Reclaiming Sulphur Base Pads – Bringing the Reality Home

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Agenda

1. The Problem - Scale and Regulatory Context

2. Balzac Gas Plant Overview

3. Review of Sulphur Data on the East Sulphur Base Pad

4. Conclusions/Recommendations

SCALE OF ISSUE

- To exploit vast natural gas reserves, several dozen sour gas processing plants were built in the WCSB during the 1950-1970s time frame

- Many of the older plants are currently running at well below inlet capacity and the end of life for these facilities has been reached or is in sight

- With increasing focus on liability management, producers have started the decommissioning/ reclamation process at many gas plants

SCALE OF ISSUE

At some facilities, elemental Sulphur (ES) was recovered from the raw gas stream and poured as a molten stream onto the ground as sulphur blocks for storage prior to marketing offsite

Source: https://www.enersul.com/sulphur-solutions/sulphur-block-pouring/

Sulphur Base Pads

- Sulphur Base Pads (SBP), where the blocks were located, are often hectares in size and the underlying impacted soils can be a significant portion of the reclamation effort at sour gas processing facilities

- Several plant reclamations that have included sulphur blocks are well underway or complete (i.e. CNOOC Okotoks, Devon Coleman), but there at least 20 more remaining across the WCSB

- Management of Sulphur-impacted soils in Alberta is directed by the *Guidelines for Landfill Disposal of Sulphur Waste and Remediation of Sulphur Containing Soils* (Alberta Environment, 2011; the "**Sulphur Guidelines**"), as well as Alberta Tier 1 and Tier 2 Guidelines

Sulphur Guidelines - Overview

Effect of Sulphur on Soil and Groundwater

- Under aerobic conditions microbes break down ES to sulphuric acid and can lead to acidification of soil and groundwater:

$$S + 3/2O_2 + H_2O \longrightarrow H_2SO_4$$

- Sulphuric acid will further breakdown in water and SO_4 will release into the groundwater

- Soils with Total Sulphur (TS) concentrations >4% must be taken to an appropriate waste management facility

- Soils with a total residual concentration between 0.05% ES (Alberta Tier 1 guideline) and 4% TS can be amended by applying lime, or an equivalent product

Sulphur Guidelines - Lime Amendment

- The calcium carbonate (limestone) weight ratio is based on the reaction:

$$H_2SO_4 + CaCO_3 \rightarrow CaSO_4 + CO_2 + H_2O;$$

Thus $CaCO_3/S = 3.2$

- Sulphur concentrations are based on results of soil sampling

- There are specifications for the size and purity of the crushed limestone

- The Acid Neutralizing Capacity (ANC) of both the liming material and the receiving soils are to be taken into account when determining the volume of lime to be applied

Sulphur Guidelines- Current Shortcomings

Data Gaps

- ANC of the soil must be taken into account but does not provide guidance for soils with a high natural buffering capacity (i.e. much of western and central Alberta)

- Focuses on soil and groundwater acidification but does not address potential sulphate loading to groundwater

Regulatory Uncertainty

- Sulphur Guidelines written by AEP but being managed by AER for oil and gas facilities

- Only a limited number of facilities have removed SBP material down to amendable range (TS <4%) to date

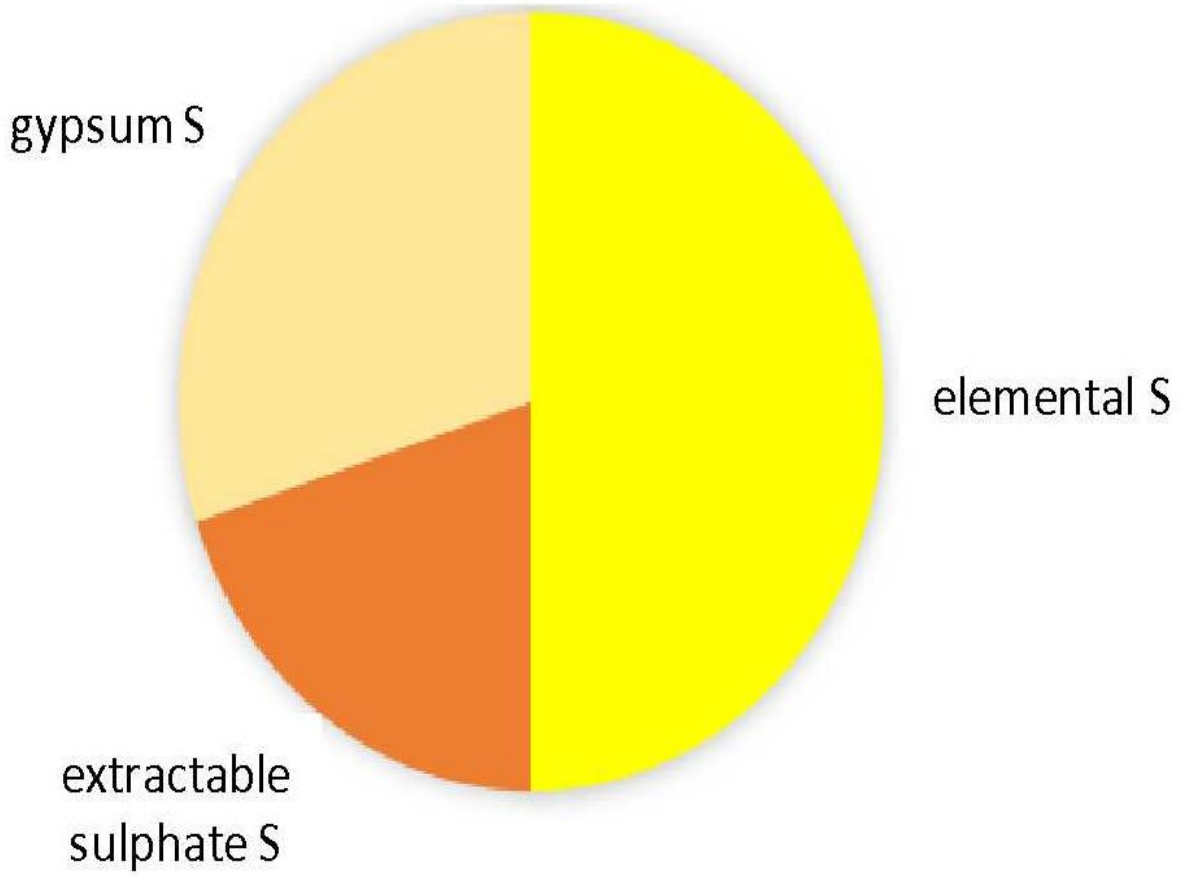
- Currently the question of what is acceptable is left to the regulatory closure stage which can be $10MMs and many years down the road

Sulphur Guidelines- Current Shortcomings

It's time to apply some science, in conjunction with the Sulphur guidelines, that the entire environmental community, including regulators, can get behind and provide certainty to operators

- To manage, need to understand:
  - Total S components
    - elemental S
    - extractable sulphate-S
    - gypsum sulphate-S
  - pH
  - Soil buffering capacity

(i.e., calcium carbonate equivalent, Acid Base Accounting)



Source: Levy and Luther, ESAA Emerging Contaminants Presentation October 2020

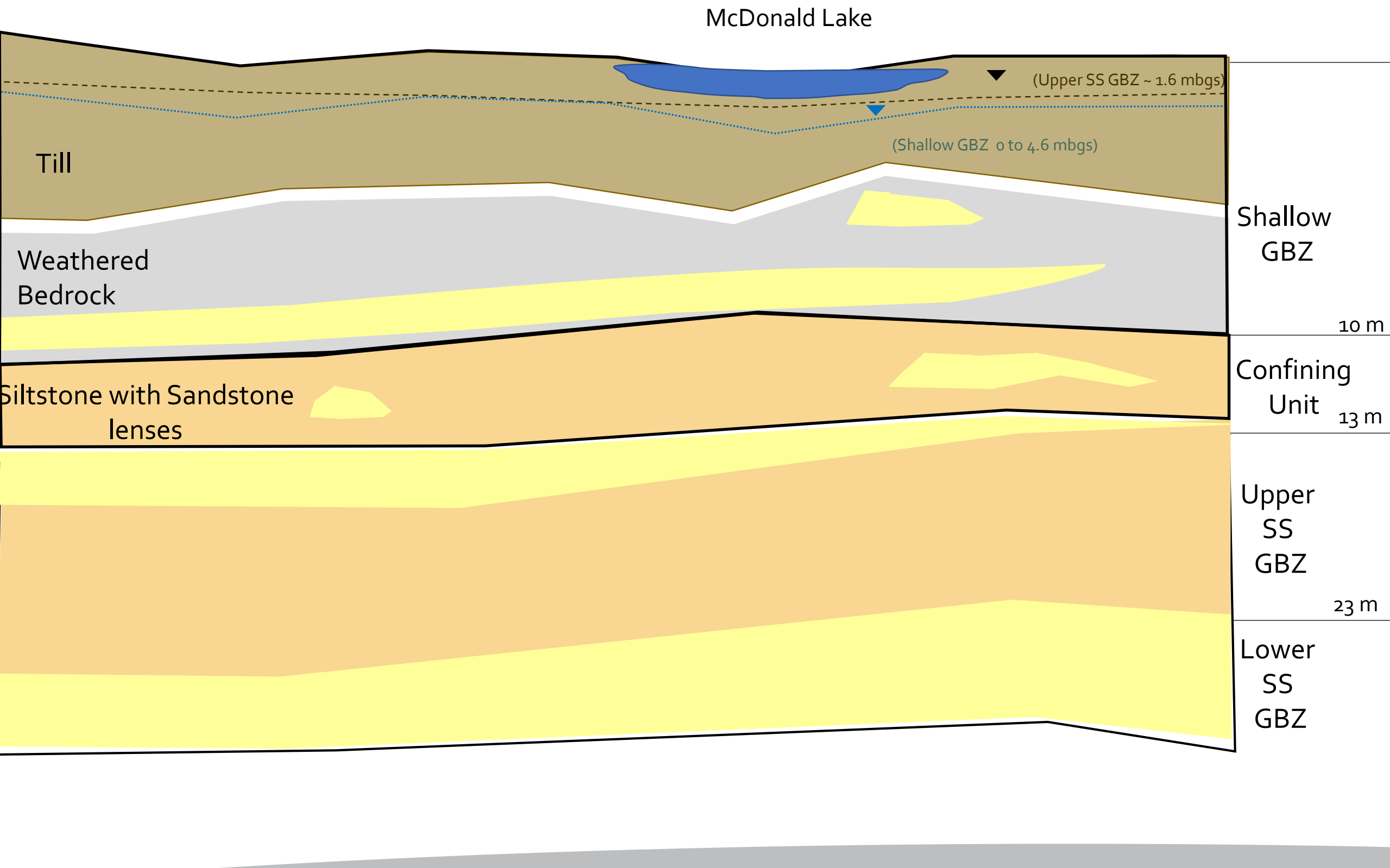
BALZAC GAS PLANT (BGP) OVERVIEW

- Operated from 1961 to 2011
- Plant Decommissioning Activities started in 2011
- Sulphur Block has been removed
- Sulphur block is ~ 7 ha
- Potentially Sulphur impacted soil present across site ~ 20 ha
- Removal of soils with > 4% TS is ongoing

Balzac Gas Plant – East Sulphur Base Pad

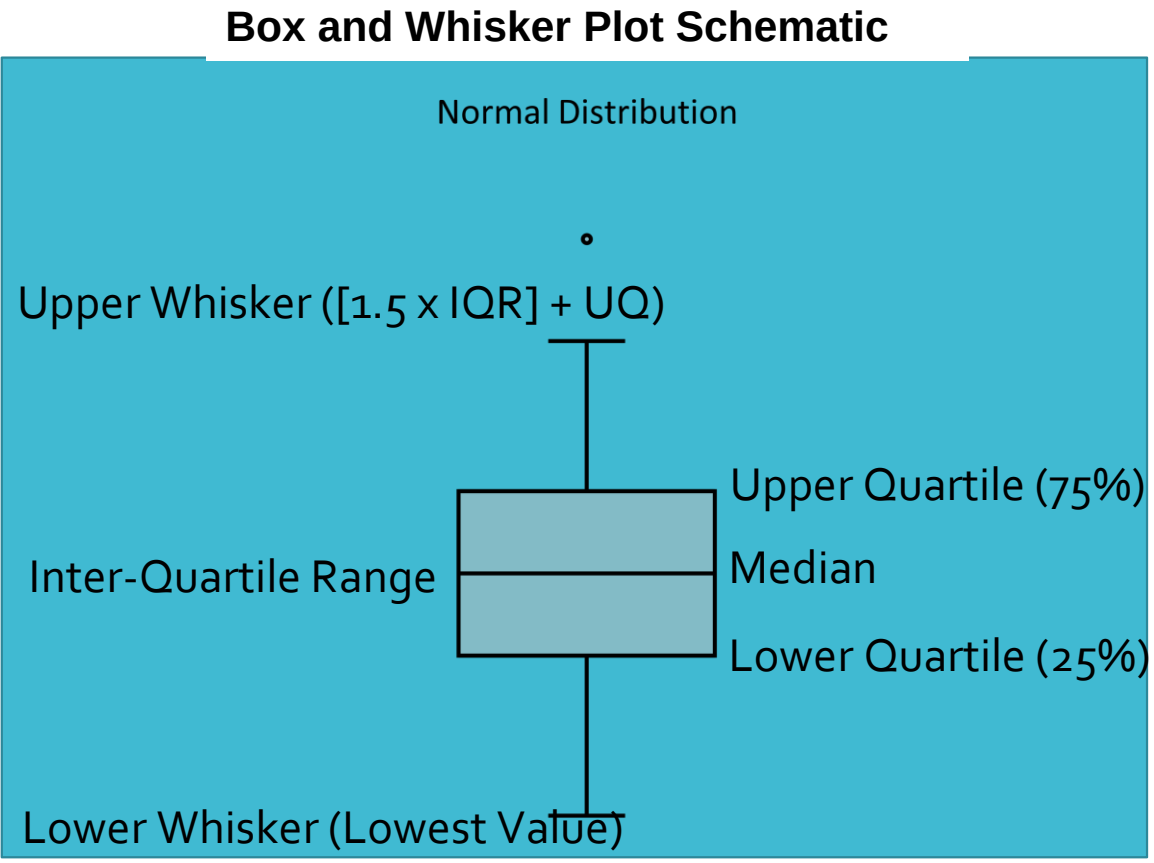
- All soils with > 4% TS have been removed
- Approximately 0.3 m of soil is impacted with soils in the amendable range

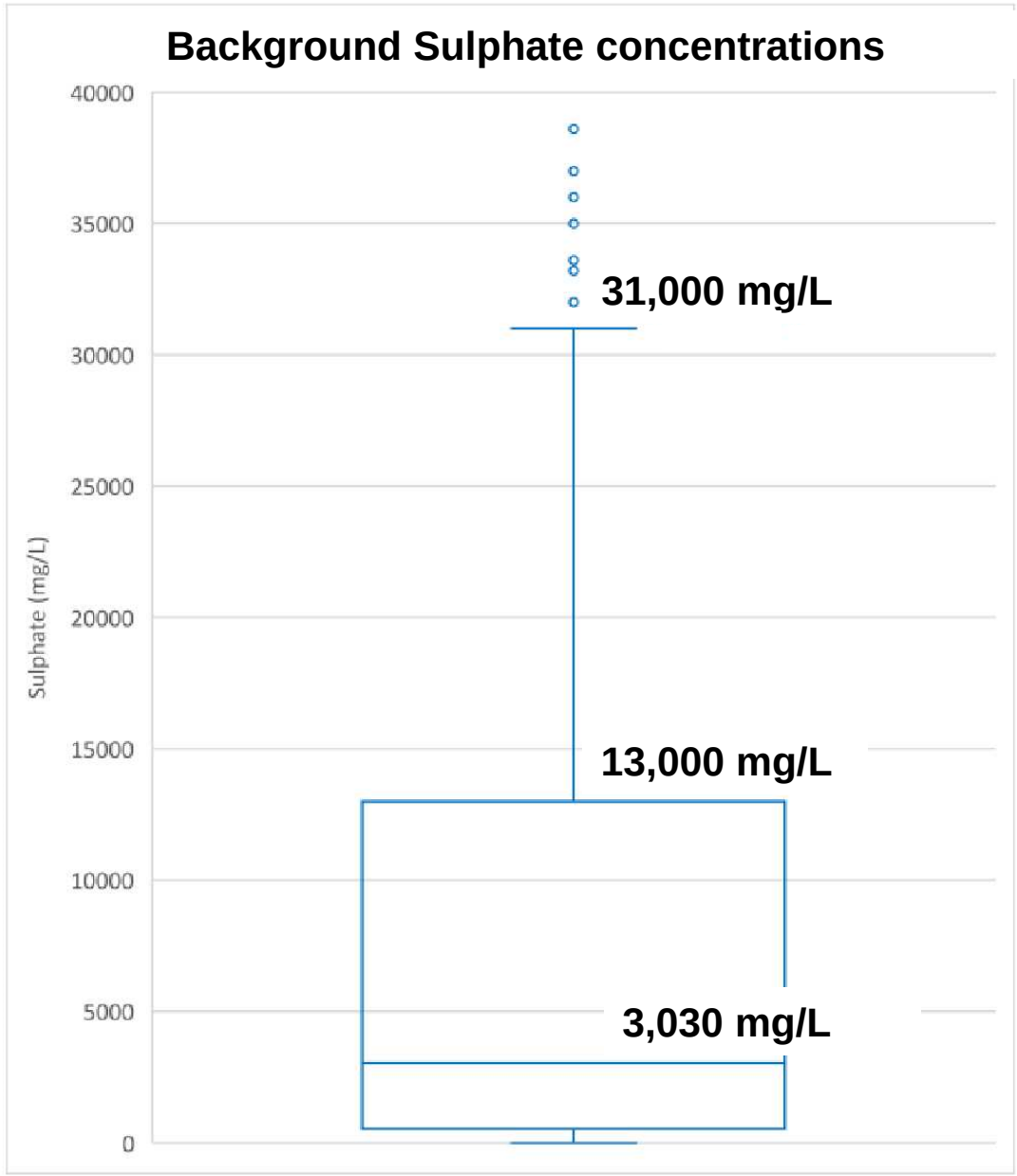
BGP – Conceptual Site Model



Background Sulphate in BGP Groundwater

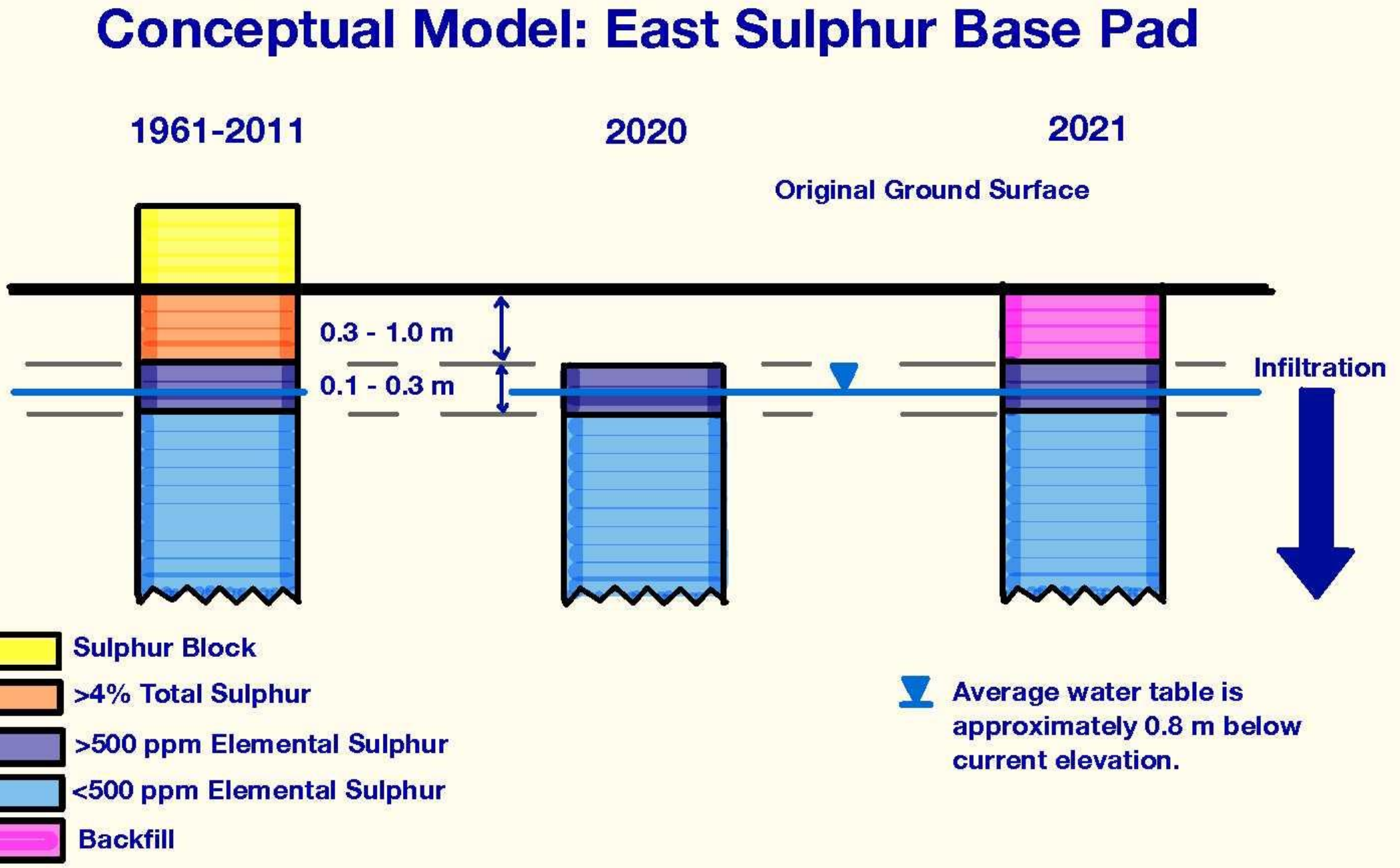
- Situated in a prairie evaporitic environment
- Naturally high $NaSO_4$ concentrations
- Dissolved SO_4 concentrations at the East SBP within background ranges





Schematic of East Sulphur Base Pad

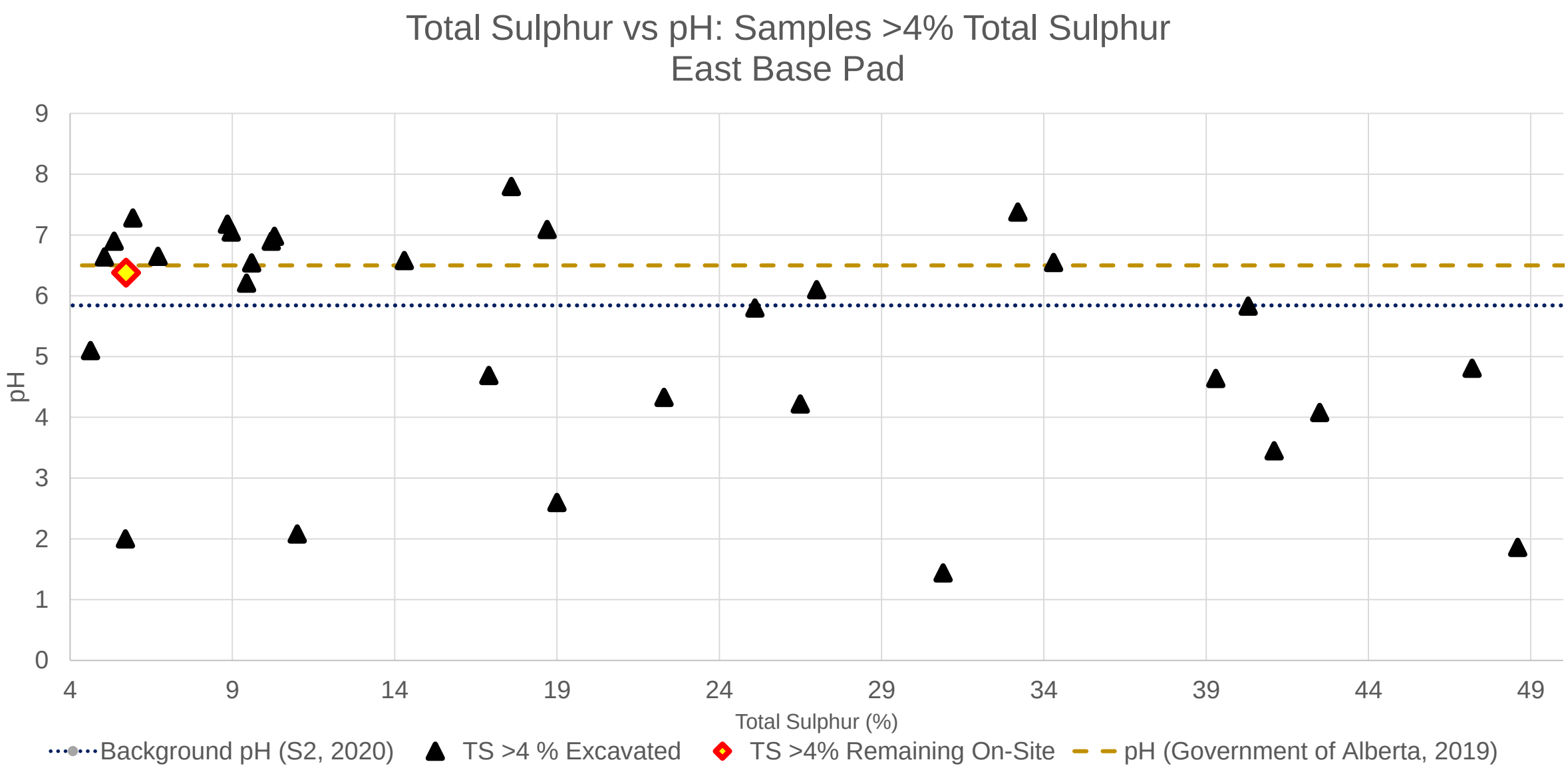
Conceptual Model: East Sulphur Base Pad



East Sulphur Base Pad

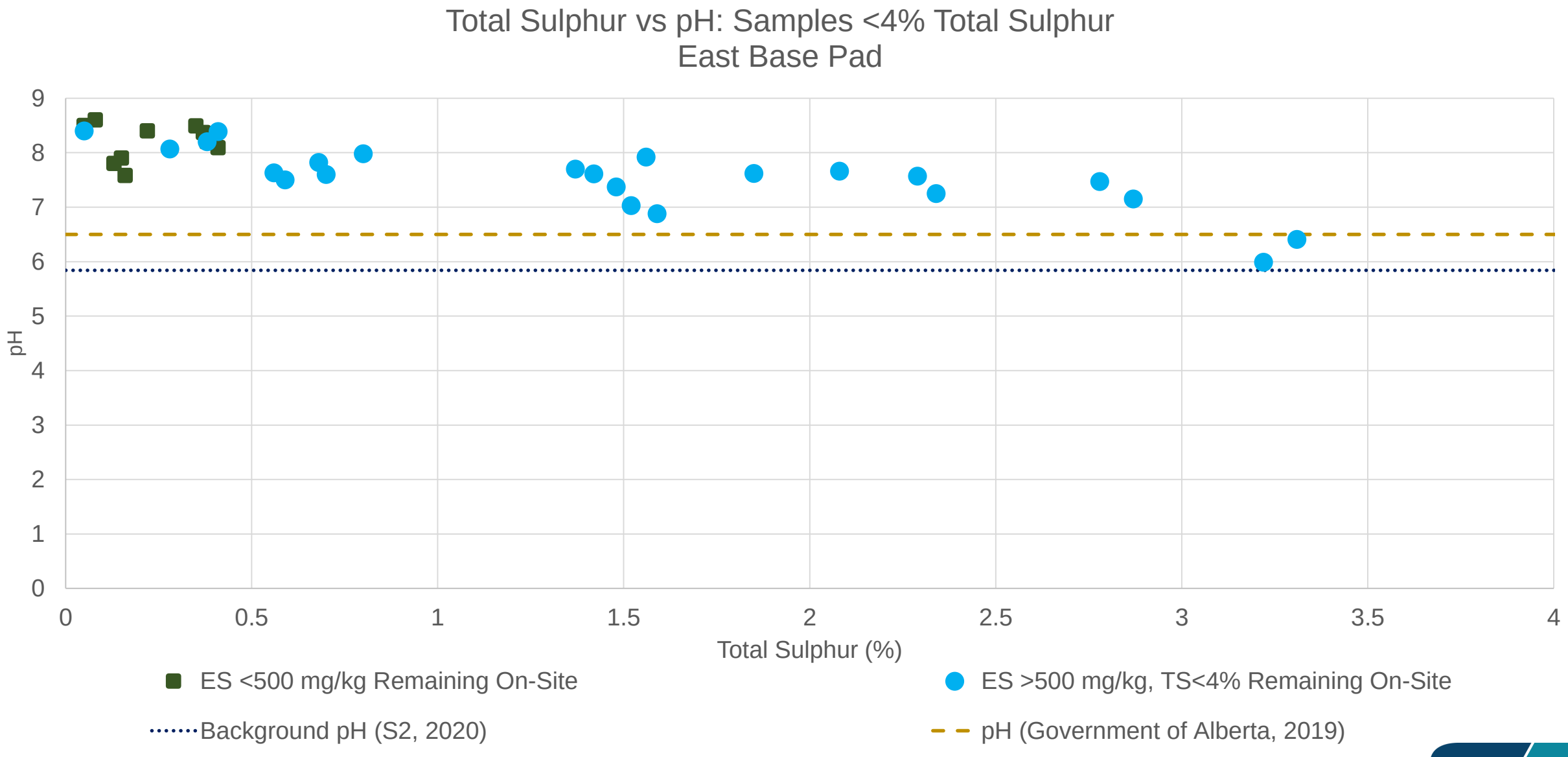
Analytical Overview

- Samples with total S >4% can have pH within background ranges due to natural buffering
- Previous assessments have shown the soils at the BGP have a high buffering capacity (Advisian, 2017)



East Base Pad
Analytical Overview

- Natural buffering is even more apparent at total S concentrations <4%
- All soil samples within the amendable range of sulphur have pH within the background range

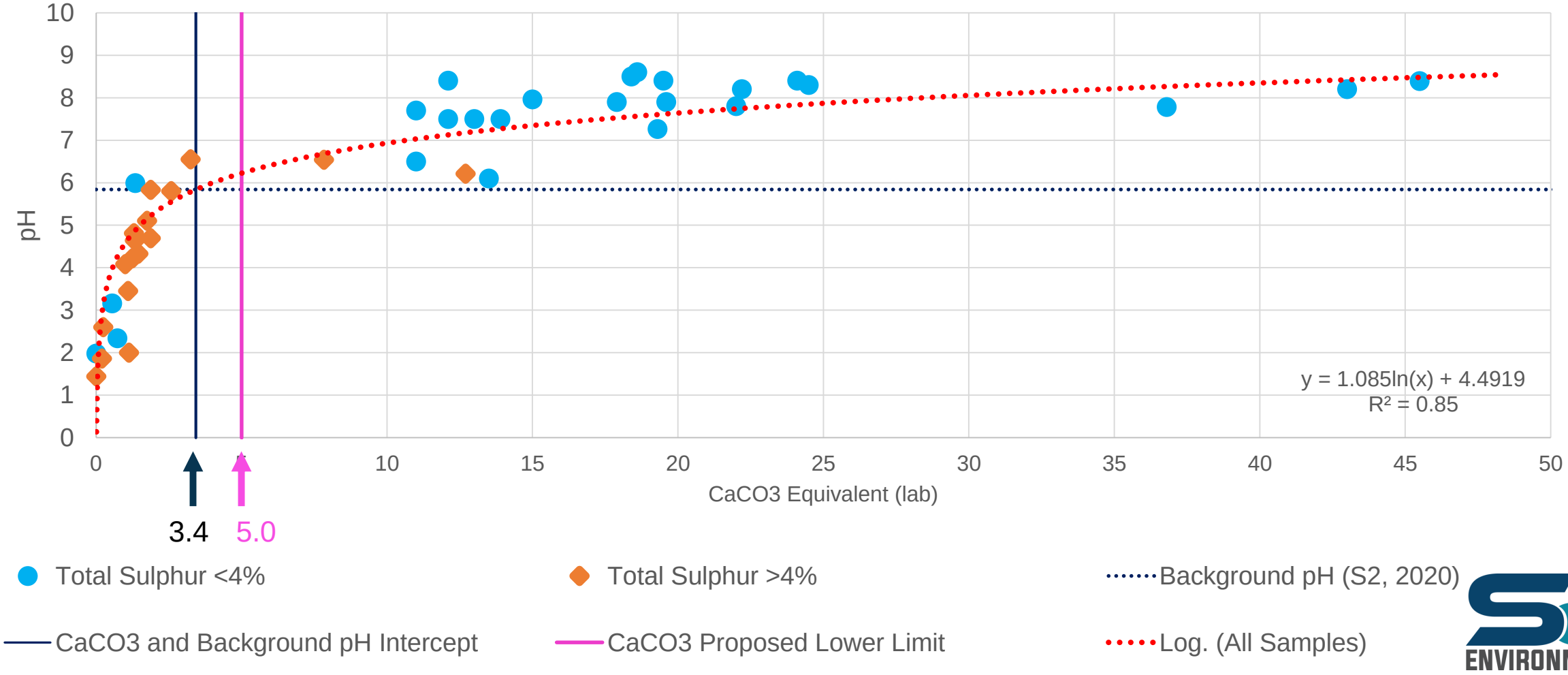


East Base Pad

$CaCO_3$ Buffering

- A high $CaCO_3$ value indicates strong acids can be added with minimal effect on pH (pH buffering capacity)
- Soil samples less than 3.4 $CaCO_3$ exhibit depressed pH
- Soil samples greater than 3.4 $CaCO_3$ exhibit pH within background range
- All soils with a Calcium Carbonate Equivalency (CCE) > 5.0 have sufficient natural buffering prior to lime addition

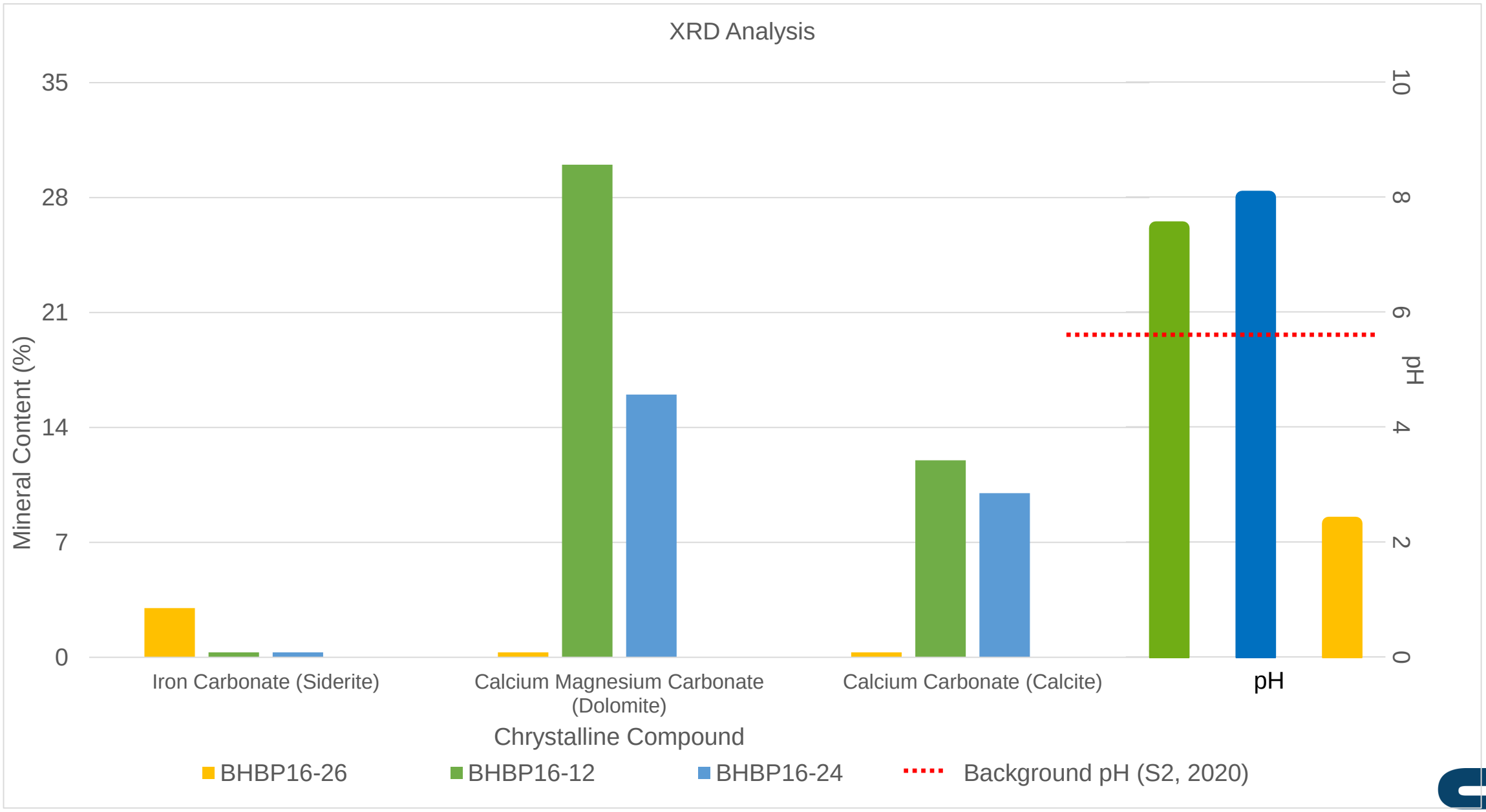
Calcium Carbonate Equivalent vs pH
East Base Pad



XRD Analysis

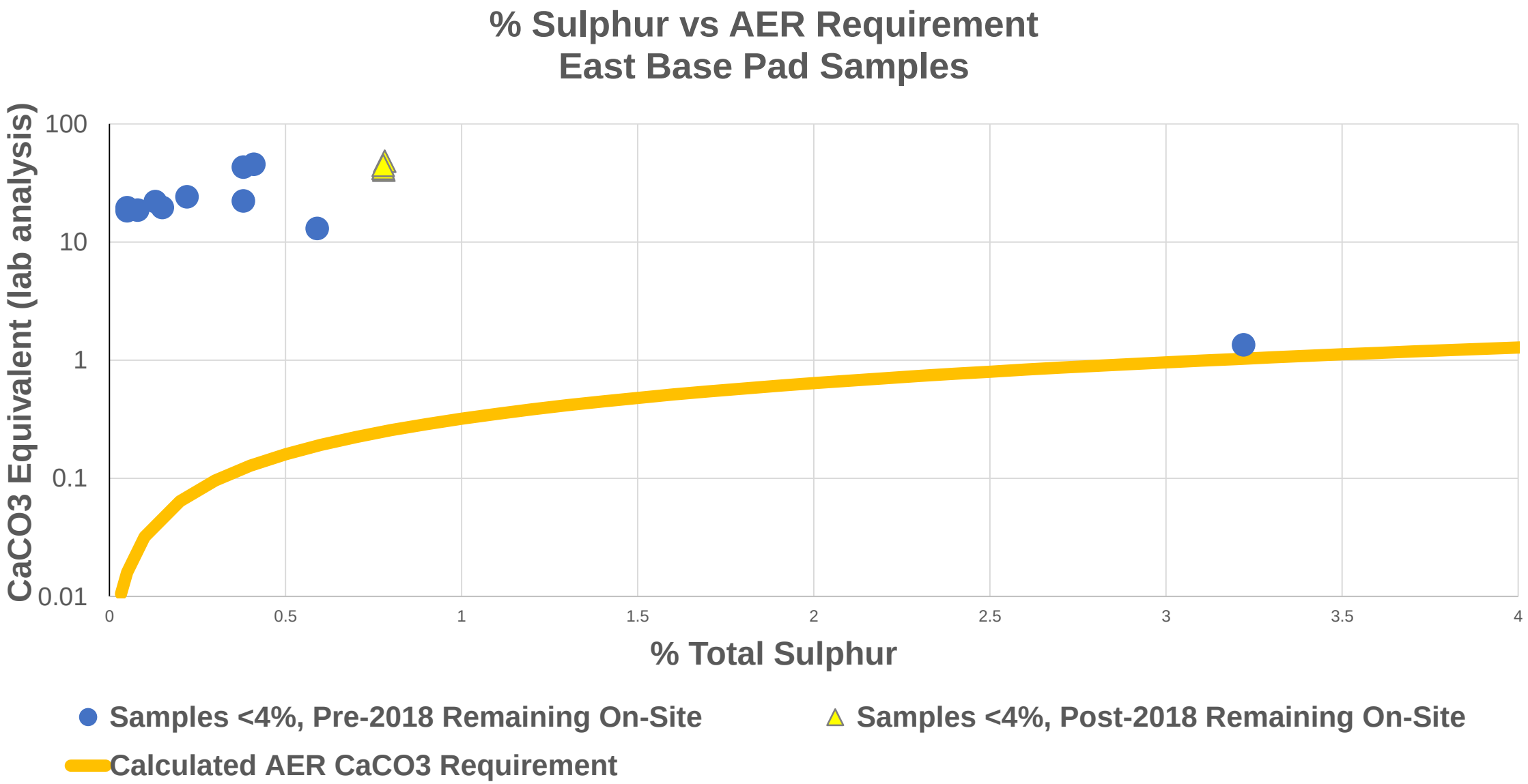
Sulphur Base Pad samples

- Historical XRD Analysis focused on high TS samples or were directly overlain soil samples with high TS
- XRD Analysis shows most of the $CaCO_3$ in two samples with neutral pH is Dolomite and Calcite

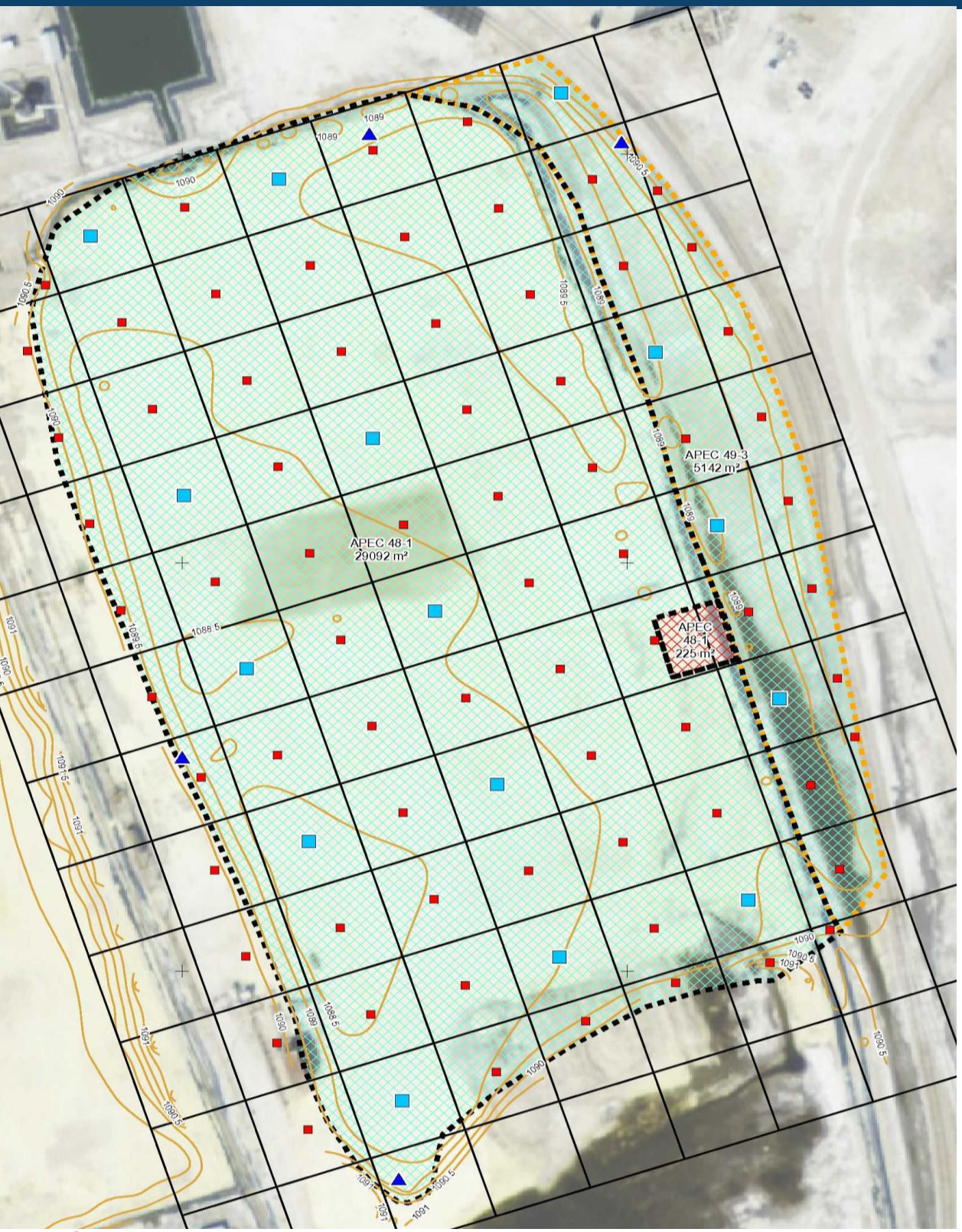


Theoretical Lime Requirement

- All samples with TS <4% on the ESBP indicate natural buffering capacity in the soils is sufficient to neutralize any remaining sulphuric acid
- Applying lime to the soils may increase the pH above the background and Tier 1 guidelines and potentially form a cemented crust on the soils



Proposed Monitoring for Natural Buffering



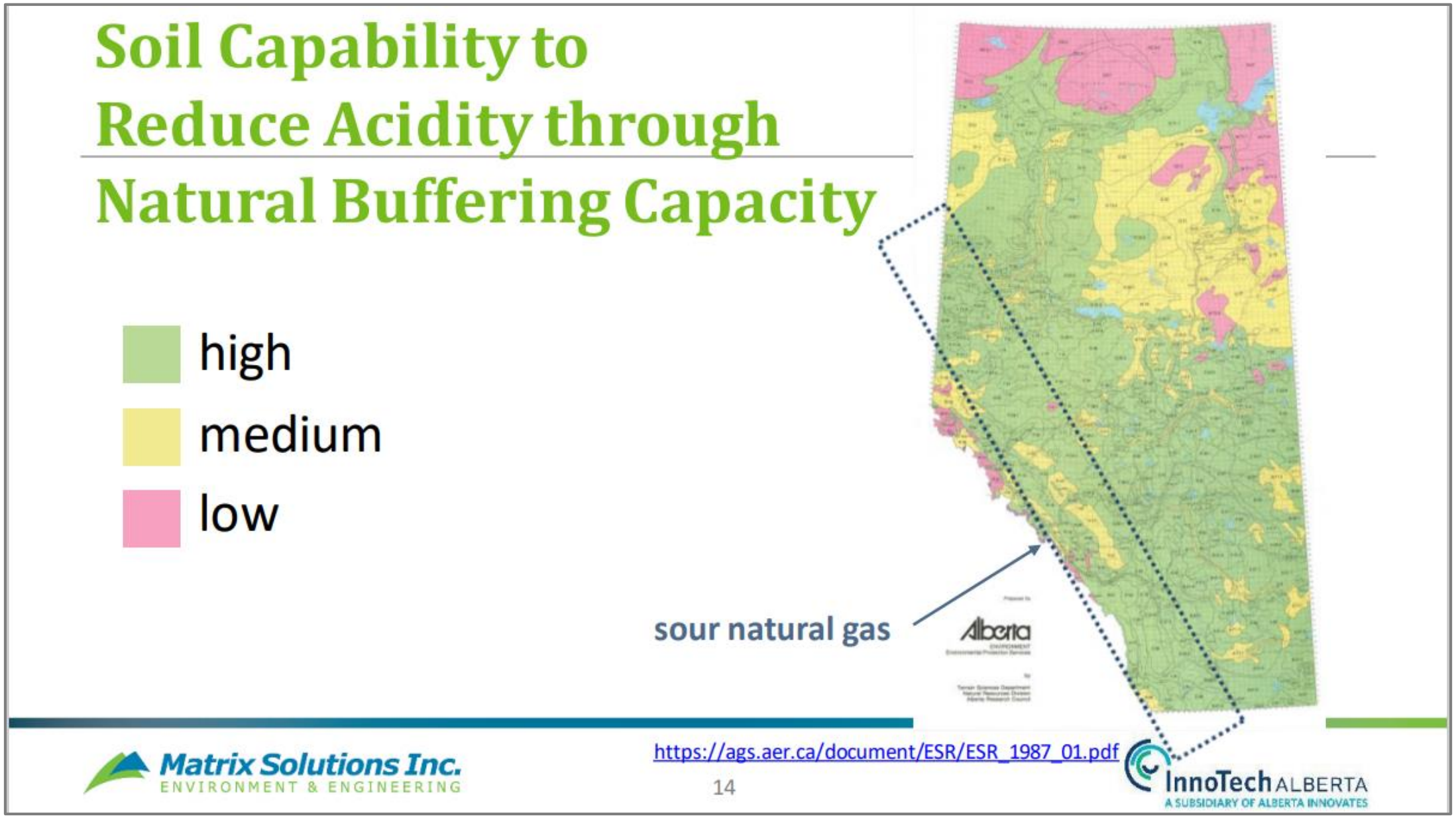
Upfront to Obtain Representative Data

- Soil sampling at 500 m^2 to collect the following:
  - Total Sulphur
  - Elemental Sulphur
  - Calcium Carbonate Equivalency
  - Salinity
  - XRD Analyses of select samples

2 Years of Ongoing Monitoring

- 15 Regulatory Soil Monitoring Locations
  - Quarterly Sampling
- 4 Groundwater Monitoring Wells
  - Annual Sampling

Natural Buffering Capacity of Soils is Well-Known



Source: Levy and Luther, ESAA Emerging Contaminants Presentation October 2020

Also pointed out by previous consultant:

- Komex (1995) stable sulphur isotope study
- Advisian (2017) geochemical study

Discussion

- There may be a lot of soils in WCSB for which little or no lime amendment is needed at <4% TS

- Want to ensure that oxidation of the remaining ES does not cause sulphate issue in soil or groundwater

- Perhaps higher TS concentrations could be successfully amended or left for natural buffering, especially if gypsum and extractable sulphate concentrations in these soils are significant

Conclusions

- Remediation of SBP can be a significant part of any liability management work at sour gas plants- $10MMs
- Owners require certainty for clean up
- There has been limited field testing of the Sulphur guidelines for regulatory closure of SBP
- Proper technical evaluation of soil ANC and potential sulphate loading to groundwater appear to be critical factors for the successful remediation of SBP when amendment is being considered
- Need aligned methodologies, timely review of site-specific data and regulatory acceptance of proposed remediation plans as our industry tackles SBP closure in western Canada

Acknowledgements

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Q&A

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