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Background Is Not Constant
Challenges and Options in Characterizing Soil Background for Contaminated Sites

envision more℠

Parsons

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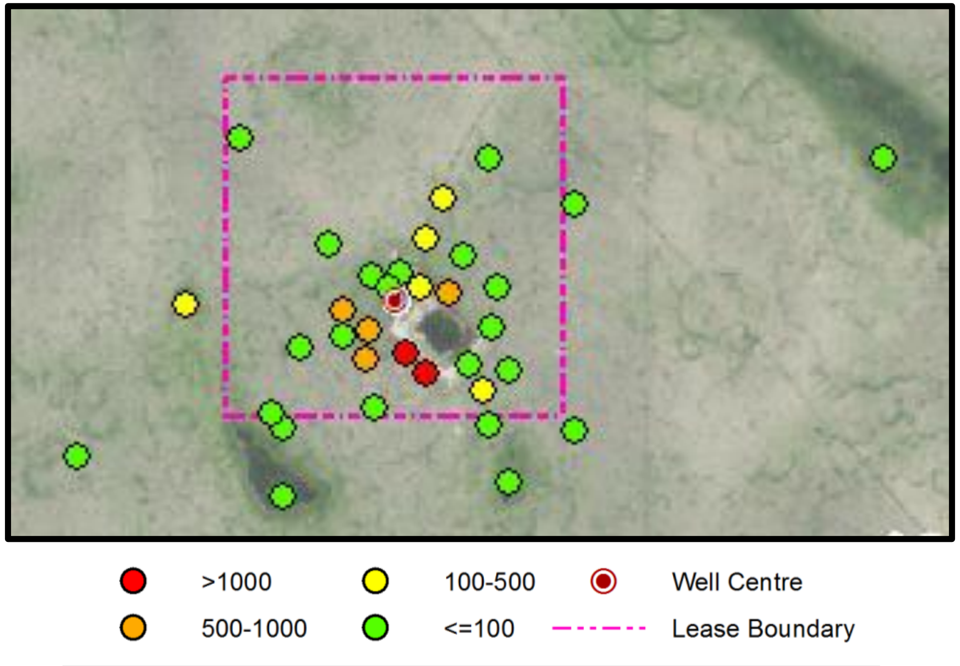
Concepts of Background

- "Alberta Tier 1 Soil and Groundwater Remediation Guidelines" (AEP 2019) provides a definition of background and principles for using the background values in site management.
- The background concentration of a substance in soil or groundwater is defined as:
  - The natural concentration of that substance in the absence of any input from anthropogenic activities or sources or;
  - The background concentration in the surrounding area as a result of generalized non-point anthropogenic sources.
- In cases when the background concentration is demonstrated to be greater than Alberta Tier 1 guidelines, the remediation level shall be set to background or to guidelines developed using Tier 2 procedures.
- The definition for background cannot be used to eliminate point source emissions, anthropogenic activities that cause redistribution of soil, or water sources with elevated substance concentrations.
  - In comparing against background, emphasis should always be placed on ensuring that anthropogenic sources are not identified as natural background.
- However, it is also important not to misidentify natural background as the site impact, since there is no need to remediate natural background.

Challenges in Characterization of Background

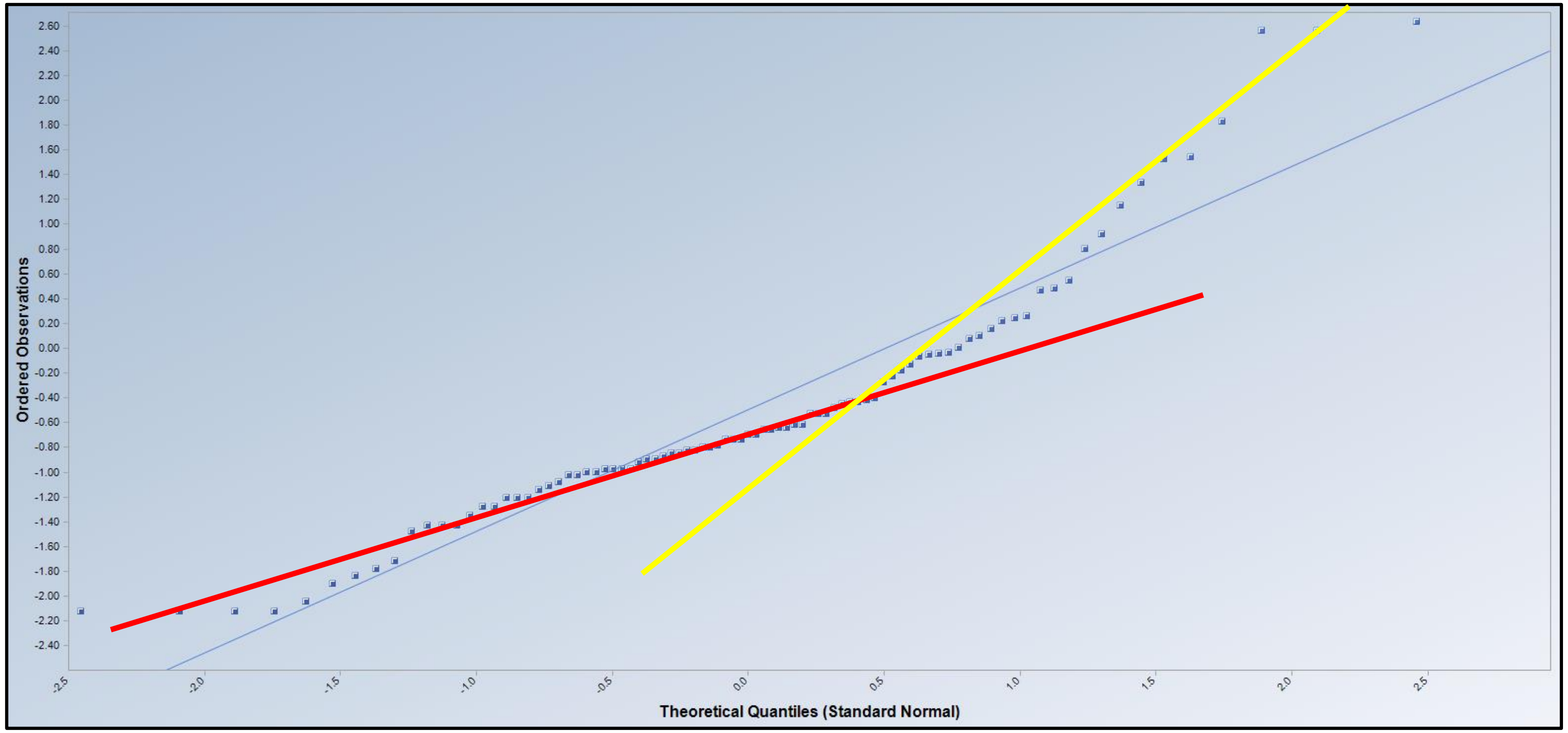
- Background concentrations will vary with soil parent material, soil depth, and hydrologic regime. These factors lead to spatial variations in background concentrations that may or may not be predictable.
- To gain a good understanding of background conditions at a site, it is necessary to take sufficient representative samples from soils with similar characteristics to the affected site, but which are taken from outside the area affected by contamination.
- Typically the background samples are not sufficient in number nor representative. There is great resistance by site owners to collect background samples offsite particularly after site delineation is completed.
- One of the solutions is to maximize the value of the available data, including the data collected onsite (find the background information onsite).

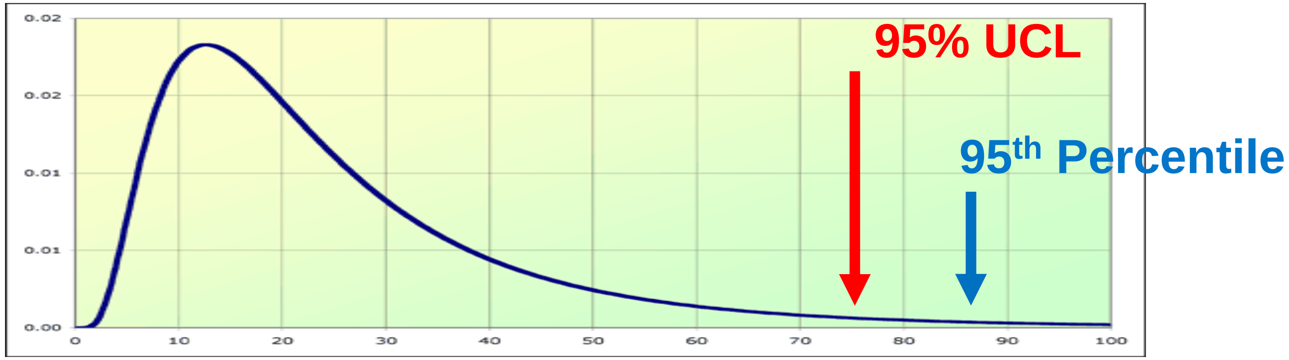


Methods to Determine Background Values

- Calculate 95th percentile
  - A common method for salt contaminated sites.
  - Debate on how to remove outliers.
- Calculate 95% UCL (Upper Confidence Limit)
  - A more robust statistical method.
  - Required to determine distributions first.
- Use mathematical functions to describe background variations
  - Correlation between chemicals of concern with geomorphological and geological parameters.
  - Correlation between chemicals of concern with known background chemical parameters.
- Chemical method to identify and remove naturally occurring substance
  - Such as environmental forensics to separate biogenic F3/F4 from petrogenic F3/F4 and remove it using silicon gel.

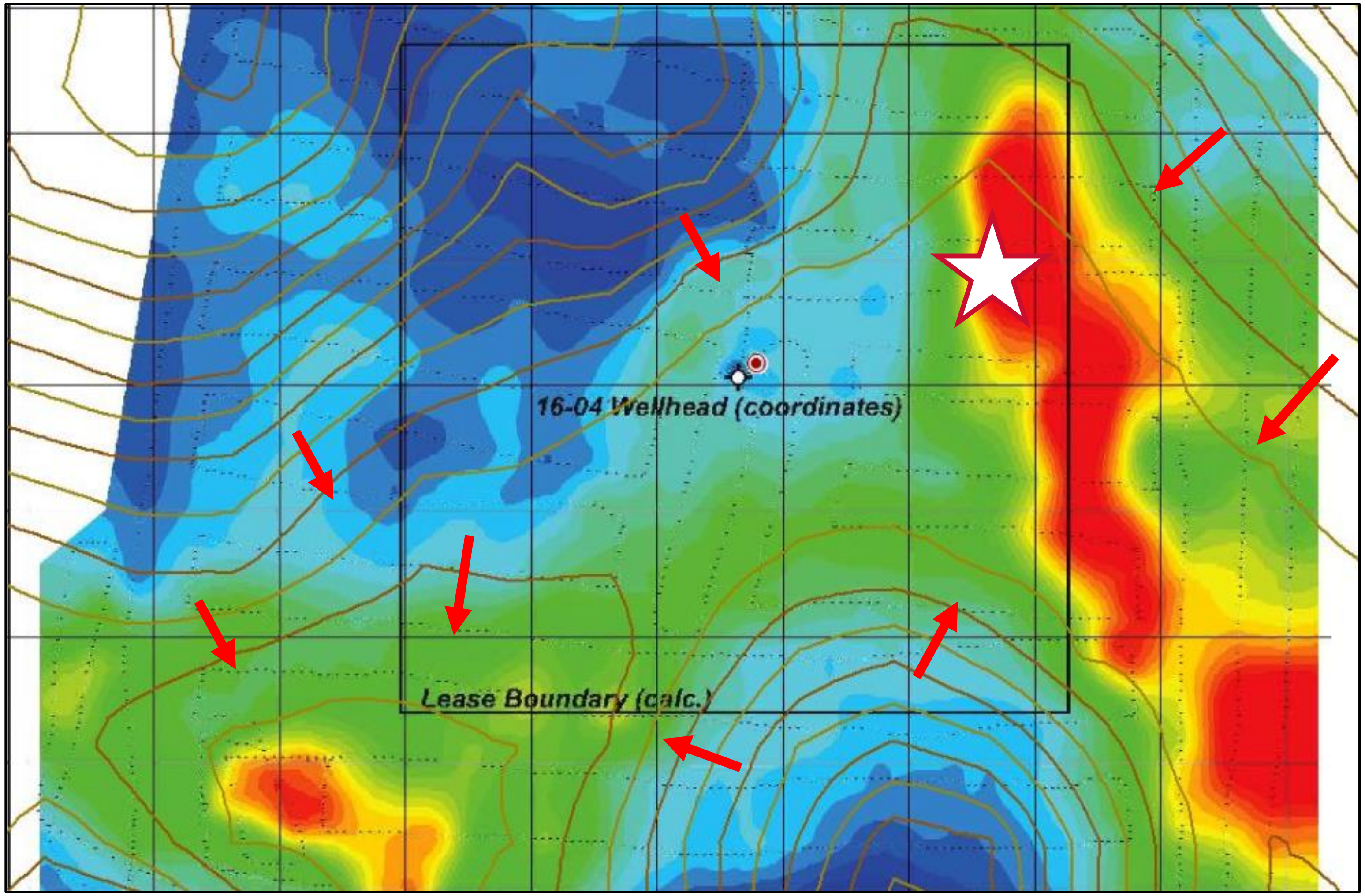
Technical Issues with 95% UCL





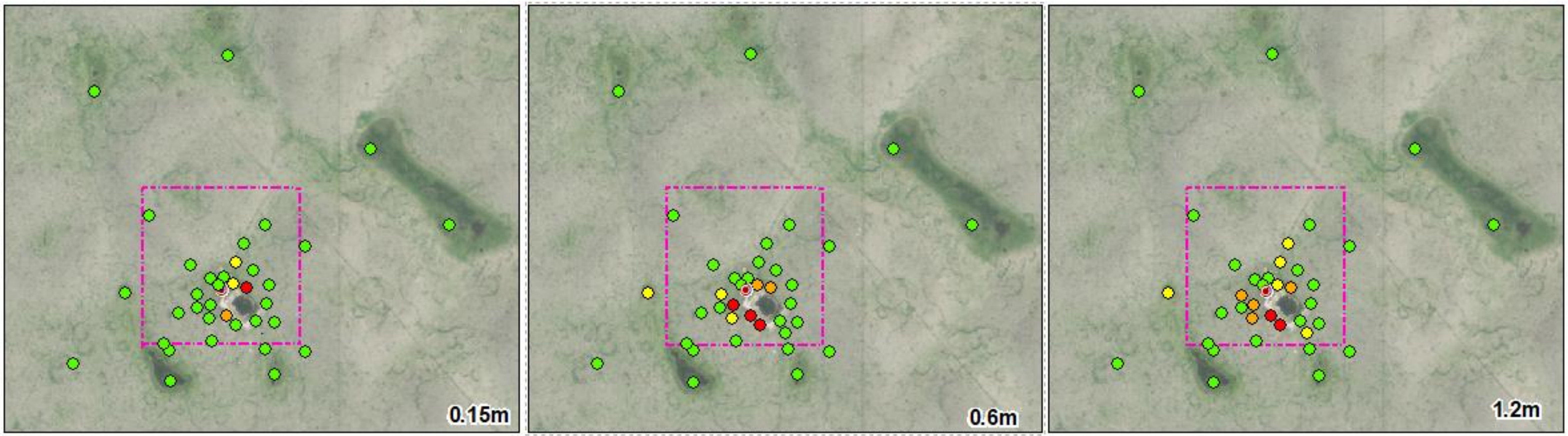
- Background data may not pass statistic tests to determine the distribution.
- May follow a bimodal distribution and add complexity to calculate UCL.
- For lognormal distribution, 95%UCL is usually lower than the 95th Percentile value, which eliminates the motivation to look for more realistic background value (or remediation objective).

An Example Showing Background Variations with Ground Elevations



- Elevated EM values apparently associated with low lying areas on ground surface.
- Soil samples show elevated chloride and sulphate values.
- Unlikely caused by historic site activities.
- What will happen if it overlaps with the former facility areas? Can we distinguish the natural elevated salinity from the combined salinity impact?

Case Study (Soil Chloride)



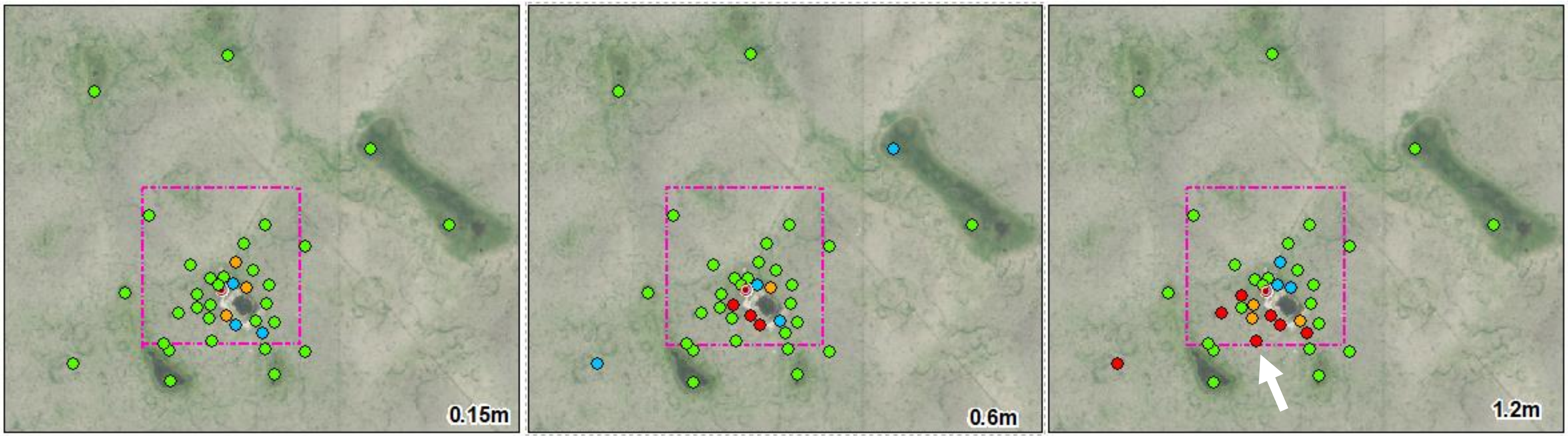
Legend

- >1000
- 500-1000
- 100-500
- <=100
- Well Centre
- Lease Boundary

Soil Chloride Concentrations (mg/kg) at Different Depths

- Abandon wellhead site with a sump for drilling waste. SE Alberta
- Not many samples from confirmed background
- Many unimpacted points are located onsite. Use them for background analysis?

Case Study (Soil EC – Electrical Conductivity)



Legend

- Unsuitable
- Fair
- Well Centre
- Poor
- Good
- Lease Boundary

Soil EC (uS/cm) at Different Depths

- Chloride is not a parameter to assess risks to root zone directly, but EC is
- Some elevated EC onsite with low chloride concentrations may represent elevated EC in background
- Use all the data with Cl< 100 mg/kg for background analysis

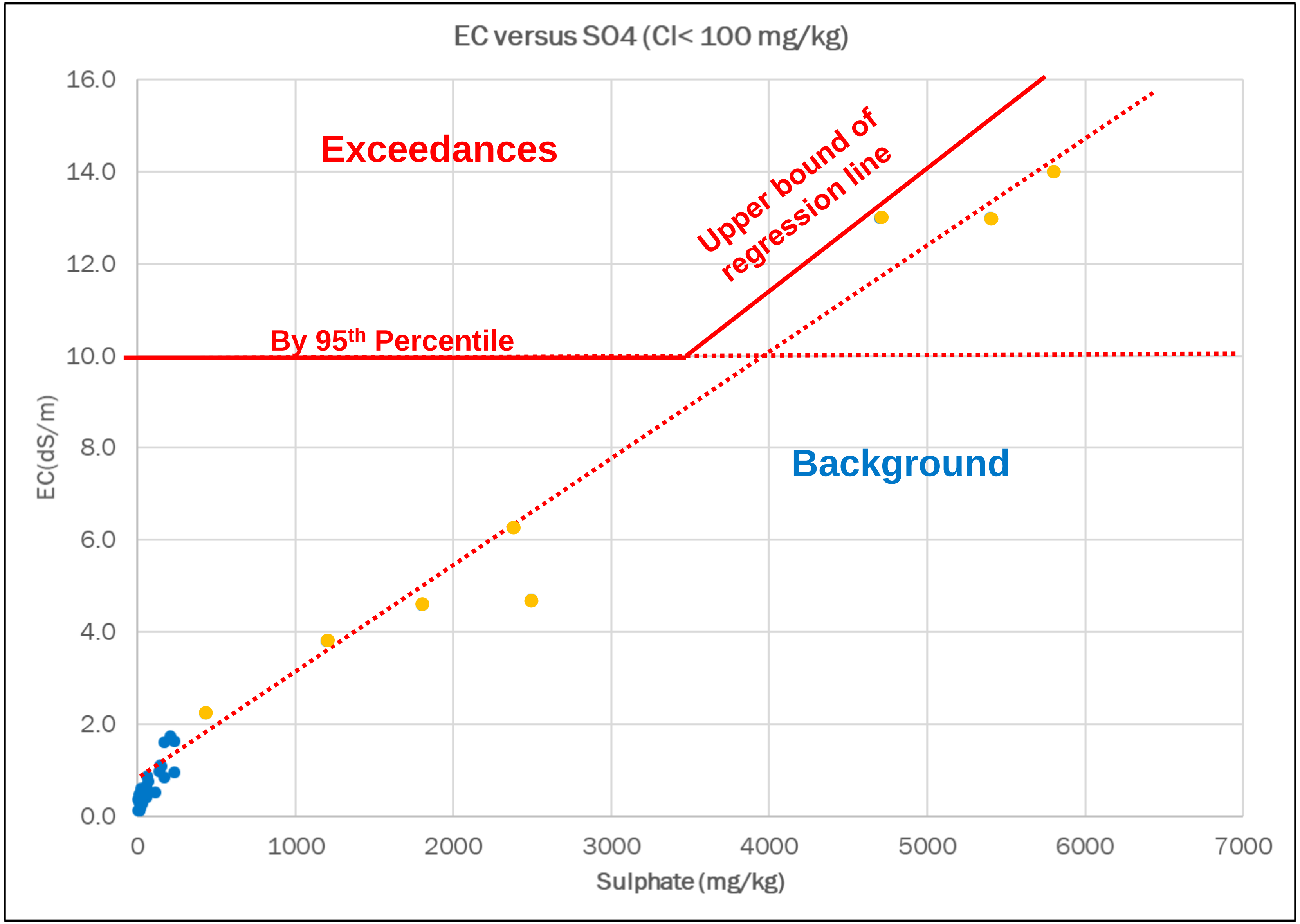
95th percentile of Background Values

Summary Statistics for Raw Full Dataset												
Variable	NumObs	Minimum	Maximum	Mean	Median	Variance	SD	MAD/0.675	Skewness	Kurtosis	CV
EC_LE_100	55	0.12	14	1.596	0.48	9.573	3.094	0.252	3.228	9.982	1.939

Percentiles for Raw Full Dataset											
Variable	NumObs	5%ile	10%ile	20%ile	25%ile(Q1)	50%ile(Q2)	75%ile(Q3)	80%ile	90%ile	95%ile	99%ile
EC_LE_100	55	0.12	0.22	0.36	0.38	0.48	0.96	1.208	4.28	8.289	13.46

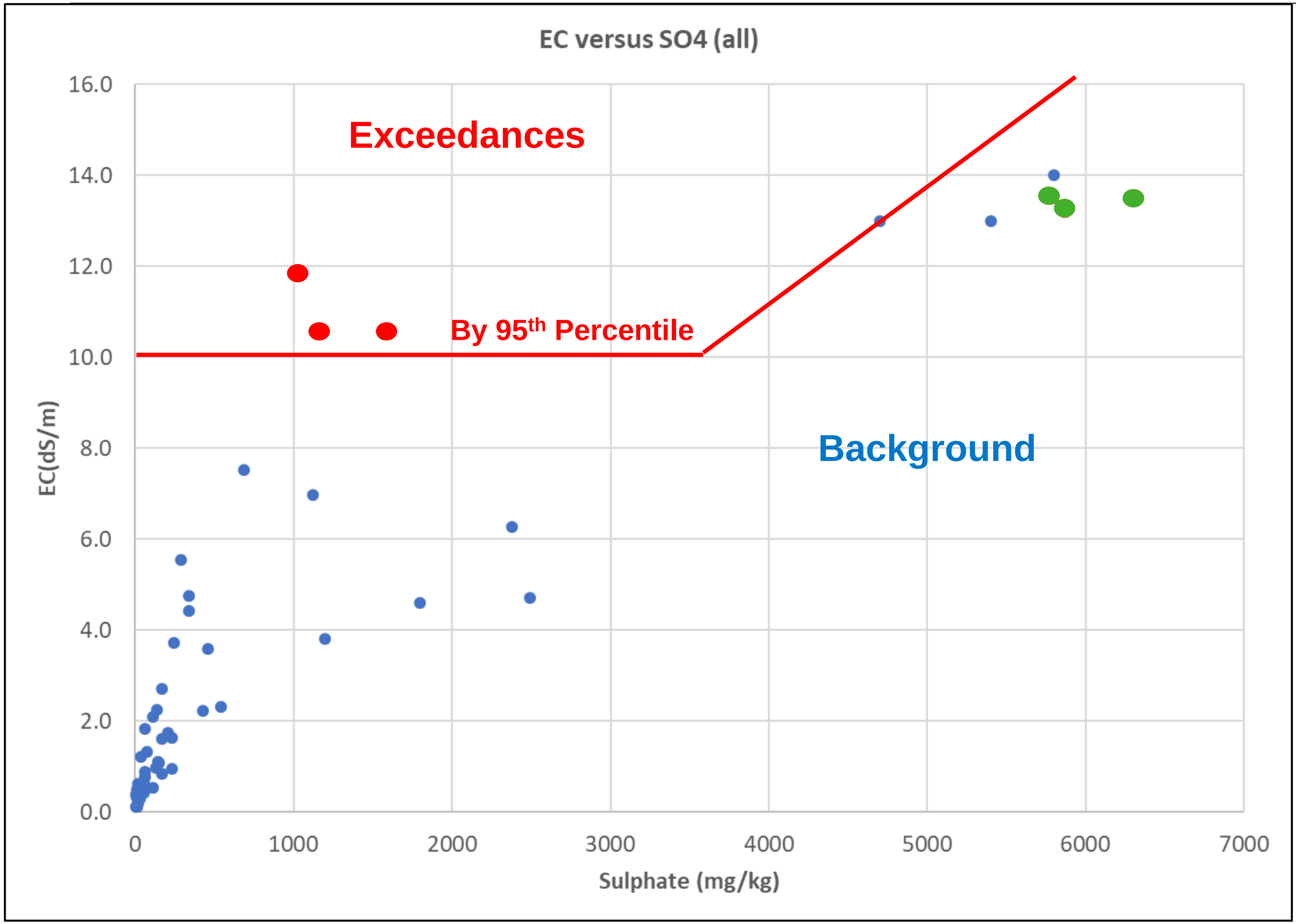
- 95th percentile = 8.29 dS/m, in “Poor” category with upper bound = 10 dS/m.
- Follow SST, after twice performing outlier removal (based on a threshold value of mean+2*std), 95th percentile = 1.5 dS/m, in “Good” category with upper bound = 3 dS/m.
- Need to check whether they are true “outliers”

EC versus Sulphate (Background Data)



- Removed "outliers" (EC>2 dS/m) are caused by elevated sulphate, which should not be removed if elevated sulphate concentrations belong to background.
- May be used to define correlation between elevated EC and the sulphate dependent background values (remediation objective) for EC values exceeding 95th percentile.
- Currently the upper bound of regression line is defined by 110% of predicted EC values.

EC versus Sulphate (All Data)

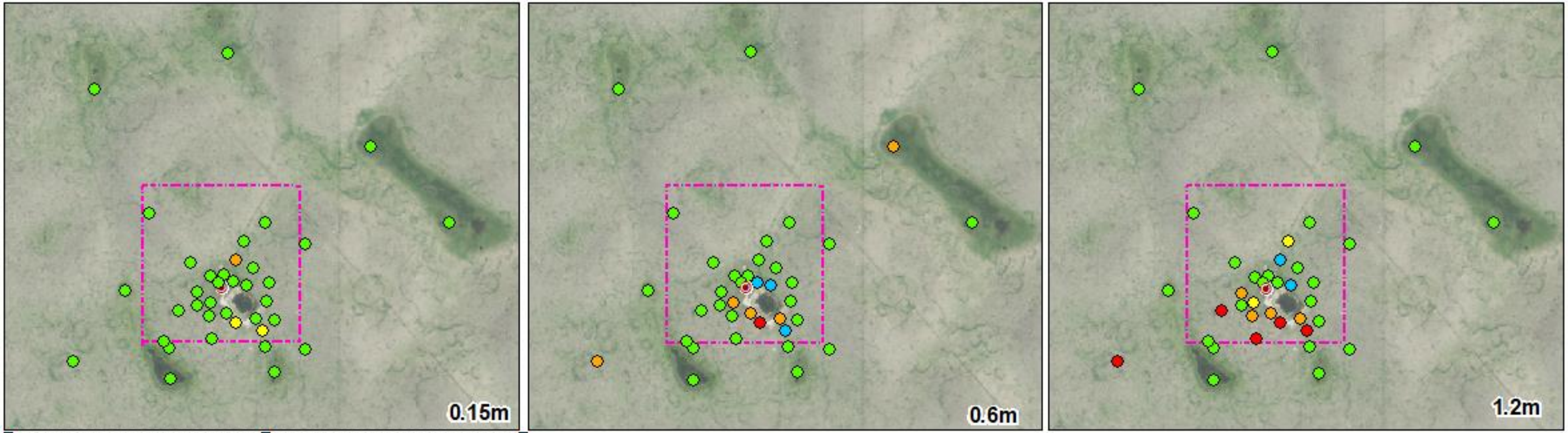


- A few data points exceed the 95th percentile value but do not exceed the modified background values (or remediation guidelines).
- These points are possibly associated with elevated background sulphate concentrations.

Exceedance

No Exceedance (although exceeds 95th percentile value)

Case Study (Soil Sulphate)



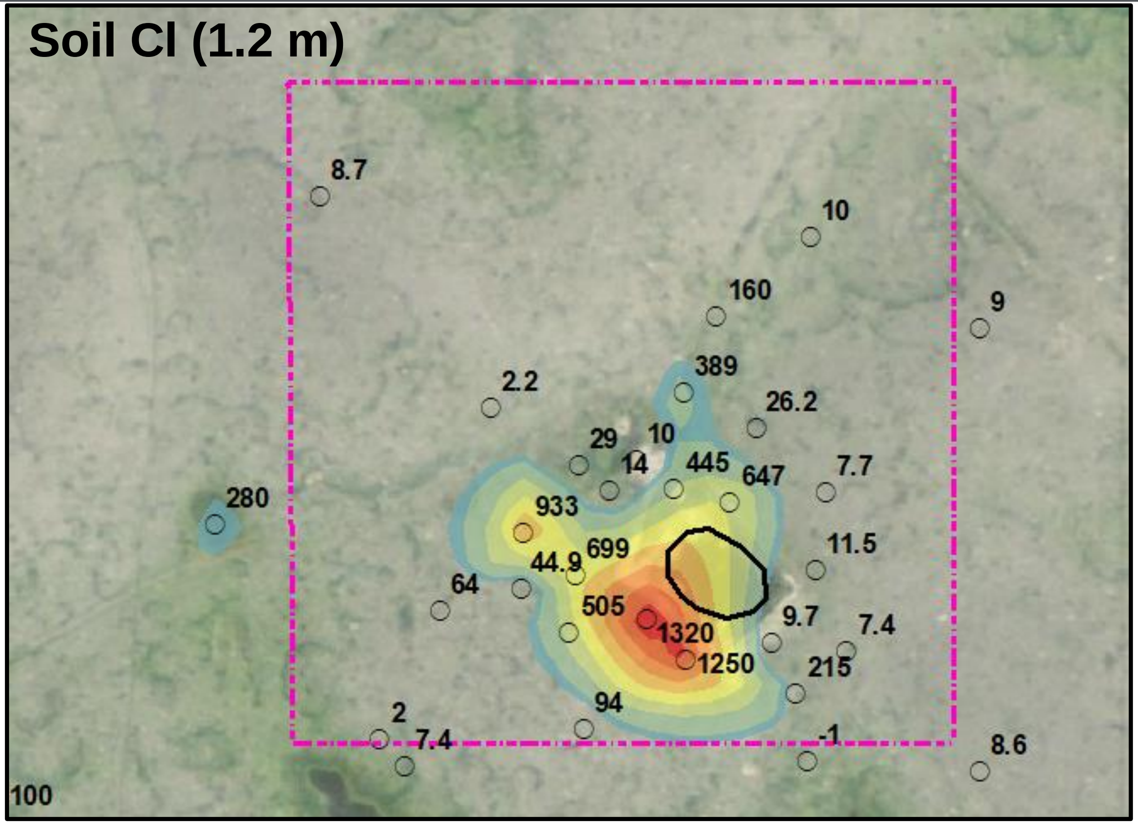
Legend

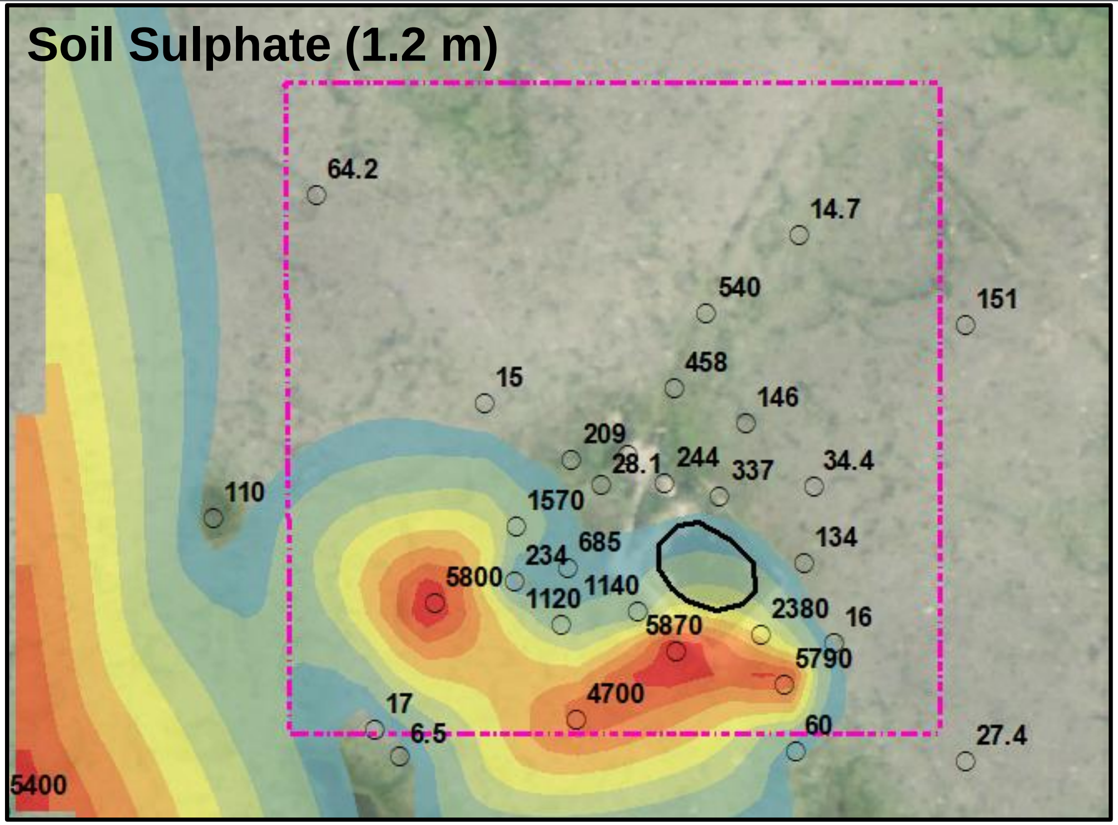
- >4000
- 1000-4000
- 500-1000
- 250-500
- <=250
- Well Centre
- Lease Boundary

Soil Sulphate (mg/kg) at Different Depths

- Distribution of sulphate concentrations are different than chloride concentrations.
- Distribution of sulphate concentrations are consistent with elevated EC distribution.

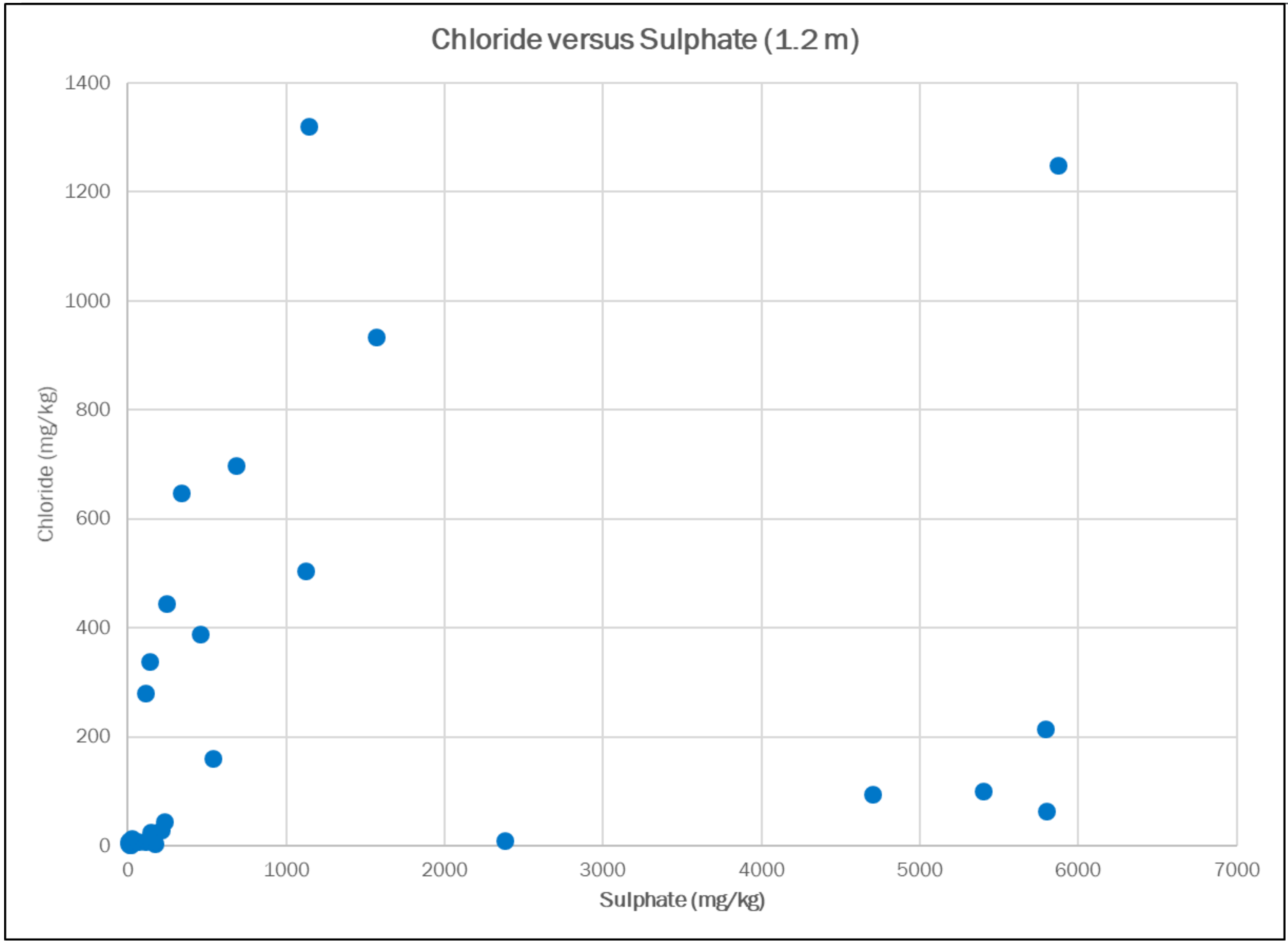
Case Study (Soil Chloride and Sulphate Distributions)





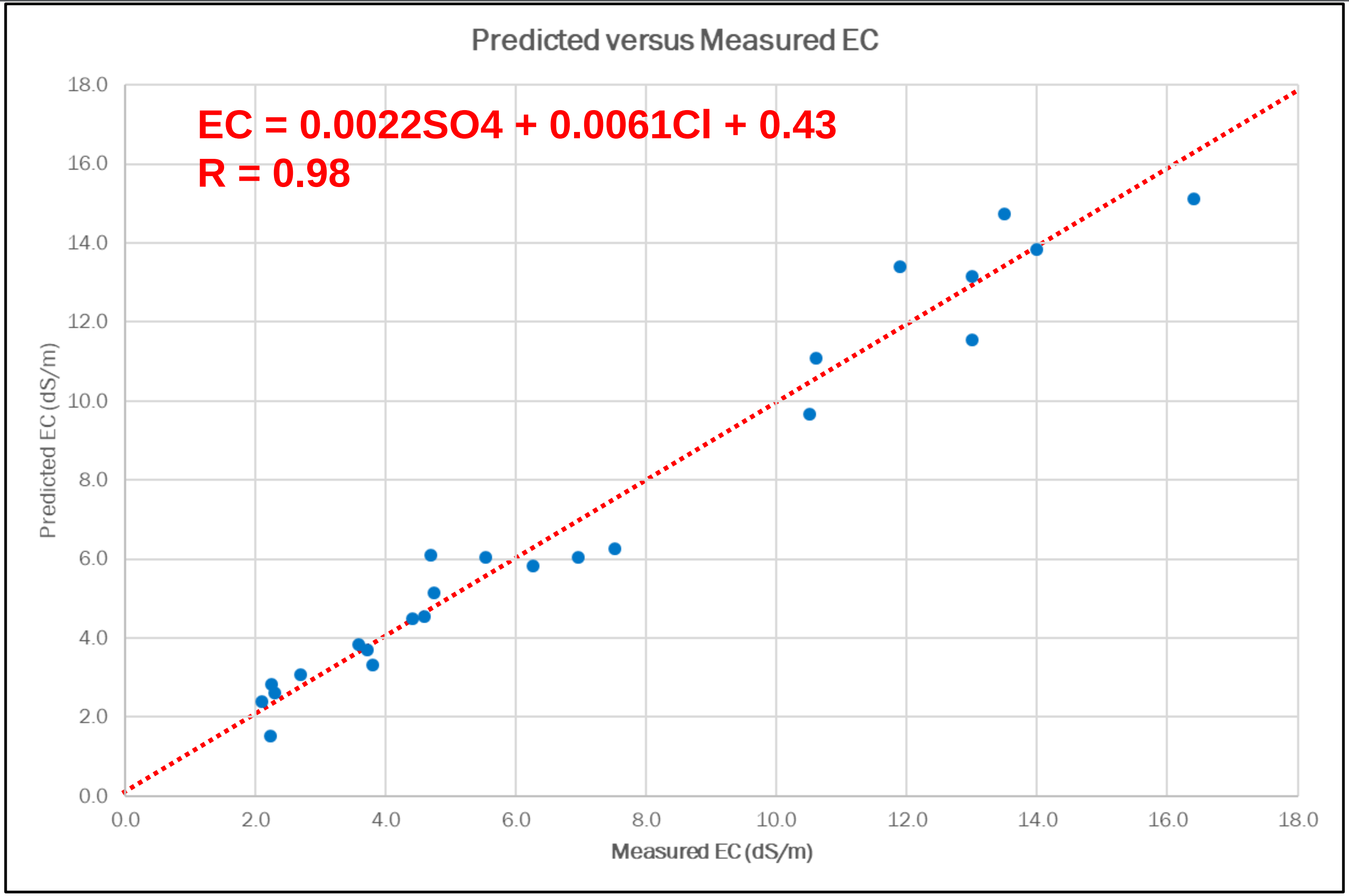
- Elevated soil chloride located near the excavated sump and elevated sulphate scattered at different locations in southwestern portion and offsite.
- Different distributions indicate different sources and elevated sulphate likely background.

Case Study (Soil Chloride versus Sulphate)



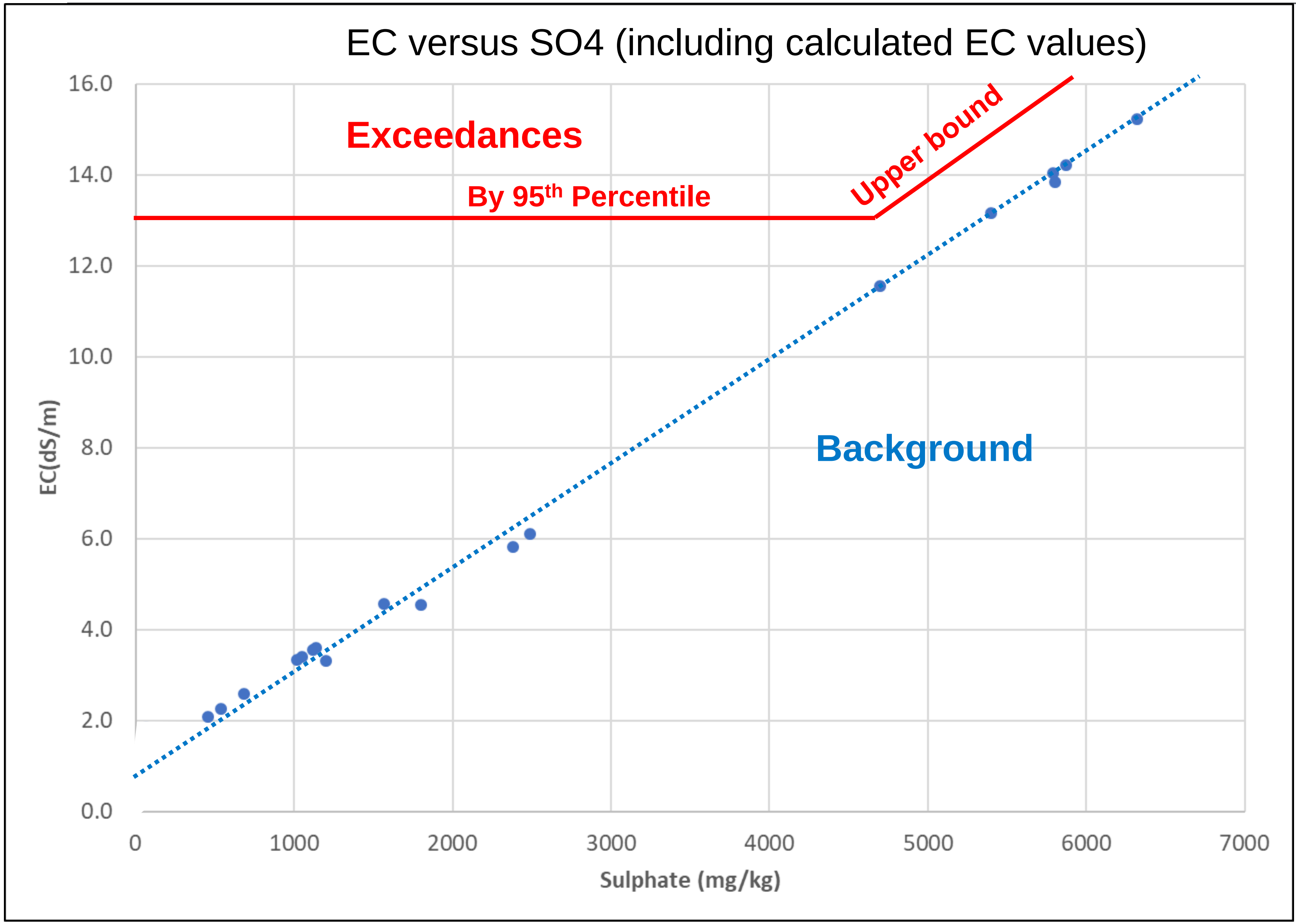
- No correlation between soil chloride and sulphate concentrations.
- However there are overlapping elevated chloride and sulphate areas.

Multi-regression for EC, SO4 and Cl (all data with EC>2 dS/m)



- Strong correlations found between EC and combined SO4 and Cl.
- Predicted EC and measured EC values show strong correlations.
- Can be used to separate the background components for the samples collected from chloride impacted areas (by assuming [Cl] = 100 mg/kg).
- Can be used to increase the background dataset.

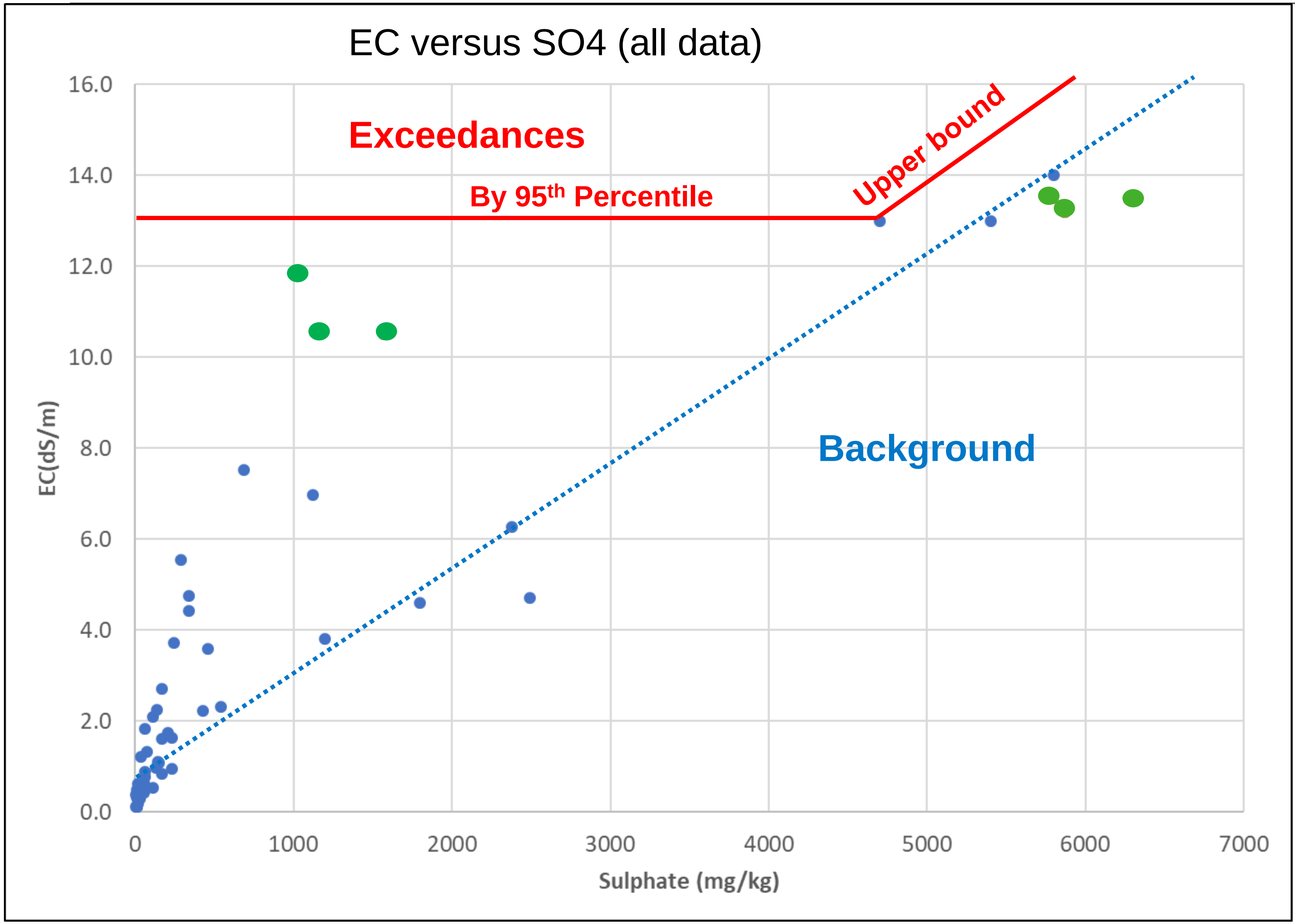
EC versus Sulphate (including calculated EC values)



- The background dataset (including calculated EC values) updates calculation of 95th percentile and the guideline lines.

- Exceedance
- No Exceedance (although exceed 95th percentile value)

EC versus Sulphate (based on increased background dataset)



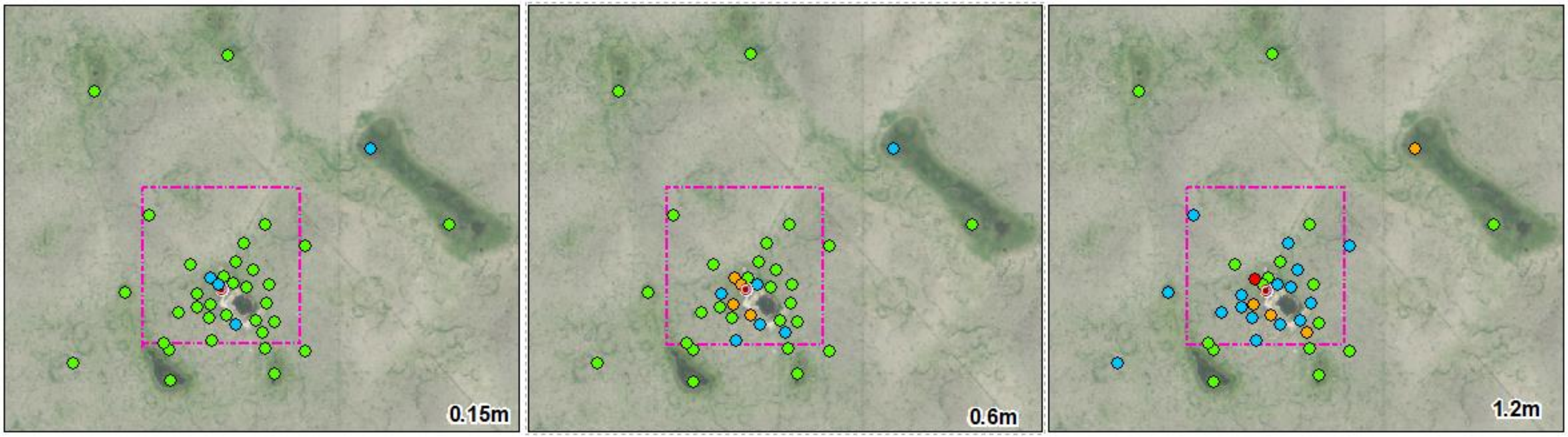
- Guidelines calculated based on the increased background dataset changes remedial decisions at the site

Exceedance
No Exceedance

Summary and Discussion

- Many factors can lead to spatial variations in background concentrations. Typically there are not sufficient data that are collected at offsite background locations to characterize the variations of chemicals of potential concern and associated geological and geomorphological conditions.
- One of the solutions is to maximize value of the unimpacted data points onsite, as well as extract the background information from the dataset reflecting both background and site impact features.
- At salinity impacted sites, correlations between parameters of concern (such as EC) and chemicals representing the background (sulphate) and site impact (chloride) may provide useful information to separate the background and site impact.
- Further research is required to regulate the data analysis process as well as tackle more complex correlations between chemical parameters (such as SAR with other chemicals).

Case Study (Soil SAR – Sodium Adsorption Ratio)



Legend

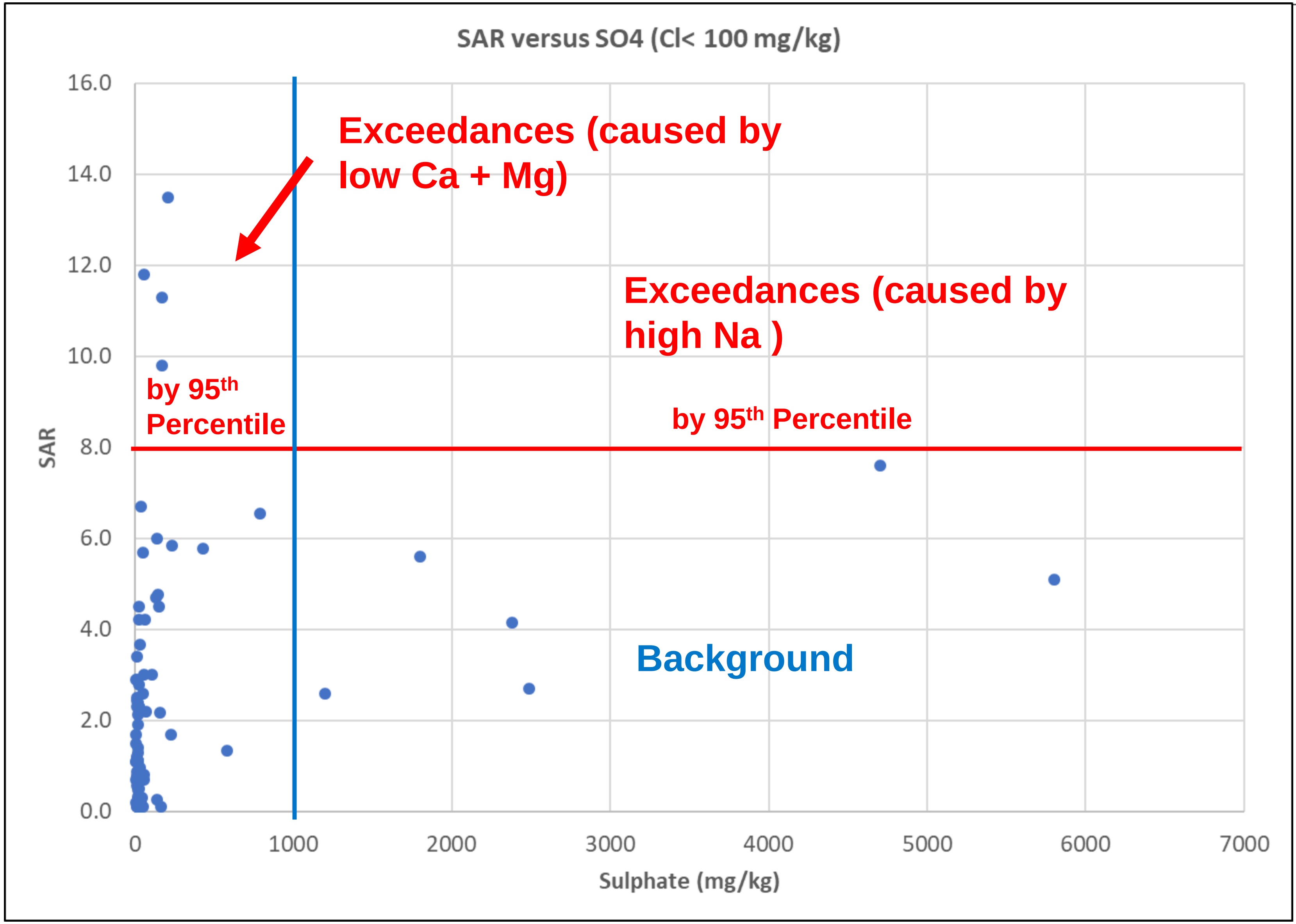
Unsuitable — Fair — Well Centre

Poor — Good — Lease Boundary

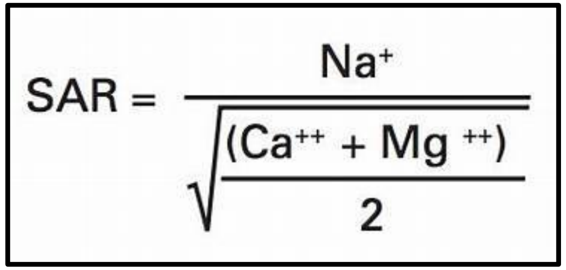
Soil SAR at Different Depths

- Clearly show elevated SAR extended offsite.

SAR versus Sulphate (Background Data)



- Direct correlations between SAR and sulphate are typically not strong.
- Multi-regression analysis may need to include Na, Ca+Mg, and SO4.



$$SAR = \frac{Na^+}{\sqrt{\frac{(Ca^{++} + Mg^{++})}{2}}}$$

Questions?

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