An Analytical Approach to Hydraulic Fracturing and Induced Seismicity Monitoring

John L. J. Duhault
STARBIRD ENTERPRISES, CALGARY, CANADA

The public’s fears about hydraulic fracturing and subsequent potential for induced seismicity are a growing concern, even in tried and true oil fields of Alberta. The stakeholders need to be shown that a well thought out approach to understanding hydraulic fracturing and potential induced seismicity can be done following a logical step by step procedure.

A Decision Tree Analysis (DTA) approach is proposed to help identify the steps needed to determine if the planned oil field activity could penetrate existing potable water aquifers or could generate induced seismic events that might cause local damage. This process would proceed in a logical manner and conclude with an option to:

- Carry on with no need for monitoring,
- Self-monitor for improved oil field knowledge and economics (completion strategy) or for sensitive areas
- Or monitor with “traffic light” environmental protocols tied to grounded scientific research

Background

“If we look at tens of thousands of wells that have been stimulated with hydraulic fracturing in Western Canada, less than half a percent are associated with induced earthquake activity.”

Dr. David Eaton, University of Calgary

Even with this simple statement the public hears hydraulic fracturing and induced earthquake activity and forgets the details in between. This is why companies operating in Alberta need to be sensitive to the area landowners and other stake-holders in order to maintain their social license to explore and develop the hydrocarbon resources on the lands they have leased from the Alberta Crown.

A DTA Approach

The Decision Tree analysis can be broken down into four general categories:

- Project Area Parameters
- Geological Concerns
- Treatment Well Style and Monitoring
- Social License to Operate

Project Area Parameters: “Location Location, Location”. The first step is to find out if there are any concerns about the local area groundwater and then determine the depth of the local potable water zones from recognized government sources. While searching the media and discussing with your field personnel, determine if your project area has had induced seismicity issues in the past. Once you know if there has been an issue or concern, and you have checked with your local government regulator to see if you are required to monitor, you can plan your operations accordingly. Are you hydraulically fracturing a tight reservoir or planning a waste water disposal well? Both will have different issues when dealing with induced seismicity. The former generally involves a lot of energy and fluid in a relatively short period of time (days), the latter can involve very large volumes of fluids or gases over a longer period of time (years), both of which can exceed the local rock stresses and create induced seismicity events.

Geological Concerns: A thorough review of the local stratigraphy, geology and geophysics would be examined. How deep is your target reservoir? Are there any mapped faults in the area? Has there been any pre-existing seismicity, whether natural or induced? How close is your reservoir to the Precambrian basement? Is your reservoir under- or over-pressured, or more precisely, what is your fracture gradient?

Treatment Well Style and Monitoring: The potential for inducing seismicity is also related to your hydraulic fracture treatment style. What is your pump rate and stage volume? Do you have any microseismic information that shows that your treatments are getting greater than 1 Mw?

Social License to Operate: You may find yourself in a situation where there is no scientific or analytical reason to monitor for induced seismicity. However, you are operating in a sensitive area with critical control structures and/or population centres that you may need to monitor in order to protect your social license.

This DTA approach will guide the user to the appropriate level of induced seismicity monitoring with or without government Induced Seismicity Monitoring (ISM) environmental protocols.

The DTA Checklist:

- Well location
- Check government regulations for new regulations
- Depth of potable water
- Waste water injection or hydraulic fracturing
- Pre-existing seismicity
- Proximity to Precambrian basement
- Reservoir pressure (over-pressured or highly depleted reservoirs)
- Mapped faults
Is your cap-rock also your seal?
Hydraulic fracture pump rate
Hydraulic fracture stage volume
Microseismic events
Sensitive public area

The steps created for this DTA were based on field data and observations, published data, personal communication, conferences and various industry, academia and government web sites. Although some of the steps can run together or in tandem, the analysis will guide geoscientists and completion engineers in the direction of what to pay attention to and what recommendations to make as to the level of environmental protocol necessary for their specific hydrocarbon extraction operation and seismic hazard assessment.

**Case Studies**

Three examples from Western Canada will show the highly variable nature of hydraulically fracturing reservoirs in the Western Canadian Basin. They will also illustrate how each area would require a different need or level of induced seismicity monitoring due to the magnitude of the induced seismicity anticipated.

The answers to the Decision Tree Checklist are highlighted as follows:

- **Green** – Proceed with no need to monitor
- **Orange** – On its own, not enough to monitor for ISM, if many, consider ISM
- **Red** – On its own consider ISM, if many, have ISM and Traffic Light Protocols in place

### Case Study Number One:
**Horn River Formation, Horn River, NEBC**
- Target reservoir is greater than 500 m below the base of potable ground water
- Hydraulic fracturing
- Pre-existing seismicity (Yes)
- Proximity to Precambrian basement (200-500 m above)
- Reservoir pressure (Highly over pressured 42 – 48 MPa)
- Mapped faults
- Hydraulic fracture rate (7 – 20 m³/minute)
- Hydraulic fracture volume (100 – 450 T/stage)
- Microseismic events (Mag up to 4.3 ML)
- Sensitive public areas

**Conclusion:** Monitor for ISM with a Traffic Light Protocol system in place.

### Case Study Number Two:
**Cardium Formation, West Central Alberta**
- Greater than 1500 m below Base of potable ground water
- Hydraulic fracturing
- Pre-existing seismicity (None)
- Proximity to Precambrian basement (> 600 m above)
- Reservoir pressure (Under – 21 mPa)
- Mapped faults (Few – deeper zones)
- Hydraulic fracture rate (6 – 9 m³/min)

**Conclusion:** Hydraulic fracturing of the Cardium in this area will not create any significant induced seismicity. Consider monitoring in sensitive areas or areas of public concern.

### Case Study Number Three:
**Bakken Formation, SE Saskatchewan**
- Greater than 1000 m below Base of potable ground water
- Hydraulic fracturing
- Pre-existing seismicity (None)
- Proximity to Precambrian basement (>1500 m above)
- Reservoir pressure (Under -14 MPa)
- Mapped faults (Near salt collapse zones)
- Hydraulic fracture rate (Low < 3 m³/min)
- Hydraulic fracture volume (Low 18 m³/stage)
- Microseismic events (< -2.0 Mw)
- Sensitive public area

**Conclusion:** Hydraulic fracturing of the Bakken will not create any need for ISM.

### Decision Tree Analysis Summary

When considering the need for Induced Seismicity Monitoring, review each area’s characteristics. Could oil field activity generate injection induced seismicity? If there is low probability of induced seismicity, proceed without need of monitoring or consider ISM calibration for future projects. If the area has natural or induced seismicity events, evaluate the need to monitor the treatment well based on the observed magnitude of the induced events, the hydraulic fracture treatment style and the reservoir pressure. If the project is in a sensitive area, implement a protocol system that recognizes the level of induced seismicity risk with the area stakeholders, in order to address their concerns and be able to proceed with field operations efficiently.

**KEEP CALM**

**CONSIDER MONITORING, ESTABLISH PROTOCOLS, THEN... FRAC ON!**

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### About the Author

**John L.J. Duhault, P.Geoph.** is a Geoscientist who graduated in 1979 and has over 37 years of industry experience including over 47,000 hours of interpretation experience in Canada and overseas. He has worked for, consulted to, and found oil and gas for integrated senior and intermediate producers and numerous junior independents. He founded and led two private juniors and is currently the Principal Geoscience Consultant for Starbird Enterprises specializing in conventional exploration and resource play seismic interpretation including completion geophysics assessments. Mr. Duhault is currently Vice President/President Elect for the CSEG.