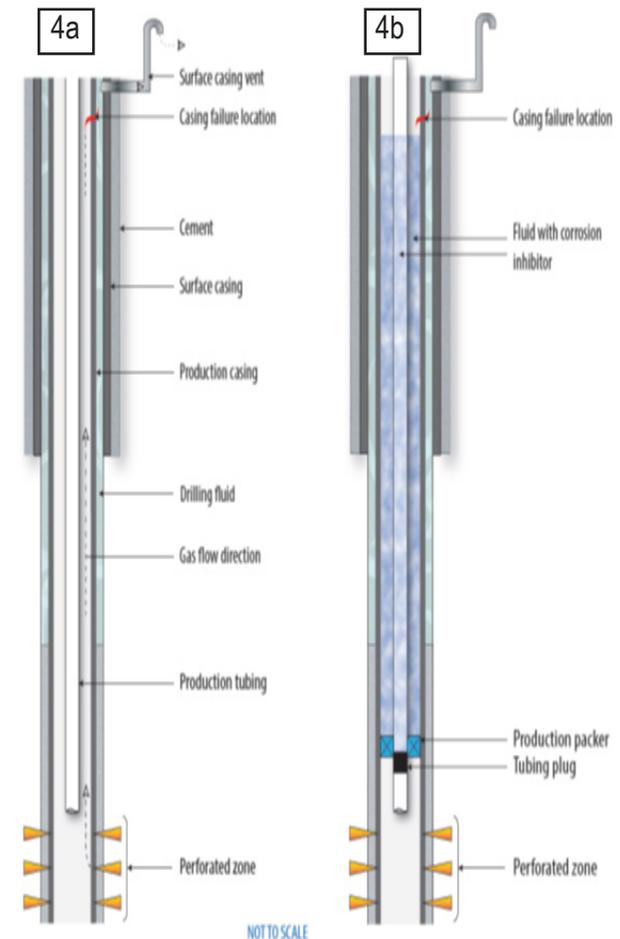


Figure 4a: Actual wellbore configuration. 4b: Reported wellbore configuration

4.2 Emergency Management

The following observations and statements are based on a review of the incident logs and responses to the information request:

- The Terra emergency response plan (ERP) was inaccurate as it identified the well was sweet and did not contain H₂S.
- The nearest residents were located approximately 500 m to the east of the incident location.
- The well failure was first identified at 15:30 on Dec. 11, 2014.
- The incident was reported to EMBC, at 17:27. The incident was classified as a level 3 emergency.
- Terra responders did not have timely access to adequate air quality monitors.
- Terra responders did not have adequate training to ignite the well if necessary. The Terra ERP did not identify a third party that could have supplied this service in a timely manner if needed.
- Notification of area residents was inadequate. Information packages were not left for residents if initial notification attempts were unsuccessful.

The Commission identified significant deficiencies with Terra's response to the incident. Terra's emergency response plan was not accurate and Terra responders did not have adequate response capability.

4.3 Air Quality Monitoring

Throughout the incident response, air was monitored on site through the use of personal gas monitors and a hand-held gas monitor. Additionally, Terra deployed a mobile air monitoring unit to monitor air quality in the vicinity of the site.

Prior to the arrival of the mobile monitoring unit, Commission inspectors took measured H₂S concentrations hourly at seven locations. The maximum instantaneous H₂S concentration was 2 ppm at 02:00 on Dec. 12, 770 m SW of the wellsite.

Firemaster Oilfield Services arrived on site and began air quality monitoring at 21:45 on Dec. 12 and continued until 18:00 on Dec. 14. The maximum H₂S concentration was 0.19 ppm at 10:45 on Dec. 13 on the Old Hope Road, 590 m E of the wellsite. There was no detectable H₂S after gas was directed to flare on Dec. 13 at 13:00.

The Worksafe BC short term exposure limit (15 minute time-weighted average) for H₂S is 10 ppm.

The B.C. Ministry of Environment (MOE) air quality objective for H₂S is 5 ppb (0.005 ppm) based on a 1-hour average. The MOE objective is based on the odour threshold for H₂S.

5. Directions

- 1. Terra shall conduct a review of all inactive wells in order to identify which wells are deficient. Terra shall develop and implement a corrective action plan.**

Terra has completed surface inspections of all inactive wells. Terra has identified which wells are deficient and has developed a corrective action plan that will prioritize work based on a risk assessment of each well. The Commission is monitoring the implementation of the corrective action plan.

- 2. Terra shall ensure all tests and inspections of inactive wells are documented and records are available for audit.**

Terra has reviewed and revised relevant internal procedures to ensure that test and inspection results are recorded and records are maintained in accordance with regulatory requirements.

- 3. Terra shall ensure its Emergency Response Plan (ERP) is accurate and current. Terra shall ensure its response capabilities are consistent with those outlined in its ERP.**

Terra has revised and updated its ERP. In addition, Terra has completed a major emergency response exercise. The Commission attended and evaluated the emergency response exercise.

6. Recommendations

The following recommendations are being pursued by the Commission:

- 1. The Commission should undertake a review of all wells that have been re-entered that may be at risk of a similar failure.**

The Commission has completed a review of all re-entry wells in British Columbia and determined there are no other wells with a similar risk profile.

- 2. The Commission should issue a safety advisory in order to advise industry of the incident cause and recommended preventative measures.**

The Commission issued a safety advisory 2015-03 in June 2015.

- 3. The Commission should continue to monitor Terra Energy to ensure all corrective actions are implemented in a timely manner and to the satisfaction of the Commission.**

This work is ongoing.

