Environmental Quality Over CO_2 Injection Sites

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CALIFORNIA AIR RESOURCES BOARD
CCS TECHNICAL DISCUSSION SERIES:
WELL MECHANICAL INTEGRITY,
MAY 12, 2016

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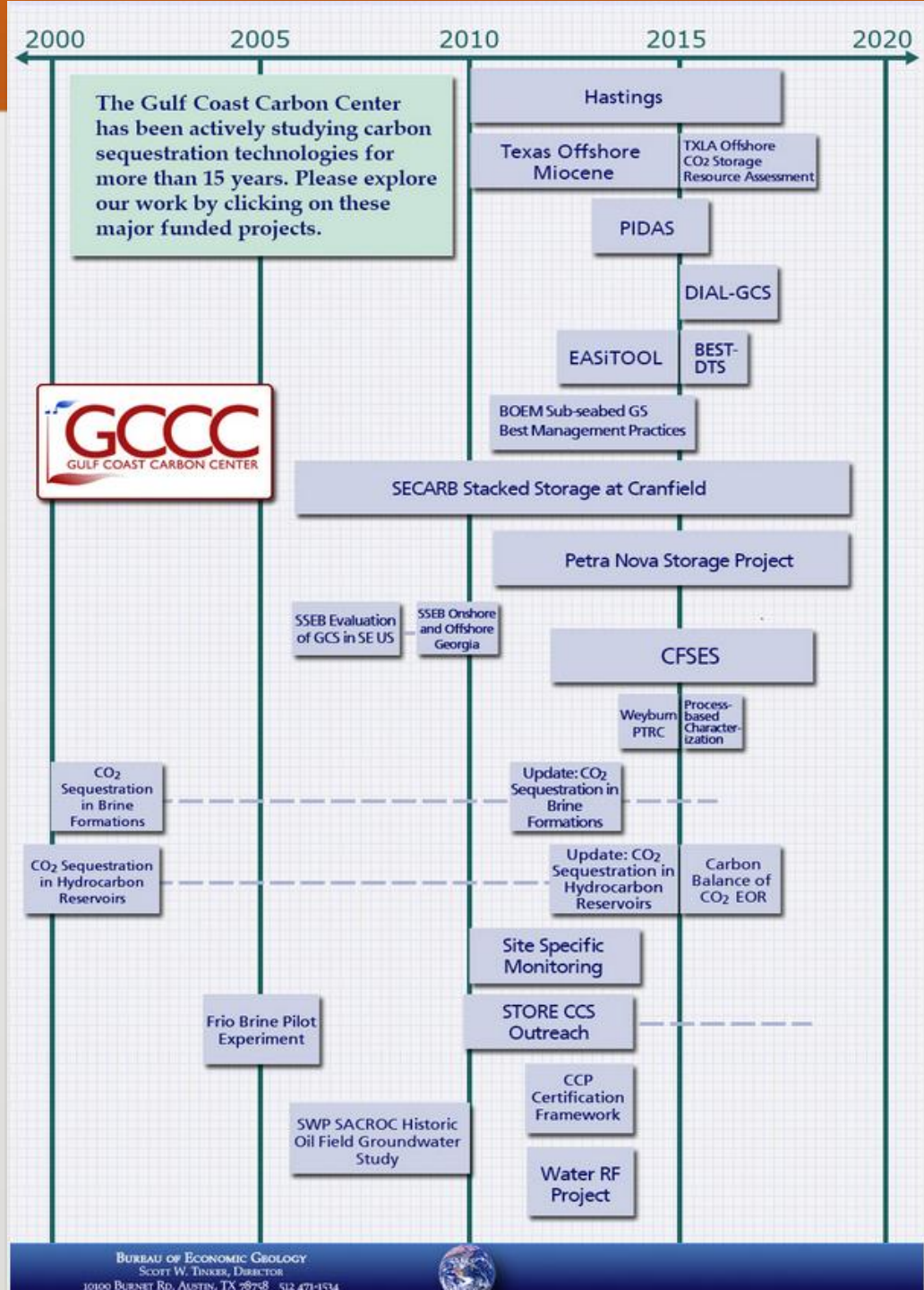
GCCC GULF COAST CARBON CENTER

The Gulf Coast Carbon Center has been conducting research on all aspects geologic CO_2 storage for over 15 years.



Talk Outline

- Scientific approach to understanding environmental impacts.
- Groundwater: SACROC Oilfield
- Soil Gas: Cranfield Oilfield
- Public Claims of leakage: Weyburn Oilfield
- Summary Points

Science Addressing Environmental Concerns

- Controlled Releases/Injections
  - Demonstration Project Deep Injection
  - Shallow Controlled Releases
- Laboratory Simulations
- Numerical Modeling
- Natural CO_2-rich Analogs
- Industrial Analogs

Potential Impacts of Concern

CO_2

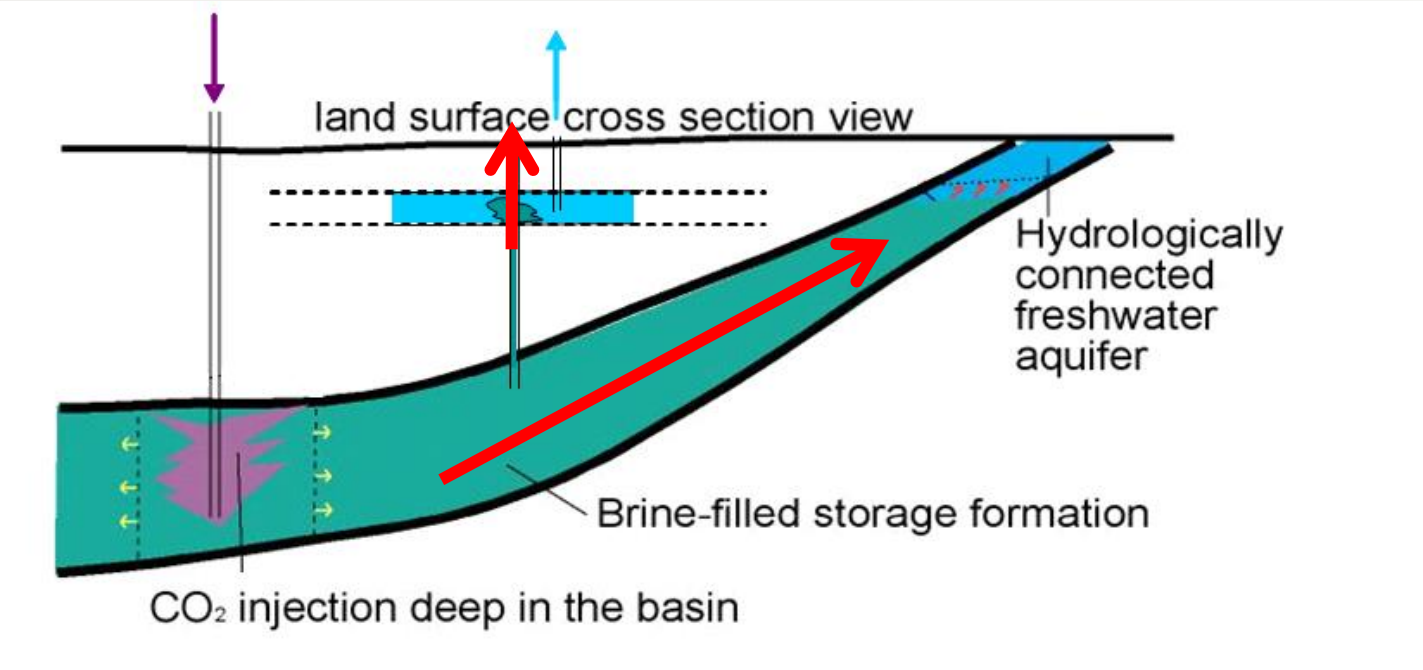
- pH decrease
- Mobilization of heavy metals
  - Mineral dissolution
  - Detachment of metals from grain surfaces

Brine

- Organics, injection impurities, total dissolved solids

Brine Migration Pathways

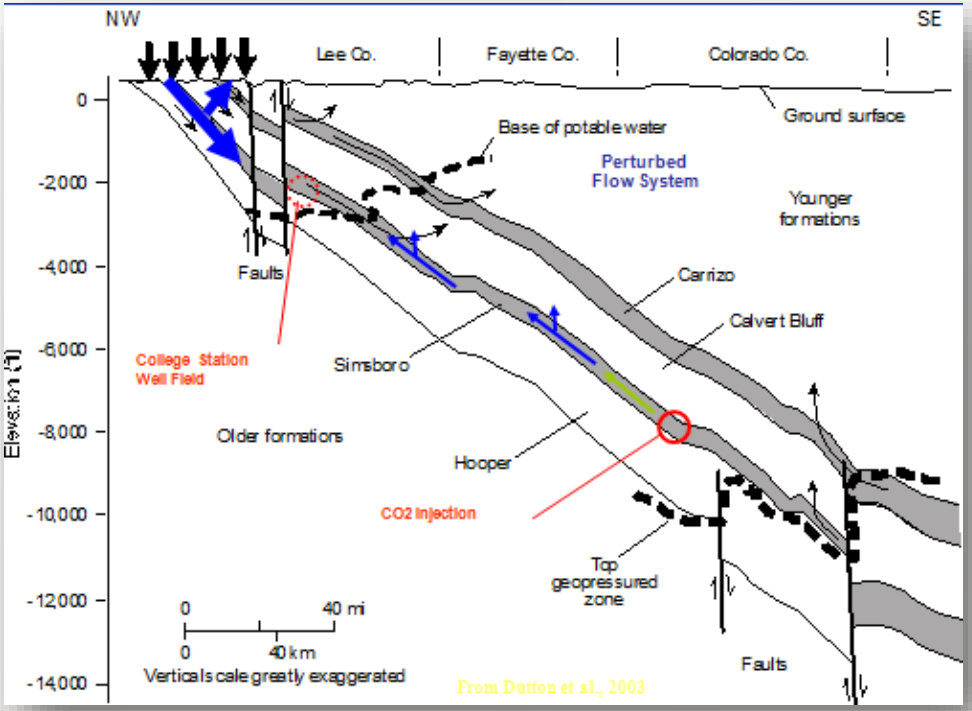
- Brine leakage through faults/wells to the shallow subsurface
- Along-dip water displacement



Nicot et. al, 200, 9GCCC Digital Publication Series #08-03g

Brine Migration

- Abandoned wells should be properly plugged.
- Best practices should be followed for new well construction
- Injection pressure management can reduce risk



Carrizo-Wilcox system
Nicot et. al, 2008

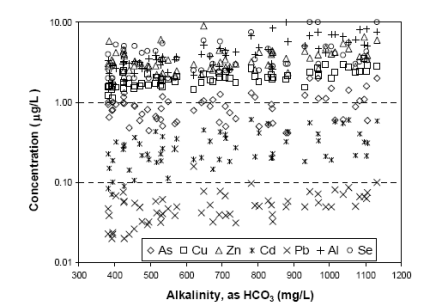
Evaluating Metal Mobilization

Laboratory:

- Rapid trace metal mobilization followed by decline. (Lu et. al, 2009)

Shallow Controlled Release (ZERT)

- Metals mobilized but were below drinking water standards and transient (Kharaka, 2010).



Natural Analogs (Mammoth Mt., Vesuvius, Chimayo)

- Metals not present in some high CO_2 environments. Metals are absorbed by mineral precipitation. (Stephens and Hering, 2004; Aiuppa et al., 1995, Keating et al., 2010)

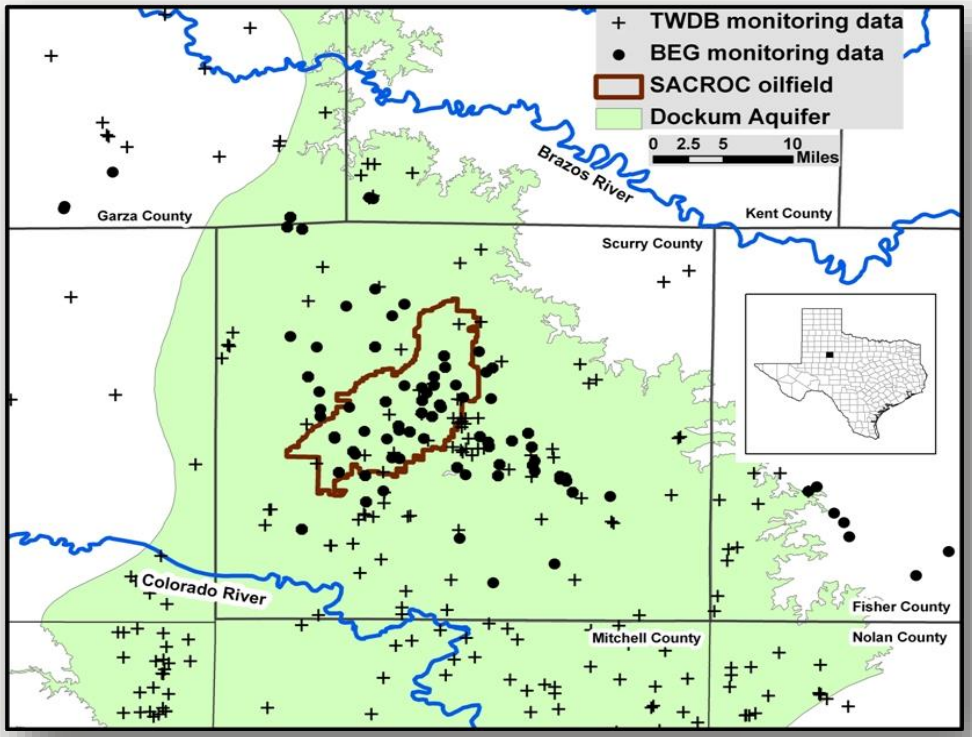
Industrial Analogue SACROC Oilfield

- CO_2 injected for CO_2-EOR since1972
- 175 Mmt CO_2 injected
- 78 Mmt recovered
- 2008 study - has CO_2 impacted environmental quality?

Smyth et al., 2009, Assessing risk to fresh water resources from long term CO_2 injection–laboratory and field studies

Romanak et al., 2012, Sensitivity of groundwater systems to CO_2

Groundwater Quality Study



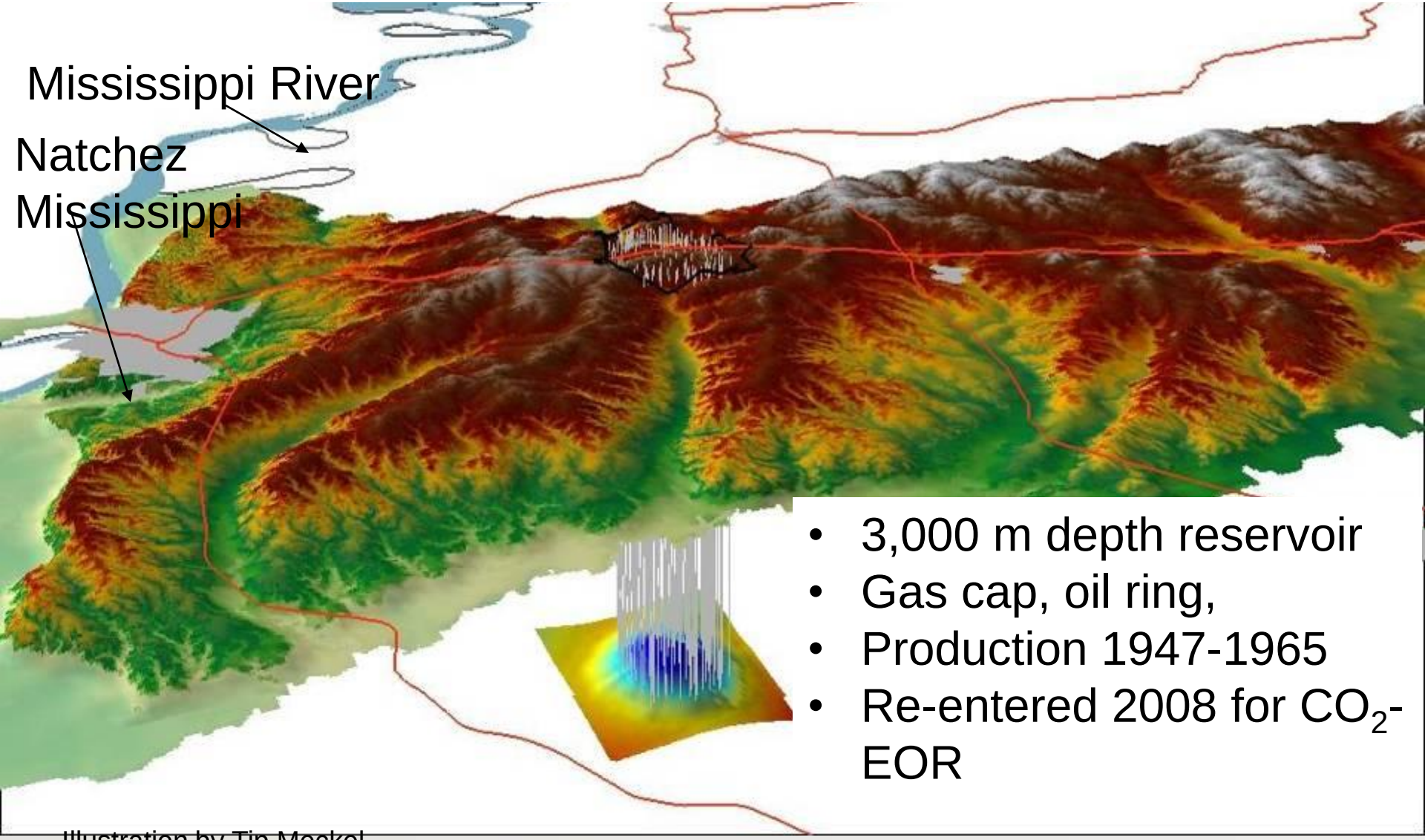
- Shallow groundwater monitored near SACROC July 2007- November 2008.
- Data from inside SACROC were compared with data from outside SACROC
- Has CO_2 injection impacted potable water?

SACROC Area Wells & Drinking Water Standards

36 wells; 17 wells inside and 19 wells outside of SACROC; filtered cations, unfiltered anions; highest concentration measured in each well.

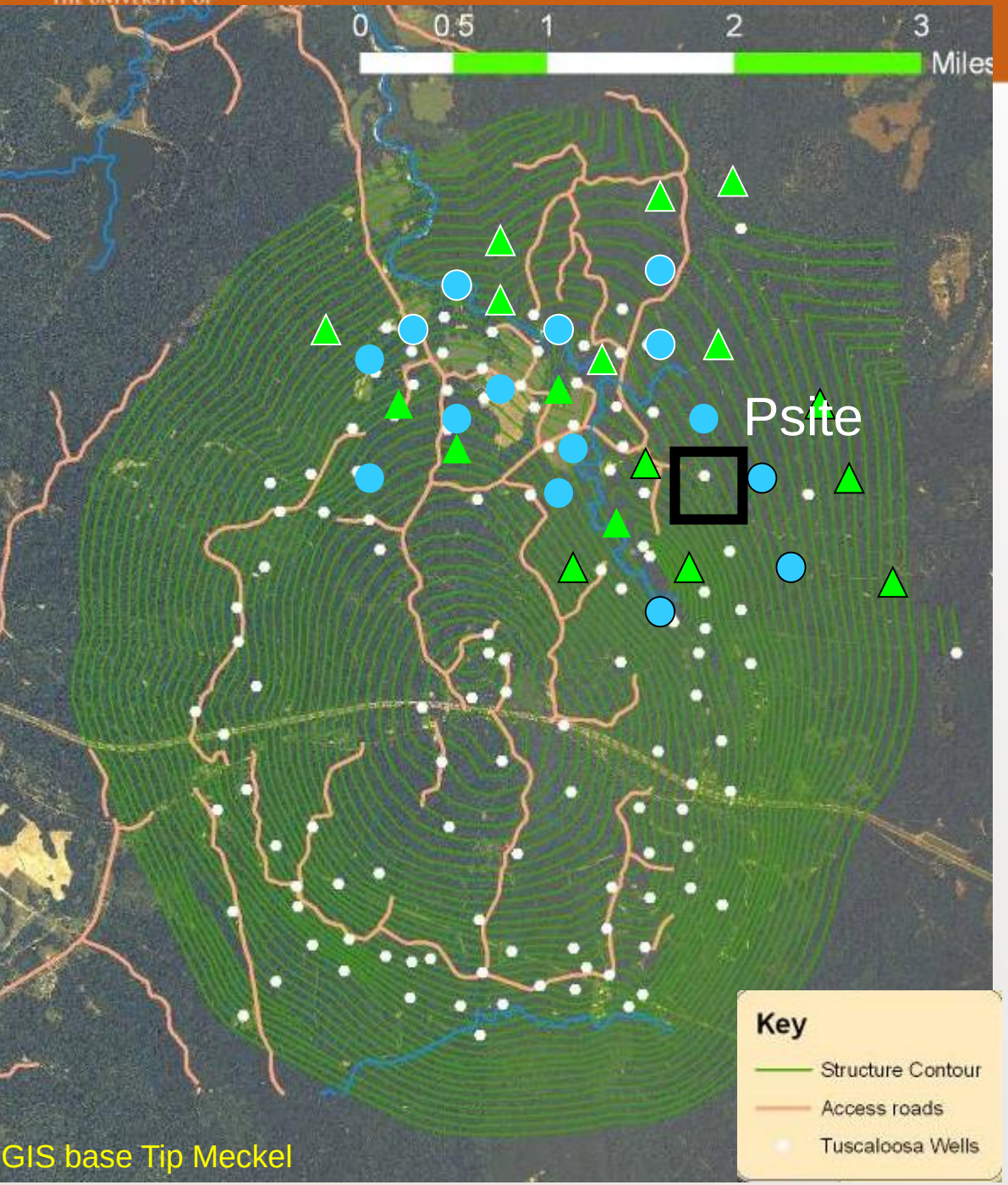
Analyte	Drinking Water Standard (DWS) (mg/L)	# Wells	Exceeding DWS Inside SACROC	# Wells	Exceeding DWS Outside SACROC
EPA Primary - Maximum Contaminant Level					
Arsenic (As)	0.01	1	2.8%	5	13.9%
Fluoride (F^-)	4.0	0	0.0%	2	5.6%
Nitrate (NO_3-N)	10	3	8.3%	2	5.6%
Selenium (Se)	0.05	0	0.0%	2	5.6%
Ag, Ba, Be, Cd, Cr, Cu,	variable	0	0.0%	0	0.0%
Pb, Sb, Th, U	variable	0	0.0%	0	0.0%
EPA Secondary Drinking Water Standard					
Aluminum (Al)	0.05	5	13.9%	6	16.7%
Chloride (Cl^-)	250	6	16.7%	4	11.1%
Fluoride (F^-)	2.0	6	16.7%	10	27.8%
Manganese (Mn)	0.05	3	8.3%	3	8.3%
Sulfate (SO_4^{2-})	250	1	2.8%	5	13.9%
Total Dissolved Solids (TDS)	1000	7	19.4%	8	22.2%
Fe, Hg, Zn	variable	0	0.0%	0	0.0%
WHO Drinking Water Standard					
Boron (B)	0.5	3	8.3%	5	13.9%

Soil Gas Study
Large Volume Injection at Cranfield



- 3,000 m depth reservoir
- Gas cap, oil ring,
- Production 1947-1965
- Re-entered 2008 for CO_2-EOR

Illustration by Tip Meckel

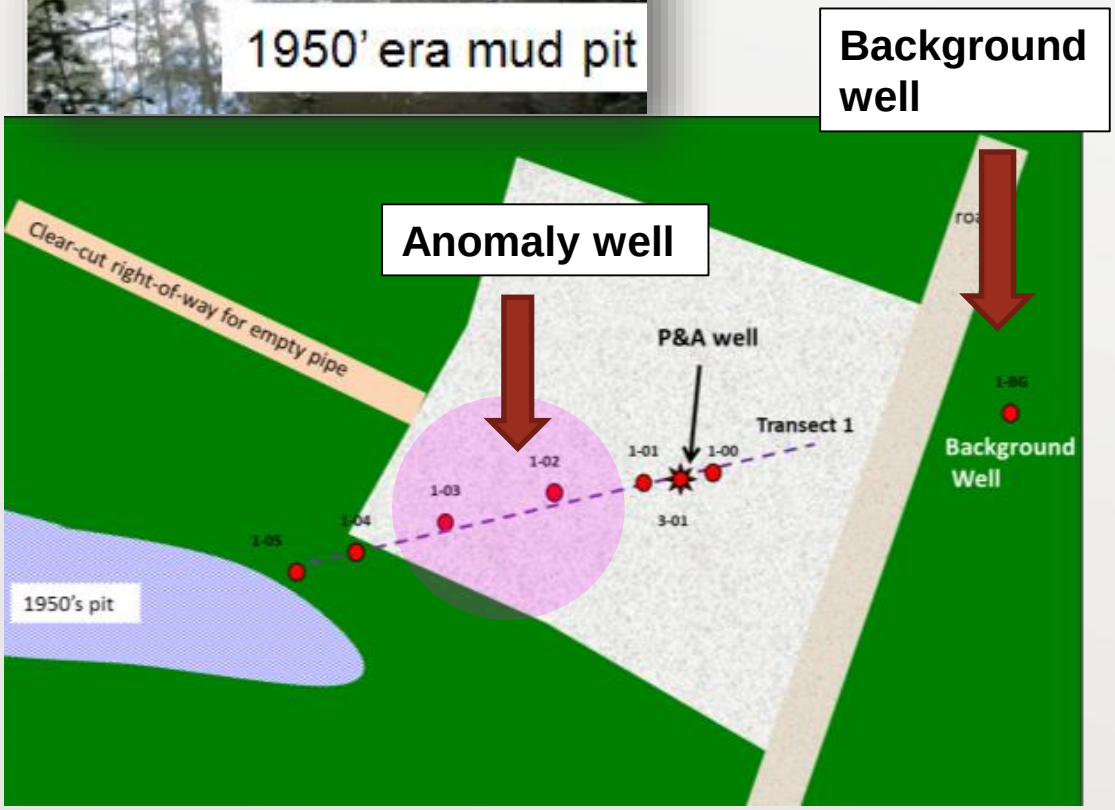


GIS base Tip Meckel

Cranfield

- ~ 100 P&A wells
- Initial injection (2008) ~500,000 tons/yr ramping up to 1 MMT/year
- Soil gas survey of P&A wells showed no surface gas flux except at one site.

Soil Gas Anomaly

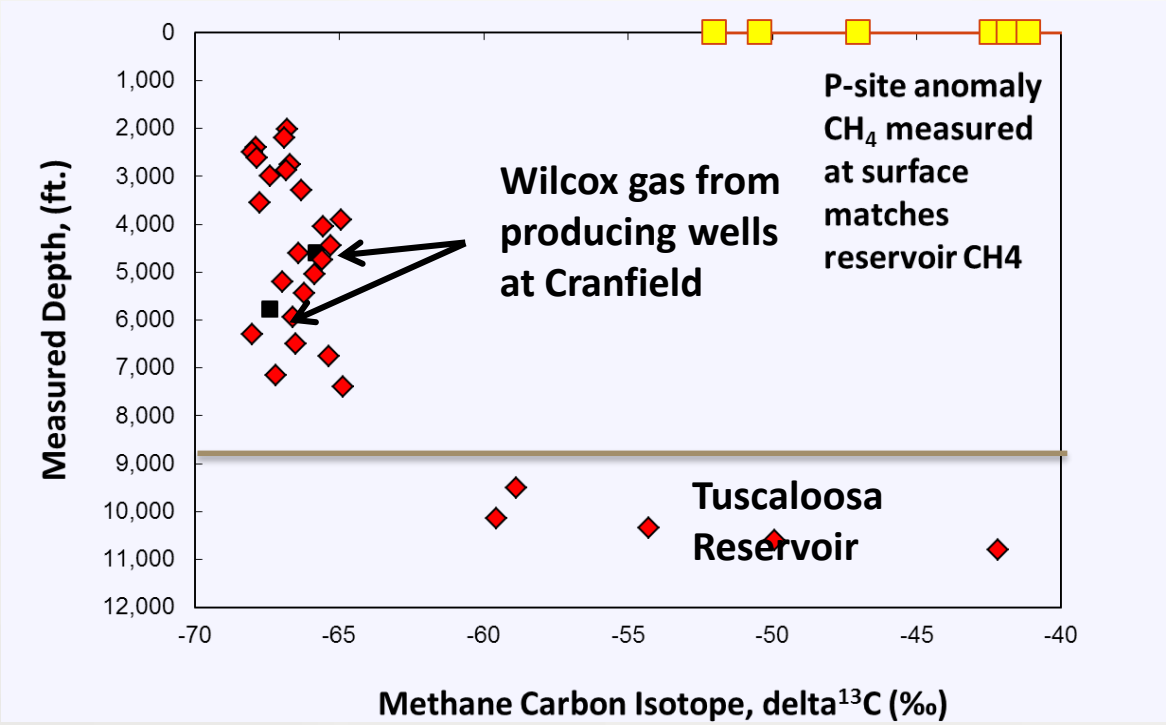


- Historic well
- Localized soil gas anomaly
  - $CH_4 \leq 50$ vol. %
  - $CO_2 \leq 45$ vol. %
- Monitored for 6 years
- 13 multi-depth soil gas sampling stations - 5 m depth
- Well re-entered in 2010 for production

Tricky Source Attribution

- Initially believed to indicate well-failure.
- Potential origin from reservoir or intermediate units
- Based on ^{14}C was found not to be from the reservoir.

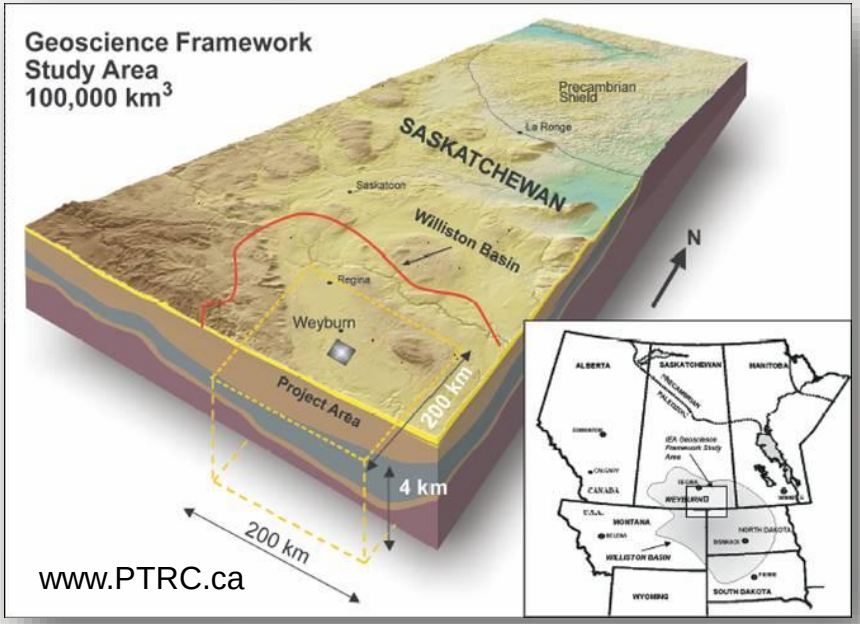
Example:Mudgas Analysis



Environmental Aspects

- Anomaly spatially compact
- Relatively low surface flux
- No visible impacts

IEAGHG Weyburn-Midale CO_2 Monitoring and Storage Project



Rostron and Whittaker, Energy Procedia 4 (2011) 3636–3643

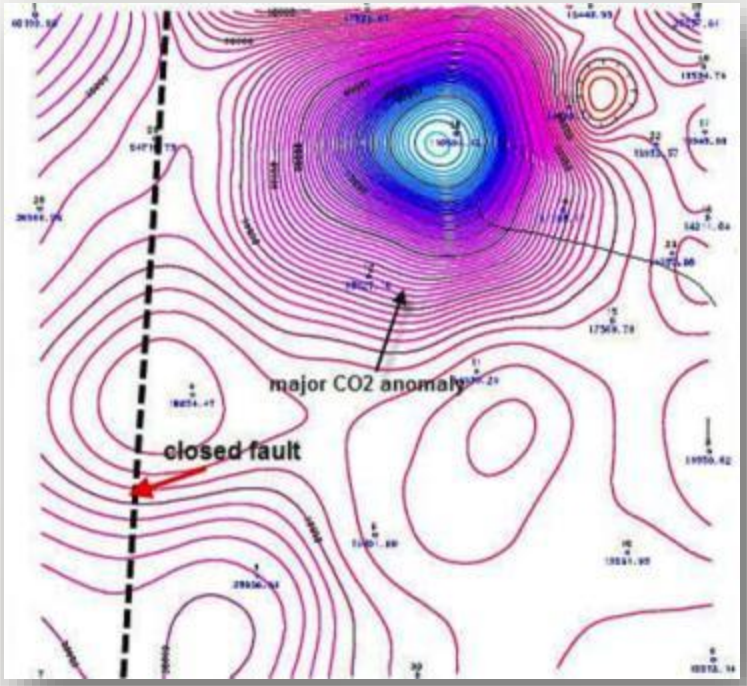
- Largest geologic CO_2 monitoring and storage project
- Since 2000 > 24 M tonnes of CO_2 injected
- CO_2-EOR operated by Cenovus Energy
- Studied by an international team of CO_2 storage experts
- Managed by Petroleum Technology Research Centre (PTRC)

2011 Kerr Farm Alleged Land Disturbances

Industry and Government Response to Kerr Complaints

- **1998**: (Operator) Weyburn Pump and Water Conditioning, groundwater test report
- **2002 – 2005**: (Operator) Farm well Inventory Project, regional groundwater analysis
- **2004**: (Operator) KBL Land Use Consulting Ltd., gravel pit water and soil samples
- **2005**: (Operator) Enviro-Test Analytical soil sample
- **2005**: (Government) Saskatchewan Health Provincial Laboratory, gravel pit and domestic well water
- **2006**: (Operator) Aqua Terre Solutions Inc., well and gravel pit water test
- **2006**: (Landowner) MR2 McDonald & Associates, water quality investigation
- **2007**: (Landowner) Consultation with Dr. Malcolm Wilson, Office of Energy & Environment, University of Regina
- **2008**: (Government) Ministry of Environment – Review of studies
- **2008**: (Government) SRC Analytical Laboratories, soil, water and air quality monitoring
- **2008**: (Government) Droycon Bioconcepts Inc., Bacteriological content of water
- **2010-2011** (Landowner) Petro-Find Geochem Ltd. Soil gas surveys.

Attribution to Leakage

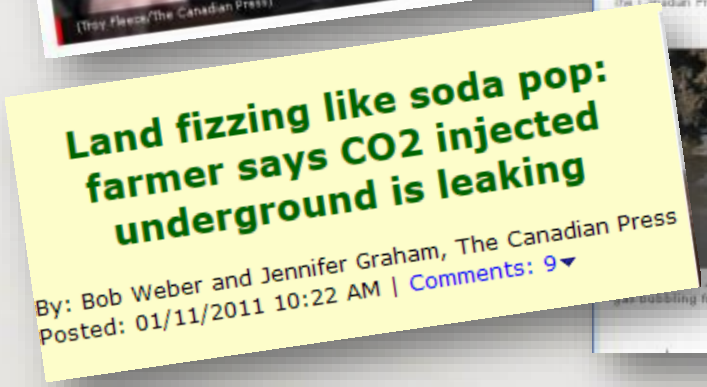


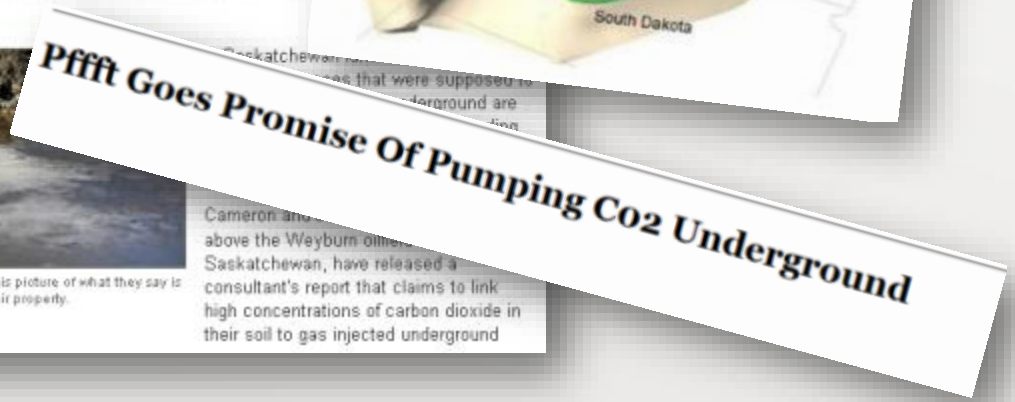
"The...source of the high concentrations of CO_2 in soils of the Kerr property is clearly the anthropogenic CO_2 injected into the Weyburn reservoir."

Source: Lafleur, P. 2010. *Geochemical Soil Gas Survey: A Site Investigation of SW30-5-13-W2M Weyburn Field, Saskatchewan. Saskatoon, SK: Petro-Find Geochem Ltd.)*

News of a "Leak" at Weyburn

January 11, 2011





Expert Investigations in Response to Leakage Claim

Investigations of alleged CO_2 leakage in Weyburn, Canada in the context of longer term surface gas monitoring.

D Jones[1], T Barlow[1], A Barkwith[1], T Lister[1], M Strutt[1], S Beaubien[2], T Bellomo[2], A Annunziatellis[2], S Graziani[2], S Lombardi[2], G Brulhant[3], F Gal[3], F, Joublin[3], K Michel[3], C Sandau[4] and B Rostron[5]

[1]British Geological Survey, Kingsley Dunham Centre, Keyworth, Nottingham, NG12 5GG, UK
[2] Università di Roma "La Sapienza", Dip. Scienze della Terra, P.le A. Moro 5, 00185 - Roma, Italy
[3]Bureau de Recherché Géologigae et Minière, 3 Avenue Claude Guillemin, BP 36009, 45060 Orleans Cedex 2, France
[4]Chemistry Matters, Cochrane, Alberta, Canada
[5]University of Alberta, Department of Earth and Atmospheric Sciences, 1-26 Earth Sciences Building, University of Alberta, Edmonton, Alberta, Canada, T6G 2E3

Abstract

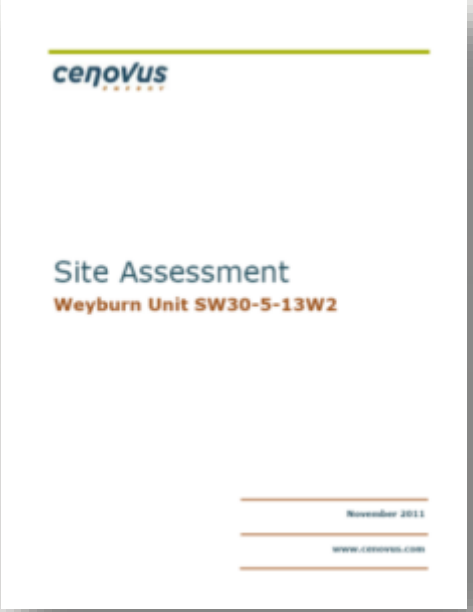
The Weyburn oilfield in SE Saskatchewan, Canada has been in production for more than 50 years. A CO_2 flood was started in 2000 to enhance oil recovery. The gas is piped from a coal gasification plant across the US border in North Dakota. In addition to boosting oil production it is expected that about 30 million tonnes of CO_2 will be permanently stored in the reservoir, at a depth of about 1400 m, by the end of the 30 year lifetime of the project.

Near surface gas monitoring has been carried out from the early stages of CO_2 injection. It forms part of the IEAGHG Weyburn-Midale research project and has received additional support from EU-funded research projects and UK national funding. The first surface gas measurements were made in July 2001, with subsequent surveys in the autumn of that year and then each autumn from 2002 to 2005. Repeat surveys were carried out in 2011 when new methods were trialled and specific investigations were made at a site of alleged CO_2 leakage.

An initial grid of soil gas and flux observations was made in 2001 covering some 13 km^2 (360 points at 200 m spacing) around the initial injection area. This was measured on each subsequent visit as were a selection of more detailed profiles (25 m spaced observations) chosen on the basis of the grid results. In 2003 the scope of work was expanded to investigate possible pathways for CO_2 migration towards the surface. This included the study of 2 abandoned/suspended well sites and lineaments that might represent the surface expression of deeper faulting or thinning of the reservoir seal. A background site with similar characteristics to the main grid, but remote from the CO_2 injection area was also added. Measurements made in the field, field laboratory and laboratory included a range of gas species (e.g. CO_2, O_2, N_2, CH_4, C_2H_6, C_3H_8, C_4H_{10}, He and Rn) and CO_2 flux. Radon probes were also buried at selected sites to monitor the temporal variations of this gas as a proxy for CO_2 migration.

In 2011 these measurements were supplemented by some continuous monitoring of CO_2 concentrations and fluxes using buried monitoring probes and an eddy covariance system. In addition, mobile open path laser measurements of CO_2 in the near ground atmosphere were made at selected sites. These methods were designed to address the potential need to locate spatially small surface leaks in a large project area and to deal with temporal variability.

Allegations of leakage of CO_2 to surface at the Kerr property, just SW of the CO_2 injection area, were made in early 2011. Consequently the area around the property was investigated with many of



cenovus energy

Site Assessment

Weyburn Unit SW30-5-13W2

November 2011

www.cenovus.com

IPAC CO2

European Research Team

The Operator

Third Party

CONCLUSION: NO LEAKAGE

How To Avoid This?

- High risk of false positives from inaccurate attribution.
- Need protocols and techniques for responding to leakage claims in place before a project begins.
- Quick response tools and protocols are being developed
  - Process-based approach
  - ^{14}C versus ^{13}C

Dixon and Romanak, 2015, Improving monitoring protocols for CO_2 geological storage with technical advances in CO_2 attribution monitoring, IJGGC vol 41

Romanak et al,. 2014, Process-based soil gas leakage assessment at the Kerr Farm: Comparison of results to leakage proxies at ZERT and Mt. Etna, IJGGC vol 30

Summary Points

- No impact to groundwater at SACROC
- No environmental impact from soil gas anomaly at Cranfield
- Risk of leakage is less than risk that leakage will be perceived when it is absent
- Techniques and protocols for attribution are critical

Dixon and Romanak, 2015, Improving monitoring protocols for CO_2 geological storage with technical advances in CO_2 attribution monitoring, IJGGC Volume 41, Pages 29–40

Thank You

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