CCS Standards/Protocols/ Projects - How the geological storage of CO_2 is being "standardized" and how this relates to projects in Alberta?

AIR & WASTE MANAGEMENT ASSOCIATION
CANADIAN PRAIRIE & NORTHERN SECTION

Alberta
Saskatchewan
Manitoba
Northwest Territories
Nunavut

Friday, February 03 2012

Rick Chalaturnyk, PhD, PEng

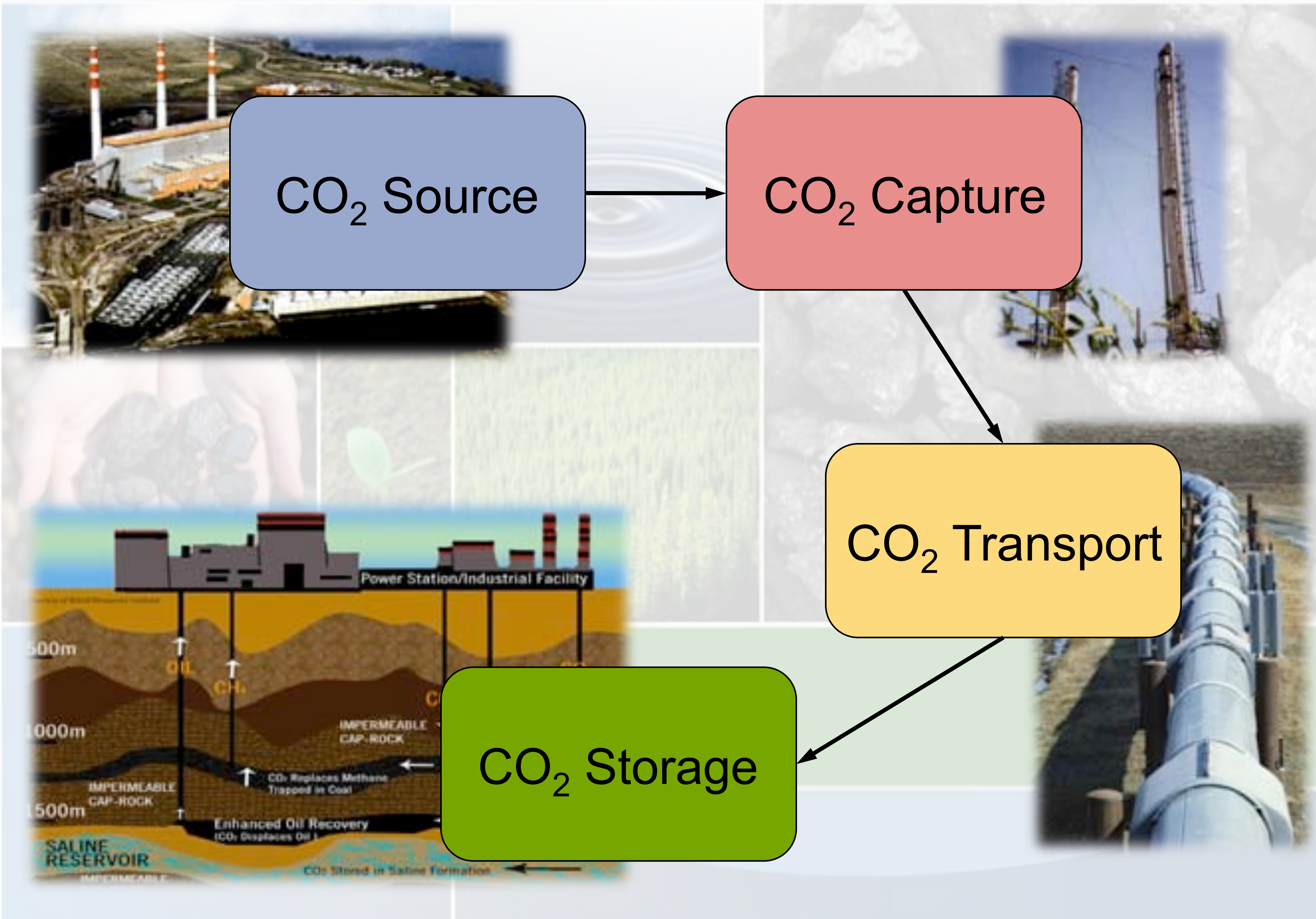
Professor, University of Alberta

Foundation CMG Chair in Reservoir Geomechanics

Outline of Presentation

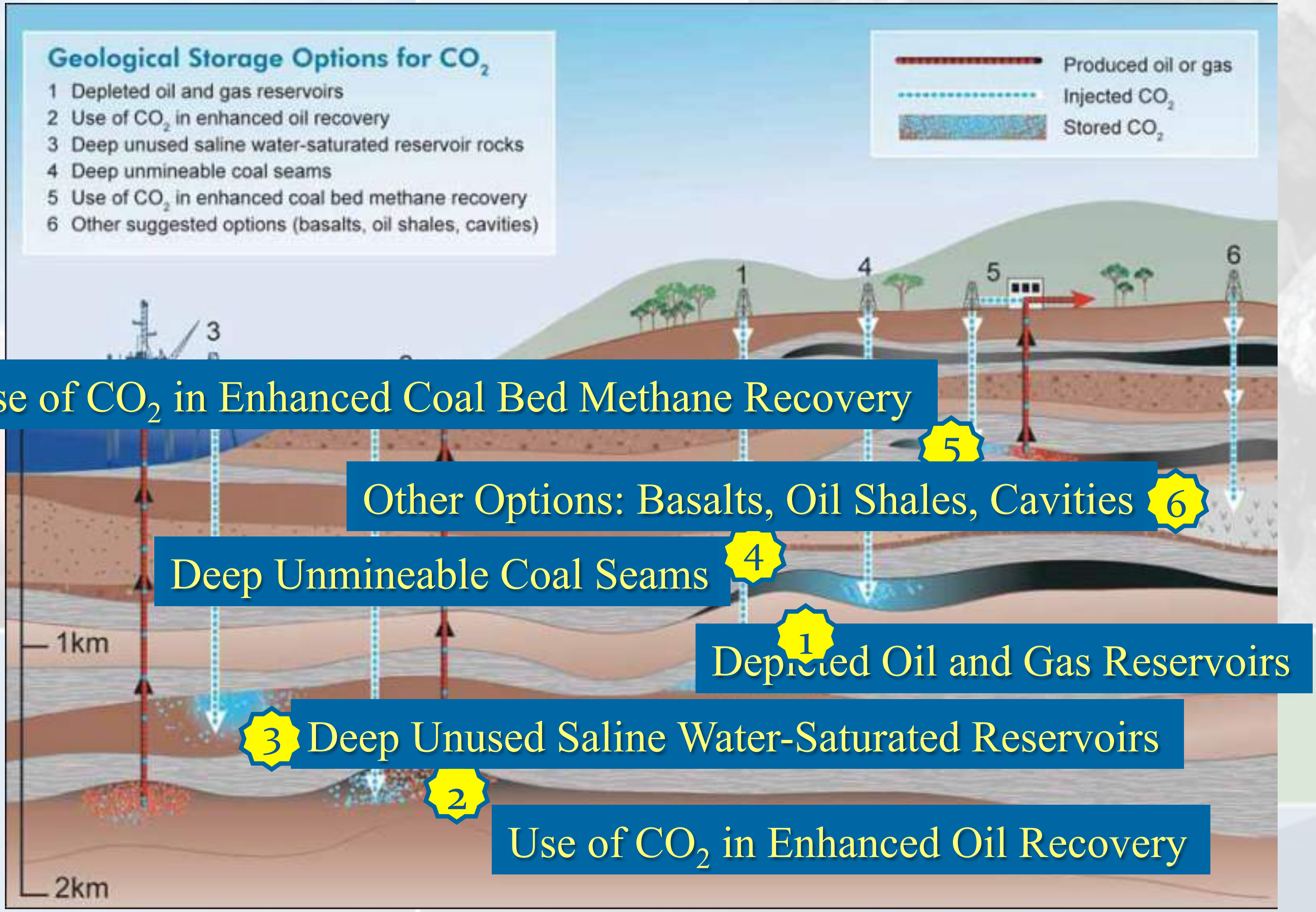
- Geological Storage of CO_2
- Questions about CO_2 Storage
- Regulations and Protocols

What is Carbon Capture & (Geological) Storage?

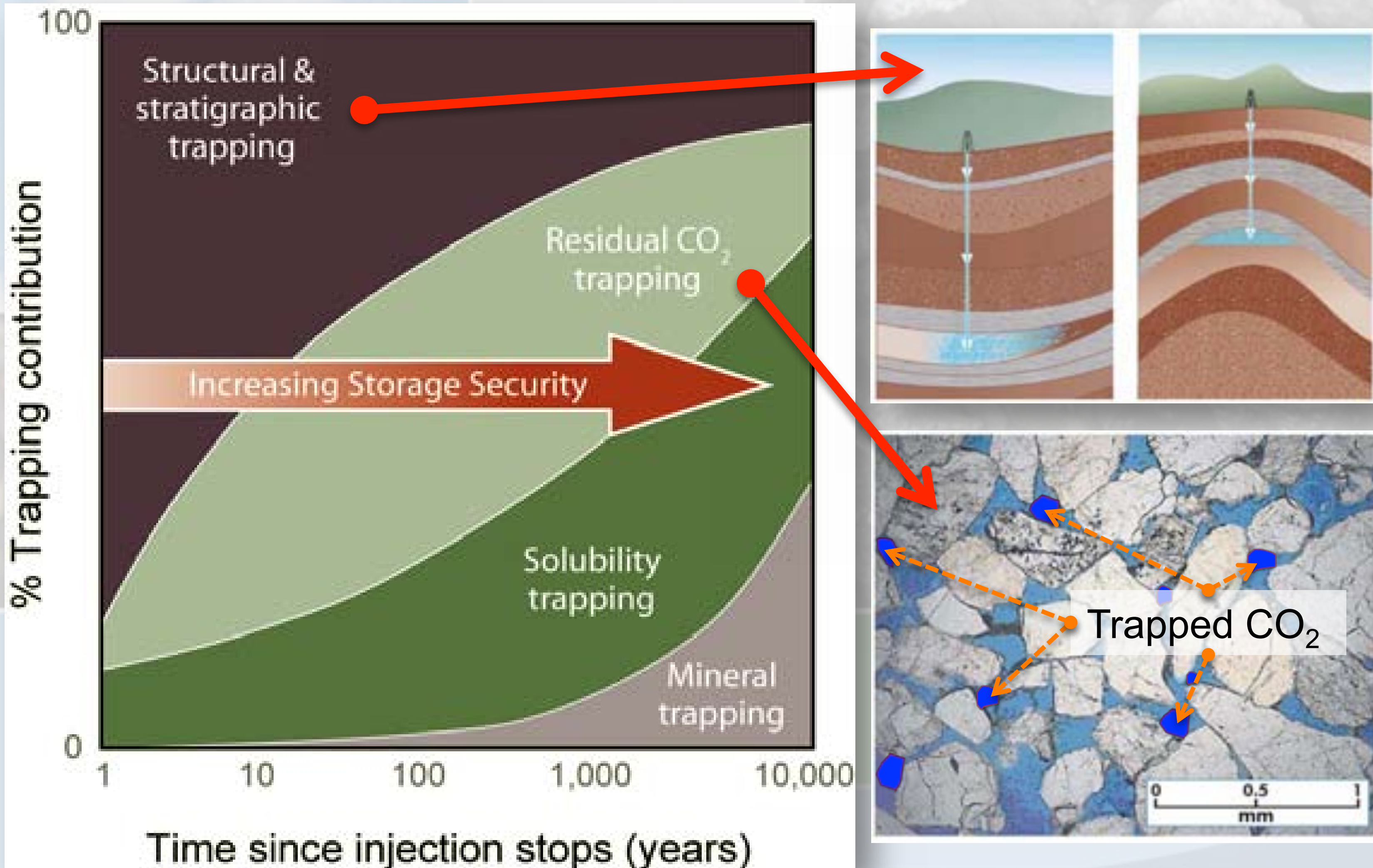


Liquid CO_2

What are the "Storage" options in CCS?

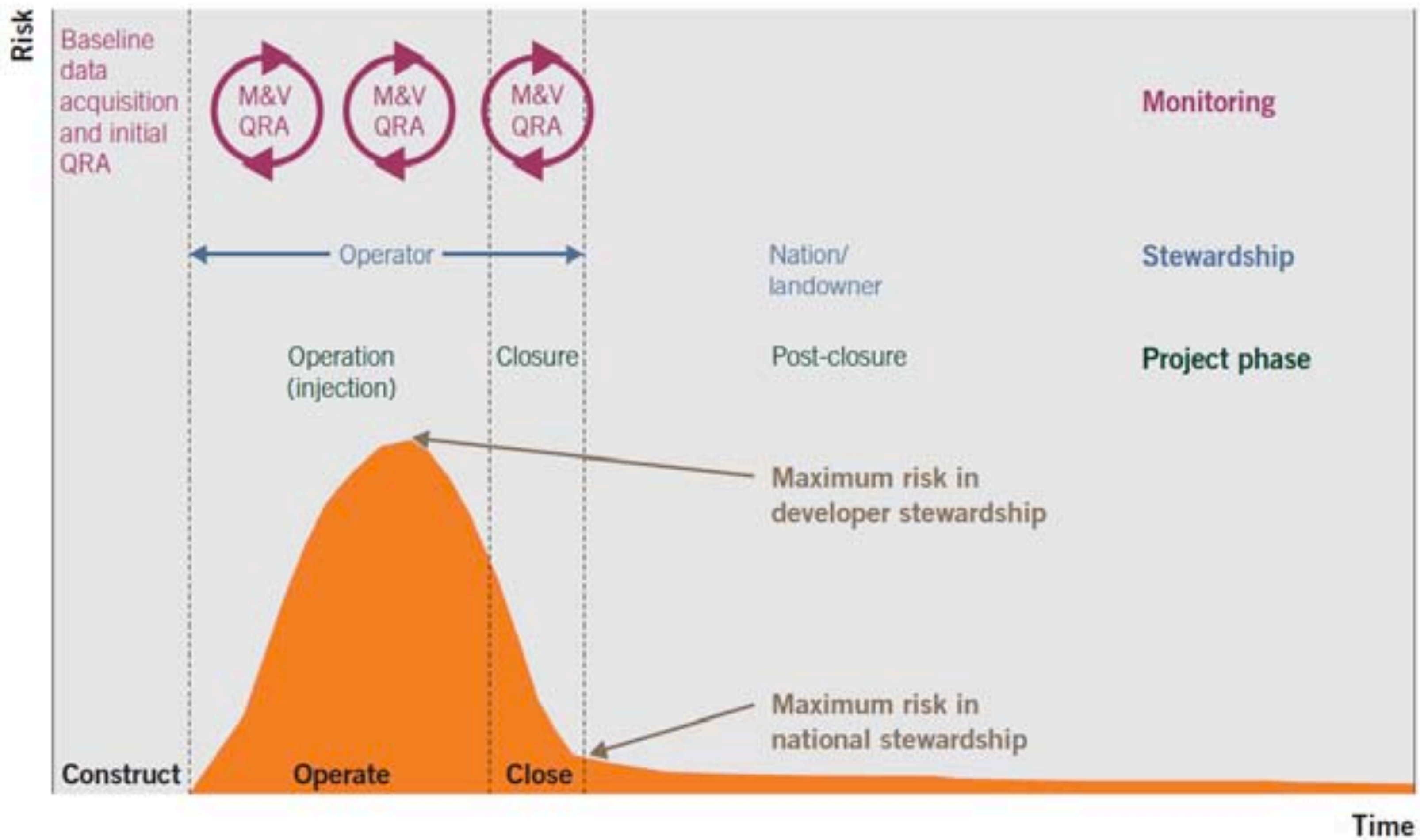


Contribution of Physical and Chemical Trapping Options over Time



Source: IPCC

Schematic Risk Profile for a Storage Project

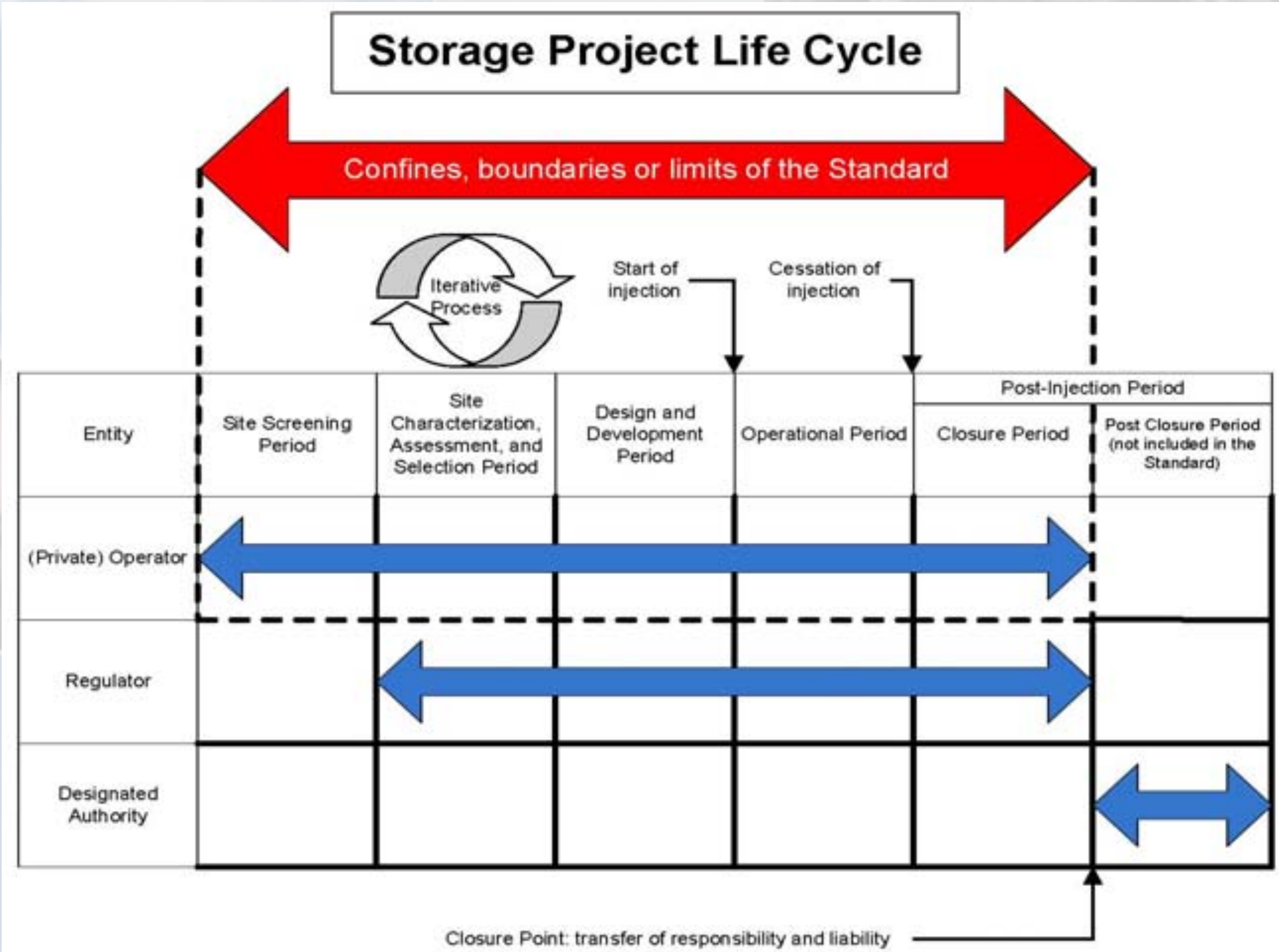


Note: Monitoring and verification (M&V) and quantified risk assessment (QRA)

Source: Wright (2011), based on In Salah

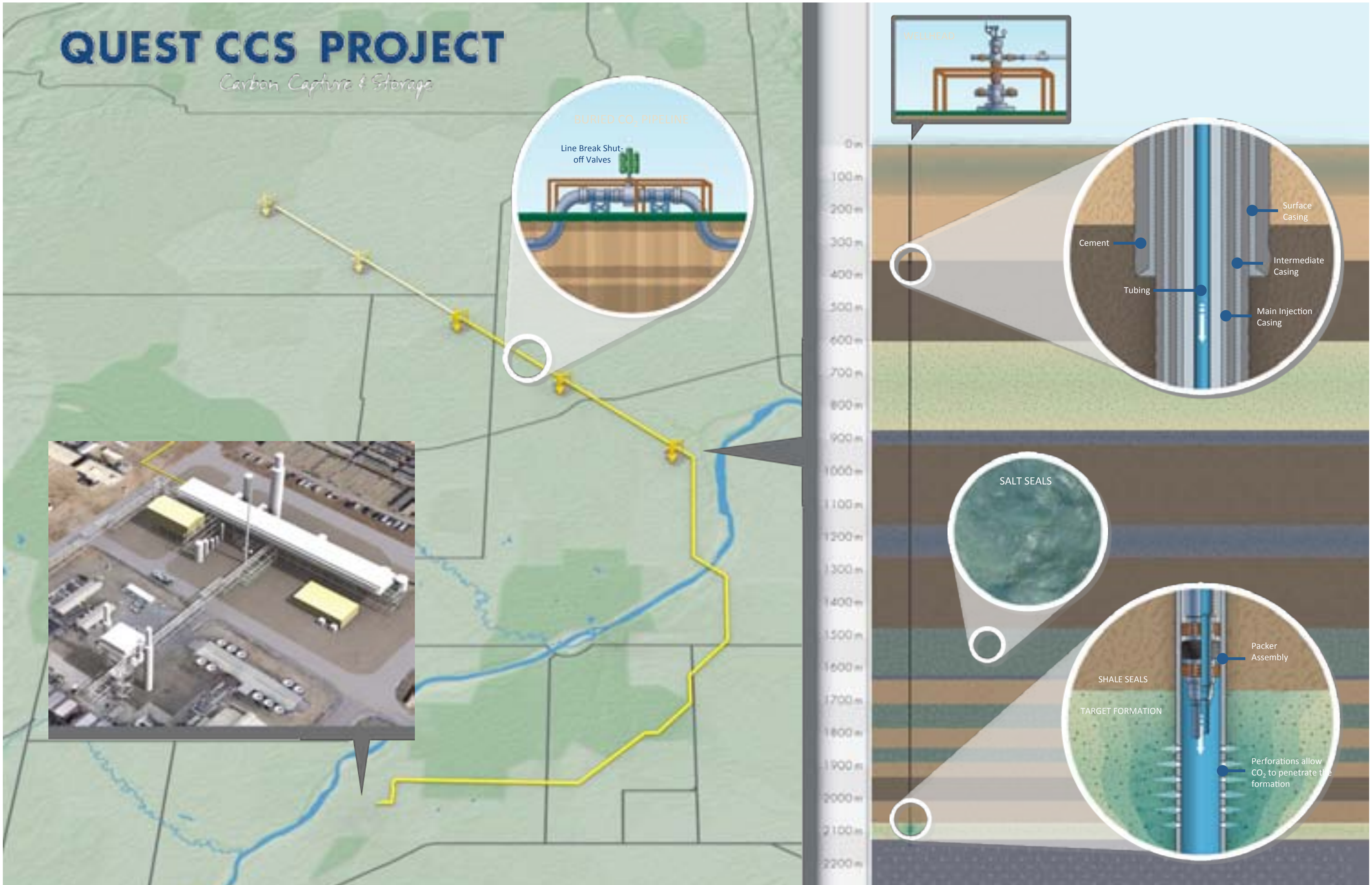
Global CCS Institute 2011, The global status of CCS: 2011, Canberra, Australia

Storage Project Life Cycle in CSA Geological Storage Standard



$2B Investment in CCS in Alberta

- Shell QUEST CCS Project
- TransAlta Project Pioneer
- Enhance Energy – Alberta Carbon Trunk Line
- Swan Hills Synfuels



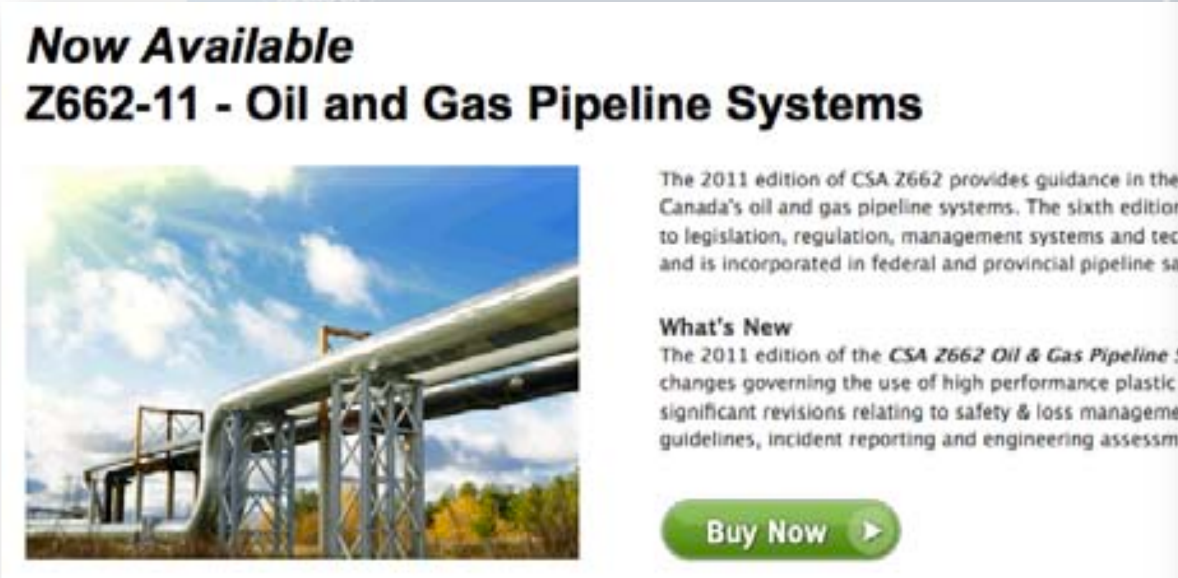
Alberta
Freedom To Create. Spirit To Achieve.

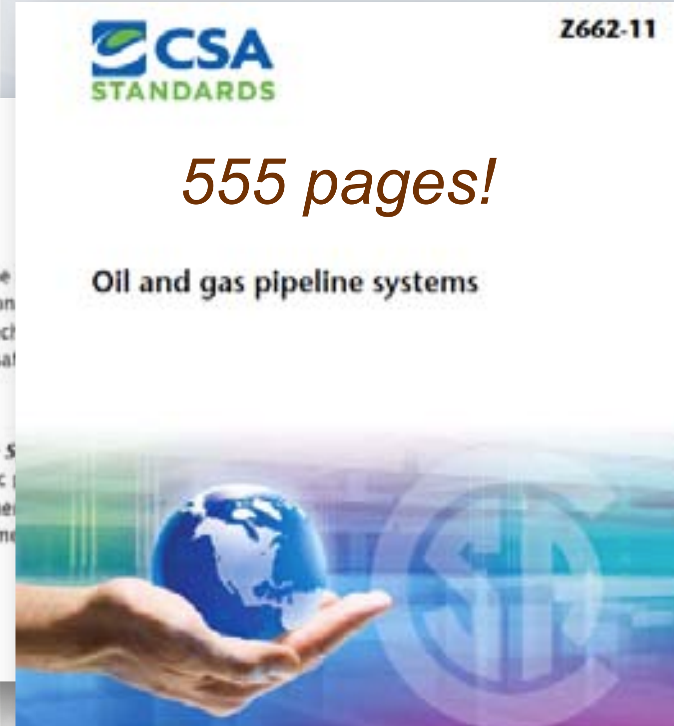
Government of Alberta

Questions about CO_2 Pipelines

- CO_2 in pipeline will be compressed, i.e., under pressure
- Stringent standards and good practices can minimize risk:
  - New Canadian Standards Association specifications for pipes carrying CO_2 are due soon
  - Pipeline buried deep enough to avoid impact from farm machinery
  - 24-hour monitoring of the pipeline pressure
  - Suitable spacing of valves to shut off flow, to limit volume of CO_2 that could escape
  - Routine maintenance by internal inspection tools (pigging) to identify weakness on inside or outside of pipeline
- Does the project meet or exceed requirements for pipeline safety?

Pipeline Standards





Many ongoing research initiatives and Joint industry Projects

- Toughness requirements, material compatibility and corrosion behavior of steel pipes in presence of pure and less-pure CO_2
- Additional European work to refine recommended practices such "Design and Operation of CO_2Pipelines"
- Corrosion and stress corrosion issues in CO_2 pipelines
- Zero Emissions Platform (ZEP)

Questions about CO_2 Pipelines

- **Risk of small leak around valves – reduced by maintenance checks, but**
  - What would happen to the pipe in the case of a small leak?
  - Would one see difference in vegetation growth?
  - Could one smell the leak (as result of some hydrogen sulphide in the pipe with the CO_2)?
- **Risk of landowner rupturing a pipeline when digging is very low, but if it were to happen**
  - What would it look like?
  - What should the landowner do?
  - What is the health risk?

Release of CO_2 – What does it look like? CO2 pipeline, Jackson Dome, MS

Normal Venting from CO2 well operations

From 1986 to 2006:

- 12 leaks from CO_2 pipelines and
- No injuries or fatalities

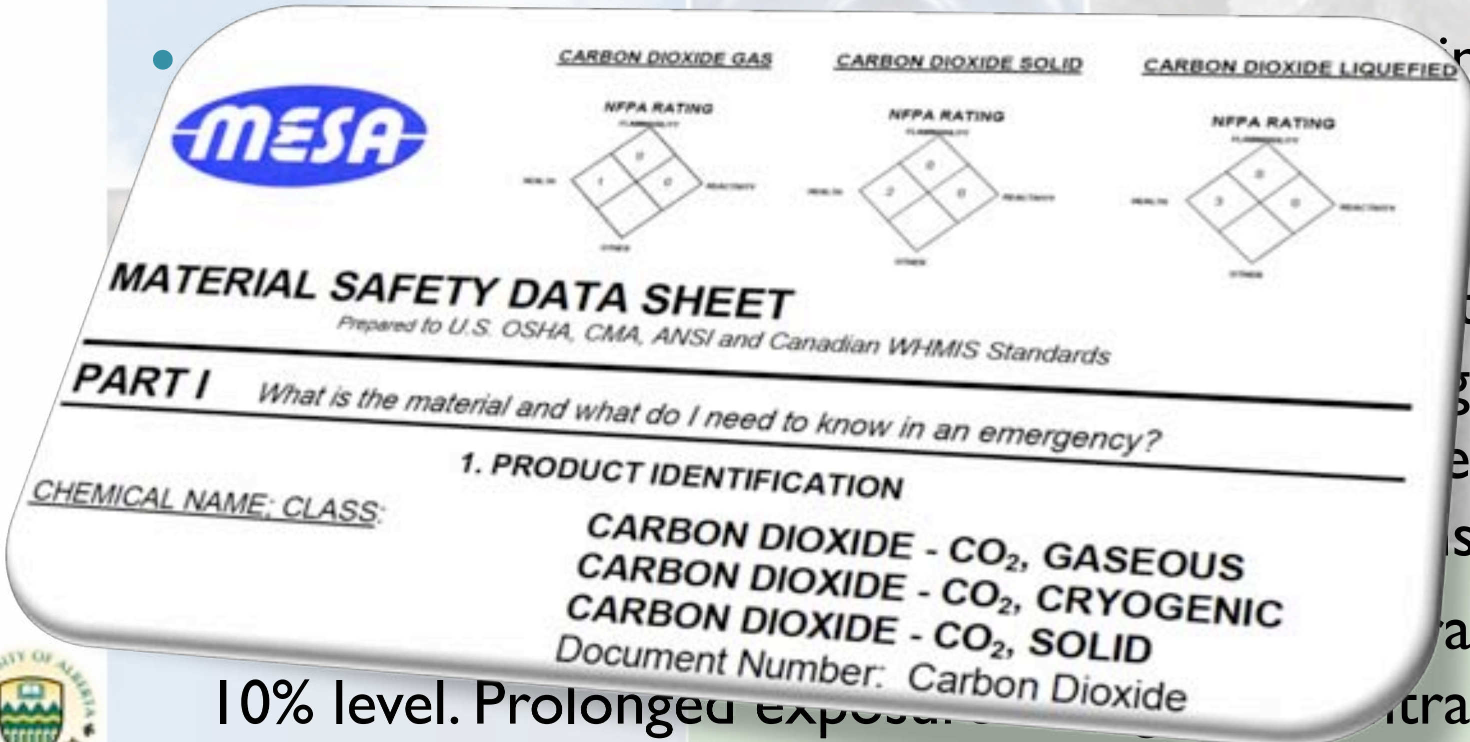
From: Risk and Monitoring Risk for CO2 Sequestration in Deep Brine Reservoirs

GCCC Digital Publication Series #08-03l
By Ian J. Duncan

Release of CO_2 – What does it look like?

What is the Health Risk? Effects of Exposure to CO_2

- 30,000 ppm (3%) Breathing increases to twice normal rate, and a person would experience impaired hearing, headache, and increased blood pressure.
- …imately four …ome evident
- …t this level a …, headache, …ent may be …sciousness.
- …rapidly above 10% level. Prolonged expos… …tration could eventually result in death from asphyxiation.


MESA

CARBON DIOXIDE GAS | CARBON DIOXIDE SOLID | CARBON DIOXIDE LIQUEFIED

NFPA RATING | NFPA RATING | NFPA RATING

MATERIAL SAFETY DATA SHEET

Prepared to U.S. OSHA, CMA, ANSI and Canadian WHMIS Standards

PART I *What is the material and what do I need to know in an emergency?*

1. PRODUCT IDENTIFICATION

CHEMICAL NAME; CLASS:

CARBON DIOXIDE - CO_2, GASEOUS
CARBON DIOXIDE - CO_2, CRYOGENIC
CARBON DIOXIDE - CO_2, SOLID

Document Number: Carbon Dioxide

Concentrations of Concern for CO_2

Exposure Limit for Carbon Dioxide	Concentration	Exposure Period
OSHA PEL	5,000 ppm	Time weighted average concentration for 8-hour work day
ACGIH TLV	5,000 ppm	Time weighted average concentration for normal 8-hour work day or 40-hour work week
OSHA STEL	30,000 ppm	Maximum concentration for 15-minute period (maximum of 4 periods per day with at least 60 minutes between exposure periods)
NIOSH IDLH	40,000 ppm	The maximum level to which a healthy individual can be exposed to a chemical for 30 minutes and escape without suffering irreversible health effects or impairing symptoms

Notes:

ACGIH = American Conference of Governmental Industrial Hygienists
IDLH = Immediately Dangerous to Life or Health
NIOSH = National Institute for Occupational Safety and Health
OSHA = Occupational Safety & Health Administration
PEL = Permissible Exposure Limit
ppm = parts per million
STEL = Short Term Exposure Limit
TLV = Threshold Limit Value

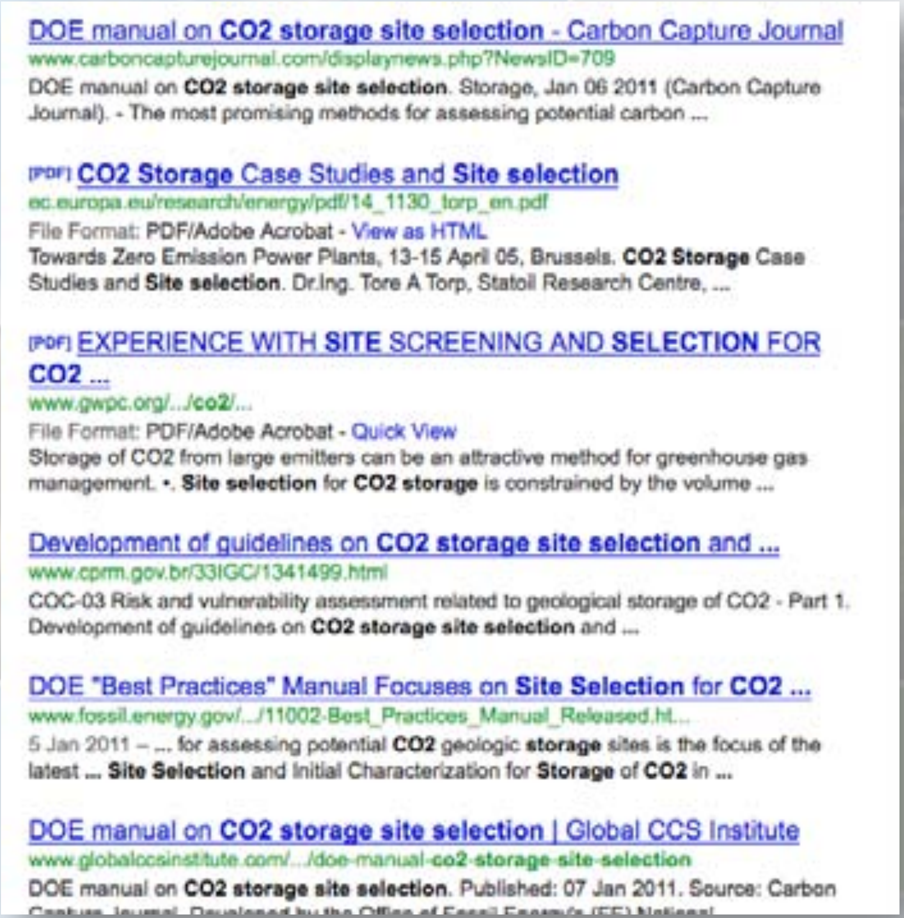
CARBON DIOXIDE PIPELINE RISK ANALYSIS
HECA Project Site
Kern County, California
By URS Corporation

Questions about CO_2 Storage

- **Careful selection of the storage location can reduce risk, for example:**
    - At least 1 km deep saline formation
    - No penetrating oil or gas wells (or thorough check on integrity of any existing well casings, etc.)
    - No evidence of natural faults
    - Several formations acting as caps to hold CO_2 in place
  - Does the Project meet or exceed these requirements?
- **Risk is reduced by meeting or exceeding regulations re injection well construction, injection pressures, etc.**
  - Will the Company be meeting or exceeding regulatory requirements for well construction?
  - What controls will be in place to ensure that injection pressures are not too high (to avoid the risk of creating fractures in the formation)?

CO_2 "Careful" Storage Site Selection

Google Search "CO_2 Storage Site Selection"…..


DOE manual on **CO2 storage site selection** - Carbon Capture Journal
www.carboncapturejournal.com/displaynews.php?NewsID=709
DOE manual on **CO2 storage site selection**. Storage, Jan 06 2011 (Carbon Capture Journal). - The most promising methods for assessing potential carbon ...

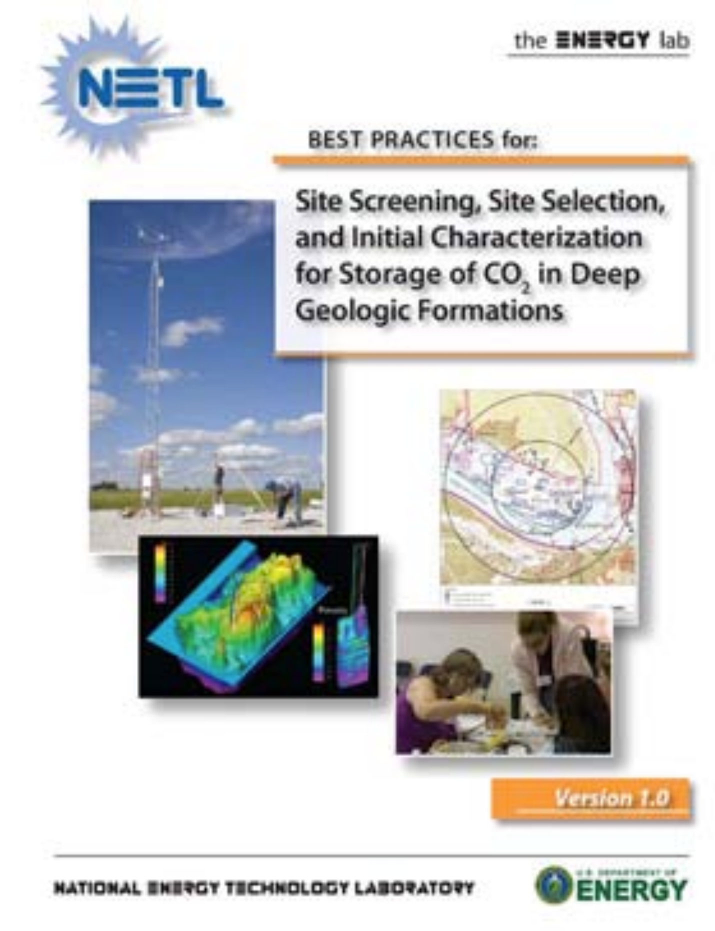
[PDF] **CO2 Storage** Case Studies and **Site selection**
ec.europa.eu/research/energy/pdf/14_1130_torp_en.pdf
File Format: PDF/Adobe Acrobat - View as HTML
Towards Zero Emission Power Plants, 13-15 April 05, Brussels. **CO2 Storage** Case Studies and **Site selection**. Dr.Ing. Tore A Torp, Statoil Research Centre, ...

[PDF] EXPERIENCE WITH **SITE** SCREENING AND **SELECTION** FOR **CO2** ...
www.gwpc.org/.../co2/...
File Format: PDF/Adobe Acrobat - Quick View
Storage of CO2 from large emitters can be an attractive method for greenhouse gas management. •. **Site selection** for **CO2 storage** is constrained by the volume ...

Development of guidelines on **CO2 storage site selection** and ...
www.cprm.gov.br/33IGC/1341499.html
COC-03 Risk and vulnerability assessment related to geological storage of CO2 - Part 1. Development of guidelines on **CO2 storage site selection** and ...

DOE "Best Practices" Manual Focuses on **Site Selection** for **CO2** ...
www.fossil.energy.gov/.../11002-Best_Practices_Manual_Released.ht...
5 Jan 2011 – ... for assessing potential **CO2** geologic **storage** sites is the focus of the latest ... **Site Selection** and Initial Characterization for **Storage** of **CO2** in ...

DOE manual on **CO2 storage site selection** | Global CCS Institute
www.globalccsinstitute.com/.../doe-manual-co2-storage-site-selection
DOE manual on **CO2 storage site selection**. Published: 07 Jan 2011. Source: Carbon



EU Directive on CCS

Directive issued in late 2009 and Guidance documents issued in 2011

Characterization of the Storage Complex

…

2.3 Different storage categories – key issues
2.4 Initial Assessment at Regional/Country Level
2.5 Screening
2.6 Data Collection for Characterization of the Storage Complex and Surrounding Area
- *2.6.2.1 Geology and Geophysics*
- *2.6.2.2 Hydrogeology*
- *2.6.2.3 Reservoir Engineering and Petrophysics*
- *2.6.2.4 Geochemistry*
- *2.6.2.5 Geomechanics*
- *2.6.2.6 Seismicity*
- *2.6.2.7 Natural and Man-Made Pathways*
- *2.6.2.8 Surface Studies*
- *2.6.2.9 Adjacent Population Distributions*
- *2.6.2.10 Natural Resources*
- *2.6.2.11 Interactions with other Sub-surface Activities*
- *2.6.2.12 CO2 Source: Proximity and Supply Volumes*

2.7 Building the Three-Dimensional Static Geological Earth Model
2.8 Characterization of the Dynamic Behaviour and Sensitivity
2.9 Risk Assessment

4. Monitoring

Figure 4: Proposed approach for CA to determine an acceptable CO2 stream

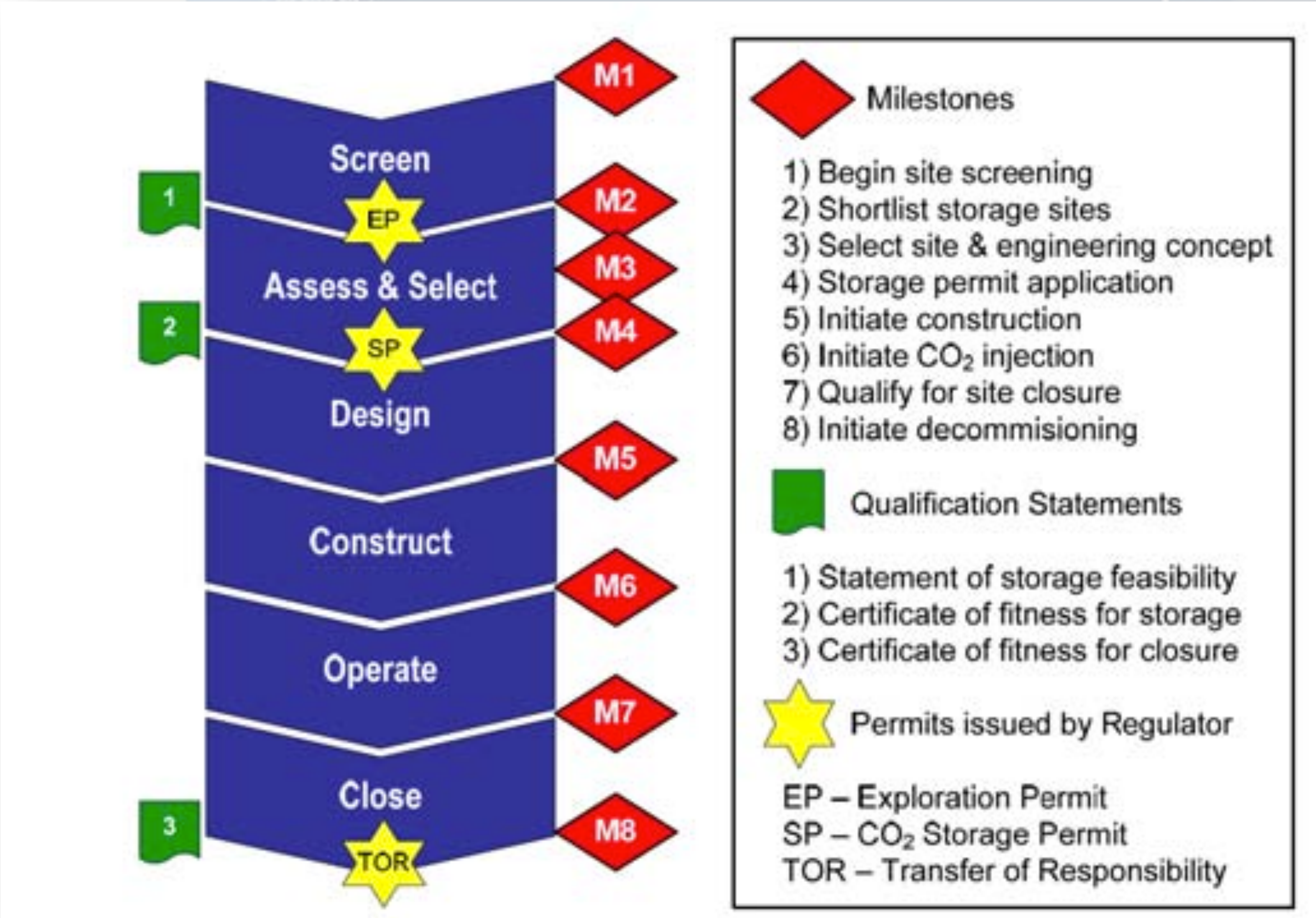
Figure 6 Different methods and techniques suitable for monitoring

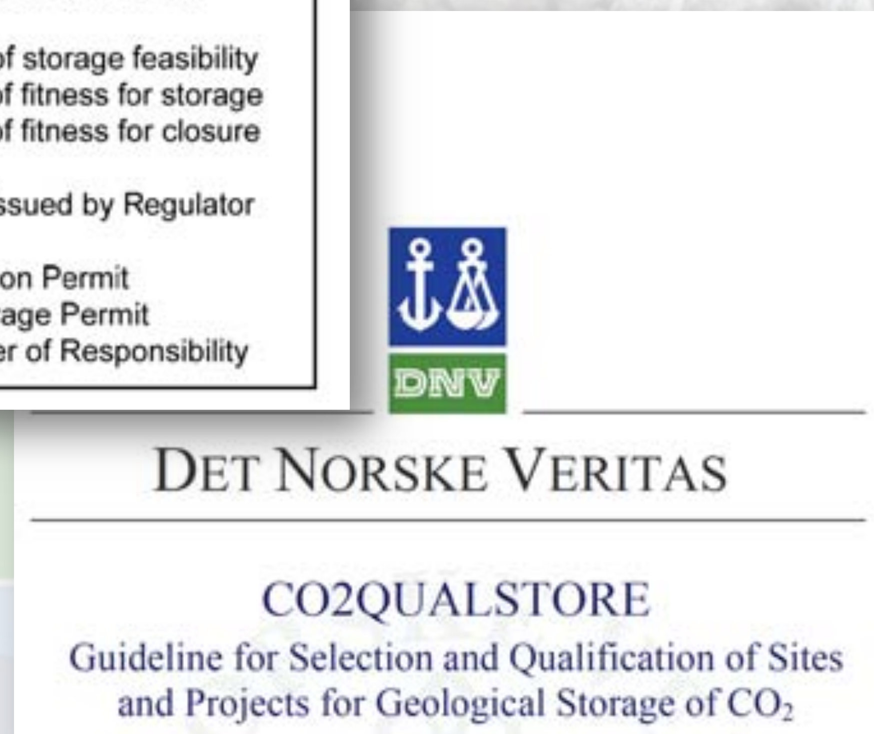
Operational	Plume	Pathways	Environmental Onshore	Environmental Offshore
• **Injection Operations** • Wellhead pressure • Formation pressure and temperature • Injection rate • Microseismicity • **Quantification of CO_2 injected** • Mass flow • Composition and phase	• Pressure and temperature • Geophysics • Well logging (CO_2 saturation) • Surface deformation methods • Tiltmeter • InSAR • Water properties	• **Wells** • Annulus pressure • Corrosion • Cement • Logging • Soil gas • **Caprock** • Formation pressure • **Faults & Fractures** • Microseismicity • Pressure interference • **Aquifers** • Water monitoring • Chemistry	• **Leak Detection** • Sampling and geochemical analysis • Seismic • pressure interference • Soil gas • Vegetation stress • Eddy covariance tower • **Leak Quantification** • Soil gas • Surface gas measurement • ... • **Impact: HSE Monitoring** • CO_2 Concentration • Water sampling/analysis • Soils acidity • Surface deformation • Ecosystems surveys	• **Leak Detection** • CO2 flux and concentration monitoring • Water sampling and geochemical analysis • High resolution geophysics • Seismic • **Leak Quantification** • Flux gas measurement • ... • **Impact: HSE Monitoring** • CO_2 Concentration • Water sampling/analysis • Ecosystems surveys

Overall Workflow – EU CCS Directive

Data Collection	3D Static Geological Model	Dynamic Modelling	Sensitivity Characterisation	Risk Assessment
Sufficient to construct 3D static geological model for site and complex	Characterisation of Storage Site and Complex	Assess Dynamic behaviour of site and complex due to CO_2 injection	Assess sensitivity of the assessment to changes in assumptions	Assessment of safety and Integrity of Site and Complex
• Geology and geophysics • Hydrogeology • Reservoir Engineering • Geochemistry • Geomechanics • Seismicity • Natural and man-made leakage pathways • Field Studies o Surface Studies o Population Distributions o Natural Resources o Interactions with other activities o Proximity to potential sources, supply volumes, and transport networks	• Geological structure mapping • Geomechanical, geochemical, and flow properties of overburden and surrounding formations • Fracture system characterisation • Areal and vertical extent of complex • Pore space volume • Baseline fluid distribution • Fault and seal integrity	• Injection rates and CO2 stream properties • Coupled processes modelling • Reactive processes • Reservoir simulator used • Short and long term simulations	• Alter parameters of models to determine sensitivity	• Hazards characterisation • Exposure Assessment • Effects assessment • Risk characterisation

CO2 Storage Site Selection




DNV

DET NORSKE VERITAS

CO2QUALSTORE

Guideline for Selection and Qualification of Sites and Projects for Geological Storage of CO_2

What about in Canada?

- **ERCB Directives**
  - Directive 56 – CO2 pipeline
  - Directive 65 – CO2 Acid Gas Injection

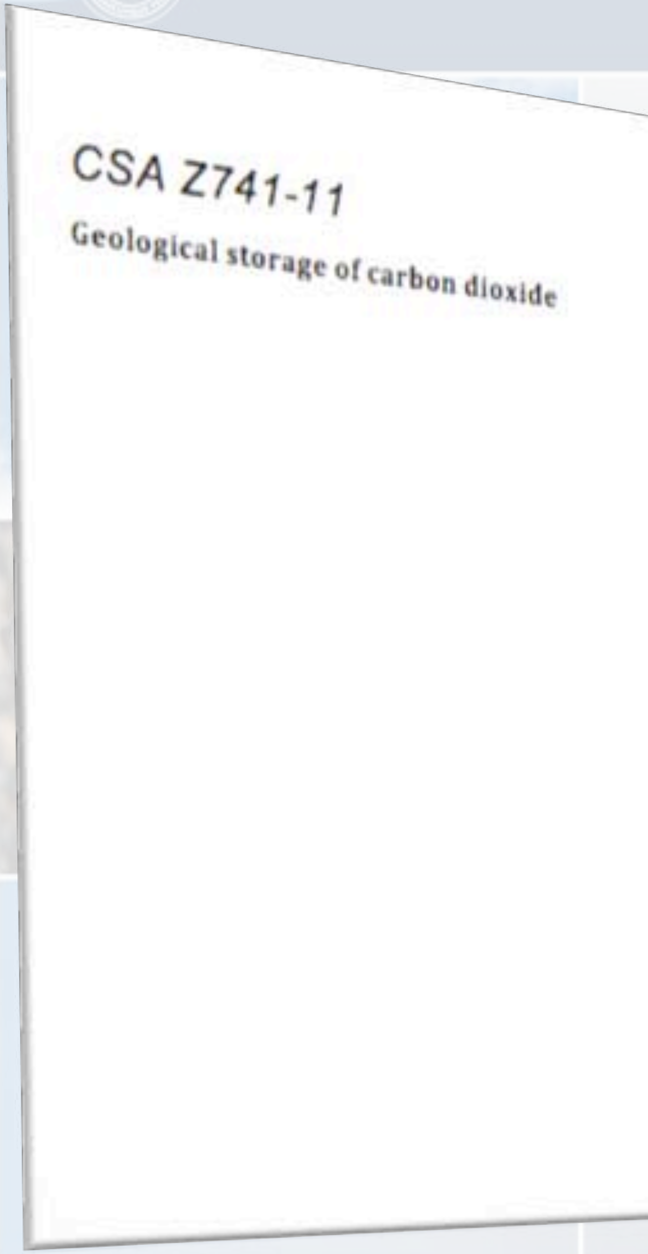
We don't yet have a specific regulation for CO_2 storage (but its coming). The ERCB uses existing regulations (as noted above) and writes detailed conditions into project-specific approvals AND we have the *Carbon Sequestration Tenure Regulation Act*

  - Alberta undergoing Regulatory Framework Assurance process
  - CSA Technical Committee developing a Standard for the Geological Storage of CO_2

Regulatory Framework Assessment - CCS

To ensure CCS projects are designed and operated in a safe and responsible way, the Government of Alberta is reviewing existing regulations through the Regulatory Framework Assessment. As part of this process, CCS experts from Alberta and around the world are examining in detail the technical, environmental, safety and monitoring requirements that apply at every stage of a CCS project.

CSA Z741-11 (..Under Review)


CSA Z741-11

Geological storage of carbon dioxide

Table of Contents

1 Scope

2 Reference publications and definitions

3 Management systems

4 Site screening, selection, and characterization

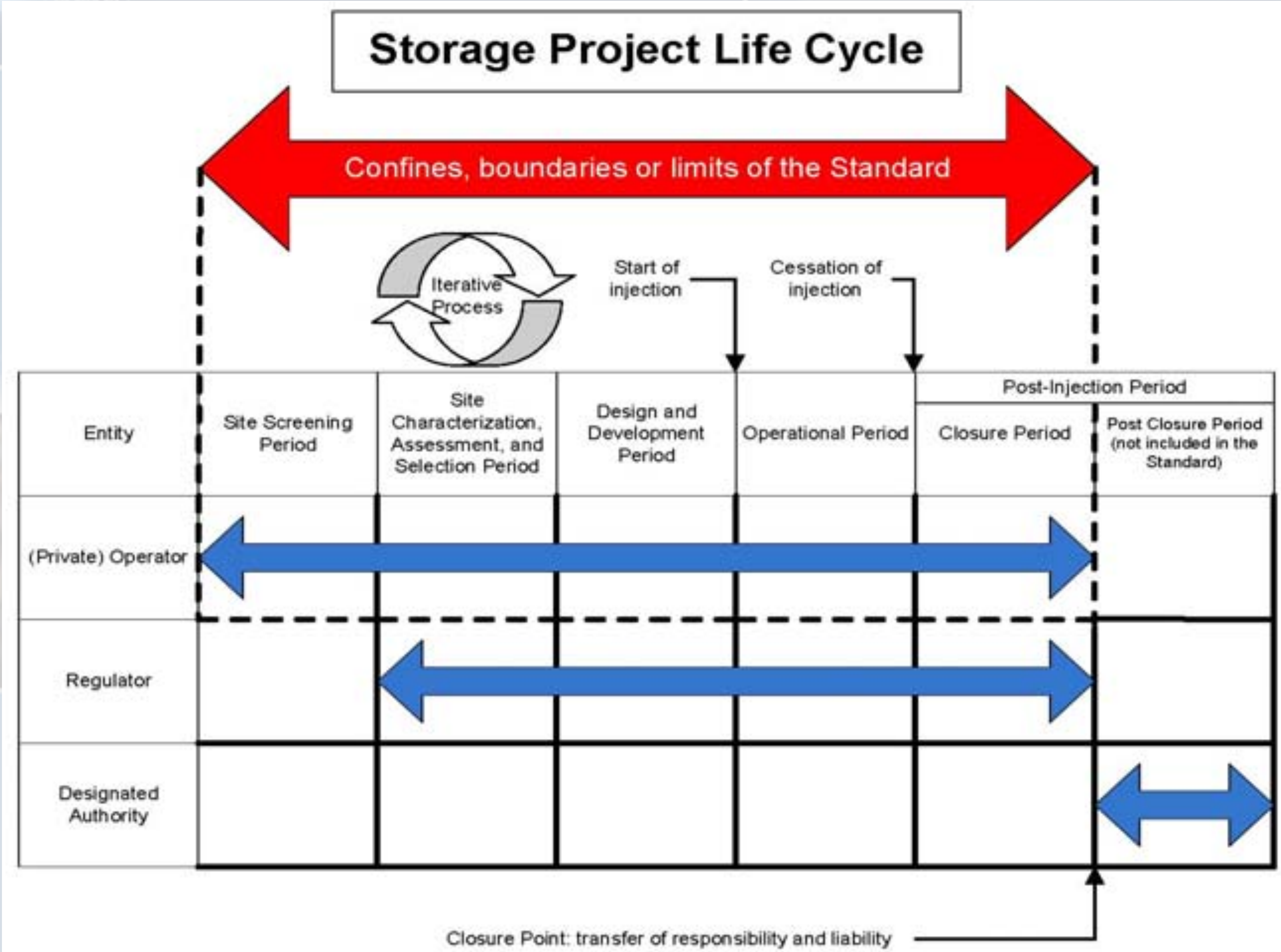
5 Risk management

6 Well infrastructure development

7 Monitoring and verification

8 Cessation of injection

Scope (Under Review)



CSA Standards Terminology

- "shall" is used to express a requirement, i.e., a provision that the user must satisfy in order to comply with the standard;
- "should" is used to express a recommendation or that which is advised but not required;
- "may" is used to express an option or that which is permissible within the limits of the standard; and
- "can" is used to express possibility or capability.

Shall's and Should's in Site Characterization

4.4.2 Geological and hydrogeological characterization of the storage unit

A geological and hydrogeological characterization of the storage unit to provide a reasonable estimate of capacity, injectivity, and containment shall be completed before injection of the CO_2 stream and should include

(a) assessment of the lateral and vertical stratigraphic and lithological properties of the storage unit to determine the extent of the storage unit and establish its boundaries. Available data from wellbores, geophysical data, facies analysis, and regional geological studies should be used for this purpose;

(b) identification and characterization of fault zones and structural features that could affect containment. 2-D and 3-D seismic and geophysics techniques should be used to identify any faults and structural anomalies. The locations of such features should be identified using the wireline log analyses, core analyses, and hydrogeological analyses described in Clause 4.4.2 (b) (e.g., comparison of flow

4.4.3.1 Primary seal (caprock)

The sealing capacity of the primary seal (caprock, or aquitard or aquiclude) shall be evaluated and qualified prior to injection of the CO_2 stream to provide adequate confidence in containment of the stored CO_2 stream. A detailed characterization of the primary seal (caprock, or aquitard or aquiclude) shall be performed and include

(a) a determination of the stratigraphy, lithology, thickness, and lateral continuity of the caprock. This should be based on data obtained from wireline logs, coring of the caprock, or other suitable means;

(b) evaluation of caprock integrity. The integrity of the caprock should be determined by taking core samples from the caprock and testing it for vertical permeability and mechanical strength, or by other suitable means. The presence and extent of micro-fractures in the caprock should also be

History and Scope of GSC TC

- Stakeholders saw a need for standardization
- IPAC-CO2 (a federal, provincial and industry funded organization) and CSA Standards offered solution
- Bi-national standard to reduce differences
- Need for international standards

MATRIX

CODE	MIN	MAX	ACTUAL	DESCRIPTION
GI	8	11	11	General Interest
OP	7	9	7	Owner/Operator/Producer
GR	5	7	6	Government/Regulatory
SC	6	9	6	Supplier/Contractor/Consultant

CATEGORIES AND MEMBERS

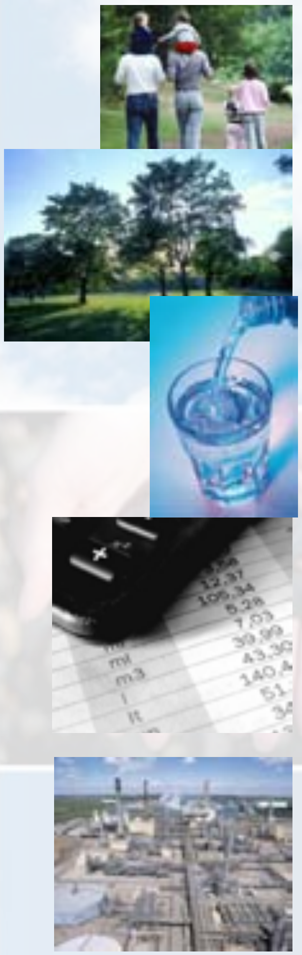
GI	OP	GR	SC
Stefan Bachu	Mike Blincow	Joe Kelly	Jorg Aarnes
Michael Celia	Kyle Durocher	Herb Longworth	Richard Baker
Rick Chalaturnyk	Richard Esposito	Bettina Mueller	Steve Carpenter
Ian Duncan	Allan Greeves	Mike Nickolaus	K. Hnottavange-Telleen
Sarah Forbes	Wayne Hillier	Richard Slocomb	Ron Sweatman
Philip Gass	Scott Imbus	Jimmy Sparks	Charlie Voss
Bill Gunter	Shane McLellan		
Mike McCormick			
Sean McCoy			
Bob Page			
Steve Whittaker			

Associate Members - Scott Anderson, Onorio Cicchini, Mark de Figueiredo, M. Fesmire, Peter Warwick
Working Group Members - Kevin Heal, Kevin Hein, Jim Kirksey, Nino Ripepi, Jim Sorensen

Vision for the Standard

- Gain public and regulator confidence in the geological storage of CO2 for mitigation
- Facilitate adoption of GSC projects
- Encapsulate current knowledge in a format that can be used to demonstrate due diligence

WRI CCS Guiding Principles



1. Protect human health and safety
2. Protect ecosystems
3. Protect underground sources of drinking water and other natural resources
4. Ensure market confidence in emissions reductions through proper GHG accounting
5. Facilitate cost-effective, timely deployment

Best Practices Manuals . . . .

	Pre-feasibility	Site Selection	Capacity Estimation	Simulation and Modelling	Construction	Operation	Closure	Monitoring and Verification	Risk Assessment	Community Consultation	Regulation
SACS	Basic	Technical	Technical	Technical	-	Basic	Detailed	Technical	Detailed	Basic	Basic
NETL (SS)	Basic	Detailed	Technical	Basic	-	-	-	-	Basic	Basic	Detailed
NETL (RA)	-	-	-	Technical	-	-	-	-	Technical	-	-
NETL (MV)	-	-	-	-	-	Technical	Technical	Technical	Basic	-	Basic
NETL (GS)	Technical	Technical	-	-	-	-	-	-	-	-	-
NETL (PO)	-	-	-	-	-	-	-	-	-	Technical	-
WRI (CCS)	Basic	Detailed	Basic	Basic	Basic	Basic	Detailed	Detailed	Detailed	Basic	Detailed
WRI (CE)	Basic	Basic	-	-	Basic	Basic	Basic	Basic	-	Detailed	Basic
DNV	Detailed	Detailed	Detailed	Basic	-	Detailed	Detailed	Basic	Detailed	-	Detailed
CO2Cap	-	Basic	Basic	-	Detailed	Detailed	Basic	Technical	Basic	-	-
GEOSEQ	-	Basic	Basic	Basic	-	-	-	Detailed	-	-	-
CO2NET	-	Basic	Basic	Basic	-	Basic	-	Basic	-	-	-
IEA	-	-	-	-	-	-	-	-	-	-	Technical
CO2Cap (R)	-	-	-	-	-	-	-	-	-	-	Technical

-	Not covered
Basic	Briefly covered in a generic way
Detailed	Comprehensive discussion, generally generic
Technical	Provides technical detail of projects, generally comprehensive

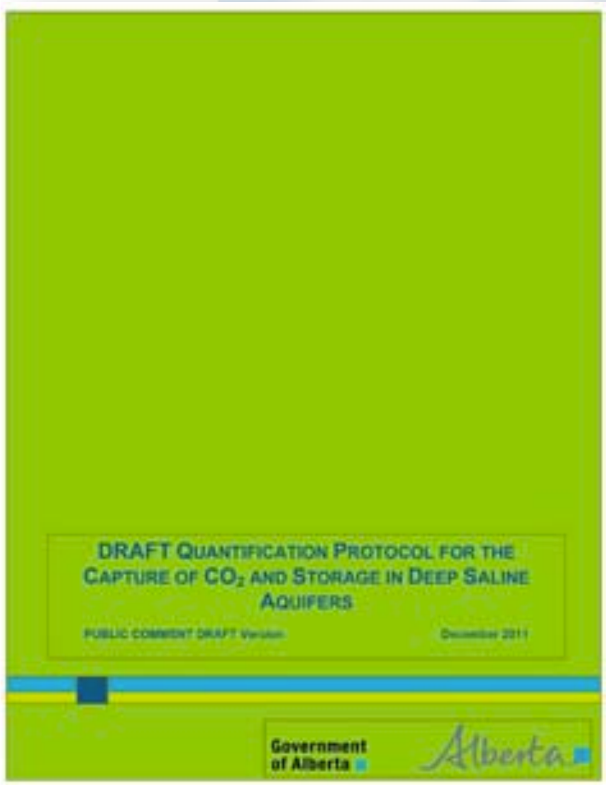
NETL (SS)	Best Practices for: Site screening, site selection, and initial characterization for storage of CO_2 in deep geologic formations
NETL (RA)	Risk analysis and Simulation for geologic storage of CO_2
NETL (MV)	Best Practices for: Monitoring, verification, and accounting of CO_2 stored in deep geologic formations
NETL (GS)	Best Practices for: Geologic storage formation classification: Understanding its importance and impacts on CCS opportunities in the United States
NETL (PO)	Best Practices for: Public outreach and education for carbon storage projects
WRI (CCS)	Guidelines for CCS
WRI (CE)	Guidelines for community engagement in CCS

CO2CRC, 2011. A Review of Existing Best Practice Manuals for Carbon Dioxide Storage and Regulation, 7p.

Already a number of guidelines, best practices, regulations out there; why a standard?

- **This is when standards are often written**
- **A key purpose is to;**
  - Harmonize (reduce contradictions & differences)
  - Simplify (single reference)
  - Improve (new learning)
  - Clarify as requirements (show compliance with BPs, language that regulators and others know)
- **What can people agree to**
- **Doesn't necessarily replace**
- **Mainstream (leading experts may not need standards; others do)**

Quantification Protocol for Capture of CO_2 & Storage in Deep Saline Aquifers - DRAFT


DRAFT QUANTIFICATION PROTOCOL FOR THE CAPTURE OF CO_2 AND STORAGE IN DEEP SALINE AQUIFERS

PUBLIC COMMENT DRAFT Version

December 2011

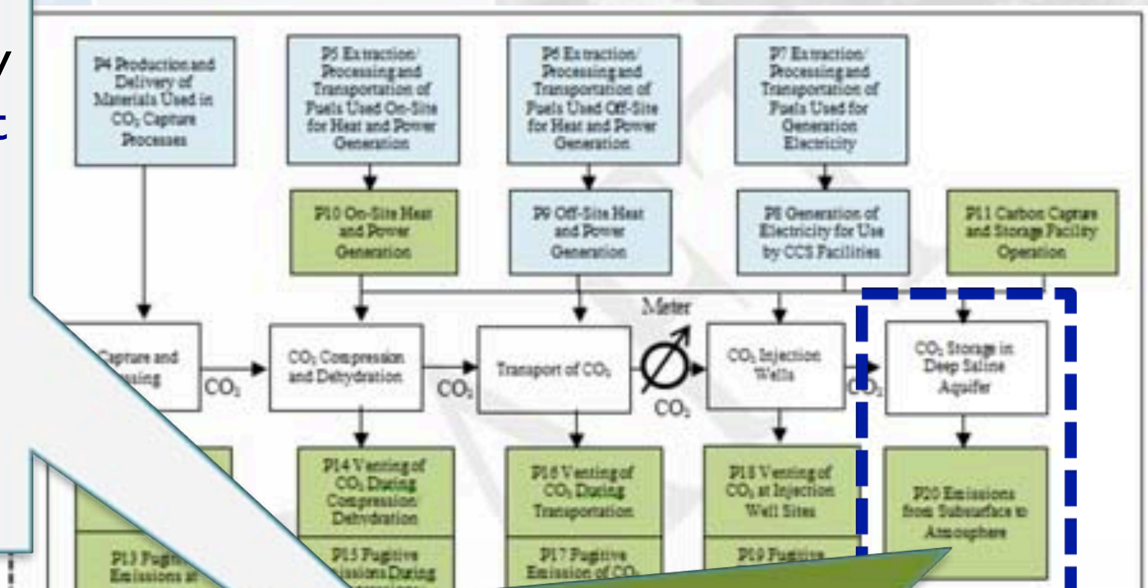
Government of Alberta

Alberta

- Opportunity for generating carbon offsets with this protocol arises from the direct disposal of CO_2 from a previous source of emissions, into deep saline aquifers.
- A typical carbon capture and storage project applicable to this protocol consists of three main components:
  - CO_2 capture infrastructure
    - separate from the industrial facilities which operate the primary process, such as steam methane reforming for hydrogen production
    - applies a CO_2 capture technology that uses a chemical solvent.
  - CO_2 pipeline to transport CO_2 from the capture facility to the injection well(s).
  - CO_2 disposal through injection wells and into deep saline aquifers.

Quantification Protocol for Capture of CO_2 & Storage in Deep Saline Aquifers - DRAFT

Estimation would be required for reporting to the regulatory authority. Direct measurement is likely not possible, but the use of engineering estimates and uncertainty would be a reasonable approach in the event leakage occurs.



P19 Fugitive Emissions at Injection Well Sites	Unintended leaks of gas at the CO_2 injection … may occur through valves, flanges, pipe connections, mechanical seals or related equipmen… …pected that the gas will be composed of CO_2 with trace amounts of other gases.	Related
P20 Emissions from Subsurface to Atmosphere	Accidental emissions may occur by way of gas migratio… …gh undetected faults, fractures and/or subsurface equipment (due to compromised casing/ce… …ellhead or packer/tubing) to atmosphere.	Related

P20 Emissions from Subsurface to Atmosphere	$Emissions_{Subsurface\ to\ Atmosphere} = Mass\ CO_{2\ leaked}$					
	Mass of CO_2 leaked from the Subsurface to Atmosphere/ Mass $CO_{2\ leaked}$	kg	Estimated	If a leakage event occurs, the mass of CO_2 leaked from the subsurface to the atmosphere shall be estimated with a maximum overall uncertainty over the reporting period of ±7.5%. In case overall uncertainty of the applied quantification approach exceeds ±7.5%, an adjustment shall be applied. Refer to Appendix D for further guidance.	N/A	Estimation would be required for reporting to the regulatory authority. Direct measurement is likely not possible, but the use of engineering estimates and uncertainty would be a reasonable approach in the event leakage occurs.

Applicability of Protocol - Storage

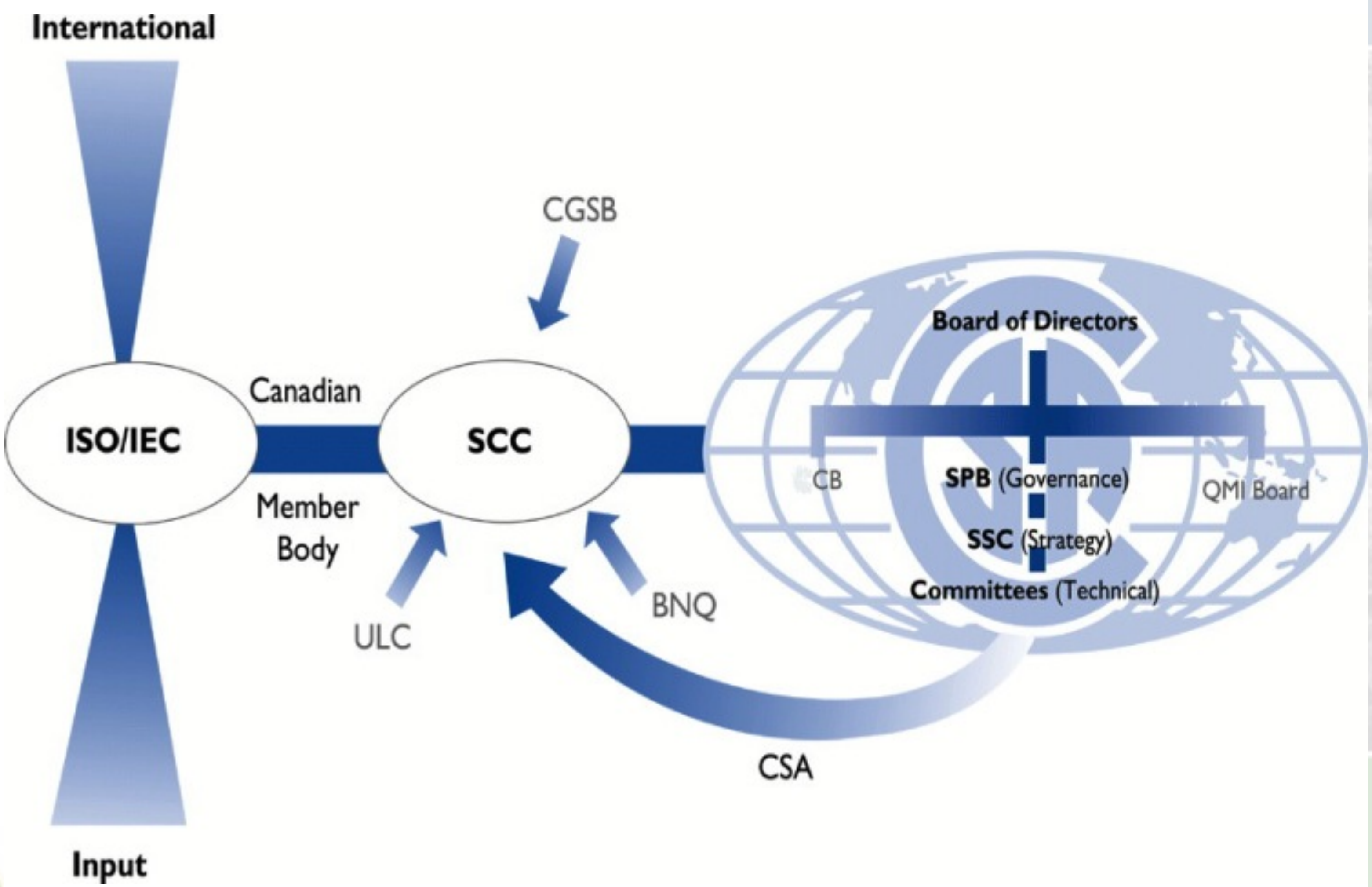
- Injection in deep saline aquifers capable of permanently storing CO_2 emissions. For each specific project, the applicant must have both:
  - Approved Carbon Sequestration Lease(s) in accordance with the *Mines and Minerals Act* and the *Carbon Sequestration Tenure Regulation* as issued by the Governme[...]ta; and

nd

d

The ERCB sets out several administrative details and processes such as requiring permit and lease holders to determine storage site suitability as well as submit monitoring, measurement and verification plans.

Harmonization-International



International Organization for Standardization

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- Processes and procedures
- Technical committees
  - Business plans
  - » List of ISO technical committees
  - Other bodies developing standards or guides
  - Participation by ISO members
  - Organizations in cooperation with ISO
  - Meeting calendar
- Maintenance agencies and registration authorities
- Standards under development
- Governance of technical work
- ISO eServices and IT Tools
- Supporting services
- Contacts for developers

TC 265

Carbon capture and storage (CCS)

- Secretariat: SCC
- Twinned secretariat: SAC
- Secretary: Mr. Jeff Walker
- Chairperson: vacant
- ISO Central Secretariat contact: Mrs. Kirsi Silander
- Creation date: 2011

- Work programme
  (drafts and new work items of TC 265)

- Business plan (TC)
- Working area on ISOTC and Public information folder

Scope:

Standardization of materials, equipment, environmental pla
and related activities in the field of carbon capture and stor

Excluded:

- equipment and materials used in drilling, production, tran

TC 265 - Carbon capture and storage (CCS)

- Participating countries: 13
- Observing countries: 12

Secretariat:

- Canada (SCC)
- China (SAC)

Participating Countries

- Australia (SA)
- France (AFNOR)
- Germany (DIN)
- Italy (UNI)
- Japan (JISC)
- Korea, Republic of (KATS)
- Netherlands (NEN)
- Norway (SN)
- South Africa (SABS)
- Switzerland (SNV)
- United Kingdom (BSI)

Observing Countries

- Argentina (IRAM)
- Brazil (ABNT)
- Czech Republic (UNMZ)
- Egypt (EOS)
- Finland (SFS)
- India (BIS)
- Iran, Islamic Republic of (ISIRI)
- New Zealand (SNZ)
- Serbia (ISS)
- Spain (AENOR)
- Sweden (SIS)
- USA (ANSI)

RG²

Leakage from Storage Questions

- **The risk of a leak may be very slight, but what could a Company do if CO_2 is found to be leaking:**
  - Into a shallower formation (but still contained by further cap rocks)?
  - Into groundwater or surface?
- **What would a release look like on the ground and how would it play out?**
  - What could residents do to protect themselves?
- **Does the risk of leakage decline over time?**

Three Basic Options

- **Reduce the pressure in the storage reservoir from which the leak is occurring;**
- **Increase the pressure in the geologic interval (generally a shallower reservoir) into which the leak is occurring; and**
- **Intercept the CO2 plume and extract the CO2 from the reservoir before it leaks, and, if possible, reinject CO2 into another formation.**

Remediation Options

Table 4. Remediation options for geological CO_2 storage projects (after Benson and Hepple, 2005).

Scenario	Remediation options
Leakage up faults, fractures and spill points	• Lower injection pressure by injecting at a lower rate or through more wells (Buschbach and Bond, 1974); • Lower reservoir pressure by removing water or other fluids from the storage structure; • Intersect the leakage with extraction wells in the vicinity of the leak; • Create a hydraulic barrier by increasing the reservoir pressure upstream of the leak; • Lower the reservoir pressure by creating a pathway to access new compartments in the storage reservoir; • Stop injection to stabilize the project; • Stop injection, produce the CO2 from the storage reservoir and reinject it back into a more suitable storage structure.
Leakage through active or abandoned wells	• Repair leaking injection wells with standard well recompletion techniques such as replacing the injection tubing and packers; • Repair leaking injection wells by squeezing cement behind the well casing to plug leaks behind the casing; • Plug and abandon injection wells that cannot be repaired by the methods listed above; • Stop blow-outs from injection or abandoned wells with standard techniques to 'kill' a well such as injecting a heavy mud into the well casing. After control of the well is re-established, the recompletion or abandonment practices described above can be used. If the wellhead is not accessible, a nearby well can be drilled to intercept the casing below the ground surface and 'kill' the well by pumping mud down the interception well (DOGGR, 1974).
Accumulation of CO2 in the vadose zone and soil gas	• Accumulations of gaseous CO2 in groundwater can be removed or at least made immobile, by drilling wells that intersect the accumulations and extracting the CO2. The extracted CO2 could be vented to the atmosphere or reinjected back into a suitable storage site; • Residual CO2 that is trapped as an immobile gas phase can be removed by dissolving it in water and extracting it as a dissolved phase through groundwater extraction well; • CO2 that has dissolved in the shallow groundwater could be removed, if needed, by pumping to the surface and aerating it to remove the CO2. The groundwater could then either be used directly or reinjected back into the groundwate;

Emergency Response Questions

- Energy Resources Conservation Board does not currently require a site specific response plan for a CO_2 pipeline or storage
- Emergency response plan is advisable, as CO_2 is heavier than air, so if it leaked it might collect in low-lying areas if no wind
- A Company will develop an emergency response plan, with an emergency planning zone of say..600 m (likely based on modelling)
  - Is this distance sufficient? How does it compare with response plan for Weyburn project?
  - Will the emergency response measures be sufficient to ensure safety?

Monitoring Questions

- **Plans for careful CO_2 monitoring can reduce risk**
  - Has the Company selected the best monitoring practices to find how the CO_2 is moving in the deep saline formation?
- **How will monitoring show:**
  - How far CO_2 has spread each year?
  - How the brine is moving in the injection formation?
  - If any CO_2 is moving out of the injection formation into or through the caprock?
  - If any CO_2 is leaking into shallow, fresh groundwater?
    - Will baseline testing of water wells (a best practice, prior to injection of CO_2) enable scientists to find out if any CO_2 in water well at a future date is coming from the Companies injection site?
  - If any CO_2 is leaking to the surface?

Back to EU CCS Guidance Documents - Summary of Method & Applicability

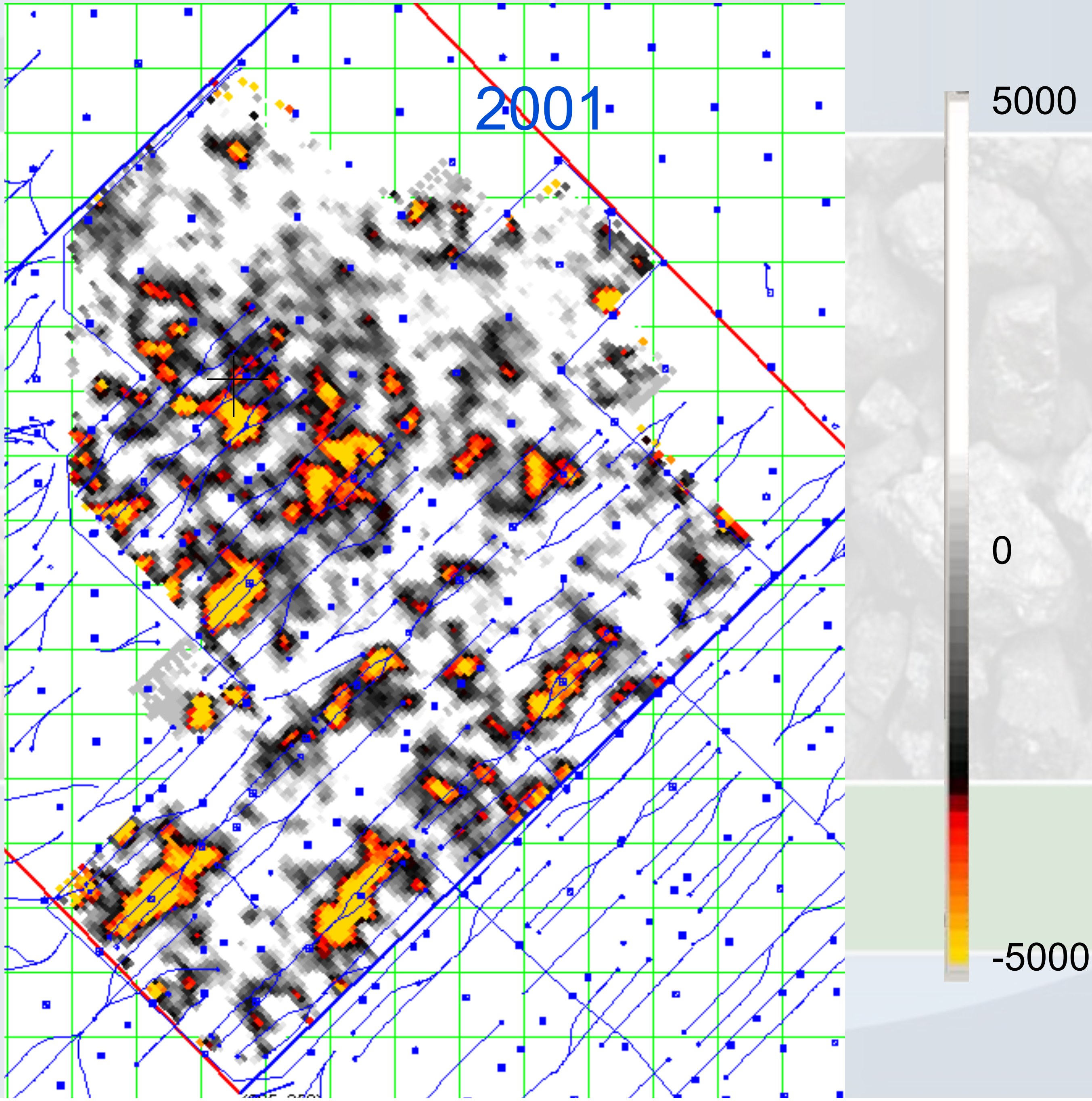
Table 11 Summary of Possible Monitoring Methods and Applicability

Category	Method/Technique	Monitoring Application				O O
		Oper.	Plume	Paths	Env.	On
Well Logging	Injection Well Logging (Wireline Logging)					
	Sonic (Acoustic) Logging					
	Cement Bond Log (Ultrasonic Well Logging)					
	Pulsed Neutron Capture					
	Density Logging					
	Optical Logging					
	Gamma Ray Logging					
	Resistivity Log					
Well CO2 Sampling	Well sampling & chemical analysis					
	Tracers					
Seismic	2-D Seismic Survey					
	3-D Seismic Multi-component & Timelapse Survey					
	4-D Seismic Array					
	Vertical Seismic Profile (VSP)					
	Cross-Hole Seismic Survey					
	Microseismic Survey (Passive)					
Shallow High resolution	Sidescan sonar					

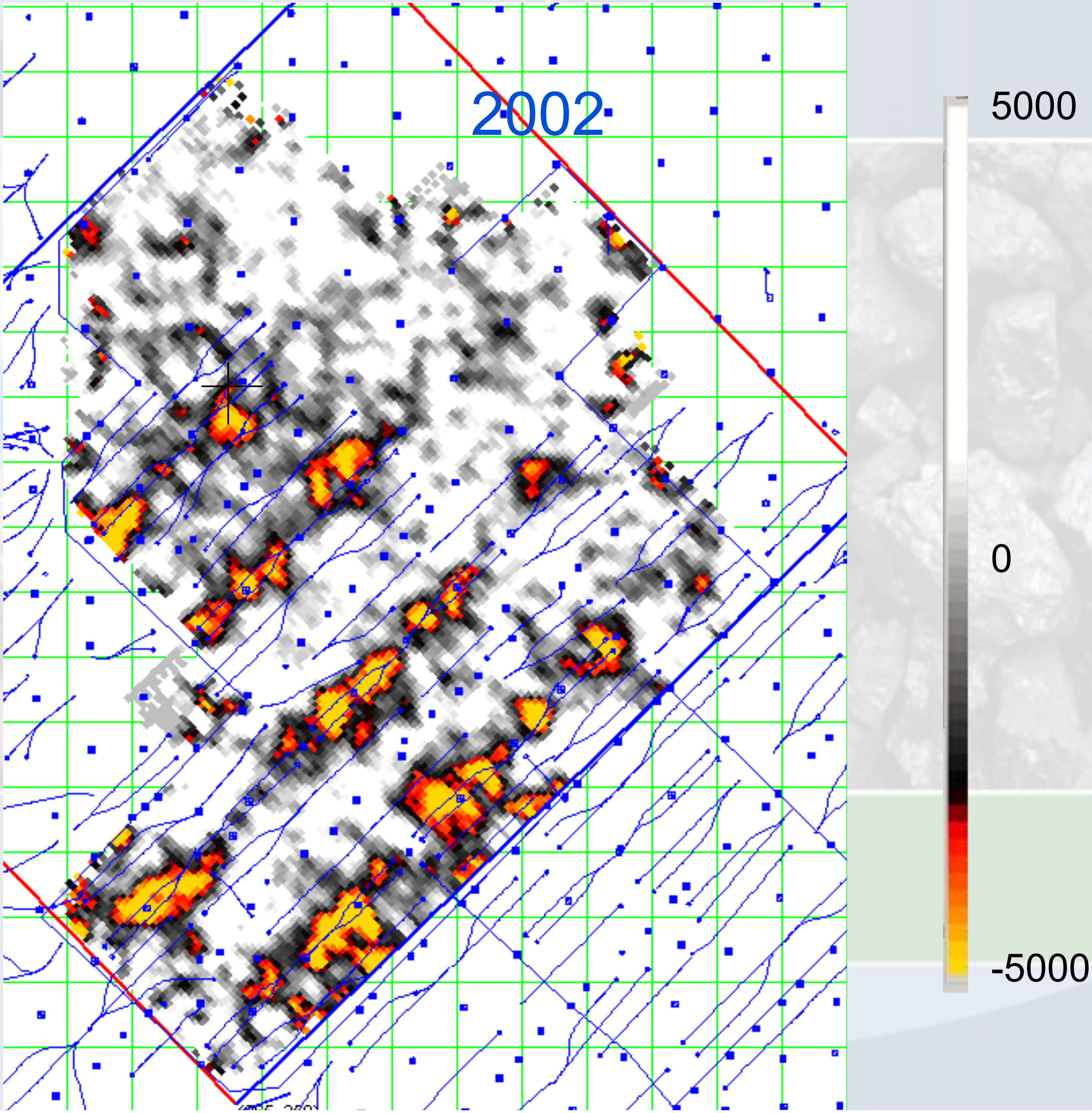
DIFFERENCE BETWEEN BASELINE SURVEY (1999) and 2001 SURVEY

2001 minus 1999

1.2 MT CO_2 Injected



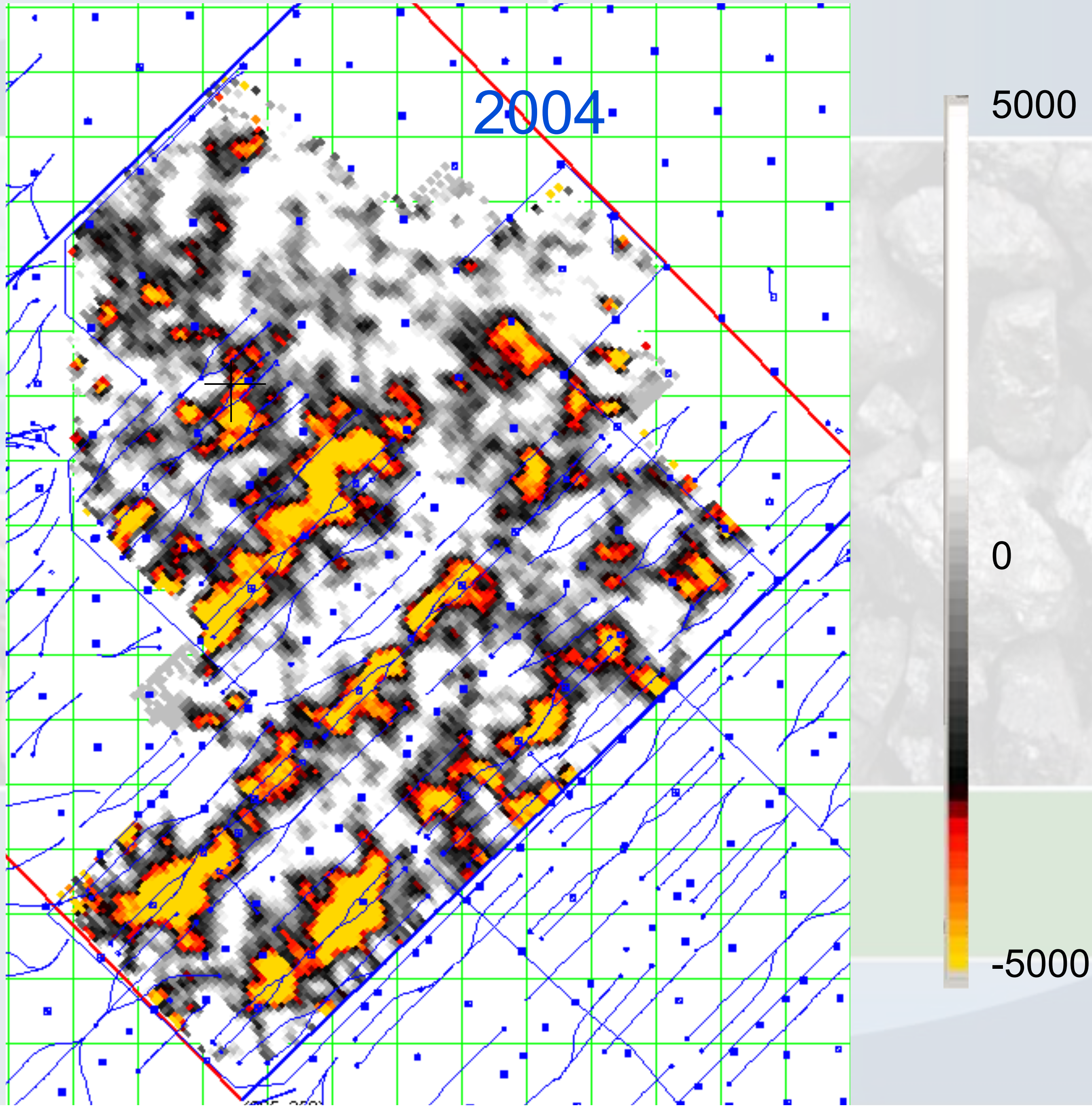
IEAGHG Weyburn-Midale CO2 Storage and Monitoring Research Project



2002 minus 1999

2.6 MT CO_2 Injected

IEAGHG Weyburn-Midale CO2 Storage and Monitoring Research Project

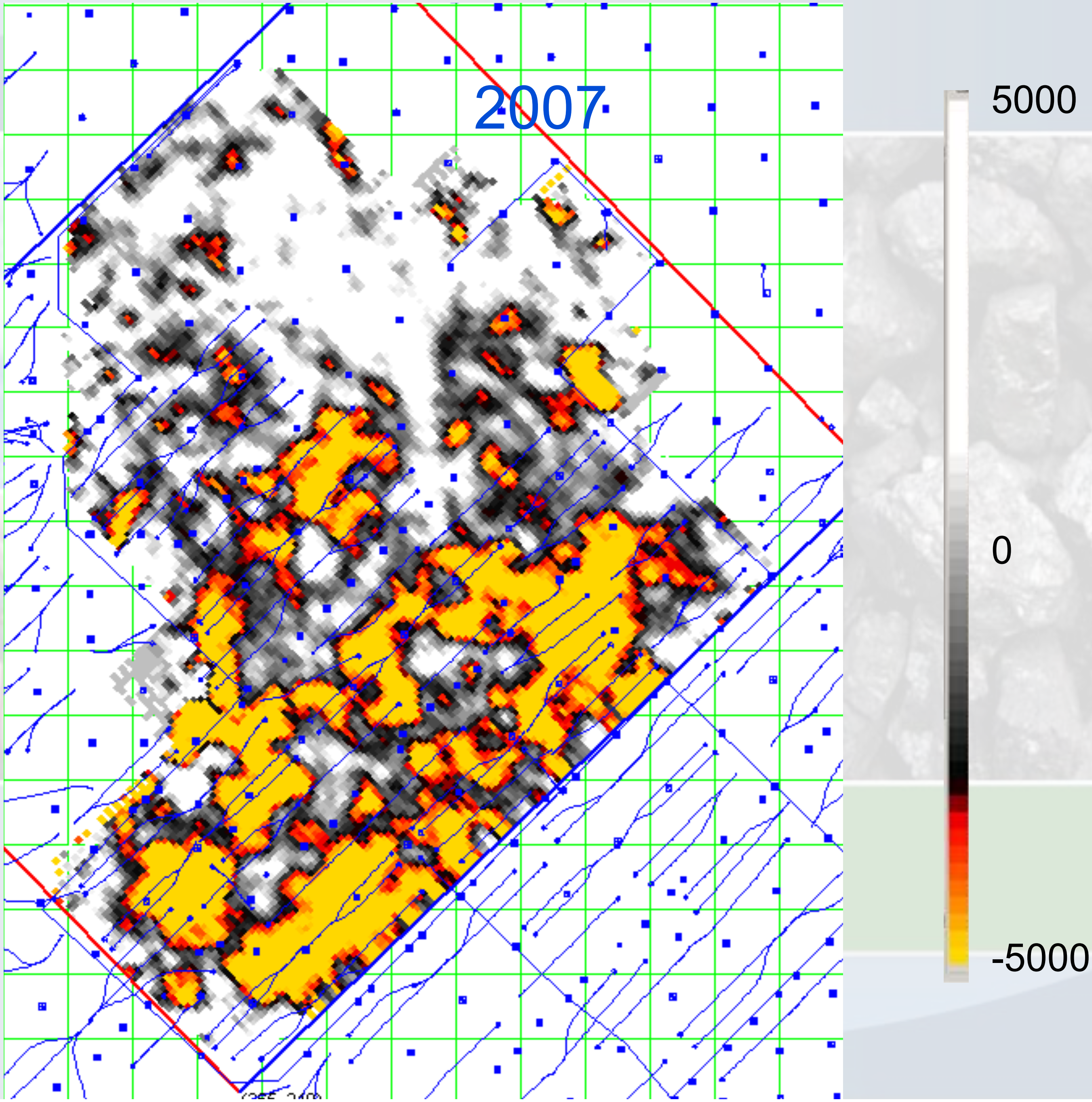


2004 minus 1999

~6 MT (?)
CO_2 Injected
(total field)

2007 minus 1999

14 MT CO_2 Injected (total field)



Applicability of Protocol - Storage

- Injection in deep saline aquifers capable of permanently storing CO_2 emissions. For each specific project, the applicant must have both:
  - Approved Carbon Sequestration Lease(s) in accordance with the *Mines and Minerals Act* and the *Carbon Sequestration Tenure Regulation* as issued by the Governme... ...ta; and

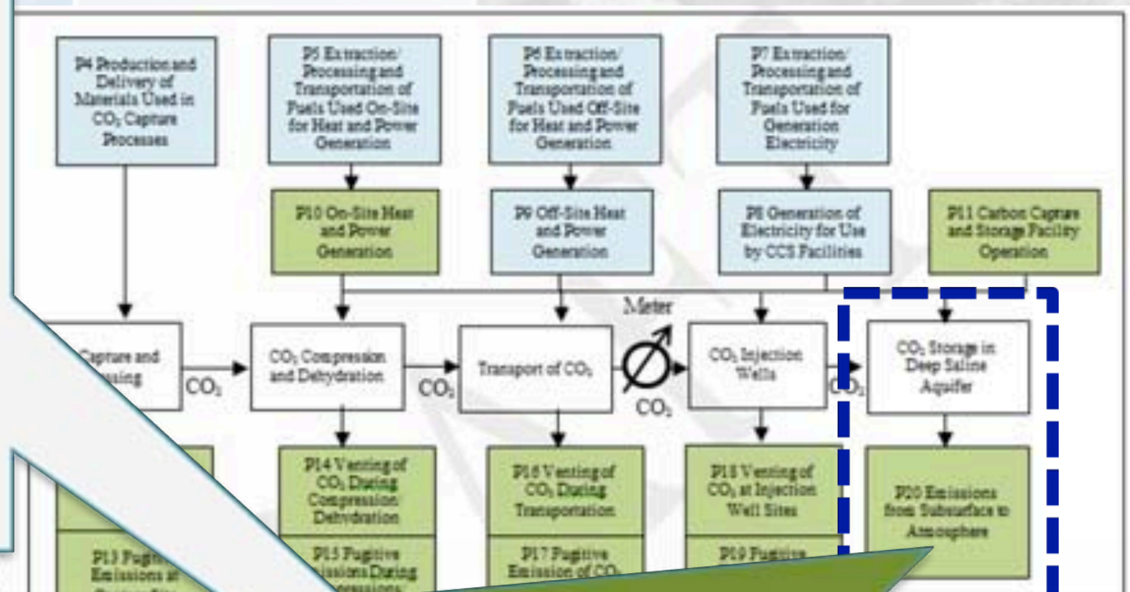
...nd

...d

The ERCB sets out several administrative details and processes such as requiring permit and lease holders to determine storage site suitability as well as submit monitoring, measurement and verification plans.

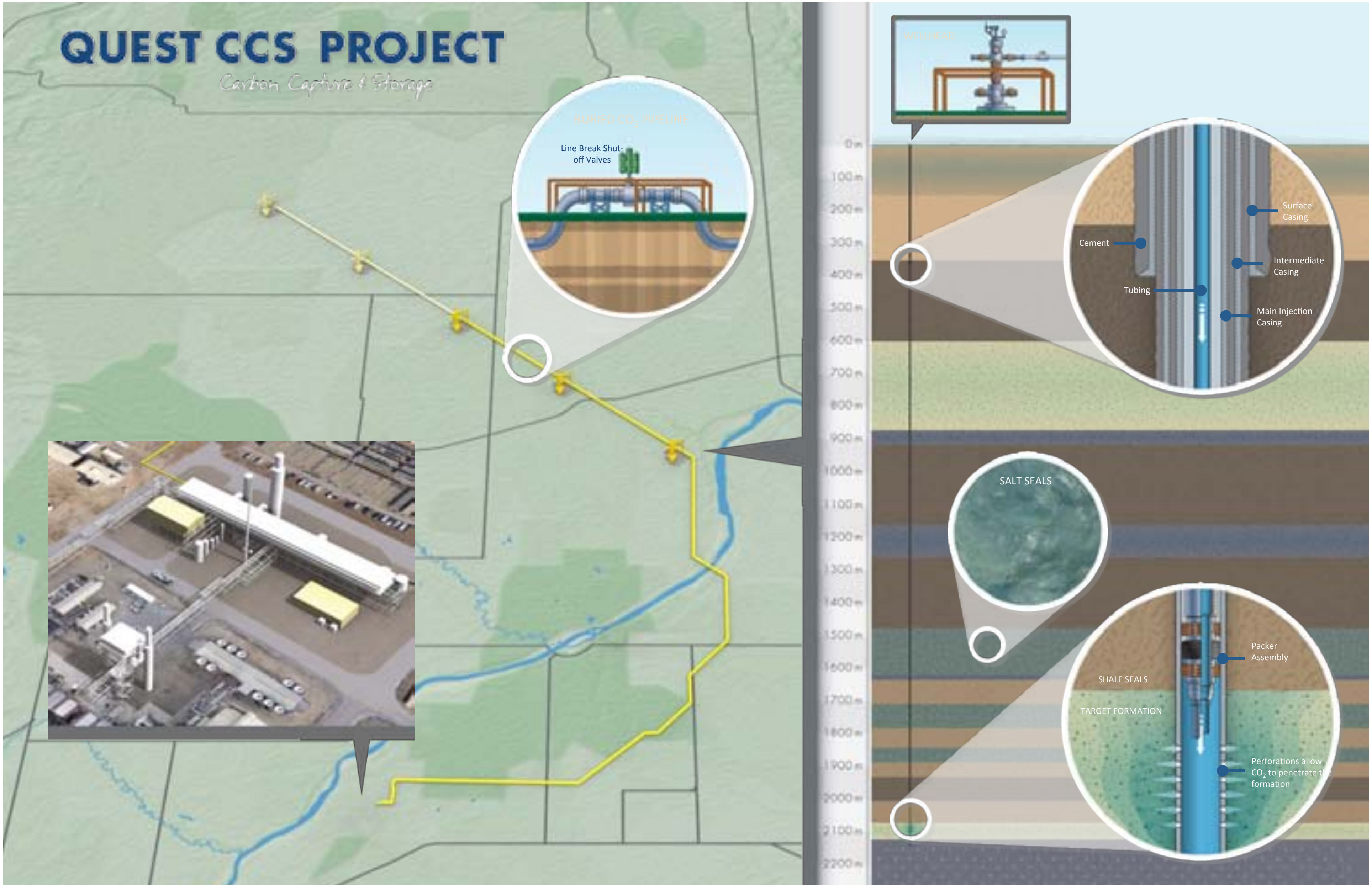
Quantification Protocol for Capture of CO_2 & Storage in Deep Saline Aquifers - DRAFT

Estimation would be required for reporting to the regulatory authority. Direct measurement is likely not possible, but the use of engineering estimates and uncertainty would be a reasonable approach in the event leakage occurs.



P19 Fugitive Emissions at Injection Well Sites	Unintended leaks of gas at the CO_2 injection … may occur through valves, flanges, pipe connections, mechanical seals or related equipmen… …pected that the gas will be composed of CO_2 with trace amounts of other gases.	Related
P20 Emissions from Subsurface to Atmosphere	Accidental emissions may occur by way of gas migratio… …gh undetected faults, fractures and/or subsurface equipment (due to compromised casing/ce… …ellhead or packer/tubing) to atmosphere.	Related

P20 Emissions from Subsurface to Atmosphere	$Emissions_{Subsurface\ to\ Atmosphere} = Mass\ CO_{2\ leaked}$					
	Mass of CO_2 leaked from the Subsurface to Atmosphere/ Mass $CO_{2\ leaked}$	kg	Estimated	If a leakage event occurs, the mass of CO_2 leaked from the subsurface to the atmosphere shall be estimated with a maximum overall uncertainty over the reporting period of ±7.5%. In case overall uncertainty of the applied quantification approach exceeds ±7.5%, an adjustment shall be applied. Refer to Appendix D for further guidance.	N/A	Estimation would be required for reporting to the regulatory authority. Direct measurement is likely not possible, but the use of engineering estimates and uncertainty would be a reasonable approach in the event leakage occurs.



Alberta
Freedom To Create. Spirit To Achieve.

Government of Alberta

CCS Standards/Protocols/ Projects - How the geological storage of CO_2 is being "standardized" and how this relates to projects in Alberta?

AIR & WASTE MANAGEMENT ASSOCIATION
CANADIAN PRAIRIE & NORTHERN SECTION

Alberta
Saskatchewan
Manitoba
Northwest Territories
Nunavut

Friday, February 03 2012

Rick Chalaturnyk, PhD, PEng

Professor, University of Alberta

Foundation CMG Chair in Reservoir Geomechanics