Recommendations for Geologic Carbon Sequestration in California: I. Siting Criteria and Monitoring Approaches, II. Example Application Case Studies

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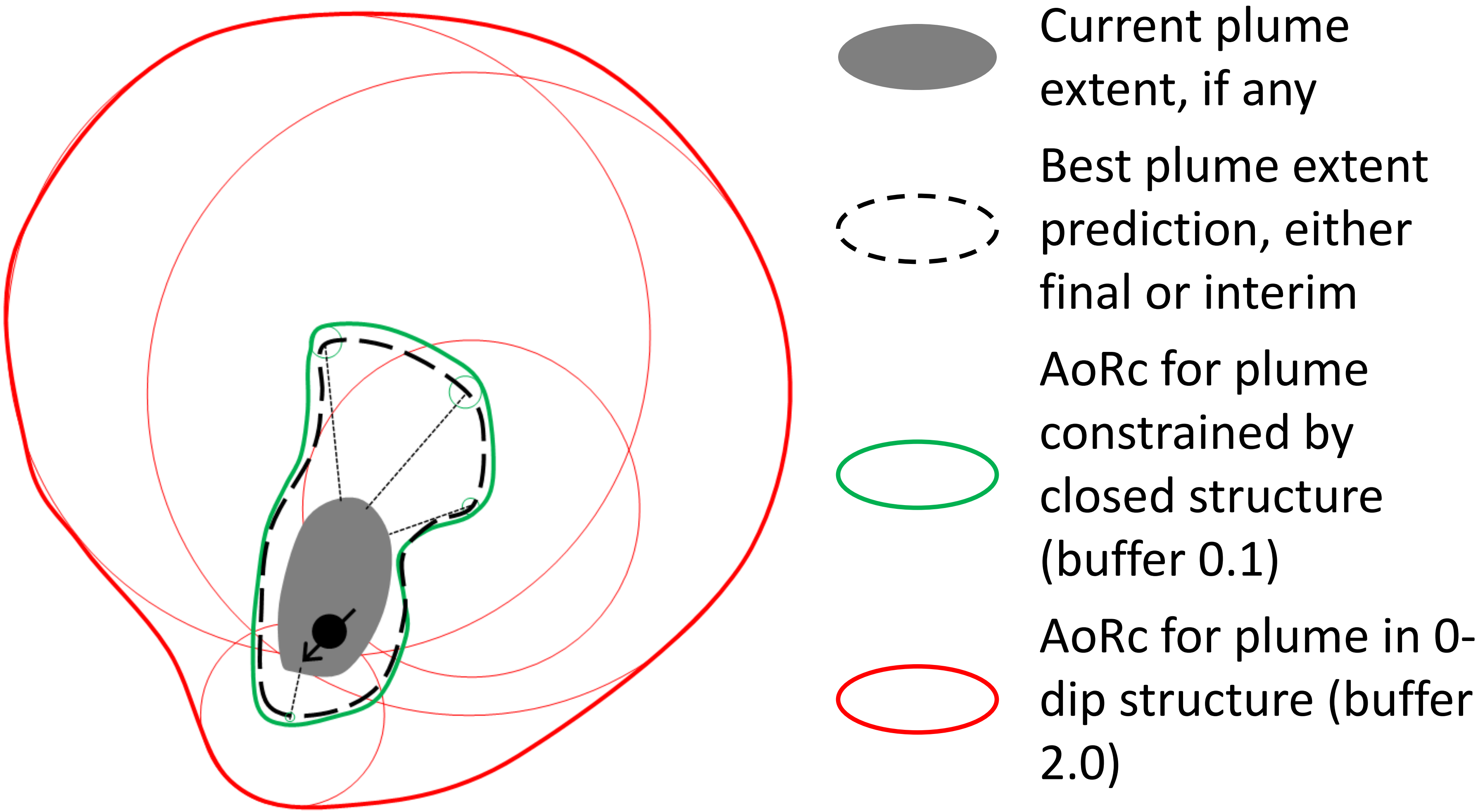
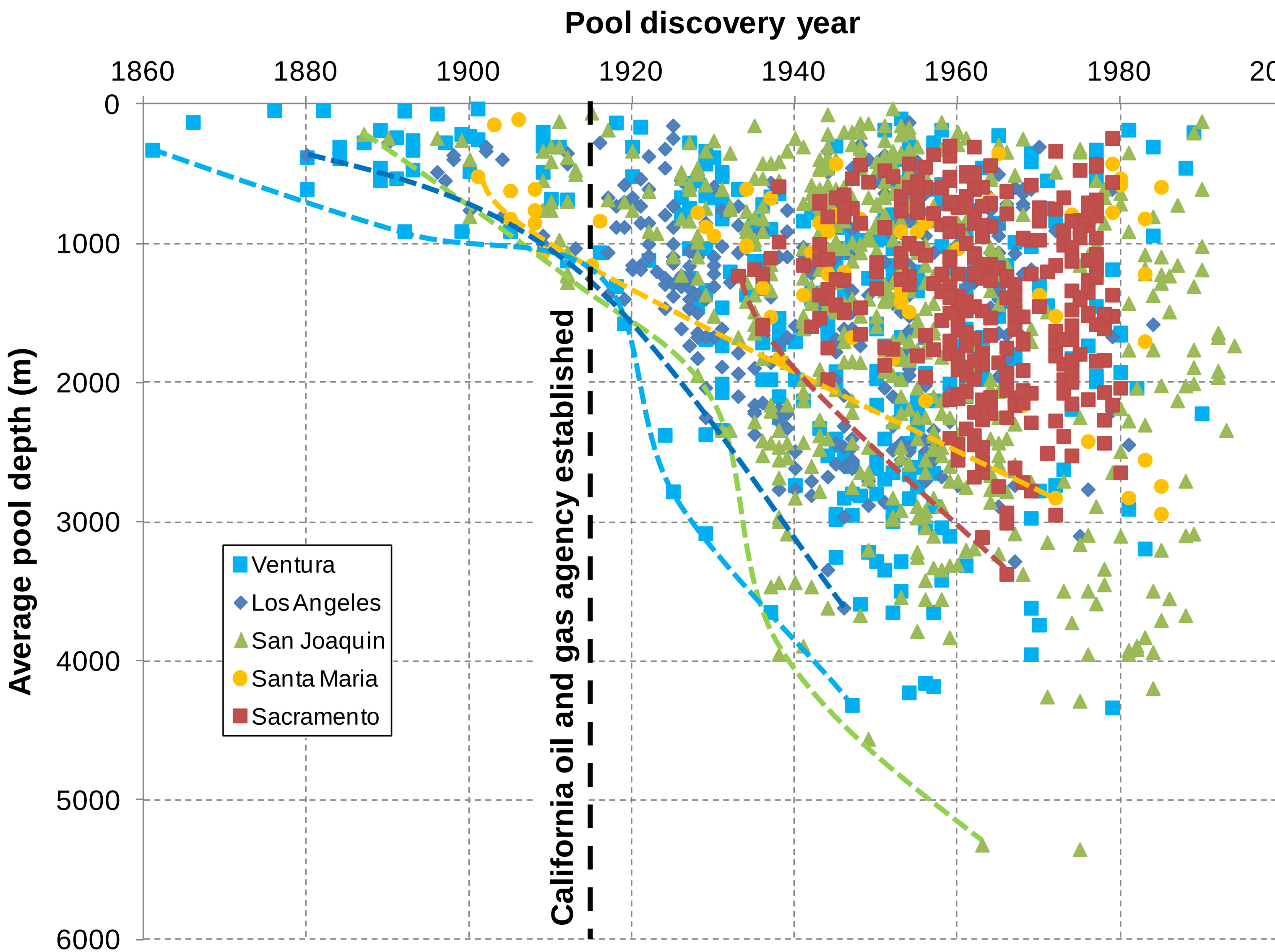
Careful site selection is the best way to ensure containment

- We recommend focusing site characterization and monitoring on the free-phase CO_2 plume and overlying area.
- Wells and boreholes are the main risk for CO_2 surface leakage.
- Areas with hydrocarbons discovered prior to 1921 in California have the highest likelihood of unknown wells.
- Uncased borings with no plugs in the primary seal create substantial risk due to lack of knowledge regarding the transimissivity of these features.
- Transmissive faults and fractures are best avoided by selecting sites with ductile seals.
- Sites with a pressure-dissipation interval between the storage zone and the base of underground sources of drinking water (USDW) reduce leakage risk and between the storage zone and the top of basement reduce seismic risk.
- A minimum injectivity is needed for any successful GCS site. This should be estimated during project design at a scale relevant to the proposed project.
- Sites in areas of low population density reduce the likelihood of impacts to people (e.g., from monitoring, pipeline transportation, injection, leakage).

Free Phase CO_2 Plume Area of Review (AoRc)



No “Early” Hydrocarbon Discoveries



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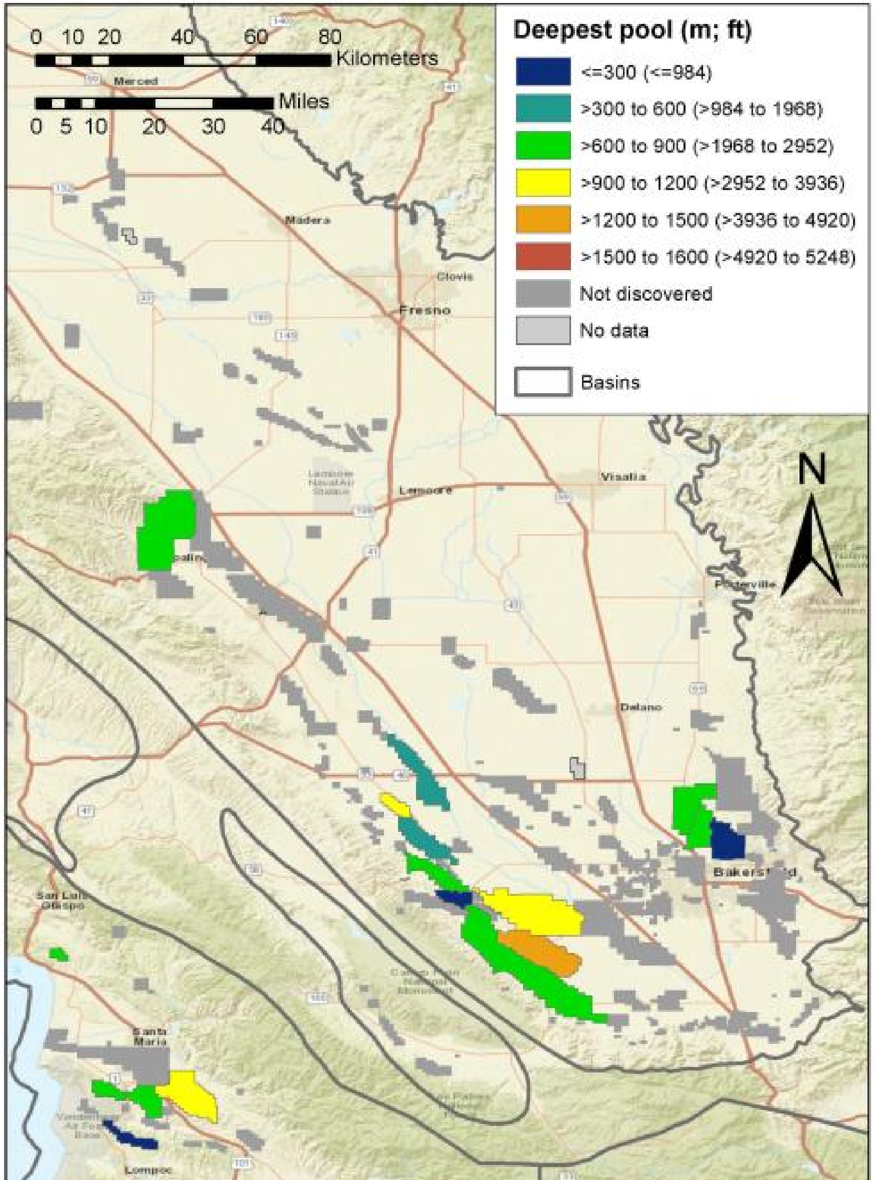
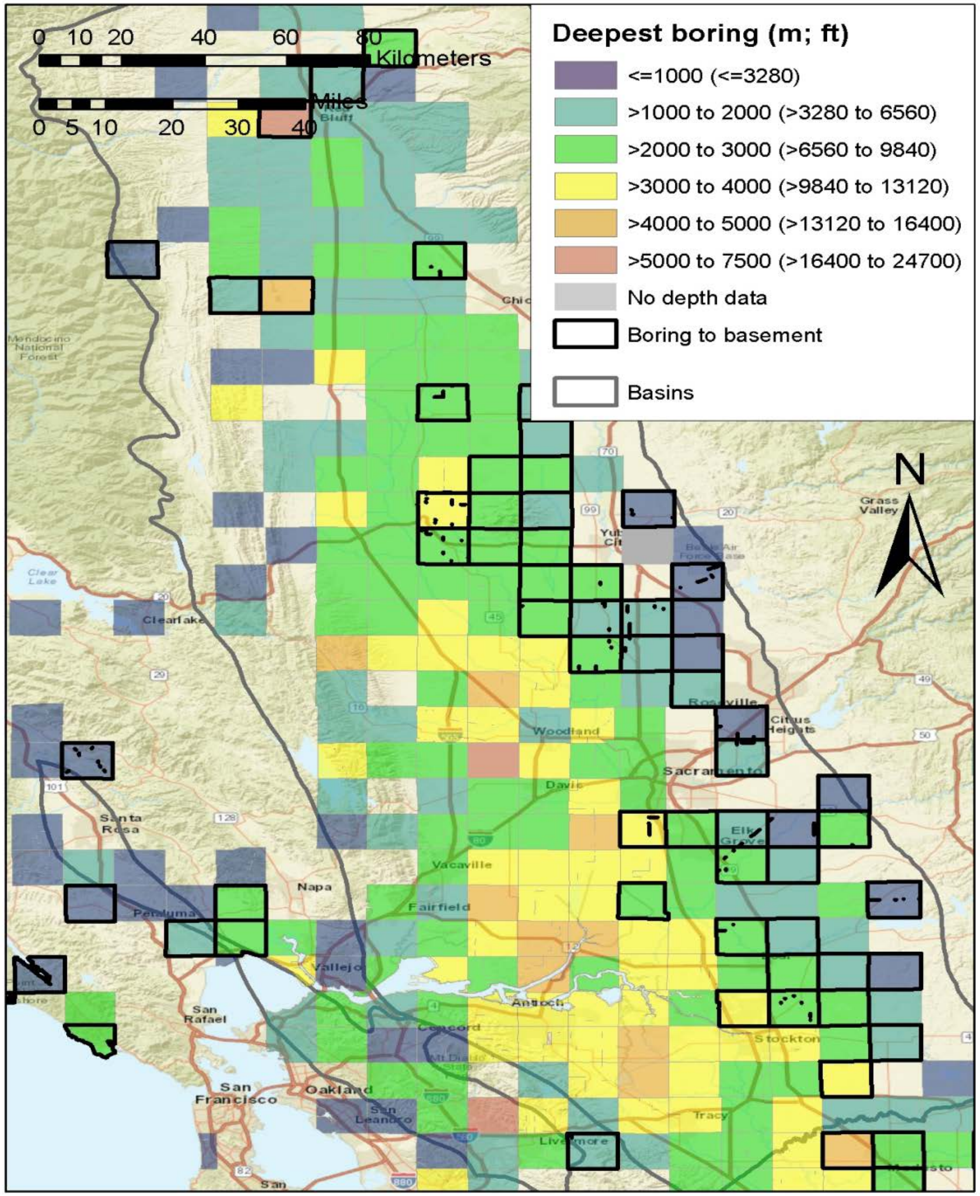


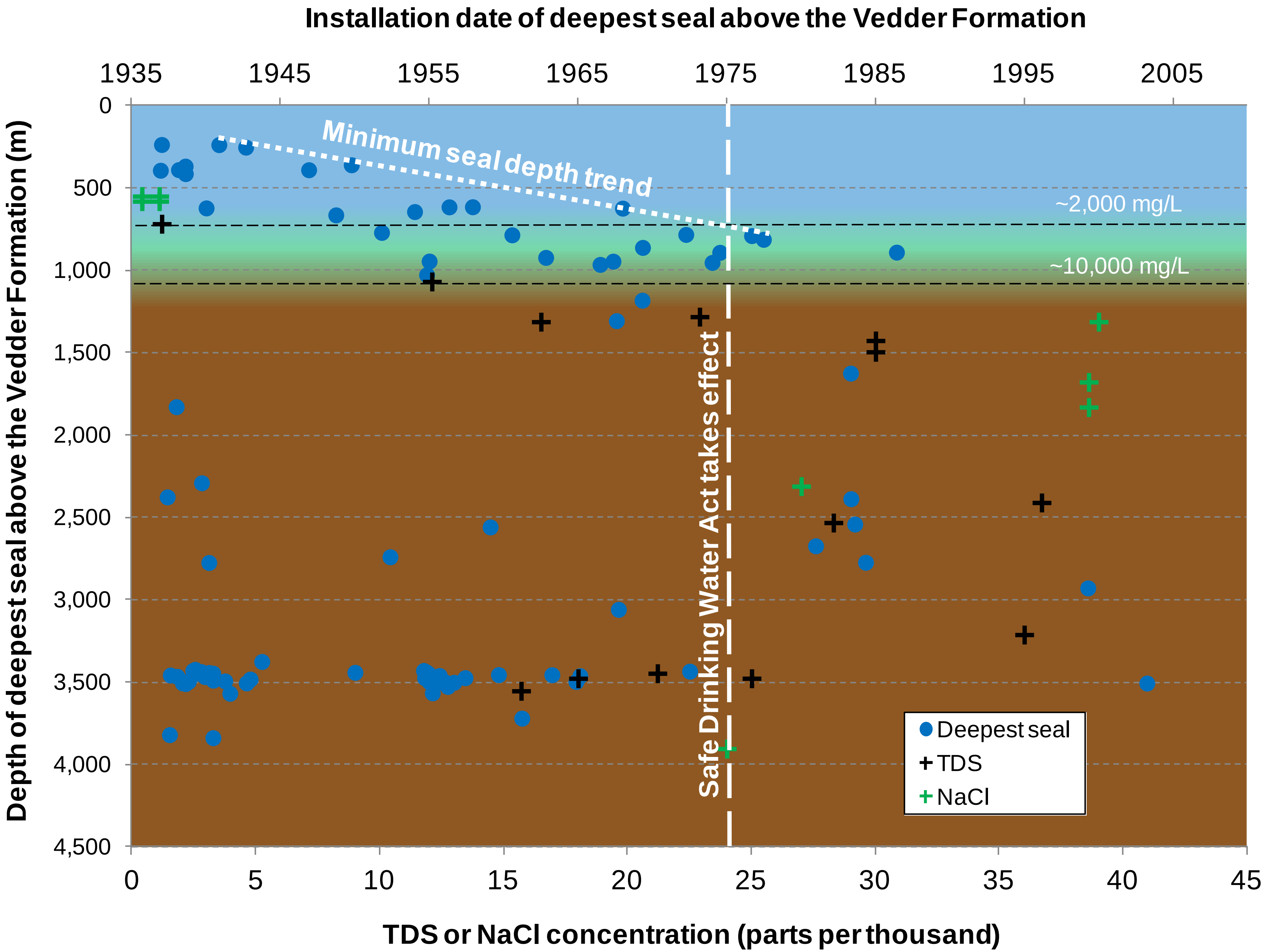
Average depth of deepest pool discovered prior to 1921

Uncased Borings Plugged In Seal



Deepest boring in each township and townships with a boring to basement prior to 1981

Wells/Uncased Borings Sealed In Seal



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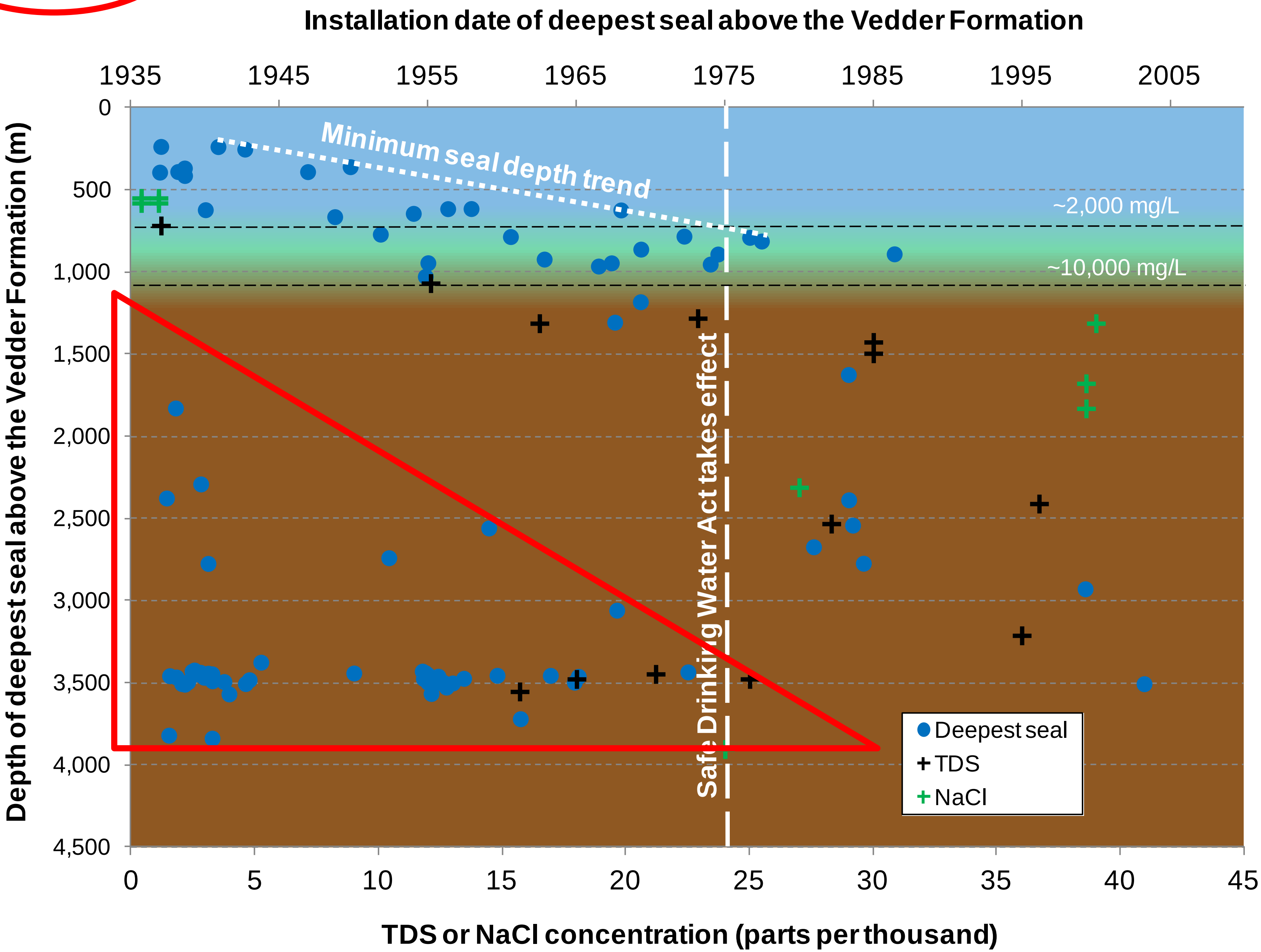

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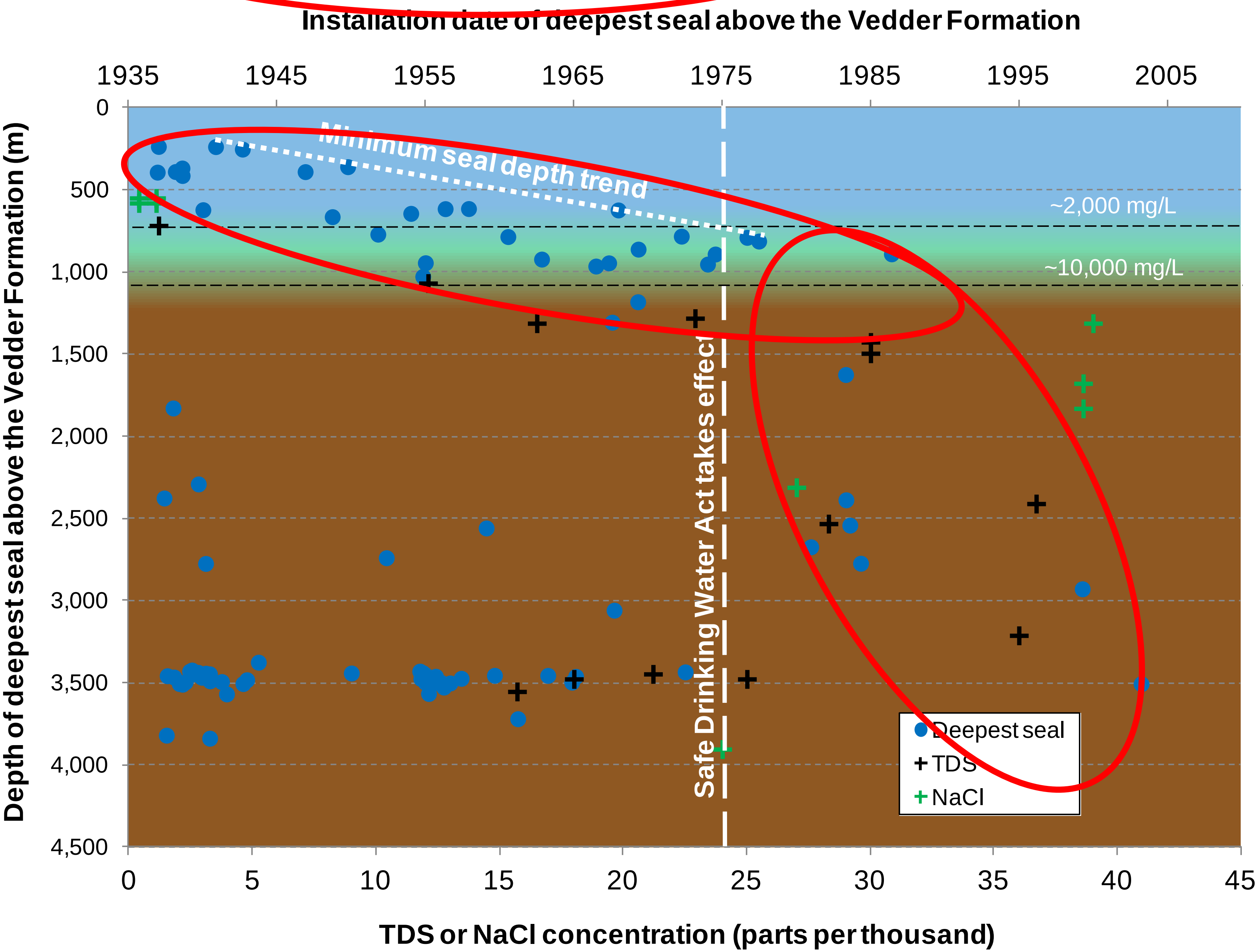

Seal with Low Brittleness

- Unconfined compressive strength less than twice normally consolidated unconfined compressive strength (little cementing or uplift)
- Unconfined compressive strength estimated from sonic velocity logs
- Normally consolidated compressive strength estimated from effective lithostatic stress

https://en.wikipedia.org/wiki/Shear_band#/media/File:X-shaped_shear_bands_in_clay.jpg

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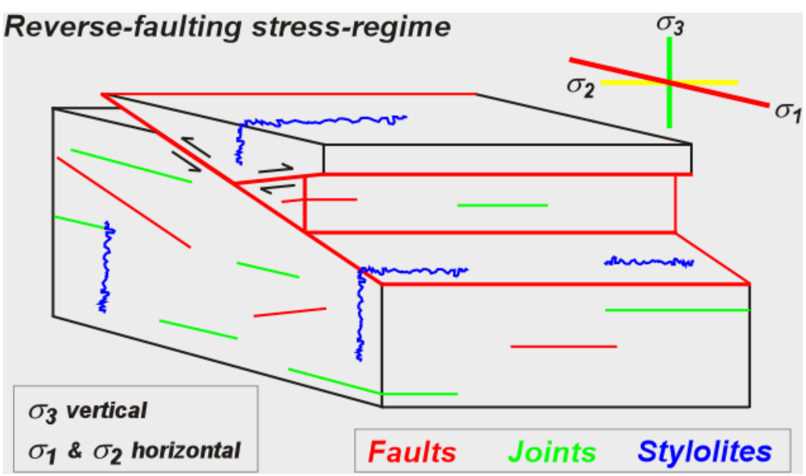
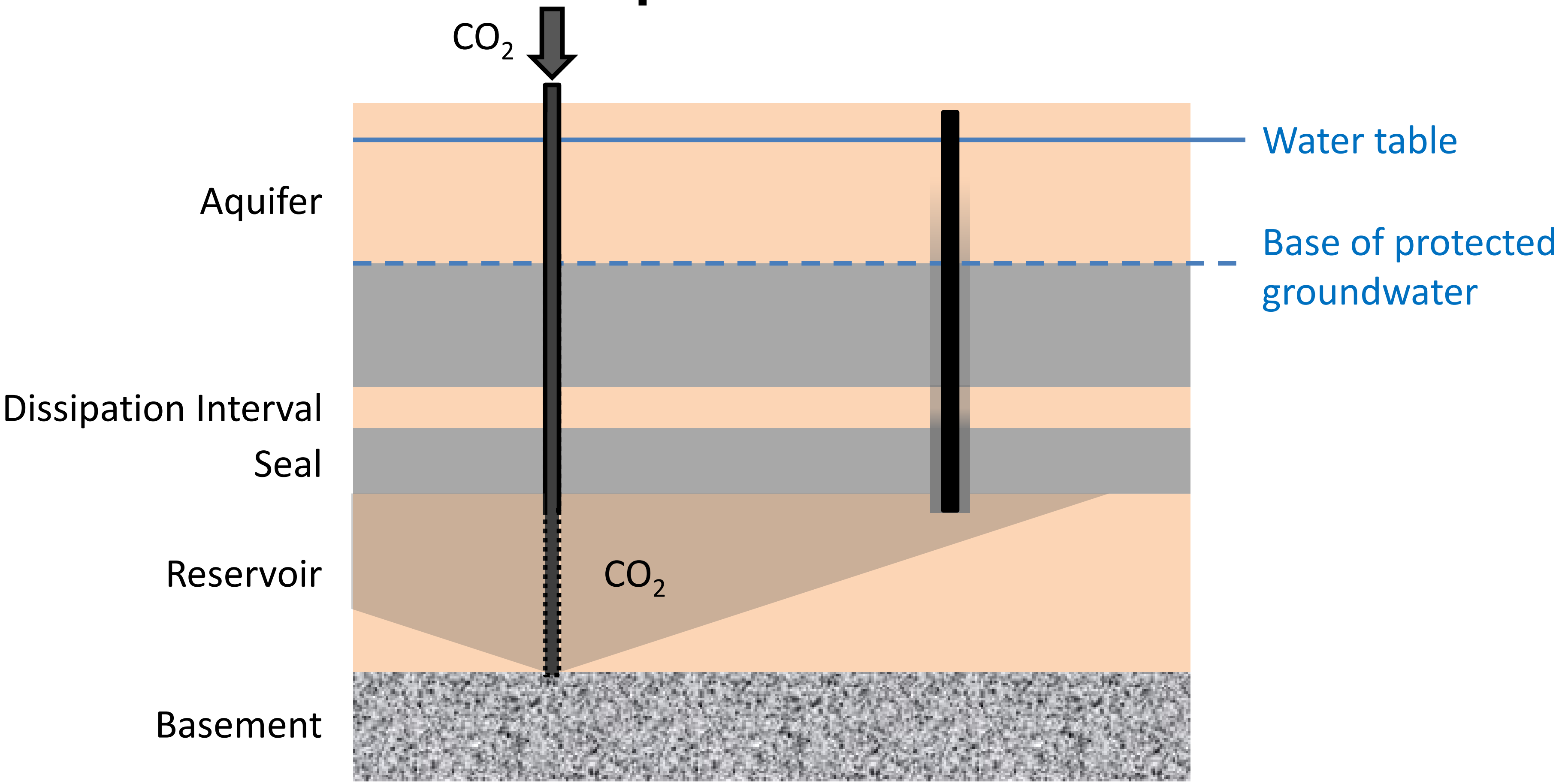
Or In Thrust Fault Stress Regime



- Vertical (lithostatic) effective stress less than horizontal stresses
- Opening fractures horizontal
- Shear fractures shallowly dip

http://www.naturalfractures.com/1.1.htm

Pressure Dissipation Interval Above



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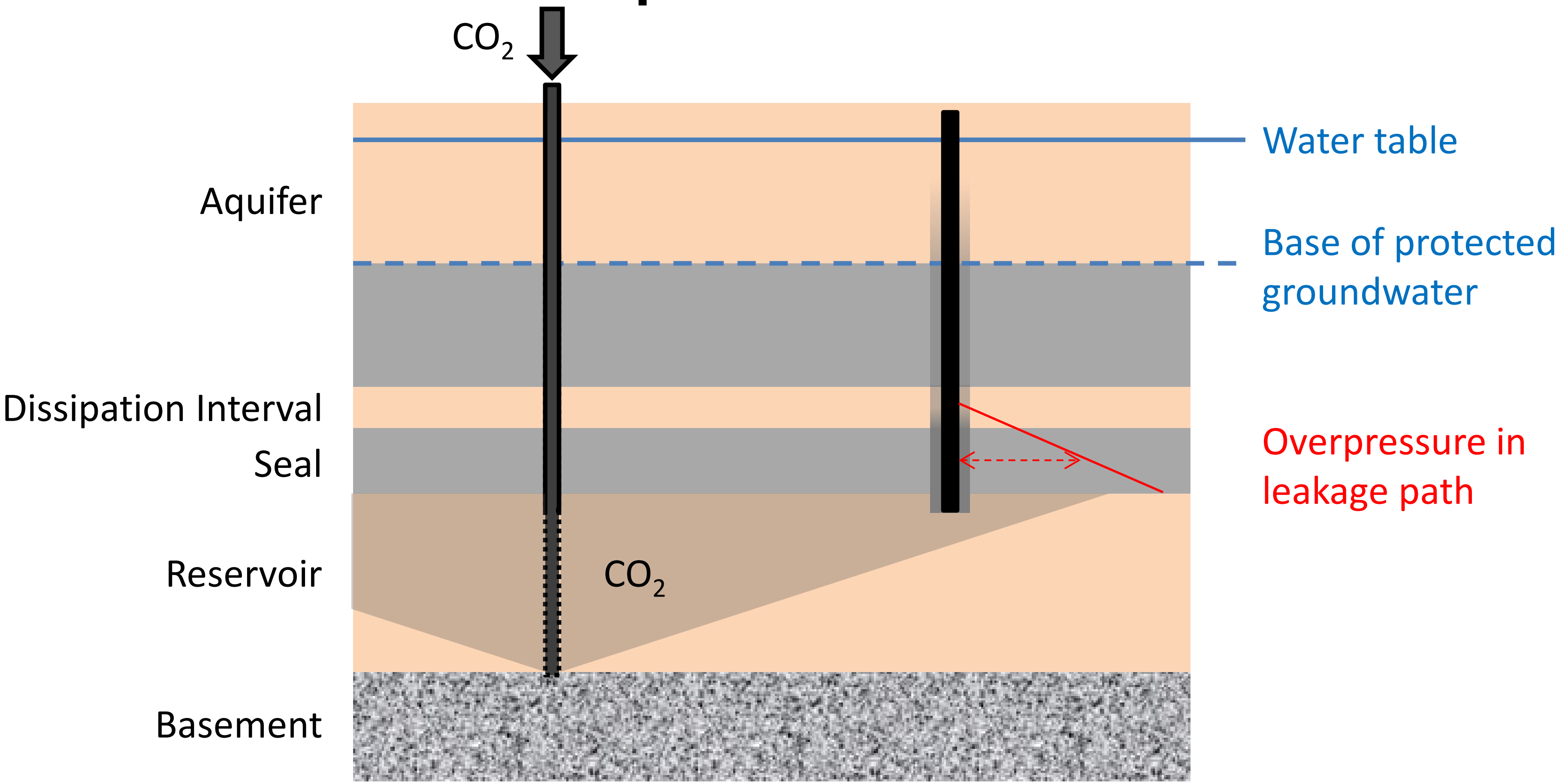

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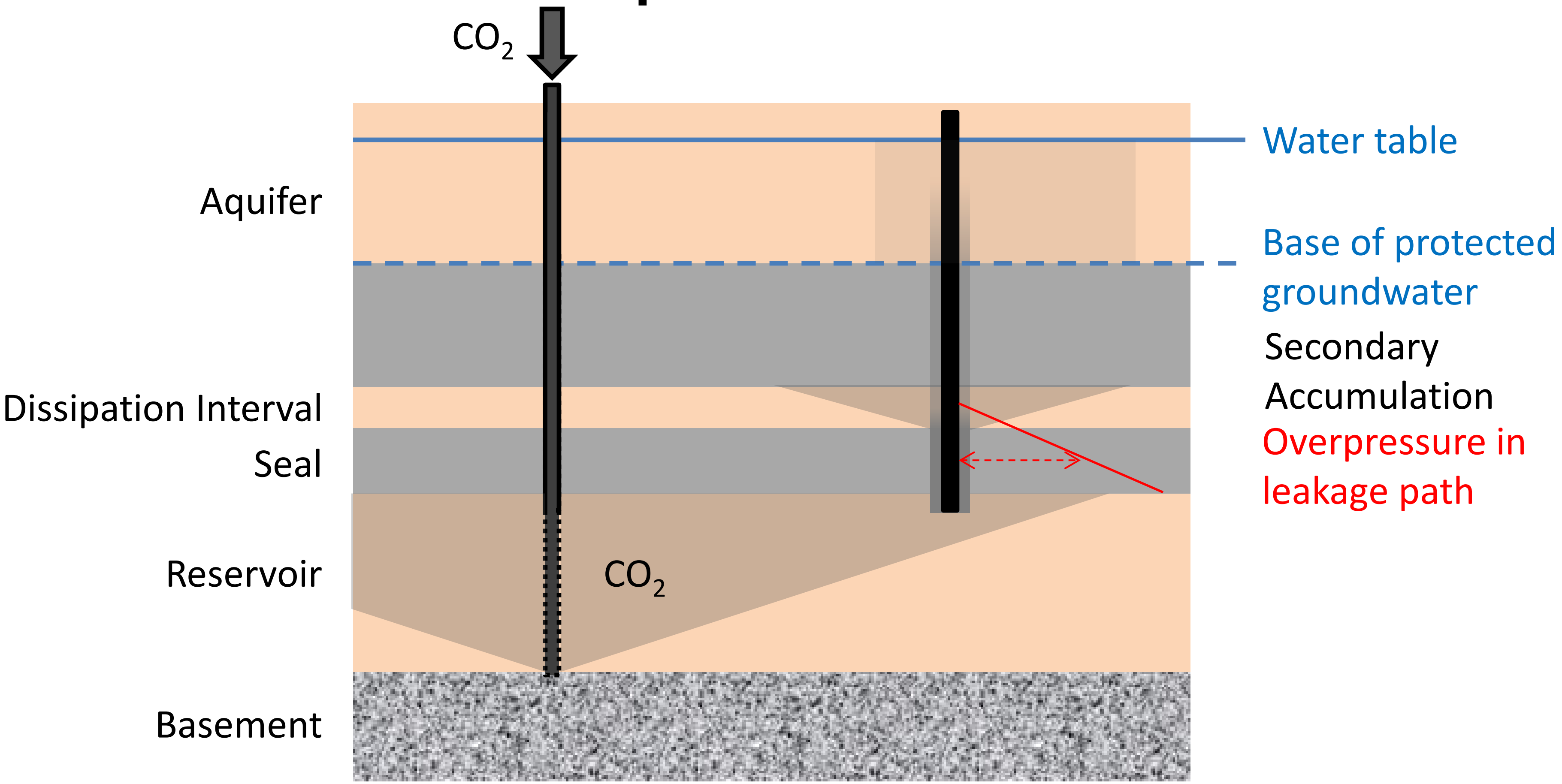

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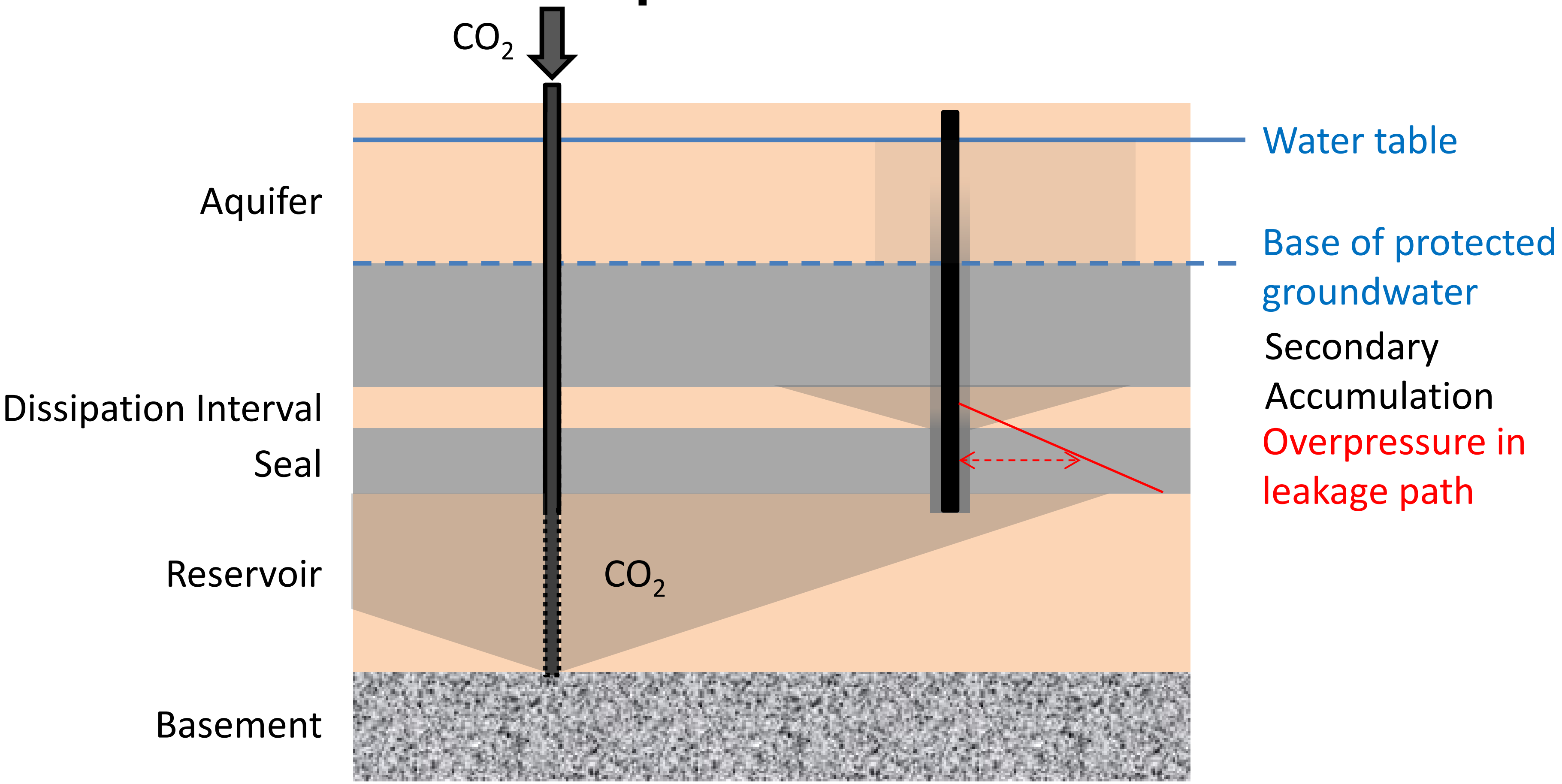
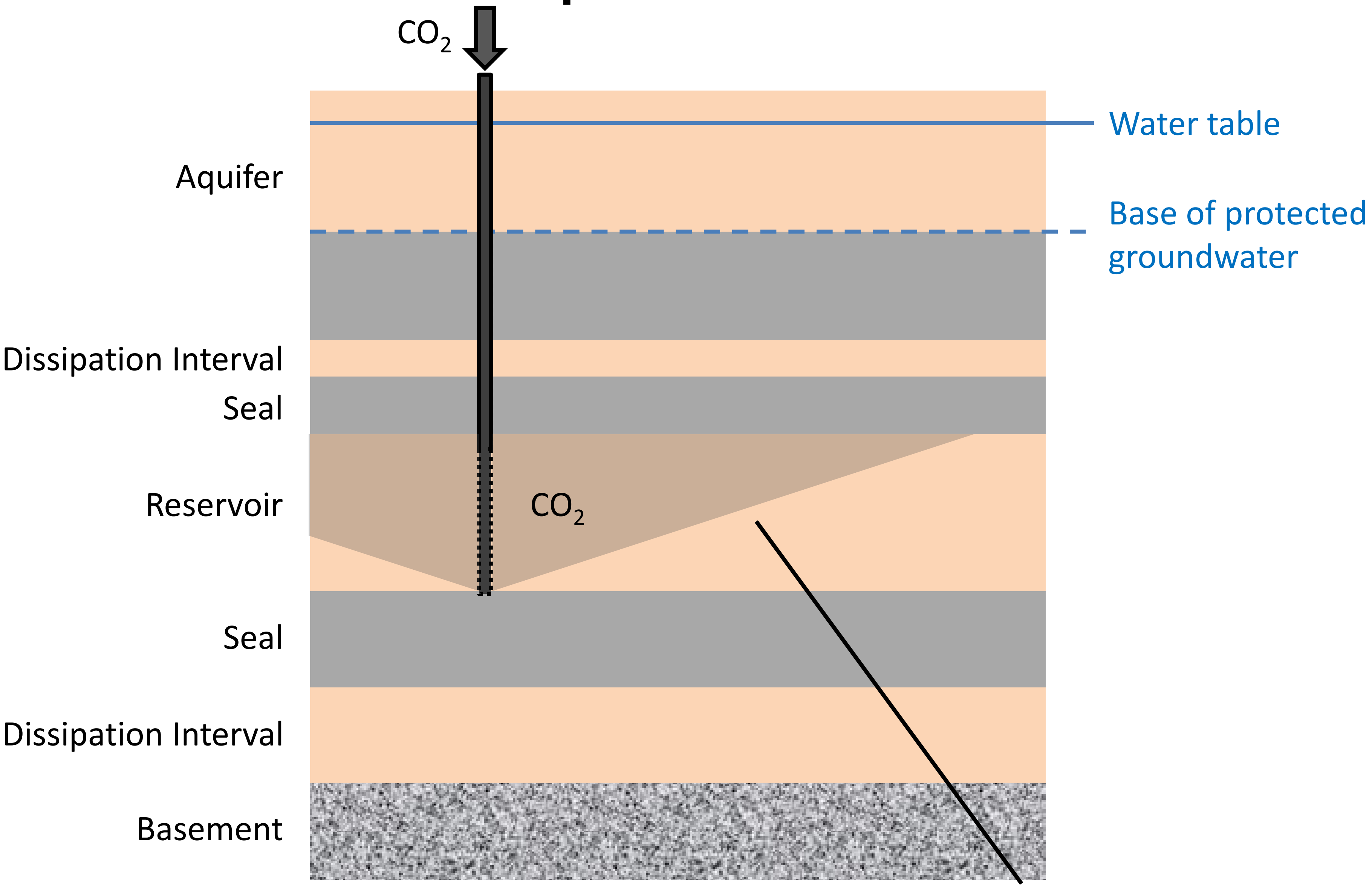


Dissipation interval above both reduces leakage to receptors and provides a monitoring target

Pressure Dissipation Interval Below



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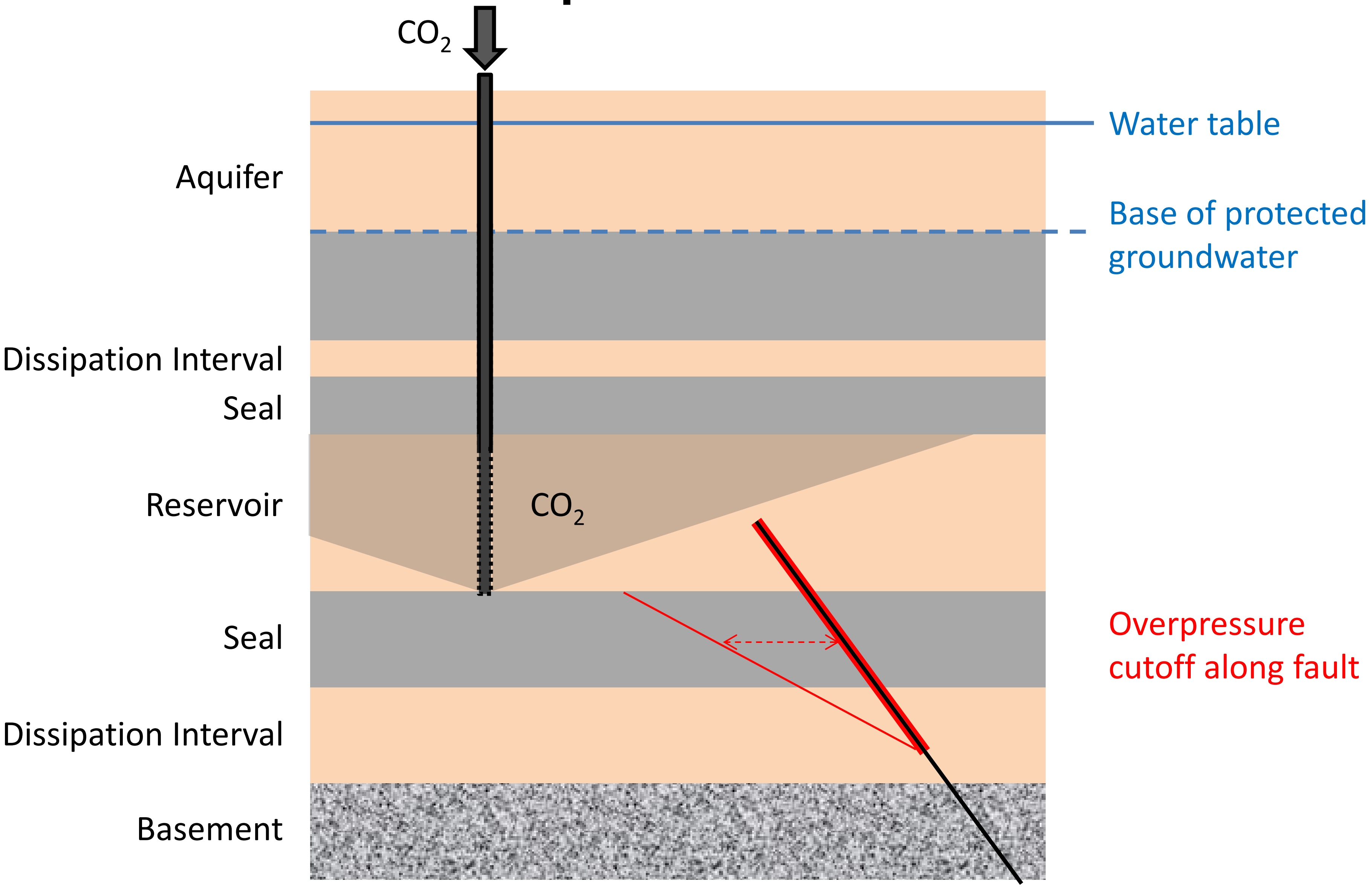
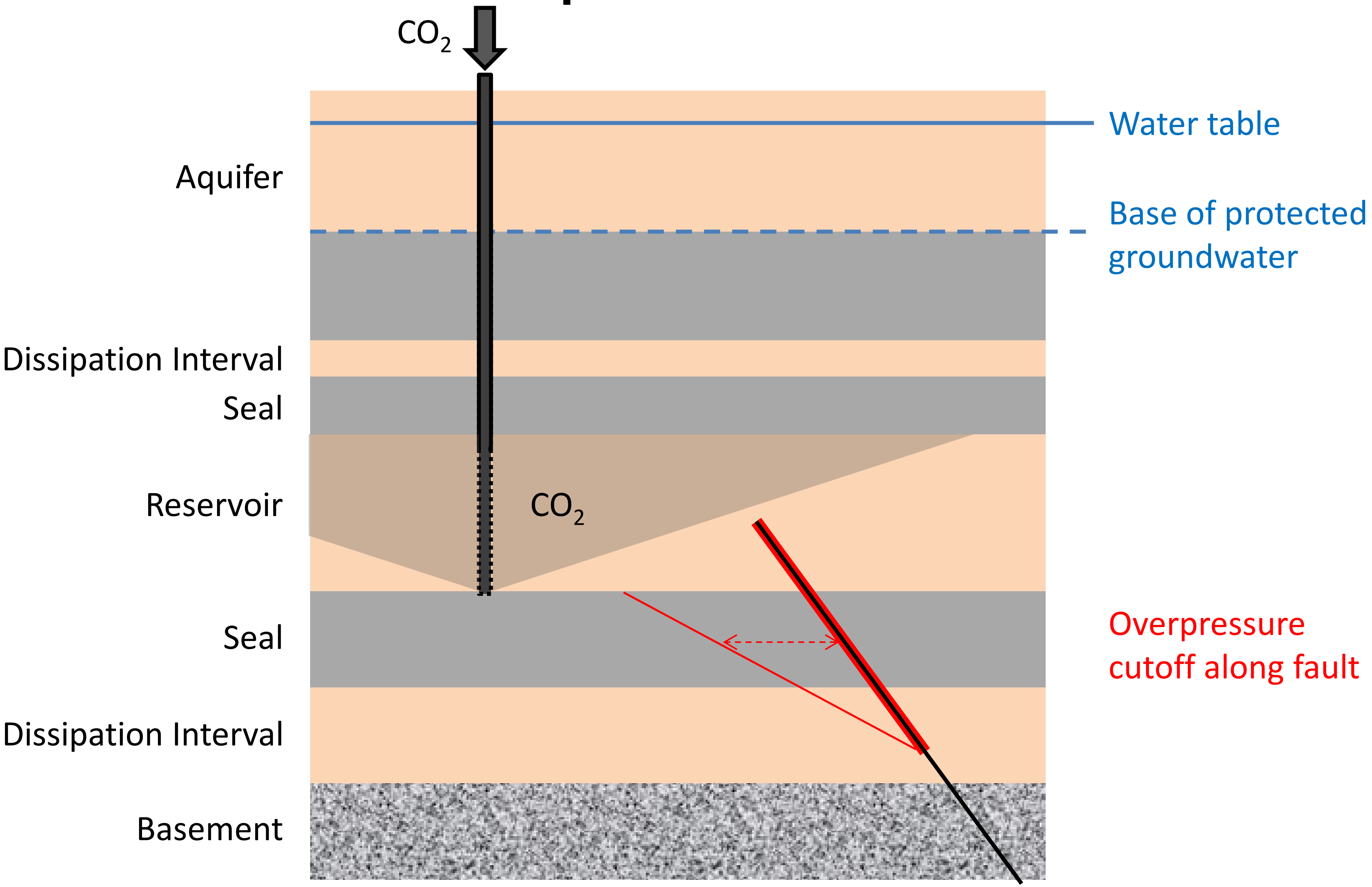
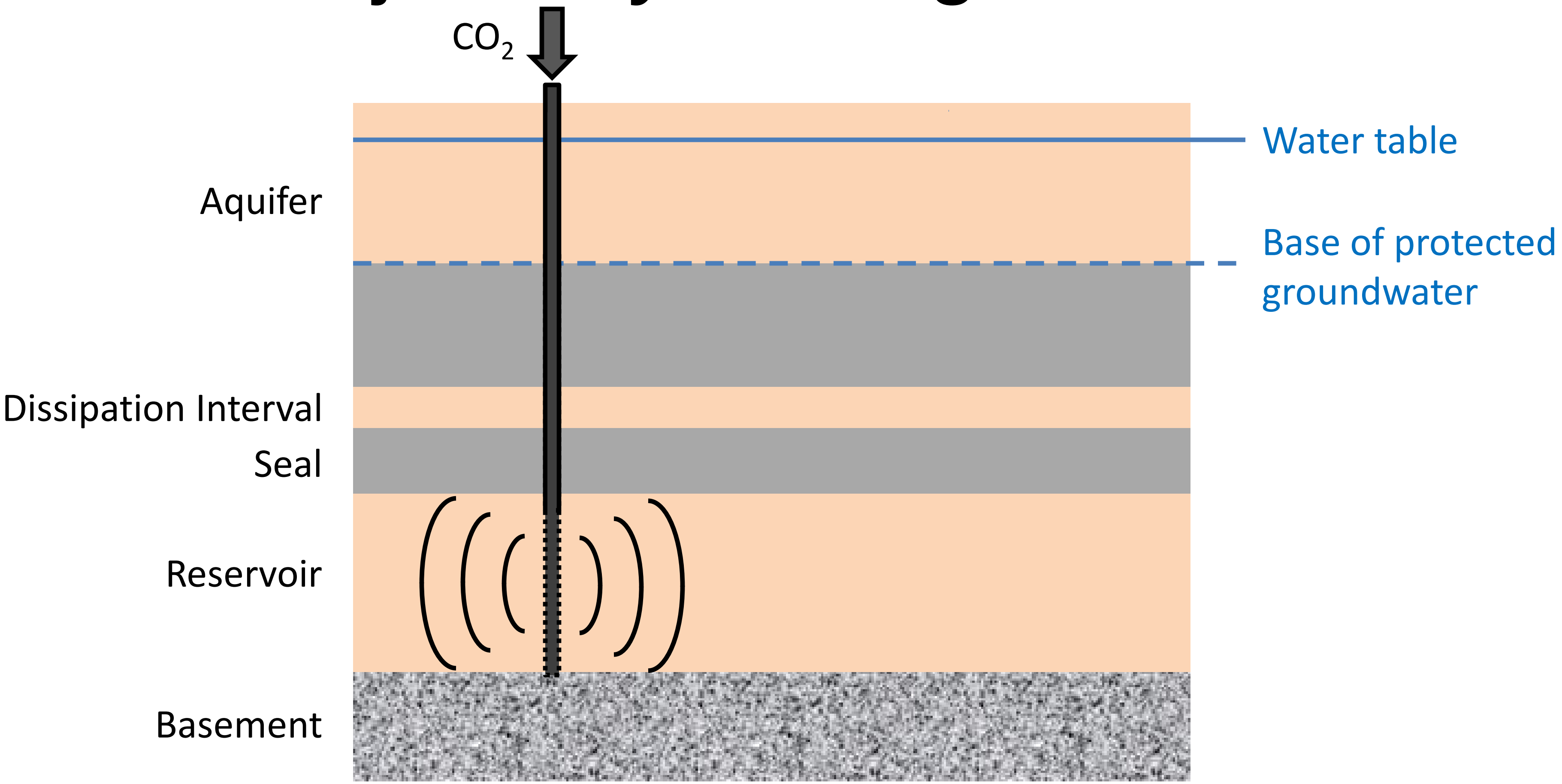


Dissipation interval below reduces seismic hazard

Pressure Dissipation Interval Below

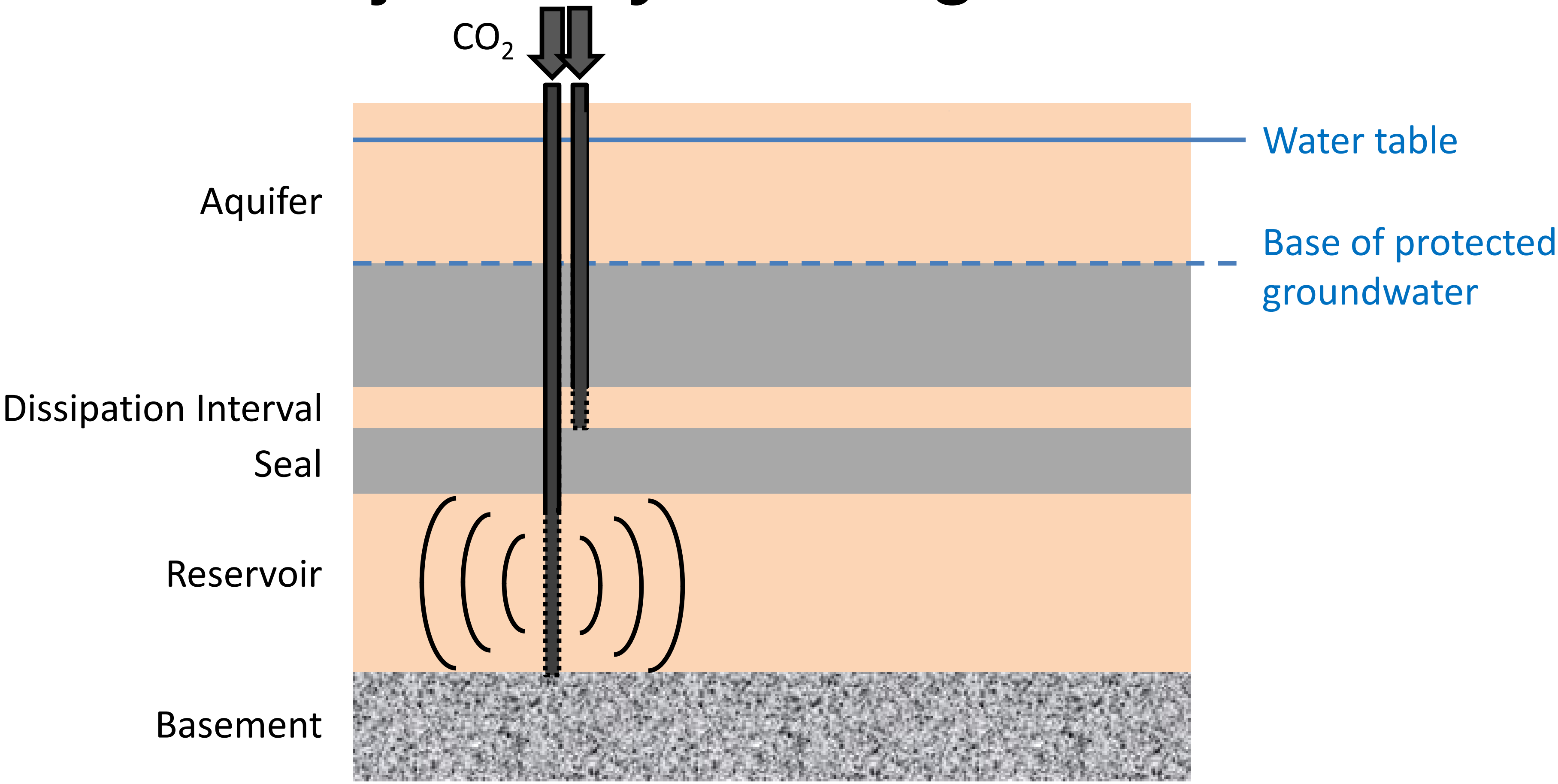


Injectivity Management



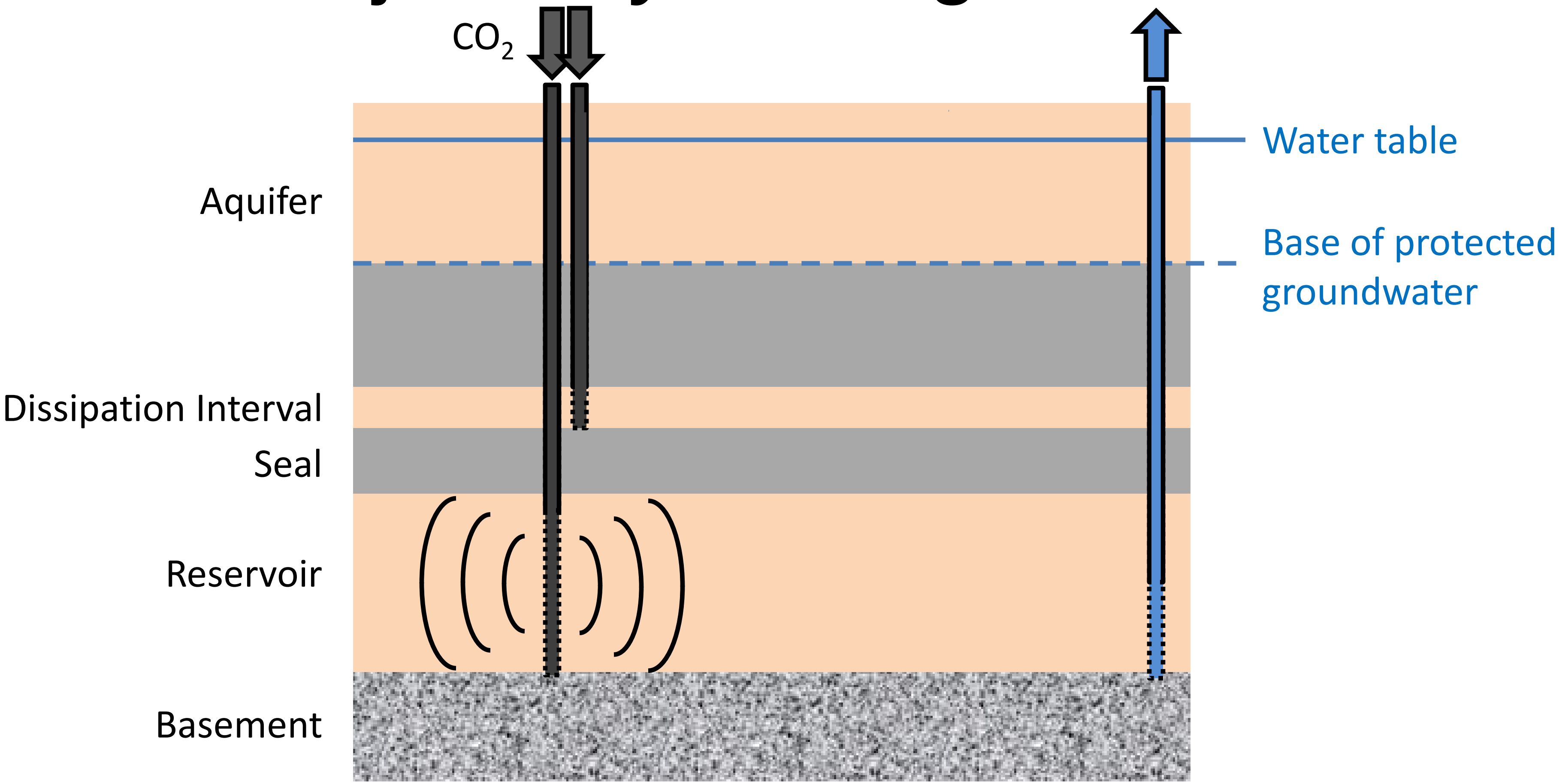
- Injectivity test stressing one tenth of AoRc

Injectivity Management



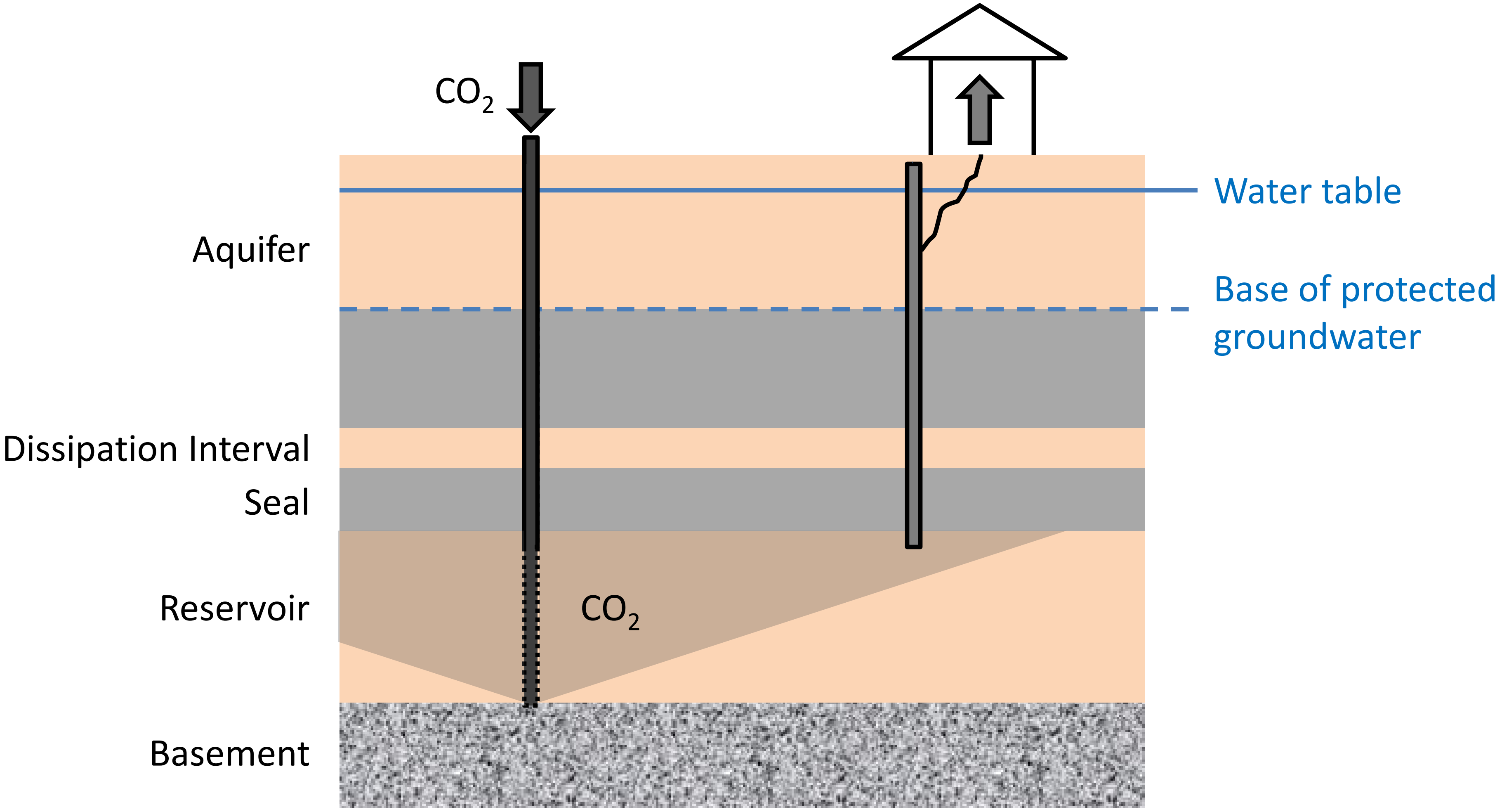
- Injectivity test stressing one tenth of AoRc
- Backup injection interval

Injectivity Management



- Injectivity test stressing one tenth of AoRc
- Backup injection interval
- Pressure management (fluid extraction)

Minimize Building CO_2 Injection Risk

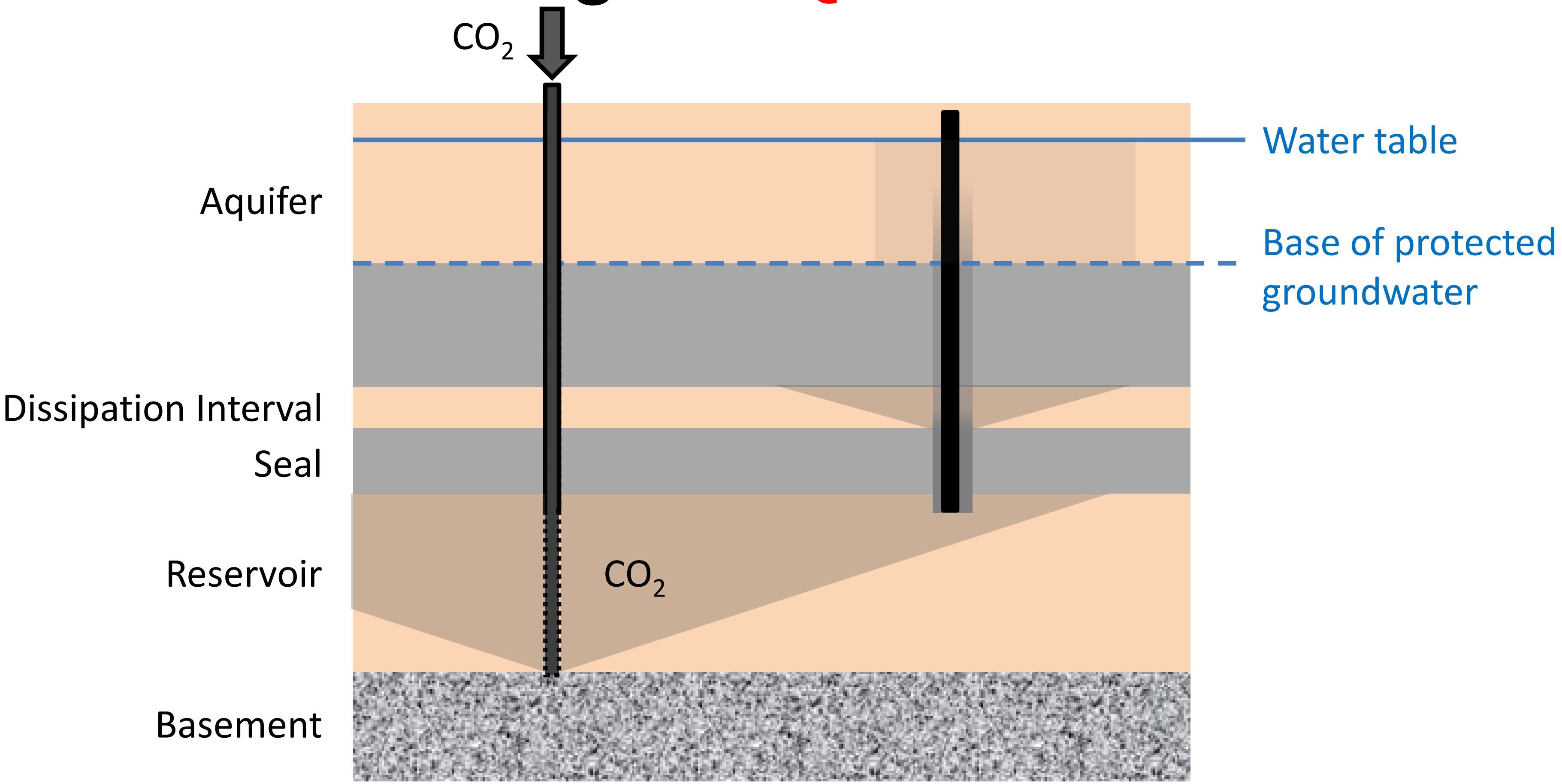


- AoRc does not include any portion of a city
- The probability of an occupant experiencing a CO_2 well blowout into the building < one in ten thousand per project (<50% globally)

Negative accounting using monitoring results to quantify storage

- We recommend monitoring plans be developed to detect secondary accumulations, as well as surface leakage.
- We recommend quantifying the mass of CO_2 stored by subtracting either the detected leakage or the leakage detection limit from the mass injected.
- We recommend conducting three-dimensional (3D) time-lapse seismic at regular intervals using the same seismic network and monitoring for changes in pressure in the overlying dissipation interval.

Monitoring for Quantification



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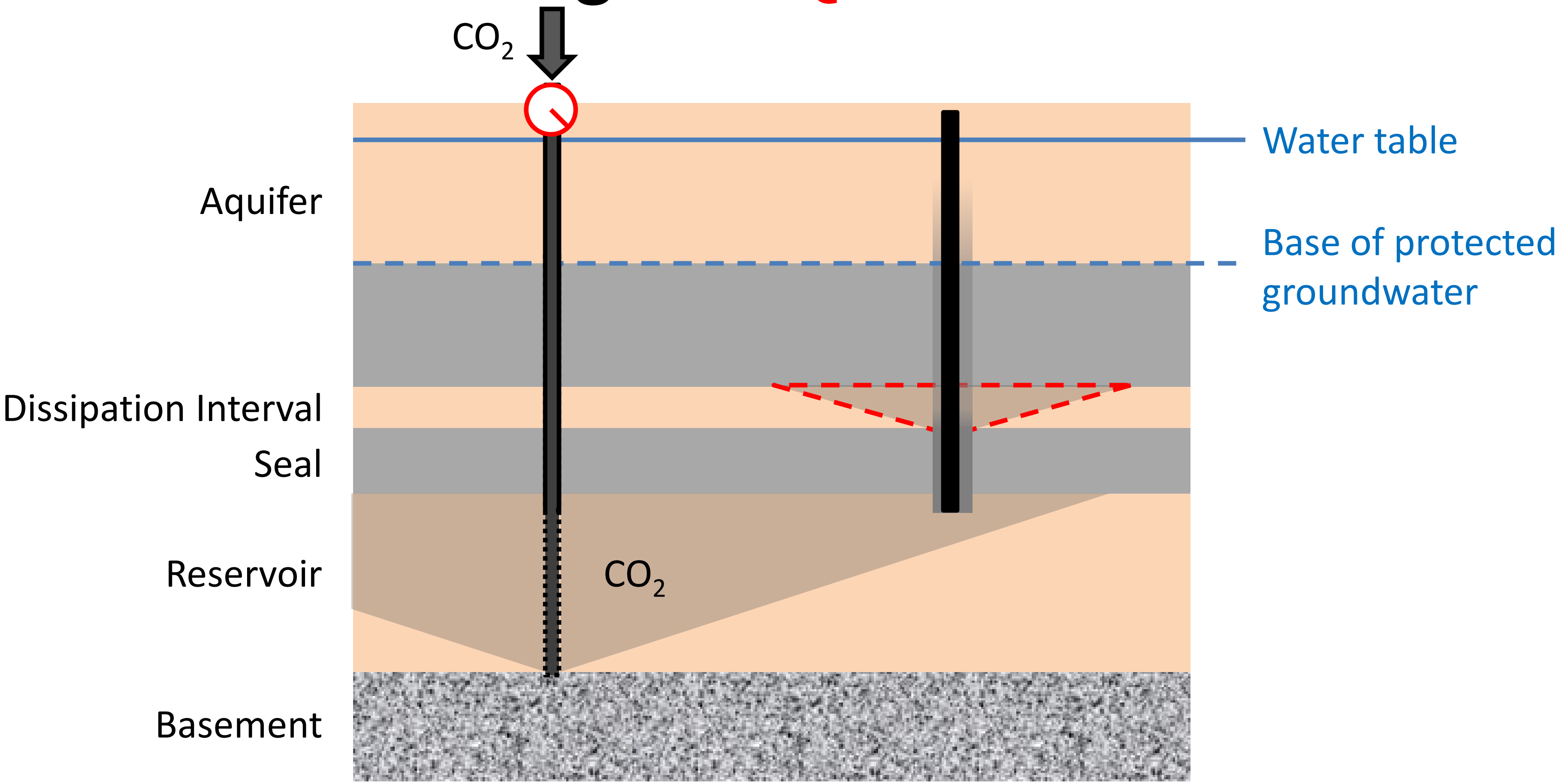
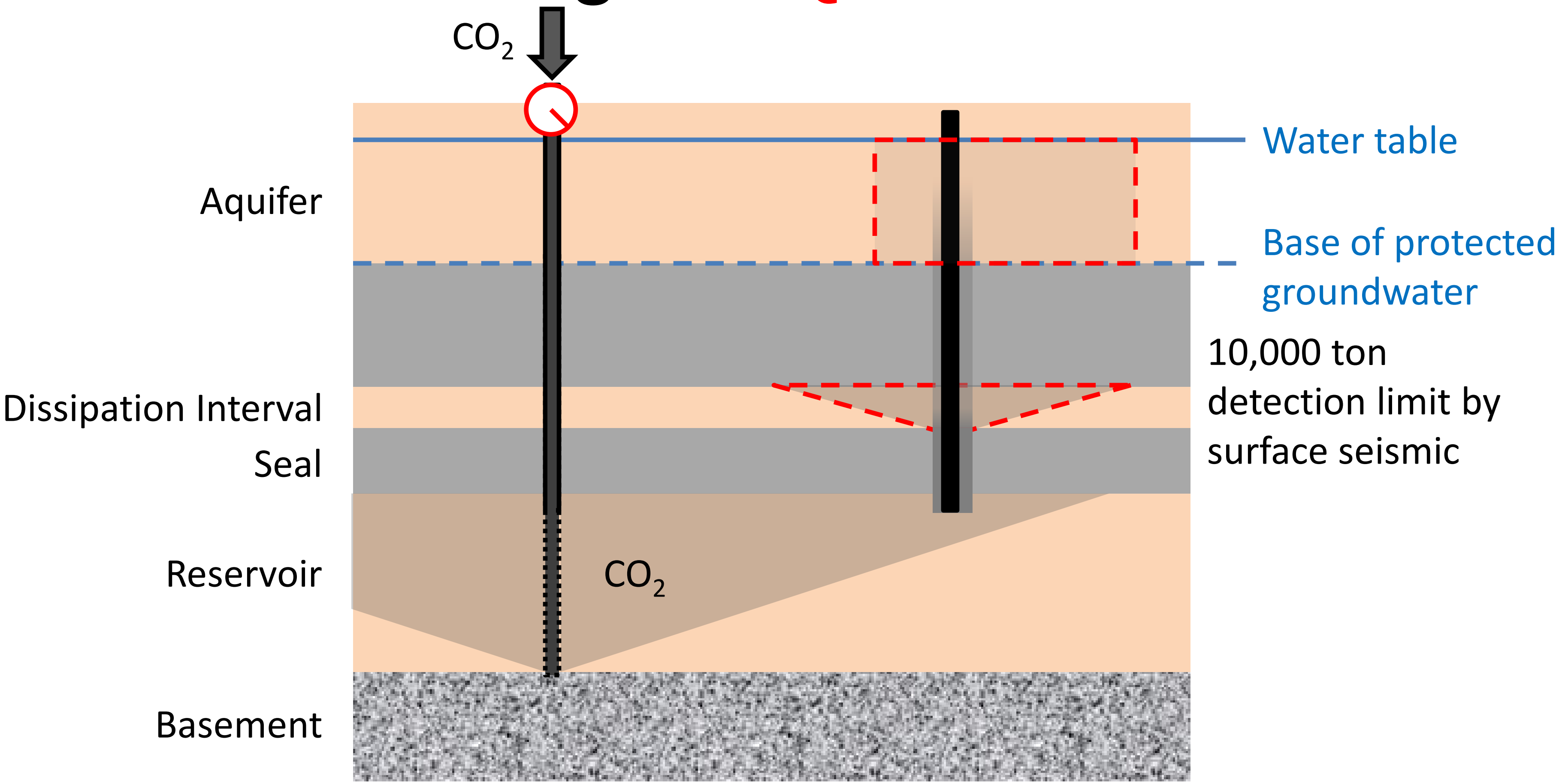


"Negative accounting"

Monitoring for Quantification



"Negative accounting"

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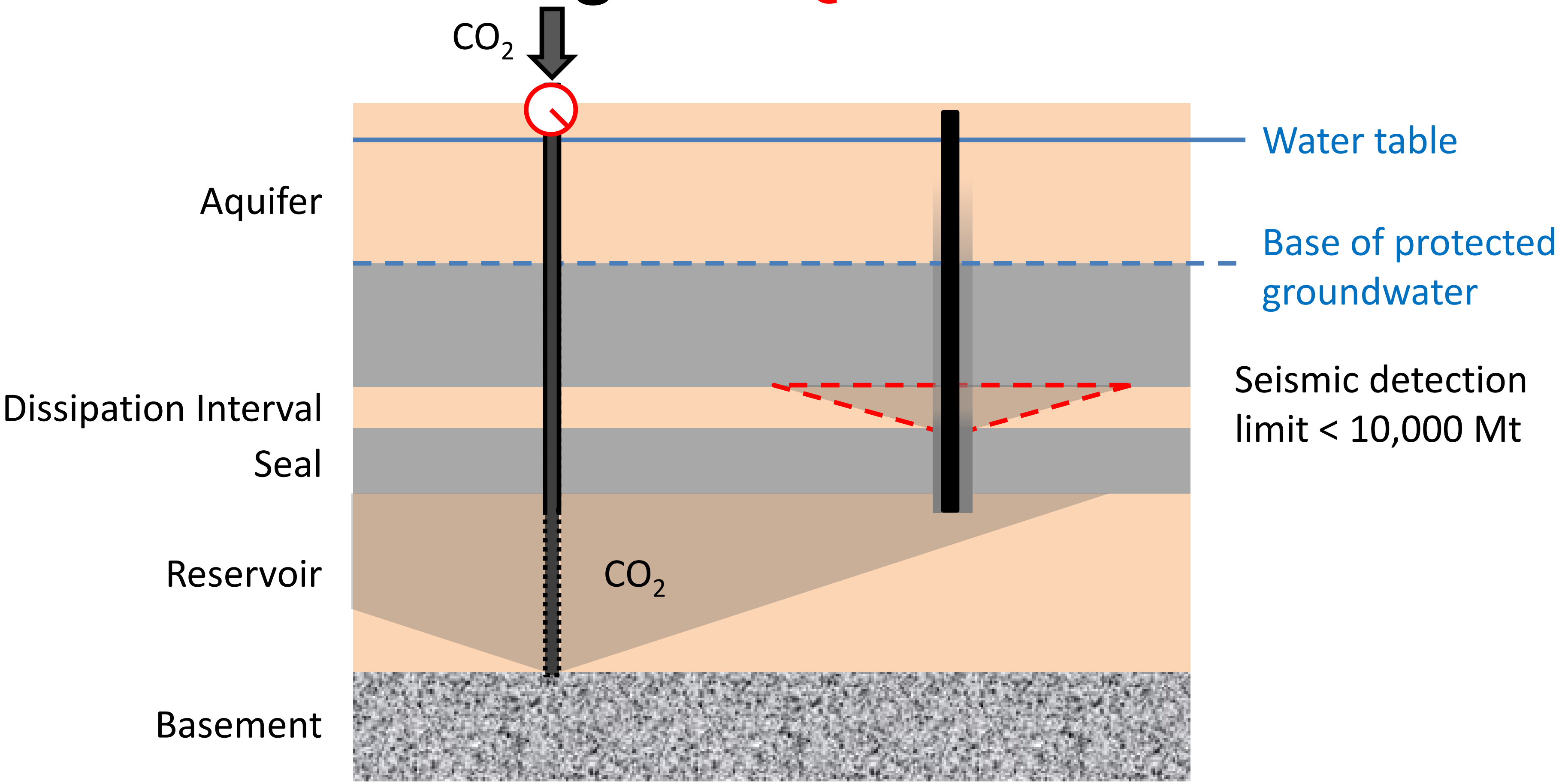
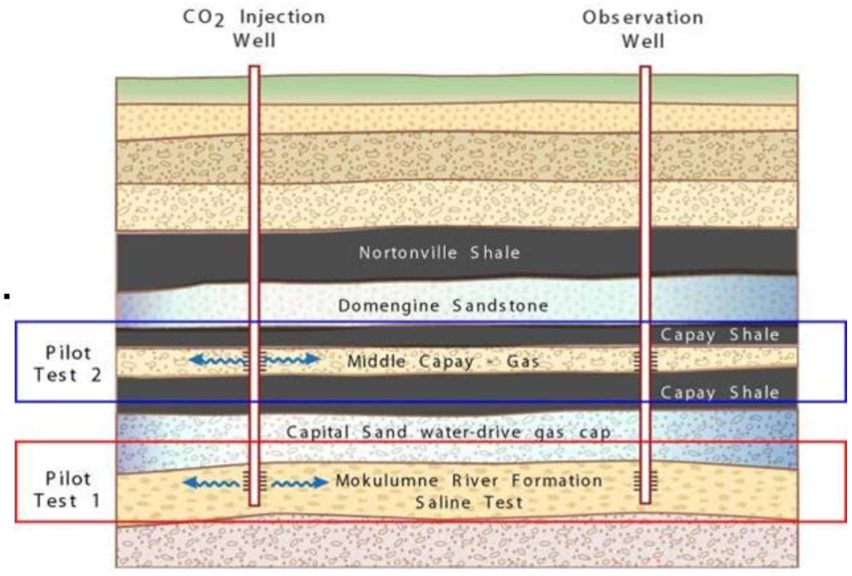


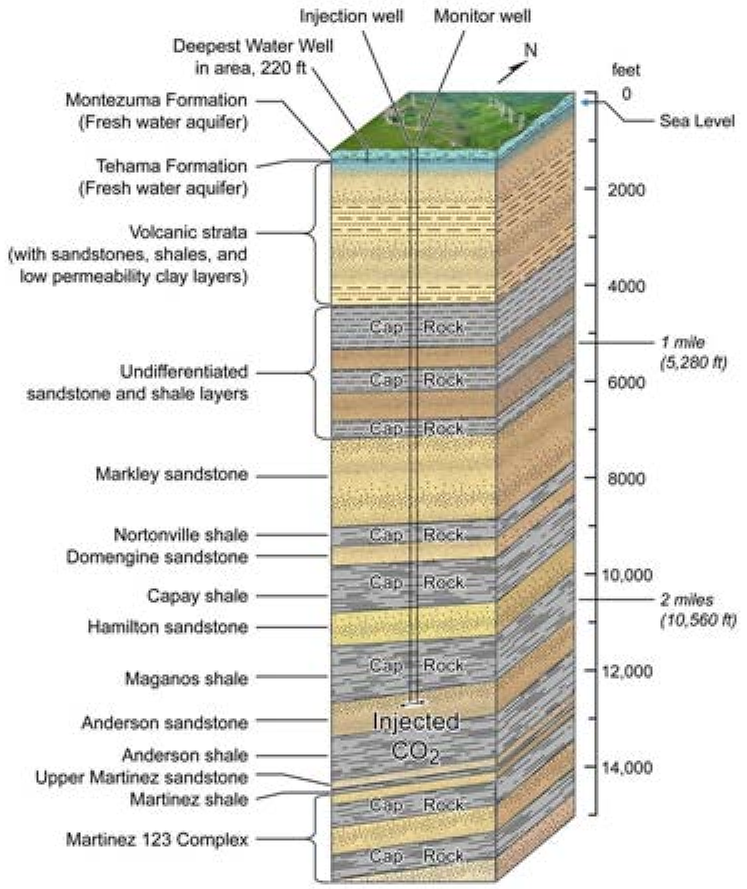
“Negative accounting”

Hoversten, M. E. Gasperikova, and S. M. Benson (2005). Theoretical Limits for Seismic Detection of Small Accumulations of Carbon Dioxide in the Subsurface. LBNL Report No. 59080. Presented at GHGT-8, 19-22 June 2006 in Trondheim, Norway.

Two case studies demonstrate the approach

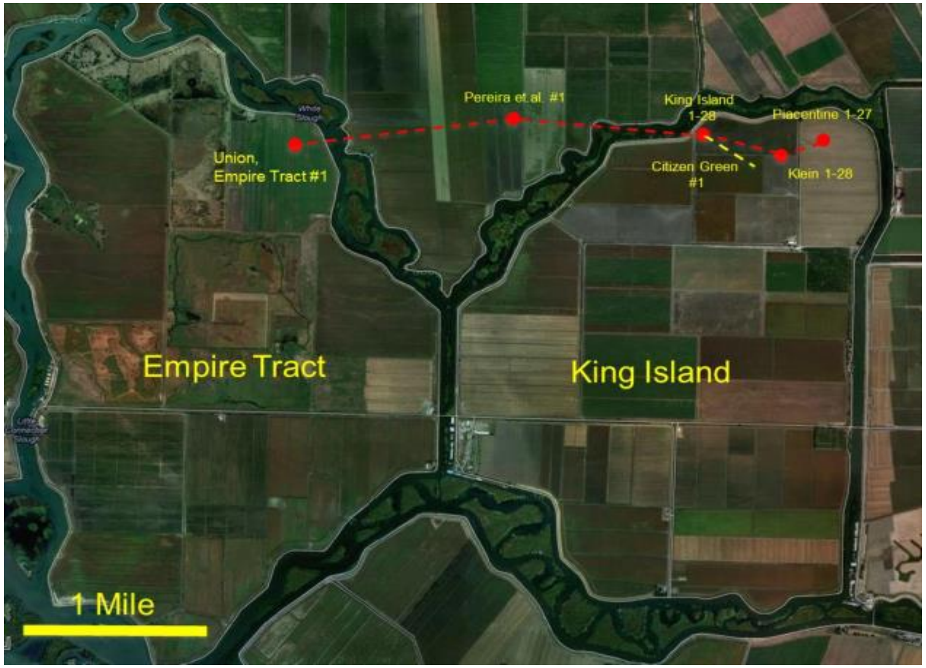
- In earlier studies by WESTCARB, four sites were screened for feasibility:
  King Island, Thornton, Kimberlina, and Montezuma Hills.
- King Island and Kimberlina emerged as the preferred sites.





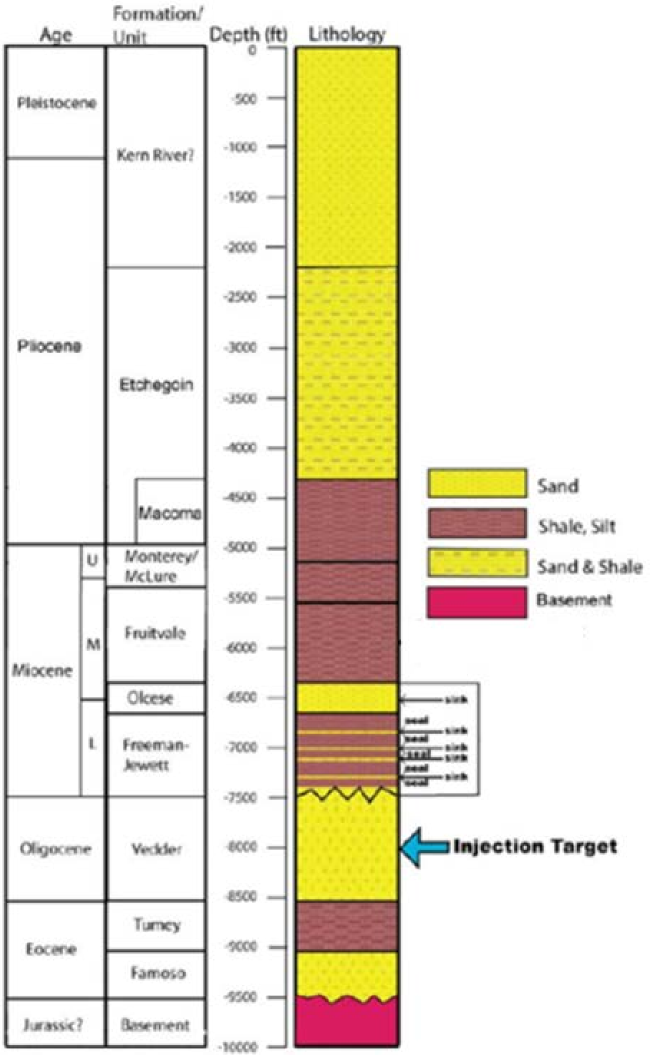
King Island is a good prospect for GCS

- Unknown wells are unlikely.
- Seal appears to be sufficiently ductile to reduce fault and fracture transmissivity to preclude detectable leakage.
- A pressure-dissipation interval exists above and below the Mokelumne River target reservoir.
- Injectivity is likely to be sufficient.
- Unknown whether seal has sufficiently high capillary entry pressure or low permeability.
- There are shallow-plugged uncased borings that need to be evaluated and monitored.
- Free-phase CO_2 plume area may extend into city limits.



Kimberlina cap rock and injectivity need more analysis

- Dissipation intervals exist both above and below Vedder Formation storage target.
- While the seal has retained oil in fields surrounding the site at some distance, there are currently insufficient data to determine if the seal is ductile.
- Unknown whether seal has sufficiently high capillary entry pressure or low permeability.
- Area of review for the free-phase CO_2 plume may include a portion of an oil field with both known and unknown wells.
- There are shallow-plugged uncased borings that need to be evaluated and monitored as potential leakage pathways.
- Injectivity is limited, suggesting a project at this site would likely require pressure management by brine extraction.



Questions?

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