SAND2023-02326C

Sandia National Laboratories

Exceptional service in the national interest

THE UTILITY OF SONARS AND THE SANSMIC LEACHING CODE FOR MONITORING CAVERN SHAPE DEVELOPMENT DURING THE RECENT UNPRECEDENTED OIL VOLUME MOVEMENTS AT THE SPR

Todd R. Zeitler, David B. Hart

SMRI Spring 2023 Technical Conference
24-25 April 2023
Detroit, Michigan, USA

OUTLINE

Recent oil movements at the SPR

Using sonars and leaching modeling to track cavern geometry changes

Uncertainty in leaching modeling

- Hypothetical cylindrical caverns
- Real SPR caverns

https://www.energy.gov/ceser/spr-storage-sites

THE STRATEGIC PETROLEUM RESERVE

Four sites in salt domes in TX, LA

714 MMB authorized storage capacity

60 caverns

Bayou Choctaw

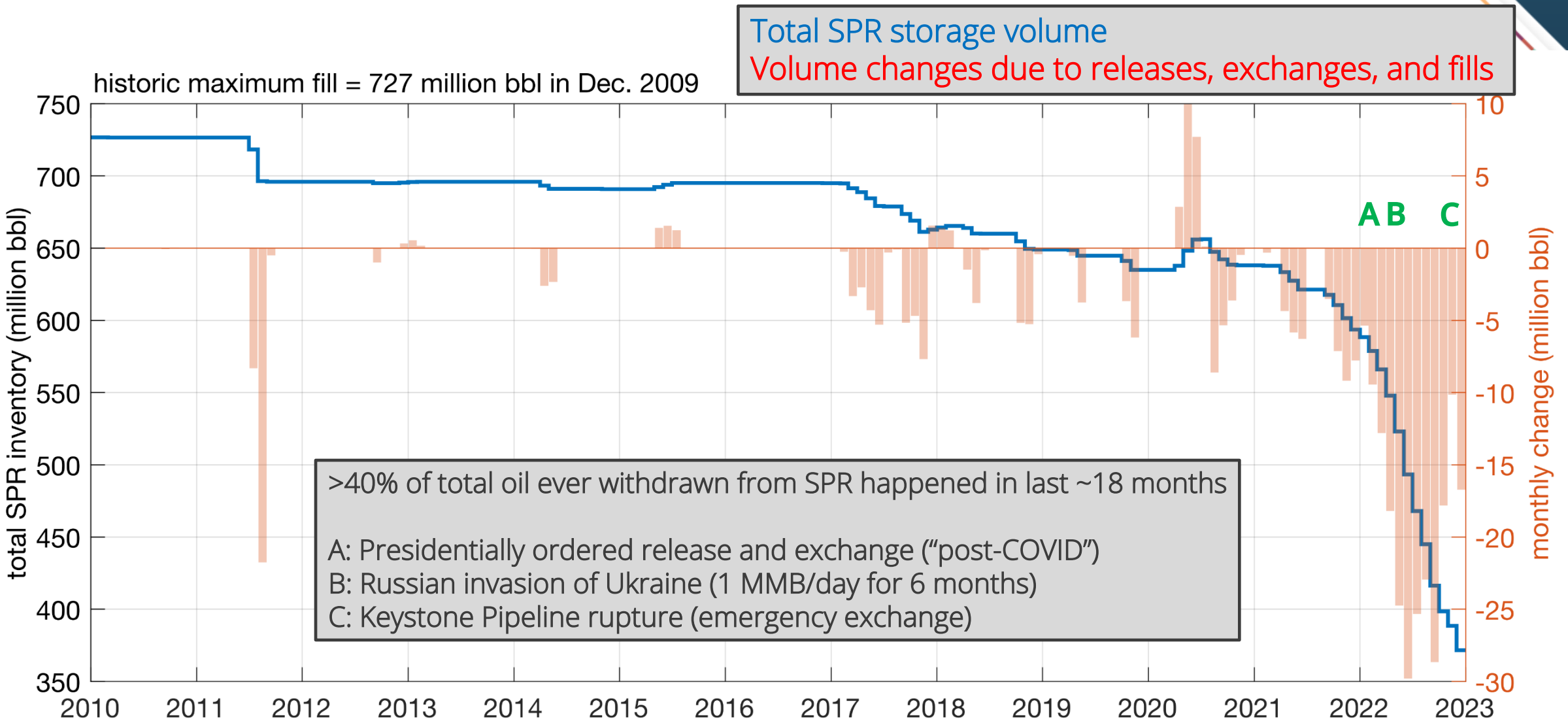
Bryan Mound

Big Hill

West Hackberry

https://www.energy.gov/ceser/spr-storage-sites

UNPRECEDENTED OIL MOVEMENTS



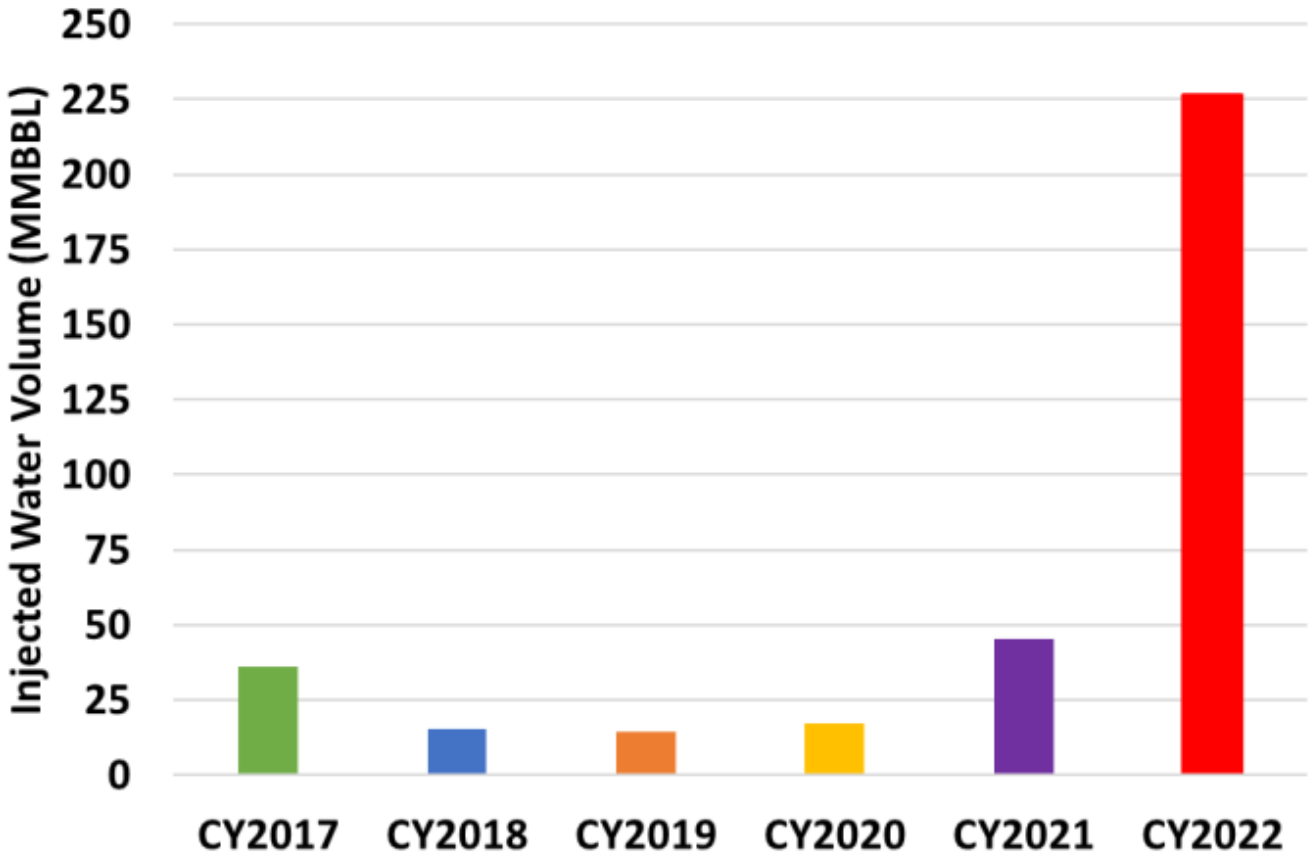
RECENT RAW WATER INJECTION HISTORY AT THE SPR

Unprecedented oil drawdowns at SPR in recent years.

Oil is withdrawn using undersaturated “raw” water injections.

Injection of raw water leads to cavern leaching as salt is removed from cavern walls.

1 bbl raw water injected: displaces approximately 1 bbl of oil and increases cavern volume by approximately 0.15 bbl (i.e., 15% leaching efficiency)



USE OF SONARS AT THE SPR

We track the development of cavern geometry changes over time using sonars.

Sonars give radius-with-depth data.

Changes in geometry may be due to:

- Leaching of cavern walls
- Salt falls
- Creep, including floor rise

Sonars are typically performed on SPR caverns:

- Every 5-10 years by state regulations.
- After 3 MMB of raw water injection (self-imposed).

Big Hill 105

West Hackberry 11

USE OF LEACHING MODELING AT THE SPR

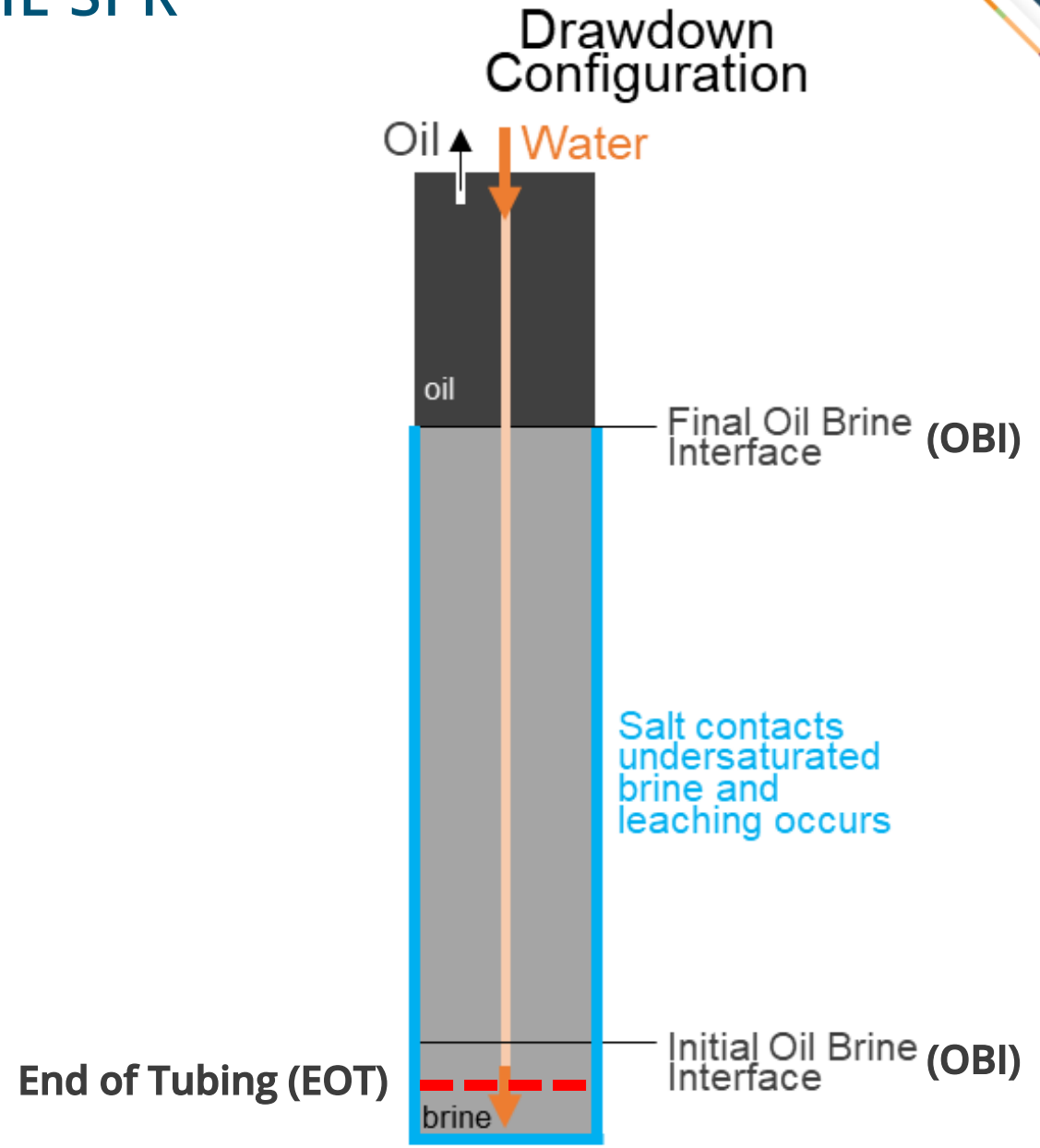
Leaching modeling is useful when raw water has been injected since the last sonar.

Sandia **S**olution **Mi**ning **C**ode (**SANSMIC**)

- Developed in 1980's
- Standard salt dissolution models

Key inputs:

- Initial cavern geometry (from sonar)
- Raw water injection history (i.e., bbls/day and duration)
- End-of-tubing (brine string) depth: EOT
- Oil-brine-interface depth: OBI



SOURCES OF UNCERTAINTY IN LEACHING MODELING

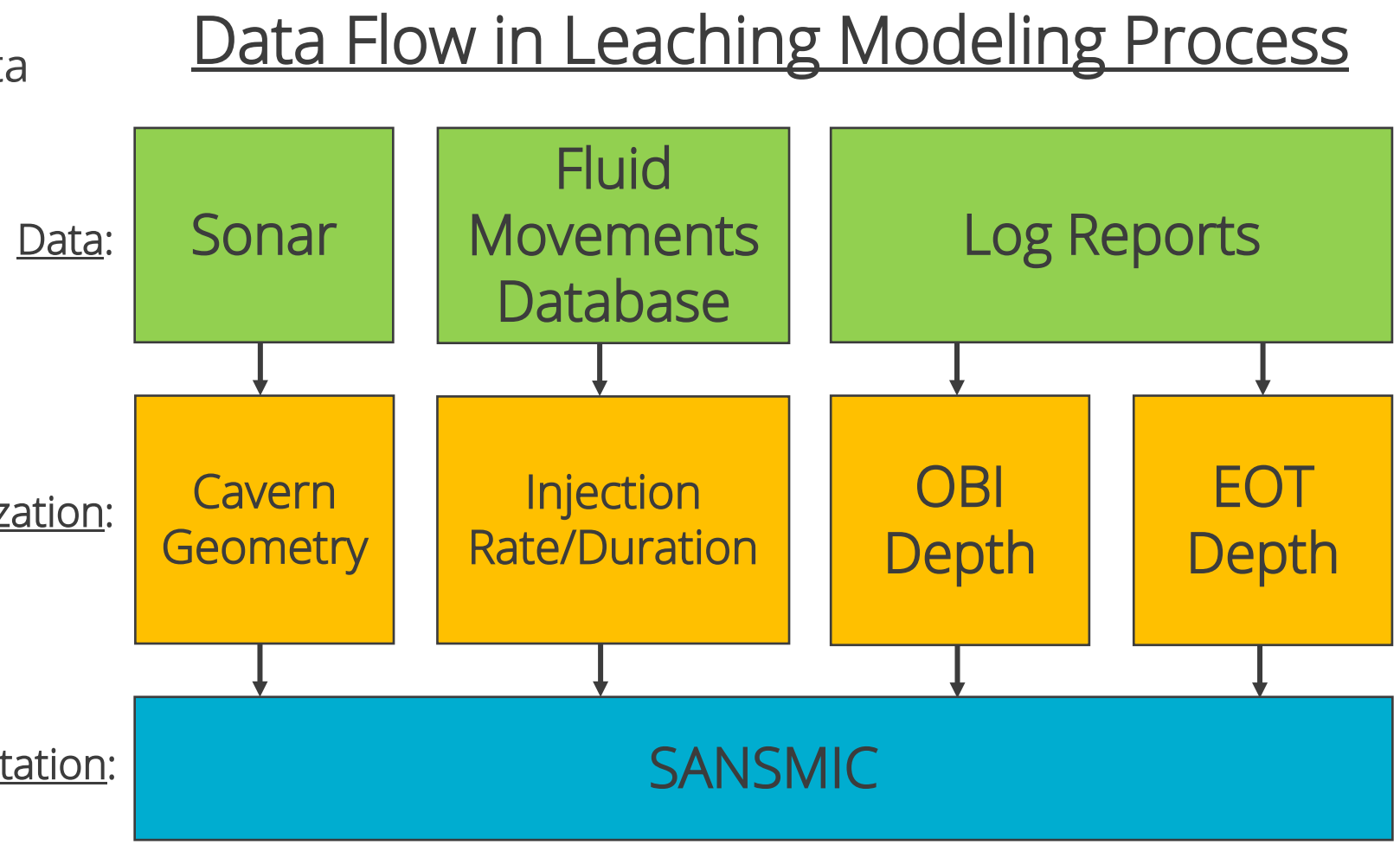
Sonar data

Raw water injection volume data

EOT/OBI depths

SANSMIC model uncertainty

- Grid resolution
- 2-dimensionality



SONAR AND FLUID MOVEMENT UNCERTAINTIES

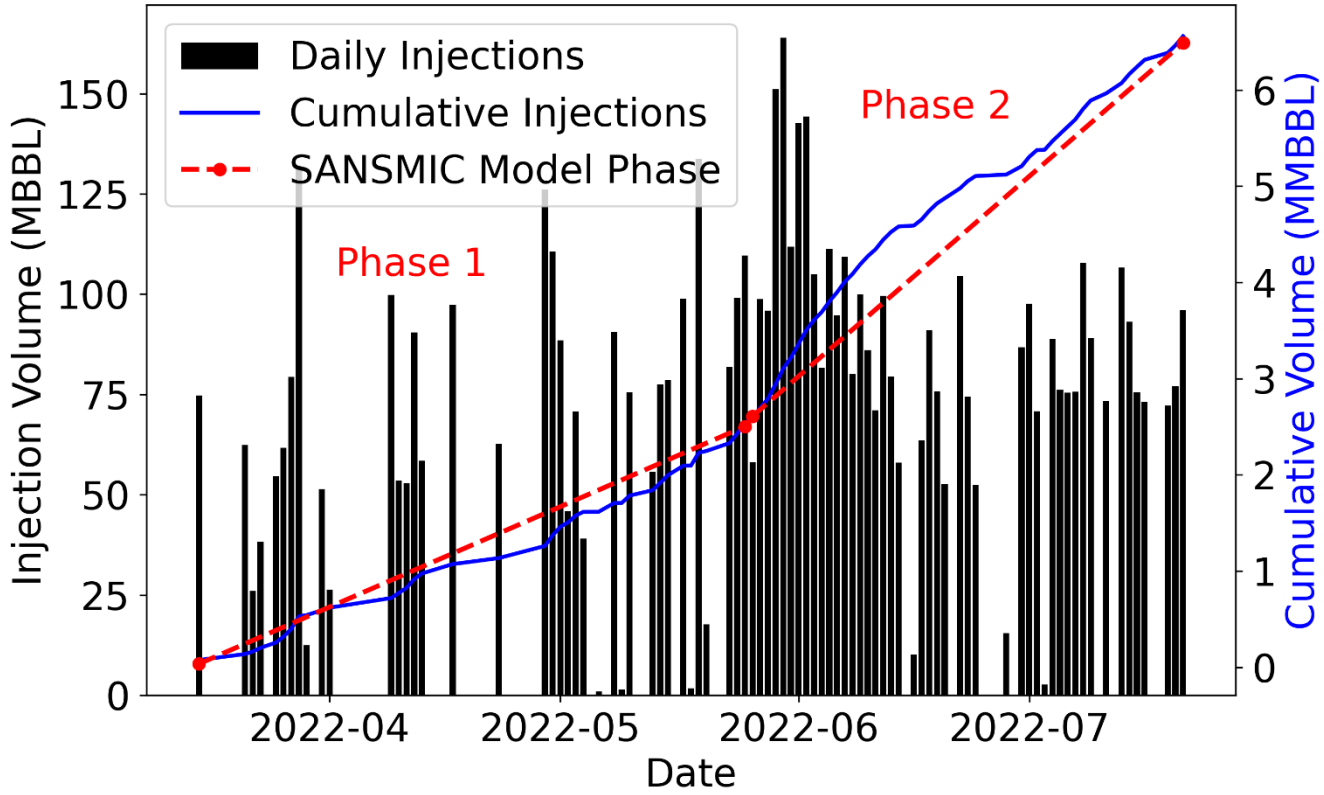
Sonar data

- Estimated ±1-5% error
- Speed-of-sound calibration/attenuation
- Number of data points

Raw water injection volume data

- Estimated ±3% error
- Wellhead meters accuracy/calibration
- Daily injection volumes input manually into CAVEMAN database (transcription error)

Example raw water injection history showing daily and cumulative volumes.



MODELING APPROACH FOR THIS STUDY

Look at two sources of uncertainty

- Independently
- Concurrently

Uncertainty levels of ±1-10%

Two cavern types

- Hypothetical cylinder
- Real SPR cavern

What are the potential impacts of these uncertainties on our model results?

Approximately what is the maximum range on resulting radius?

HYPOTHETICAL CYLINDRICAL CAVERN WITH IDEALIZED FLUID INJECTION RATE

Caverns of radius 100, 150, 200, 250 ft

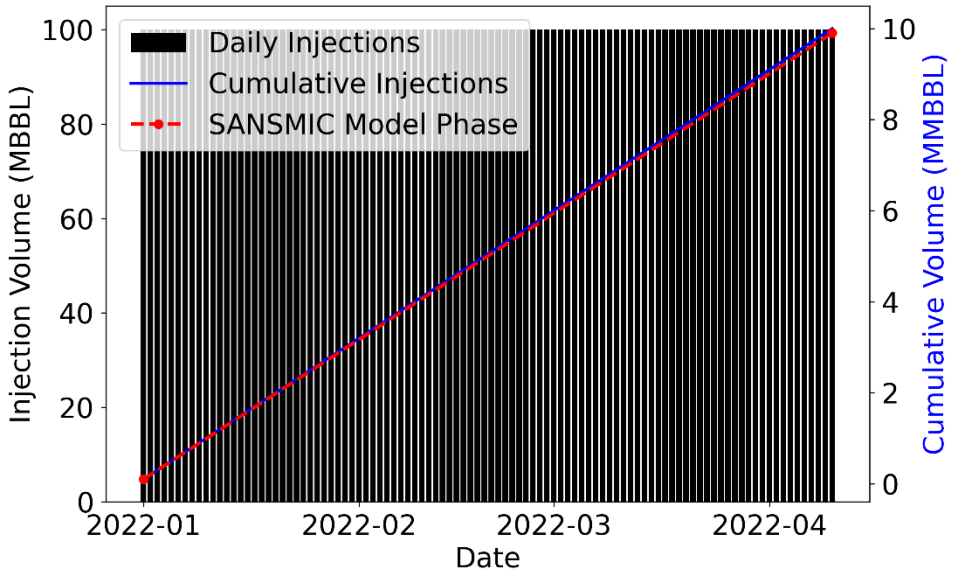
Cavern total height: 2000 ft

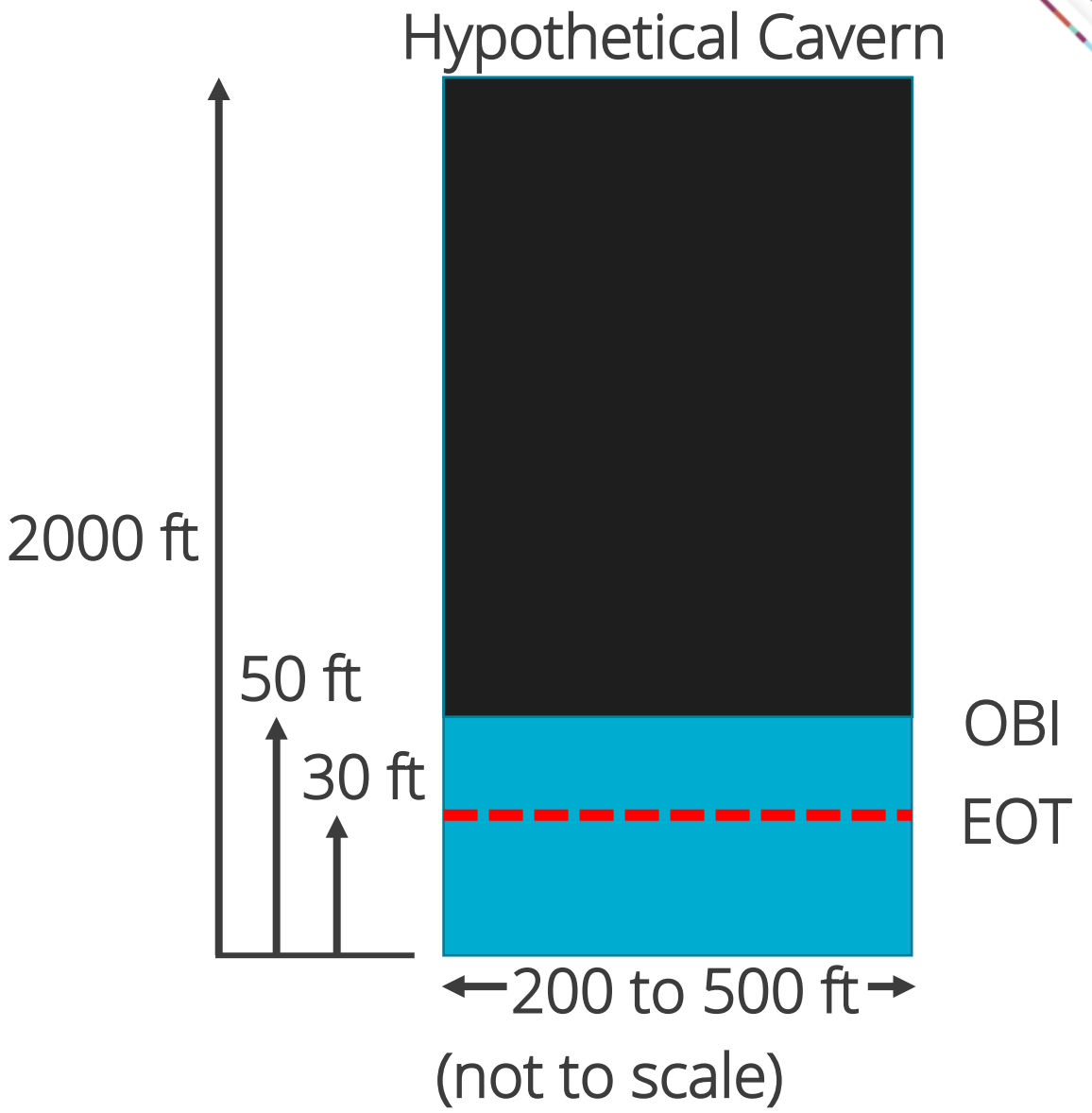
EOT: 30 ft above cavern floor

OBI: 50 ft above cavern floor

Raw water injection:

100 MB/day for 100 days = 10 MMB





HYPOTHETICAL CAVERN - RESULTS

100 ft radius cylinder

±3% uncertainty for both sources

Key takeaway:

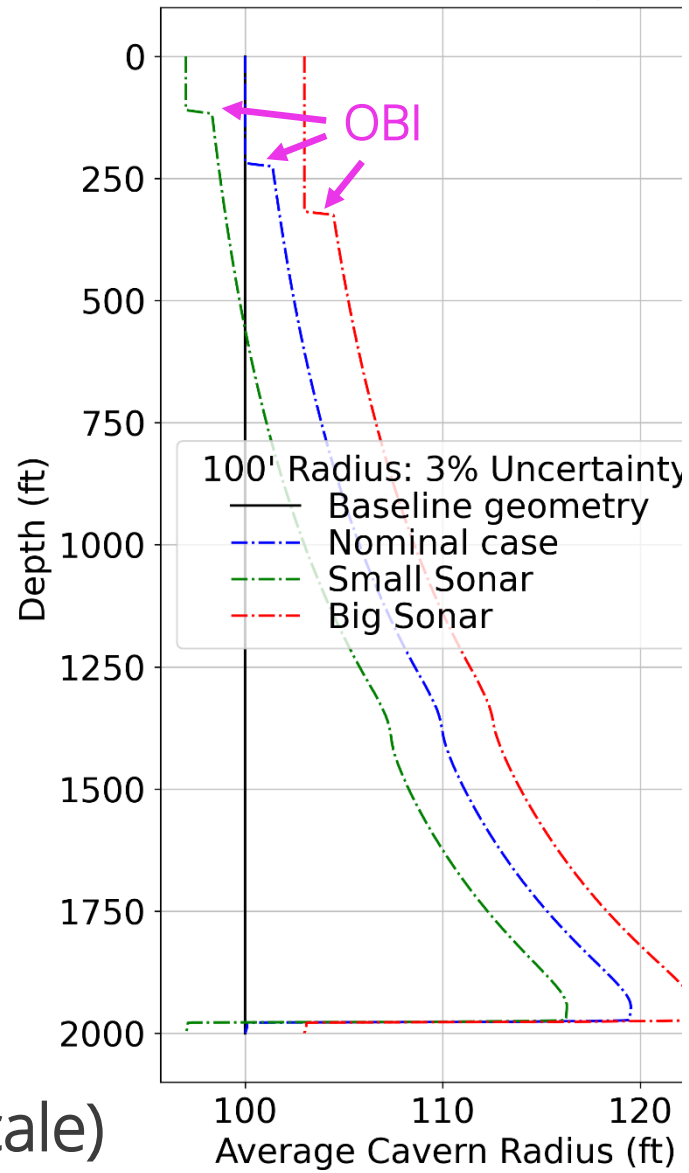
- Impact of injection volume relatively small compared to sonar survey for same level of uncertainty.

This makes sense as uncertainty in injection volume is tempered by ~15% leaching rate.

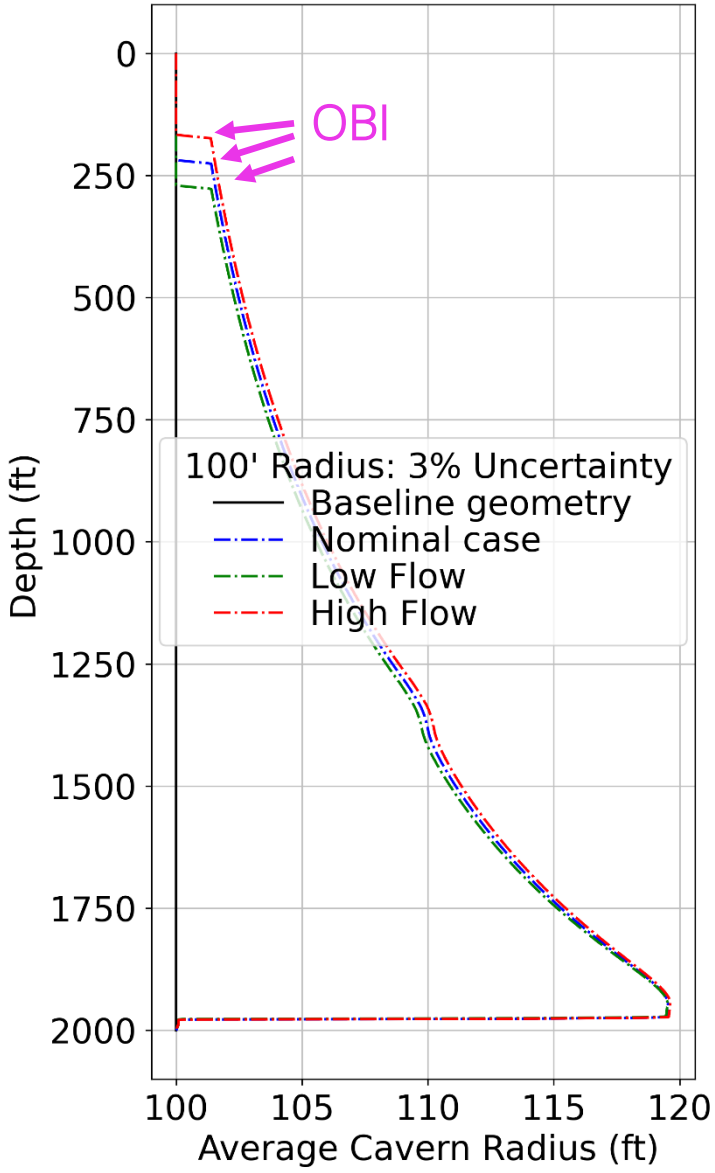
Increased confidence that SANSMIC code is working well.

(not to scale)

Sonar Uncertainty



Flow Volume Uncertainty



HYPOTHETICAL CAVERN - RESULTS

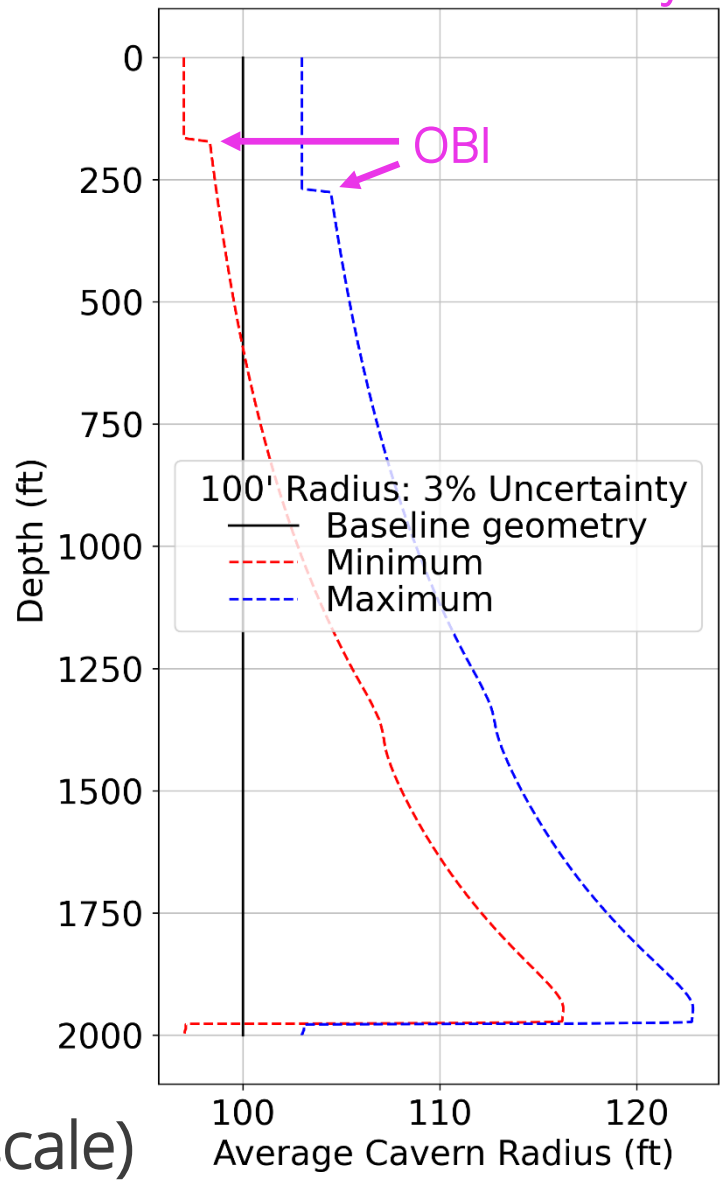
Combined potential effect of ±3% uncertainty for both sources.

Maximum radius range (MAX – MIN) tabulated for different initial cavern radii.

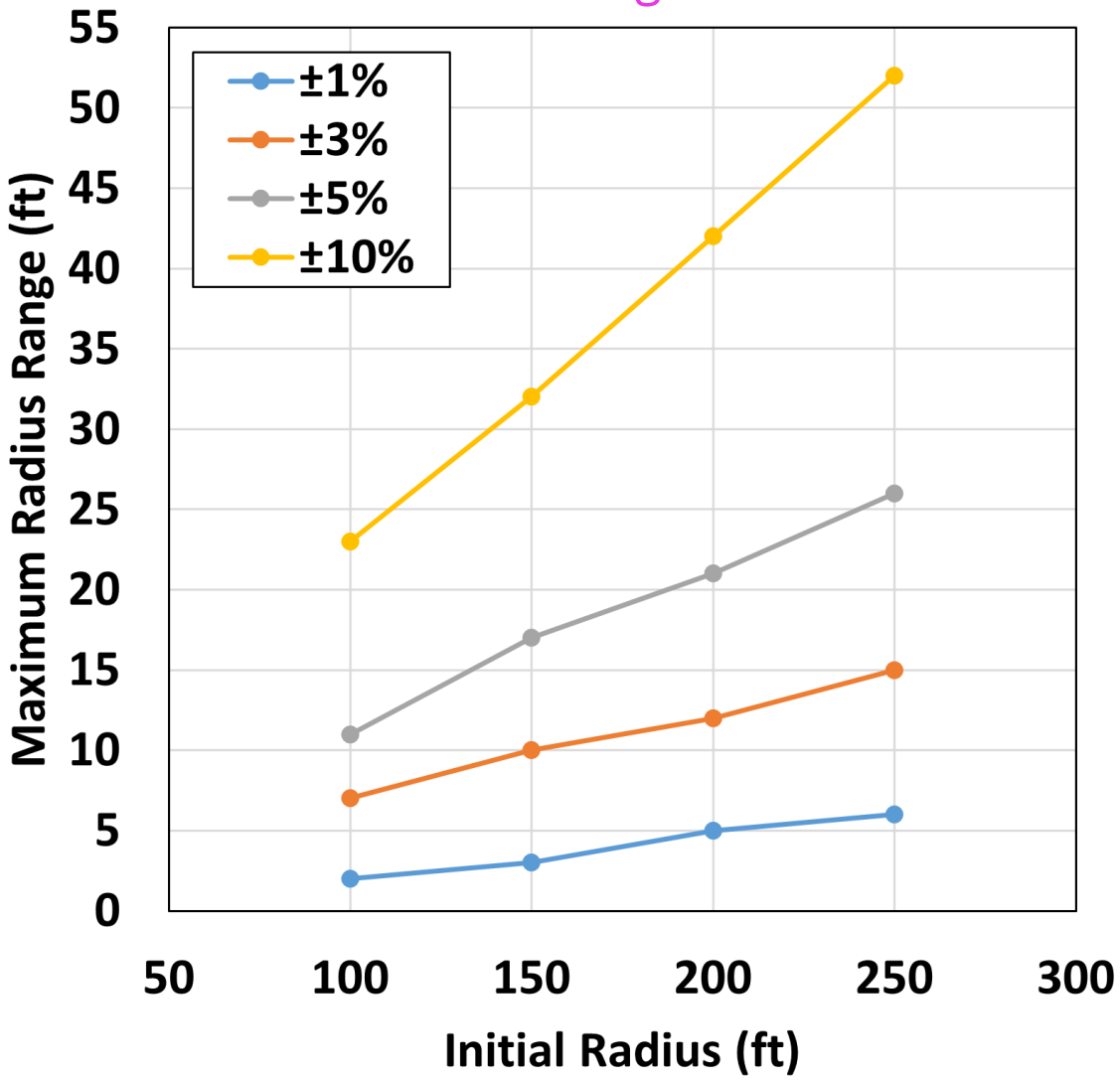
Radius range = $r_{MAX} - r_{MIN}$ at each depth

(not to scale)

Combined Uncertainty



Maximum Radius Range vs. Initial Radius

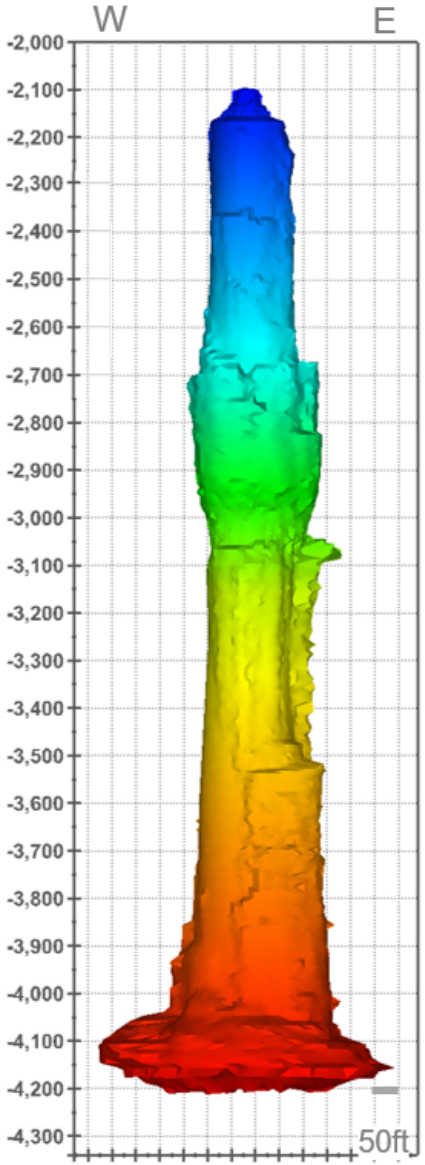


SPR CAVERN BAYOU CHOCTAW 18 WITH ACTUAL FLUID INJECTION HISTORY

2020 sonar

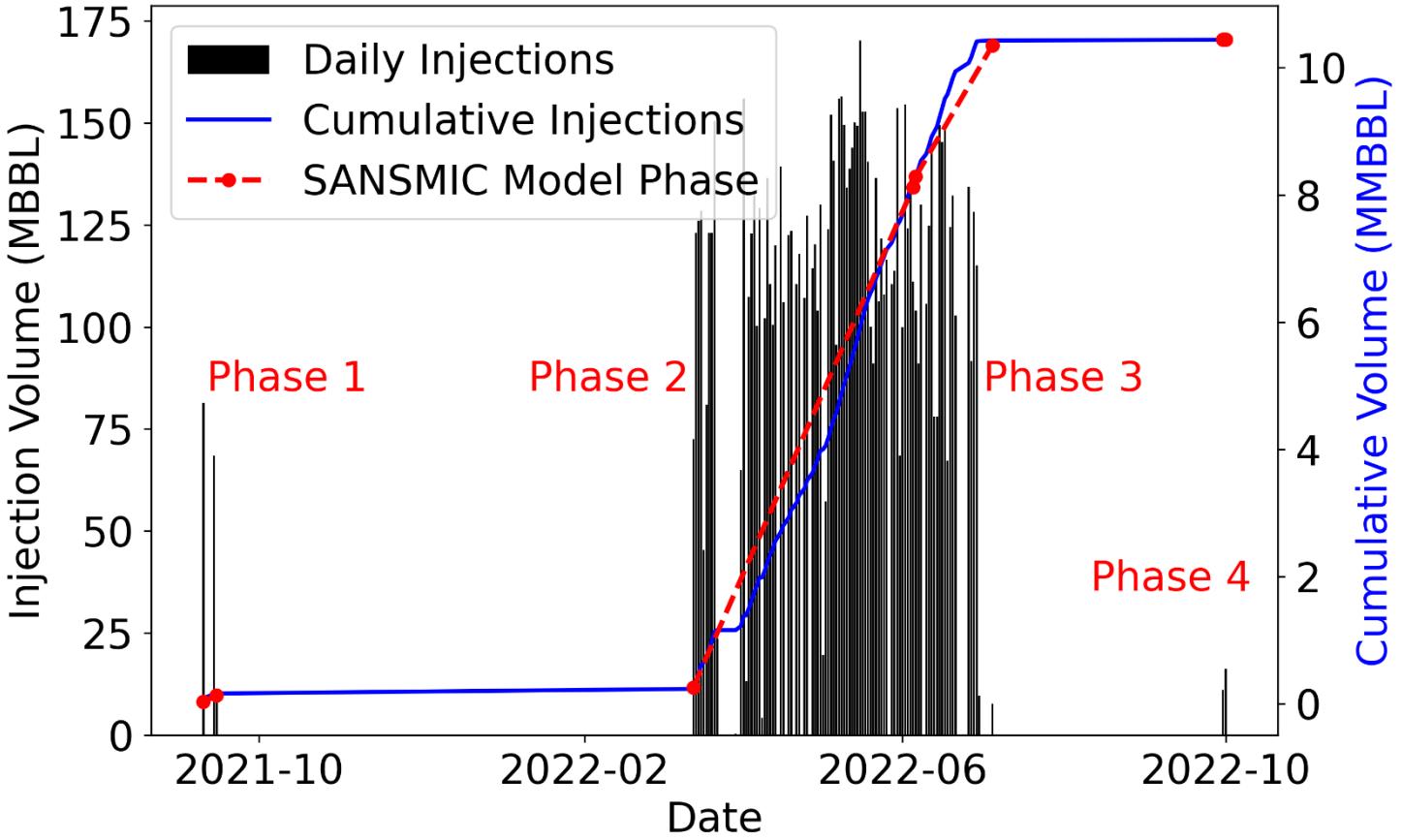
2022 sonar

~10 MMB raw water injected



2020 sonar

(colored by elevation)

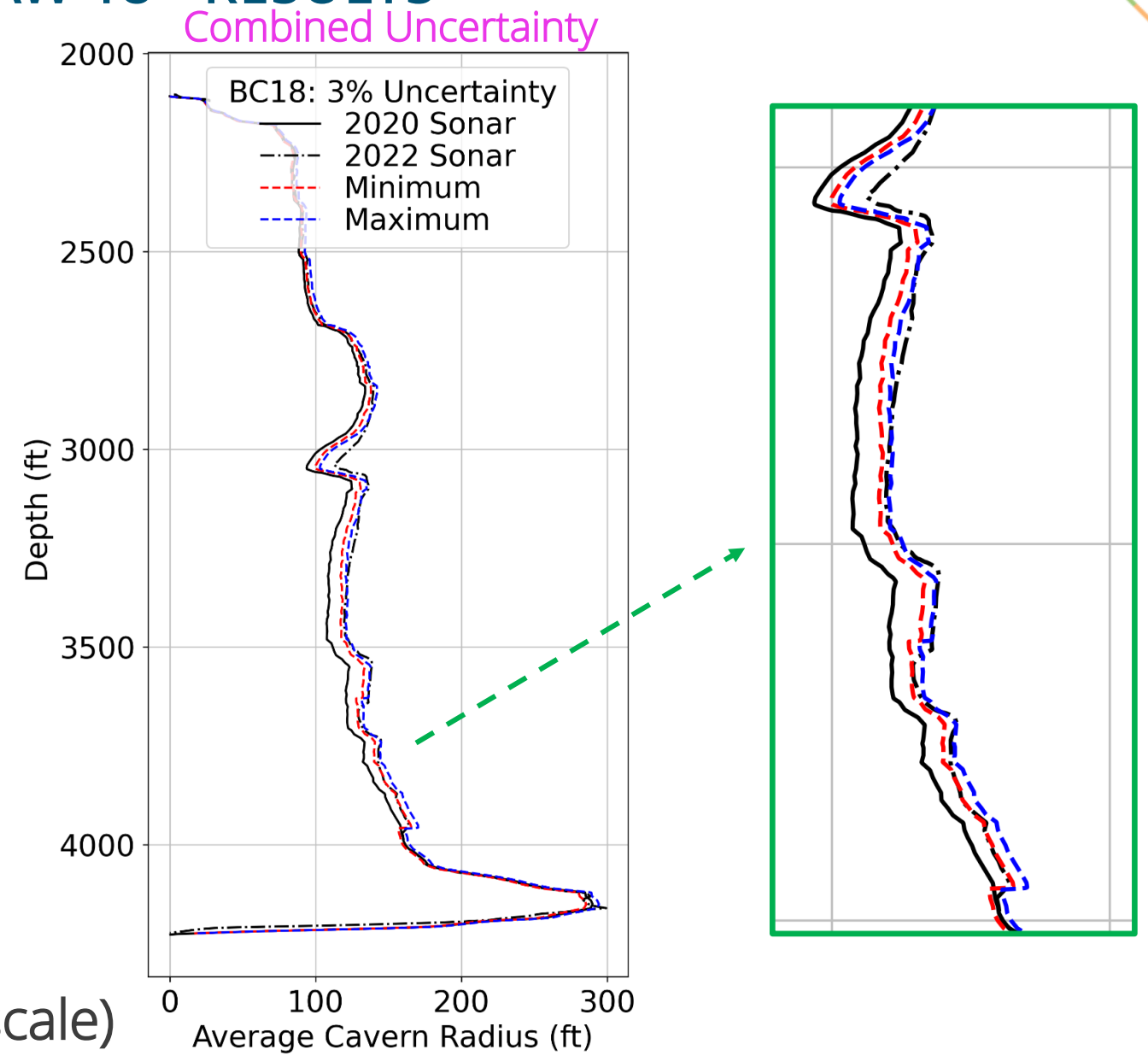


Raw water injection history for BC-18 between 2020 and 2022 sonars.

SPR CAVERN BAYOU CHOCTAW 18 - RESULTS

SANSMIC-predicted growth is similar in shape and extent to the resultant growth shown in 2022 sonar.

2022 sonar results generally bounded by ±3% uncertainty but in some cases not bounded until ±5% level.



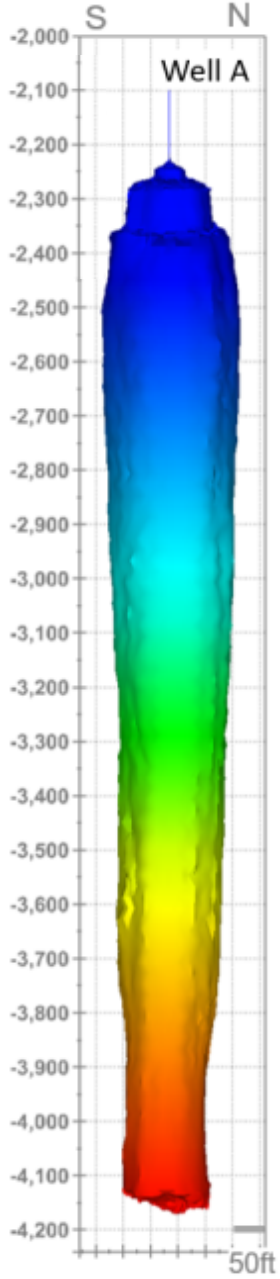
(not to scale)

SPR CAVERN BIG HILL 109 WITH ACTUAL FLUID INJECTION HISTORY

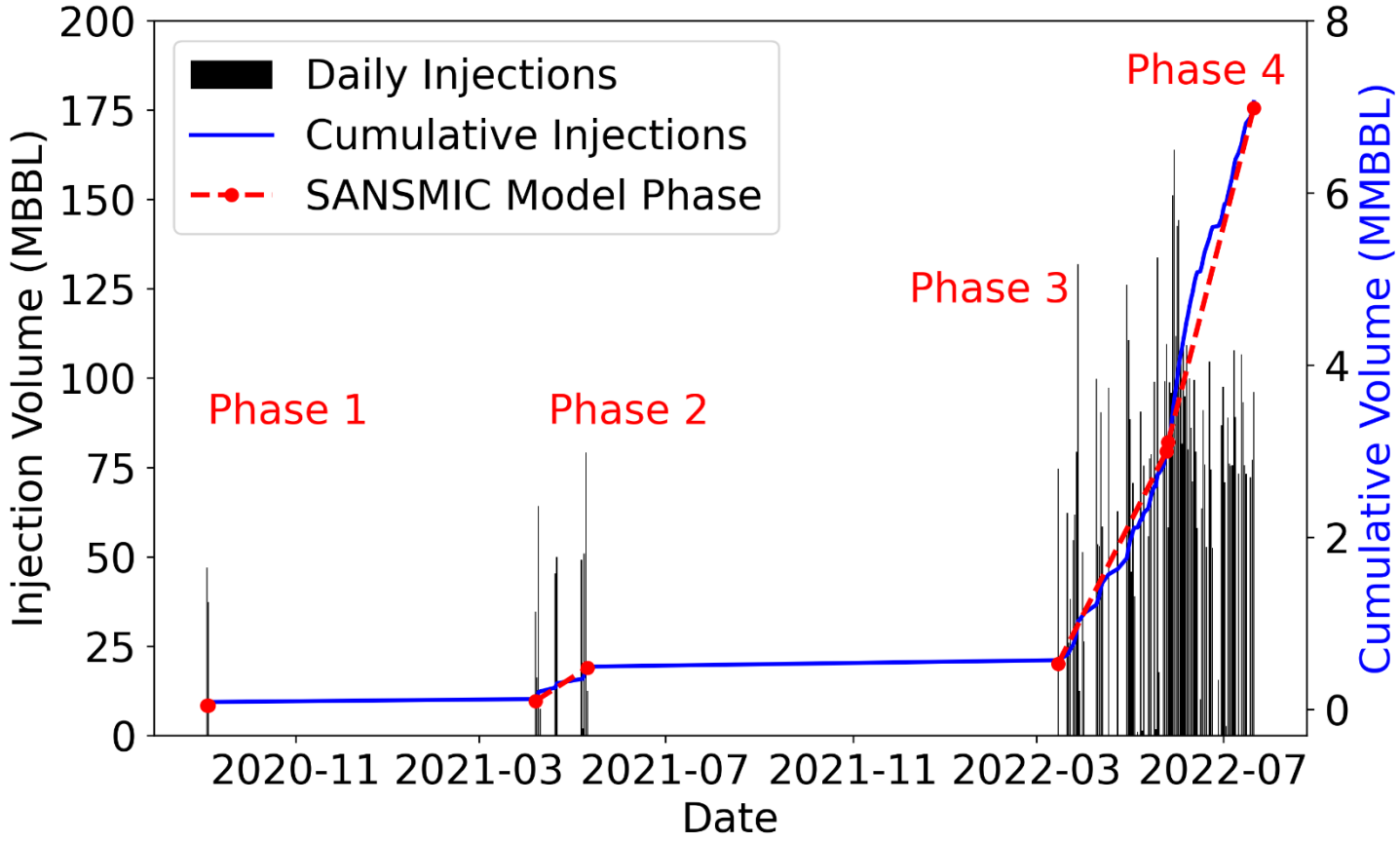
2020 sonar

2022 sonar

~7 MMB raw water injected



2020 sonar
(colored by elevation)



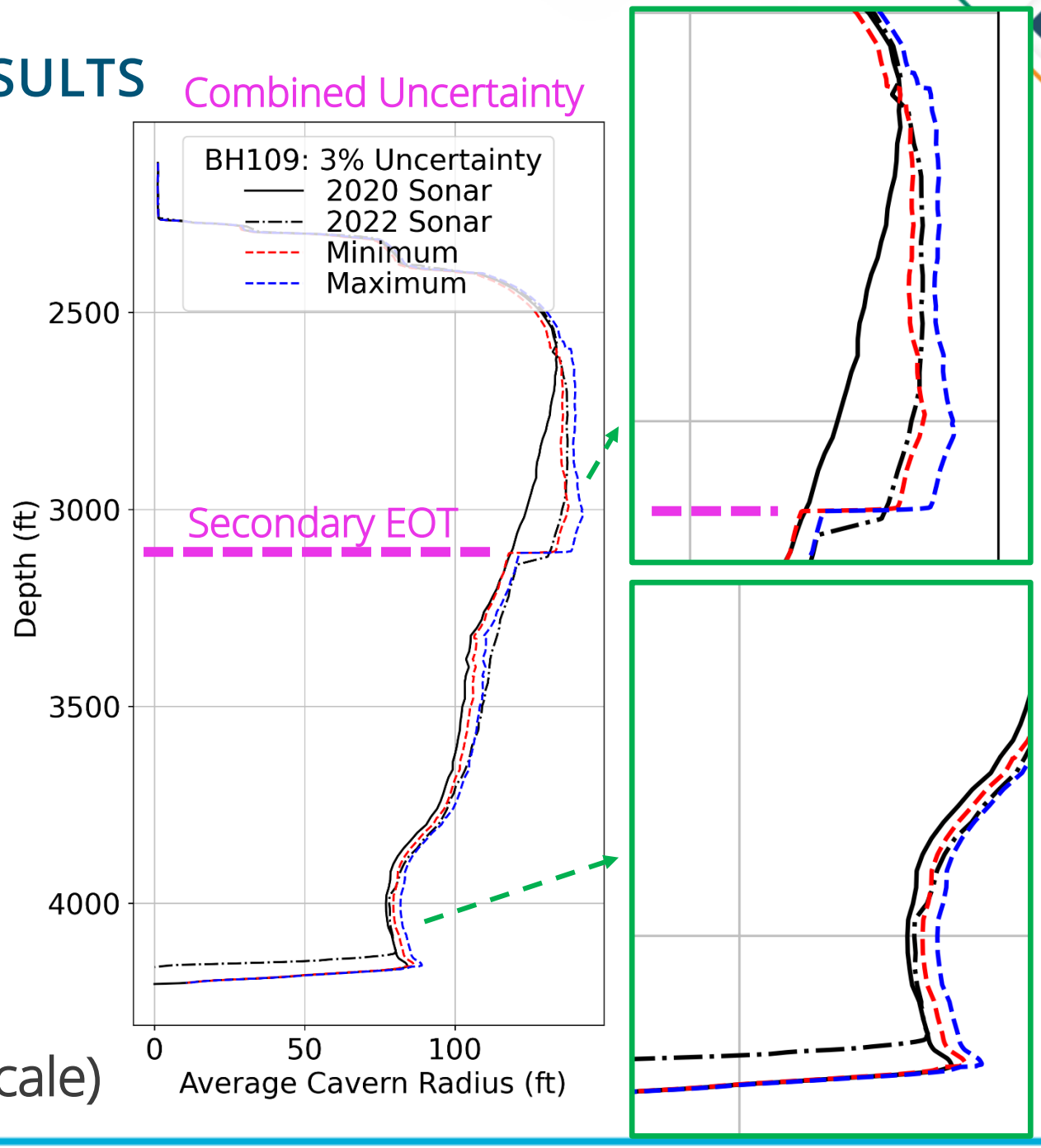
Raw water injection history for BH-109 between 2020 and 2022 sonars.

SPR CAVERN BIG HILL 109 RESULTS

SANSMIC-predicted growth generally agrees with the resultant growth shown by the 2022 sonar.

In the lower part of the cavern, SANSMIC-predicted results exceed the sonar results even for the ±5% level of uncertainty.

- May be attributed to floor rise between sonars.



(not to scale)

SUMMARY AND CONCLUSIONS

Current levels of uncertainties in raw water injection volumes and sonar surveys to be relatively unimpactful to the results of our leaching models.

At the same uncertainty level, injection volumes are much less impactful than sonar surveys.

For a “typical” uncertainty of ±3% in the injection volume and ±1% uncertainty in the sonar survey, we expect about ±1.5 ft (±0.5 m) uncertainty in the location of the cavern wall for a 100 ft radius cavern.

As we move forward with planned changes to SANSMIC, we believe we have a good software basis.

Wellhead at Bryan Mound site

https://www.energy.gov/fecm/photos/strategic-petroleum-reserve