Resman
Tracer Technologies

Delivering Verifiable CO_2 Storage: Tracer Technology for High-Integrity MMV and Leak Detection

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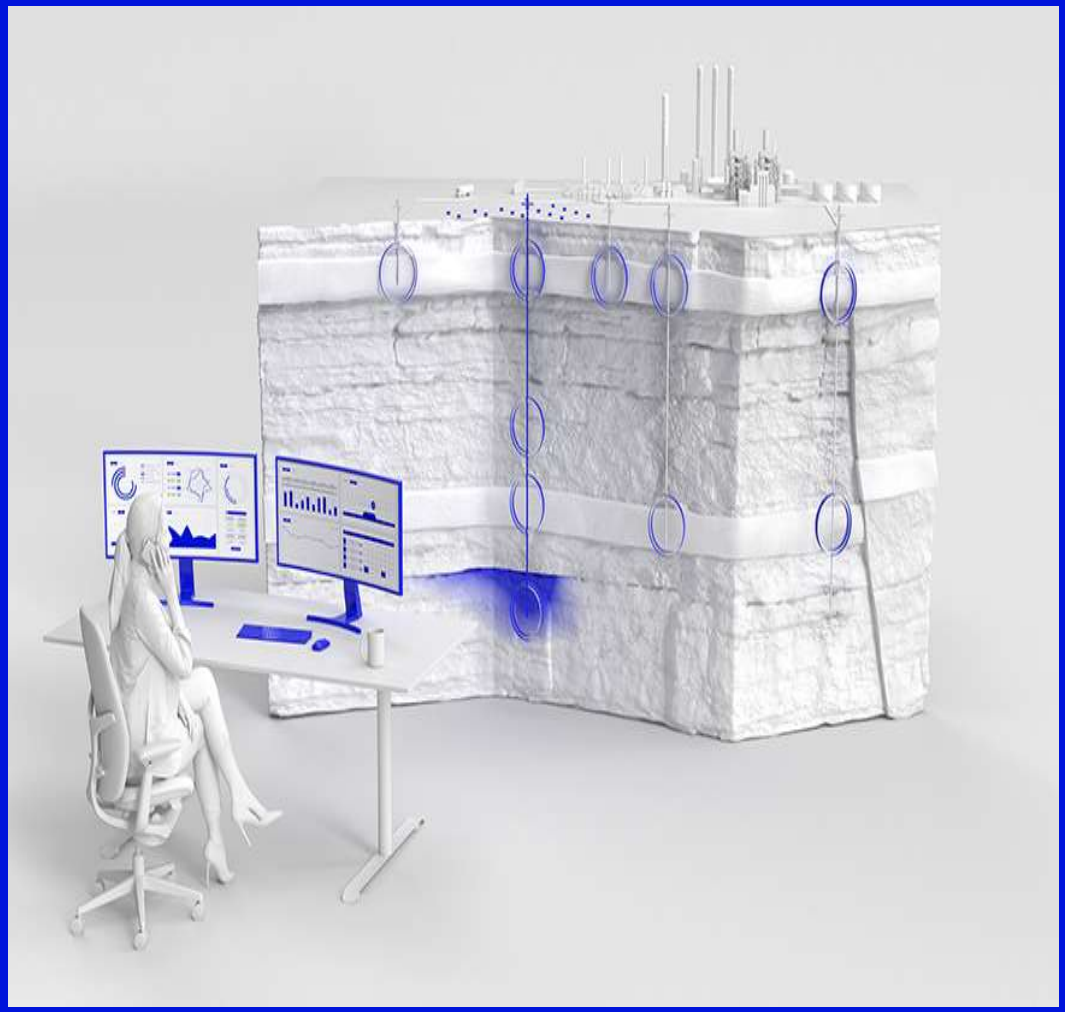
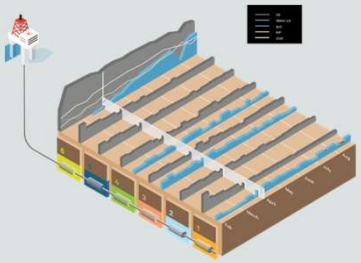
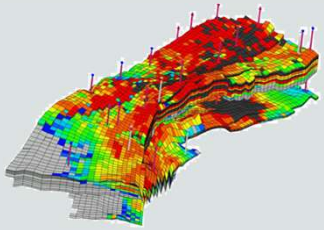
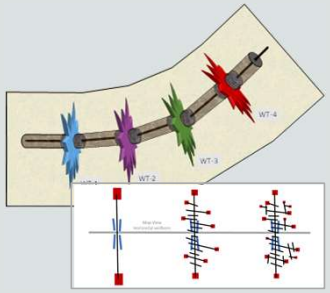
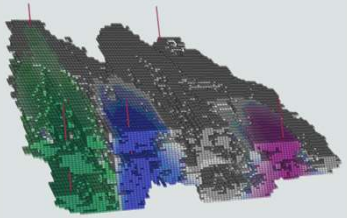
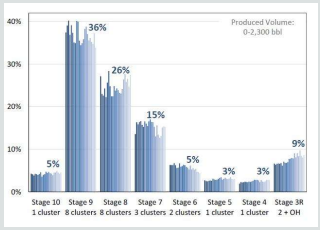


Resman offering

Tracer Track visualization solution

Digital enabled end user experience

Production	Reservoir	Stimulation	Carbon storage	Geothermal
				
2005	2013	2025	2007	2024
Subsurface data: Risk-free and cost effective	Evidence-based reservoir modeling	Measure the once unmeasurable	Fingerprint for peace of mind	Reliability at high temperatures

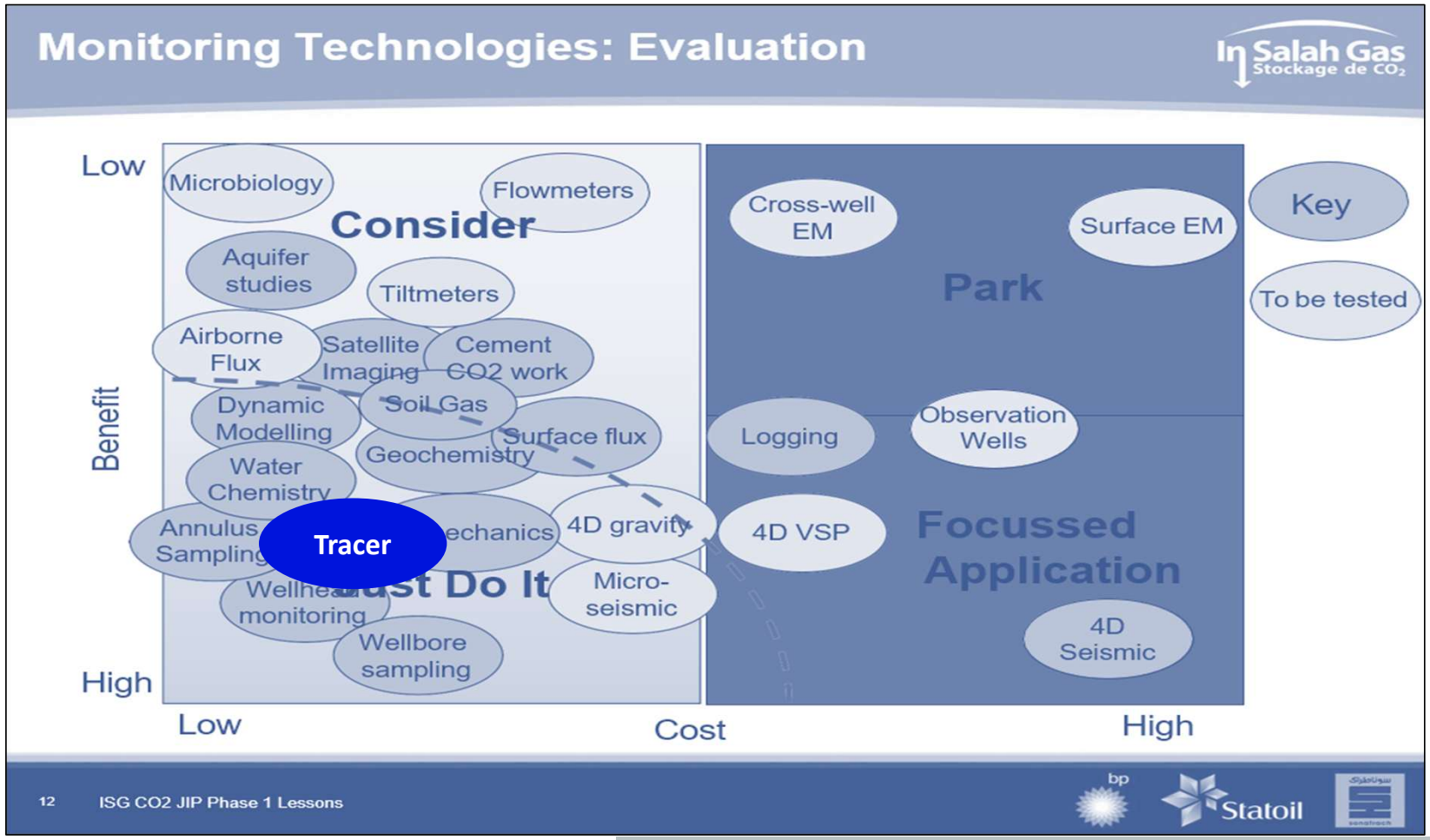
Using the natural energy of the reservoir to gain direct insights

100+	38	62	140
Technical papers	Patents granted	Countries	Reservoirs

CCS monitoring technology evaluation by Customer

Resman has 18-year monitoring track record with this project (still ongoing)

Evaluators:



Publication reference: Mathieson, CGS Conference – Ankara, Turkey, 14 June 2012

Tracer technology

Tracers are organic tags to reservoir fluids

- Follows the flow without impacting transport process
- Fluid from specific source can be identified

Tracer properties

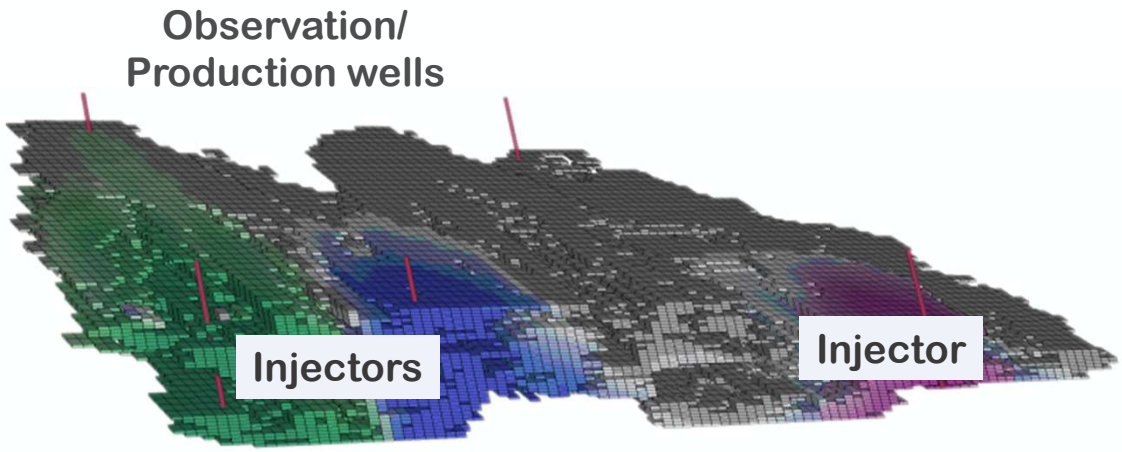
- Inert
- Non-radioactive and low toxicity
- No natural occurrence in reservoir fluids
- No absorption to rock
- Detectable at extremely low concentrations – detection level in part per quadrillion range (1E-15)
- Cost effective

Only Proof of mass transport

- Direct Measurement
- Quantifiable data; communication pattern, significance and sweep
- Model calibration

RESMAN CCS tracers have no measurable degradation

- will last through both injection period
- And the required post-injection monitoring period of multiple decades



Chemistry

Tracer properties

- Inert
- Non-radioactive and low toxicity
- No natural occurrence in reservoir fluids
- No absorption to rock
- Detectable at extremely low concentrations
- Cost effective
- 12 unique tracer signatures for CCS

Biotech Lab

Industry highest resolution, beyond nano, **Parts per Trillion** or better Detection Limits (Part per quadrillion)

500,000 + **Empirical data base** Tracer concentration field experience data point

ISO certified since 2009
9001 Quality | 14001 Environment | 45001 HSE

Fluid Enabled Telemetry
Powered by reservoir Flow

Risk free conveyance & Integration

Simple Sampling

Small Operations footprint

Operational Simplicity

Tracer is the **ONLY Proof of Mass Transport**.

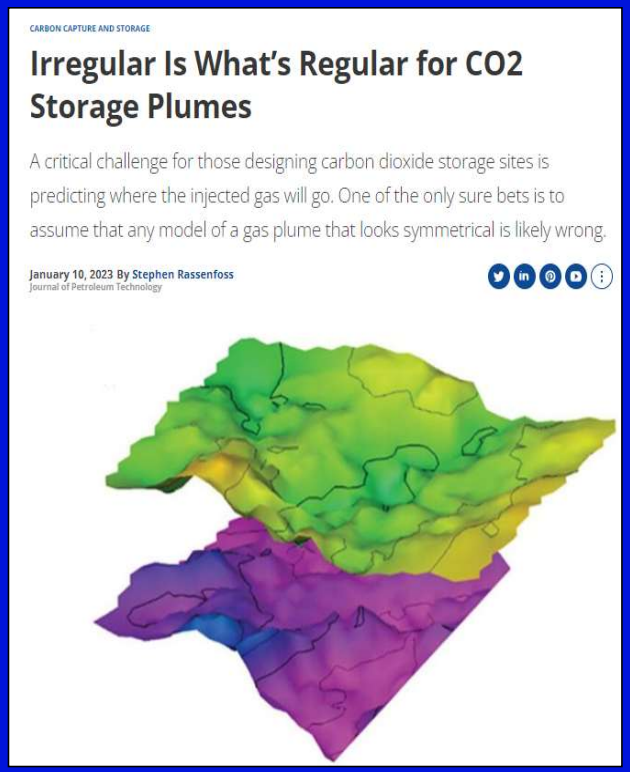
A **direct** measurement

Interpretation based on fundamental laws of physics

Quantification techniques for all reservoir, productions and new energy challenges

Physics

Call for Action …



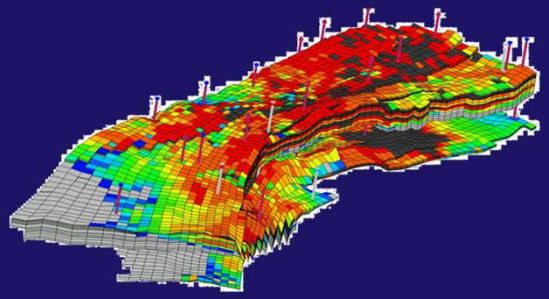
https://jpt.spe.org/irregular-is-whats-regular-for-co2-storage-plumes?utm_source=linkedin&utm_medium=social&utm_content=article&utm_campaign=jpt

JPT KEY POINTS | INDUSTRY RECOGNIZED GAP

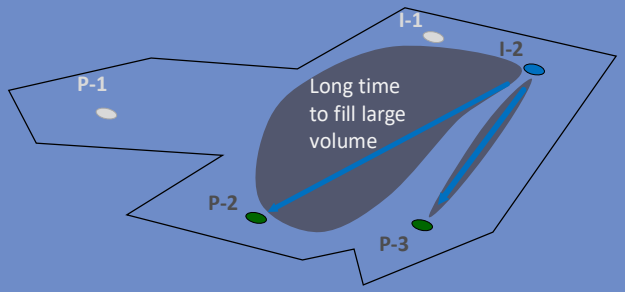
	SLB Resman's Technology
*"One of the only sure bets is to assume that any model of a gas plume that looks symmetrical is **likely wrong**"*	✓
*"It's hardly news to petroleum engineers that reservoir models fail to convey where gasses will flow in the formations full of features that regularly do **not show up in seismic** and other tests. What is new is the sort of trouble that can be associated with getting that wrong in a CO2 storage project"*	✓
"This becomes a problem for a storage project if the plume migrates into pores that were leased for storage."	✓
*"In North Dakota, the worst-case scenario is "you may be in **noncompliance of your permit** and have to stop injection" because it has invaded pore space not leased for the project."*	✓
*"Based on long experience in CO2 enhanced oil recovery (EOR), runaway injections can lead to **conflicts with neighbors** with subsurface rights, such as lawsuits from nearby natural gas producers who are paying to remove rising levels of migrating CO2 from their production."*	✓
*"It's really hard with 3D seismic to **detect all the baffles or barriers** that can influence gas migration,"*	✓
*Even a well-known, closely examined formation can surprise….unexpected growth of the CO2 plume at the Snøhvit Field offshore Norway….The unexpectedly wide spread of the CO2 **threatened to contaminate a nearly producing gas field**. Carbon dioxide injection at the site has since been shut down.*	✓
*Philip Ringrose, adjunct professor at the Norwegian University of Science and Technology, advised the audience to "**expect surprises when you start injection**."*	✓

Carbon Storage Challenges

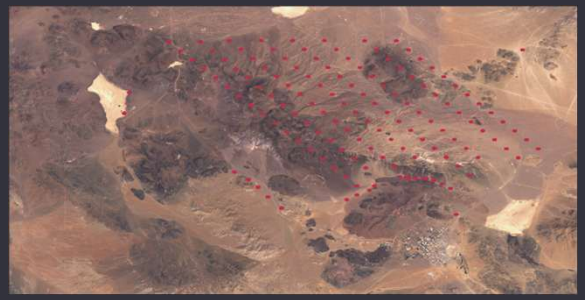
Where does it move?



How much fast does it move?



What the risk of leakage?



For projects with observation wells:

Tracer is the ONLY **proof of mass transport**	Enables optimization of injector performance. **Physical Verification of Storage Volume**	**Economical physical detection of CO_2** High-integrity, high-sensitivity leak detection by **tracers**
Ability to track and see **connections between wells.** Enable **actual calibration point to reservoir models**	Enable injector optimization, determining **sweep volume of breakthrough conduits**	Tracer has ability to **delineate source of CO_2 origin** between multiple injectors, or natural CO_2
Tags CO_2 upon injection to enable **direct measurement, monitors for DECADES in reservoir**	Ability to find & confirm **source of CO_2 breakthrough** **Quantify residency time**. Pressure Management	Enhances seismic resolution, **CO_2 plume tracking**

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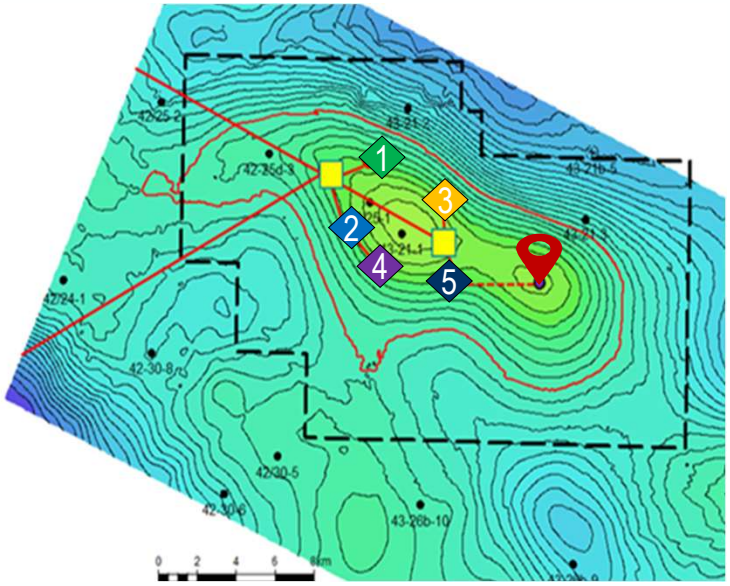
Be Storage Confident

Customer Objectives in Monitoring Technology

1 Tracer 1
2 Tracer 2
3 Tracer 3
4 Tracer 4
5 Tracer 5
Observation well

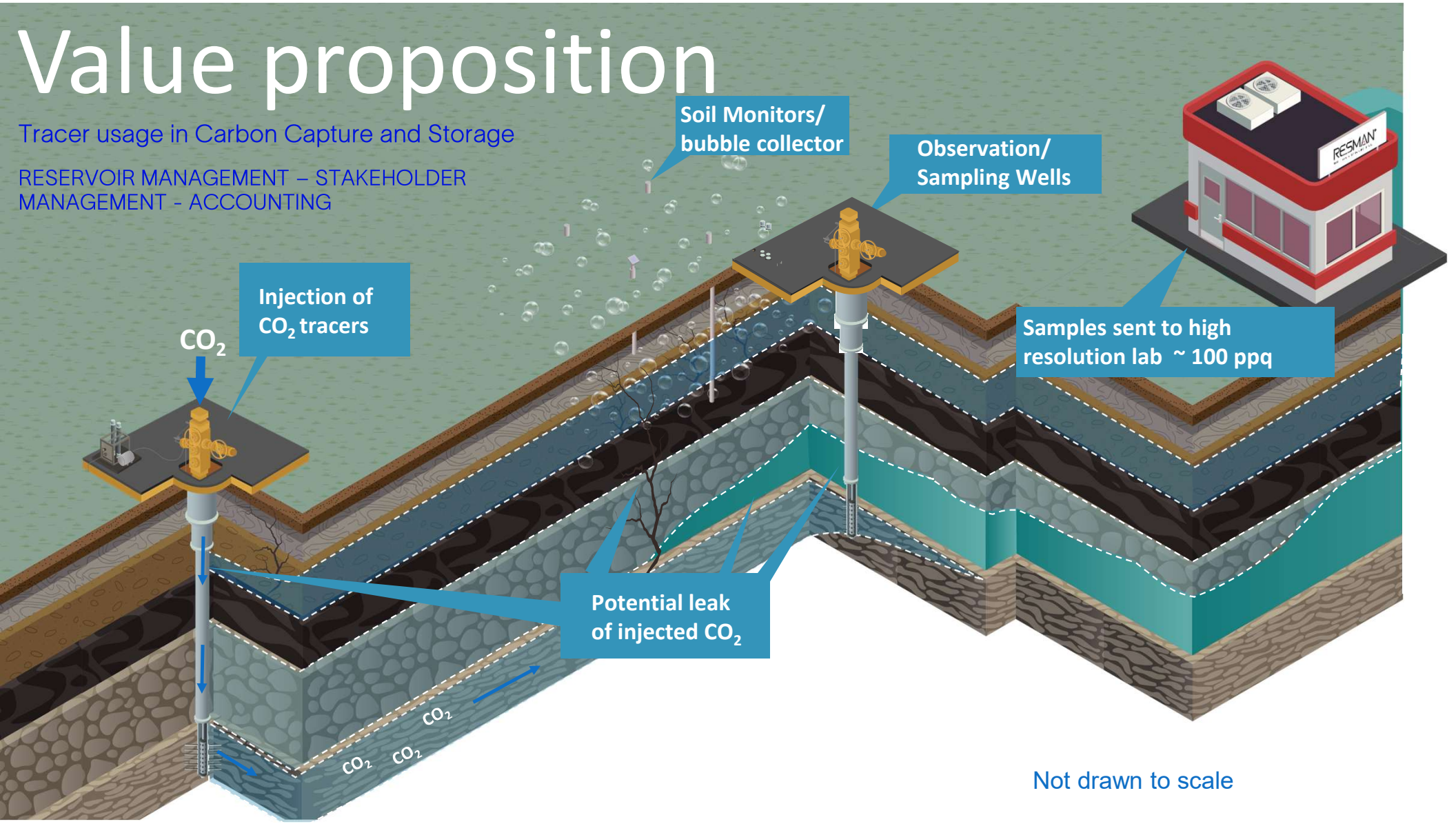


- ❑ Find source of CO_2 breakthrough through unique tracers in each injection well
- ❑ Quantify rate of CO_2 leakage from the storage in the subsurface (out of licence area, into nearby (gas) fields)
- ❑ Detect seeps/leaks to surface, and their injector origin
- ❑ Detect seeps/leaks in connection with legacy wells, and their injector origin
- ❑ Determine sweep volumes of any unwanted fast breakthrough conduits (for EOR or observation wells)
- ❑ Establish flow direction and spread of CO_2 plume
- ❑ Use CO_2 tracer data to optimize reservoir model through simulation study

Value proposition

Tracer usage in Carbon Capture and Storage

RESERVOIR MANAGEMENT – STAKEHOLDER MANAGEMENT - ACCOUNTING



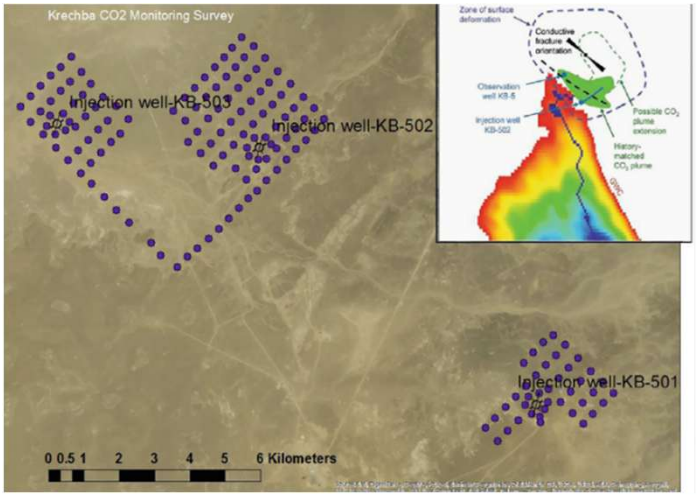
Not drawn to scale

RES•HIDS for Caprock Leak/Seep Detection

- Identify possible leakage areas based on geological information
- Deploy RESMAN HIDS (High integrity Detection system) for soil sampling, or bubble collection from seabed
- Place RESMAN tracer sampling devices in soil sampling well or transfer collected bubbles to RESMAN sampling tubes
- Gas sampler will integrate exposure to leakages in the period it is in well
- The sampling well can be fitted from 1 to 5 meter depth
- Tentative recommended sampling frequency: Quarterly
- 33 000 times more sensitive than competing technology
- **Deployed and named core technology in ADNOC CCS pilot**

Seabed bubble collectors

HIDS soil sampling system



Source: *F Zeboudj and L Bahi «Best Practices in Monitoring CO2 at Krechba Field-Algeria AGI CO2 Tracer Gases Detection Technique» Proceedings of the International Petroleum and PetrochemicalTechnology Conference 2020, pp. 584–599, 2021*

Tracer identifying plume migration into gas reservoir

Algeria

Different CO_2-tracers injected into each of 3 CO_2 injection wells

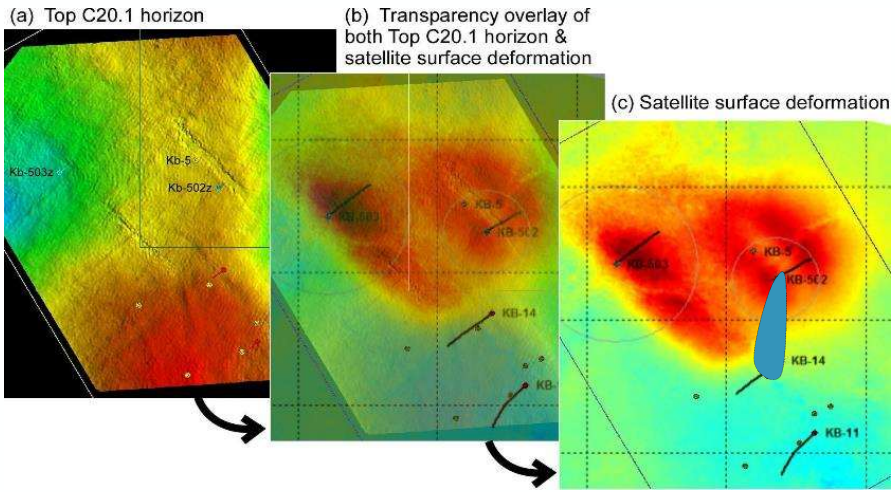
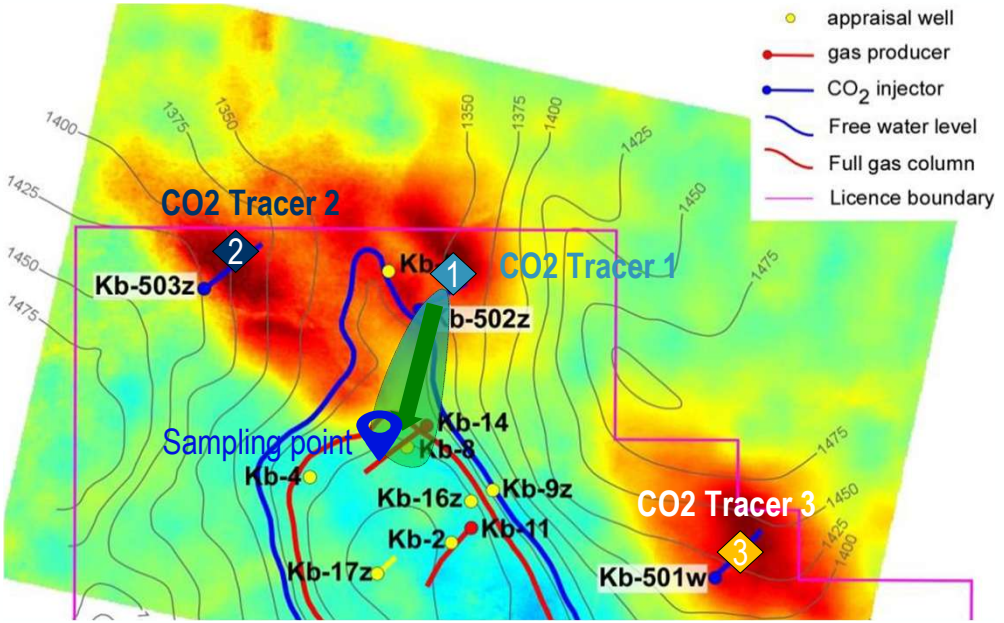


Fig. 4. NW-SE linear features seen on 2009 3D seismic data compared with InSAR surface deformation data.

Findings

- Tracer saw CO_2 break-through from Kb-502 to KB-14 after ~5 years, provides source identification and proof of mass transport
- Not obvious from seismic or other data
- Resulted in model refinement and re-interpretation of fracture data



Source: Wright, NFCCC SBSTA CCS Workshop, September 8th 2011, Abu Dhabi

Source: Ringrose et. al. Energy Procedia 37 (2013) 6226-6236i

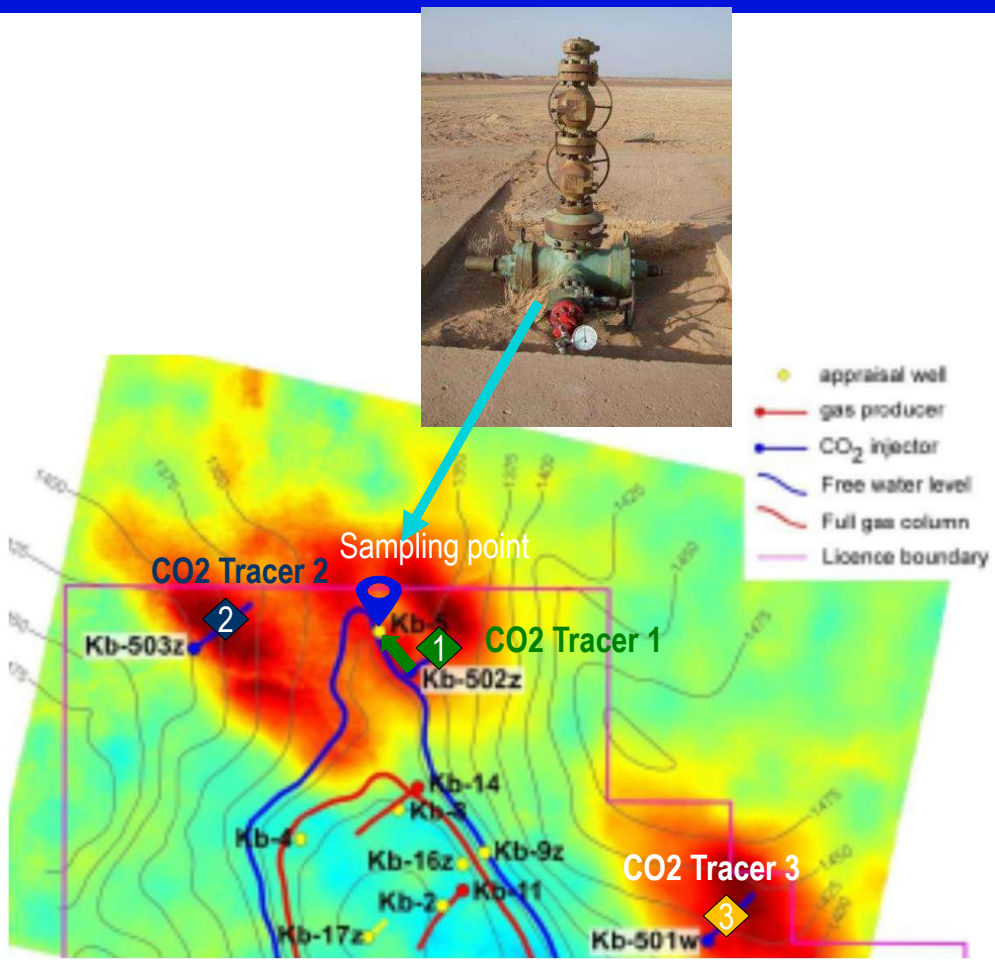
Legacy well integrity

Algeria

Legacy well Kb-5 drilled in 1980 and temporarily suspended by 2007

Well and wellhead integrity issues caused CO_2 leak in Kb-5 in 2008, leak confirmed with tracer and injection source (Kb-502) determined by tracer

Well was fully decommissioned with CO_2 resistant cement



Sources: Wright, NFCCC SBSTA CCS Workshop, September 8th 2011, Abu Dhabi

Enhanced gas recovery & CO_2 Storage

Providing improved reservoir understanding to the K12-B project

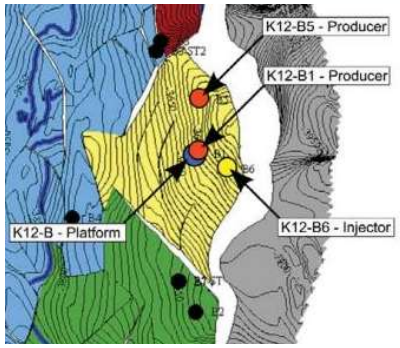
The Netherlands

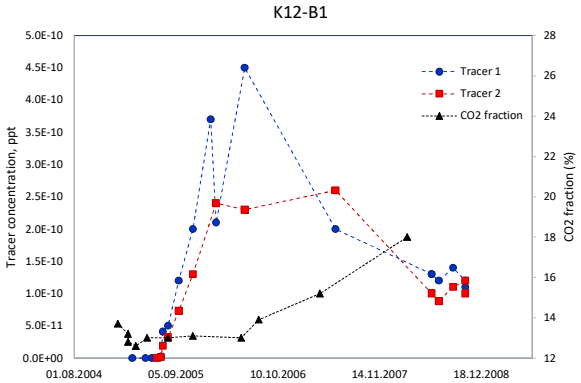
2005 First application in CCS

- K12-B **first in world** CO_2 –injection into same reservoir from which it originated
- Initial CO_2 concentration in field 13%
- Project objective: feasibility of CO_2 injection and **storage in depleted natural gas fields**
- Objective: Optimization of injection and **understanding of flow of re-injected CO_2**

Customer Relevance

- **Communication** between CO_2 injector and nearest producer **proven with tracers**
- **Arrival of tracers ~4 months** after start of CO_2 injection
- CO_2 concentration increase in production wells observed much later - proving the **sensitivity of tracer**
- Tracer data use to validate and interpret pressure data





Without the tracers it would be difficult to accurately determine the physical communication between injector and producers because the injected CO_2 originates from the reservoir gas and therefore cannot be distinguished from the naturally occurring CO_2 in the reservoir gas."

***Tracers have significantly contributed to an improved understanding** of the reservoir and how the pressure data could best be interpreted.*
Simulation** studies yields a breakthrough time of CO_2 that **correlates excellently with tracer data

(Van der Meer et al 2006)

Publication reference: 71st EAGE Conference and Exhibition incorporating SPE EUROPEC 2009 | TNO | Knowledge for Business, CO2 Storage

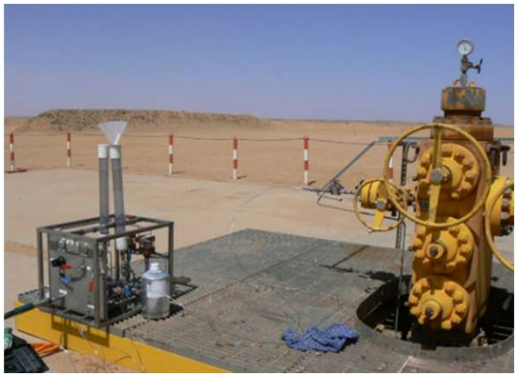
CO_2 Storage | Shallow Surface Monitoring

The highest resolution - lowest carbon footprint technology in market

UAE

2024 Adnoc Demonstration Project Detail

- 2024: **First** deployment of RES-HIDS (High Integrity Detection System) in a CCS project for ADNOC in UAE (2024)
- 1st commercial success pilot of Shallow Surface wells monitoring (RES-HIDS)
- Joint SPE Paper w/ Adnoc – SPE-222348-MS
  - *Chemical Tracer for Soil CCS Monitoring Application: Monitoring CO_2 Storage in Saline Aquifers Using Advanced Chemical Tracer and Detection Technology*



Customer Relevance

Summary and Conclusion

- CO_2 tracer technology is an accurate method to understand CO_2: migration, monitoring and early detection CO_2 leakage.
- Tracer technology is a proven technology to have high benefits and relatively low cost in reservoir monitoring and CCS domain.
- The utilized specialized CCS tracer has a high-resolution detection limit (100 ppq = 0.1 ppt). This results in reducing the cost, environmental impact and the carbon footprint dramatically.
- The contractor CCS-tracer is operationally easy to execute and has a small operational footprint.
- Once the pilot has proven successful, this technology will be expanded for other upcoming projects.

*"The CO_2 tracers are considered the **most accurate** method to confirm any CO_2 leakage through the cap rock"*

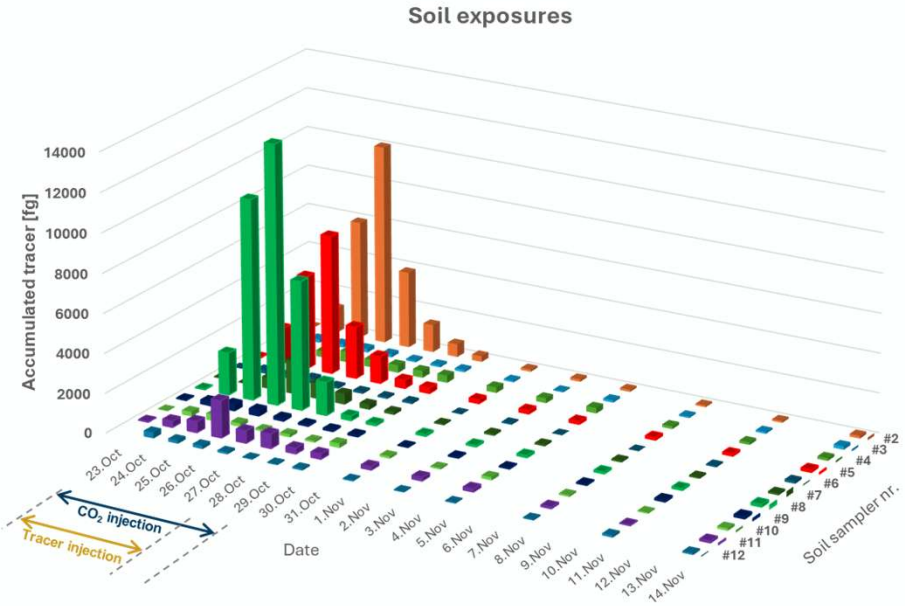
ADNOC (SPE-222348 presentation, ADIPEC 2024)

أدنوك ADNOC

How can we trust the Zero ? Soil monitoring demonstration project

Norway

- Tracer co-injected with CO_2 in a non-caprock test field at ~65 meter depth, water saturated sand, 6 days of CO_2 injection
- HIDS soil sampling technology deployed in 12 surface wells
- Tracer signal monitored for 2.5 months



- A rapid rise in tracer signal was observed in samplers close to the injection well (**Well# 2 / 5 / 8**) peaking after three days of tracer injection
- Tracer was detected up to 21 m away from the sampling injection well within one day of injection (**Well #7** and **#11**)

slb 100

Be storage **confident**