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Factors Affecting or Indicating Potential Wellbore Leakage

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Old Wells or New Wells?

Should we worry more about the integrity of future CO_2 injection wells, or about the existing and future wells drilled for purposes other than CO_2 injection?

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Deep Wells Drilled in Alberta

End of 2004

- 316,439 total
- 108,706 abandoned

End of 2006

- 362,265 total
- 116,550 abandoned

Oldest: 1893

Area: 664,332 km^2
(256,610 sq.mi)

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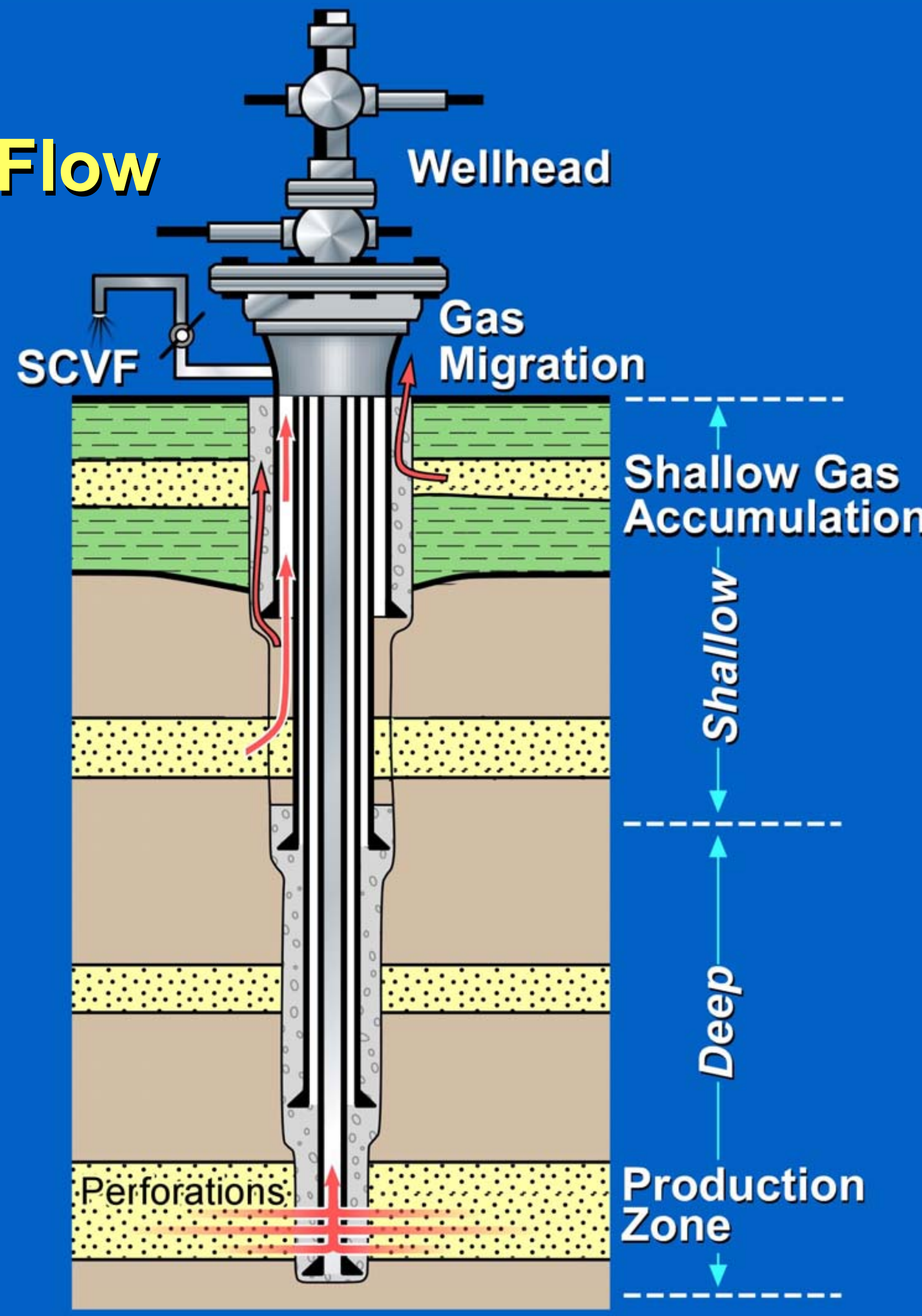
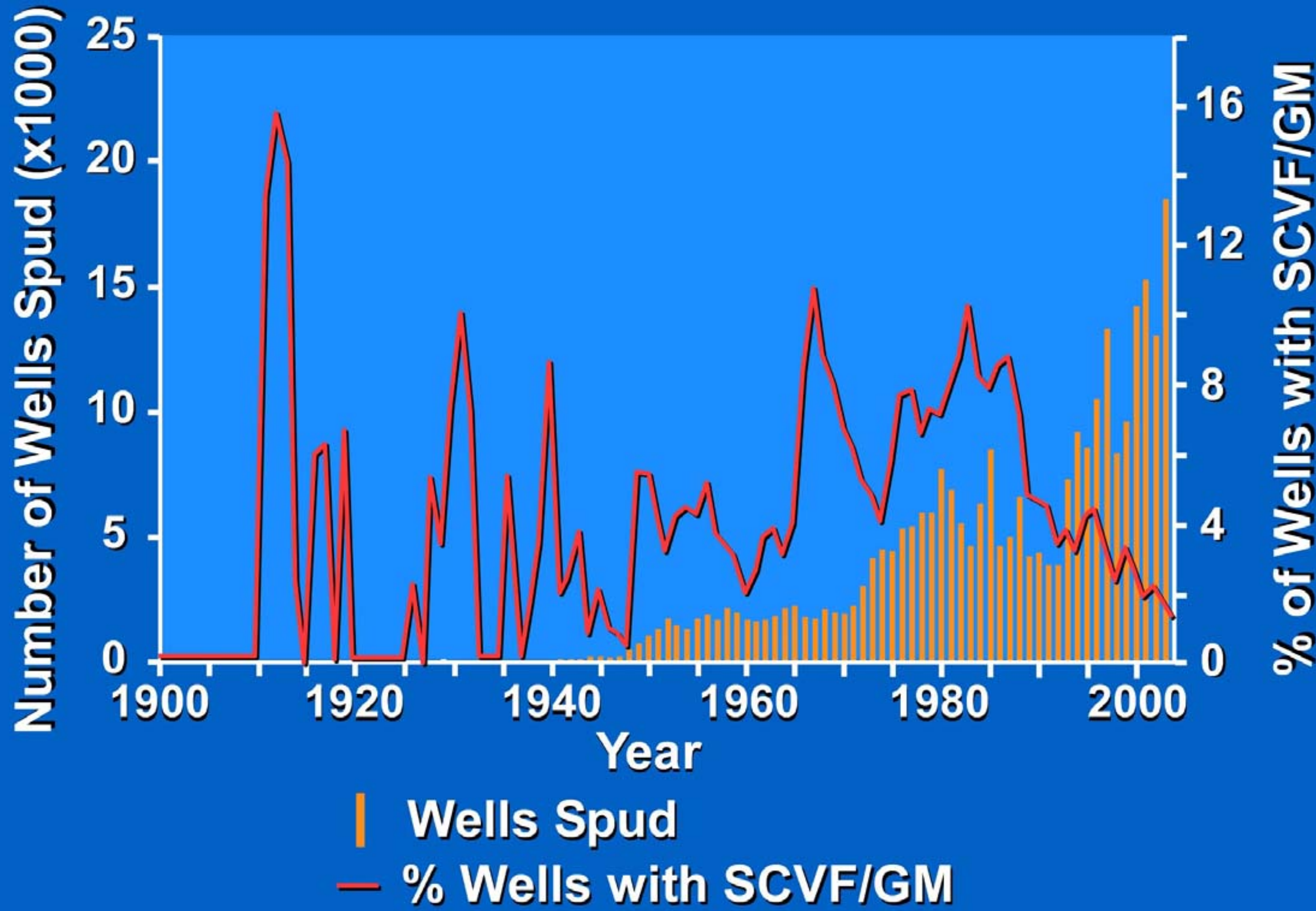
Conditions for Well Leakage Occurrence

- Leak source
- Driving force (head differential, buoyancy)
- Leakage pathway
  - Poorly cemented casing/hole annulus
  - Casing failure
  - Abandonment failure

Surface Casing Vent Flow and Gas Migration Flow Pathways in a Well



Wells with SCVF/GM Compared with Wells Drilled - Annual Basis -



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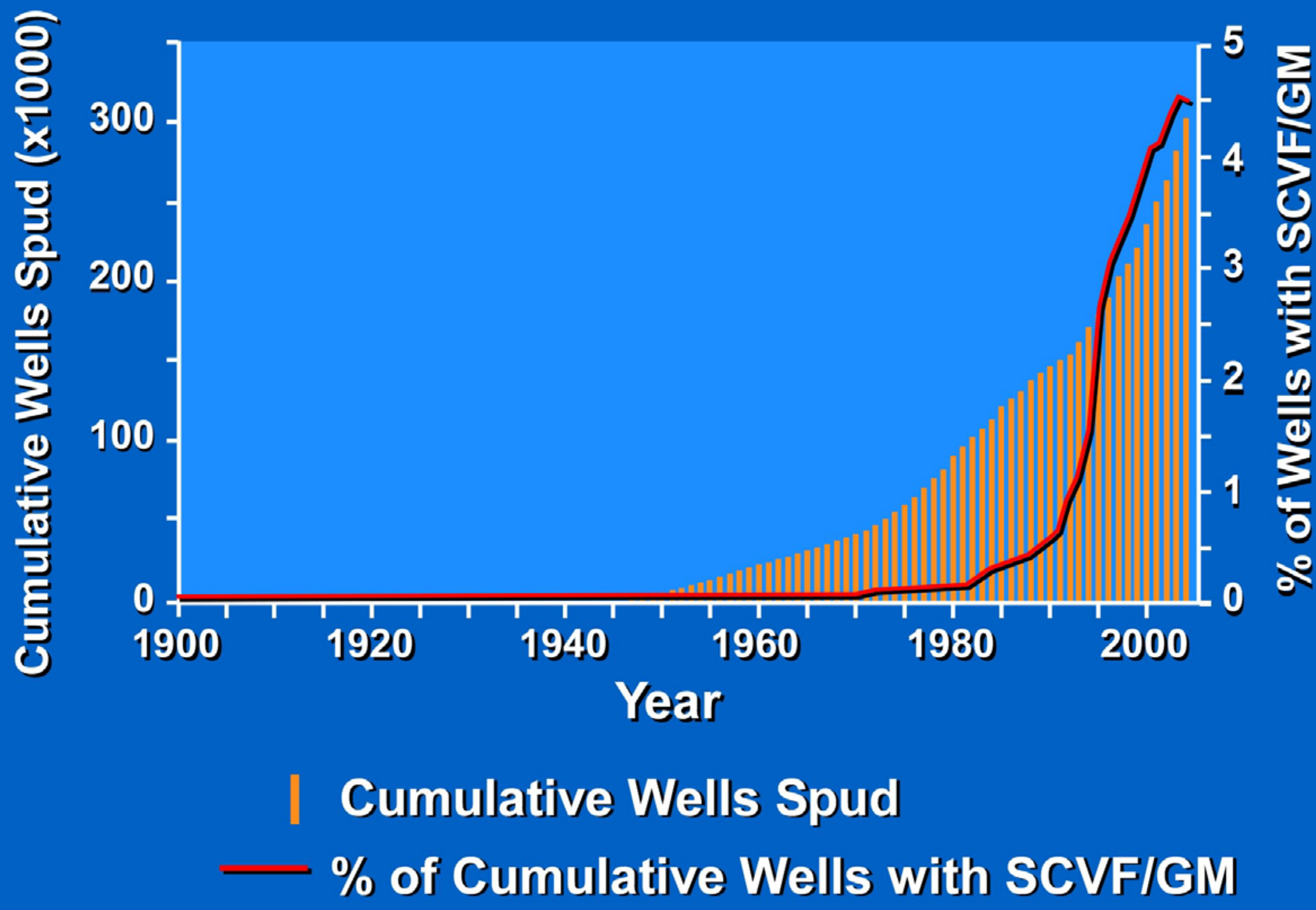
Wells with SCVF/GM Compared with Wells Drilled - Cumulative -



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Example of SCVF and GM Testing

① Testing for SCVF ② Testing for GM

Abandoned Well Leaking Brine and Gas near Peace River, Alberta

Gas Bubbling at the Cap Welding of the Surface Casing

Gas Bubbling at the Cap Welding of the Production Casing

Analysis of Factors Affecting Well Leakage

- Data mining
  - EUB's public databases on wells and production
  - EUB's databases on SCVF, GM, casing failure and non-routine well abandonment
- Historical documents and regulatory changes
- Casing inspection logs and cement logs for ~500 wells, of which 142 had adequate data for full evaluation
- Depth of groundwater protection

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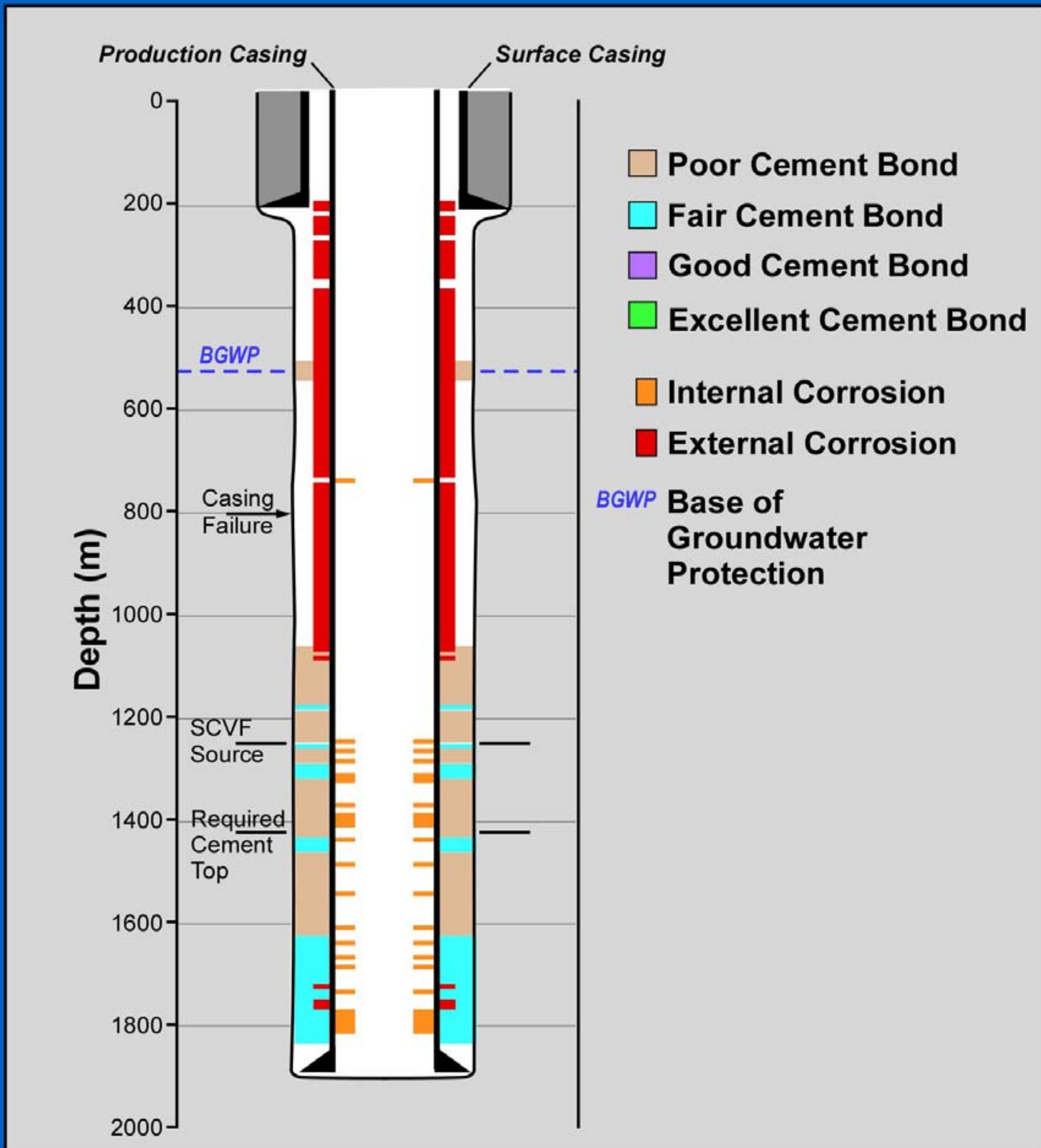

Example of Cement and Casing Quality in a Well in the Haynes Field, Alberta

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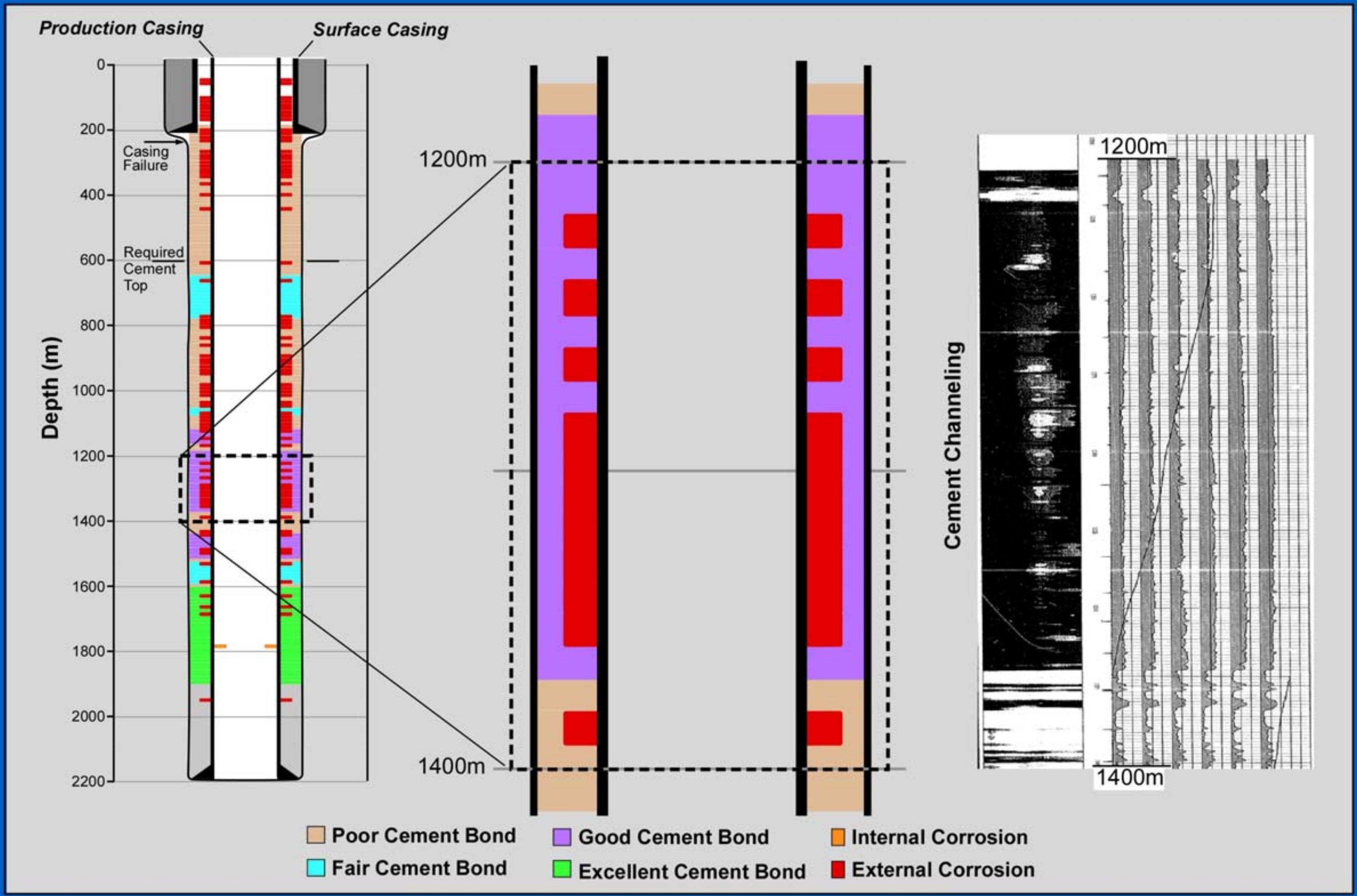
Example of Well Log Analysis Showing Corrosion Due to Cement Channeling



Factors of No Apparent Impact

- Well age
- Well operational mode: production, injection or disposal
- Completion interval
- Presence of H_2S and/or CO_2

Factors of Minor Impact

- Licensee
- Depth of surface casing
- Total depth
- Well density
- Topography

Factors of Major Impact

- Geographic area (Test Area)
- Well deviation
- Well type:
  - drilled and abandoned (SCVF/GM incidence rate of 0.5%)
  - cased and abandoned (SCVF/GM incidence rate of 14%), for 98% of the total
- Abandonment method (bridge plugs, welded caps)
- Economic activity, regulatory changes and SCVF/GM testing
- Uncemented casing/hole annulus!

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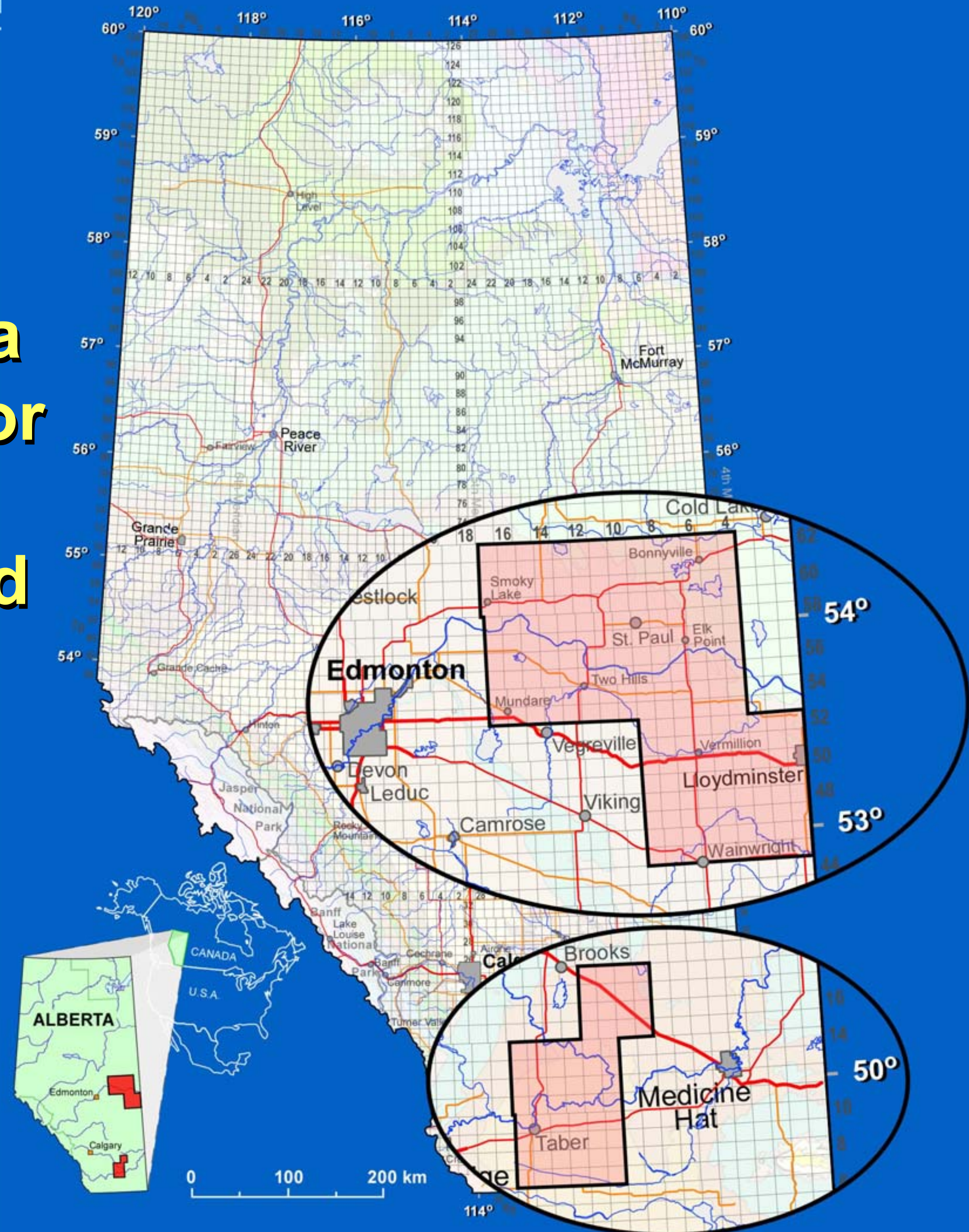
Areas in Alberta where Testing for Gas Migration was/is Required



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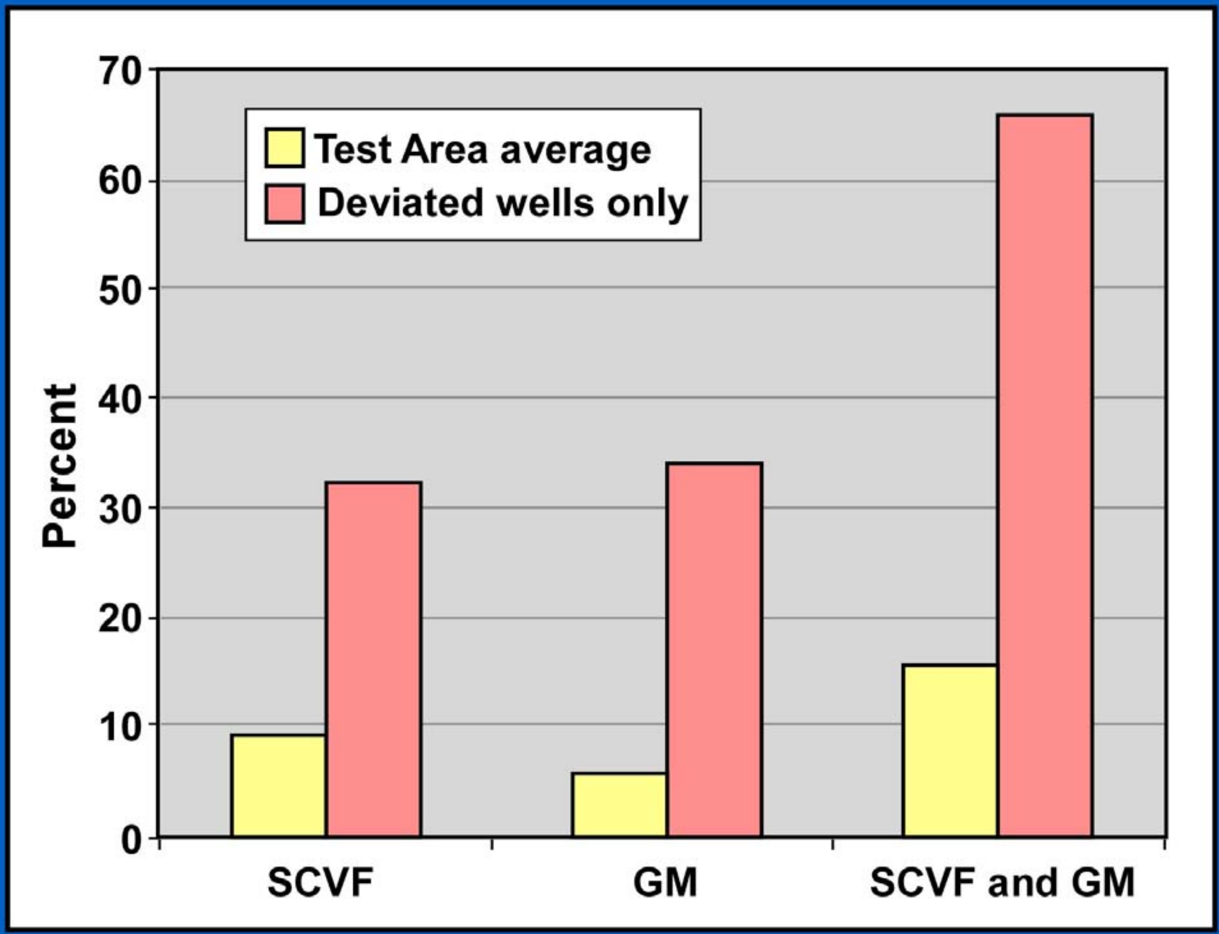
Occurrence of SCVF/GM in the Test Area, Alberta



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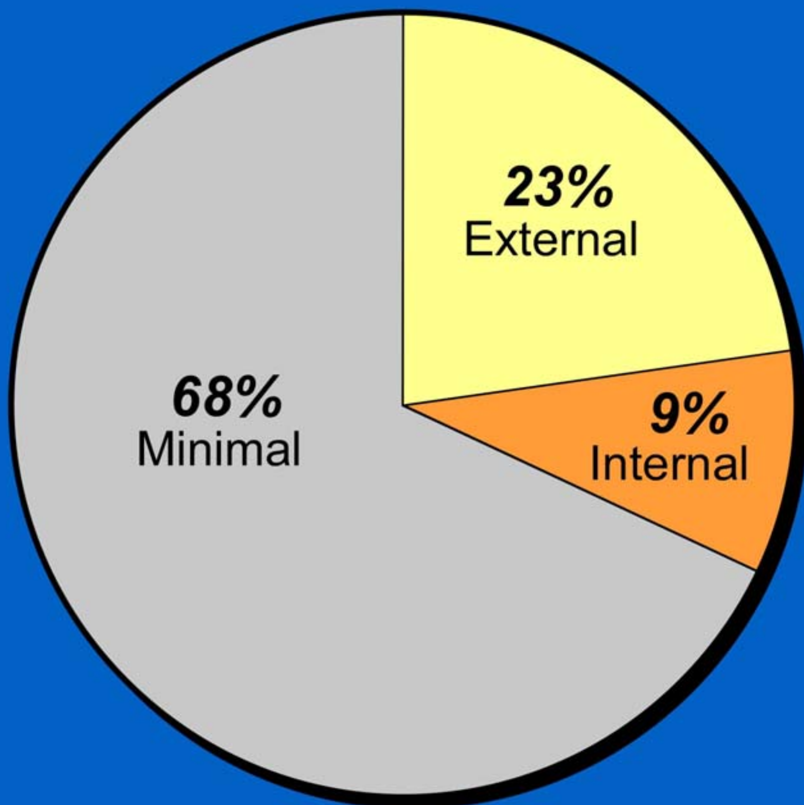
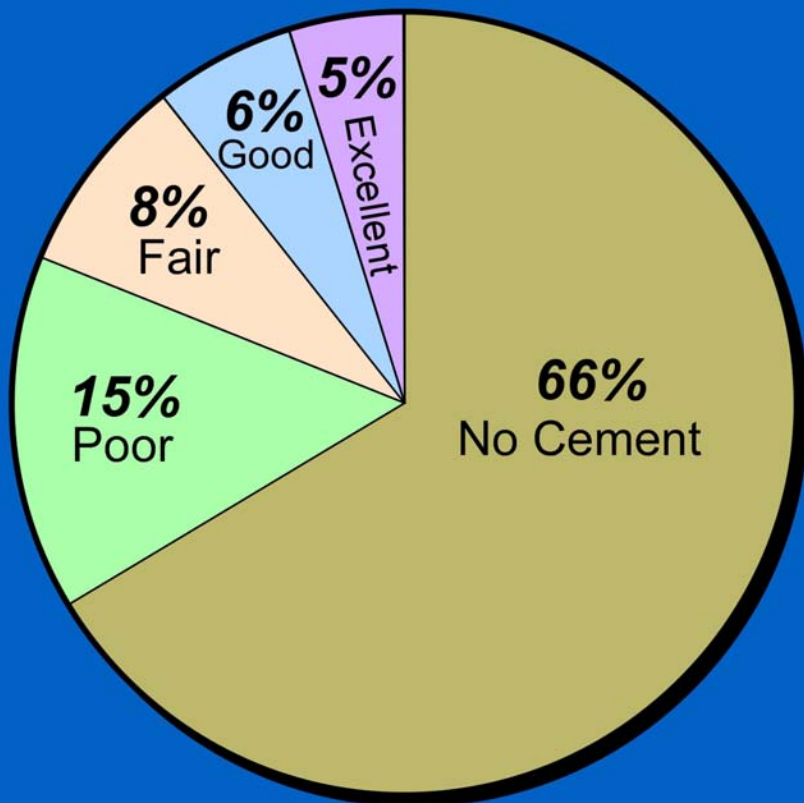
Corrosion Location



129,773 m logged in 142 wells

External Corrosion versus Cement Quality



10,442 m logged in 142 wells

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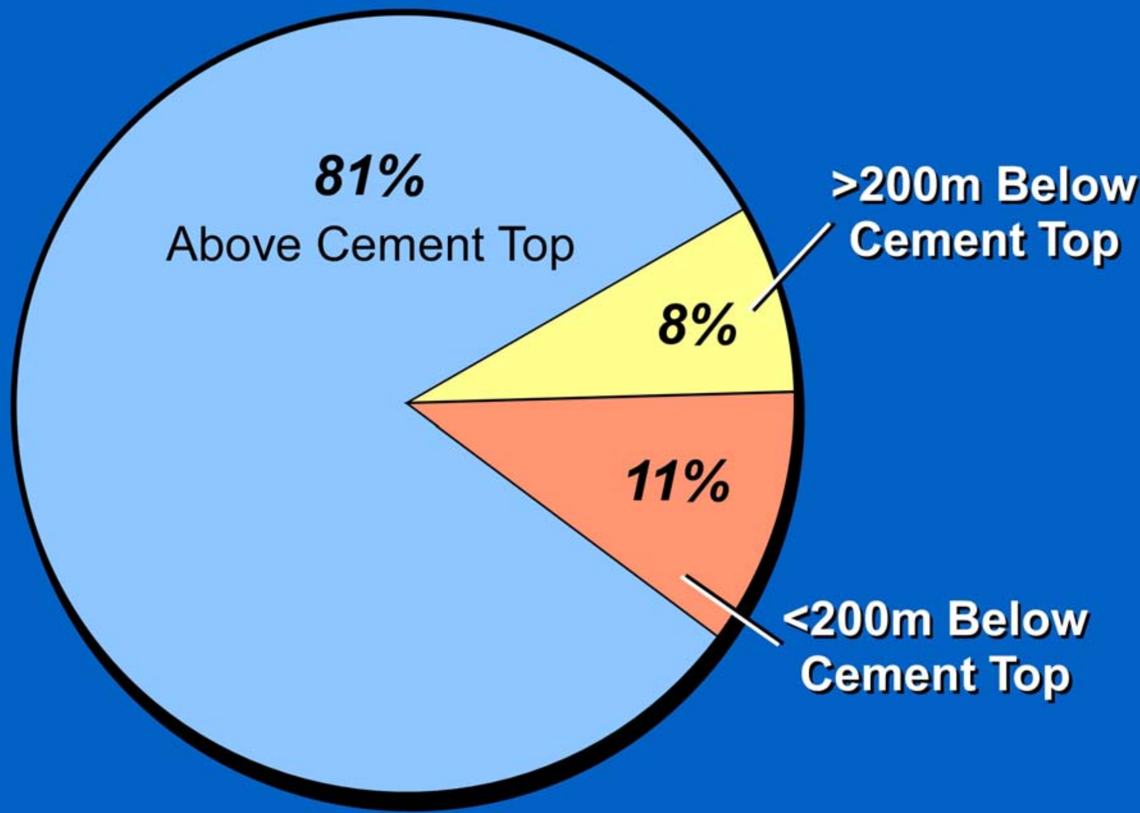
Location of SCVF/GM Source versus Cement Top



64 wells

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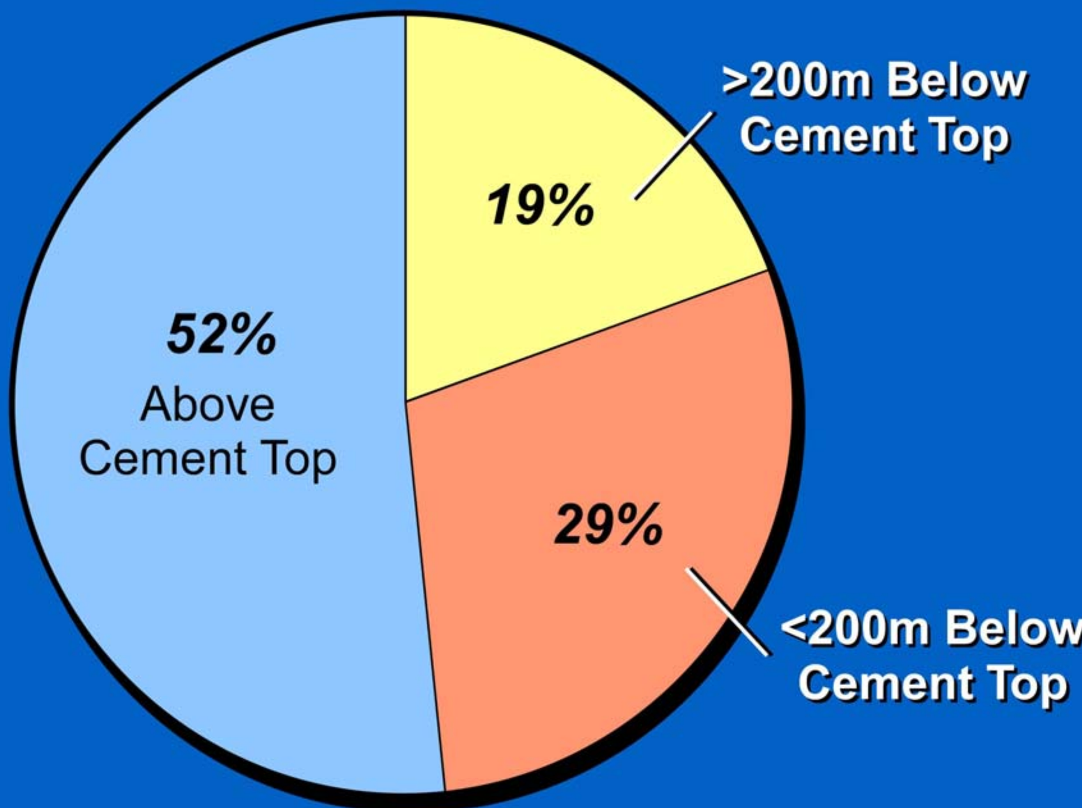
Location of Casing Failure versus Cement Top



64 wells

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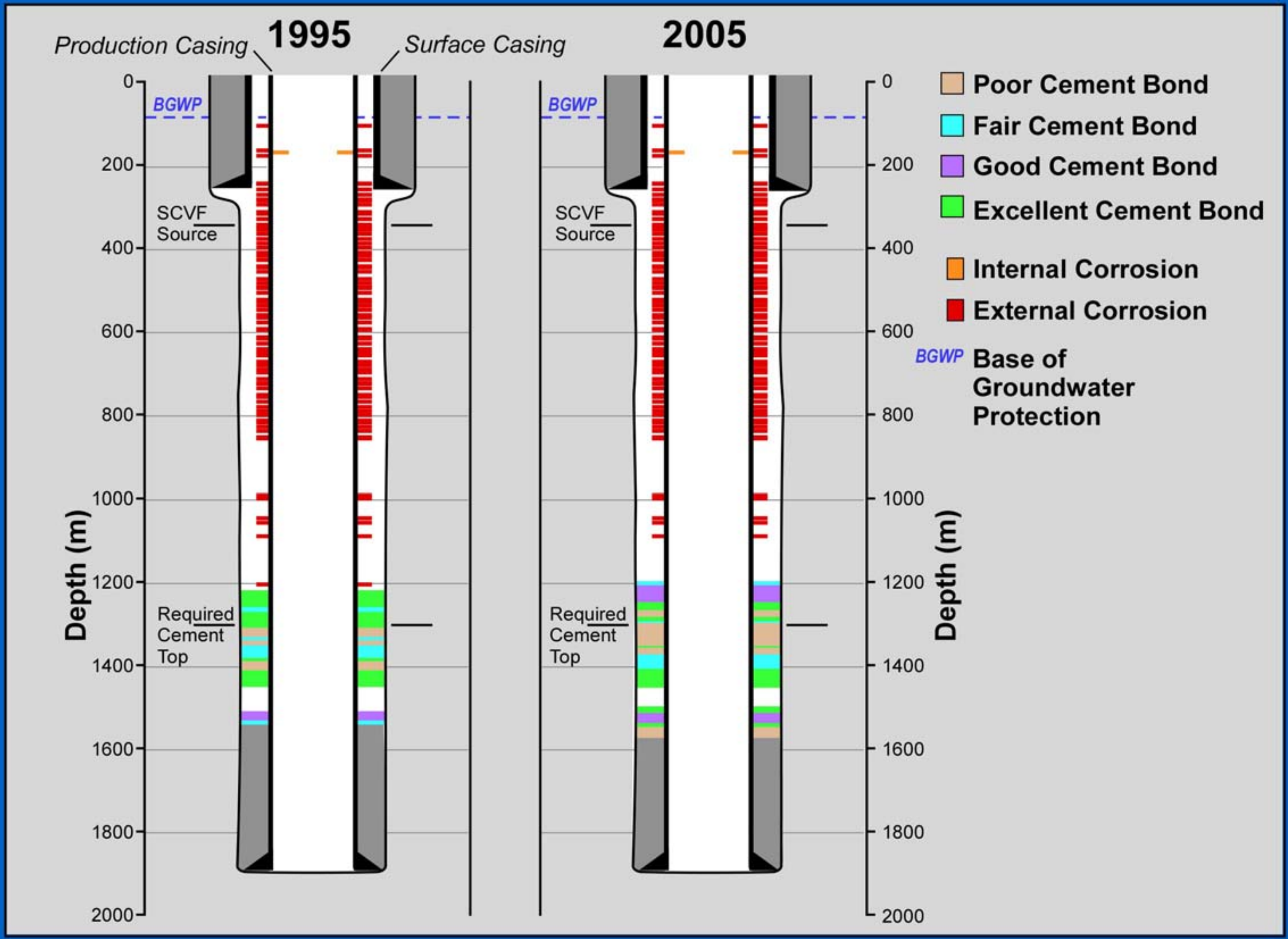
Interpretation of Cement Bond Logs in the Same Well in the Zama Field



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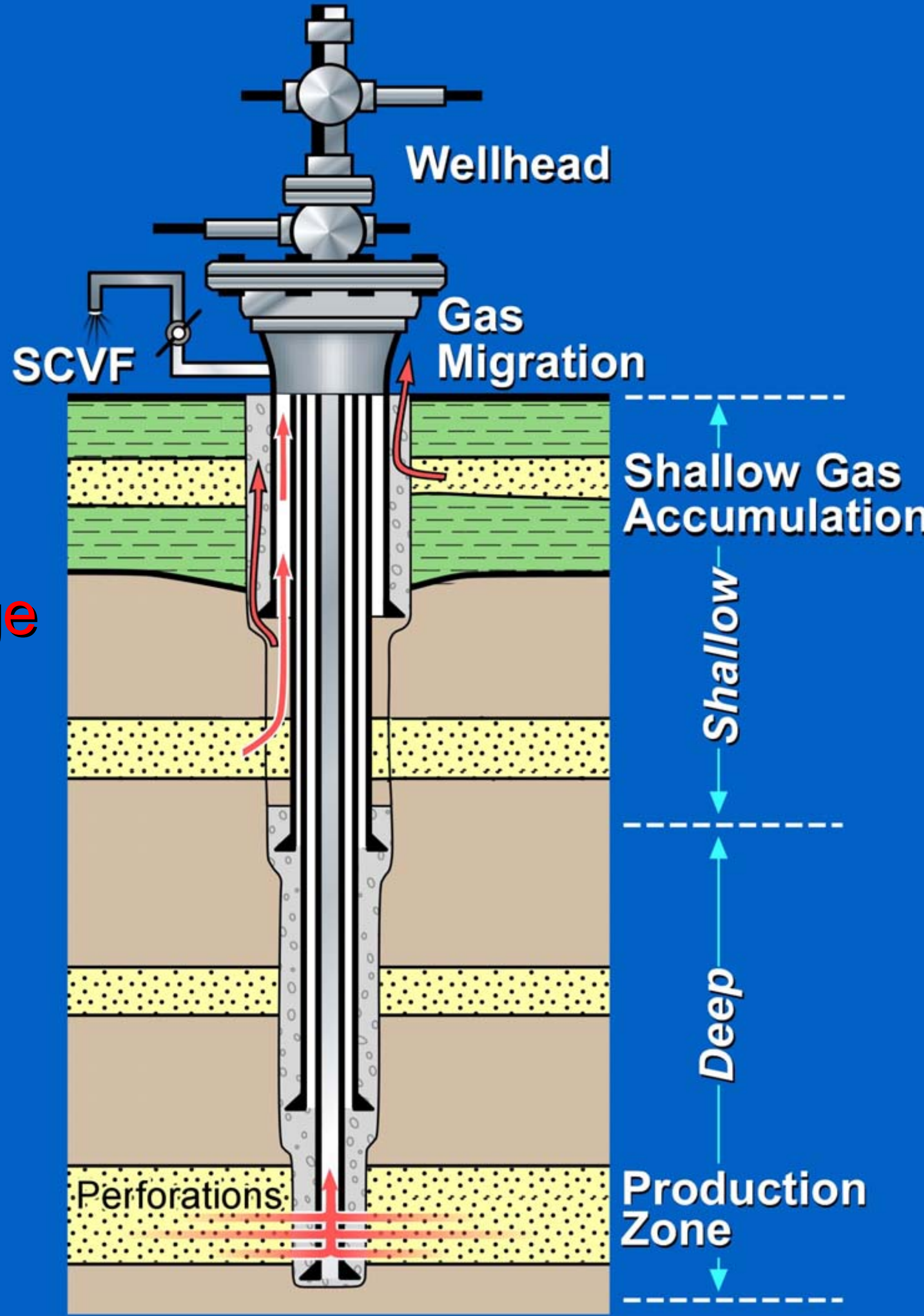
Leakage Potential along a Well

Shallower, upper part

Higher potential for leakage

Deep, lower part completed in producing zones

Less potential for leakage



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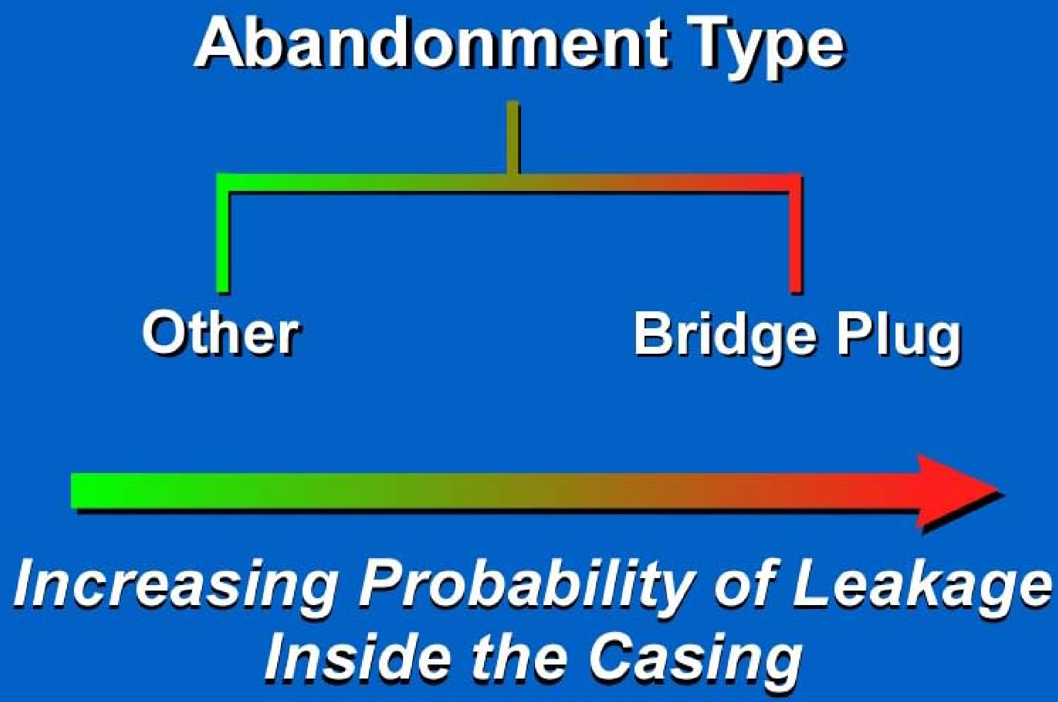
Well Attributes for Leakage Assessment in Alberta

- Type: drilled and abandoned, or cased
- Cementing requirements and practices
- Location (in Test Area or outside)
- Direction: vertical or deviated (including horizontal)
- Time of drilling in relation to economic activity and regulatory changes
- Time of abandonment in relation to regulatory changes

Potential for Well Leakage Inside Production Casing



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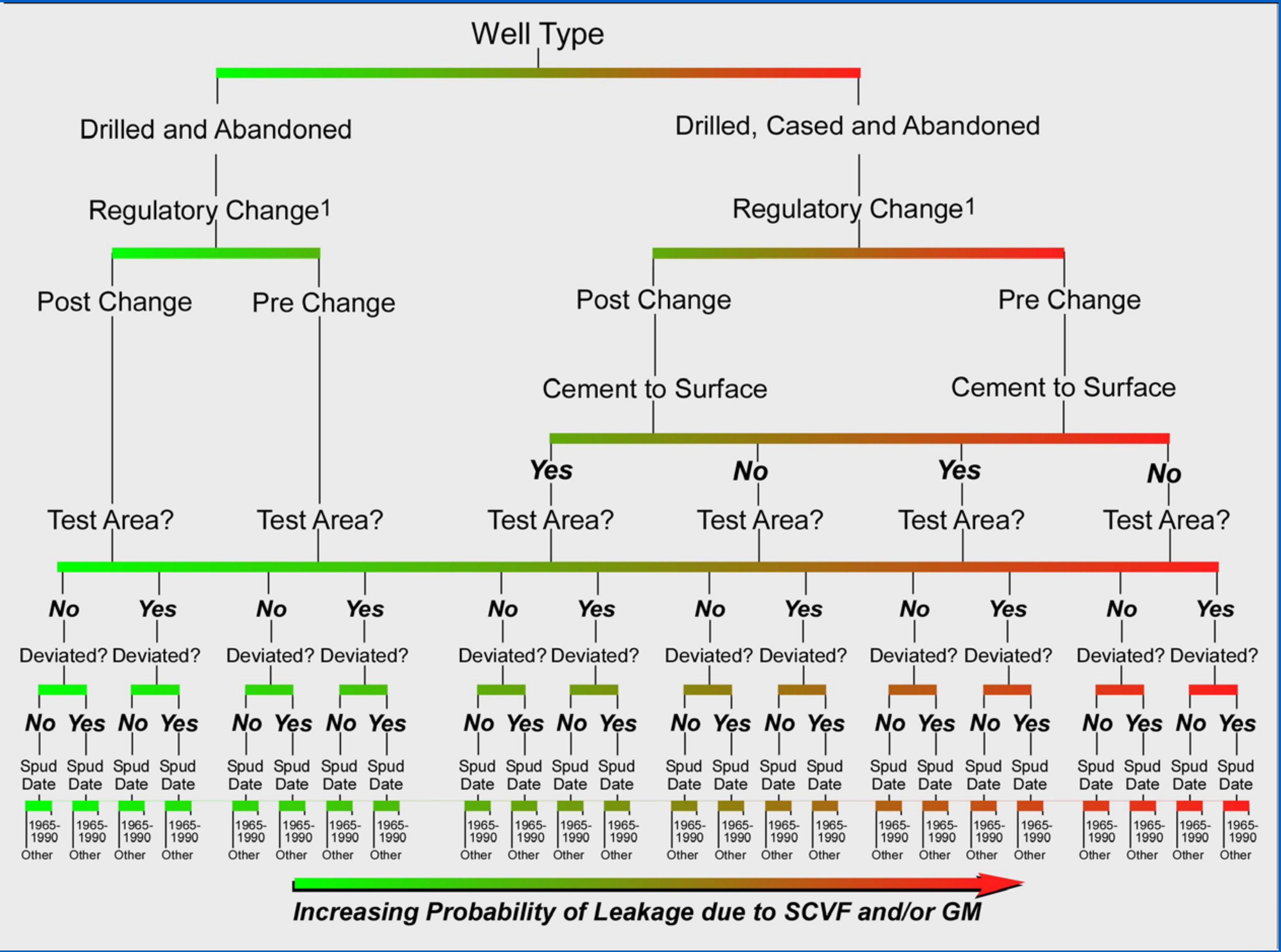
Assessment of the Potential for Well Leakage



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Conclusions

- The majority of well leakage is due to time-independent mechanical factors controlled during well drilling, construction or abandonment, mainly cementing

- Uncemented casing is the main factor in SCVF/GM and/or casing failure occurrence

- Good quality cementing will likely protect wells against cement degradation and casing corrosion

- The deep portion of wells is usually well cemented and zonally isolated

- Good and properly-enforced regulations are key in controlling and detecting well leakage

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Answer to Question on the First Slide

It is not the CO_2 injection wells that may/will pose a risk, they will be properly constructed and monitored, and, relatively speaking won't be too many.

It is the existing wells that will pose the greater risk!

Bachu and Watson – Possible Indicators for CO_2 Leakage along Wells, GHGT-8, 2006
Watson and Bachu - Factors Affecting or Indicating Potential Wellbore Leakage; SPE Paper 106817, 2007