Monitoring Systems for Deep Geological Repositories and Unconventional Gas Development: Similarities and Differences

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North American DGRs

Deep Geological Repositories

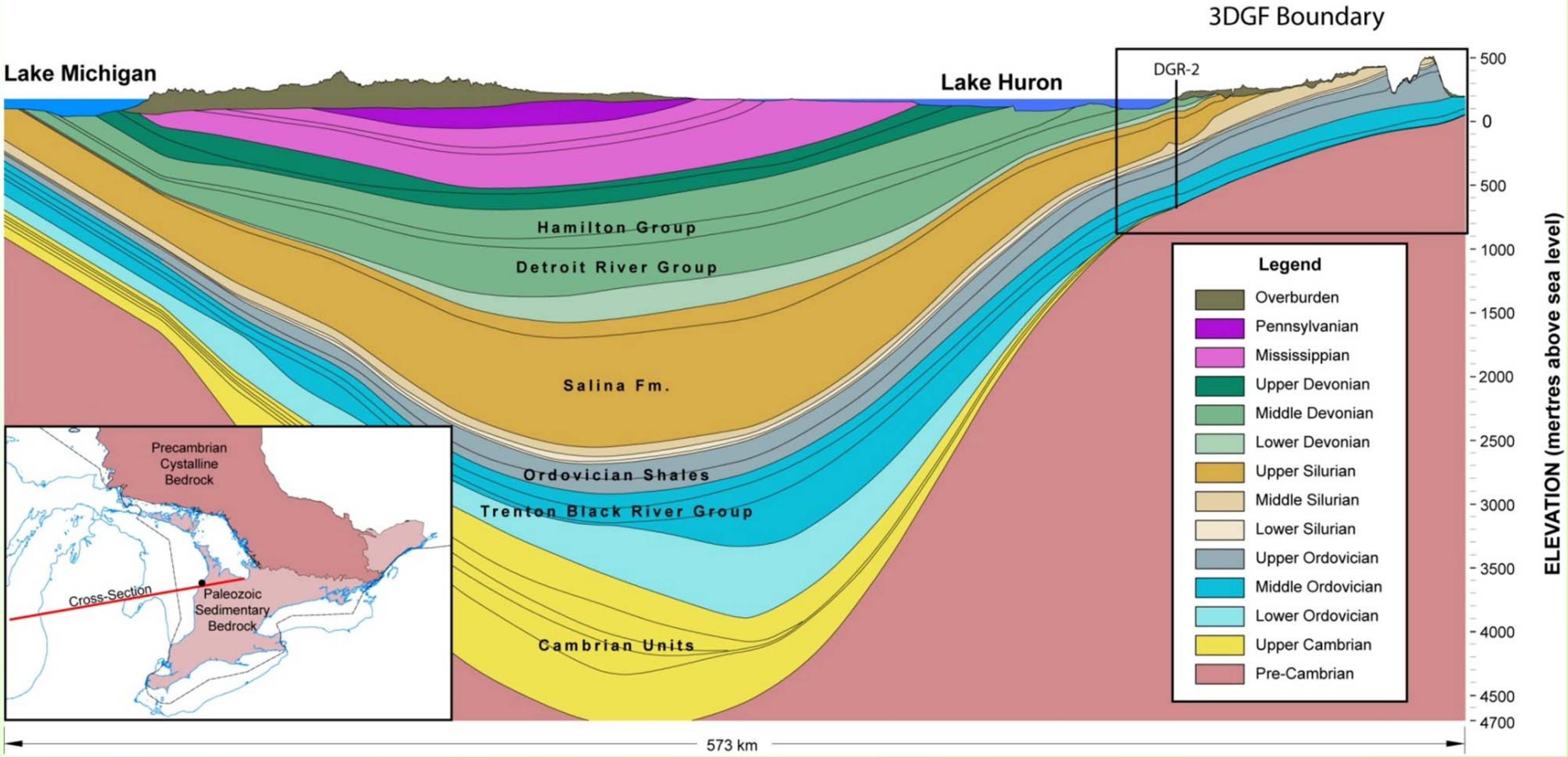
- Example of DGRs
  - Waste Isolation Pilot Plant, Carlsbad NM
  - Yucca Mtn Project
  - Olkiluoto, Finland
  - Forsmark, Sweden

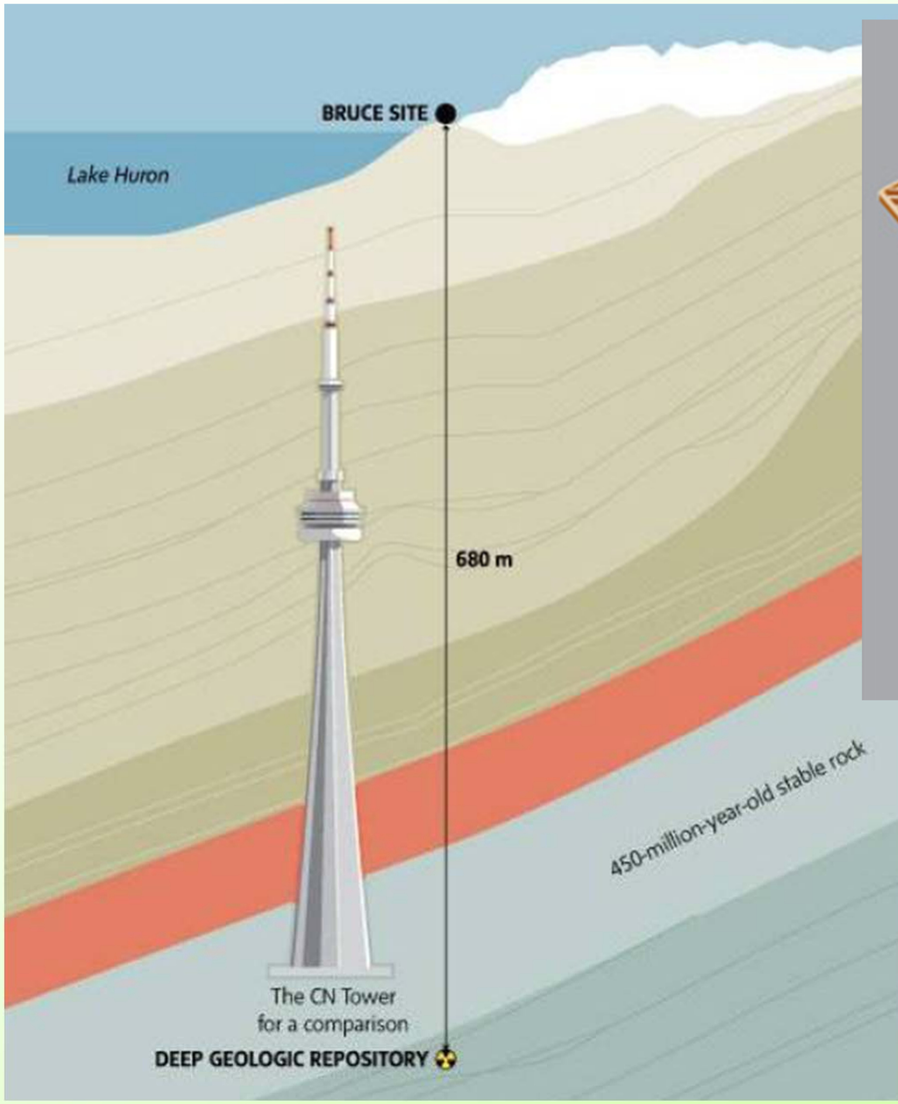
Shallow Geological Repositories

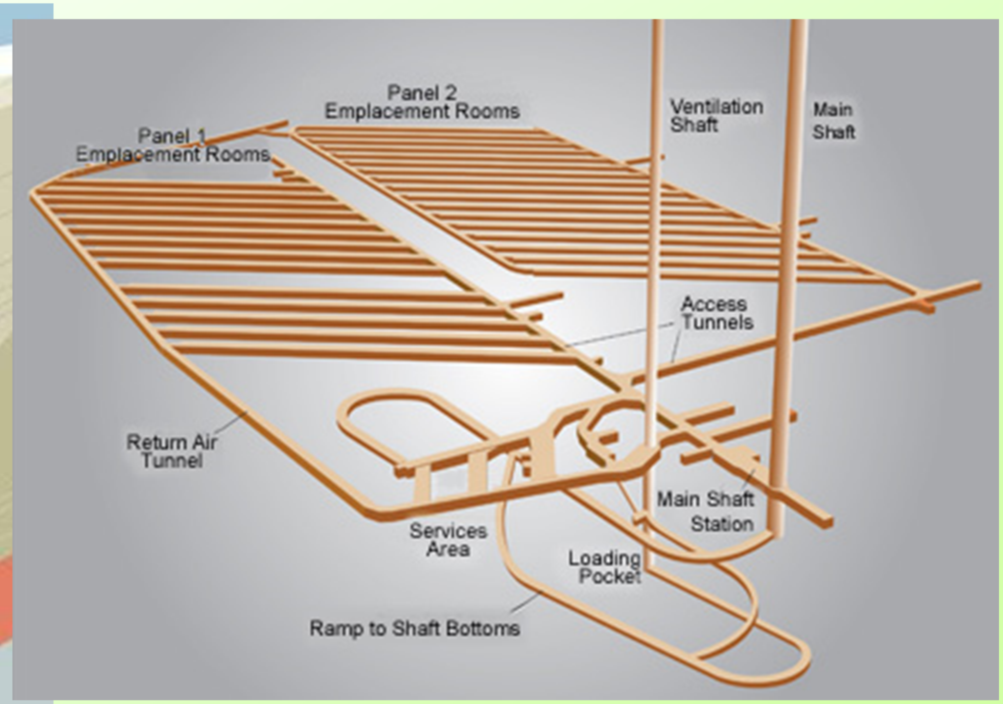
- *Low/Intermediate Level Waste*
  - WCS Andrews County, Texas
  - DOE facilities

Conceptually Similar DGRs

The Michigan Basin

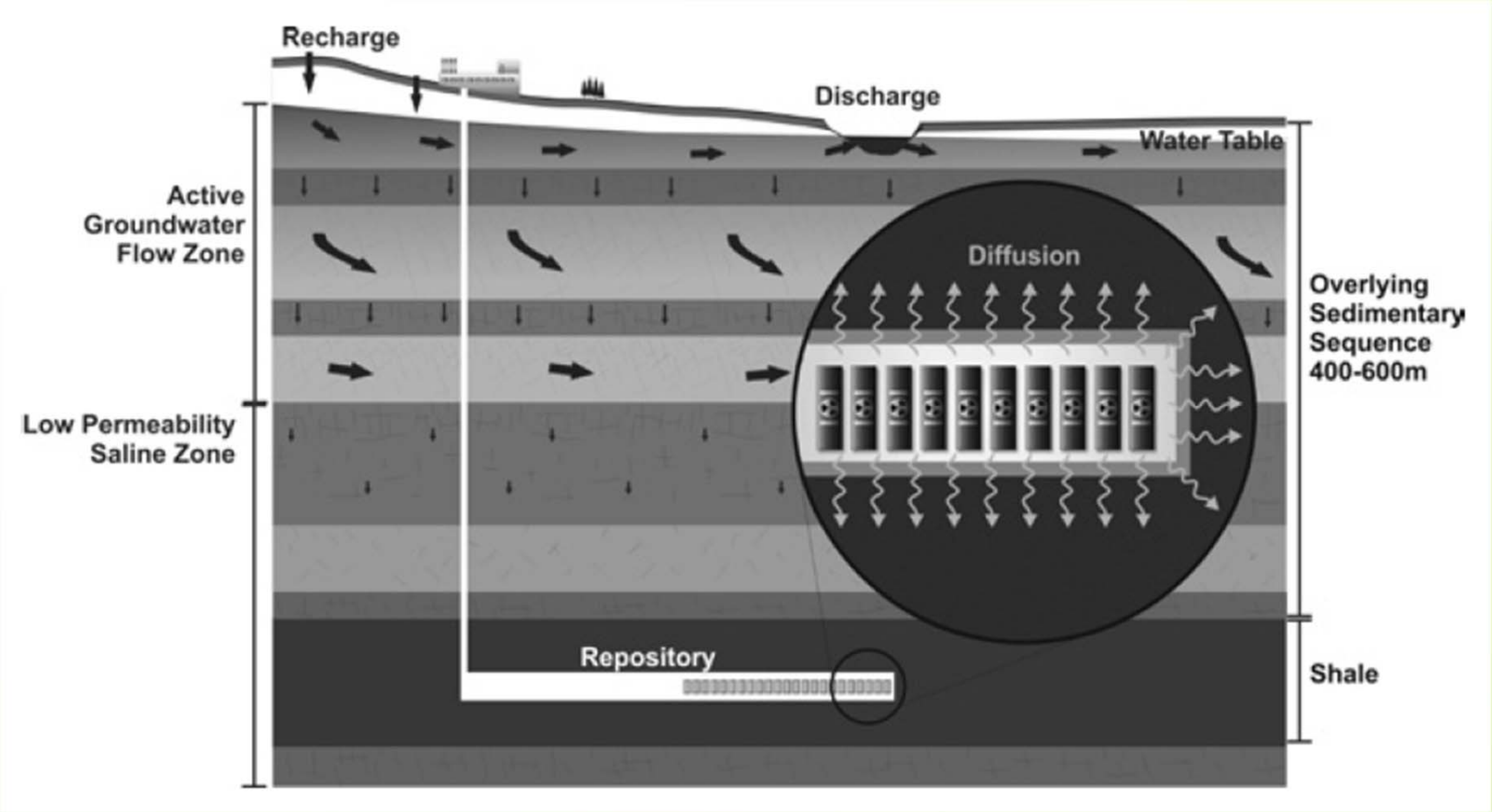






A mine-like DGR at 2,000 ft below ground for Low & intermediate level radwaste [not spent fuel]

Conceptual Canadian DGRs



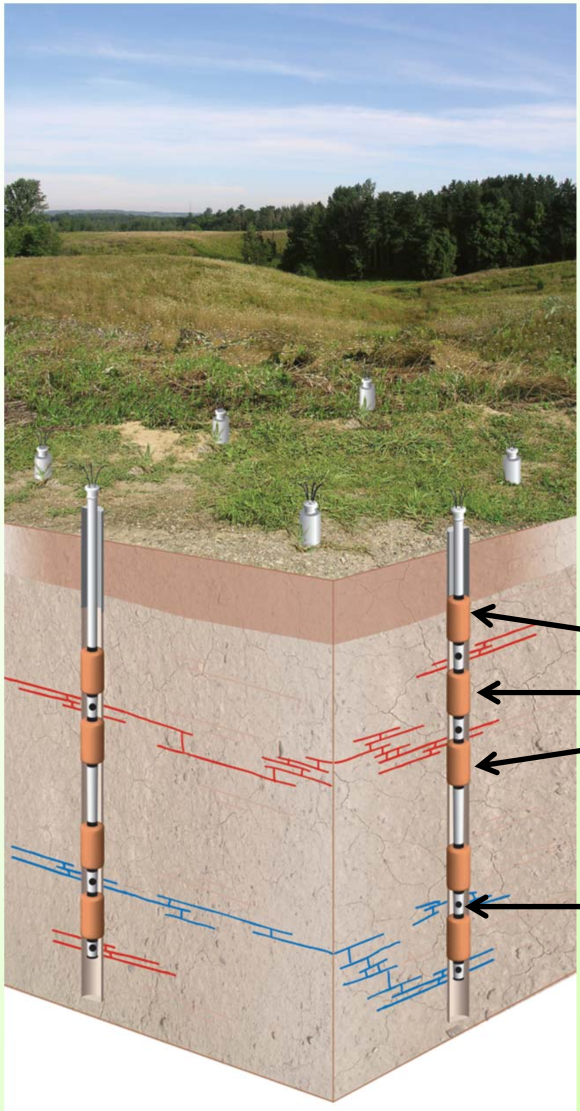
DGRs rely on low-permeability rocks to prevent groundwater flow and ensure radionuclide transport is only by *diffusion*

Deep Geological Repositories

- But how to monitor for contaminants <u>potentially</u> migrating
  1) ***from great depth → the ground surface?***
  2) ***through uncertain pathways?***

- → **Multi-depth monitoring wells**

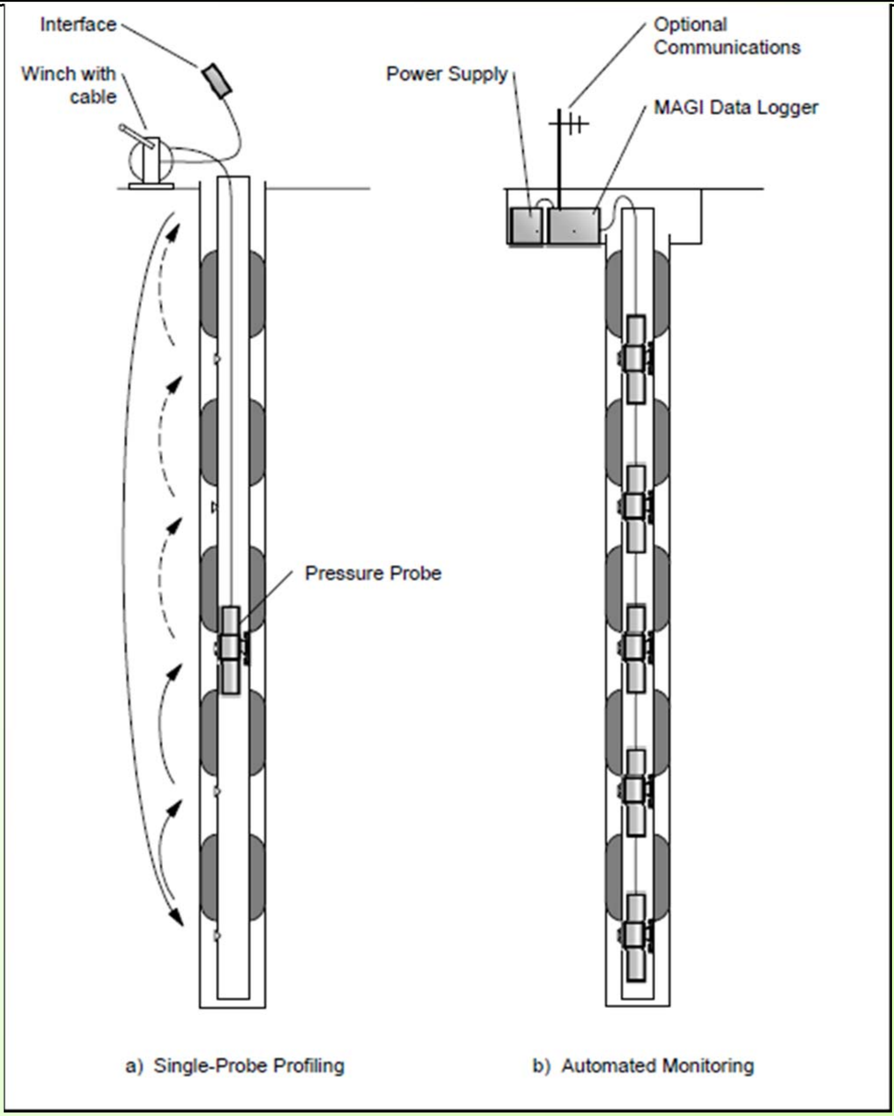
Multi-depth MWs



Discrete intervals are isolated by inflated packers

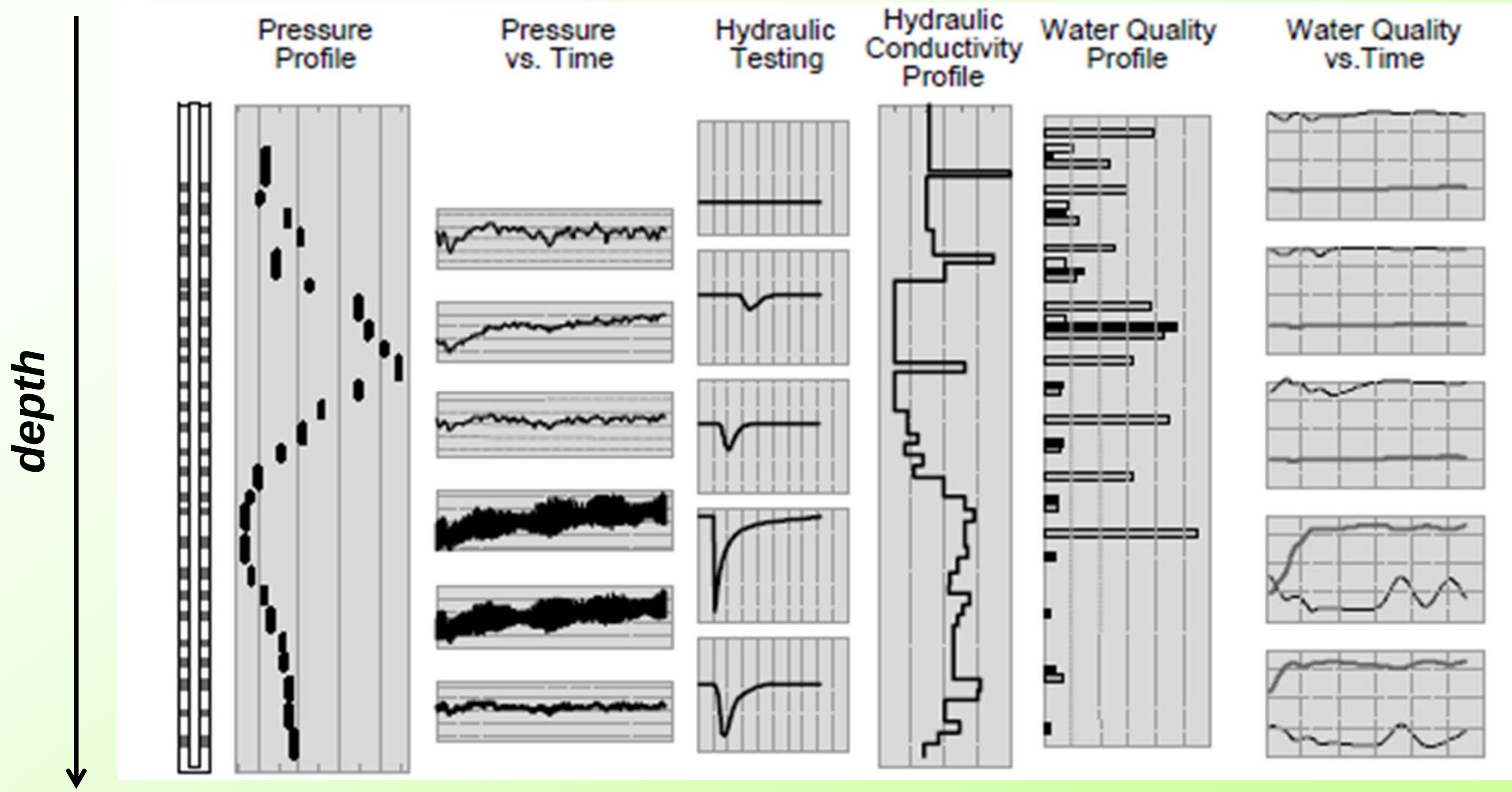
Discrete intervals in the rock are monitored for contaminants

Multi-depth MWs

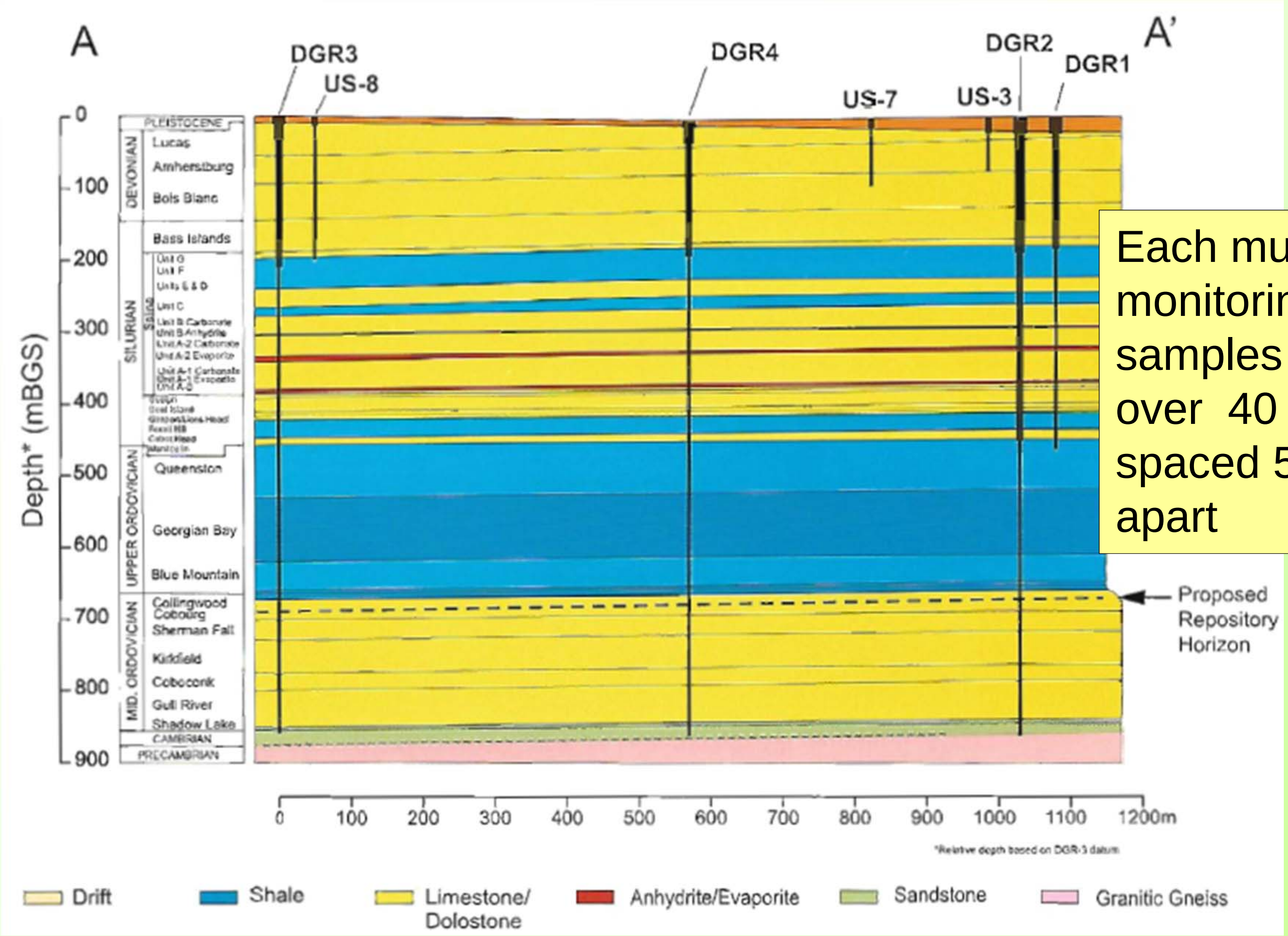


Monitoring of *discrete* intervals allows us to build continuous profiles of information

In-situ characterization

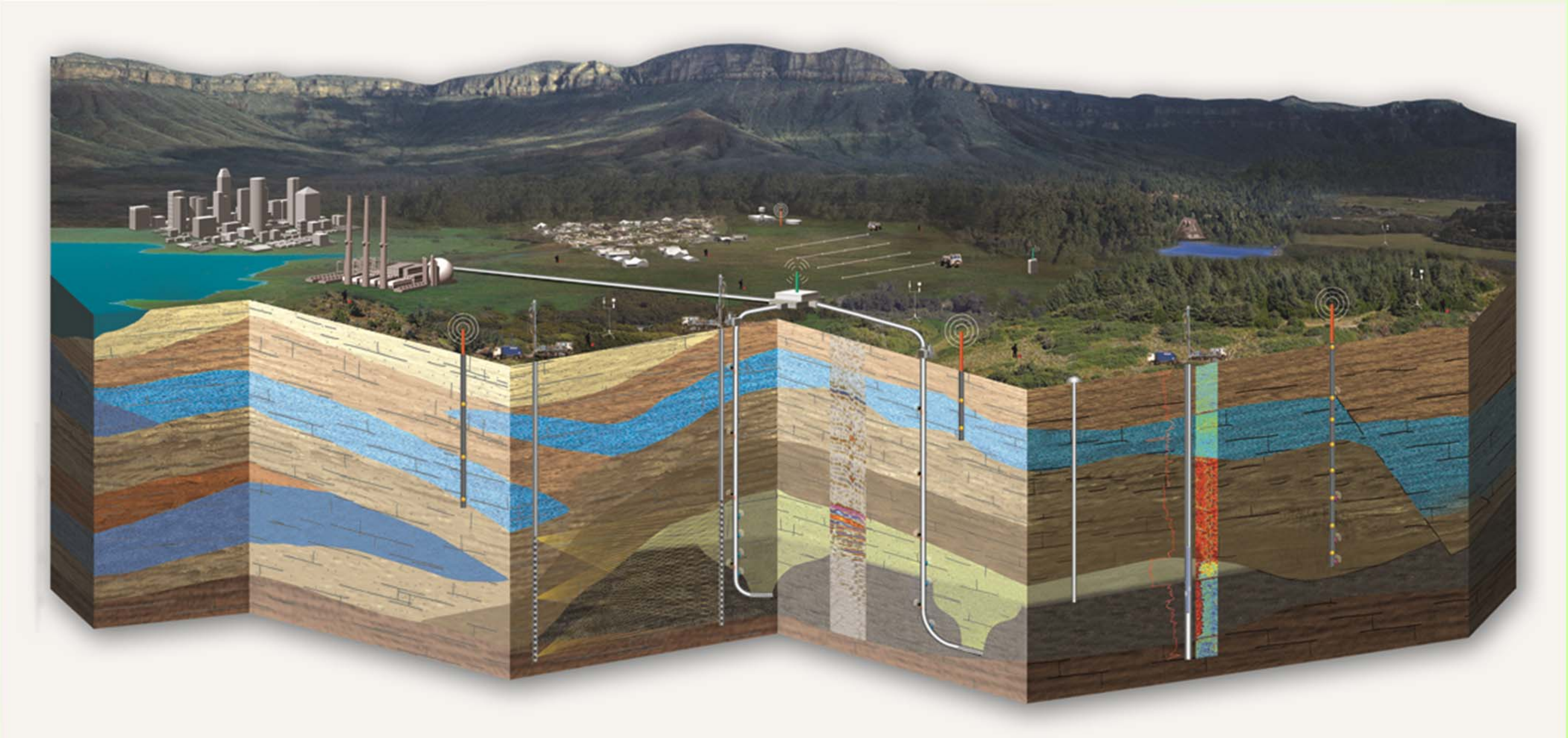


At the Bruce DGR



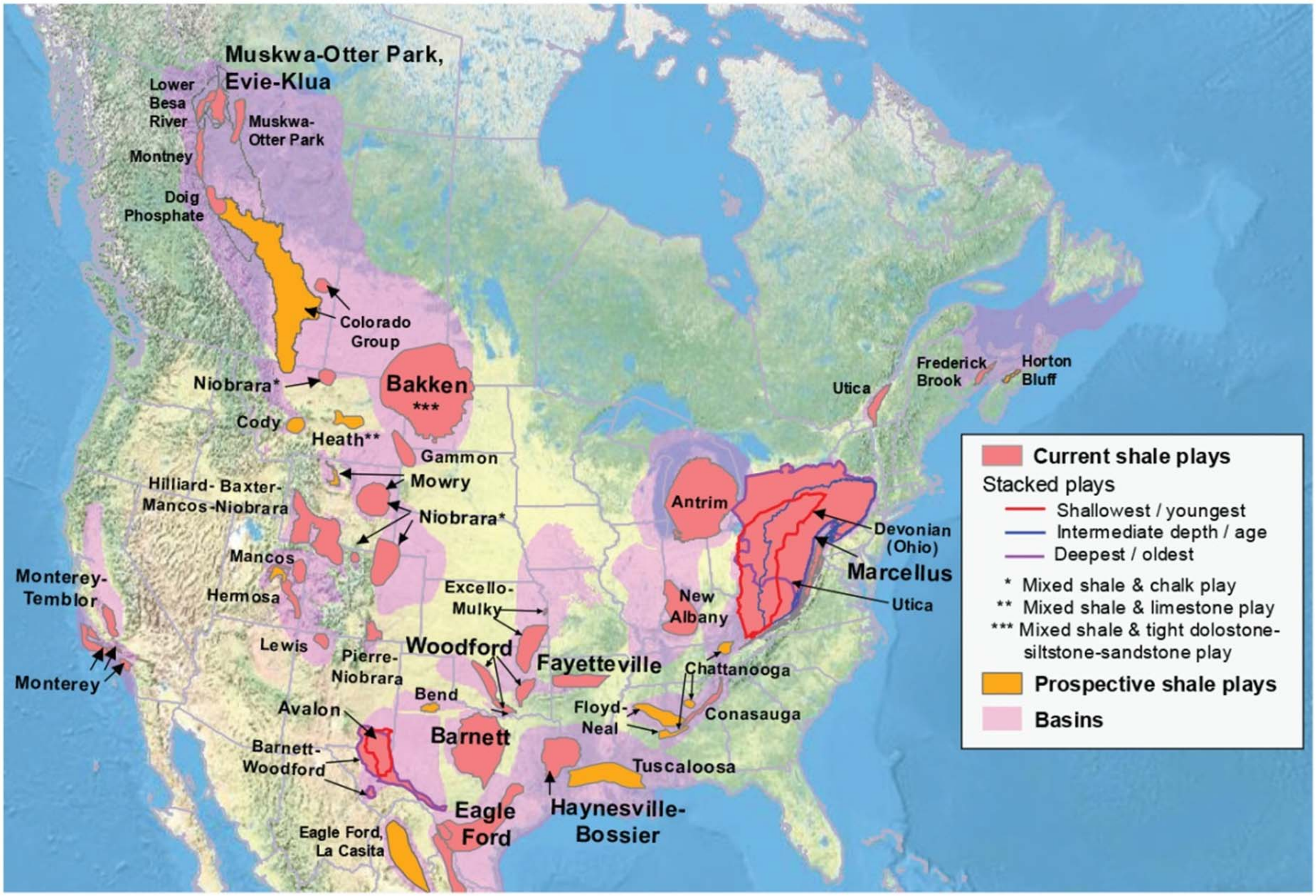
Each multi-depth monitoring well samples P and GW over 40 ft intervals spaced 50-100 ft apart

Deep Monitoring for CO_2 Sequestration



1) Beware of (a) producing oil & gas wells and (b) legacy wells
2) Continuous monitoring and data transmission from monitoring wells

Unconventional Gas in North America



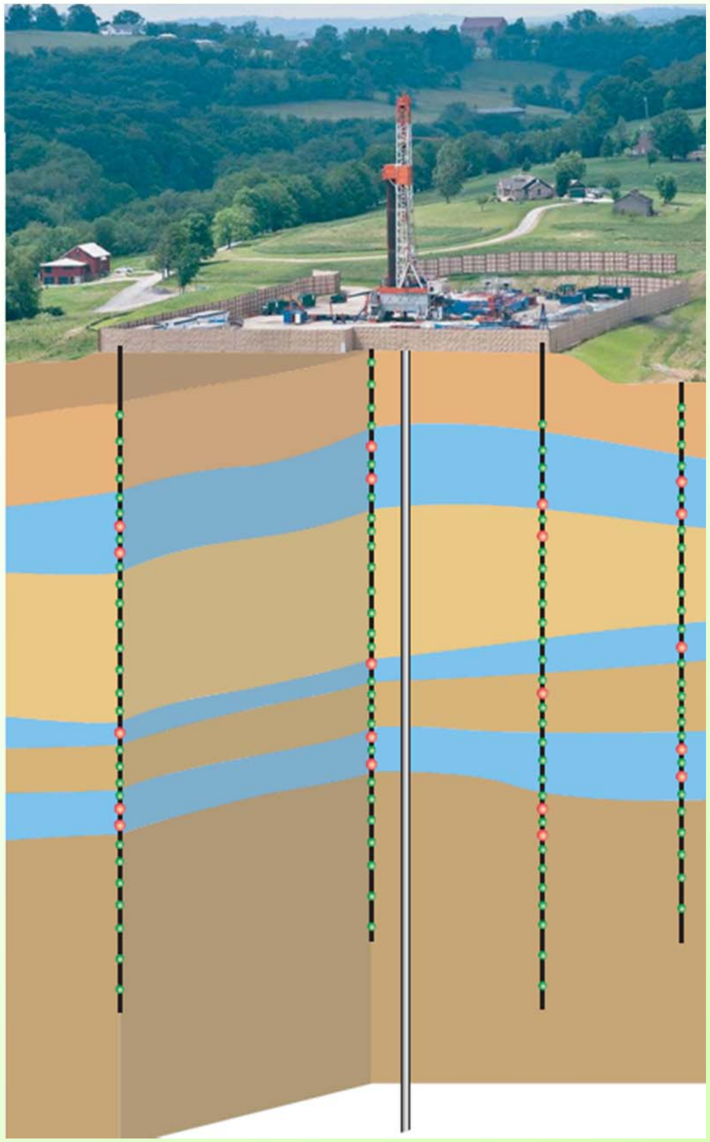
Canadian Shale Gas Plays

	Geological Formation				
	Horn River	Montney	Colorado	Utica	Frederick Brook/ Horton Bluff
Geographical Location	Northeast B.C. (extends into YT and N.W.T.)	Northwest Alta., northeast B.C.	Southern and central Alta.; southern Sask.	South shore of St. Lawrence River between Montréal and Québec City	Southern N.B.; central N.S.
Potential Gas in Place (Tcf)	144–600+	445 Tcf	>100	>120	> 130
Depth of Formation (m)	2,500–3,000	1,700–4,000	300	500–3,300	1,120–2,000+
Shale Thickness (m)	150	Up to 300	17–350	90–300	150+
Well Cost (M $)	7–10 (horizontal wells)	5–8 (horizontal wells)	0.35 (vertical wells)	5–9 (horizontal wells)	unknown

Updated 2013 to a huge value:

445 Tcf

Deep Monitoring for Shale Gas Extraction



With shale gas and tight-gas sands, our principal concerns are:

1) *Leaky wellbores;*
2) *Nearby stand-off wells;*
3) *Nearby legacy wells;*

Annular Pathways in Cement Sheaths

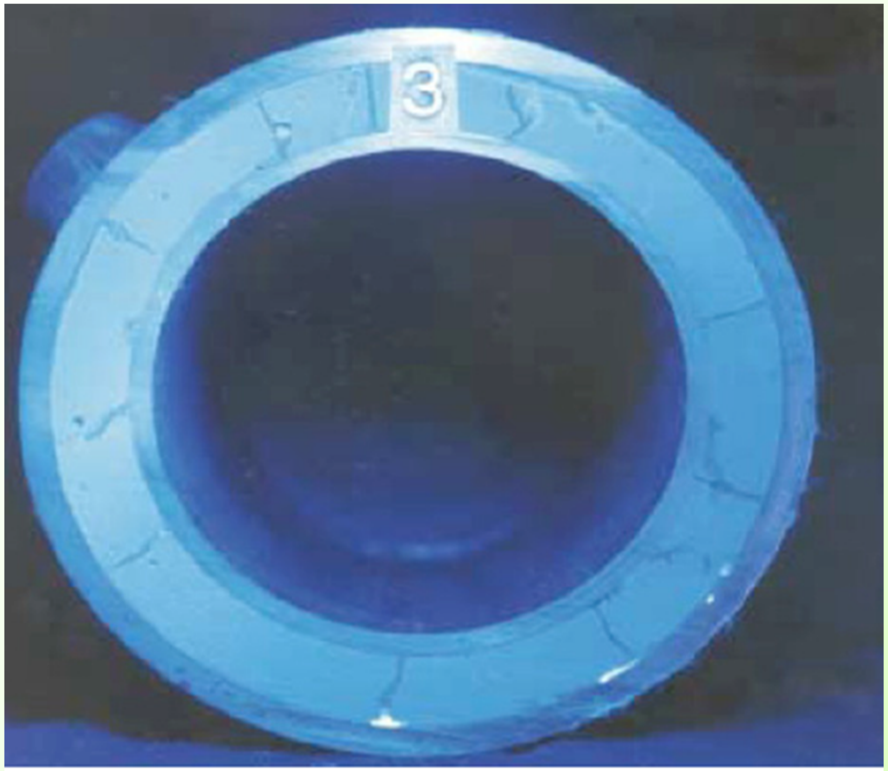
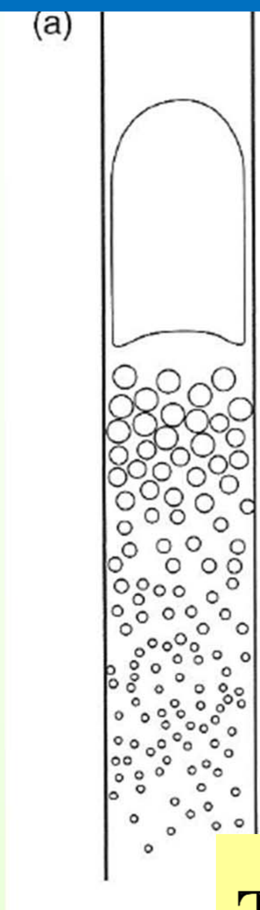


Figure 3: Cement sheath failure and resulting cracks developed from pressure cycling.[3]

Figure 4: Incomplete displacement of drilling mud and resulting cement and drilling fluid channels. Over time, the gels in the drilling fluid well shrink, forming a gas flow path in the annulus.[3]

Watson, T., 2004, CIMM Petsoc, paper 2004-297, Calgary AB

In the wellbore annulus, pulsing may be constrained by gas accumulation rates



Taylor bubbles

a. Bubble-to-slug transition occurs when gas volume fraction ~0.25

b. Slug migration depicted is for cylindrical tubes of <100 mm

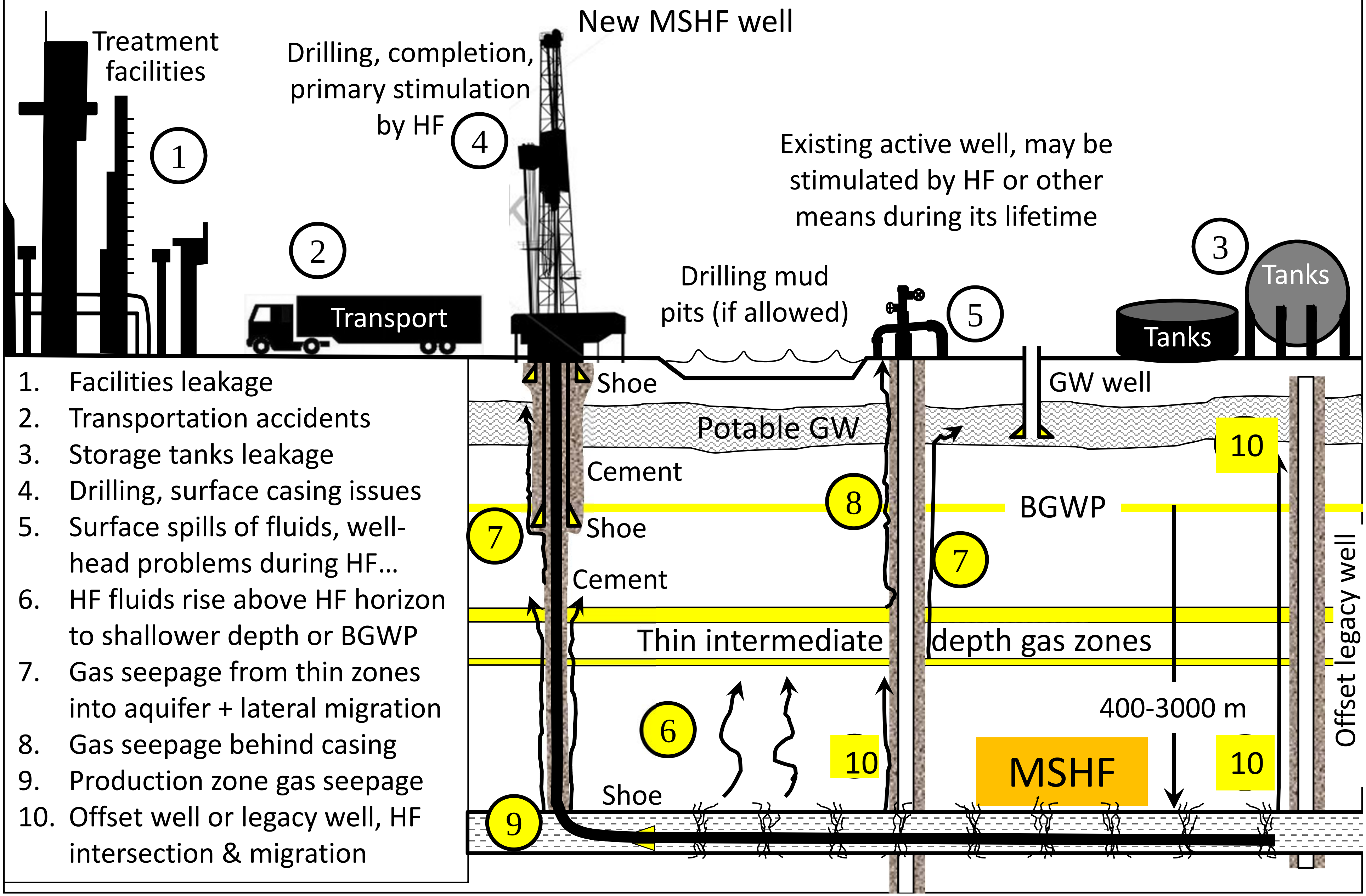
c. Slug ascent ***periodic*** depending on coalescence times and gas flux from formation

d. Displacement pressure of the slug:

$$P_d = z \cdot g \cdot (\rho_w - \rho_g)$$

z = ht of gas column
g = gravitational constant
ρ_w = density of brine
ρ_g = density of gas

Potential Groundwater Contamination Pathways



Innisfail, Alberta

Midway Energy Ltd.
Hydraulic Fracturing Incident:
Interwellbore Communication
January 13, 2012

ERCB Investigation Report
Red Deer Field Centre

December 12, 2012

Inter-wellbore Pathways

- Maximum distance of IWB (*pressure kicks*) in British Columbia (BC OGC): *2.6 miles*
- Undetected fault zones likely involved
- Distance between wellbores in Alberta:
  - **Closest IWB: 90 ft**
  - **Furthest IWB: 1.5 miles**
  - **Average IWB: 1164 ft**

MSHF Stimulation

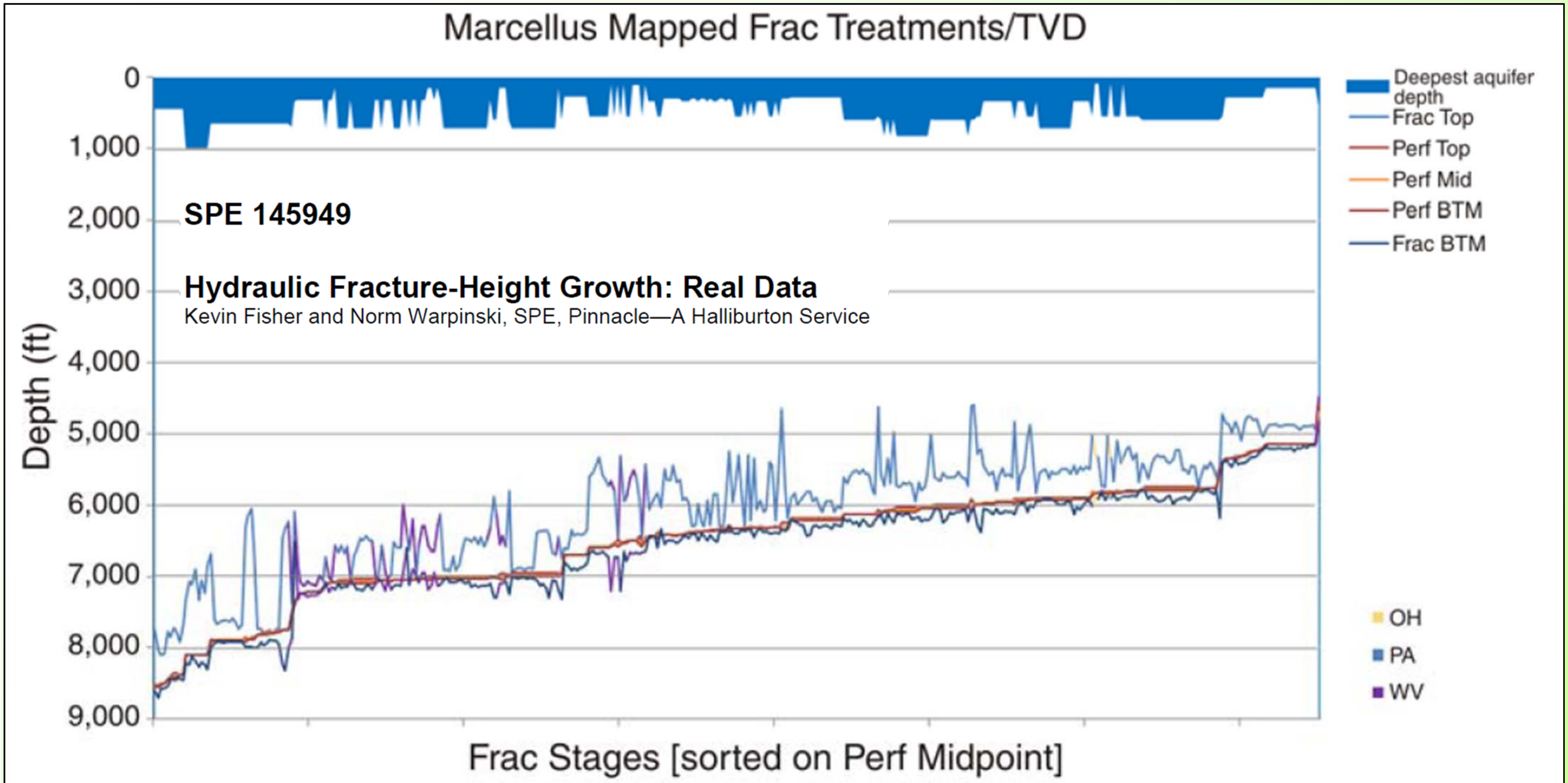
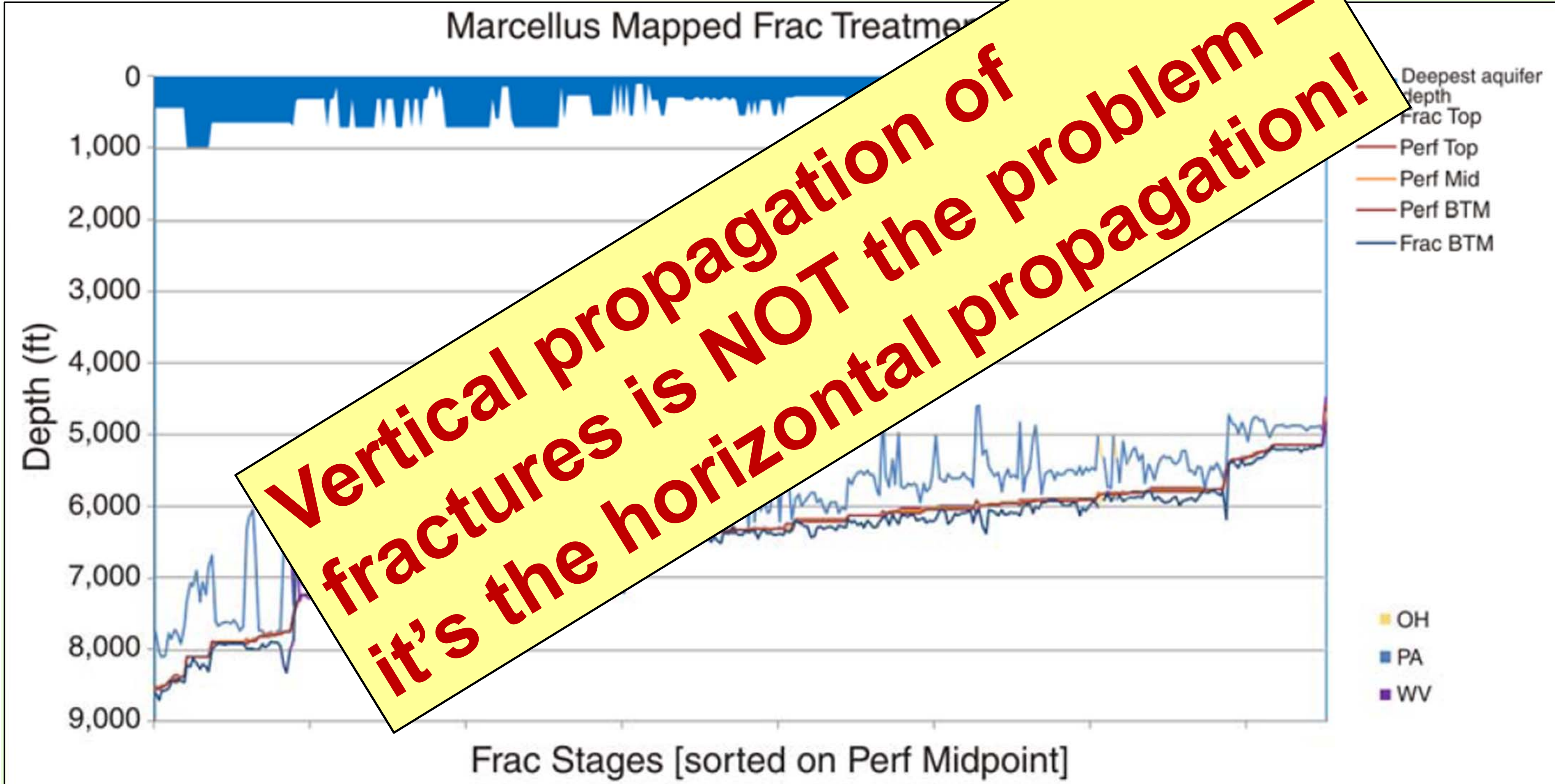


Fig. 4—Marcellus shale measured fracture heights sorted by depth and compared to aquifers.

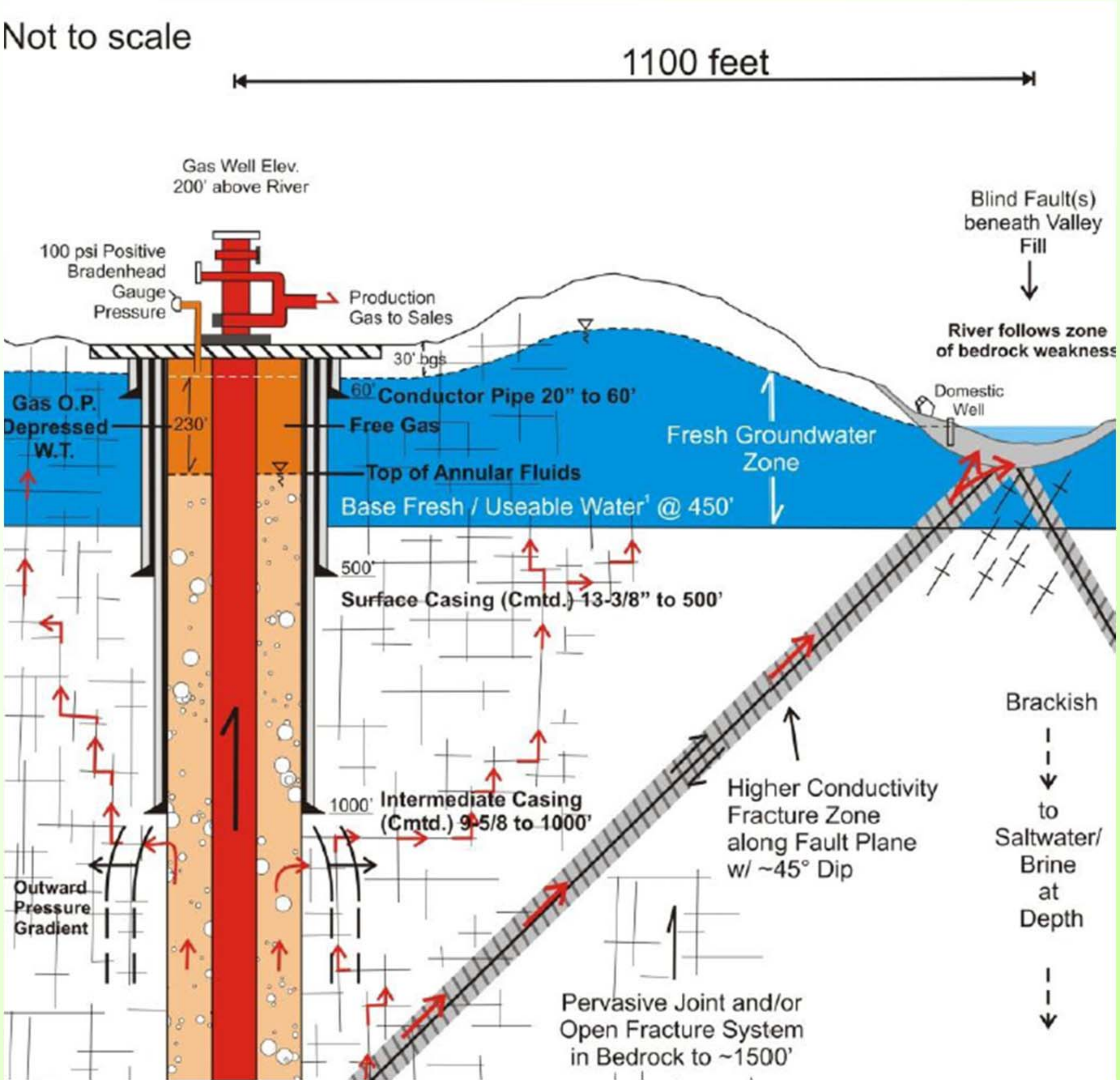
MSHF Stimulation



Vertical propagation of fractures is NOT the problem – it's the horizontal propagation!

Fig. 4—Marcellus shale measured fracture heights sorted by depth and compared to aquifers.

Happens in Pennsylvania too!



'Marcellus well'

Courtesy of Pete Penoyer,
US NPS, Fort Collins CO

It is US practice to 'shut-in' valves at the wellhead during production

This may cause pressure buildup beneath the surface casing –

Gas daylights *up to* 2100 ft away!!

- Why the long migration distances?
  - *Rock fracture networks are complex*
  - *Buoyant gases can migrate by discrete fractures at depth*
- Reinforces the need for multi-level monitoring

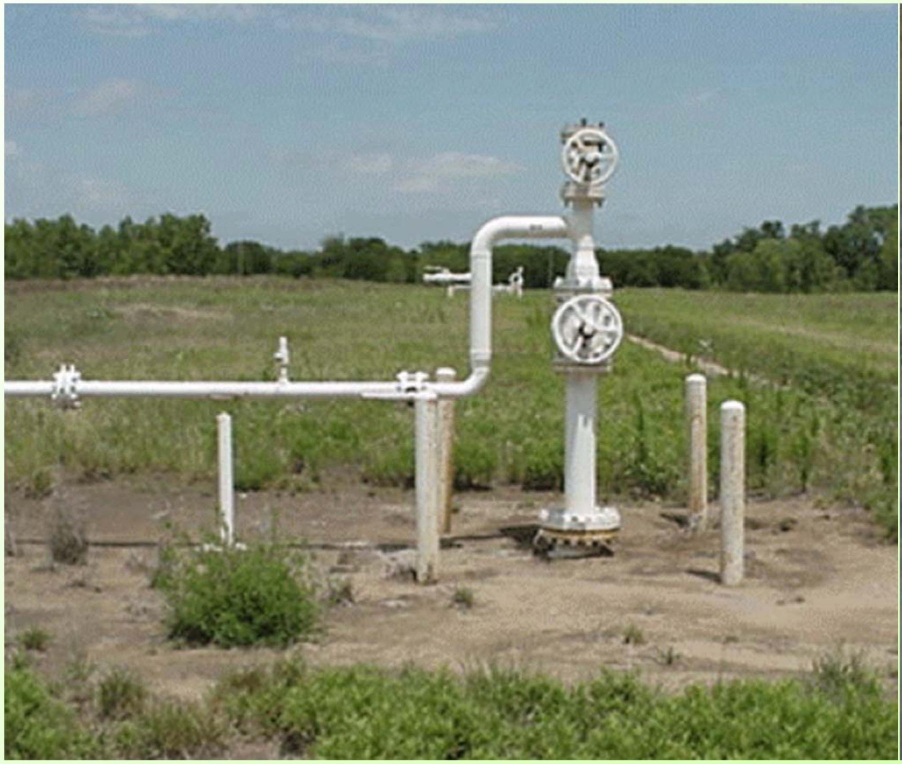
Hutchinson, Kansas, January 2001

The fire dept reported at the end of the day that the fires would not burn out

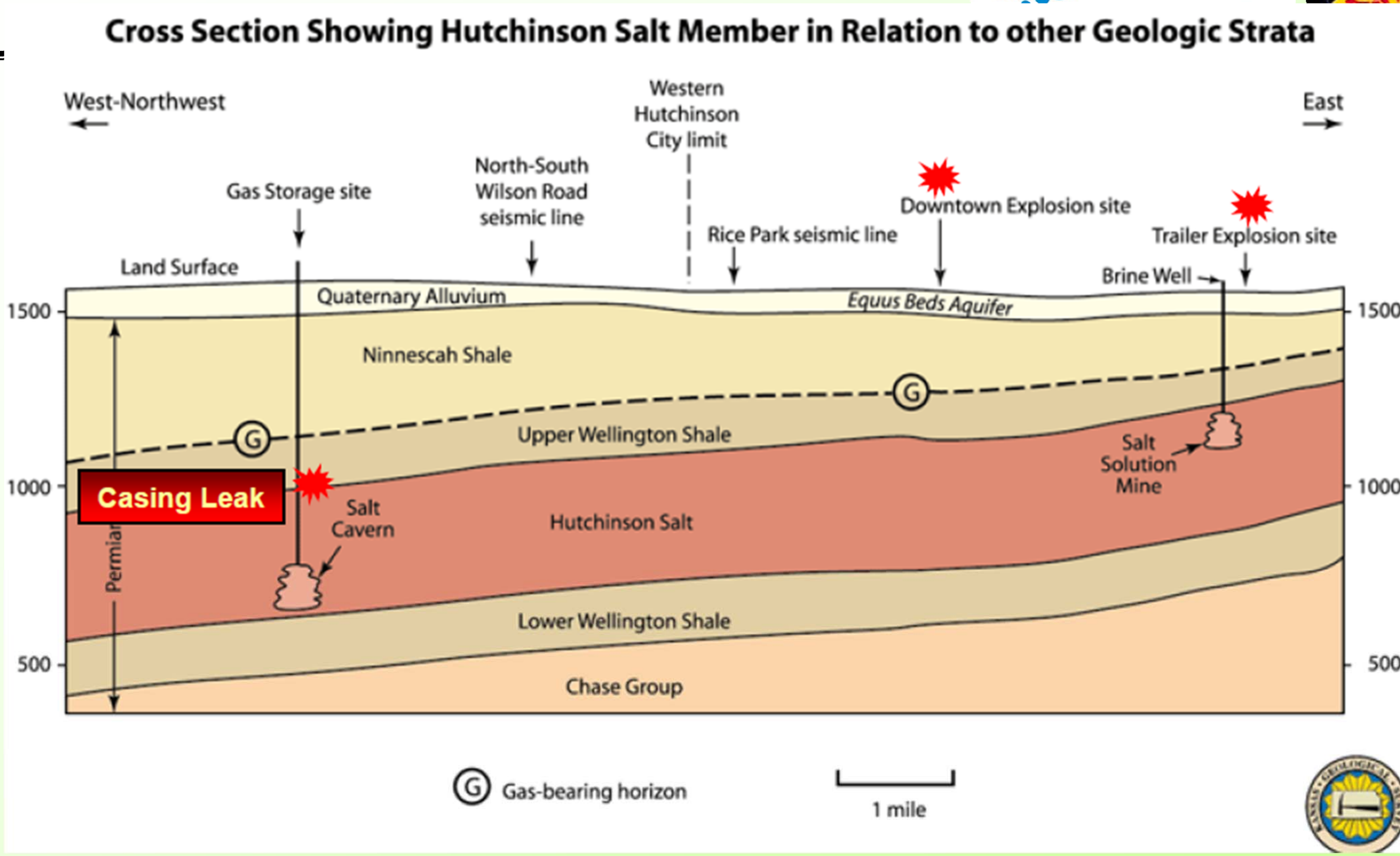
Geyers noted from abandoned brine wells

KGS’ working hypothesis

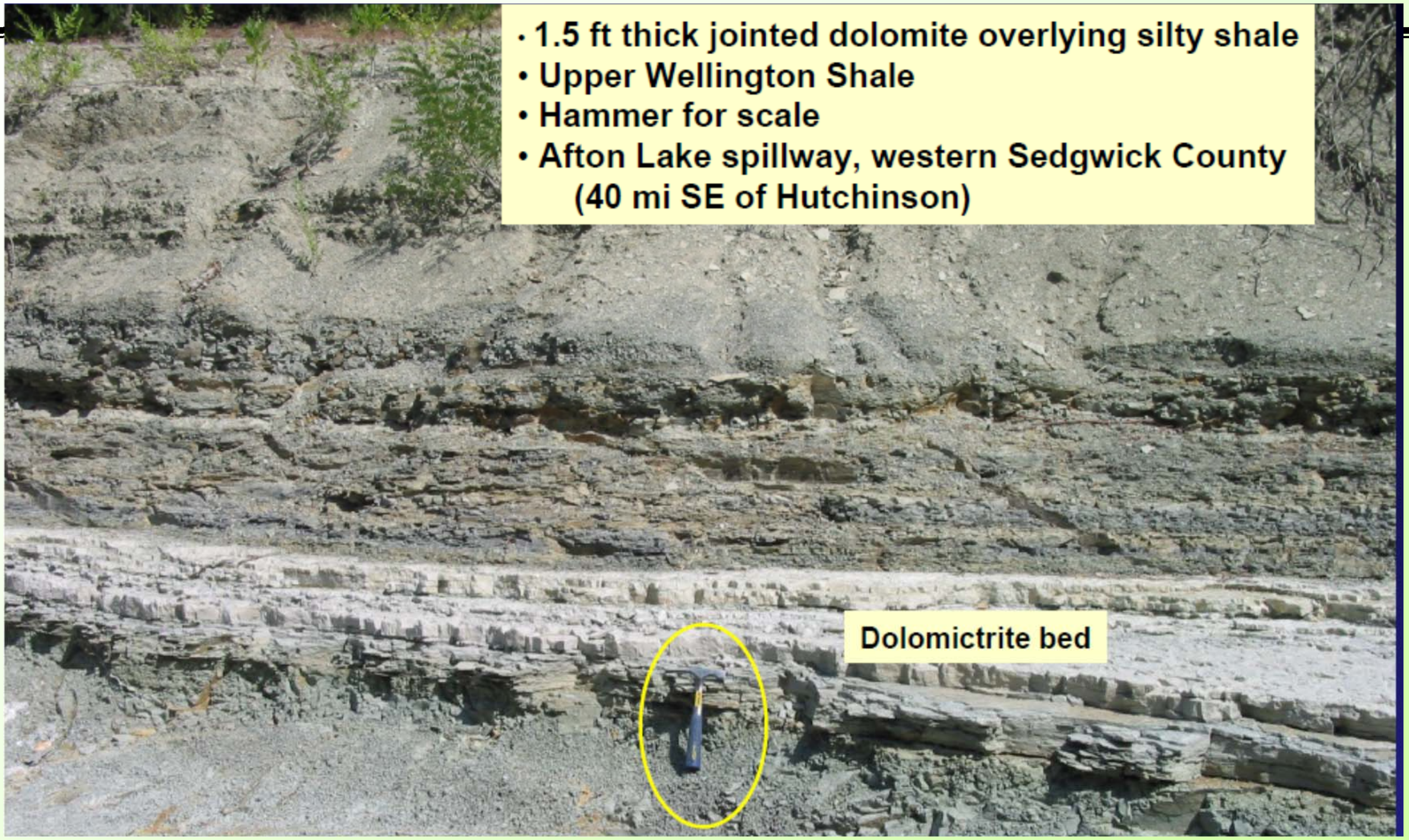
1) Gas leak at storage cavern outside town
2) Gas migrates 14 km to downtown Hutchinson
3) Gas vents via some of 160 abandoned brine wells



Identification of gas-bearing horizon

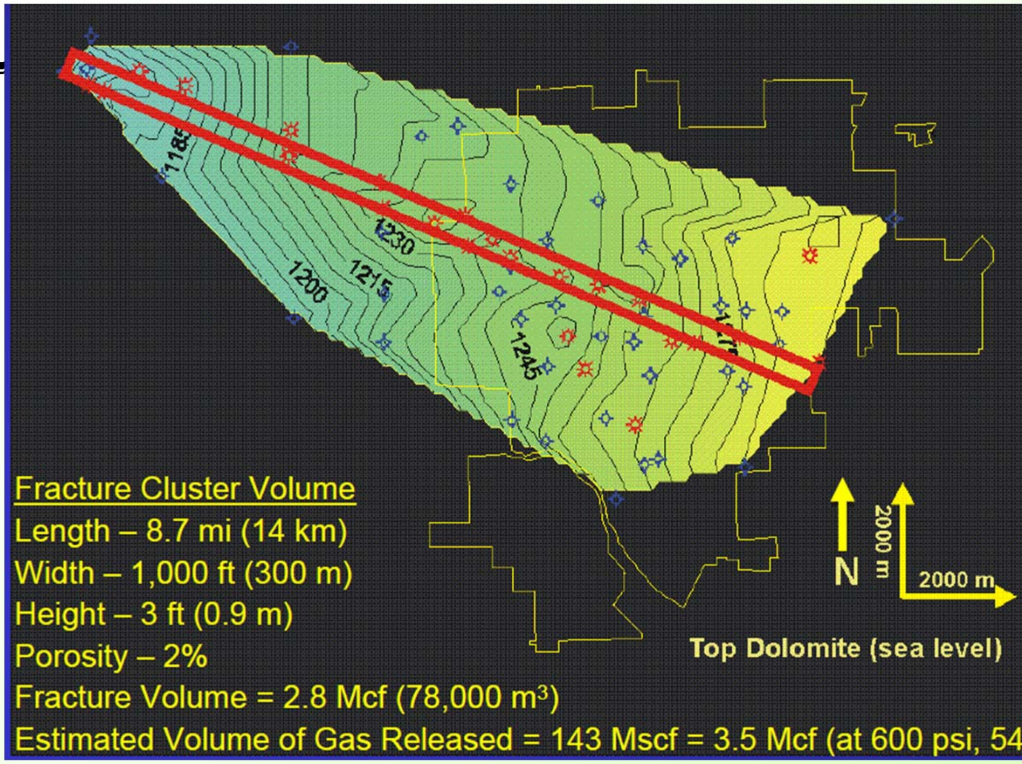


Gas migration pathways are complex



Gas migrated at ~650 psi (4.4 MPa) in three thin (<1m) beds of dolomicrite up the crest of an anticline in joints in the dolomicrite.

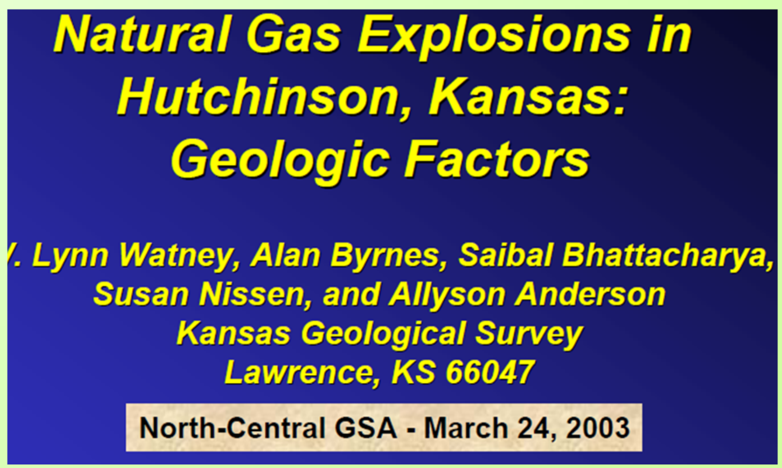
Status of understanding 2 yrs after the catastrophe



Conclusions:

Identification of gas migration pathways will be exceptionally difficult in fractured rock

Monitoring will need to focus on discrete intervals



First attempt at groundwater monitoring during MSHF –

NETL

Update on Moshannon Groundwater Monitoring Project

Daniel J. Soeder

Office of Research and Development, National Energy Technology Laboratory

the **ENERGY** lab

DOE’s Moshannon Project

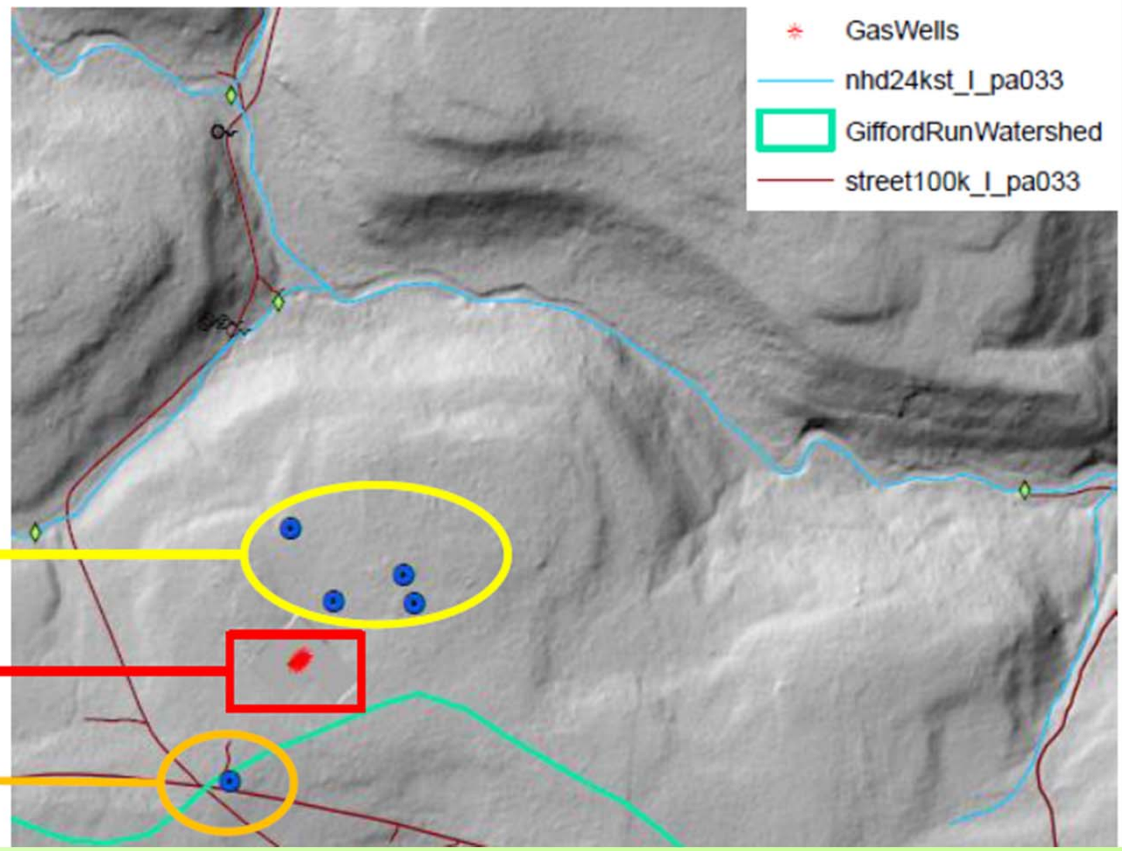
Moshannon State Forest site groundwater wells located to capture groundwater flow pathways relative to future well pad location

- Exact location of groundwater monitoring wells determined by hydraulic gradient and groundwater flowpaths.
- Hydrogeology to define flow paths prior to well placement is in progress (complicated)

Downgradient wells
(3 only, locations flexible)

Future shale gas well pad

Upgradient well



DOE's Moshannon Project

Groundwater Monitoring

- **Research Objectives:**
  - At least one year of baseline monitoring of groundwater and surface water surrounding a gas lease, including methane gas, pressure changes, major ions, metals, organics, TDS.
  - Baseline will determine flow pathways. Multi-level samplers will enable the measurement of discrete flow paths and provide a greater understanding of the site hydrogeology.
  - Continuous groundwater monitoring during top-hole drilling through aquifer, and during hydraulic fracturing.
  - Post-drilling water quality monitoring for acute or chronic water quality changes due to drilling.

- **Configuration:**
  - Up-gradient reference well, initially 300 ft deep, open hole completion, equipped with a highly precise methane detector to measure headspace gases. Eventual completion to 1500 ft reaching depth of deepest freshwater.
  - Three down-gradient monitoring wells; nominal depth 300 ft; open hole completions, two equipped with multilevel samplers, the other equipped with continuous electronic monitoring.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Questions?