WorleyParsons
resources & energy

Groundwater Baseline Optimization in support of Hydrocarbon Exploration

Presented by: Lucien Lyness

EcoNomics

Acknowledgements

- Ms Megan Hughesman, MSc. PGeol.
- Lightstream Resources

Influential Factors

- Popular media – public perception
- Spatial variation – natural
- Agricultural impacts – anthropogenic
- Well issues – natural and/or maintenance

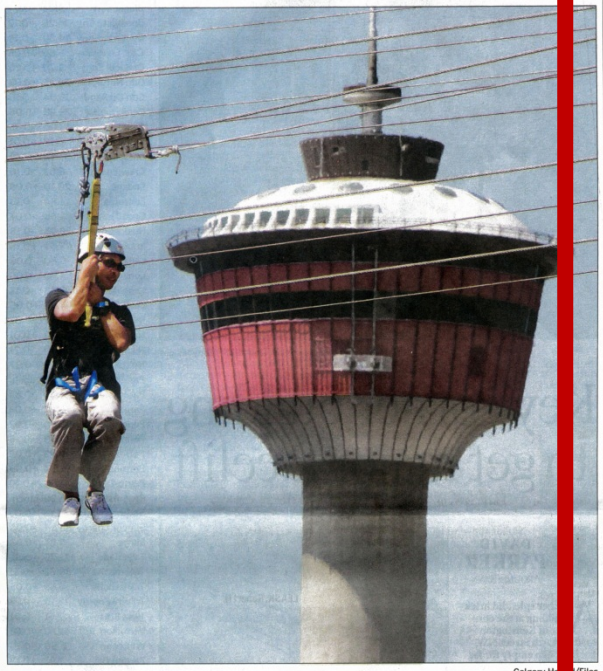
INSIDE COMMODITIES: Prices rebound forecast Page C4 WEATHER: Today's forecast and more Page C16

CALGARY BUSINESS

BREAKING NEWS AT CALGARYHERALD.COM/BUSINESS

EDITOR: STEVE JENKINSON 403-235-7580 SJENKINSON@CALGARYHERALD.COM FRIDAY, DECEMBER 21, 2012

CALGARY TOURISM SOARS



Calgary Herald/Files

A visitor slides down the zipline at the Calgary Stampede which enjoyed record attendance in its 100th year. The city drew almost three million visitors in 2012 and led the country in tourism spending growth.

Visitors to Calgary open wallets to tune of $1.4B

AMANDA STEPHENSON
CALGARY HERALD

For the second straight year, Calgary's tourism industry has led the nation in visitor spending growth.

The Conference Board of Canada's Autumn 2012 Travel

Canadian 2012 visitor numbers

	Visitors	Change	Spending
Toronto	9.9 million	+1.7%	+4.7%
Montreal	7.9 million	+0.9%	+3.5%
Vancouver	5.3 million	+1.4%	+4.3%
Quebec City	4.5 million	+0.7%	+4.3%

The Calgary Zoo, in part because of the popularity of its new Penguin Plunge exhibit, shattered an attendance record in place since 1988 and has already surpassed 1.4 million visitors this year.

"It has been a fantastic year for us," said zoo spokesperson

Fracking accident pollutes water

Calgary firm won't be fined over incident

SHEILA PRATT
EDMONTON JOURNAL
EDMONTON

Leaked fracking fluid contaminated groundwater at a well site near Grande Prairie last year, according to an investigation by the Energy Resources Conservation Board.

Calgary-based **Crew Energy Inc.** "inadvertently" released toxic fluids at too shallow a level in a natural gas well and then failed to realize the leak was occurring underground, said the regulator in a report released Thursday.

"There were multiple opportunities to recognize that a problem existed which could have prevented or at least minimized the impact of hydraulic fracturing operation above the base of groundwater protection," says the report.

Despite the infraction, neither the ERCB nor Alberta Environment is imposing fines on the company.

While a drinking water source near the surface was not affected, a groundwater basin below it was contaminated, said ERCB spokesman Daren Barter, adding the event in September 2011 considered a "serious" if rare incident.

The ERCB gave the company a "high risk enforcement action" ordering it to supply a revised fracking plan.

Hydraulic fracturing involves injecting fluids under high pressure into underground rock formations to cause cracks or fractures to release natural gas or oil.

Only non-toxic fluids can be used above the base of groundwater. The level is set for each region by Alberta Environment.

About 40 cubic metres of propane gel injected underground remains there, so no drilling is allowed in a 200-metre radius of the well site.

Alberta Environment tested the contaminated water this fall and found chemicals from fracking fluid, including benzene, toluene, ethylbenzene and chloride.

SEE ERCB, PAGE C5

Comedy of errors on frack job no laughing matter

environmental concerns with fracking — nobody is laughing.

Workers on the well site failed to heed a number of

TOURISM: International market targeted

FROM C1

"To have all those things in place and then not hit a home run would have been disappointing," he said. "I think I'm most proud that the industry took full advantage of what was going on all around us."

Calgary hotel occupancy rates have grown for 21 consecutive months, with overall occupancy up four percentage points and weekend occupancy up 3.8 points. Tourism Calgary figures show that during the first three-quarters of 2012, 134,515 more rooms were sold than the same time in 2011.

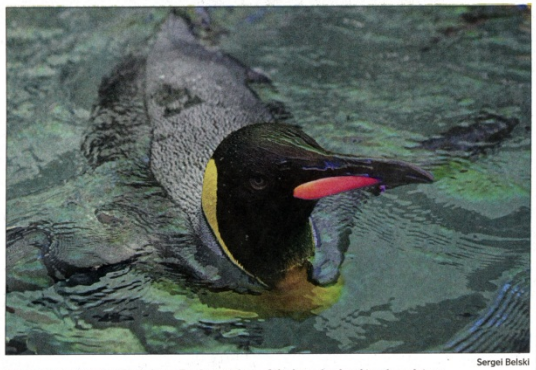
In the wake of such a banner year, the Conference Board is predicting a return to more modest growth in visitor spending for Calgary — in the range of 2.3 in 2013.

Williams said while it's unlikely local attractions will see record-breaking crowds again next year, Calgary is still fresh in the mind of prospective visitors because of all the publicity it received last year.

Tourism Calgary plans to ramp up its international market efforts.

"We've lived off our domestic market in Calgary and Canada too long," Williams said. "We have to do better at getting the overseas market."

The Conference Board report says that with the U.S. economy still vulnerable, and many parts of Europe mired in recession, much of the Canadian tourism industry's future growth is expected to come from emerging economies such as China, India, and Brazil.



Sergei Belski

The penguin exhibit at the Calgary Zoo is one piece of the booming local tourism picture.

ASTEPHENSON@CALGARYHERALD.COM

ERCB

FROM C1

A sandstone layer separates the two water sources so the risk to drinking water was deemed "insignificant," says Alberta Environment.

Alberta Environment will continue to monitor the contaminated water "for some time" to make sure the toxic fluids do not migrate or spread underground, said department spokesperson Jessica Potter. If that happened, "we would have to deal with it," she added.

Rob Morgan, chief operating officer for Crew Energy, said his company contracted fracking on site to Caltex Energy Inc. The operation was monitored at the Crew Calgary office.

The company has been working with the ERCB and the environment ministry since the incident and has already changed its fracking process to avoid any recurrence.

Toxic fluids are now put down the well casing and cannot be released until ports or openings in the casing are far enough underground.

"If the casing does not go down far enough then the toxic fluid is not released," he added.

Barter also said the ERCB did not release details of the incident at the time because the location was considered remote and there was no impact on the public.

EWART: Fracking calls for a cautious approach

FROM C1

"Crew and the on-site service company's personnel did not adequately manage the risks ... there were multiple opportunities to recognize that a problem existed, which could have prevented or at least minimized the impact of the hydraulic fracturing operation above the base of groundwater protection," said the Energy Resources and Conservation Board.

Crew, meanwhile, said it is "embarrassed" about the incident and has made sweeping changes to its well-site monitoring and fracking practices.

It should. Injecting toxic chemicals at shallow depths that could impact the water supply is one of the cardinal sins of fracking.

"There's no question of our appreciation of the severity of this," said Rob Morgan, the chief operating officer for Calgary-based Crew. "Pretty much all of the personnel who were involved in this particular circumstance are no longer with the company."

Hydraulic fracturing involves injecting fluids under pressure into underground rock formations to cause cracks to release natural gas or oil. More than 42 cubic metres of propane used by Crew in its fracking process couldn't be recovered and remains underground.

The ERCB required Crew to develop and implement a detailed plan to prevent similar incidents occurring again. Crew must also provide to the ERCB the analysis from groundwater monitoring Alberta Environment is conducting on site.

In its own documents to address public concerns on the threats to groundwater, the ERCB states it "has regulations that strictly limit the depth of shallow fracturing, distances to water wells, limit the fracture volumes that can be used and specify the use of non-toxic fracture fluids to ensure groundwater protection."

Inadvertent or not, Crew violated the regulations. However, its marching orders largely amount to working to ensure it doesn't happen again.

Alberta Environment said monitoring indicates only the lower aquifer, which is not used for water supply, was contaminated with propane and other toxins but a shallower aquifer that's used for some wells in the sparsely populated area wasn't affected.

Neither the ERCB nor Alberta Environment intends to fine Crew or GasFrac.

The regulator said such incidents are rare among the 5,000 fracturing operations in Alberta since 2008. Spokesman Darin Barter notes the ERCB's ability to issue fines is limited and there is a bigger impact from halting production.

"What we've found over 75 years when you slow down a company or stop a company from performing their business there is a bottom line impact," Barter said.

"Although there isn't fine ... the industry becomes safer when we insist the company move forward with action plans."

In this case, the $5 million Crew spent on the well produced a dry hole.

Technologies to develop unconventional oil and gas, such as fracking, have proliferated across North America recently but have proved controversial. Fracking has been linked to groundwater contamination and causing small earthquakes.

This month the ERCB released a draft directive to address subsurface issues around fracking and invited public comments in its review. The Canadian Association of Petroleum Producers has voluntary guidelines for its members that urge using additives with the least environmental risks, protection of groundwater, and disclosure of fracking fluids.

Crew, a mid-sized oil and gas producer, acquired the well in its takeover of Caltex Energy in July 2011 and said the operations were being integrated when the incident occurred. Morgan acknowledged that "we're embarrassed that it came under the Crew name and obviously very sorry."

Last week, the ERCB concluded a well blowout near Innisfail last January that spewed 500 barrels of oily liquid over a field was caused by a company fracking a nearby well. It said "communication" between a well fracked by Midway Energy and a nearby well operated by Wild Stream Exploration caused the blowout.

No enforcement order was issued because the action didn't violate regulations in place at the time.

Barter said the problem at Crew's well was that people misread or ignored pressure gauges or other indicators that signalled something was wrong.

"There is no amount of regulation that can overcome human error," he said.

True, but at least some fine from the government could reinforce the safety messages from the top executives to the bottom line.

STEPHEN EWART
IS A CALGARY HERALD COLUMNIST

SKIING THE JEWEL OF THE ROCKIES
CROSS-COUNTRY ENTHUSIASTS BATTLE TO SAVE TRAILS AROUND EMERALD LAKE Outside, Page C5

CALGARY FESTIVAL DANCES ON THE EDGE
Entertainment, Page D1

CALGARY HERALD

BREAKING NEWS AT CALGARYHERALD.COM PROUDLY CALGARY SINCE 1883

iTunes 12 DAYS CHRISTMAS

On the 9th day of … iTunes and the … two videos and a song … Visit calgaryherald.com

QUITTING 'NOT AN OPTION' FOR SURVIVOR

Christina Ryan/Calgary Herald

Victoria Boehm, 16, says she "floated all day" Nov. 29 after being told she had won her battle with Hodgkin's lymphoma.

Determination helps teen beat cancer

BRYCE FORBES
CALGARY HERALD

It was six months ago when Victoria Boehm learned of the challenges she'd endure after being diagnosed with Hodgkin's lymphoma: two rounds of chemotherapy and 11 radiation treatments.

For some 16-year-olds, it would be too much to ask. But she took it all in stride, still managing to pi… spire hundreds of p… and be cancerous. She was given a … SEE TEEN, PAGE A5

eventually beat cancer.

"I'd show up and do my best," she explained, still playing hockey. "The coaches would say, 'Victoria, if you need to go home, you can go home.' But it's not an option, quitting has never been an option. When people would tell you it's OK to go home, no it's not. You don't quit till the buzzer goes."

It was June 27 when the world came crashing in on Victoria.

90.0 per cent chance of survival, but it wasn't going to be easy.

She created a Twitter account (@CuzIHaveCancer) where she talked about the challenges of being a teenage cancer patient. As word spread of her story, she received words of encouragement from the likes of hockey personality Don Cherry, Dragon's Den star Arlene Dickinson and women's hockey superstar Cassie Camp-

> When people would tell you it's OK to go home, no it's not. You don't quit till the buzzer goes."

Fracking goes to Hollywood with new Matt Damon film

MICHAEL RUBINKAM
THE ASSOCIATED PRESS
ALLENTOWN, PA.

The new movie Promised Land digs into the fierce debate over fracking, the technique that's generated a boom in North American natural gas production while also stoking controversy over its possible impact on the environment and human health.

Written by and starring Matt Damon and John Krasinski, the film comes at an opportune time for a big-screen exploration of the issues surrounding the shale gas revolution, with cheap natural gas transforming the continent's energy landscape and "fracking" now a household word.

But viewers shouldn't necessarily expect a realistic treatment of drilling and fracking. It's not that kind of film.

Lending an air of authenticity, the movie was shot in Pennsylvania, where thousands of wells have been drilled and fracked in recent years as industry heavyweights pull huge volumes of gas from the sprawling Marcellus Shale, a rock formation deep below the Earth's surface.

SEE FRACKING, PAGE A4

Focus Features

Matt Damon plays a gas company salesman who tries to convince residents of the benefits of drilling.

ALSO SEE

■ Damon's search for a Promised Land D1, D4

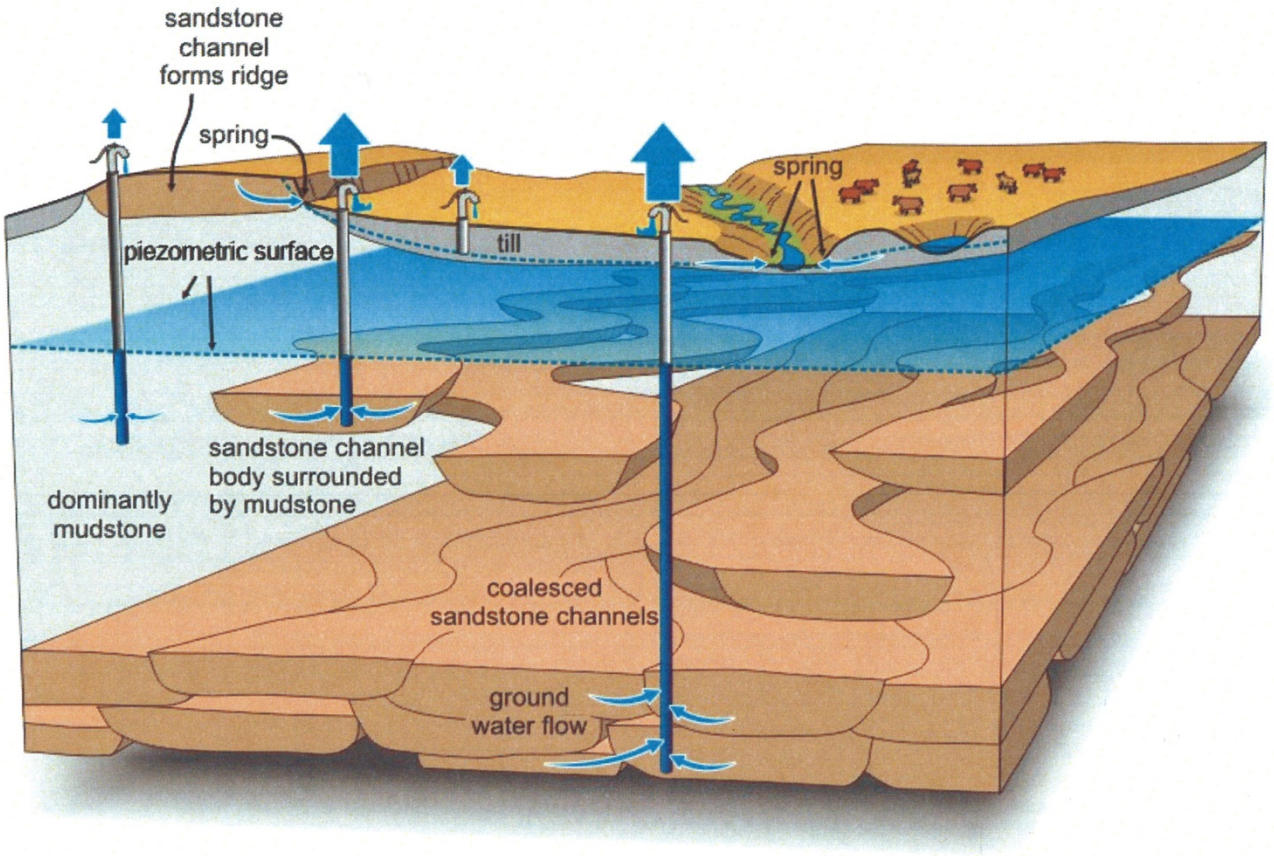
FISCA… CLIFF

MARKETS S… ON WASHING… 11TH-HOUR …
Calgary Busi… Page E1

U.S. STILL PL… CHICKEN W… ECONOM…
Deborah Ye… Page E1

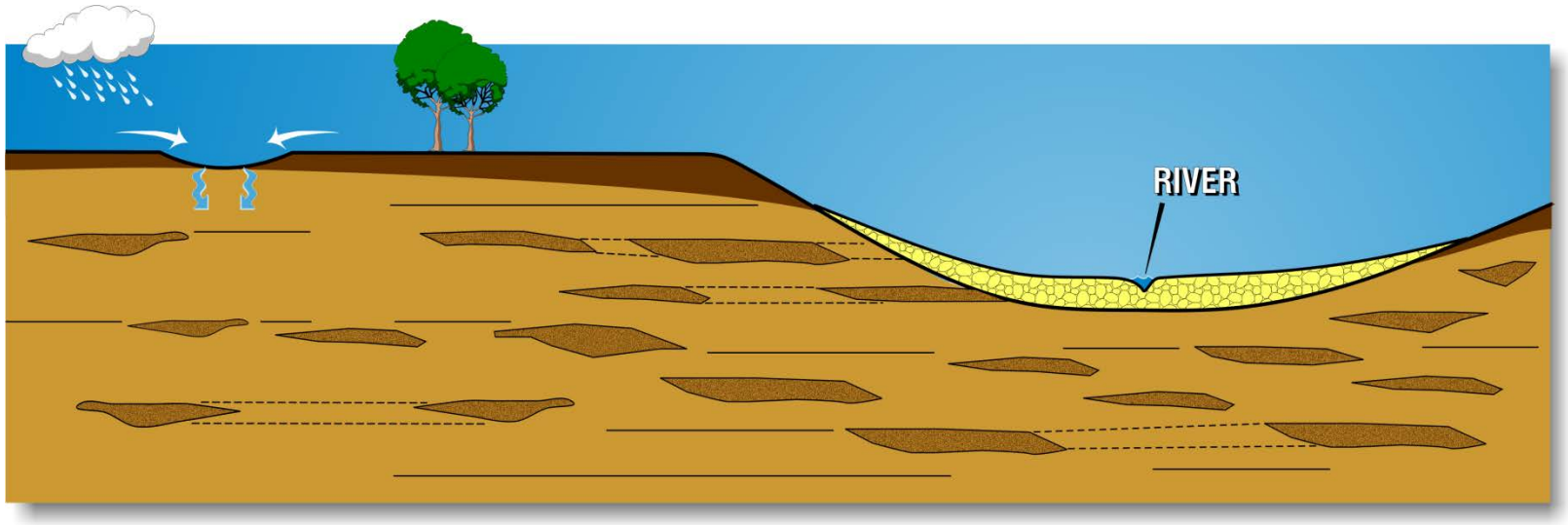
STRATHMORE, LANGDON STRUGGLE WITH POLICING
Top News, Page A3

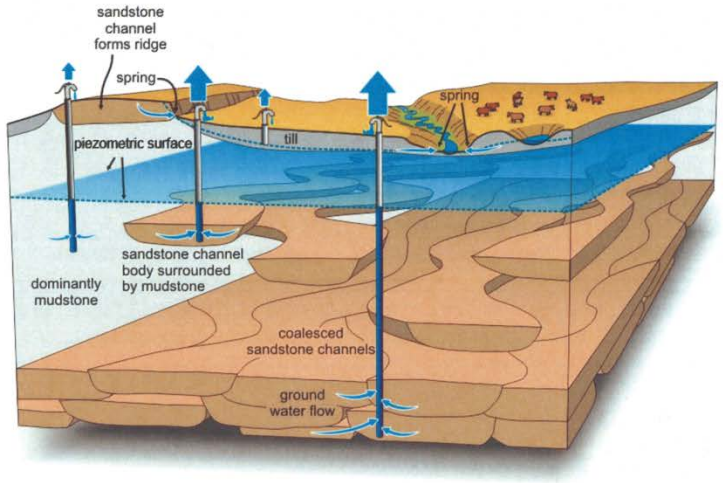
Conceptual Hydrogeologic Framework
Paskapoo Formation Aquifer System



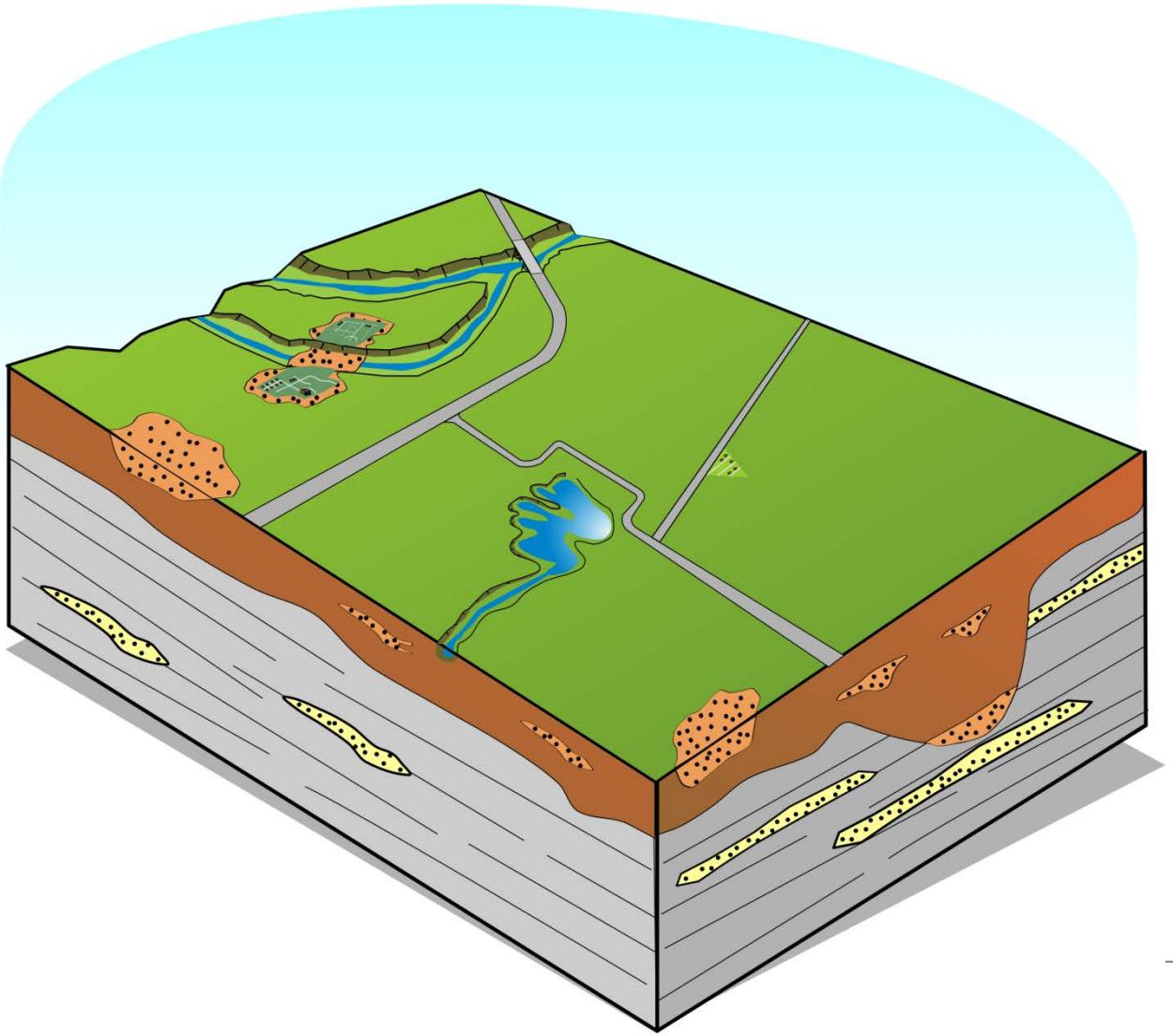
From: Geological Survey of Canada (Grasby et al 2008)

Setting

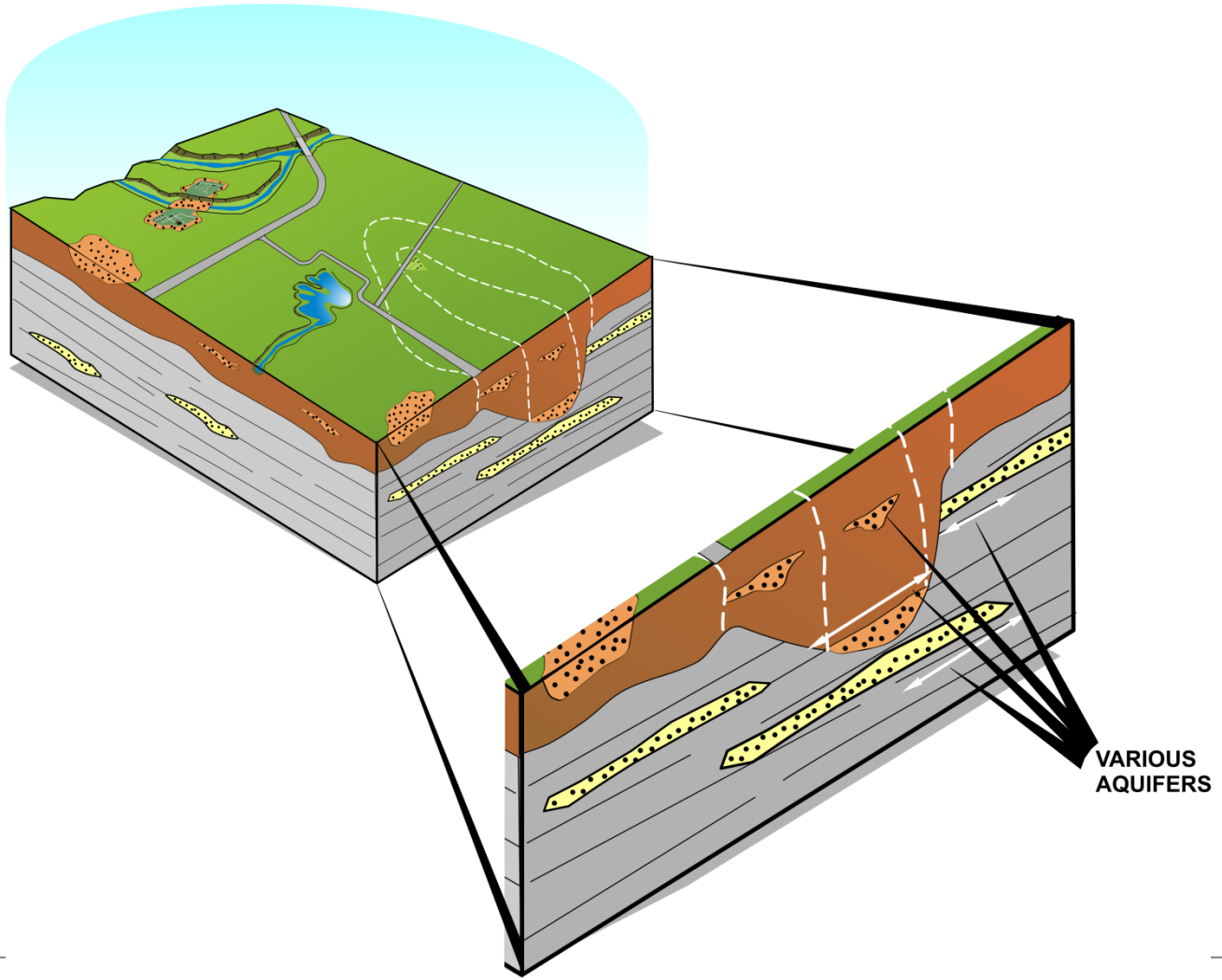

RIVER


sandstone channel forms ridge
spring
spring
piezometric surface
till
sandstone channel body surrounded by mudstone
dominantly mudstone
coalesced sandstone channels
ground water flow

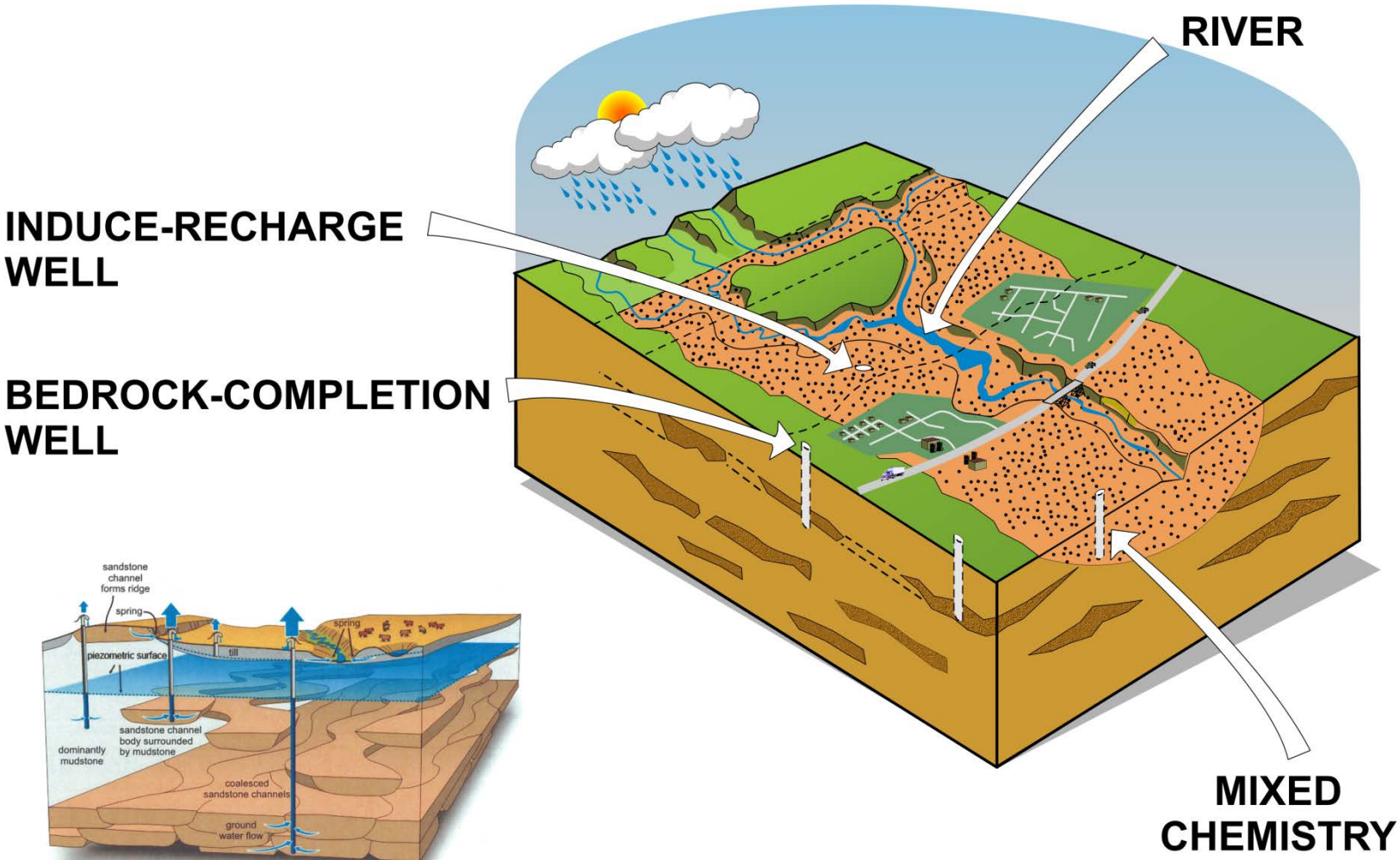
Strong Spatial Variability in Aquifer Occurrence (1)



Strong Spatial Variability in Aquifer Occurrence (2)



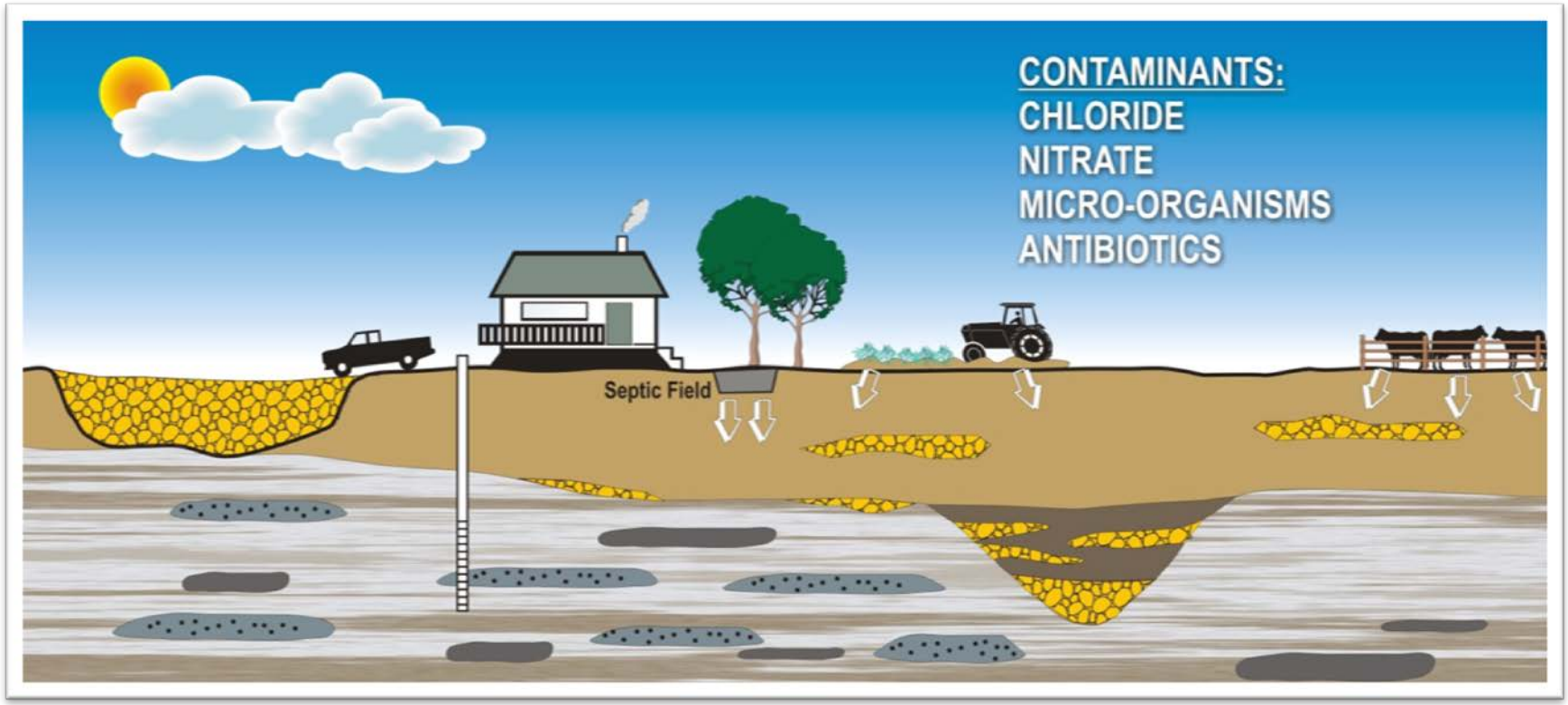
Strong Spatial Variation in Hydrochemistry



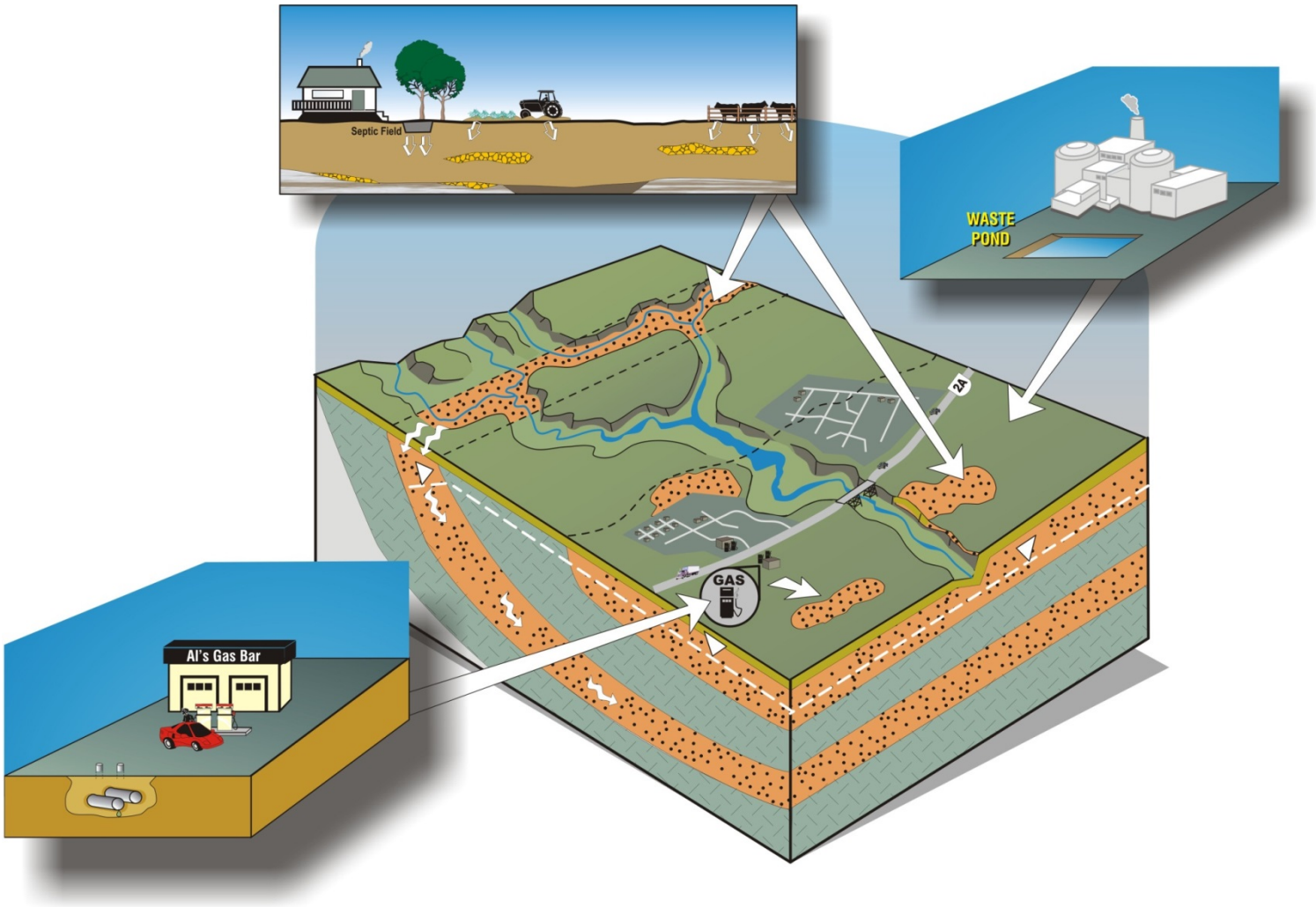
Water Wells, Naturally-occurring Issues

- Dissolved gas
  - Methane
  - H_2S
- Microbial activity
  - SRB and IRB
  - Coliforms
- Inorganic constituents
  - High mineralization
  - Iron and manganese

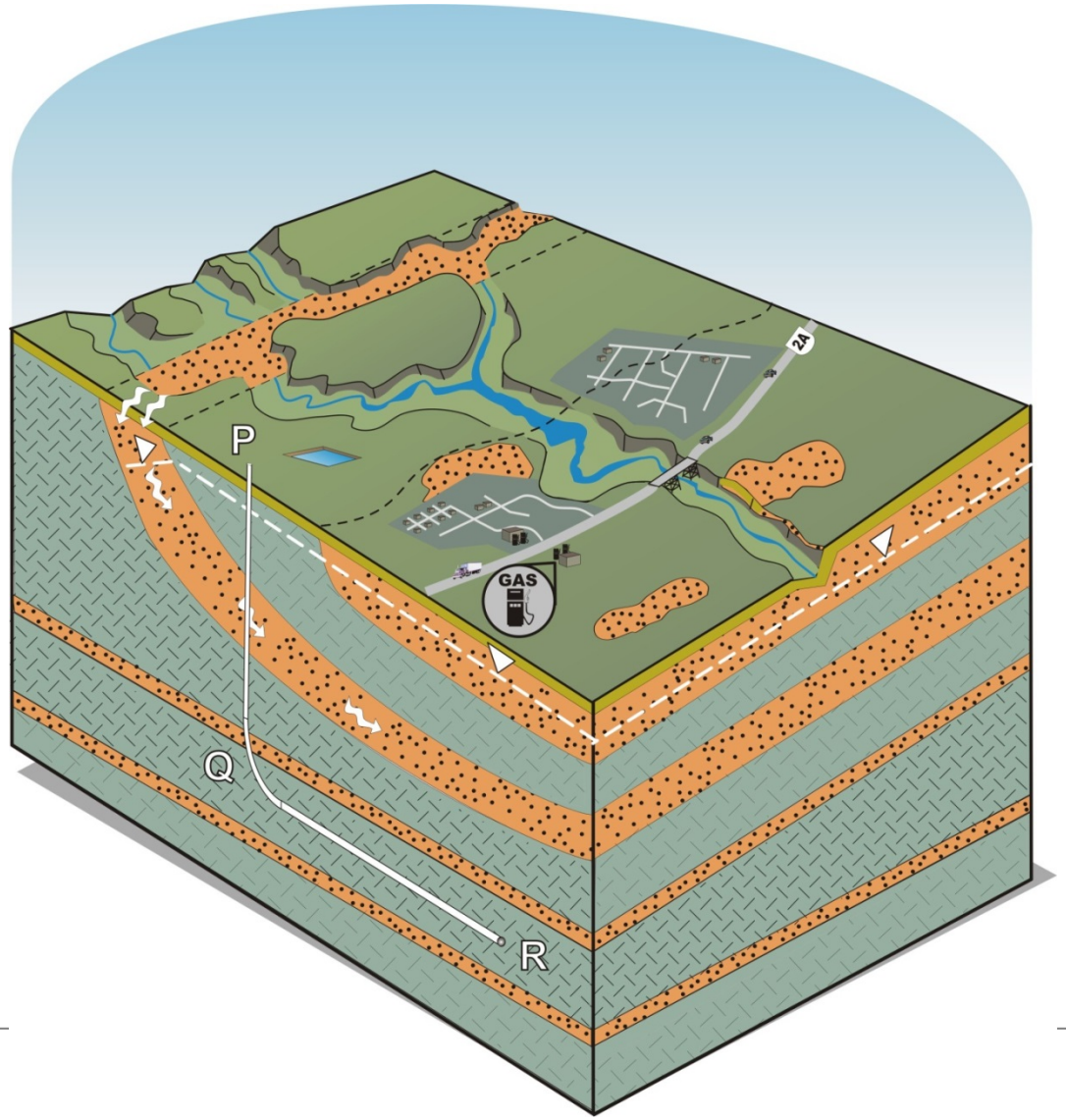
Agriculture & Groundwater Contamination



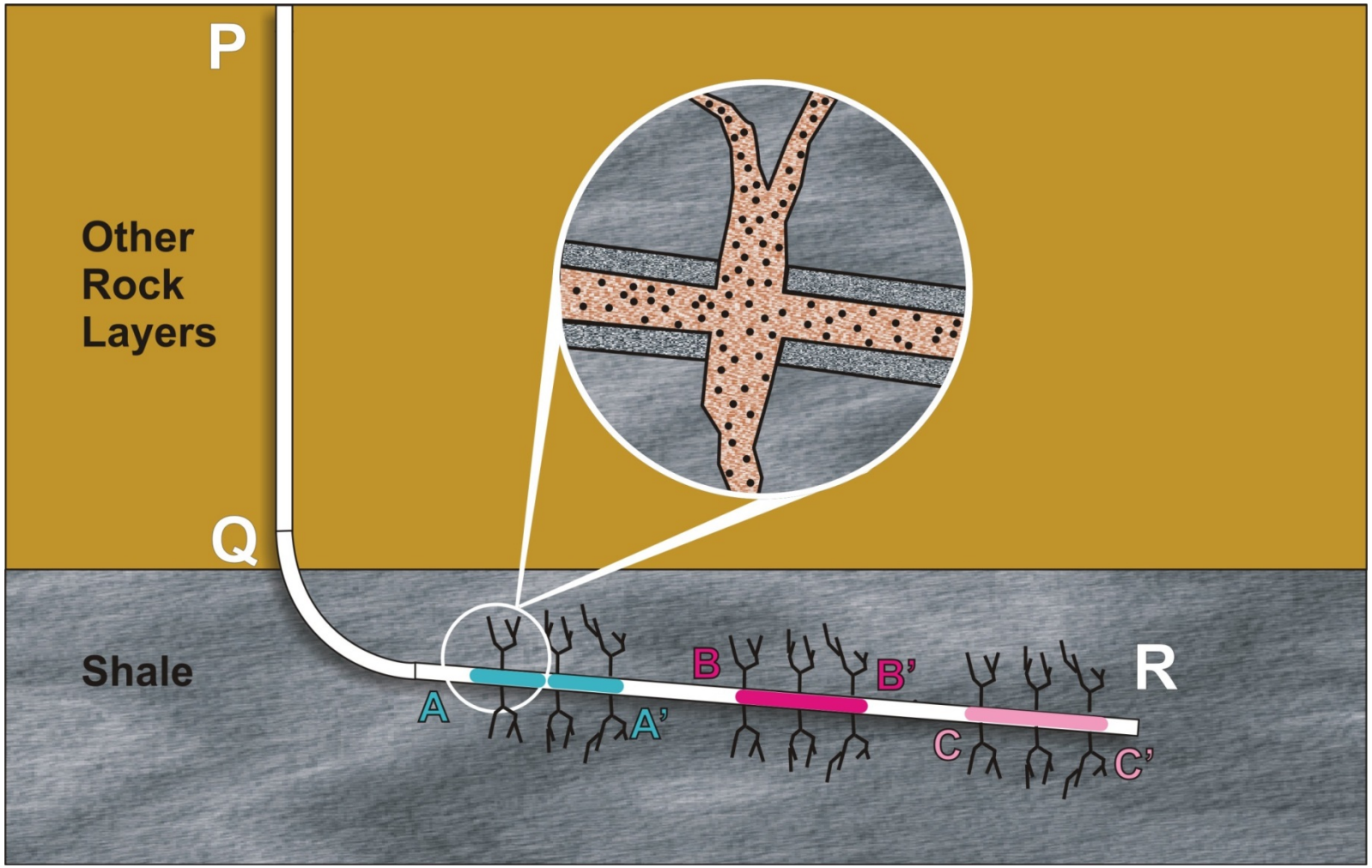
Aquifer Vulnerability



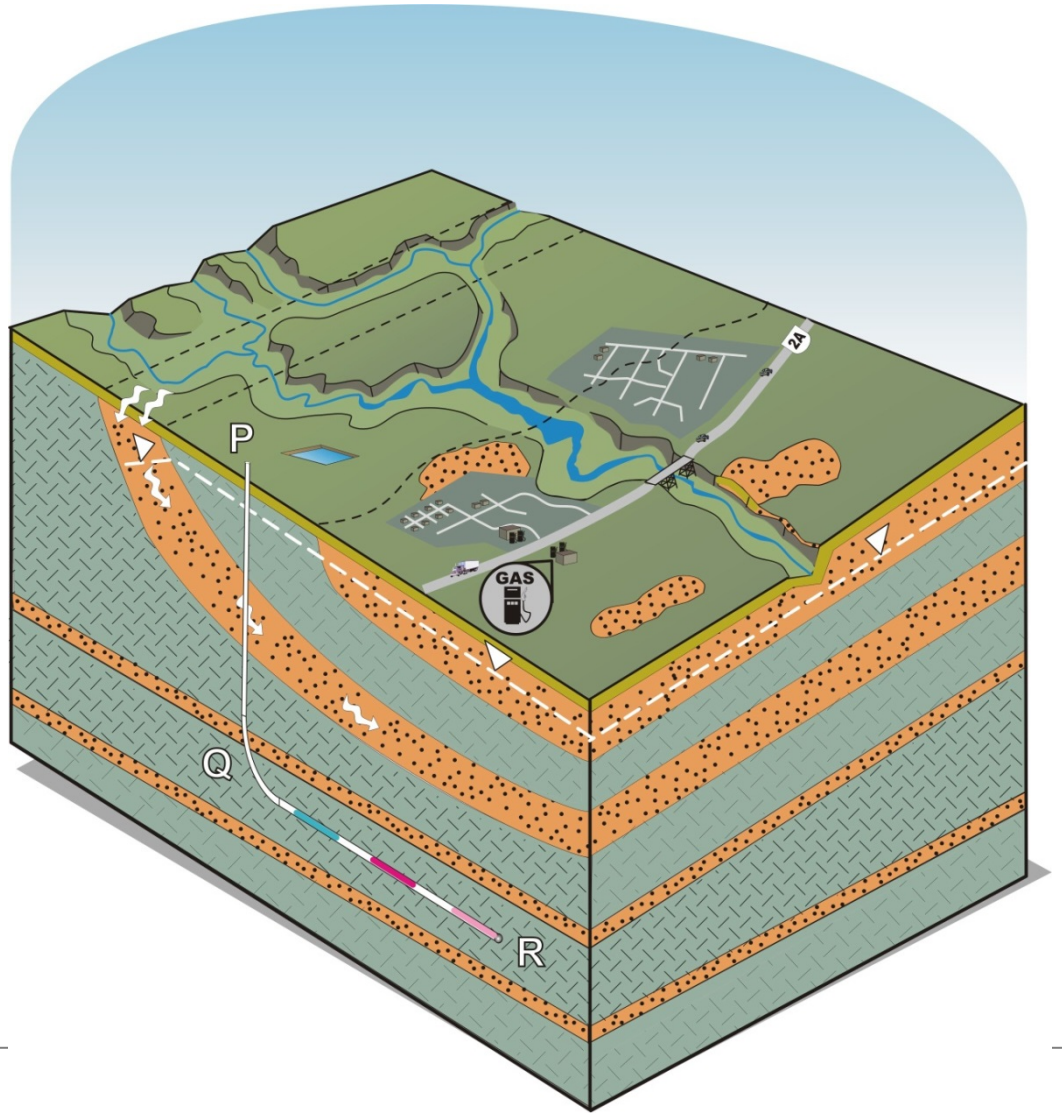
A Conceptual System (1)



Fractures



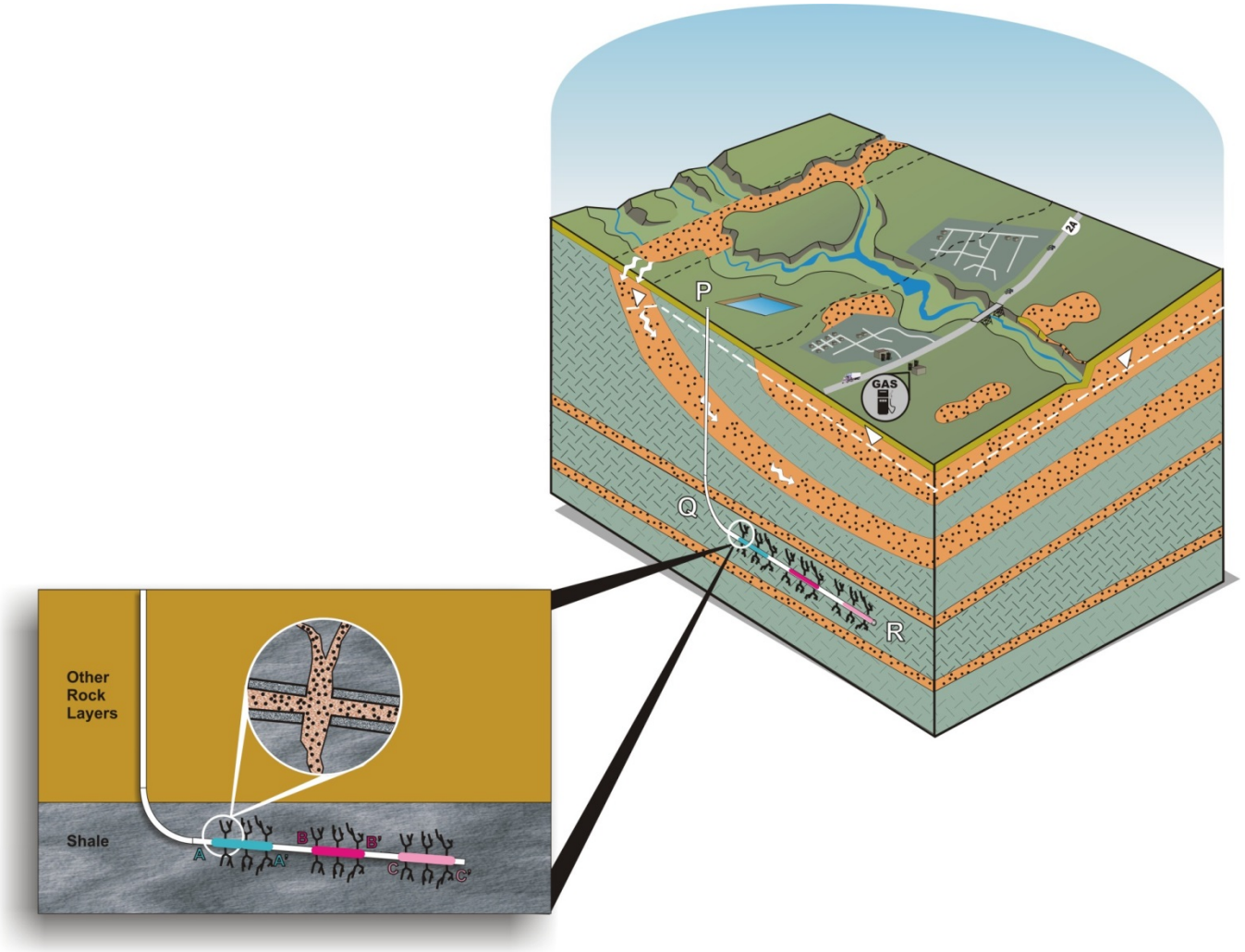
A Conceptual System (2)



Failure Mechanisms: Literature-recognized Potentials

1. Fracture propagation
2. Wastewater control
3. Well bore integrity
4. Induced seismicity
5. NORMs

A Conceptual System (3)



Case History 1

- Baseline: routine and coliforms
- Later, black particulate material reported
  - Particulate: copper, lead, and zinc
  - Water: elevated copper, lead, and zinc
  - BTEX: <D.L.
- Investigation:
  - Routine
  - Trace metals (dissolved)
  - Trace metals (total)
  - Sulphide as H_2S
  - IRB and SRB

Key Results (Case History 1)

Constituent	Well Itself (duplicated)	Household Taps/Tanks
Copper (total)	Low or < DL	Elevated
Copper (dissolved)	Low or < DL	Low or < DL
Lead (total)	< DL	Mostly elevated
Lead (dissolved)	< DL	Mostly < DL
Zinc (total)	< DL	Elevated
Zinc (dissolved)	Low or < DL	< DL

Key Results (Case History 1) – cont'd

Constituent	Well Itself (duplicated)	Household Taps/Tanks
SRB	< DL	< DL
IRB	< DL	< DL or low
H_2S	0.2 mg/L	lower

Case History 2

- Baseline: routine and coliforms
  - Elevated iron, manganese, turbidity
- Later, resident reported:
  - Black particulate material
  - Strong odor
- Follow-up: routine, coliforms, BTEX/F1-F4
  - Elevated iron, manganese, turbidity
- Investigation:
  - Routine
  - Trace metals (dissolved)
  - Trace metals (total)
  - coliforms
  - Sulphide as H_2S
  - IRB and SRB

Key Results (Case History 2)

Parameter	Well Itself (duplicated)	Household Taps
IRB	9,000 CFU/mL	9,000 CFU/mL
H_2S	20 x DL	< DL

Detection Limit, IRB = 25 CFU/mL
Issue threshold, IRB = 2,300 CFU/mL

Conclusions

- Naturally-occurring phenomena
- Compounded by absence of routine maintenance


Thank you.