Hydrogeologic assessment in support of the development of the Peace River Oil Sands

a case study concerning a pilot-scale *in-situ* SAGD operation

Back to previous page

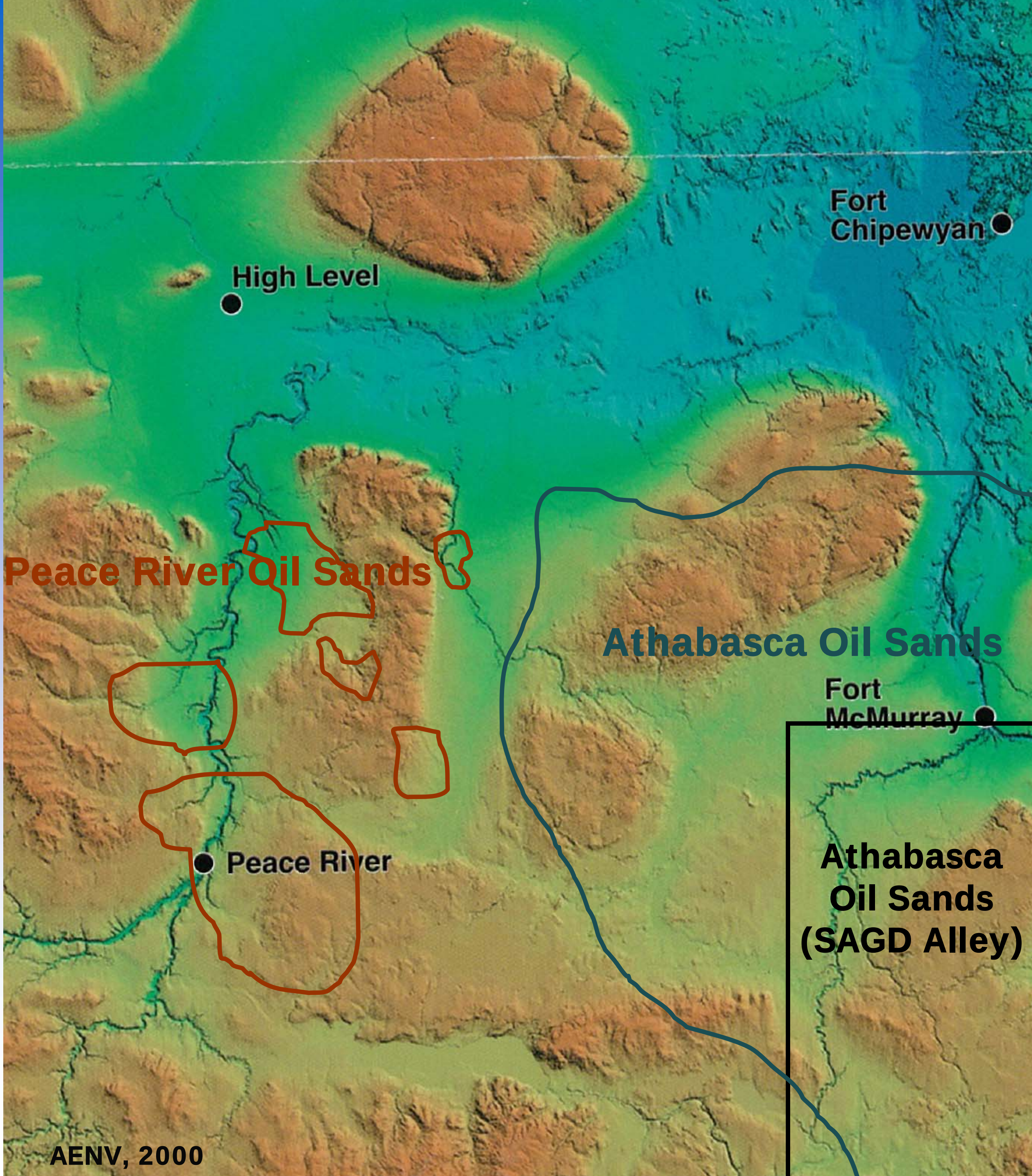
William Wilmot, Matrix Solutions Inc.

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

Objective

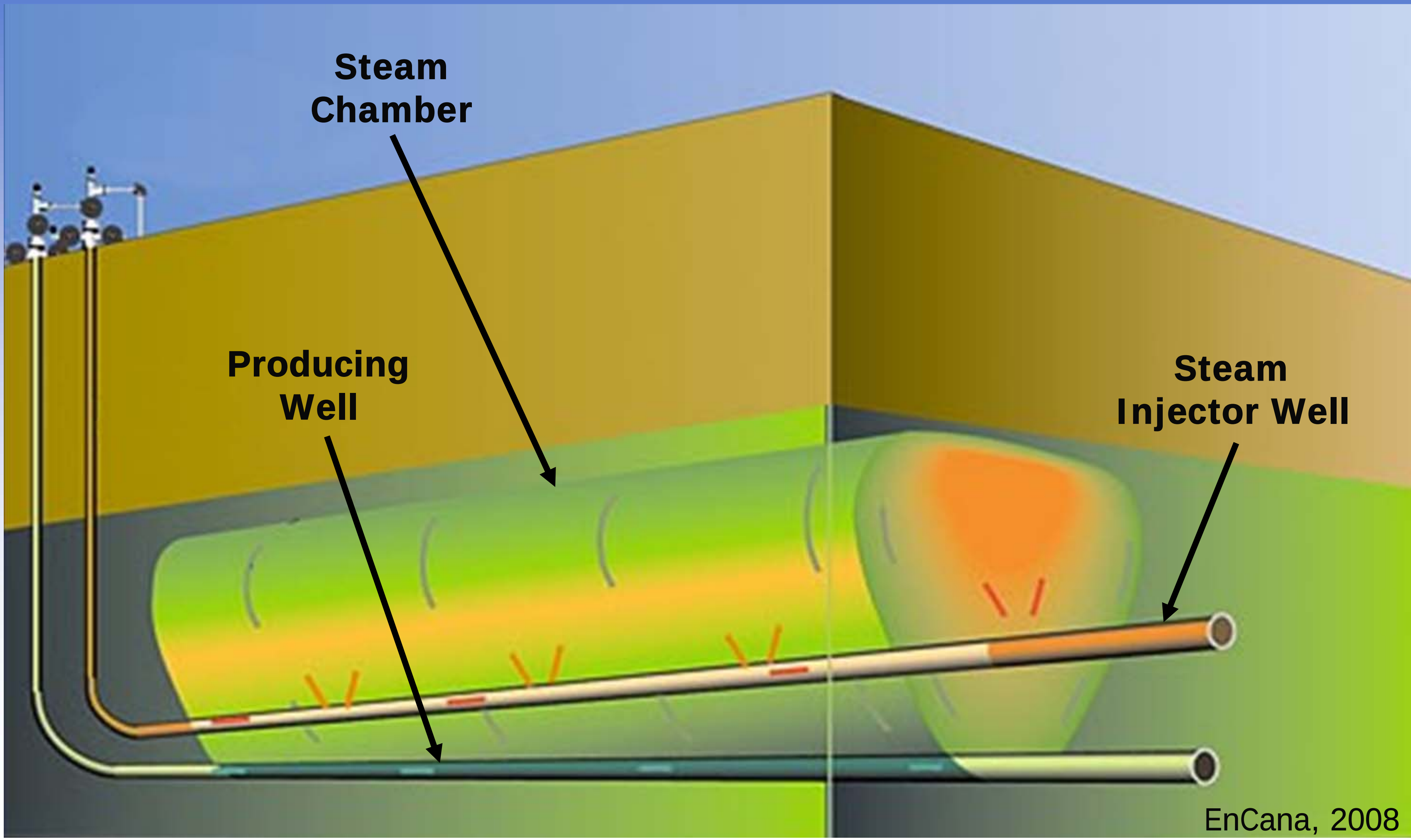
- Create a preliminary hydrogeological characterization in an area where there is limited hydrogeological data
- Use this characterization to identify potential source and disposal aquifers to test for SAGD development

Oil Sands

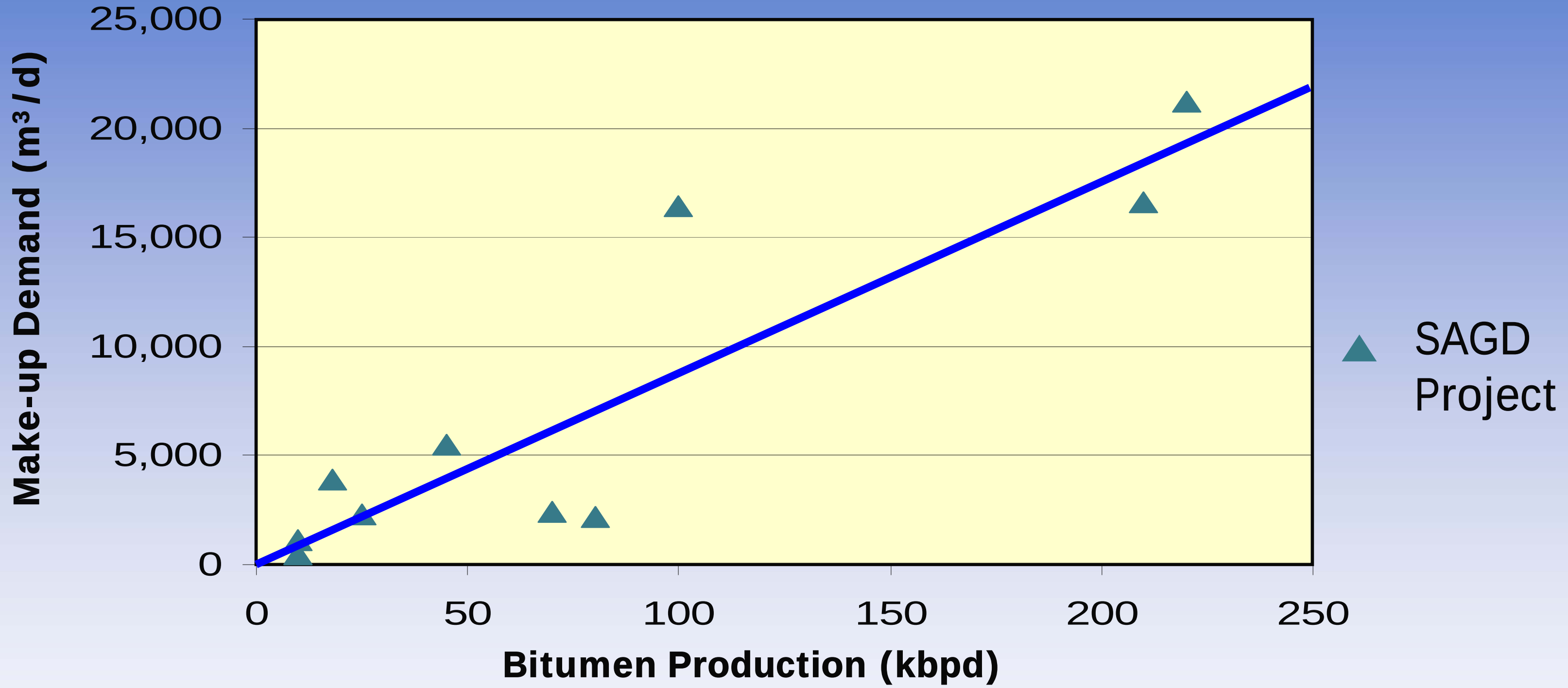


50 km

Steam Assisted Gravity Drainage (SAGD)



SAGD Water Demand (SAGD Alley)



- Make-up dependent on RR, process efficiency, upgrading, ZLD, etc...
- SAGD produces wastewater ≈ make-up water demand
- Need to test and secure aquifers

Criteria for Selecting Aquifers to Test

Salinity

- Disposal (>4,000 mg/L Total Dissolved Solids)
- Source (4,000 mg/L < TDS <10,000 mg/L)

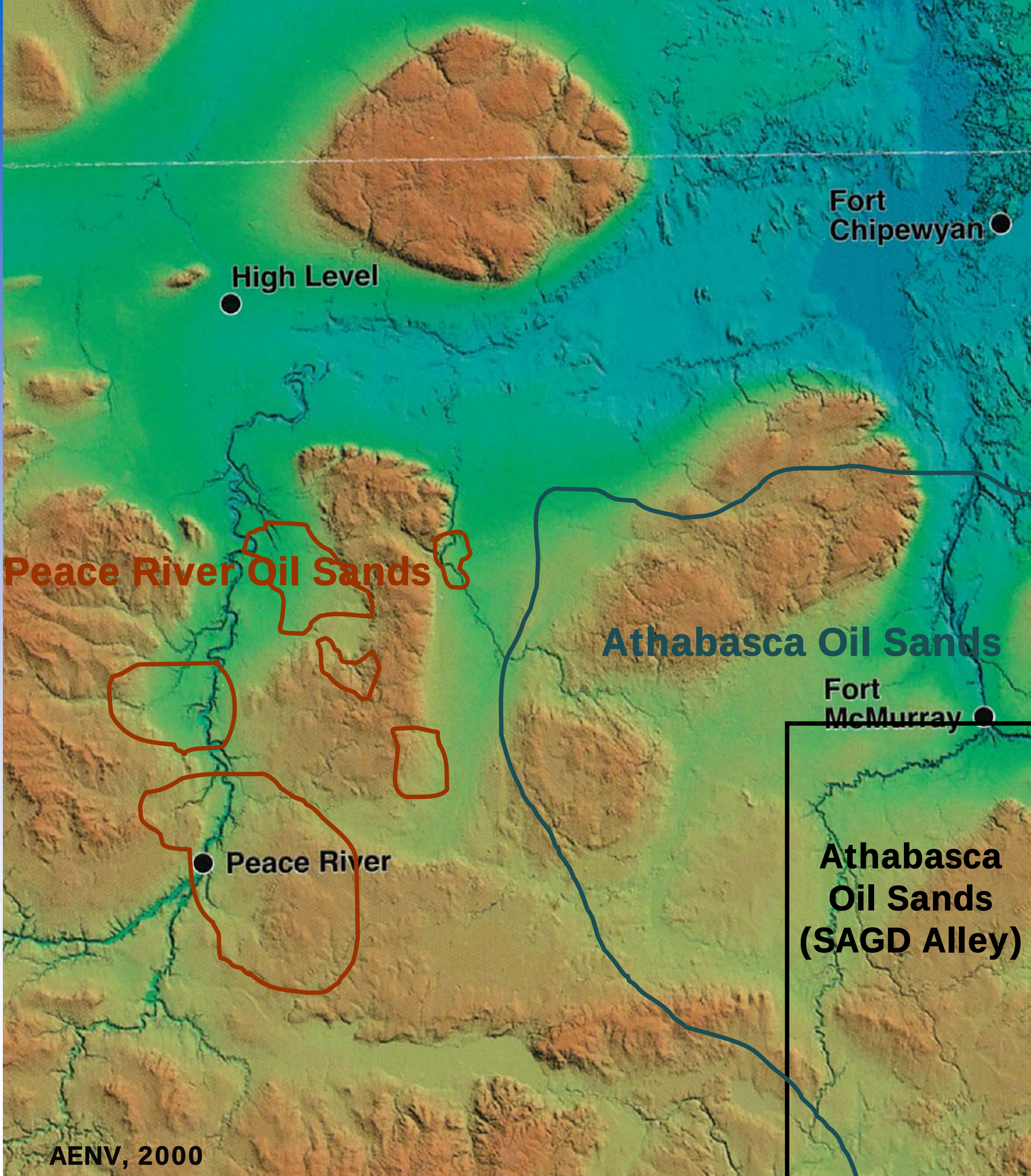
Productivity

- Aquifer extent/thickness
- Aquifer permeability
- Acceptable pressure change

Responsible Use

- Conflicts with other groundwater users
- Potential environmental impacts

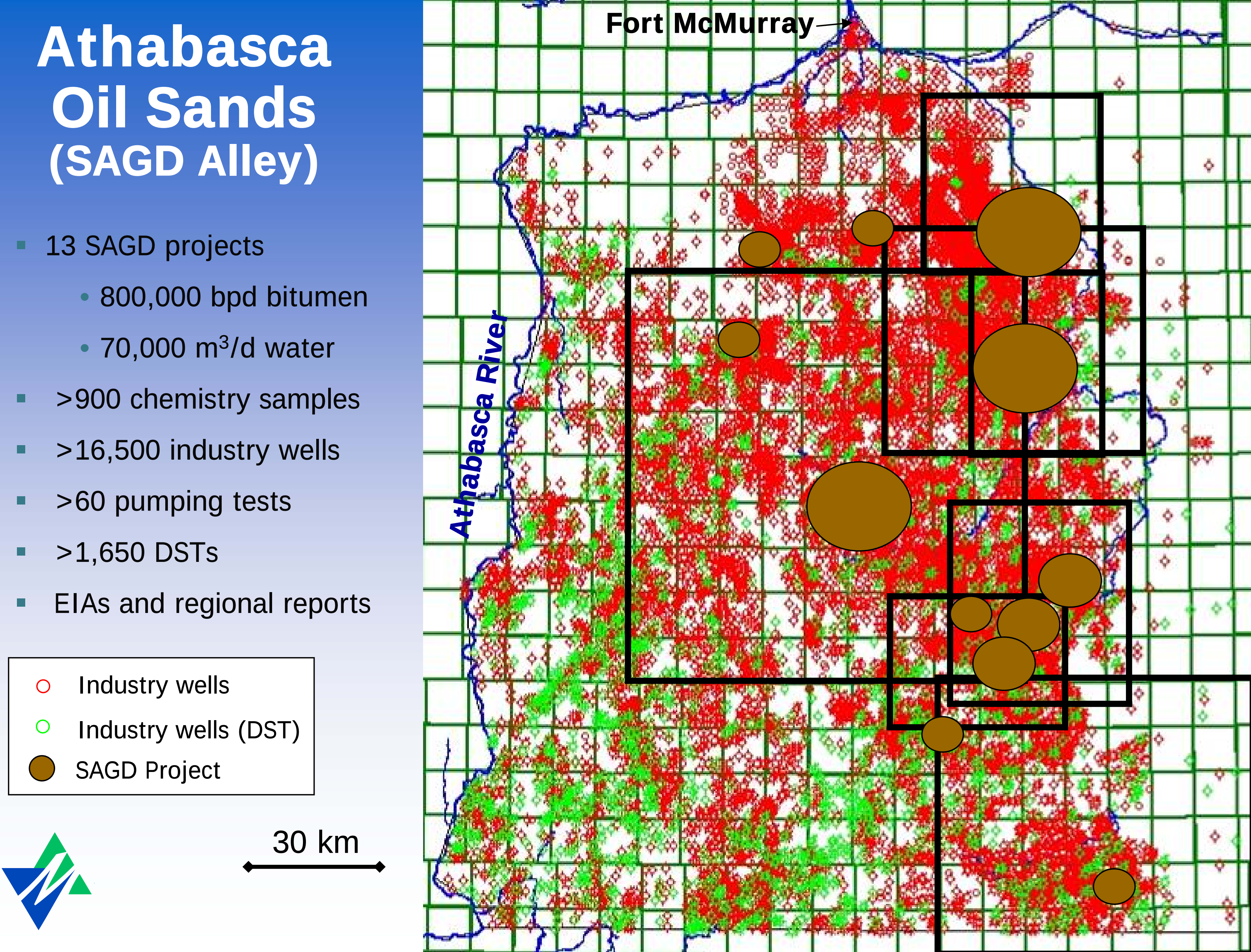
Oil Sands



50 km

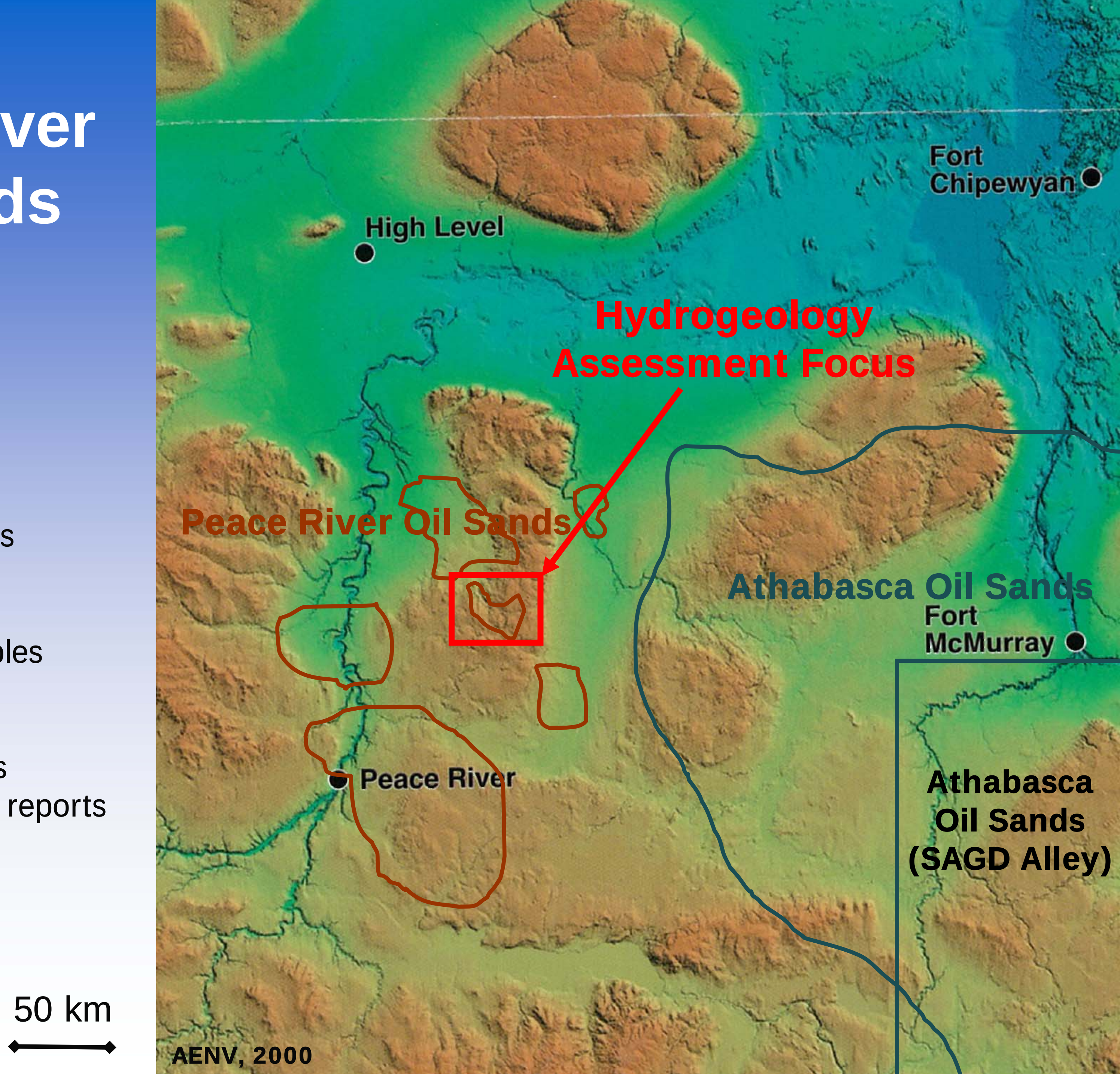
Athabasca Oil Sands (SAGD Alley)

- 13 SAGD projects
  - 800,000 bpd bitumen
  - 70,000 m^3/d water
- >900 chemistry samples
- >16,500 industry wells
- >60 pumping tests
- >1,650 DSTs
- EIAs and regional reports



Peace River Oil Sands

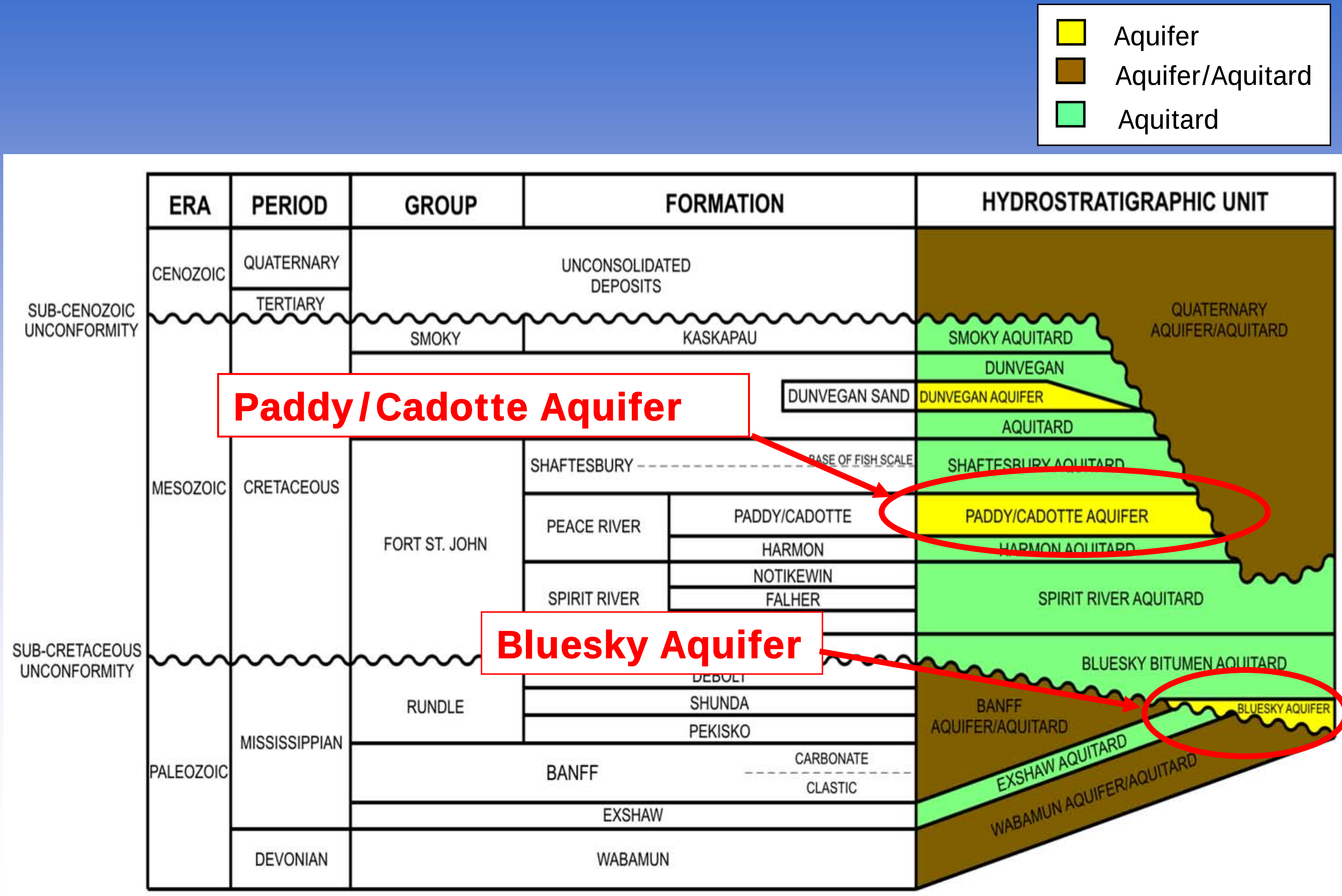
- ✓ 143 industry wells
- ✓ 68 not cased
- ✓ 2 DSTs
- ✓ 3 chemistry samples
- ✓ 8 core
- ✓ 0 pumping tests
- ✓ 0 SAGD operators
- ✓ Regional geology reports



The Issue

- Drilling and testing deep aquifers is expensive!
- How do we identify these target aquifers with limited data?

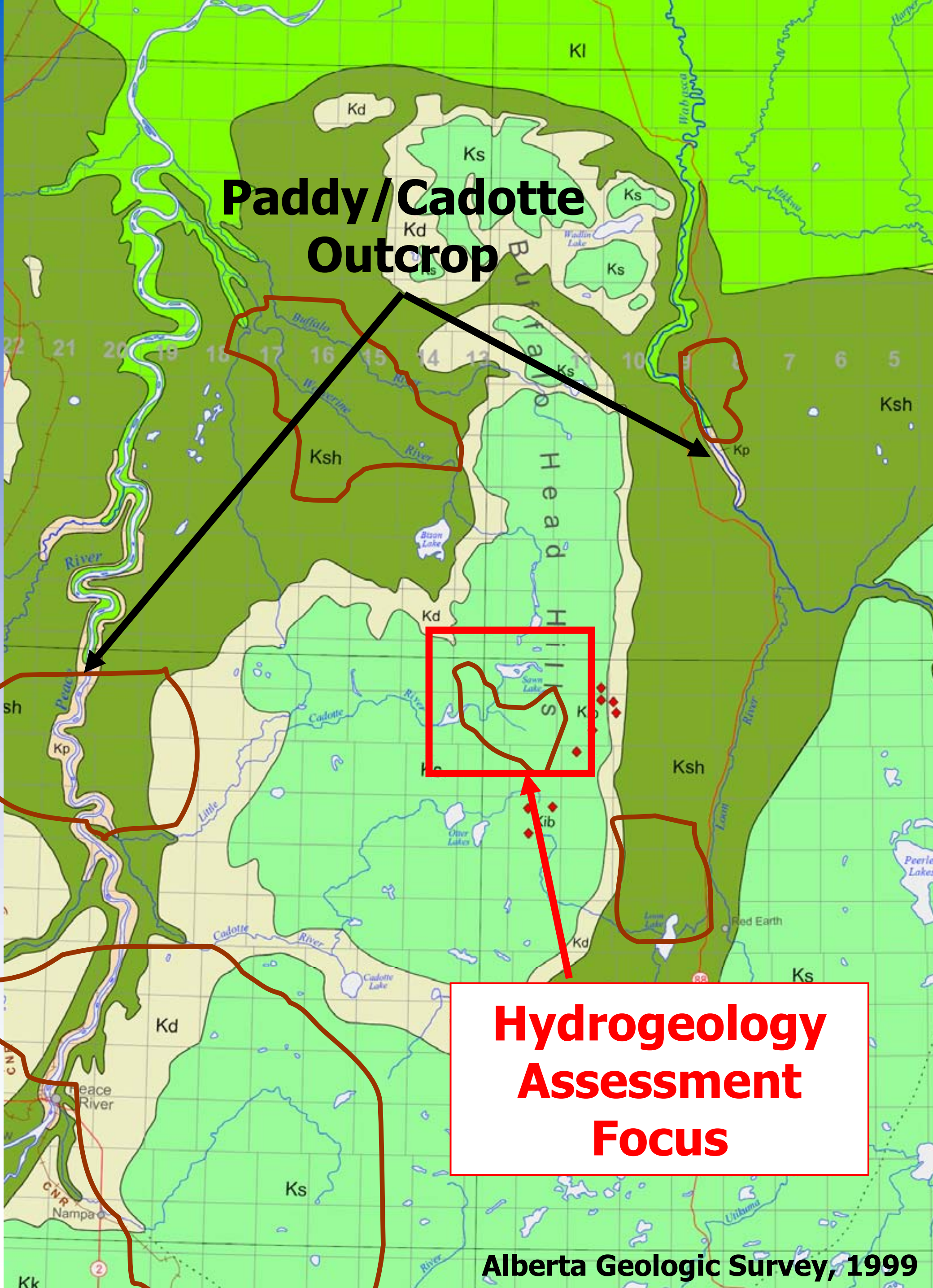
Hydrostratigraphic Column



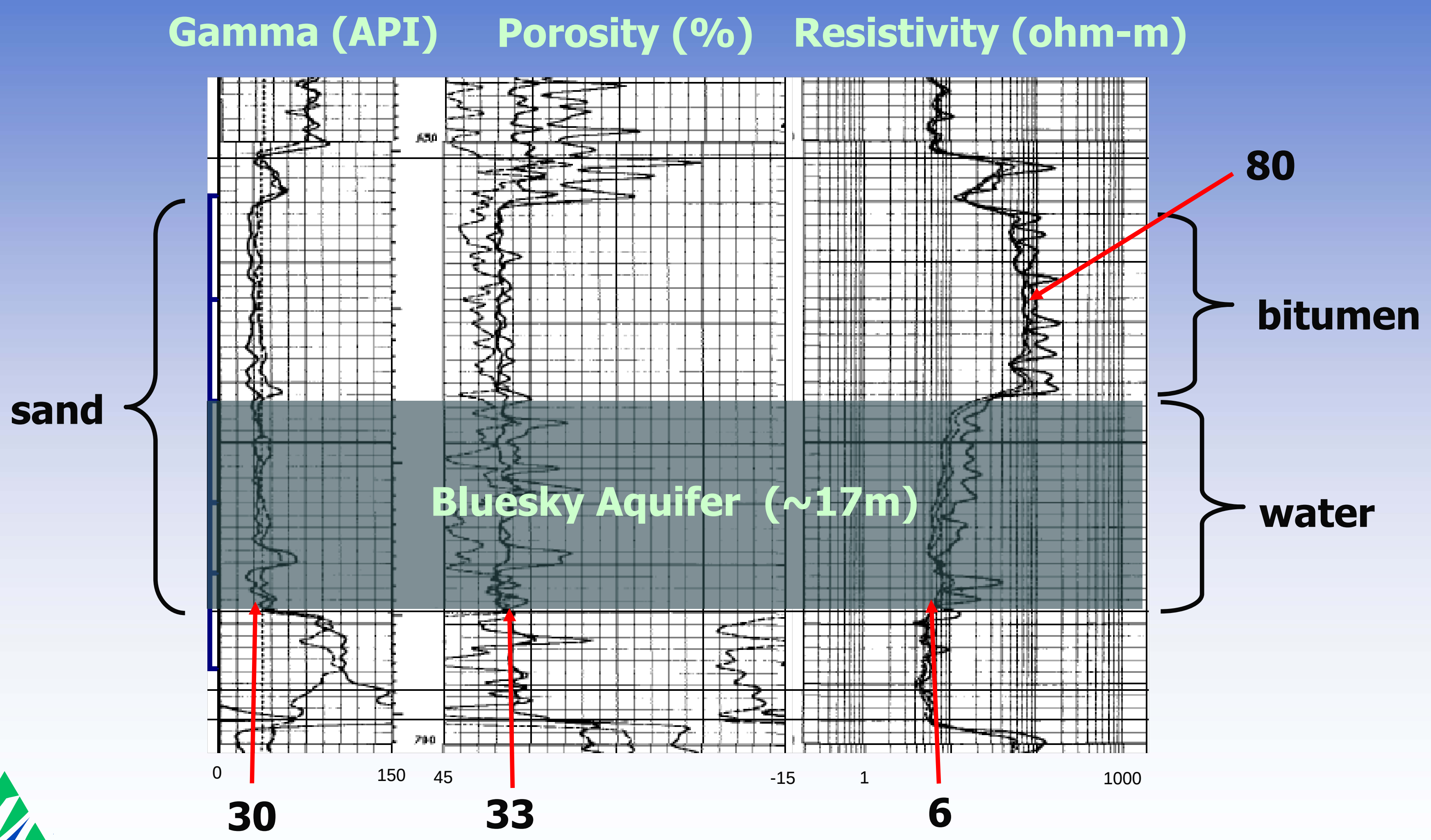
Geologic Subcrop Map

—	Peace River Oil Sands
■	Smoky Aquitard
■	Dunvegan Aquifer
■	Shaftesbury Aquitard
■	Paddy/Cadotte Aquifer
■	Spirit River Aquitard

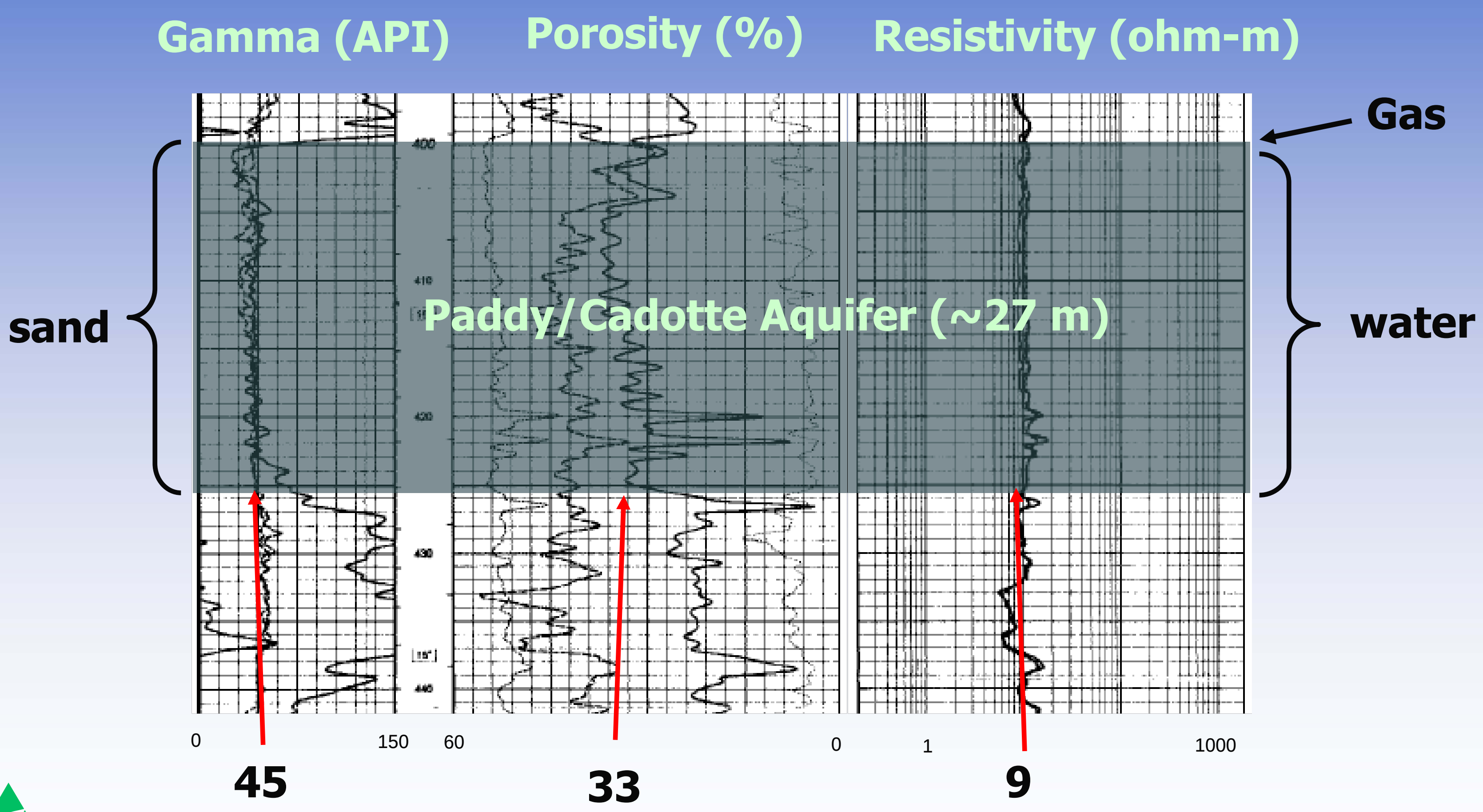
30 km



Petrophysical Type Log Bluesky Aquifer



Petrophysical Type Log
Paddy/Cadotte Aquifer



Aquifer Salinity Methodology

- Only 3 chemistry samples (Bluesky)
- 68 uncased well logs with deep resistivity measurements
- These resistivity measurements can provide estimate of salinity

[Equation 1 - calculate resistivity of the brine (Archie, 1959)]

$$R_t = a\phi^{-m} S_w^{-n} R_w$$

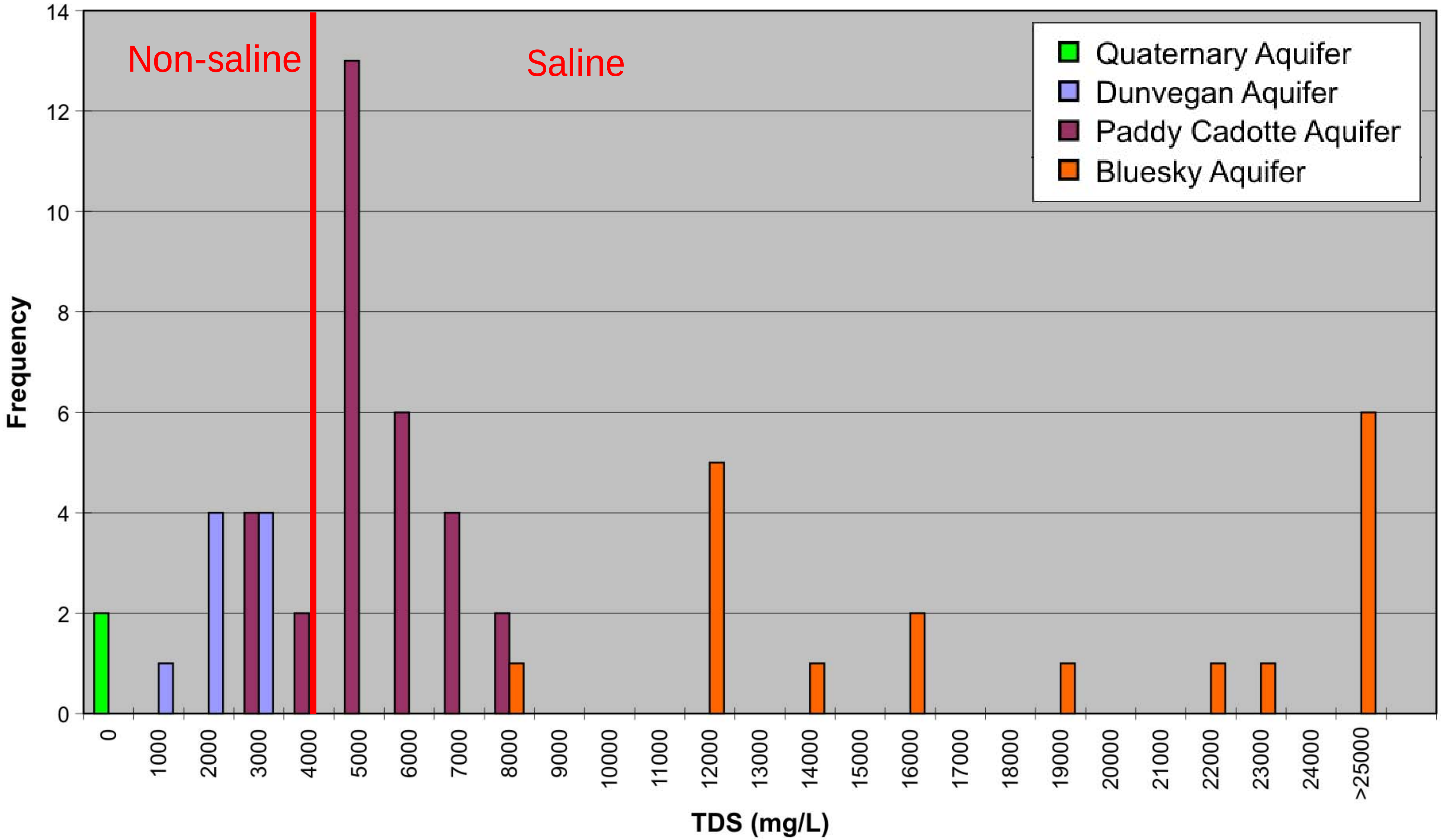
Where:

ϕ	Porosity
R_t	Resistivity of the fluid saturated rock (deep resistivity from logs)
R_w	Resistivity of the brine (Aquifer)
S_w	Brine saturation (1)
m	Cementation exponent of the rock (usually in the range 1.8–2.0)
n	Saturation exponent (usually close to 2)
a	Constant (1)

[Equation 2 – calculate TDS (Rakhit, 1997)]

$$R_w = TDS^{-0.854387} \times 4.51686$$

Aquifer Salinity Estimate



Will Productivity be Sufficient?

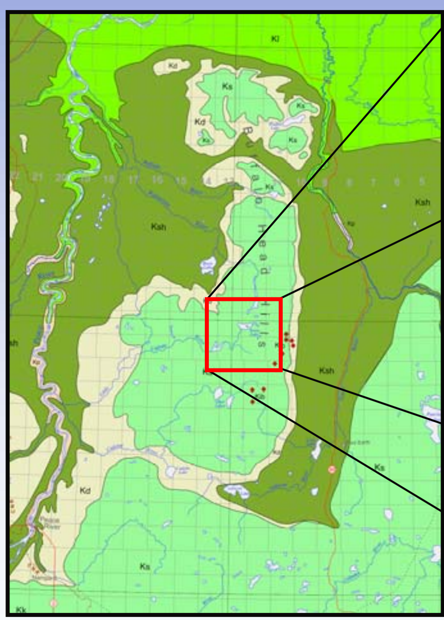
- Productivity is constrained by 3 parameters
  - Aquifer extent/thickness
  - Aquifer permeability
  - Acceptable pressure change

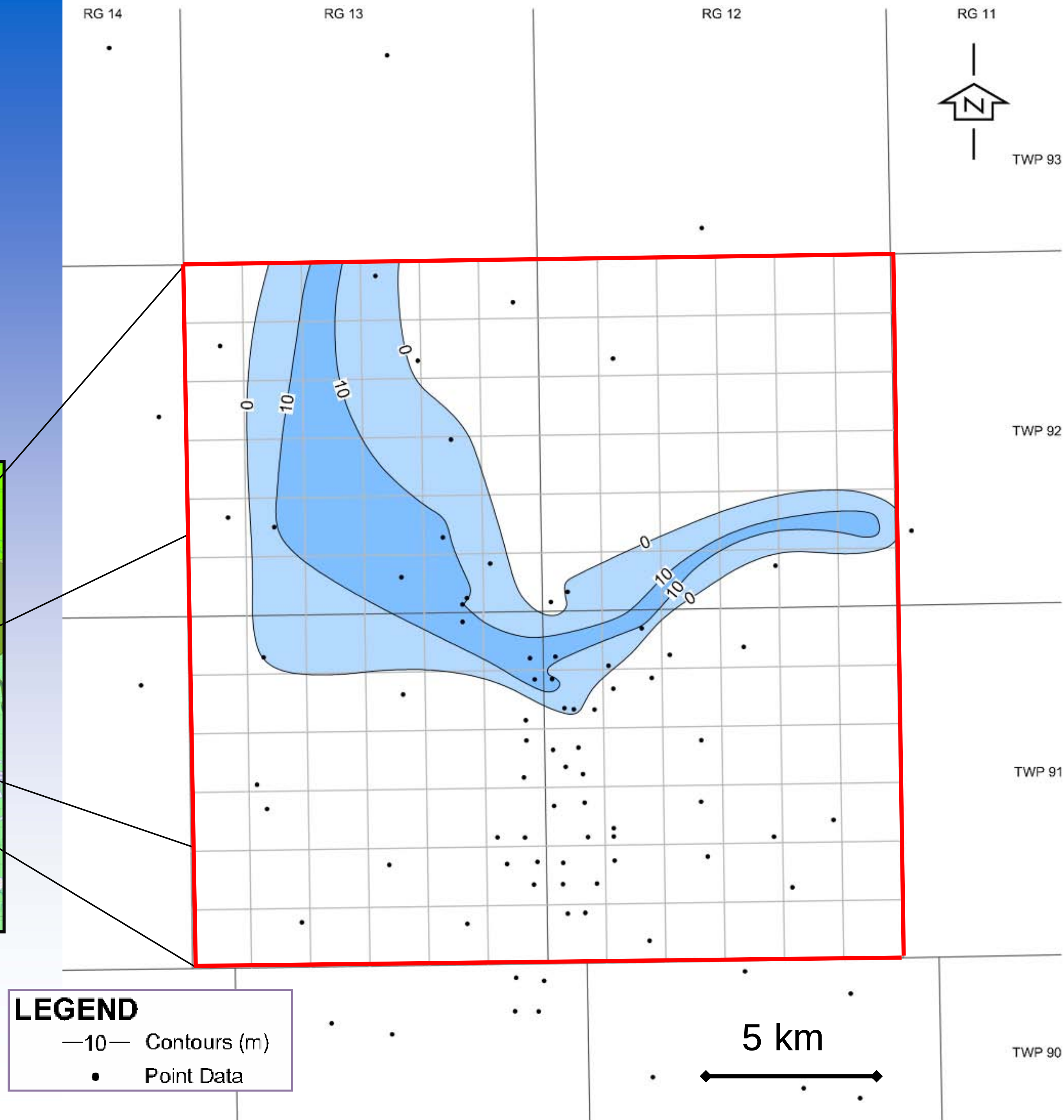
Aquifer Productivity Methodology

- Aquifer extent/thickness
  - Map aquifers using 143 well logs
- Aquifer permeability
  - No pumping tests, therefore, estimate permeability of both aquifers referencing 8 Bluesky cores analysis
- Acceptable pressure change
  - Only 2 Bluesky DSTs to estimate aquifer pressure in both aquifers

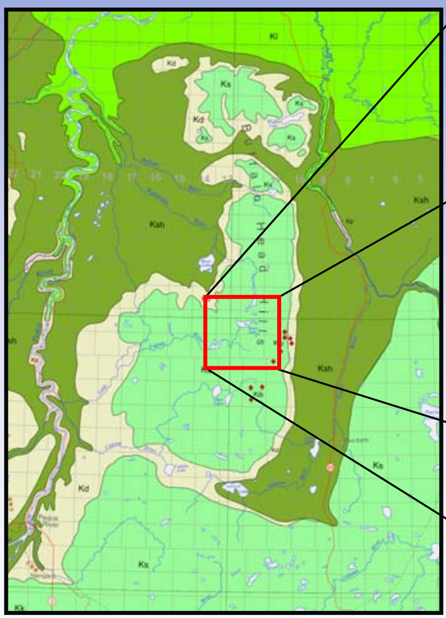
Bluesky Aquifer Isopach

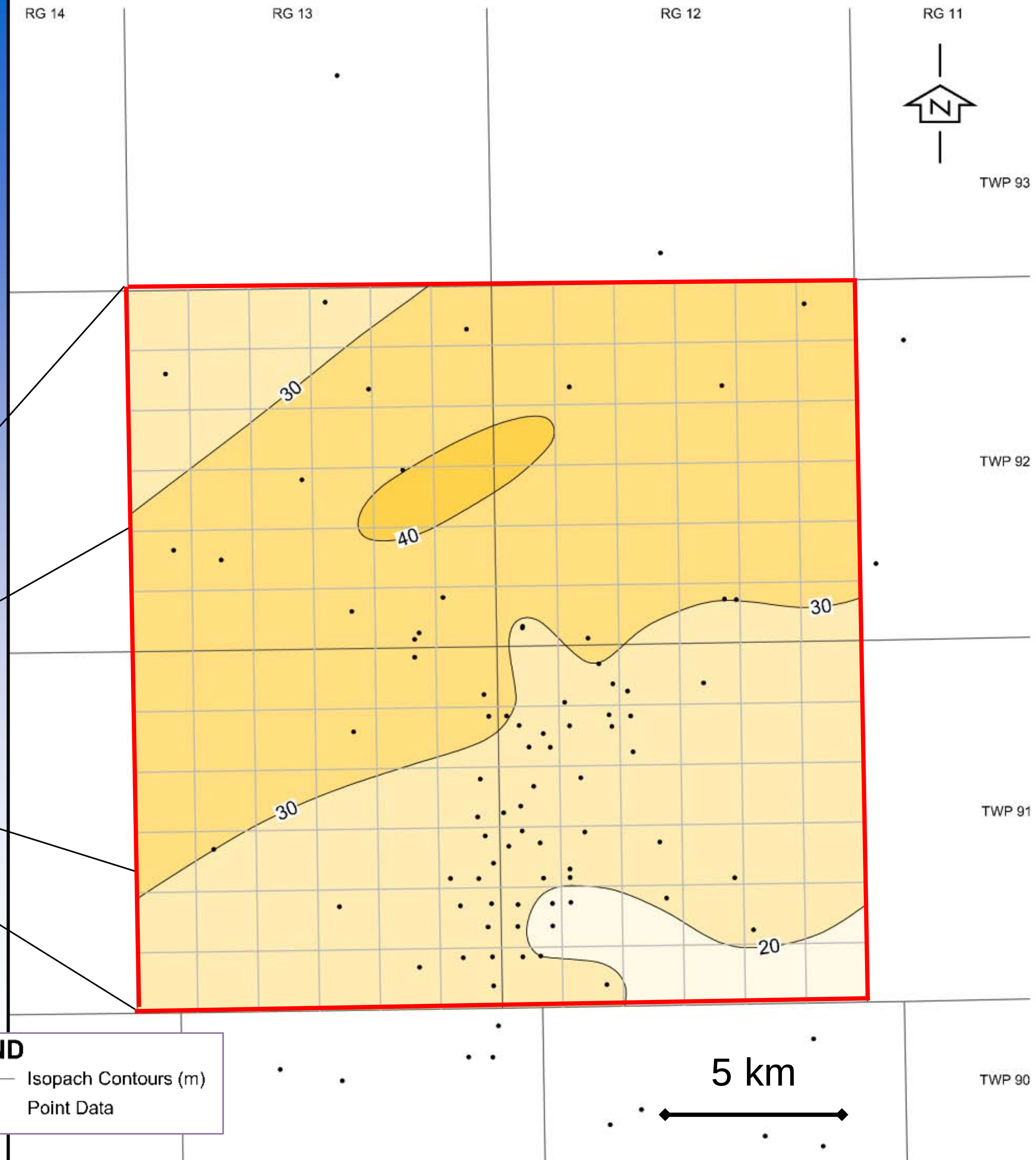
(mapping results)





Paddy/Cadotte Aquifer Isopach
(mapping Results)

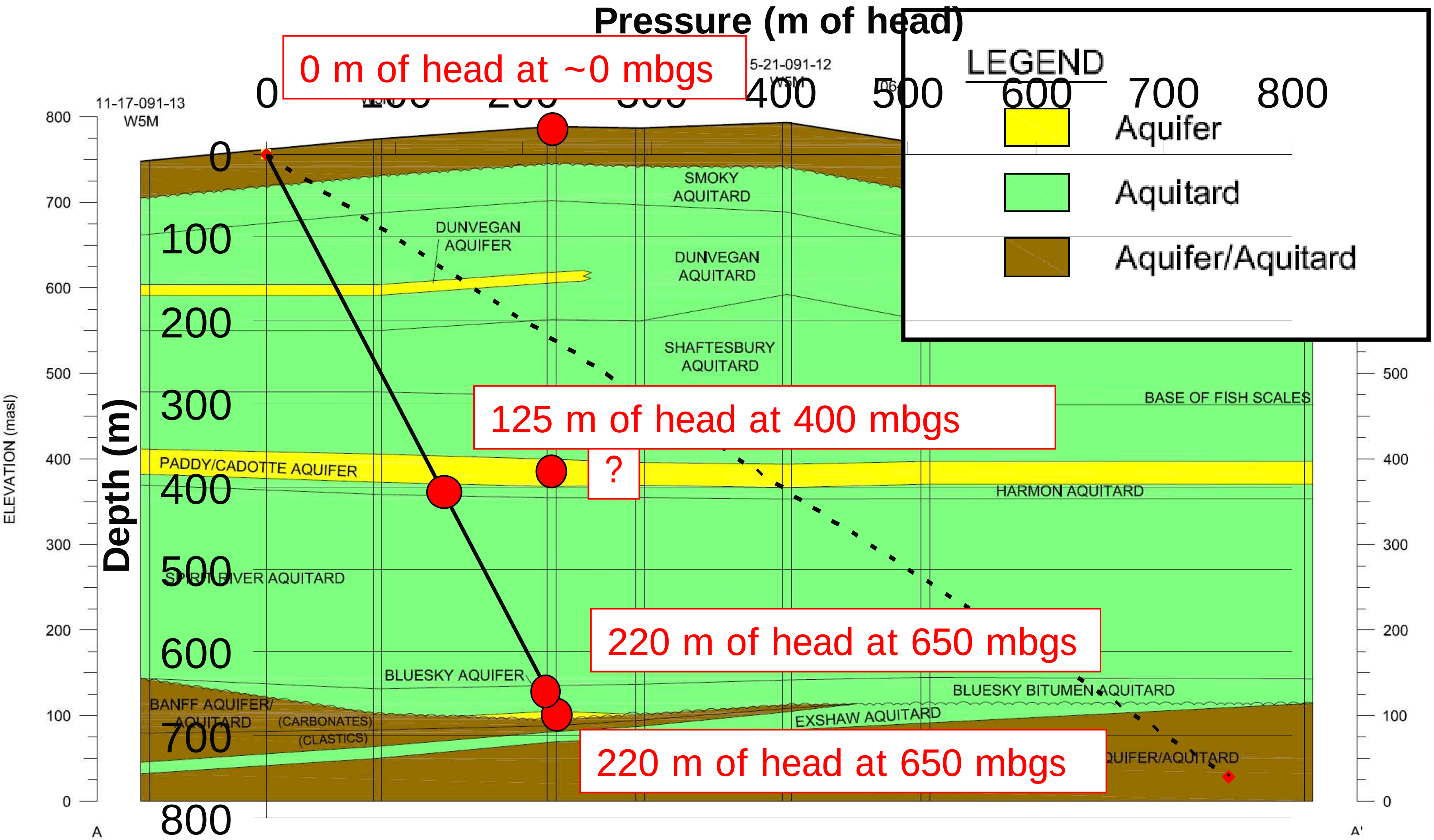




Aquifer Permeability Estimate

- Bluesky
  - Core analysis (4 to 10 D)
  - Gamma <45 API, Porosity >30%
  - Very clean sand
- Paddy/Cadotte
  - Gamma <45 API, Porosity >30%
  - Very clean sand
  - Assumption – Paddy/Cadotte ≈ Bluesky
- Best Guess
  - Bluesky 5D and Paddy/Cadotte 2D
  - Conservative 1D (used for calculations)

Available Head Estimate



Conservative estimate for available head is 100 m and 200 m for the Paddy/Cadotte and Bluesky aquifers, respectively

Paddy/Cadotte Aquifer Productivity

- Given;
  - Aquifer thickness *(b)* ≈ 25 m
  - Hydraulic conductivity *(K)* ≈ $1x10^{-5}$m/s (1D)
  - Available Head *(AH)* ≈ 100 m

[Equation 3 – calculate yield of well Farvolden (1959) Method]

$$\boxed{Q_{20} = (0.68)(Kb)(AH)(0.7)}$$

Q_{20} ≈ 1,000 m^3/day

Bluesky Aquifer Productivity

- We know the Bluesky Aquifer is permeable
- Acceptable pressure change is constrained by fracture pressure
- ERCB Directive 051 suggests a pressure head build-up of 800 m (8,000 kPa) is acceptable in this aquifer

Responsible Use of Aquifers?

- Both aquifers are deep and saline
- Very thick aquitards mitigate vertical pressure propogation
- No other users of aquifers in area (no conflicts)
- Using Theis (1935) we can estimate drawdown at Paddy/Cadotte subcrop

[Equations 4 and 5 – calculate drawdown Theis (1935)]

$$dd = \frac{Q}{4\pi Kb} W(u) \qquad u = \left\{ \frac{r^2 Ssb}{4Kbt} \right\}$$

Where:

dd	drawdown (m)	*b*	aquifer thickness (25 m)
W	well function	*r*	radius (40 km)
Q	pumping rate (1,000 m^3/day)	*Ss*	specific storage (1×10^{-6} m^{-1})
K	conductivity (0.9 m/day)	*t*	time (5 years)

- Negligible (<1 mm) drawdown at Paddy/Cadotte Aquifer subcrop

Conclusion

Absence of traditional hydrogeological data →

Industry data

- Petrophysical logs
- Core samples
- Drill stem tests

+

Conceptual understanding of hydrogeological system

=

Recommendation for SAGD project

- Testing the Bluesky as a wastewater disposal aquifer
- Testing the Paddy/Cadotte as a source aquifer