Monitoring Issues: CCS Directive and Beyond

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Introduction (What is ICF?)

- ICF is a consulting firm providing end-to-end management, technology, and policy services — advise, implement, improve
- ICF has been working on technical, economic, regulatory, and policy issues related to CCS since 2005
- *Europe*: Supporting the EC with the development of the Guidance Documents (recently published), with ongoing support to EC on related issues; Working with EC and private clients on other energy/env't issues
- *North America:* Technical and regulatory support to U.S. EPA in developing CO2 injection rules and reporting, monitoring, verification rules for geological storage; Economic modelling for storage (supply curves) and pipeline networks in US/Canada
- *Global*: Integrated fuel and power sector modelling includes CCS as an option—used for public and private sector clients

Outline

- Monitoring Goals in CCS Directive
- Key Issues from GD2
- Defining Monitoring Areas
- Baseline Monitoring Issues

This presentation does not represent the views of the European Commission. It is primarily aimed at fostering a discussion on issues relevant to monitoring in the European context.

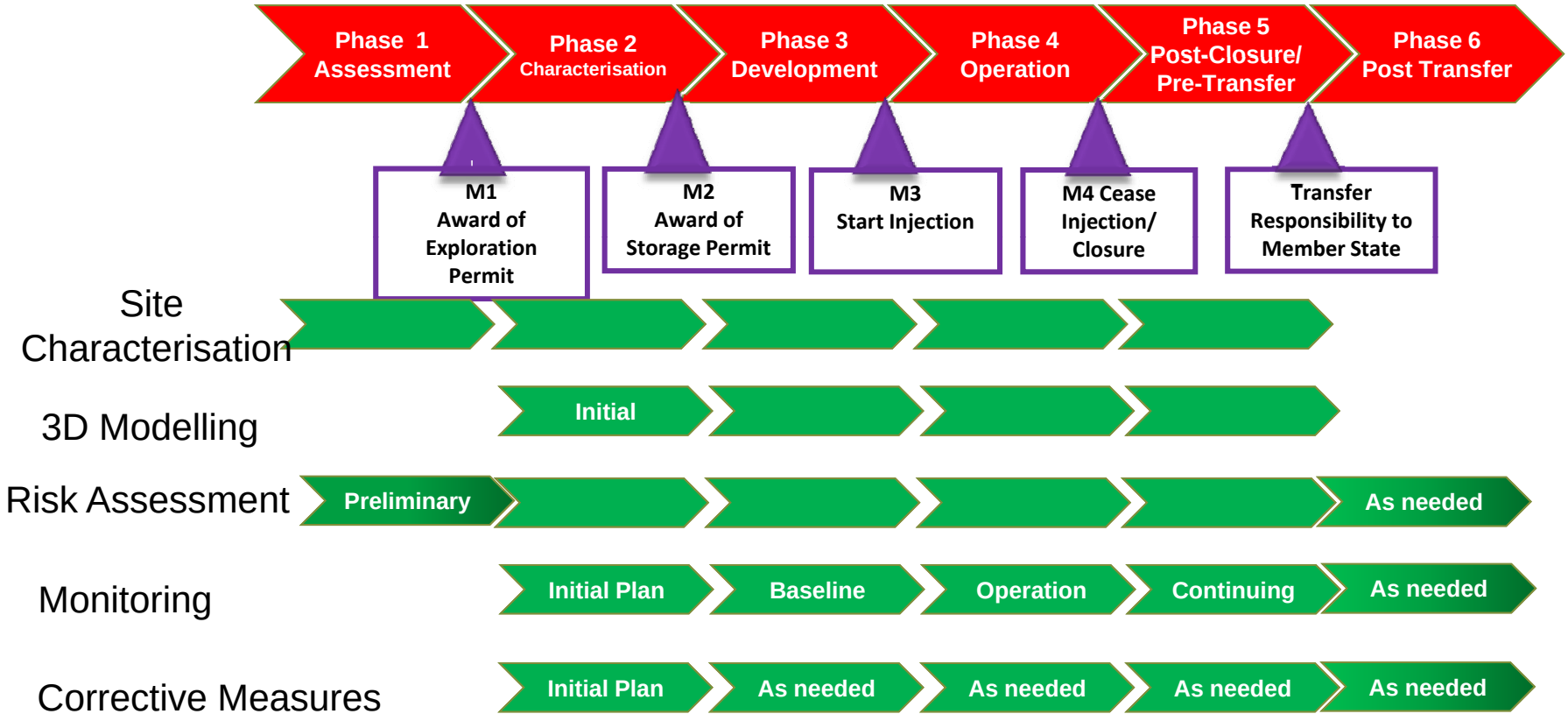
Goals of Monitoring in the CCS Directive

- Comparison between the actual and modelled behaviour of CO2 and formation water, in the storage site *(are the models accurate?)*;
- Detecting significant irregularities *(i.e., what are risks/potential for leakage? how to detect these risks?)*
- Detecting migration of CO2 *(where is CO2 in the Complex?)*;
- Detecting leakage of CO2 *(has CO2 left the Complex?)*;
- Detecting significant adverse effects for the surrounding environment, including in particular on drinking water, for human populations, or for users of the surrounding biosphere *(what is the leaked CO2 doing?)*;
- Assessing the effectiveness of any corrective measures *(are the fixes to stop leakages and impacts working?)*;
- Updating the assessment of the safety and integrity of the storage complex in the short- and long-term, including the assessment of whether the stored CO2 will be completely and permanently contained *(is the site meeting the Transfer of Responsibility criteria?)*.

Monitoring in "Guidance Document 2"

- Monitoring Plans: based on site characterisation, modelling, and risk assessment
- Monitoring Plans need to meet the goals of the CCSD, and would cover different areas, with different scales/intensities, at different times
- Regular reporting and updating of Monitoring Plans – new knowledge from operations, updated risk management, new technologies, etc. needs to be incorporated
- Technology-neutral: Operator is free to select appropriate best-available cost-effective technologies, as long as it meets the specific objectives based on identified risks at a particular site
  - Monitoring techniques (resolution, accuracy, spatial and temporal acquisition pattern) will be influenced by site-specific characteristics – portfolio based
  - Baseline monitoring and statistical analysis will be critical for distinguishing irregularities from background
  - Some monitoring will likely be based on wells, but benefits of dedicated monitoring wells need to be weighed against seal penetration (creation of new leakage pathways)

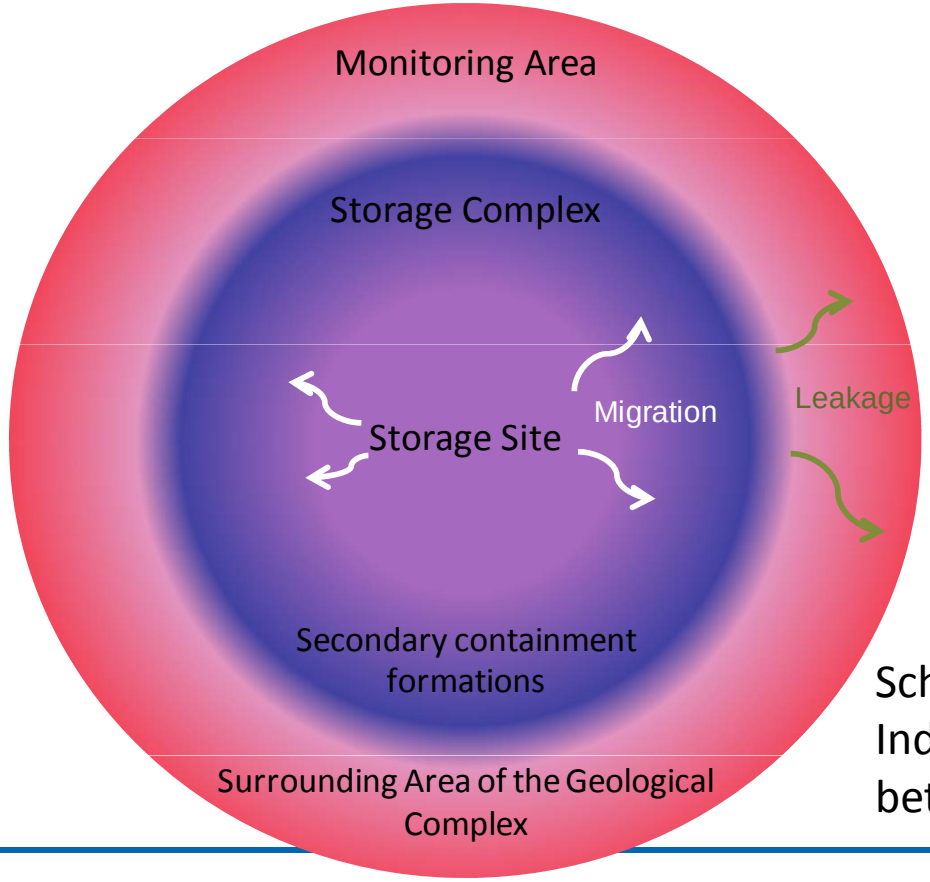
Monitoring During Project Phases and Milestones



Active and continuous monitoring needed throughout the operation phase and after closure up to transfer of responsibility, with scale and intensity dependent on risk characteristics

Defining Relevant Areas in the CCS Directive

- Several specific areas implicitly and explicitly defined in the CCS Directive:
- Exploration Permit Area; Storage Site; Storage Complex; Surrounding Areas of the Complex (Monitoring Area)



Schematic from GD2 Indicating relationships between different areas

Exploration Permit Area

- In the Exploration Permit, CA has to define a surface area within which the permit holder can conduct scientific studies in order to identify suitable storage sites and complexes.
  - All geological volume under the permitted surface area can be explored
  - Some geological formations/volume may be excluded for consideration as potential storage sites – allows for CA to allow for multiple uses of geological formations, along with storage (drinking water sources, coal/oil/gas resources, geothermal, etc.)
- Site characterisation and initial baseline monitoring data will be obtained during exploration within the permitted area
- Some development oriented activities (test injections) may also happen with the Exploration Permit

Storage Site

- There are two components to the storage site:
  - Surface area with injection, monitoring, and associated facilities
  - 3D geological volume with the primary reservoir/seal pair(s) and any other geological feature that bounds the storage site (e.g., faults, structure, facies change, etc)
- 3D volume is determined by maximum extent of CO2 plume as determined by modelling, with a buffer region to account for modelling uncertainties
  - Function of the amount and rate of CO2 injected, geologic characteristics of the primary reservoir-seal pair (geometry, thickness, permeability, porosity, and the amount of heterogeneity and anisotropy within the reservoir and the seal), and modelling resolution.
- Monitoring in the Storage Site is critical for matching the modelling with actual observations, tracking CO2 plume migration, assessing geochemical changes, etc.

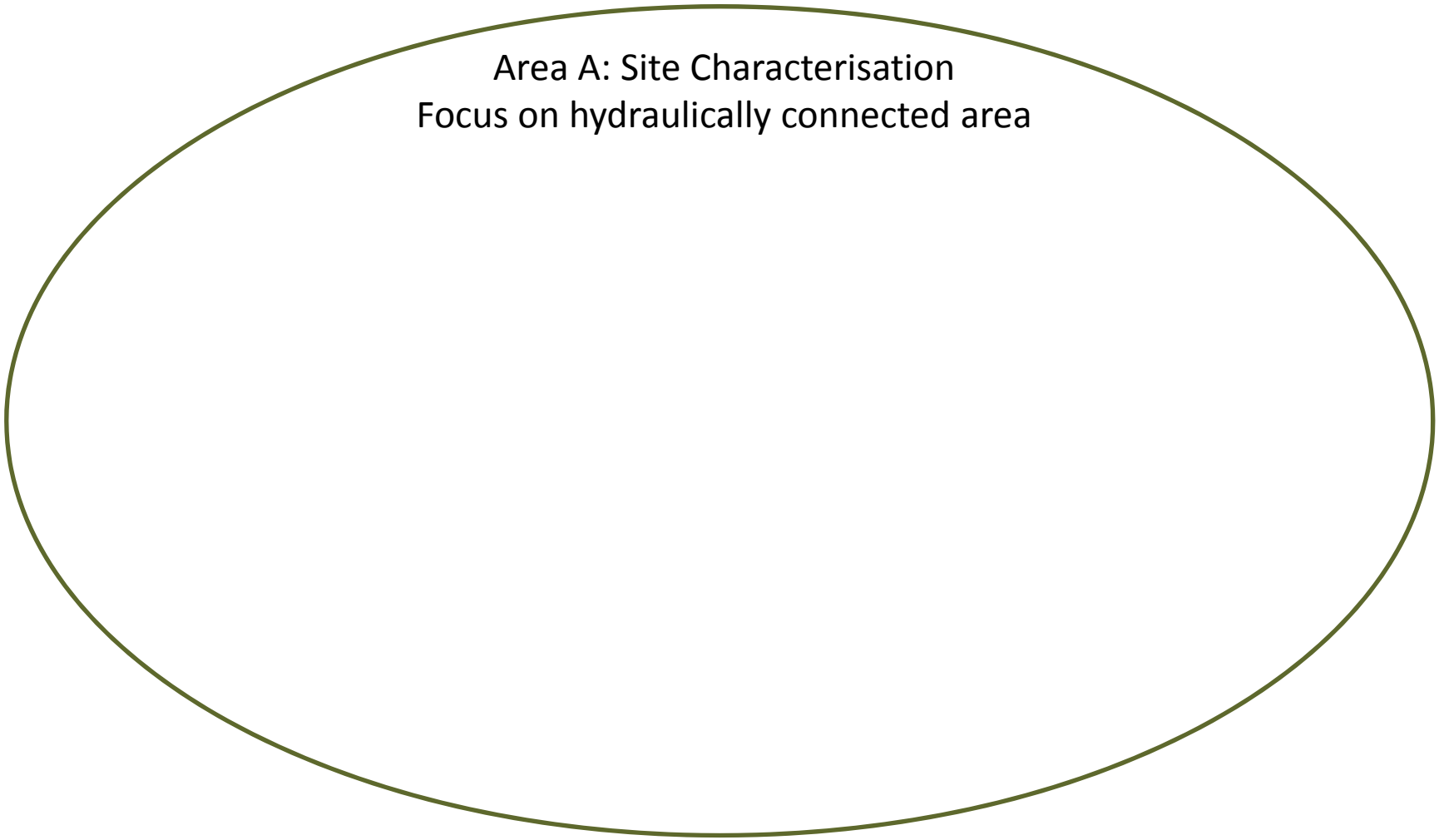
Storage Complex

- Complex = Site + Secondary reservoir/seal pair(s) + geological features that may be reached by the CO2 plume, based on modelling
- Complex needs to be monitored for pressure impacts, CO2 migration, and indications of leakages
- Extent of secondary reservoir/seal pairs included in the Complex is a tradeoff between monitoring costs and increased 'safety'
- Boundary of Complex is important as it determines "leakage"
- Important for Transfer of Responsibility, wherein monitored data in the Complex needs to be history matched with modelling
- Complex boundaries may be altered, if CA approves, as part of the storage permit updating process based on actual injection/monitoring data and updated modelling

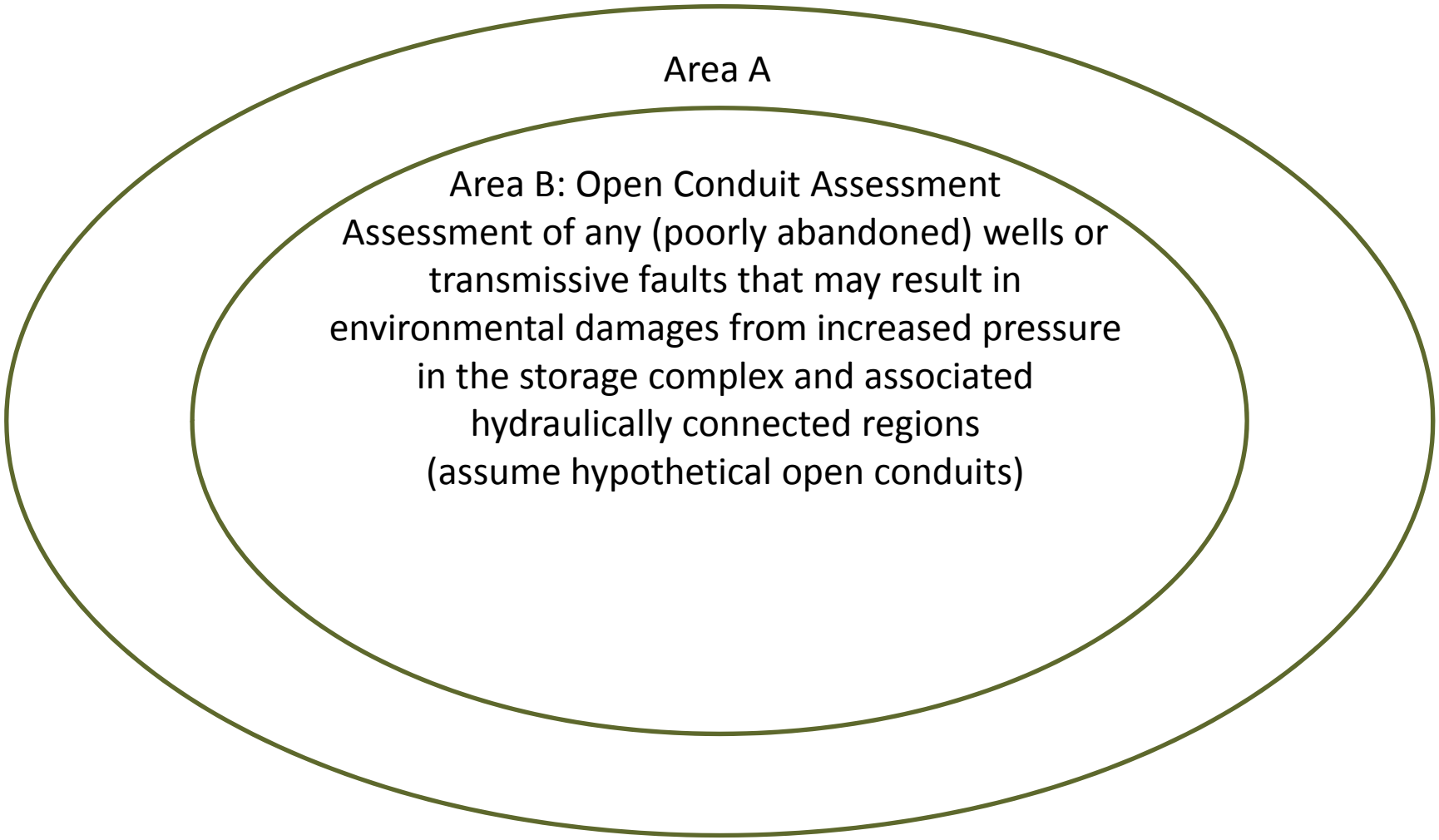
Surrounding Areas of the Storage Complex

- Implicitly defined in Annex I and Article 13 on Monitoring
- Monitoring in the Surrounding Areas is critical for:
  - Detecting leakages
  - Assessing adverse impact of environment (esp. drinking water)
  - Evaluating/quantifying 'leaked emissions' for ETS
  - Assessing effectiveness of any corrective measures undertaken
- Different boundaries in the Surrounding Areas with different goals:
  - Area A: Site characterisation
  - Area B: Open conduit pressure impact assessment
  - Area C: Risk-based pressure impact monitoring
  - Area D: Risk-based leakage and leaked emissions monitoring

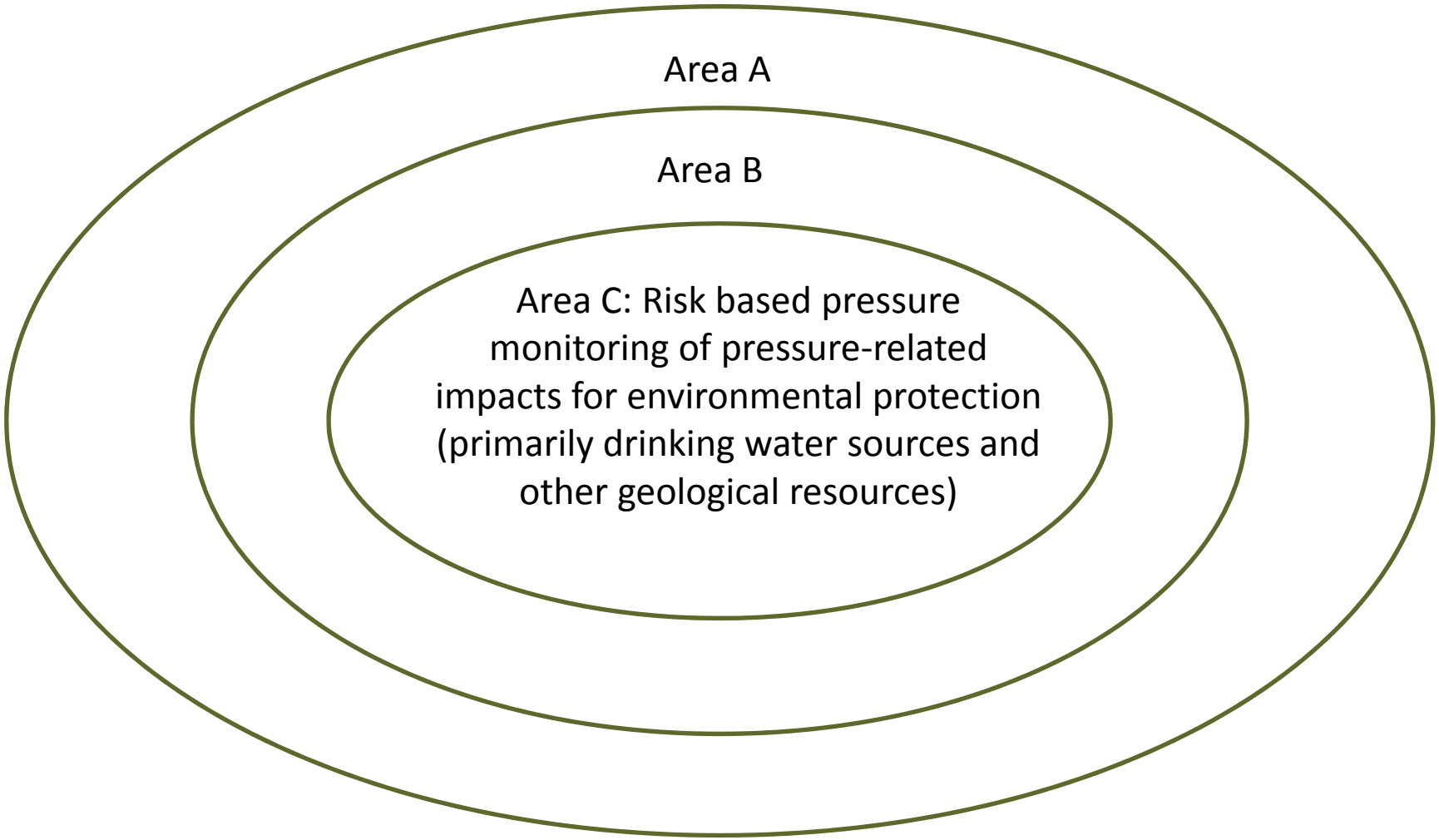
Area A: Site Characterisation



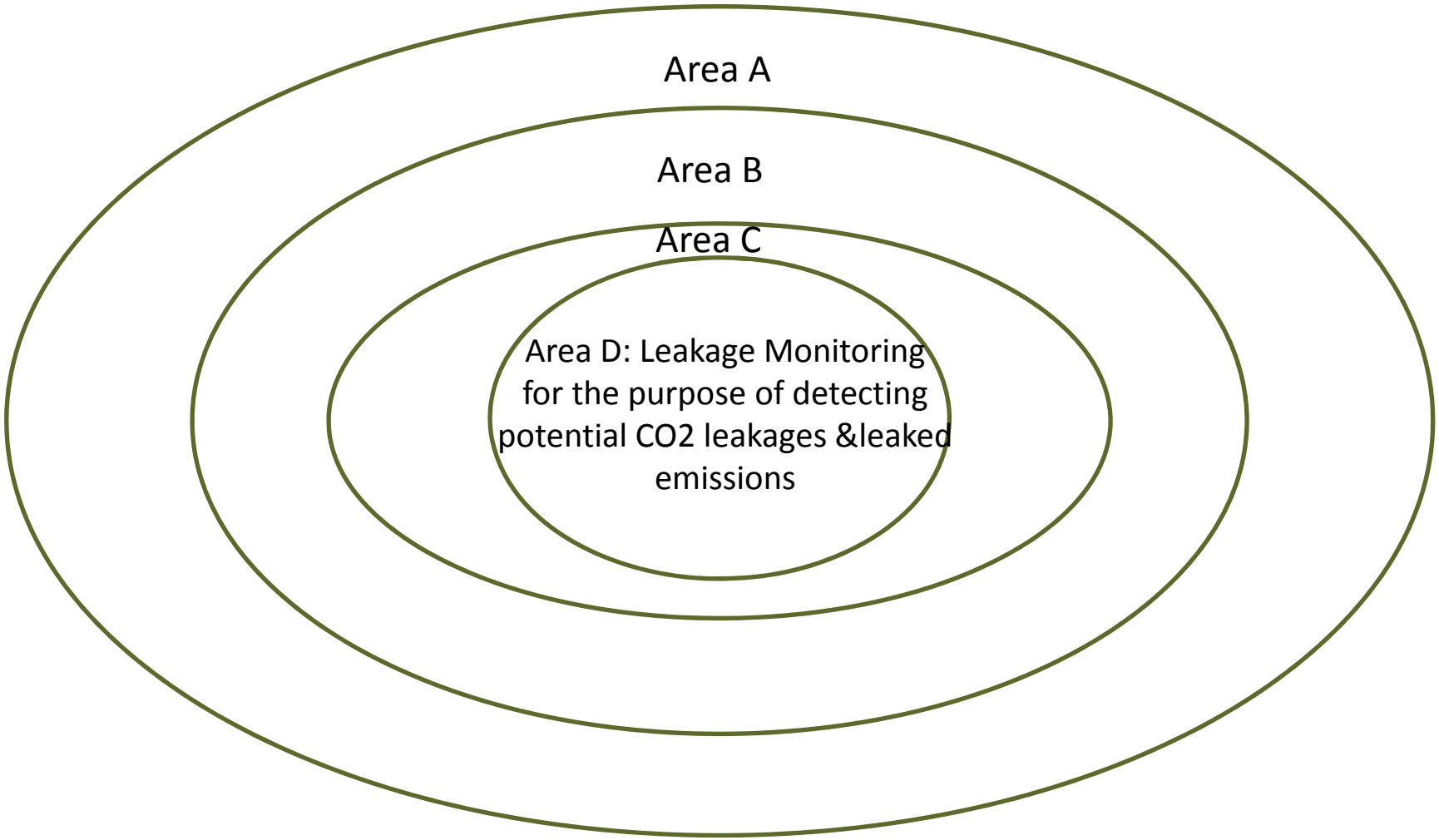
Area B: Open Conduit Assessment



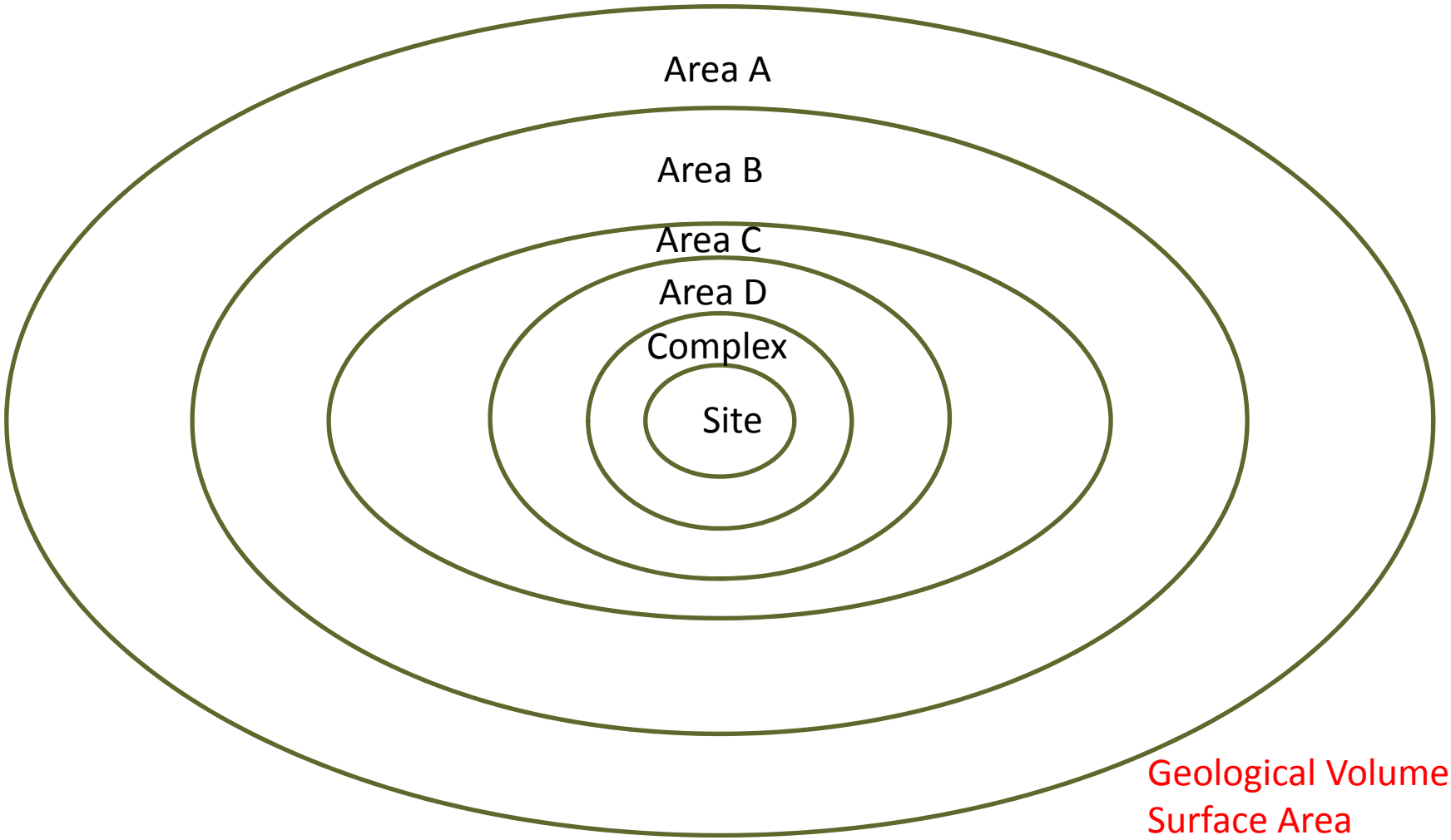
Area C: Pressure impact monitoring



Area D: Leakage monitoring



Overall Relationships



Geological Volume + Surface Area

Liability Trigger Boundaries

- Impact of leakages needs to be monitored in the context of several boundaries that would trigger different kinds of liabilities
- For example, the land and subsea surface are trigger boundaries, wherein if CO2 leakage crosses them, then they would be considered as emissions, and the operator is liable for surrendering ETS allowances
- Similarly, CAs may want to consider boundaries related to underground drinking water sources, oil/gas/coal reserves, geothermal resources, etc.
- Trespassing of these boundaries by any CO2 leakages could result in specific liabilities
- Such 'trigger' boundaries are useful for operators in planning responses to leakages and corrective measures

Importance of Baseline/Contingent Monitoring

- Before injection, it is critical to identify all possible baseline data that might be needed throughout the project life cycle including the operations, post-injection, as well as for contingency monitoring
  - Formation gas and fluid characteristics in the storage reservoir, surrounding complex and formations that might be affected by potential leakage, including drinking water sources
  - Background CO2 emissions at surface or sea floor
  - Surface and near surface environmental surveys
  - Seabed surface or near surface baseline surveys to define any pre-existing leakage indicators such as pock marks
- Statistical analysis of baseline data should be able to distinguish natural fluctuations from definite signatures of leakages and thresholds for significant irregularities
- Additional monitoring needs to be planned in case of significant irregularities to verify, locate, and quantify potential leakages

Summary

- The Guidance Documents provide a framework for developing monitoring-oriented regulations in different member states
- Monitoring regulations needs to consider specific site/complex/surrounding area boundaries
- CAs will need to work with permit applicants to ensure that appropriate boundaries for monitoring are selected
- Baseline data and analysis, along with rigorous and statistically valid monitoring plan, is critical for determining how leakages can be detected and for assessing their impacts

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