Assessing risk in abandoned and suspended wells in close proximity to urban development.
Outline

- Risky abandoned and suspended wells: what is problem? What should municipalities and developers be aware of?
- Background: Cross section of a typical wellbore
- How do we assess abandoned and suspended wells in close proximity to urban development?
- Risk Matrix
- Case studies of abandoned wells in Calgary and Airdrie
- Headlines
- Conclusions/Recommendations
Introduction: Abandoned and suspended wells near municipalities

According to 16 x 9, there are 22 million meters of inactive well infrastructure buried in Alberta. How much of this infrastructure is leaking?

Introduction: Abandoned and suspended wells near municipalities

- Licensee of the well is responsible for the well indefinitely.
- CITY is liable for the approval and the developer is responsible for the risk assessment.

**Problem:**
Who is responsible?


— Graphic illustration by Kevin Salvatierra, Global News
Cross-section of a typical Alberta wellbore

Figure from Dessault et al., 2015

Base of the ground water protection
How many of those present today have seen this flowchart?
<table>
<thead>
<tr>
<th>Risk Matrix</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>SCVF or GM History (4)</th>
<th>Well Deviation (3)</th>
<th>Cement Top (3)</th>
<th>TVD (mKB) (2)</th>
<th>Casing Failure History (3)</th>
<th>Well Age (3)</th>
<th>Inactive Well Status Date (4)</th>
<th>Well Operation type (3)</th>
<th>H₂S (4)</th>
<th>Land Use (5)</th>
<th>Protection of Useable Water (3)</th>
<th>Proximity to Nearest drinking Water Well (4)</th>
<th>Well Accessibility (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serious SCVF or GM</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Casing breakdown 50% or greater</td>
<td>Unknown</td>
<td>Unknown / Non-Compliant</td>
<td>Not Reported</td>
<td>Unknown</td>
<td>Unknown</td>
<td>Priority 1: Seniors or School, Hospital</td>
<td>Unknown</td>
<td>WSW ≤ 100 m Drinking Water</td>
</tr>
<tr>
<td>Non-Serious SCVF or GM</td>
<td>Directional</td>
<td>C.T. &gt; 1000 mKB or if C.T.A&lt;300 mKB</td>
<td>1000-1399 mKB</td>
<td>Casing breakdown 30%</td>
<td>Spud 1975-1985 faulty casing history</td>
<td>5-10 years Non-Compliant</td>
<td>Class 2,3 and CO₂ injection/Disposal Wells</td>
<td>H₂S &gt; 25%</td>
<td>Priority 2: Residential Area Playgrounds</td>
<td>Useable Water, Aquifers not Protected</td>
<td>WSW ≤ 100 m Non-Drinking Water</td>
<td>Under Surface Structure</td>
</tr>
<tr>
<td>Not Tested</td>
<td>Vertical no logs</td>
<td>Vertical with well logs</td>
<td>New Casing</td>
<td>Spud After 2008</td>
<td>6 Months</td>
<td>No H₂S</td>
<td>Priority 7: Heavy Industrial</td>
<td>All Useable Water Aquifers Protected</td>
<td>VSW &gt; 1 km</td>
<td>GPS and Monitoring Equipment installed</td>
<td>Access with 50m setback</td>
<td>TOTAL SCORE</td>
</tr>
</tbody>
</table>

Notes:
- SCVF: Subsurface Contaminant Vulnerability Factor
- GM: Gas Migration
- TVD: True Vertical Depth
- C.T.: Casing Thickness
- H₂S: Hydrogen Sulfide
- VSW: Vertical Spacing Water
- GPS: Geophysical Surveying
- BGP: Base Geophysical Parameter

Legend:
- Green: Low Risk
- Yellow: Medium Risk
- Red: High Risk

**Notes:**
- SCVF or GM history is based on the last 18 months with minimal results.
- Well deviation and cement top are critical factors in assessing well integrity.
- TVD and Casing Failure History are used to determine well age and inactive status.
- Well operation type and H₂S concentration influence land use and protection of useable water.
- Proximity to drinking water wells and well accessibility are important considerations for well siting.
Which wells are high risk?
In NORTH CALGARY:

The majority of old wells do NOT have surface casing that extends below the base of the ground water protection (BGWP).

Therefore OLD surface casing does not protect groundwater.

Wells circled in blue have less than 50,000 ppm H₂S; wells circled in red have greater than 200,000 ppm H₂S.
# H₂S Concentrations and its Effects

<table>
<thead>
<tr>
<th>Concentration (ppm)</th>
<th>Symptoms/Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00011-0.00033</td>
<td>Typical background concentrations</td>
</tr>
<tr>
<td>0.01-1.5</td>
<td>Odor threshold (when rotten egg smell is first noticeable to some). Odor becomes more offensive at 3-5 ppm. Above 30 ppm, odor described as sweet or sickeningly sweet.</td>
</tr>
<tr>
<td>2-5</td>
<td>Prolonged exposure may cause nausea, tearing of the eyes, headaches or loss of sleep. Airway problems (bronchial constriction) in some asthma patients.</td>
</tr>
<tr>
<td>20</td>
<td>Possible fatigue, loss of appetite, headache, irritability, poor memory, dizziness.</td>
</tr>
<tr>
<td>50-100</td>
<td>Slight conjunctivitis (&quot;gas eye&quot;) and respiratory tract irritation after 1 hour. May cause digestive upset and loss of appetite.</td>
</tr>
<tr>
<td>100</td>
<td>Coughing, eye irritation, loss of smell after 2-15 minutes (olfactory fatigue). Altered breathing, drowsiness after 15-30 minutes. Throat irritation after 1 hour. Gradual increase in severity of symptoms over several hours. Death may occur after 48 hours.</td>
</tr>
<tr>
<td>100-150</td>
<td>Loss of smell (olfactory fatigue or paralysis).</td>
</tr>
<tr>
<td>200-300</td>
<td>Marked conjunctivitis and respiratory tract irritation after 1 hour. Pulmonary edema may occur from prolonged exposure.</td>
</tr>
<tr>
<td>500-700</td>
<td>Stagerring, collapse in 5 minutes. Serious damage to the eyes in 30 minutes. Death after 30-60 minutes.</td>
</tr>
<tr>
<td>700-1000</td>
<td>Rapid Unconsciousness, &quot;knockdown&quot; or immediate collapse within 1 to 2 breaths, breathing stops, death within minutes.</td>
</tr>
<tr>
<td>1000-2000</td>
<td>Nearly instant death</td>
</tr>
</tbody>
</table>

Table
Abandoned well case studies

Wells in Calgary and Airdrie, Medicine Hat and Lethbridge

Find the peanut....
Abandoned in 1961
Surface casing depth 191.7: there is NO OTHER casing in this well
There is no cementing, plug back OR abandonment data for this well
Lies UNDERNEATH airport building
### Risk Matrix

<table>
<thead>
<tr>
<th>SCVF or GM History</th>
<th>Well Deviation</th>
<th>Cement Top</th>
<th>TVD (mKB)</th>
<th>Casing Failure History</th>
<th>Well Age</th>
<th>Inactive Well Status</th>
<th>Well Operation</th>
<th>H₂S Content (%)</th>
<th>Land Use</th>
<th>Protection of Useable Water Aquifers</th>
<th>Proximity to nearest water wells</th>
<th>Well Accessibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Historical SCVF or GM</td>
<td>Vertical no well logs</td>
<td>Unknown</td>
<td>1000-1999 mKB</td>
<td>Casing breakdown 50% or greater</td>
<td>Spud pre 1975</td>
<td>N/A</td>
<td>all other well types</td>
<td>No H₂S</td>
<td>Priorty 1: Seniors/School/Hospital</td>
<td>Useable Water, Aquifers not Protected</td>
<td>500m &lt; WSW ≤ 1 km Non-Drinking Water</td>
<td>Under Surface Structure</td>
</tr>
</tbody>
</table>

Risk matrix total is 1640 out of 3080. This is a low to medium risk well.
Well 14-35-025-01W5M AbaData View

Location: Calgary, Alberta
Abandoned Date: April 24, 1962
### Risk Assessment of Abandoned Well 14-35-25-1W5M

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>SCVF or GM History</th>
<th>Well Deviation</th>
<th>Cement Top</th>
<th>TVD (mKB)</th>
<th>Casing Failure History</th>
<th>Well Age</th>
<th>Inactive Well Status</th>
<th>Well Operation</th>
<th>H₂S Content (%)</th>
<th>Land Use</th>
<th>Protection of Useable Water Aquifers</th>
<th>Proximity to nearest water wells</th>
<th>Well Accessibility</th>
<th>SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Historical SCVF or GM</td>
<td>Vertical with well logs</td>
<td>Unknown</td>
<td>1000-1999 mKB</td>
<td>Casing breakdown 50% or greater</td>
<td>Spud pre 1975</td>
<td>Compliant</td>
<td>all other wells types</td>
<td>No H₂S</td>
<td>Priority 4: Agriculture</td>
<td>Useable Water, Aquifers not Protected</td>
<td>100 m &lt; WSW ≤ 500 m Non-Drinking Water</td>
<td>Not Under Surface Structure</td>
<td>1560</td>
<td></td>
</tr>
</tbody>
</table>

- **Well Name:** Canpet Sarcee Calgary 14-35-25-1.
- **Current Licensee & Operator:** TAQA North Ltd.
- **Cement Top:** Unknown. Also, it can be assumed that, as the well was drilled & completed before 1975, so the probability of presence of cement around the surface casing from below the BGWP to surface will be low or even if its present it will be degraded condition, therefore, it can be concluded that groundwater is not protected from gas migration.
- **Surface Casing Shoe Depth:** 187.1 m & BGWP: 472.2 m
- **Perforations:** 1794.7 m to 1798.6 m.
- **Bridge Plug Capped with Cement:** At 1769.4 m.
- **Risk Assessment Score:** 1560 out of 3080.
- Therefore, it is a medium risk well.
Sour Gas Pipelines in Calgary

ALL pipelines are currently operating and have 10 ppm H2S.

At 10 ppm H2S, health effects include: painful eye, nose and throat irritation, headaches, fatigue, irritability, insomnia, gastrointestinal disturbance, loss of appetite, dizziness.

The two Lexin wells are operating at 41,990 & 37,490 ppm

The southern pipeline is operating at 400,000 ppm whereas the eastern one is operating at 20,000 ppm & the pipeline is 4.2 km away from Calgary South Hospital.

12.75" outside diameter
Max operating pressure 719 psi
10 ppm H2S

16" outside diameter
Max operating pressure 891 psi
10 ppm H2S

Foothills Hospital
Peter Lougheed Center
Rockyview Hospital
Calgary South Hospital
Location: Airdrie, Alberta
Abandoned Date: August 25, 1977
Risk Assessment of Abandoned Well 06-12-027-01W5M

Well Name: Tipperary Et Al Crossfield 6-12-27-1.


Cement Top: Unknown. Also, it can be assumed that the well was drilled & completed before 1975, so the probability of presence of cement around the surface casing from below the BGWP to surface will be low, therefore, it can be concluded that groundwater is not protected from gas migration.

Surface Casing Shoe Depth: 371.2 m & BGWP: 542.4 m

Perforations: 2705.1 m to 2714.9 m.

Bridge Plug Capped with Cement: 2651.8 m to 2667.0 m.

Risk Assessment Score: 1950 out of 3080.

Therefore, it is a medium to high risk well.
H$_2$S Gas Pipelines around Airdrie and Crossfield

- H$_2$S Content: Minimum of 10.1 mol/kmol (10,100 ppm) to 500 mol/kmol (500,000 ppm) [Approx. figures]

[Data & Image Source: AbaData]
Operating Pipelines around Airdrie and Crossfield

LEGEND:
Green: Crude Oil
Blue: Fresh Water
Purple: Alberta Products Pipe Line Ltd. (LVP like Condensate, Diesel Fuel, Heating Oil, etc.)
Red: Natural Gas, Fuel Gas, Sour Natural Gas, Misc. Gases, Oil Well Effluent, etc.
How can we be assured that monitoring equipment in pipelines under municipalities can detect small, pinhole leaks?

Nexen responds to suspension of 95 pipeline licences

Spilled oil rests on the dirt and grass near Nexen’s Long Lake facility near Fort McMurray on Friday, July 17, 2015. The spill, which is enough to fill two Olympic-sized swimming pools, was discovered Wednesday afternoon.

http://www.edmontonjournal.com/Nexen+responds+to+suspension+of+pipeline+licences/11327409/story.html
Five homes were demolished in Calmar in 2010 for re-abandonment due to sweet gas leaking from an old abandoned well.

Residents were asked to leave in 2013 and 2015 while Imperial Oil tried to fix the leak.

Shockingly, the well is still leaking today.
- Dozens of families were housed temporarily in hotels during the time of re-abandonment (approx. 3 weeks).

- Property values decreased for those houses bordering the well.

A court case involving the town and the developers was started involving $400,000 in house compensation and $300,000 in additional damages (CBC News: 05/11/2011)

This is the municipality’s liability!
Calmar
100/01-36-49-27W4

Risk matrix total is 2040 out of 3080
This is a medium risk well that leaked.
UPDATE: Residents return to their homes, after sour gas leak southwest of Airdrie

By Alyssa Julie  News Producer  Global News

Aboriginal Affairs says this well is not currently a threat to people or the environment, but is showing signs of corrosion.

Oil leaking from an abandoned well in a Southfield neighborhood is running into a culvert that drains into a creek that goes to the Rouge River.
In summary, it is the responsibility of the developer or landowner (proponent) of the proposed subdivision and/or development to take measures to identify any abandoned wells within that property and to apply the required setback as set out in the ERCB directive. It is the responsibility of the municipality, as part of the subdivision and development application process, to ensure that the proponent of the subdivision or development has taken these measures and has applied the required setback. These efforts will ensure that abandoned wells are appropriately identified and suitable setbacks are incorporated in planning, development and construction decisions. The information that follows in this bulletin further explains these processes.
Medicine Hat
Lethbridge
Oilfield meets Municipal
Smallest intervention rig

The SMALLEST coiled tubing unit that WISE Interventions has for well-site workovers is 3.3m wide by 12m long (pictured above).

Additionally, ~2-3 meters is required between the wellhead and the back of the unit.

The AER only requires a 5m setback from old abandoned wells: Obviously, as the Calmar example illustrates, 5m is simply not enough room to intervene and re-abandon a leaking gas well.

As well we need clear ACCESS to the wellbore.
Why are leaky wells risky?

Methane makes up the majority of natural gas leaks. Methane is combustible, sinks in low lying areas that, if pooled in poorly ventilated buildings, can result in serious explosions.

March 1937 New London school in Texas
388 Children and teachers died
Accumulation of gas blamed for explosion

Methane leaks above the Base of the Ground Water Protection can potentially contaminate groundwater.
Emergency Preparedness


- 5.2.4 Ignition Criteria 5.2.4.1 Sour Well Releases 8) The licensee must • include ignition procedures (e.g., ignition criteria flowchart) in its ERP, including a description of the equipment to be used in the event ignition criteria are met, and • acknowledge in its ERP that ignition authority will be assigned to a licensee representative on site.

- H2S become SO2 upon ignition, floating to aprx. The 5th floor height of a building.

- NOT ACCEPTABLE
Water vs Nitrogen

- The application of internal pressure to a closed system causes stress to be applied to individual components of the system. Those components may experience elastic deformation which, in turn, can result in leaks. Unfortunately, there is no current way of establishing the pressure integrity of a system without actually applying pressure.

- For this reason, oil and gas handling systems are pressure tested prior to being placed into operation.

- If a system is designed to operate with natural gas at high pressure, it is desirable to prove the system's integrity as closely as possible to its designed operating parameters. Should a leak develop or a component fail, it is preferable that this occurs with an inert gas rather than with a highly flammable material such as methane, with the consequent risk of explosion. The use of nitrogen as a pressure test medium allows a follow-up test under circumstances which simulate actual operating conditions.
Oilfield meets Municipal

- Ramping up for preparedness what does that look like?
- Liability – Risk
- Mutual Aide
Conclusions/ Recommendations

- Urban Development is encroaching on abandoned and suspend wells
- According to the Alberta Government Municipal affairs, liability for development lies with the municipality
- Use of the Risk Matrix will help assess the risk level of each individual well
- Municipalities should consider increasing the set-back distance from 5 m to at least 15 m to allow a small service rig to intervene and re-abandon a leaky well.
- Municipalities need to make sure there is clear access to each wellhead.
- Once the wells are located and risk assessed, should we consider implementing technology that will provide continuous monitoring of the wellhead to immediately indicate if SCVF or GM begins in an abandoned well?
  - Should we implement technolgy that will detect SCVF/GM when it is at its initial stage right in the borehole without even waiting for it to come to surface? Is there a downhole monitoring tool which may be permanently installed and could provide continuous real-time monitoring?
- From the municipal land use bylaws, municipalities are required to, within the scope of their jurisdiction, utilize mitigative measures to minimize possible negative impacts. This takes us back to implementing continuous monitoring in abandoned wells in municipalities.
Thank you

Acknowledgements:
Thanks to Deidre Macht
Lieu Le and Afia Natoma for help with developing the Risk Matrix
Greg Chapin from Wise Interventions for the photo of the intervention rig
Ed Davis from Abadata for letting us use their fantastic software

Questions?