SRR-CWDA-2016-00112

SRR Savannah River Remediation
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October 20th, 2016

Interagency Steering Committee on P&RA
CoP Annual Technical Exchange Meeting

EVALUATION & INTERPRETATION OF PROPERTIES FOR EMPLACED SALTSTONE

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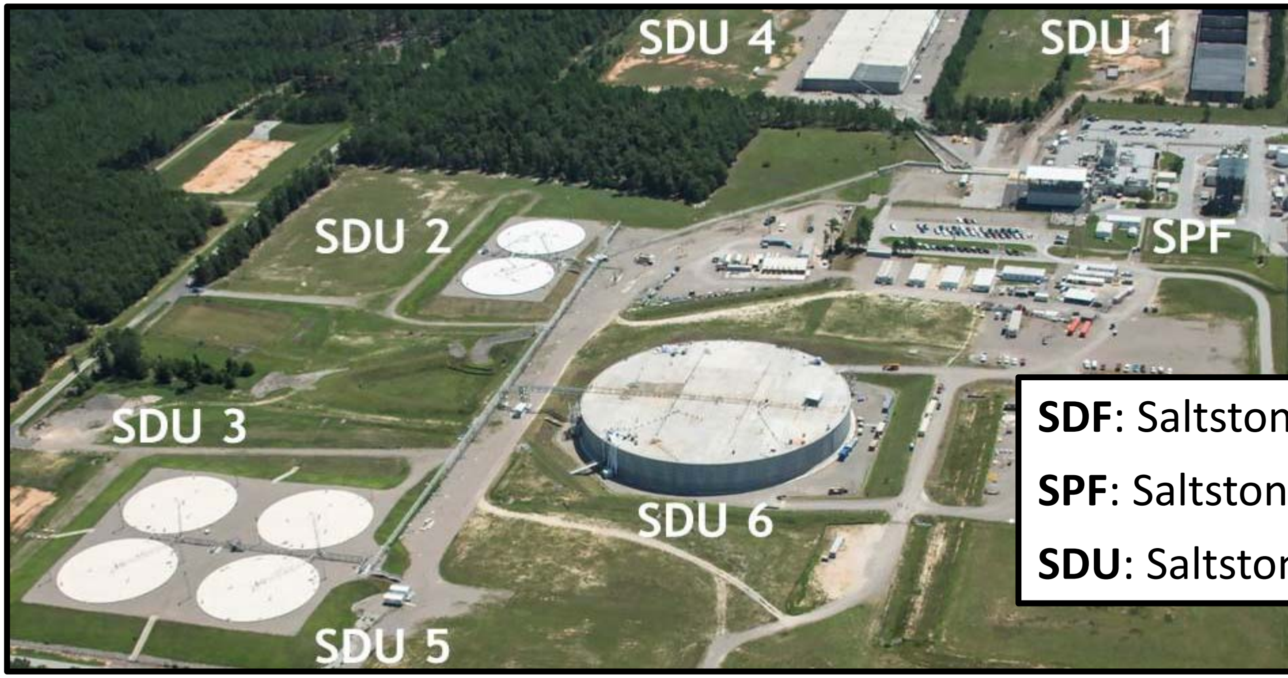
Overview

- **Background:**
  - Saltstone Disposal Facility (SDF) & Performance Assessment (PA)
- **Objectives for Extracting SDU-emplaced Saltstone**
  - Laboratory vs. field comparison
- **Preparation for Extracting SDU-emplaced Saltstone**
  - Multiple mock-ups, optimization, operator training, etc.
- **Core Extraction and Analysis**
  - Physical properties (density and porosity)
  - Key PA-related properties (K_{sat} *and* K_d)
- **PA Impacts**
  - Comparison of data for actual saltstone compared to PA modeling values

SDF Background



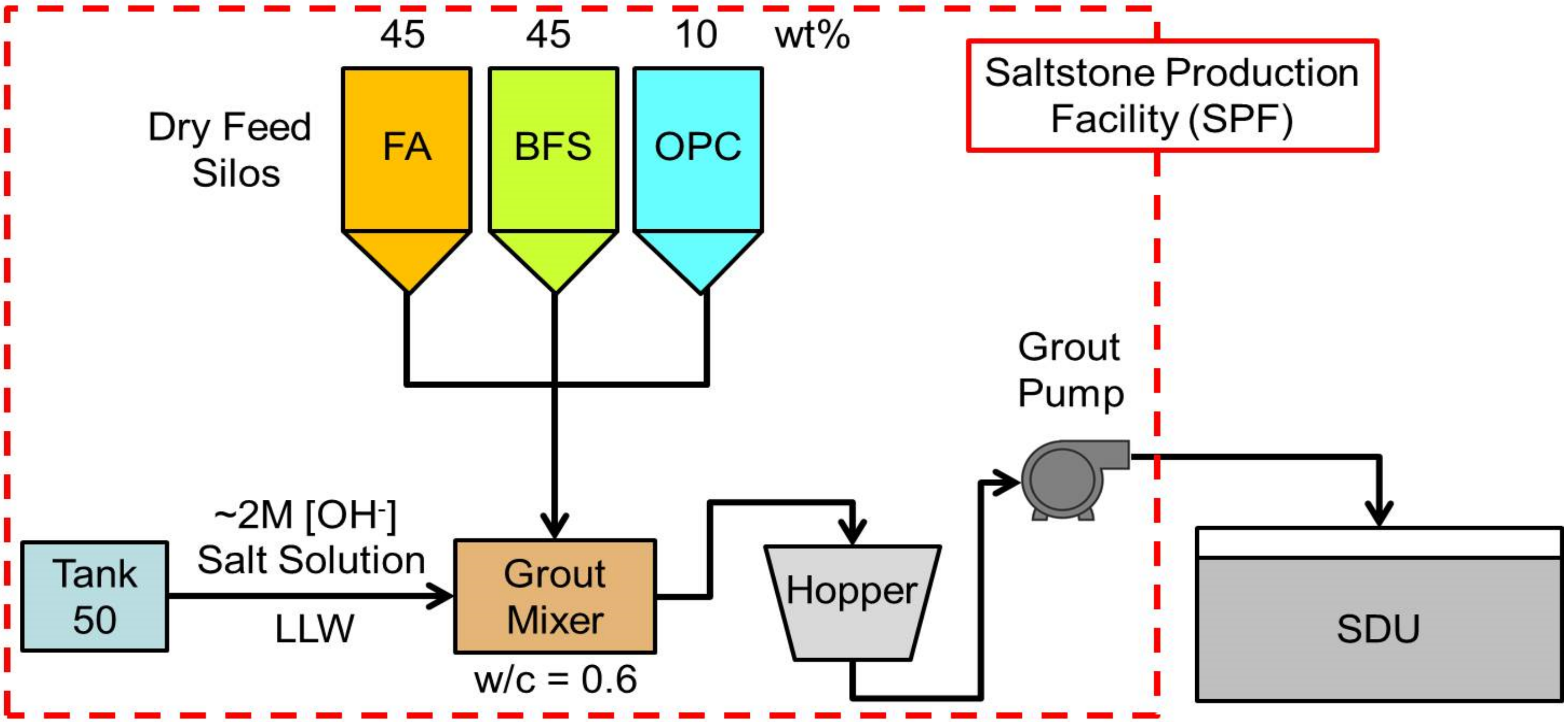
SDF: Saltstone Disposal Facility

SPF: Saltstone Production Facility

SDU: Saltstone Disposal Unit

- Liquid waste treatment at SRS will generate ≈100 million gallons of low-level salt solution containing <0.1% of total SRS radionuclide inventory.
- Salt solution combined with cementitious materials in the SPF to form saltstone grout ⇨ emplaced in permanent SDUs.
- The PA models fate and transport of constituents in SDUs to determine the long-term potential for future interactions with the environment and public.

Saltstone Processing



- Time from mixing to emplacement ≈5 min. depending on SDU-transfer distance (≈2000 ft.).
- Approximately 65,000 gallons of grout can be processed in 8-hour shift period.

Objectives

- Most PA-modeled saltstone properties are derived from testing lab-prepared simulant samples ⇨ but are lab samples representative of field samples?

PARAMETER	LAB-PREPARED	FIELD-PROCESSED
Dry Feed & Liquid Ratios	• Components accurately measured	• Bulk process – potential for processing variations: ⇨ Avg. dry feed rate ≈30 ton/hr (± 1%) ⇨ Avg. salt soln. feed rate ≈90 GPM (± 2%) ⇨ Periodic system flushing with water
Mixing	• Small-scale lab batch mixing (≈1 gal.)	• Large-scale continuous mixer (≈135 GPM)
Delivery	• Gently poured into curing molds	• Transferred through ≈2000 ft. pipe from SPF to SDU using peristaltic pump • Free-falls into SDU and spreads to extremities
Curing Environment	• Environmental chamber with controlled temperature and RH	• Curing temperature profile dependent on location in SDU
Storage Environment	• Samples often maintained in sealed containers and/or inert, humidity-controlled environments	• Samples maintained in variable, field-emplaced environment

- Strategy is to extract emplaced saltstone from an SDU to compare to lab-processed samples.

SPF Processing & SDU Curing

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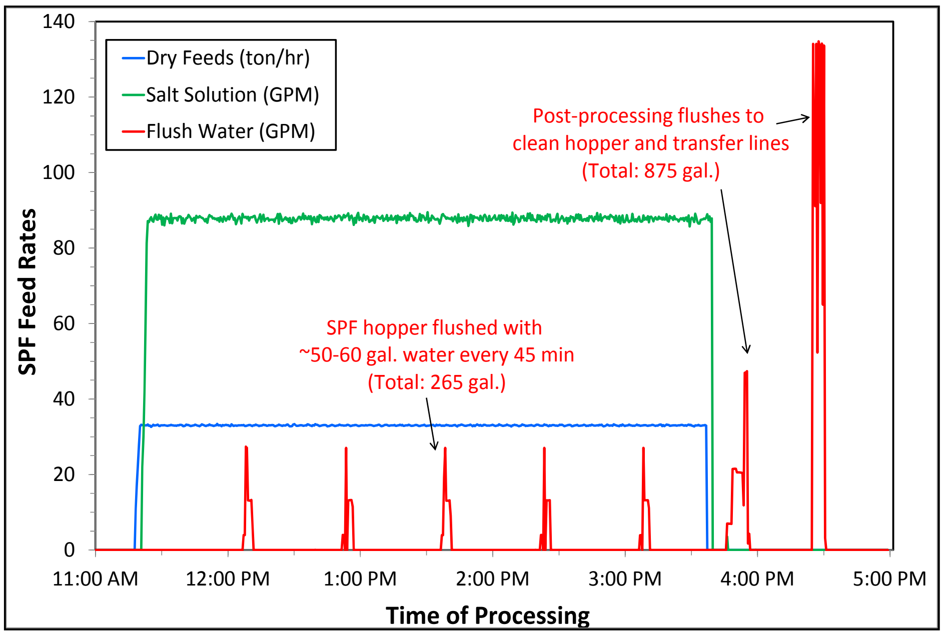
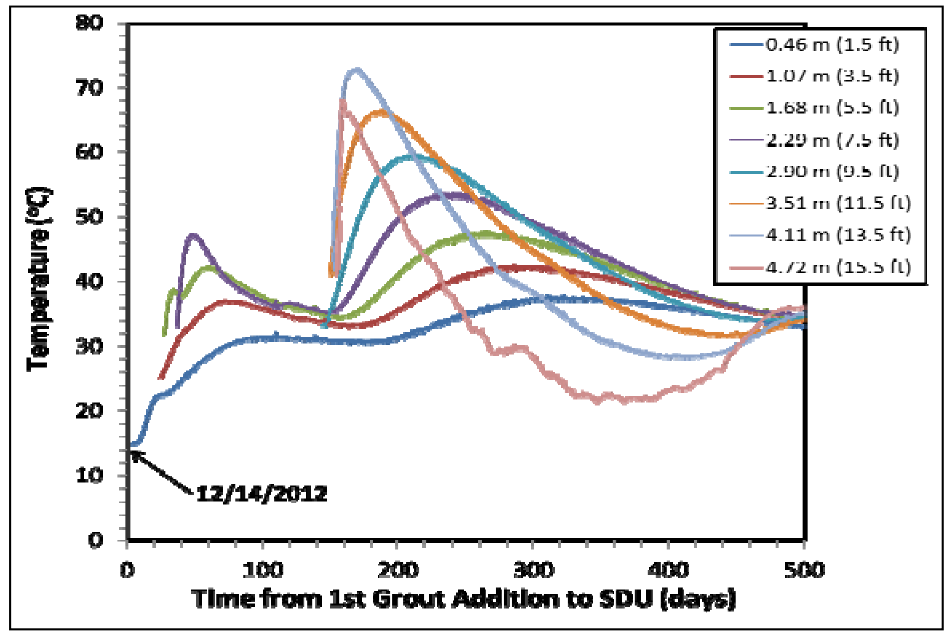
- SPF system flushes and variable SDU curing temperatures are potentially significant disparities between lab and field processing.





Laboratory vs Field Strategy

- On August 12th, 2013 ≈ 33,000 gallons of saltsone (3-inch lift) emplaced into SDU 2A at ≈16-foot SDU elevation.

- Intent was to ultimately extract saltstone samples from around the 16-foot elevation and conduct property comparison with lab-processed samples.

Lab-Processed Samples

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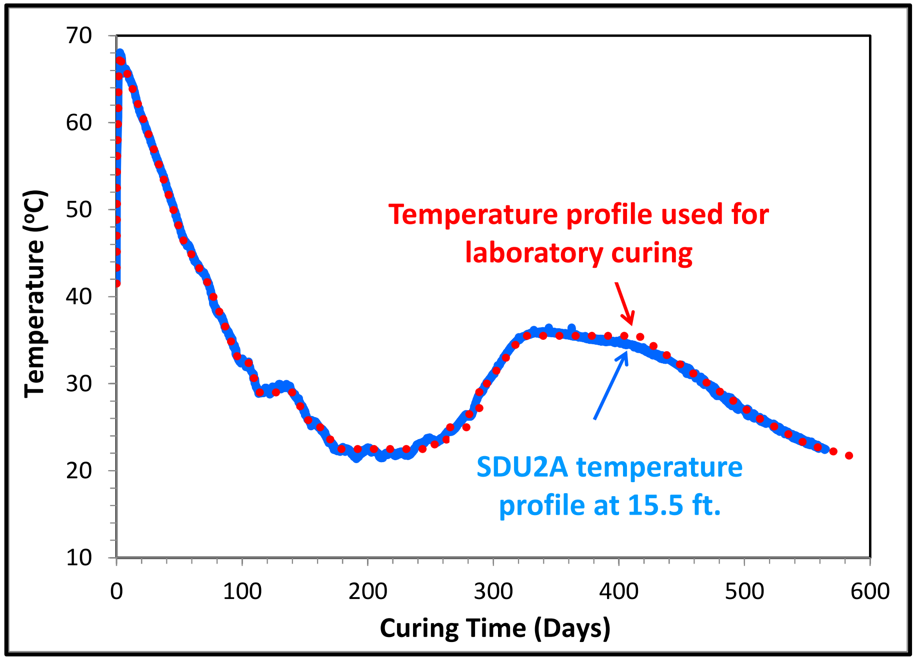
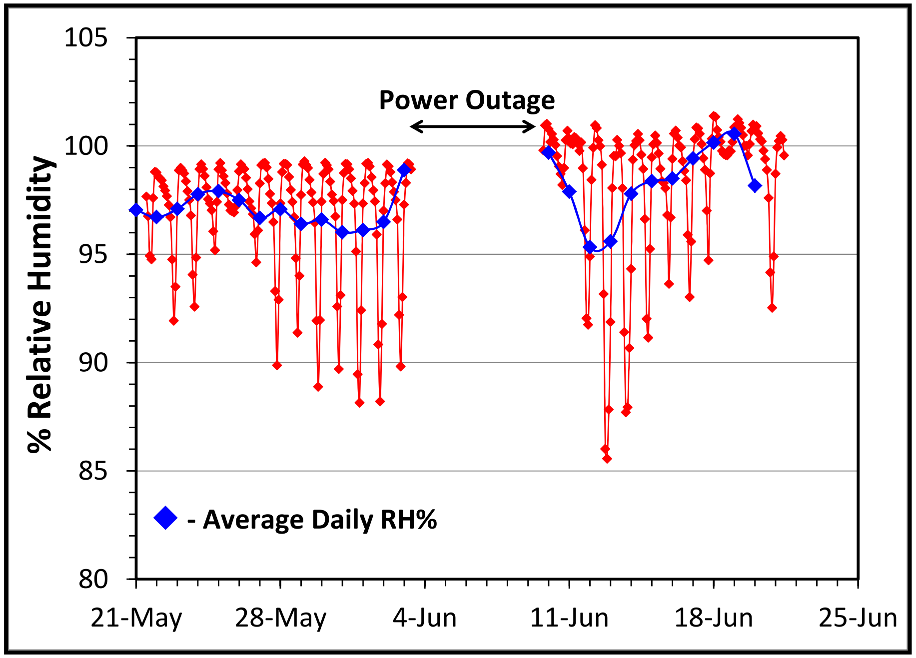
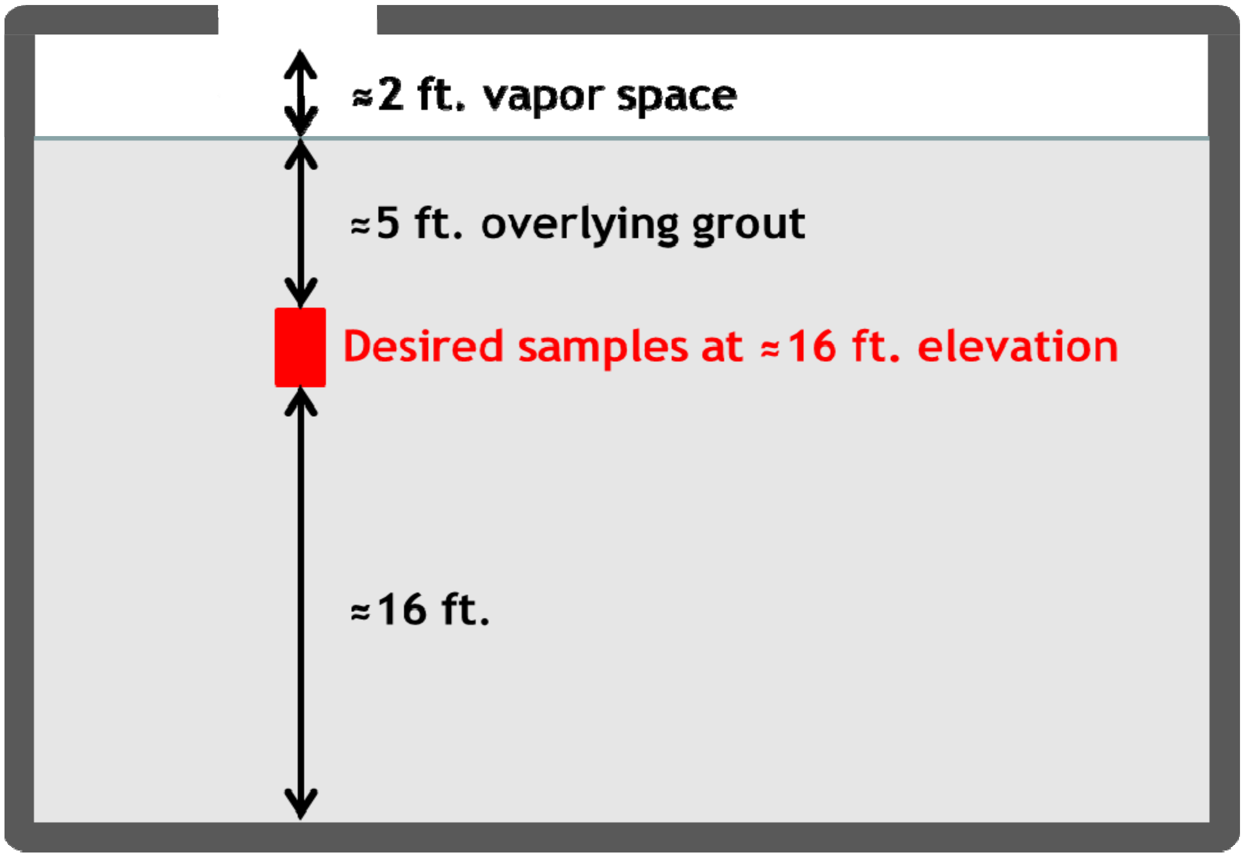
- Lab samples cured according to SDU2A measured environment.
- Thermowell temperature measurement at ≈16-foot elevation in SDU2A.
- Relative humidity measured in SDU2A vapor space (used average RH 95%).





Planning for Sample Extraction

- 18 months dedicated to developing and optimizing techniques to drill and extract saltstone cores from SDU2A.



Optimizing the Extraction Technique

- **Three separate mock-ups were used to:**
  - Evaluate wet and dry core-drilling techniques
  - Test off-the-shelf and in-house fabricated drilling equipment options (motors, drill bits, etc.)
  - Simulate SDU configuration drilling via a camera port through 2-feet of vapor space and 5-feet of overlying grout
  - Overcome technical issues that compromised sample integrity: drill bit skidding, drill binding, sample fracture, etc.
  - Develop a technique and equipment to retrieve the sample from the core hole once drilling process complete
  - Simulate operator environment on SDU roof ⇨ no line of sight (reliant on video monitor), required to develop sense of touch
  - Allow operators to train in rad protection suits
  - Post-extraction sample inerting, storage, and transport.

Mock-Up Core Drilling

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Mock-Up Core Extraction

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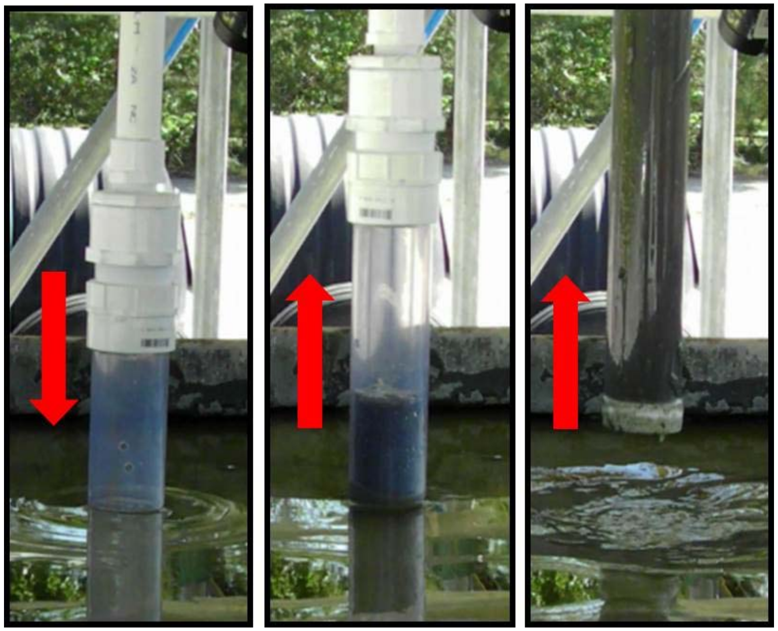

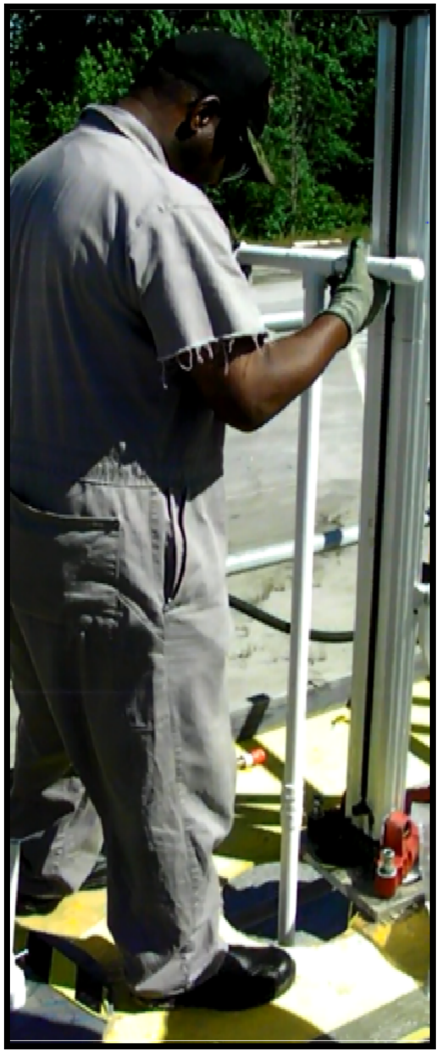

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SDU2A Drilling & Extraction

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Laboratory Storage

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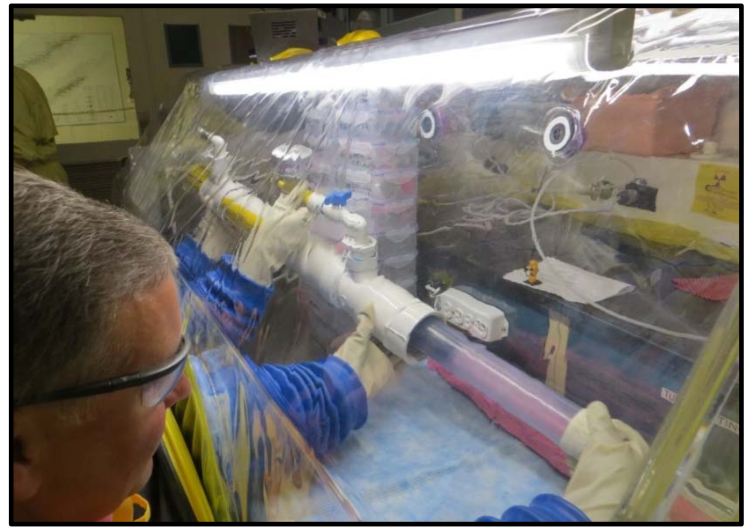

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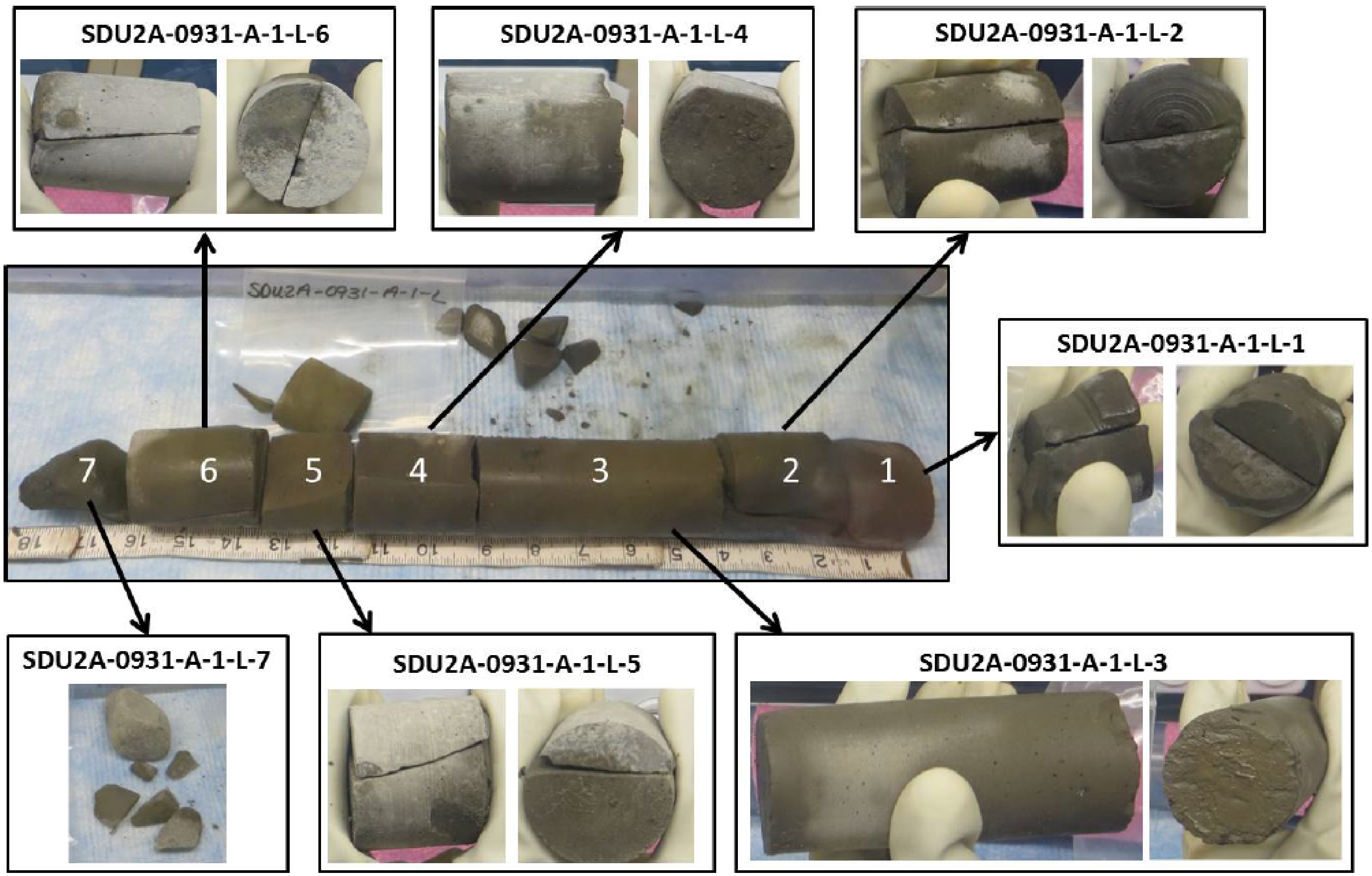
Core Appearance

Sample ID: SDU2A-0931-A-1-L (Lower Core Portion Extracted from Port A – Drill Position 1 on May 6, 2015)



Core Appearance

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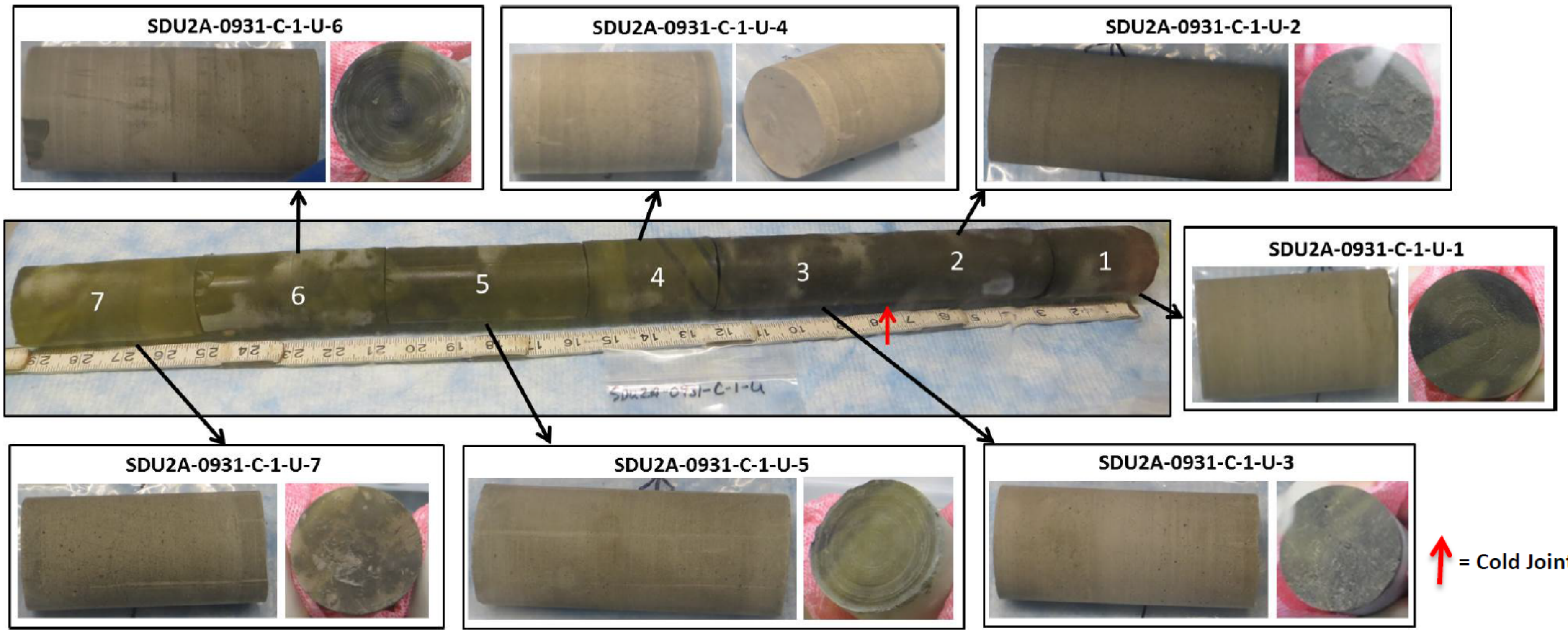
Sample ID: SDU2A-0931-C-1-U (Upper Core Portion Extracted from Port C – Drill Position 1 on April 28, 2015)



Sample Analyses

PROPERTY		RATIONALE
Density / Porosity		• Determine if variability of saltstone field- processing, transfer, and environment impact the physical properties. • How do changes in physical properties impact other performance indicators?
K_{sat}		• Saturated hydraulic conductivity of saltstone impacts: ⇨ groundwater ingress into saltstone, and ⇨ leaching of radionuclides/contaminants to the SDF environment
^{99}Tc	*Solubility (Anoxic)*	• ^{99}Tc designated as contributor to long-term, radiological dose to public. • PA assumes that under anoxic conditions ^{99}Tc is controlled by the solubility of reduced ^{99}Tc species.
	K_d *(Oxic)*	• In oxic environments ^{99}Tc is considered oxidized (and highly soluble) and leaching is controlled by adsorption.
^{90}Sr & ^{129}I K_d *(Oxic / Anoxic)*		• ^{90}Sr and ^{129}I designated as contributors to radiological dose to public. • In oxic/anoxic environments ^{90}Sr and ^{129}I leaching controlled by adsorption.

Physical Properties

Density, Porosity, & Water Content

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Sample Type	Bulk Density (g/cm³)	Total Porosity (vol. %)	Open Porosity (vol. %)	Water Content (wt. %)
SDU2A (18 discrete sub-samples)	**1.71 – 1.76** $\bar{x}$ = 1.73	**63.6 – 68.8** $\bar{x}$ = 65.8	**41.9 – 46.6** $\bar{x}$ = 43.7	**29.0 – 32.1** $\bar{x}$ = 30.3
Lab-Prepared Samples (9 discrete sub-samples)	**1.75 – 1.77** $\bar{x}$ = 1.76	**58.3 – 60.9** $\bar{x}$ = 59.8	**40.1 – 42.1** $\bar{x}$ = 40.8	**29.9 – 30.1** $\bar{x}$ = 30.4

PARAMETER	LAB-PREPARED	FIELD-PROCESSED
Dry Feed & Liquid Ratios	• Components accurately measured	• Bulk process – potential for processing variations: ⇨ Avg. dry feed rate ≈30 ton/hr (± 1%) ⇨ Avg. salt soln. feed rate ≈90 GPM (± 2%) ⇨ Periodic system flushing with water
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Saturated Hydraulic Conductivity (K_{sat})

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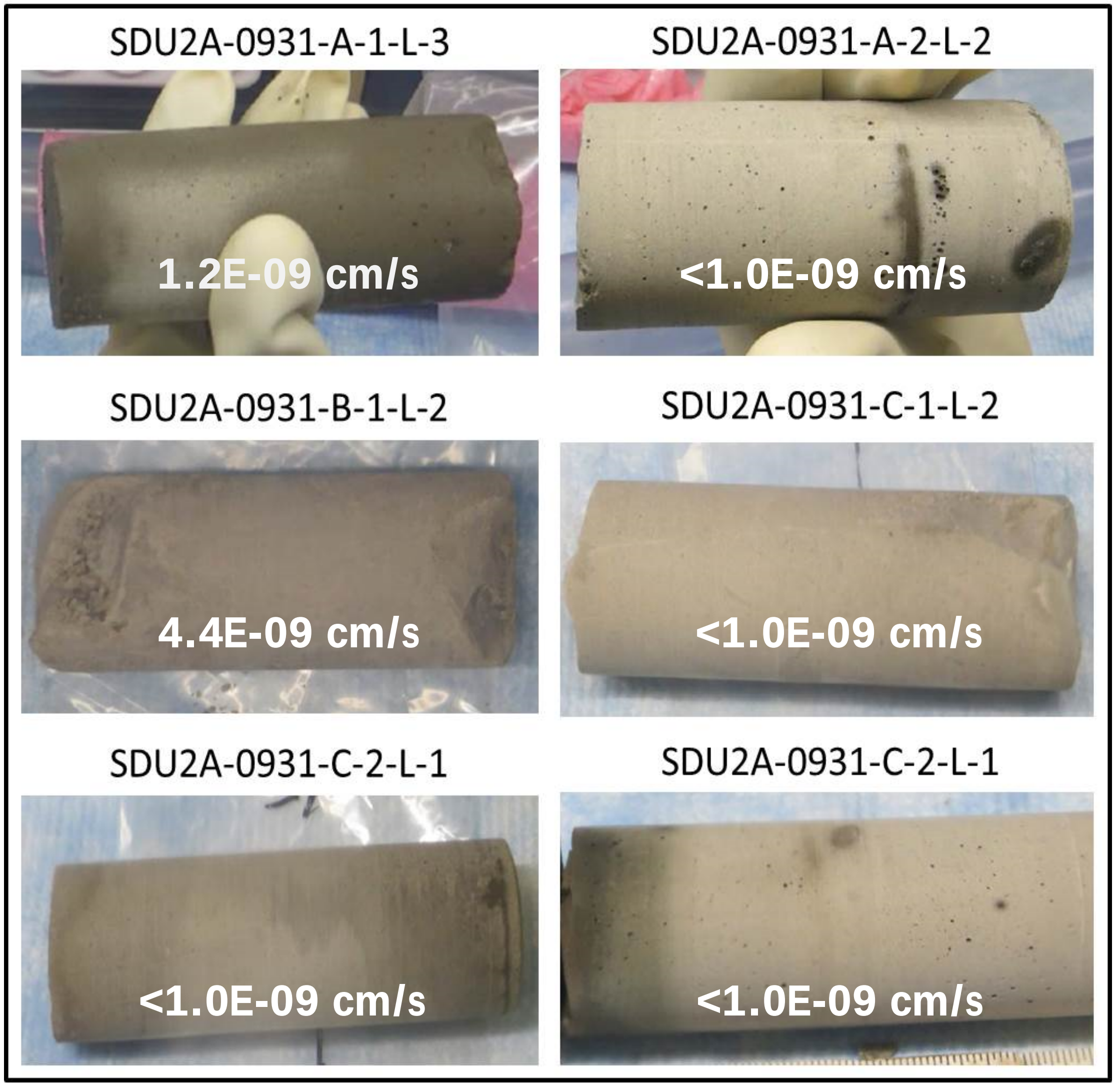


- Despite higher open porosity for SDU cores impact to K_{sat} is insignificant.
- All lab-prepared samples indicated K_{sat} <1.0E-09 cm/s.
- Lab = demolded samples without surface defects.
- PA-utilized K_{sat} = 6.4E-09 cm/s.

Radionuclide Leaching

SDU2A Contaminant Leaching Behavior

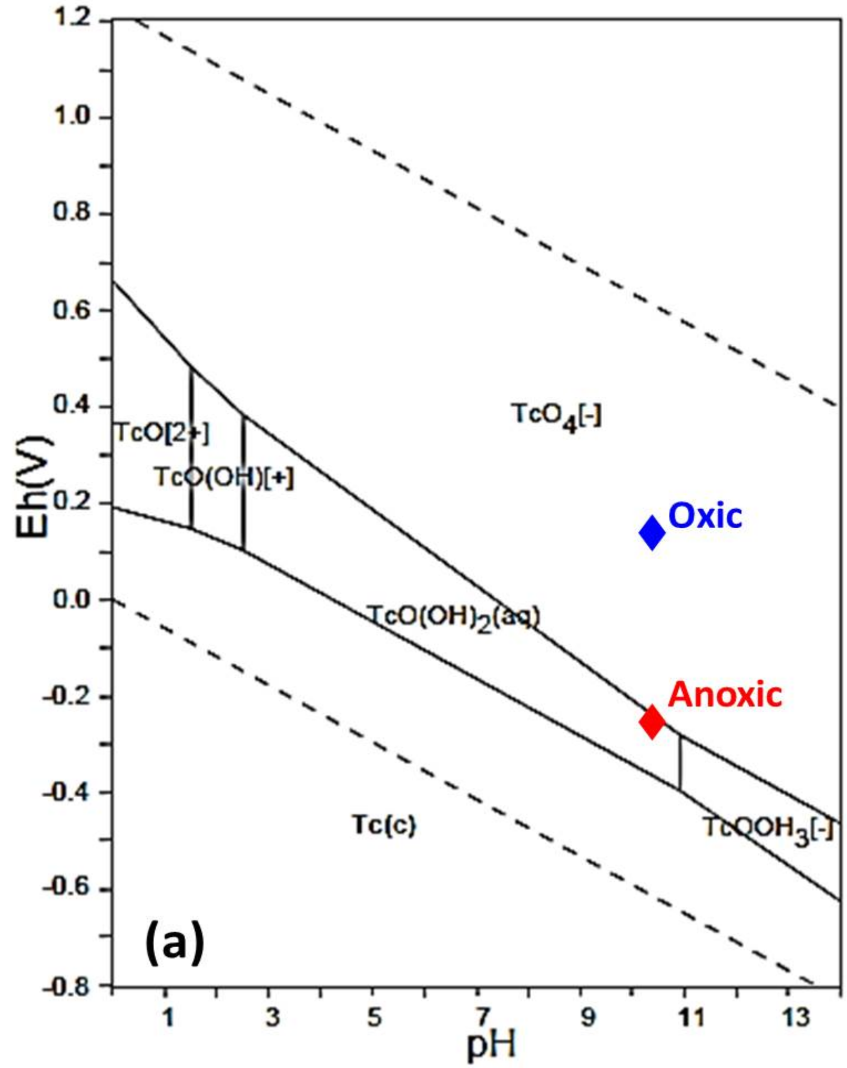
- Tests involved mixing 1 gram of ground SDU2A core with 10 mL leachate.
- One set of leachates contained 8 ppm O_2 (oxic); other set boiled to remove dissolved O_2 (DO) (anoxic).
- Six discrete measurements for each environment.
- Samples equilibrated for 7 days and leachates analyzed for ^{99}Tc, ^{90}Sr, ^{129}I, E_h and pH .
- PA transport model:
  - ^{99}Tc assumed to be in reduced, sparingly soluble Tc(IV) form in anoxic, high pH environment ⇨ leaching behavior solubility controlled.
  - In oxic environment Tc(VI) assumed to be transformed to highly soluble Tc(VII) (pertechnetate) ⇨ leaching behavior controlled by adsorption to saltstone particle surfaces (liquid-solid partitioning K_d).
  - ^{90}Sr and ^{129}I leaching controlled by adsorption in both oxic and anoxic environments (liquid-solid partitioning K_d).

^{99}Tc Solubility (Anoxic)

Predicted Tc Species

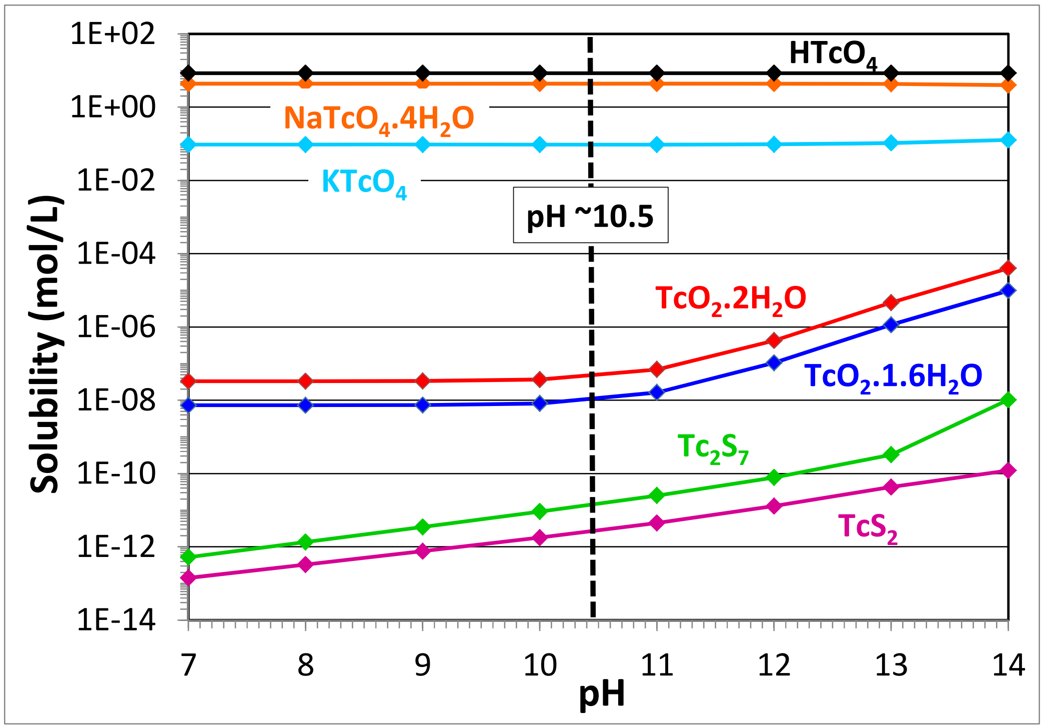
Anoxic	
pH	E_h (mV)
10.4 to 10.6 $\bar{x}$ = 10.5	-186 to -240 $\bar{x}$ = -217

Oxic	
pH	E_h (mV)
10.6 to 10.8 $\bar{x}$ = 10.7	+144 to +178 $\bar{x}$ = +155



^{99}Tc Solubility (Anoxic)

Sample ID	^{99}Tc Conc. (mol/L)
SDU2A Cores(6 samples)	7.0E-09 to 3.9E-08 $\overline{x}$ = 2.2E-08
SDF PA Model	1.0E-08



- ^{99}Tc concentrations in leachate (anoxic) ≈2E-08 mol/L.
- Agrees with predicted solubility of reduced $TcO_2.xH_2O$ species at measured pH.
- Suggests leaching behavior is controlled by reduced Tc-species solubility as modeled in PA.
- Measured ^{99}Tc solubility 2x that utilized for PA model – impact?.

Liquid-Solid Partitioning (K_d)

Desorption (Reverse) K_d

Sample ID	Reverse K_d (mL/g)				
	^{99}Tc (Oxic)	^{90}Sr (Anoxic)	^{90}Sr (Oxic)	^{129}I (Anoxic)	^{129}I (Oxic)
SDU2A Samples	25 to 32 $\overline{x}$ = 28	36 to 70 $\overline{x}$ = 55	79 to 176 $\overline{x}$ = 112	-5 to +4 $\overline{x}$ = 0.3	-5 to +2 $\overline{x}$ = -2
SDF PA Model Input	0.5	15	15	9	15

- K_d for ^{99}Tc and ^{90}Sr > assumed PA value.
- For ^{129}I lowest feasible K_d is zero.
- Unfeasible negative K_d for ^{129}I may be partially associated with low ^{129}I concentration (≈5 pCi/g) and analytical uncertainty of radiochemical analyses.

PA Transport Model Impacts

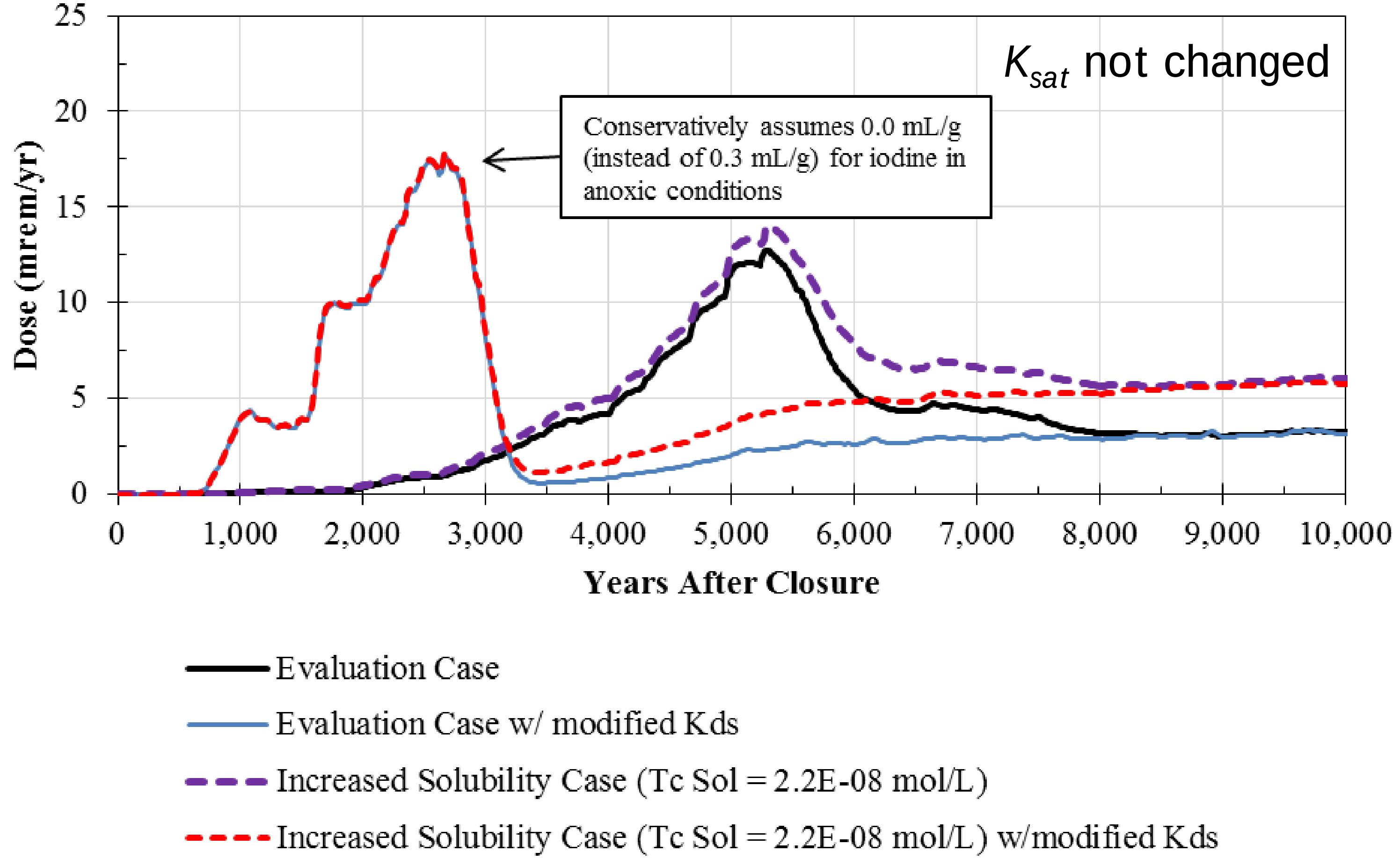
Collective Impacts

- **With the exception of the modified I K_ds, all of the measured K_d values improve the expected results (or have negligible impacts)**
  - The adverse impacts of the modified I K_ds are expected to be partially mitigated by the lower K_{sat}.
  - Due to the analytical approach used to estimate the I K_ds, there is some uncertainty (i.e., the negative values from the reverse K_d analysis are not realistic)
  - Assuming a value of 0 mL/g is intended to bound this uncertainty

Note: A lower cementitious degradation rate for saltstone within the first 3,000 years after closure would significantly limit the release of ^{129}I.

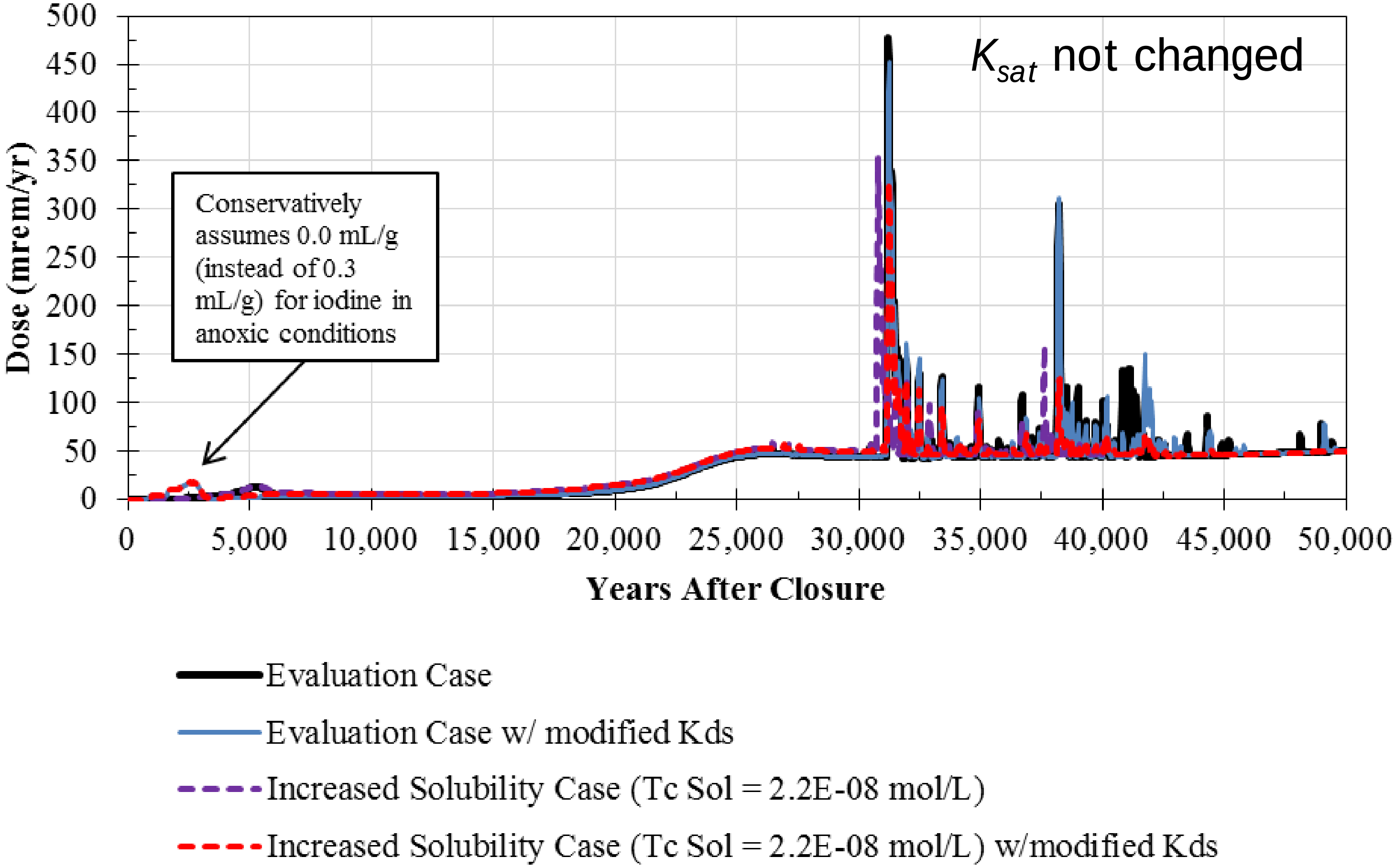
Collective Impacts

- Incorporating the results of the SDU 2A Core Sample Analysis gives a higher and earlier ^{129}I dose peak.



Collective Impacts

- Incorporating the results of the SDU 2A Core Sample Analysis gives a lower ^{99}Tc dose peak.



SDU2A Core Analysis Summary

- Differences in SDU2A core sample densities and porosities reflect anticipated variability associated with field processing. Variations insignificant with respect to key saltstone properties.
- Higher K_{sat} which indicated equivalent performance to lab-processed samples.
- Under anoxic conditions the leaching behavior of ^{99}Tc is controlled by the solubility of reduced $TcO_2.xH_2O$ phases as modeled in the SDF PA transport model.
- Measured ^{99}Tc solubility of 2.2E-08 mol/L compared to 1.0E-08 mol/L assumed in PA transport model.
- ^{90}Sr and ^{99}Tc K_d higher than modeled in SDF PA transport model.
- ^{129}I K_d < 1 ml/g and potentially zero; lower than currently assumed in PA transport model.
- PA impacts ⇨ earlier and higher ^{129}I peak dose
  ⇨ lower ^{99}Tc peak dose.

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