Carbon Capture and Storage Site Selection: Assessment and Risk Mitigation

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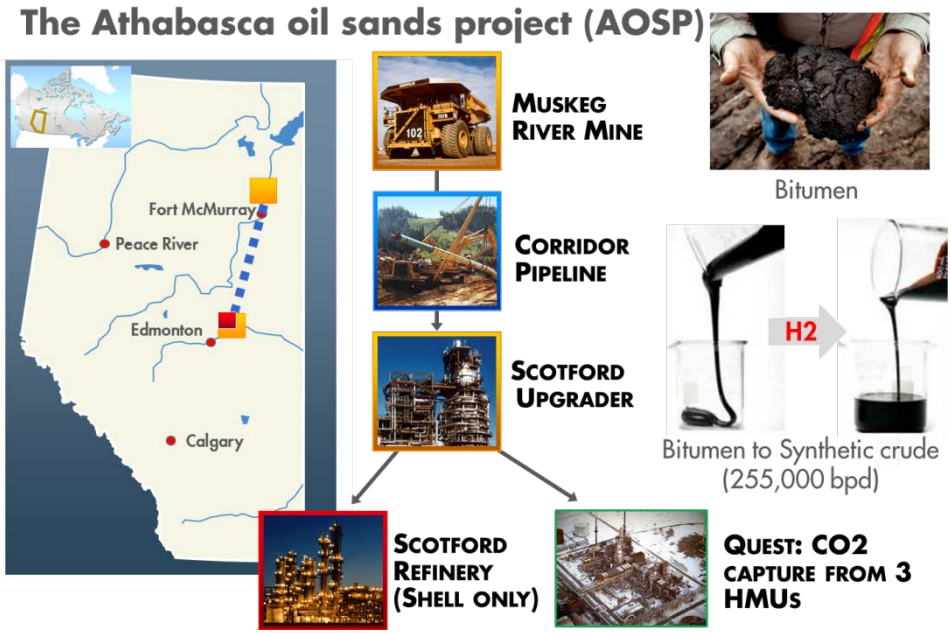
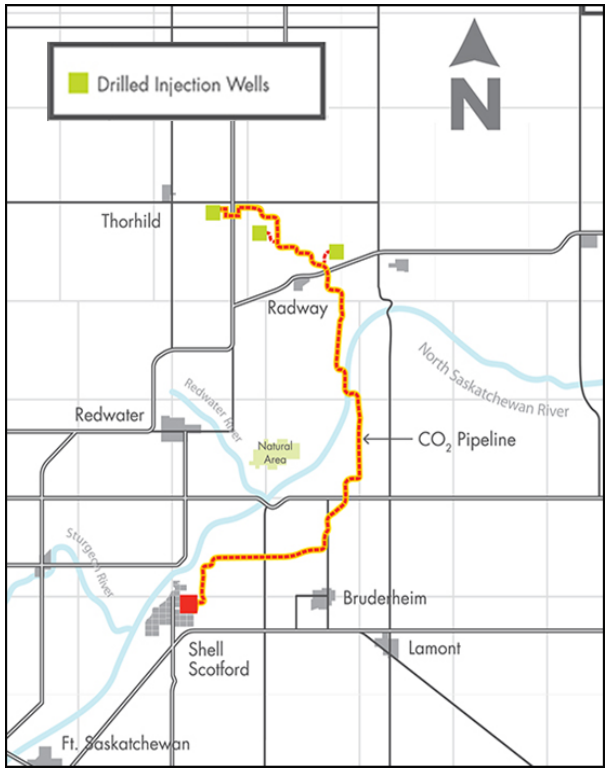
The Quest project

- CO2 capture from 3 hydrogen manufacturing units at the Scotford Upgrader, with an average expected rate of 3000 tonnes/ day.
- CO2 compressed to about10 MPa so that it is in dense phase throughout the system
- Compressor includes dehydration to minimize the amount of water in the system
- 65 km pipeline with 6 block valves (every 4-15 km)
- Currently injecting into two wells at less than 1 MPa above background reservoir pressure (third well provides contingency)
- Total injected volume through to today is more than 1,000,000 tonnes.





An Opening Thought

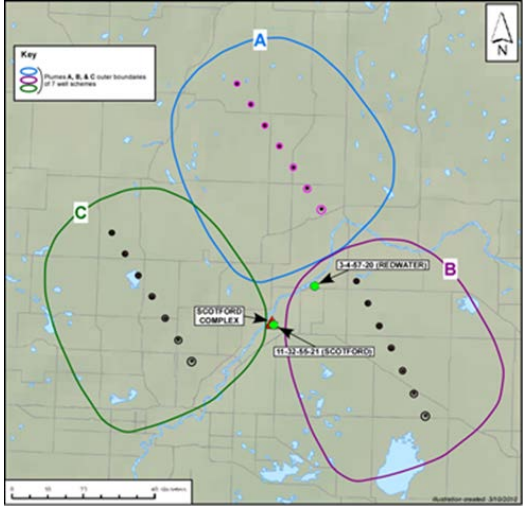
"Probability is not really about numbers; it is about the structure of reasoning"

Pearl, Shafer; 1983

"Perhaps the most important aspect is not the probability number, but the evidence and reasoning it summarizes"

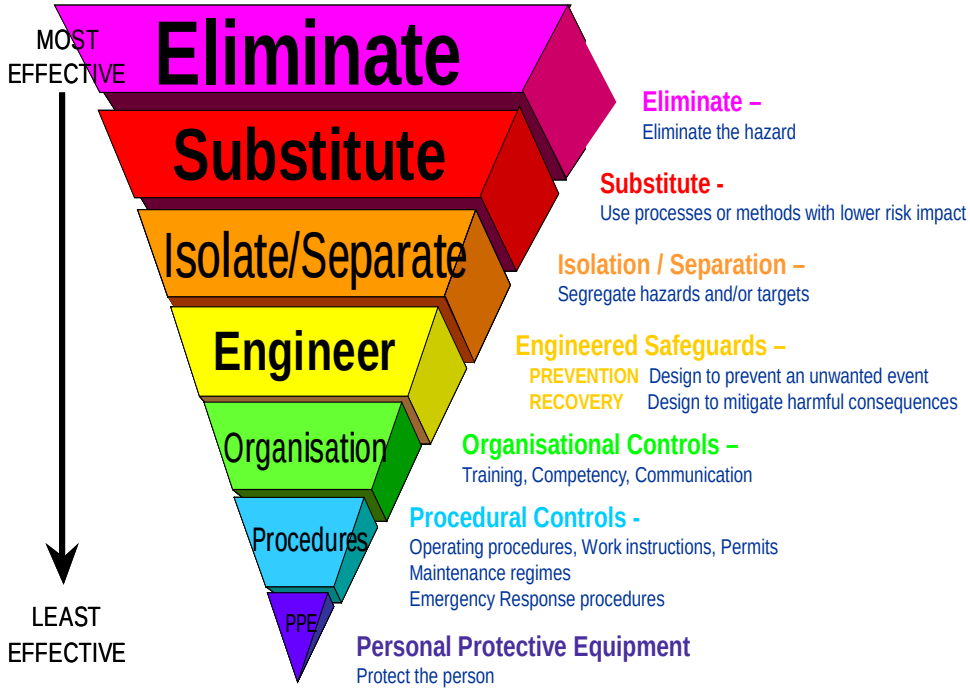
North; 1995

Site Selection: Risk Elimination



Selection criteria, scores and rational -> targets risk reduction

- Eliminate or Isolation from key risks
- Favourable ranking of site "A" (lowering risk) choice over "B" or "C", even at higher cost
- Better ability to engineer and control safeguards (MMV and site operations)



Selection Criteria	Selection Rationale	Option		
		A	B	C
Containment	Thickening seals updip	++	+	-
	Legacy wells	++	+	-
Capacity	BCS thickening E-NE	+		
Injectivity	BCS reservoir quality	++	+	-
MMV	Better access and less interference	++	+	-
Pore Space Access	Freehold –vs-crown	++	- -	- -
Cost	Most proximal site		+	+
Growth		++		-

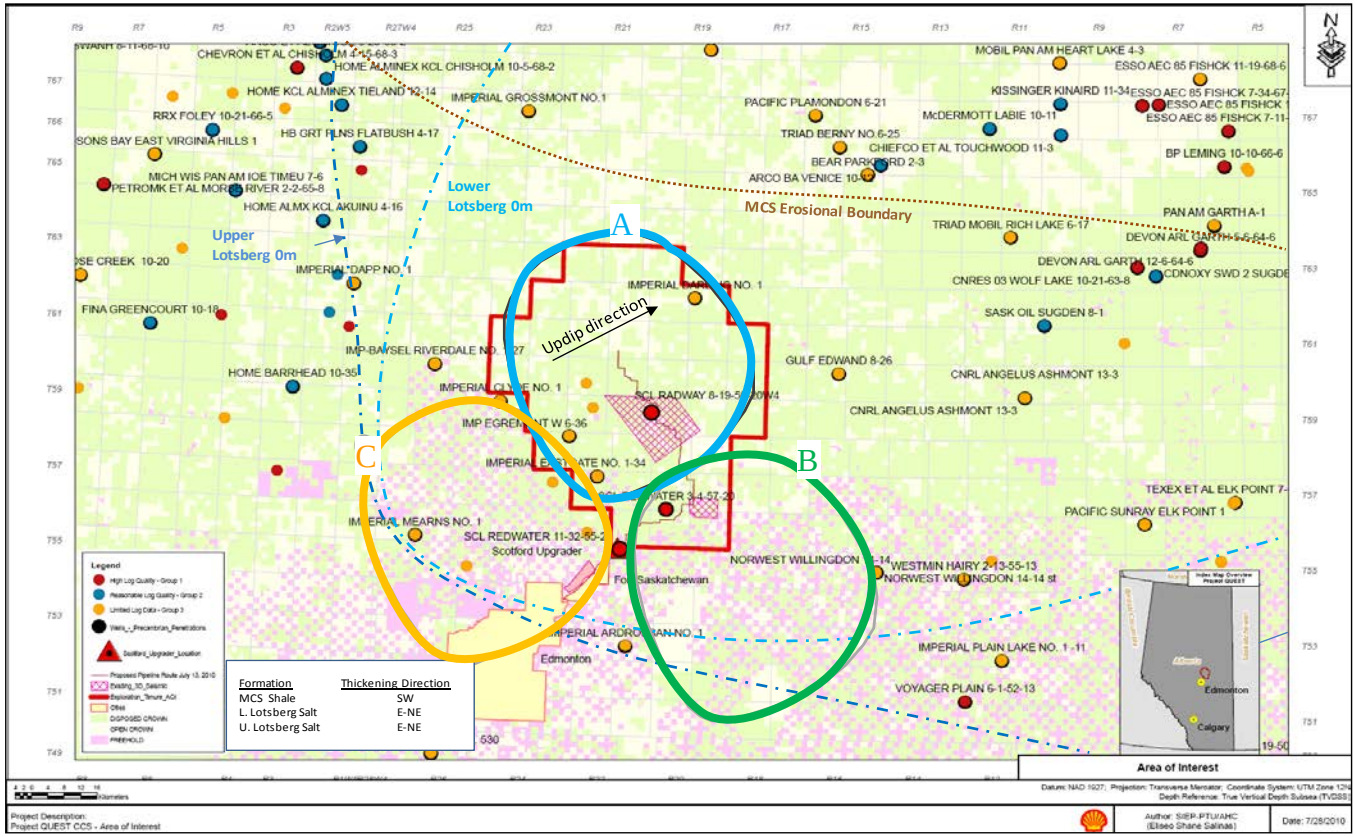
Screening Stage

- Define screening basis
- Develop screening plan
- Review available data and identify potential sites
- Estimate capacity and level of uncertainty
- Identification and assessment of uncertainty and risks
- Select site(s) for assessment. Produce Screening Report

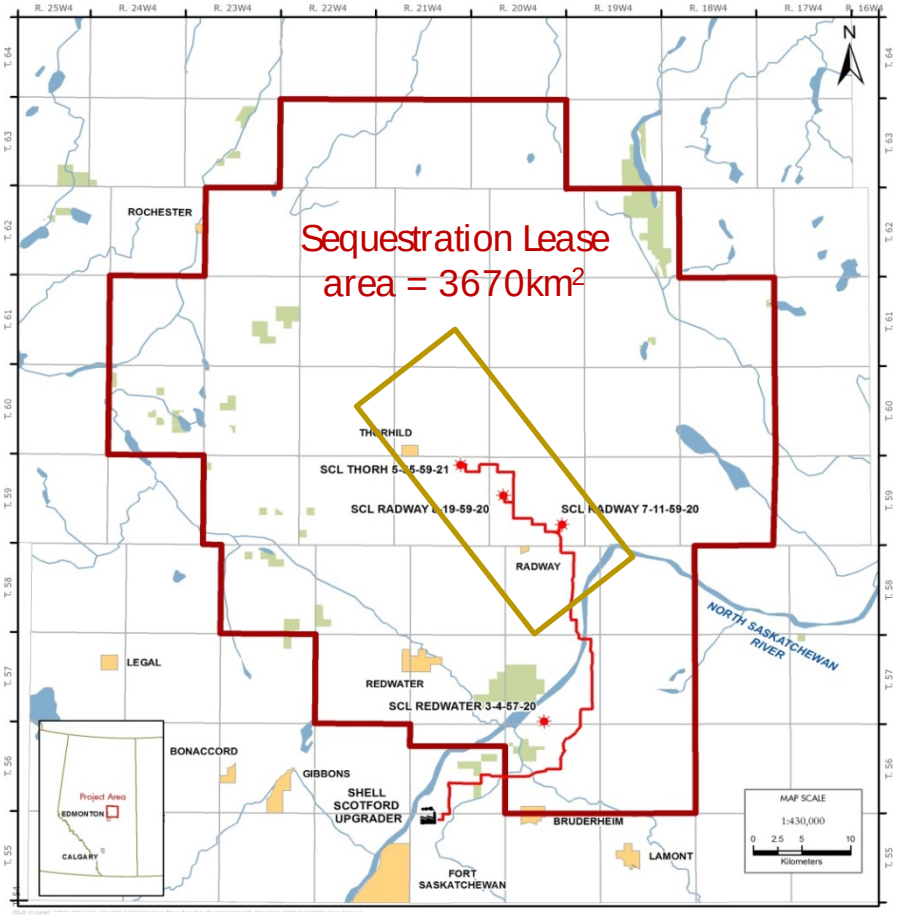
Pre-feasibility

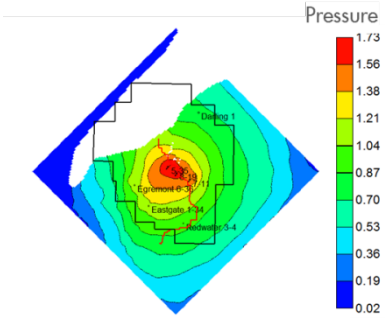
Feasibility →

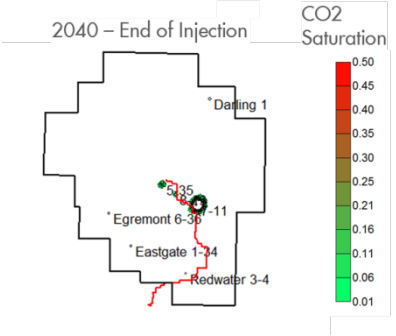
SR

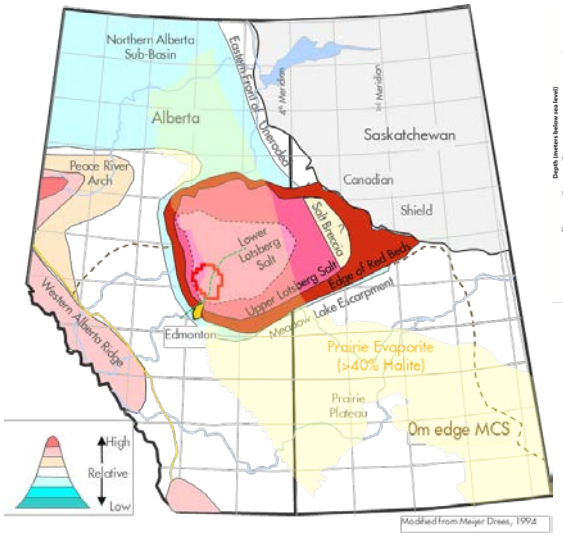


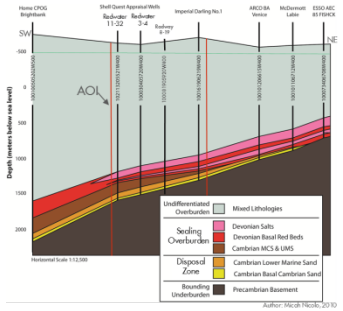
QUEST Site Selection











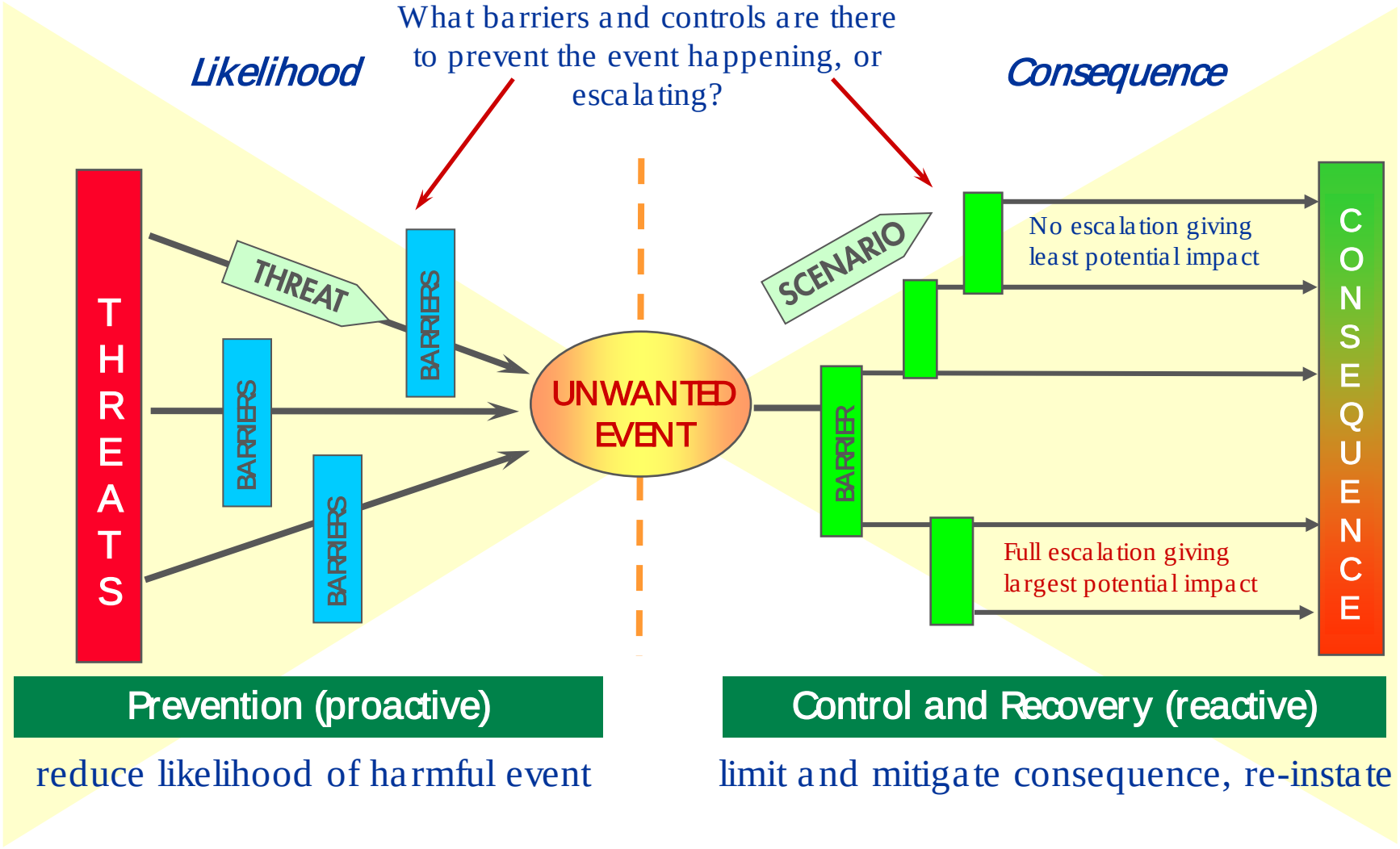
Selection based on many factors:

Reservoir quality, seal placement, fractures/ faults, predicted pressure response, stakeholder concerns, legacy wells, ability to conduct MMV…

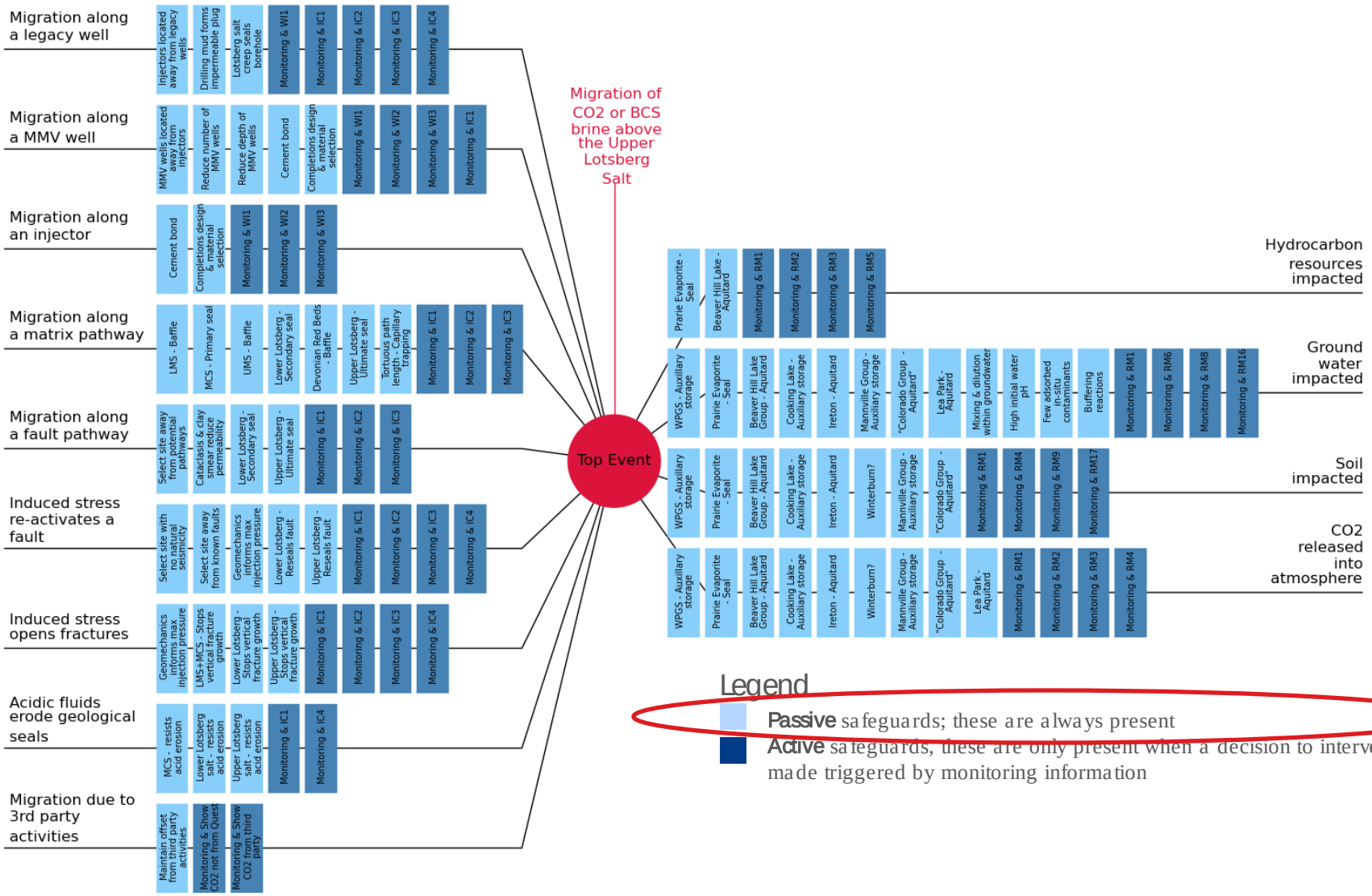
Subsurface Risks And Uncertainties

Risk Group	Risk Description	Key Uncertainty	Addressed
Wells	Loss of Containment Through Wells	Ability to drill & cement gauge hole DTS (for leak detection) Integrity of Legacy Wells	3rd Well 3rd Well Study in Progress
Containment	LoC through the Subsurface	Structural interpretation Regional correlation of seals Geomechanics	HRAM, 2D,3D, VSP 2D, logs Core, logs
Injectivity	Non-commercial rates of injection	Permeability height (Kh) Skin Non-Darcy skin, relative permeability Connected volume CO_2 injectivity	H_2O inj. test H_2O inj. test No, SCAL (core) HRAM, 2D, 3D CO_2 inj. test
Capacity	Low connected pore volume	Compartmentalisation Reservoir properties (h, N/G, phi & cr)	HRAM, 3D, ext.H_2O inj. test 3rd well, core
MMV	Conformance risk	Unexpected plume migration Differentiation CO_2 contamination Detectability	HRAM, 2D, 3D, 3rd well Water sampling ..... MDT, sampling, INSAR

Managing Risk – The Bow tie Concept



Bow-tie: CCS Storage Containment Risk Example

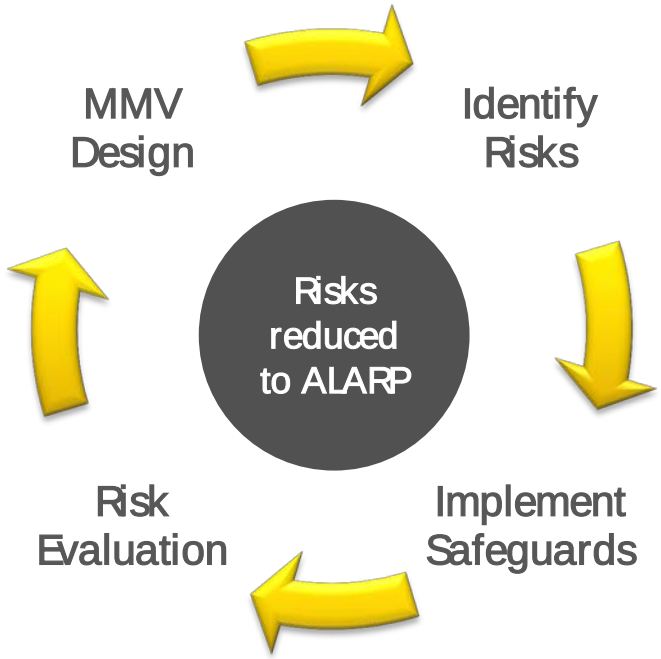


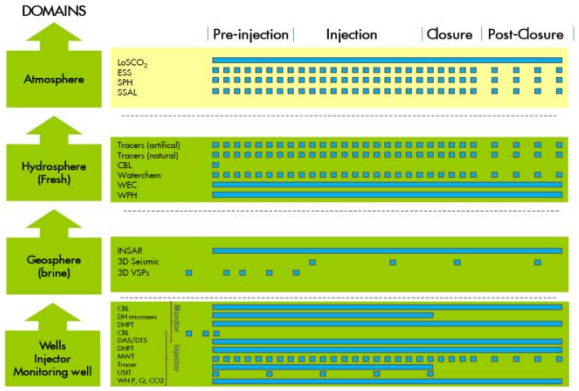
Systematic Evaluation of Passive Safeguards

- Evidence based using collective expert judgement (internal and external)
- Informed by appraisal data and site characterization studies
- Subject to independent expert review
- May steer further studies/ data gathering to reduce white space

Threats	Safeguard	Evidence For	Evidence Against	EF	EA
Migration along a legacy well	Injectors located away from legacy	1. IHS database identifies legacy wells 2. Shortest offset distance is 21km	1. IHS database may not be complete 2. IHS database may be inaccurate	0.8	0.1
	Drilling mud forms impermeable plug	1. Weighted drilling fluid used 2. Settlement creates low K filtrate plug 3. Plug forms at bottom hole over several	1. Plug may not cover first seal	0.4	0.2
	Lotsberg salt creep seals borehole	1. Open-hole over Lotsberg salts 2. Documented shrinkage in LPG caverns 3. Small hole (<10 in) - long time (50 yr) 4. Thick salt layers (55-127 m) 5. Greater than 90% halite	1. None	0.7	0
	Cement plugs	1. Well abandonment and drilling reports 2. Four wells with plugs inside BCS complex	1. No positive pressure test results reported 2. Cement may degrade over c. 50 years 3. Darling lacks plugs in storage complex	0.3	0.4

MMV – Risk Analysis & Mitigation





Risk-Based

- Verify geological & engineered safeguards
- Reduce containment risk to ALARP

Site-Specific

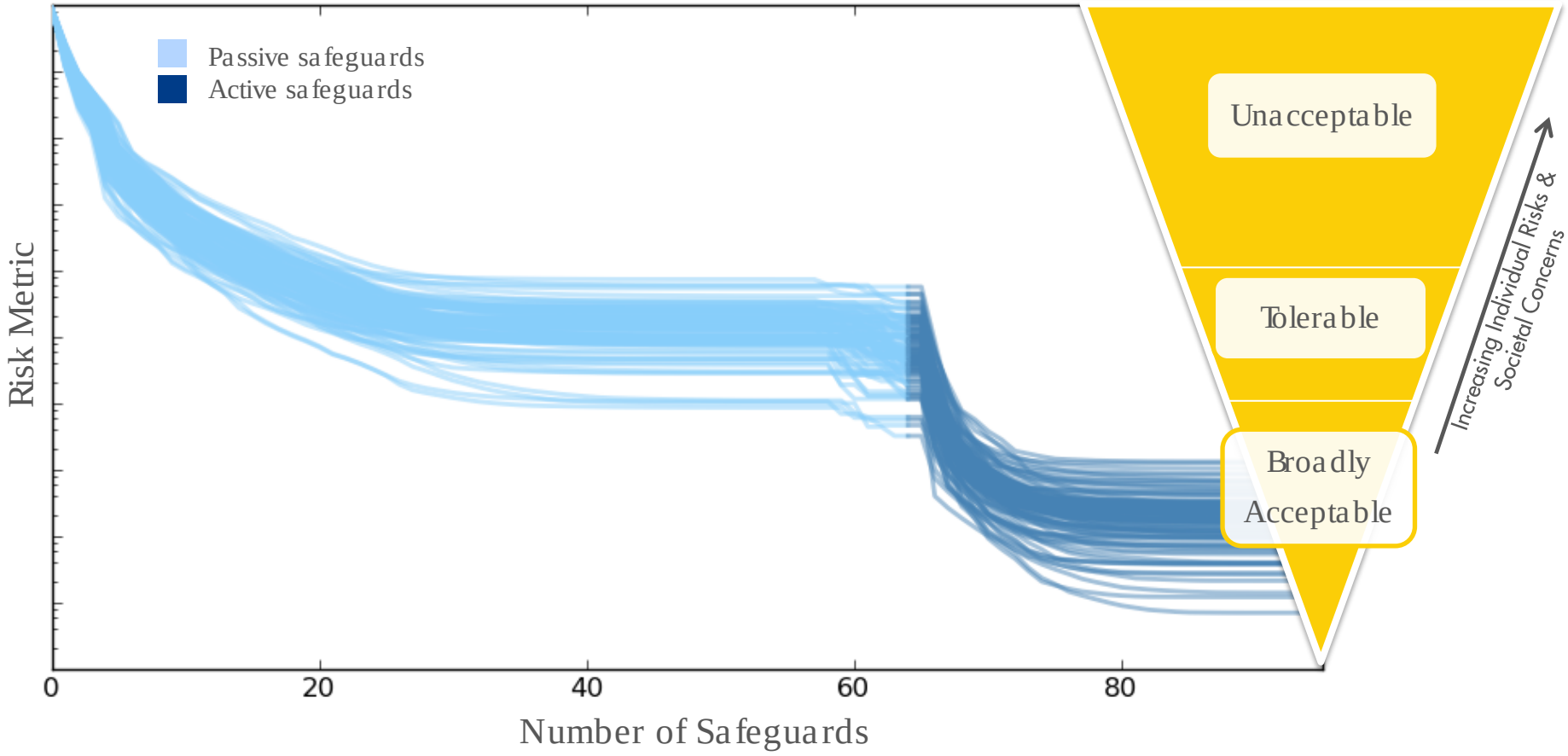
- Tailor-made monitoring
- Informed by appraisal data

Adaptive

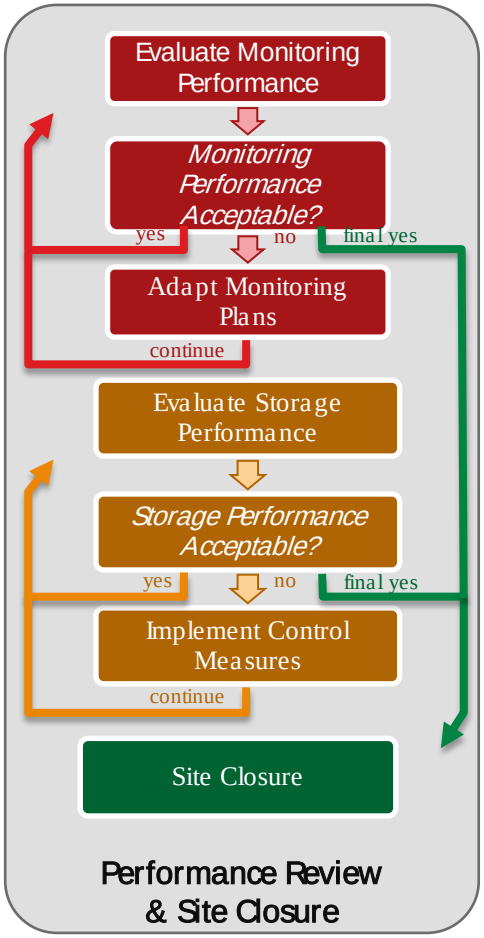
- Respond to observed performance
- Contingency plans in place

Active Safeguards: Risk Profile

- Informed by appraisal data and feasibility studies
- Based on collective expert judgement



Performance & Closure



The Government or Regulators View Of Remaining Risk

Closure Plan Outline
Intro
Project Overview
Storage Performance Tasks for Site Closure - CCS Targets from the Regulator
Storage Performance Data -Well inventory -CO2 inventory - Containment Performance - Conformance Performance
Operating Plan Updates -SDP changes -MMV changes
Proposed Closure Activities -Storage site reclamation -Well decommissioning
Site Closure Certification -Post-closure monitoring -Transfer of infrastructure
Reporting & Documentation

Summary

Risk & Uncertainty needs to be addressed at every phase of the project:

- Site Selection – Elimination/ Isolation/ Reduction from risk
- Site Characterization – Reduction in uncertainty and remaining risk
- MMV/ Injection – Risk monitoring and mitigation
- Site Closure – Verification & Liability Transfer

Different stakeholders will focus on different risk elements

- Landowners – HSSE, Containment
- Government, Regulator – HSSE, Containment, Capacity and Long Term Liability
- Management – HSSE, Containment, Capacity, Long Term liability, Injectivity, Financially Sound

An Industrial Scale Integrated project needs to manage all risks to ALARP

A Final Thought

"Probability is not really about numbers; it is about the structure of reasoning"

…….Judea Pearl, Glen Shafer; 1983 - Defaults & Probabilities, Extensions & Coherence

"Perhaps the most important aspect is not the probability number, but the evidence and reasoning it summarizes"…….Oliver North; 1995