Equilibrium Environmental Inc.

Using Laboratory Saturation Percentages to Estimate Soil Texture 13-AU-SGRC-09

FINAL

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1 INTRODUCTION

This document provides a study of trends in soil saturation percentages and texture data in a sample population of Alberta subsoils, for the purpose of determining saturation percentage threshold through which an approximate assessment of soil texture could be made in lieu of texture by hydrometer data. This project was completed for Petroleum Technology Alliance Canada (PTAC) and championed by Michelle Young of Imperial Oil. This study has potential benefit to Oil and Gas producers, regulators, and consultants by providing a means to enhance datasets on soil texture and particle size information, derived from routine soil salinity data (via saturation percentage). Analytical costs can be decreased since may be possible to reduce the number of soil texture analyses without compromising quality or regulatory requirements.

Laboratory saturation percentage can be examined in relation to clay content. Saturation percentage is the mass ratio of water to soil in a saturated paste, multiplied by 100 (US Department of Agriculture (USDA), 1954). As reported by Stiven and Khan (1966), saturation percentages are generally based on clay content of soils. In general, soils with low clay content have a lower saturation percentage and soils with a higher saturation percentage have higher clay content, excluding organic soils. Relatively large amounts of organic constituents require larger amounts of water to create a saturated paste. Available literature data (albeit limited) suggests that saturation percentages are greater for finer-grained soil (Stiven and Khan, 1966; USDA, 1954). The USDA (1954) dataset is shown in Table 1. Values for coarse-textured soils (16-43.1%) had an overlap with those derived for fine soils (41.8-78.5%), while sandy and silty loam soils in the medium textural category overlapped both categories (26.4-60%).

Table 1. Literature-derived saturation percentages by texture

Texture category*	Saturation percentage (%)	Applicable texture classes*
Fine	41.8 - 78.5	silty clay loam, clay loam, silty clay, clay
Medium	26.4 - 60	sandy loam, silt loam, sandy clay loam
Coarse	16 - 43.1	sand, loamy sand

**Texture classes assigned by applying derived saturation percentage ranges to literature-based texture classes (Campbell, 1985).*
(Source: derived from USDA, 1954, Campbell, 1985)

One key objective of this project is to assist in lithology determination (*i.e.*, coarse versus fine) for the Alberta Environment and Sustainable Resource Development (ESRD) Subsoil Salinity Tool (hereafter referred to as 'SST') and Tier 2A/2B chloride guidelines. SST groupings of soil texture are based on clay content thresholds where values of 18% and 60% define whether soils are coarse, fine, or heavy clays. Of interest, an 18% clay content was defined historically as the boundary between fine (medium clay) and coarse soils by the USDA (1954). Previous literature datasets appear relatively limited. Furthermore, there would be value in analyzing a dataset specific to Alberta soils. The focus of this project was on non-organic (*i.e.*, not peat or topsoil) subsoils (> 1.5 m below ground surface), which were not impacted by produced water (*i.e.*, the focus was on background soils – a chloride criteria of 105 mg/kg was used to identify unimpacted soils – this criteria is in close proximity to the ESRD SST closure criteria).

2 METHODOLOGY

2.1 DATA COMPILATION AND FILTERING

Data from sites across Alberta were compiled – this information was provided to Equilibrium by more than 20 different oil and gas organizations. A catalogue of data entries was constructed that included salinity and texture data from more than 114 sites, which were sorted into the four natural regions of Alberta (Parkland Natural Region, Grassland Natural Region, Foothills Natural Region and Boreal Forest Natural Region; see Figure 1). Figure 2 presents graphical counts of sites located within each region. Approximately half (51%) of the sites were in Central Alberta (Central Parkland), while 26% were located in the Grassland Natural Region in southern to central Alberta. Approximately 20% of the sites were located in the northern Boreal Forest Natural Region. The remainder (3%) were located in the Foothills Natural Region extending northeast into central Alberta from the Rocky Mountain region.

Figure 1. Alberta Natural Regions and Subregions

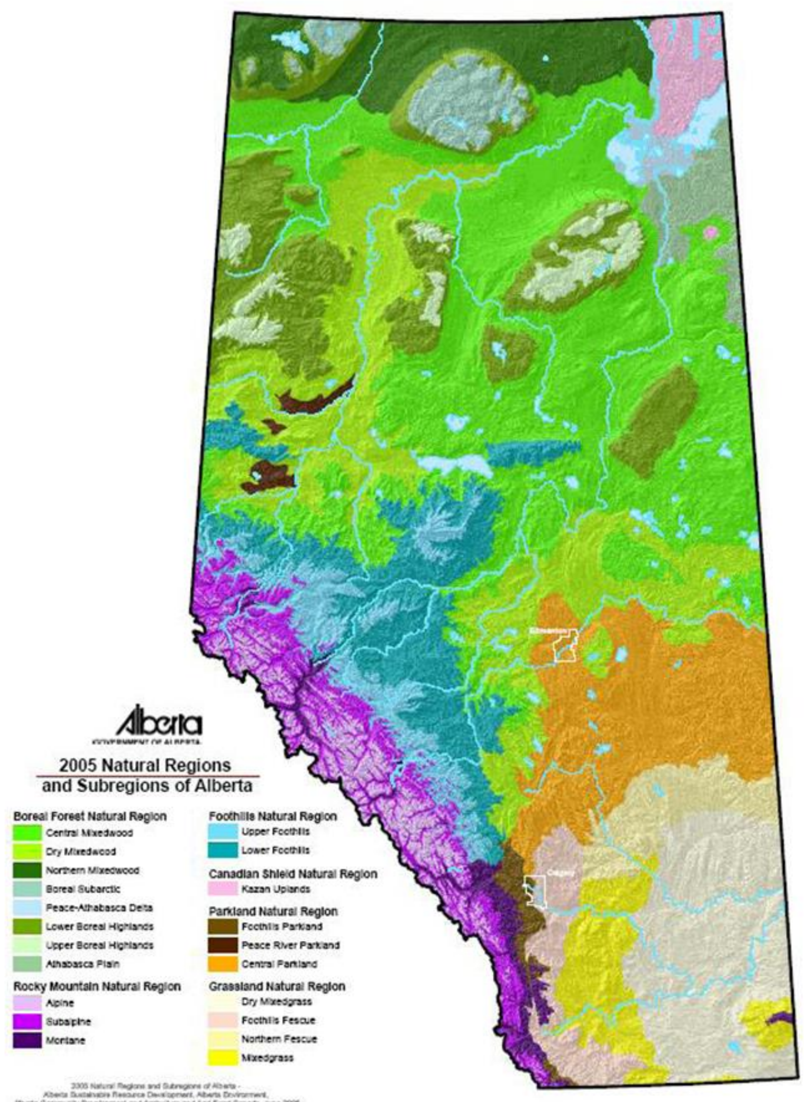
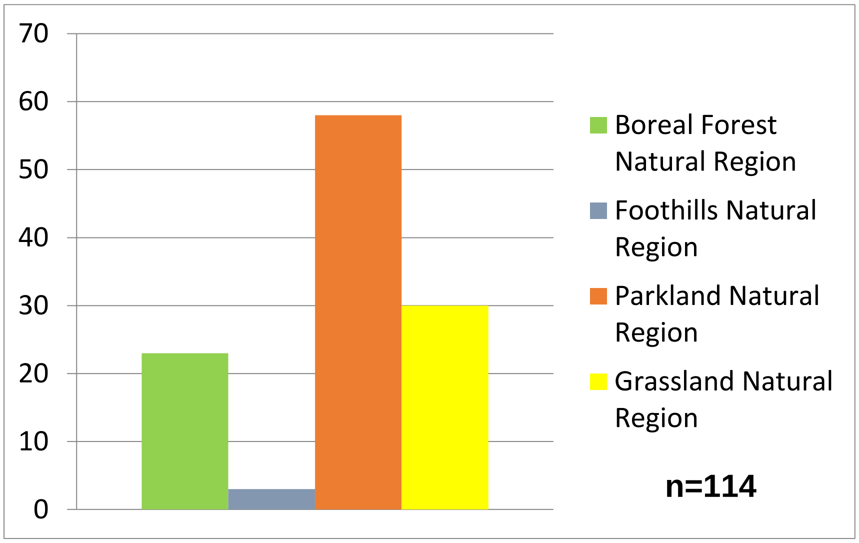


Figure 2. Distribution of Sample Sites by Alberta Natural Region



2.2 Parameter Distribution

A total of 1,656 subsoil data points were identified that had texture information by hydrometer, which were plotted on the Canadian Soil Texture Triangle in Figure 3. The data appeared to be fairly evenly distributed across the triangle, with the exception of silt soils. The textural data was determined to be methodologically consistent as it was primarily derived from three major Alberta labs (AGAT, Maxxam, and Exova) whom reported that standard lab analysis methods for texture by hydrometer and saturation percentage salinity parameters have been in place for as long as they have been operating in Alberta.

The textural dataset was truncated based on the absence of salinity data for the same soil samples. The truncated dataset contained 1,325 data points for EC and SAR with matching texture information. Statistics were calculated for EC and SAR after data were removed for chloride concentrations greater than 105 mg/kg. The 95^{th} percentile for EC was 12.9 dS/m, placing the bulk of the data set in the Tier 1 Good to Poor Soil Quality Categories (*i.e.*, 0 to 3, 3 to 5, and 5 to 10 dS/m) and some data in the Unsuitable category (see Figure 4). The 95^{th} percentile for SAR was 24, as shown in Figure 5.

The frequency of soils with different clay, sand, or silt contents (Figures 6 to 8, respectively) suggests the most common soil type was a loam. This may be reflected in the saturation percentage frequency histogram shown in Figure 9.

Figure 3. Texture Dataset on Canadian Texture Triangle

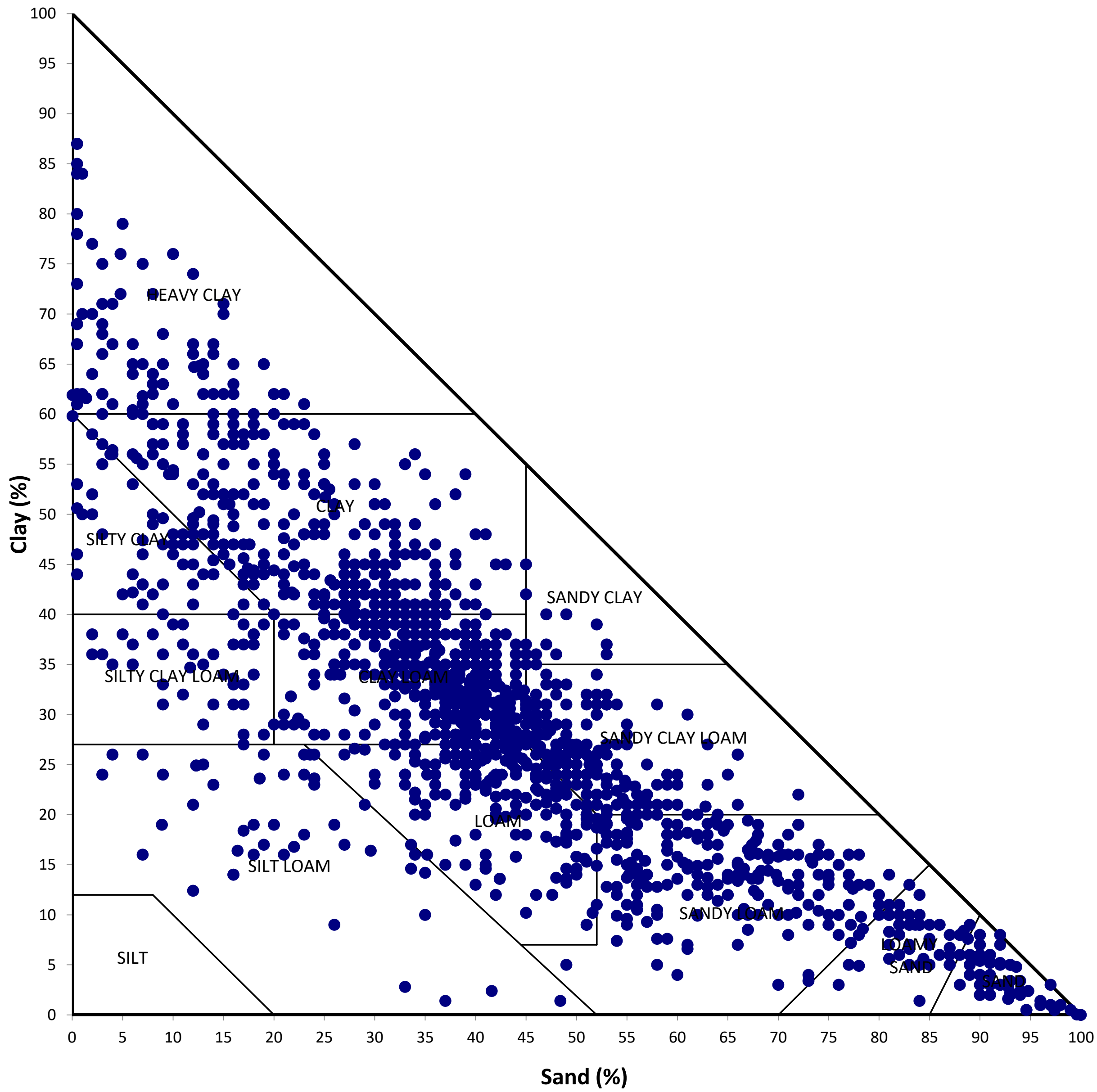


Figure 4. Electrical Conductivity (EC) Histogram

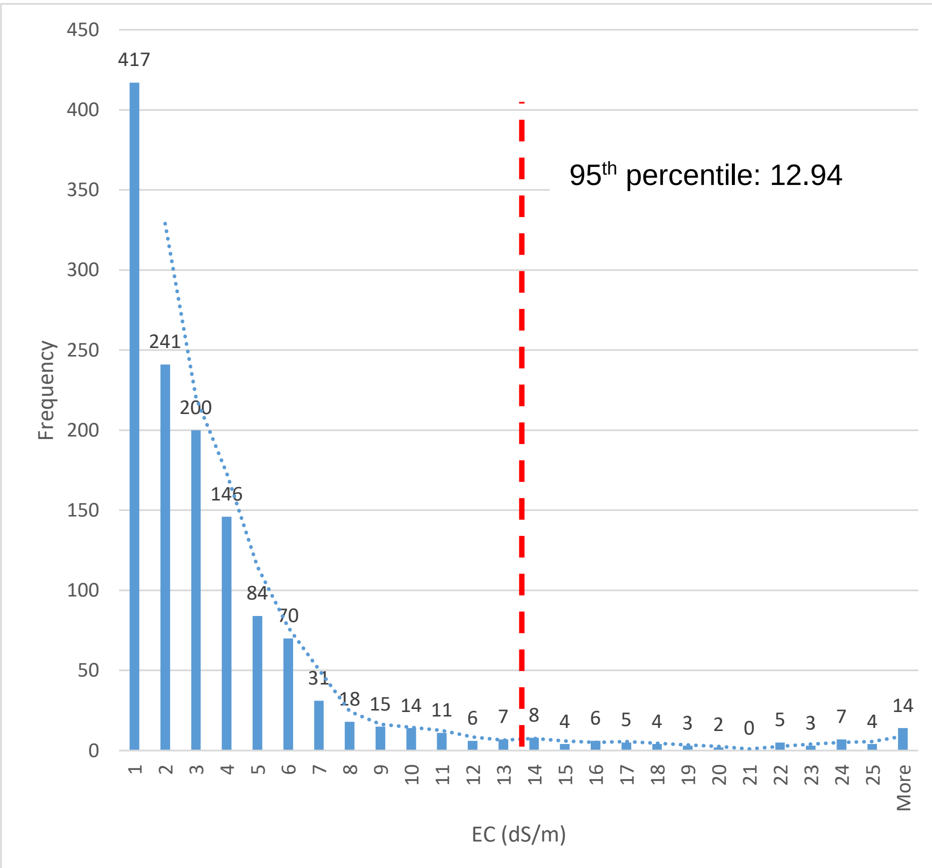


Figure 5. Sodium Adsorption Ratio (SAR) Histogram

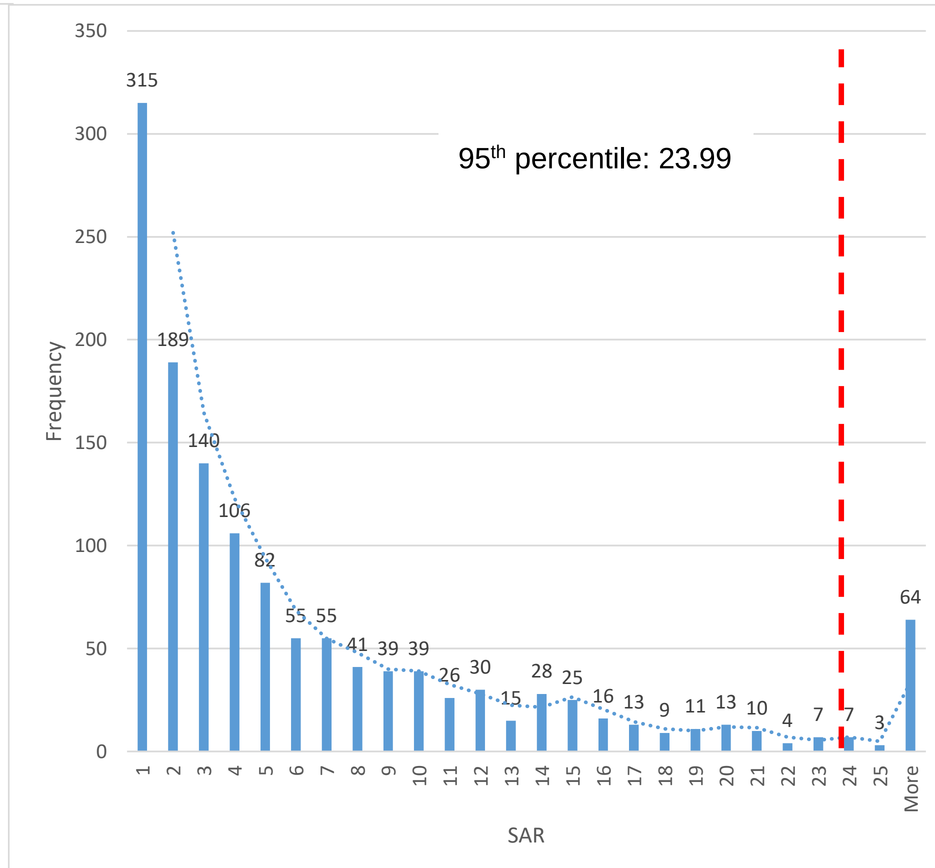


Figure 6. Clay Content (%) Histogram

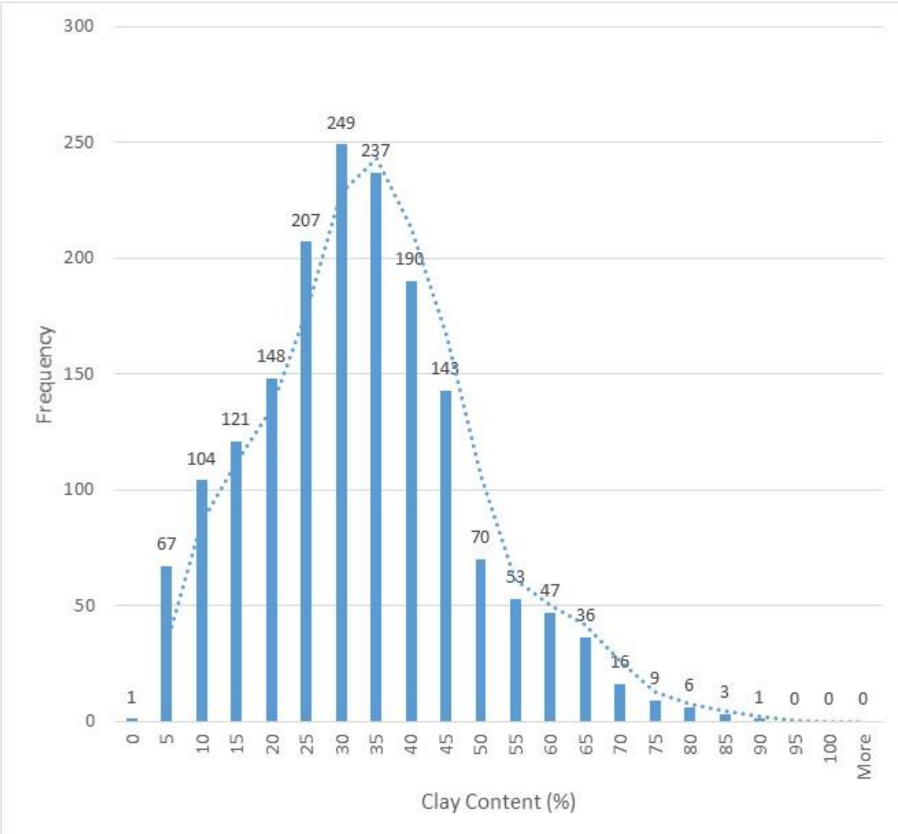


Figure 7. Sand Content (%) Histogram

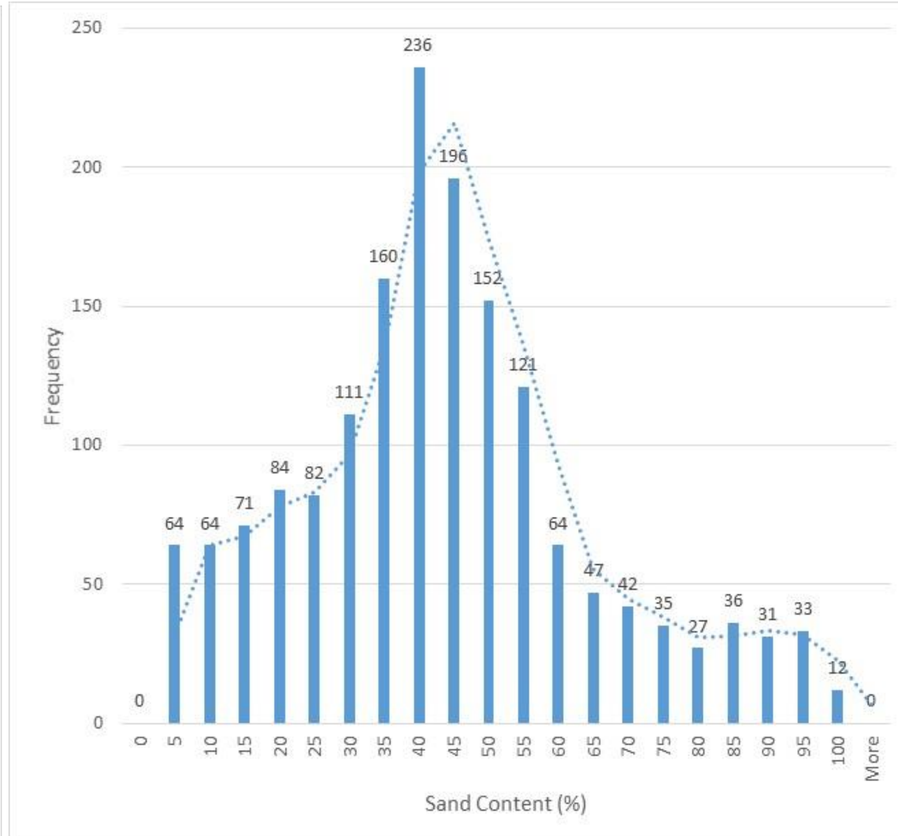


Figure 8. Silt Content (%) Histogram

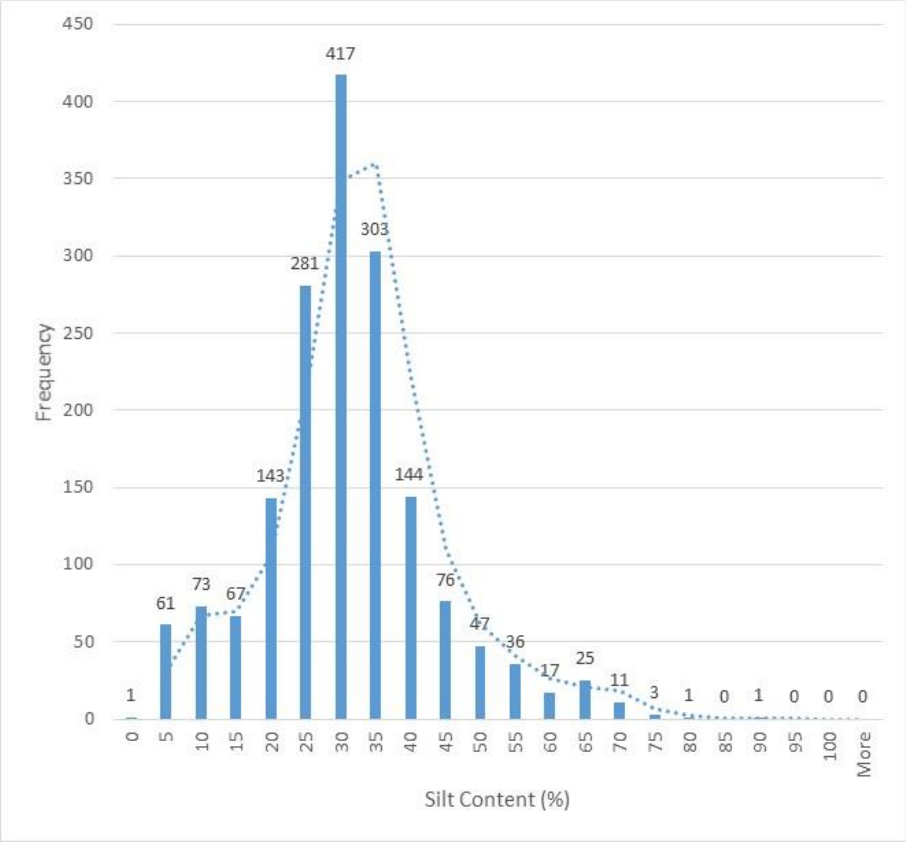
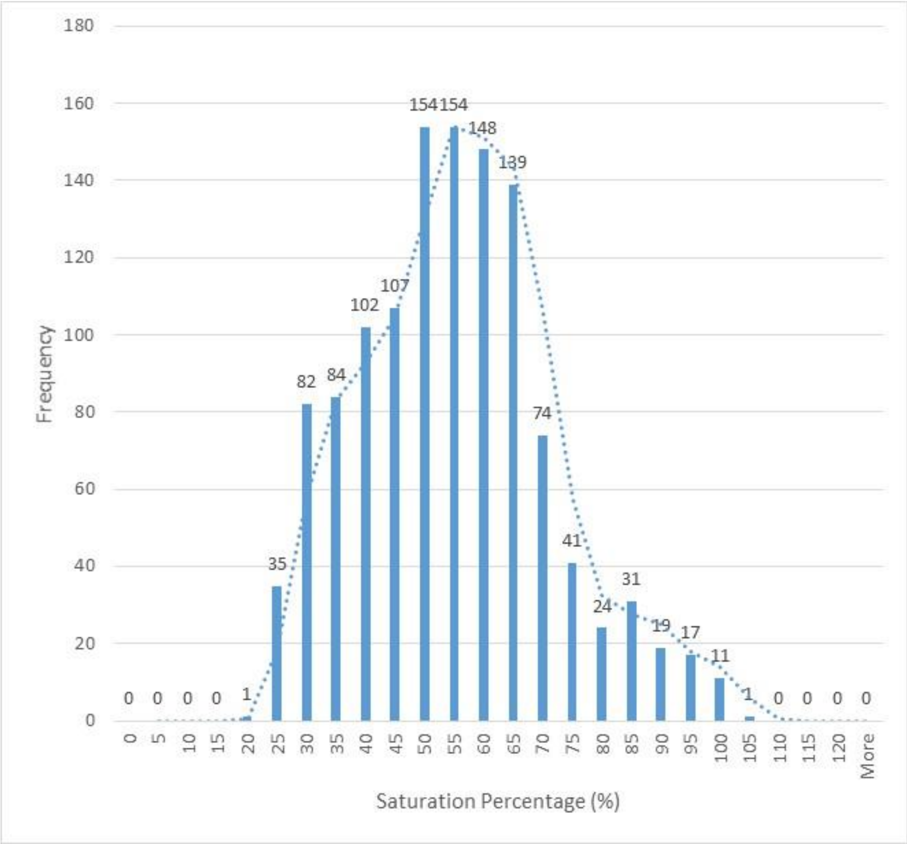


Figure 9. Saturation Percentage (%) Histogram



As mentioned, the first iteration of filtering was to remove data points with saturation percentages over 100% that may represent heavy clays, muskeg, or organic subsoils. Samples with saturation percentages greater than 100% were discarded. Regression analysis of saturation percentage versus clay content for the data points with saturation percentages < 100% determined an r^2 value 0.5505 (n= 1336 data points; Figure 10). Saturation percentage values can also be increased in soils with high SAR and low EC, particularly in higher clay content soils (Equilibrium, 2013).

The database contained a number of samples with chloride concentrations greater than 105 mg/kg, considered indicated of produced water impacts (this threshold is slightly greater than the ESRD SST closure criteria threshold). These data points were filtered out in the second iteration, bringing the r^2 value to 0.5777, using 1,085 data points (Figure 11).

Although the dataset was previously truncated via elimination of data points without salinity data (identified by EC and AR values), some data points had values for most salinity parameters with the exception of chloride. As a result, the third iteration removed data points where chloride concentrations were unknown, resulting in a regression of 0.5913 based on 944 data points (Figure 12).

A statistical summary showing dataset populations following different filtration steps, including dataset size (n), correlation coefficient for linear regression (R^2), and statistical significance (p) following ANOVA analysis of the regression, is provided in Table 2.

Table 2. Statistical Summary of Data After Different Filtration Steps

	n	**R^2**	**p (significance)**
Filtration Step 1	1336	0.5505	0.0001
Filtration Step 2	1085	0.5777	0.0001
Filtration Step 3	944	0.5913	0.0001

n – number of data points

Figure 10. Saturation Percent versus Clay Content (Filtration Step 1)

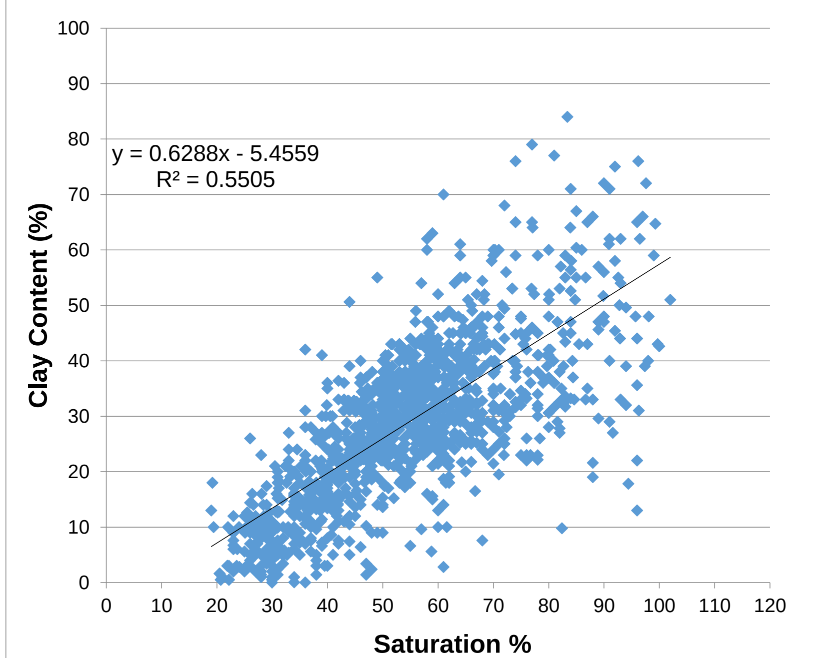


Figure 11. Saturation Percent versus Clay Content (Filtration Step 2)

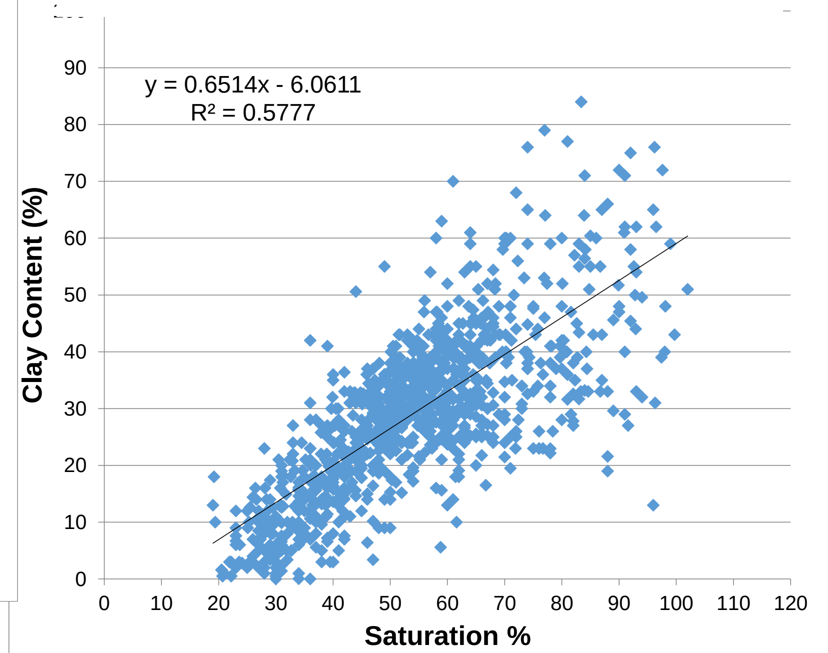
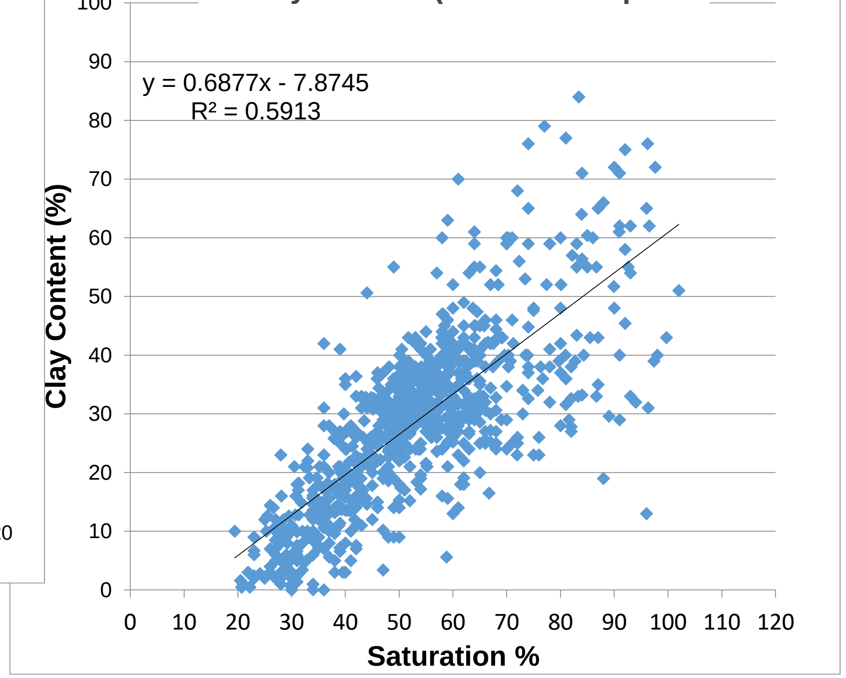


Figure 12. Saturation Percent v. Clay Content (Filtration Step 3



2.3 THRESHOLD ANALYSIS

The dataset was analyzed to determine saturation percent thresholds that could assist to determine whether a particular background subsoil sample is coarse or fine, at a given level of confidence. Coarse limits were assessed iteratively testing different saturation percentage thresholds and evaluating the number of data points that would incorrectly identify the actual soil texture as determined by hydrometer analysis. In other words, the proportion of the data base was quantified, where clay contents were less than 18% as indicated by a given saturation percentage threshold. If 5% or less of the database was incorrectly identified in terms of texture, the threshold was considered practical and applicable for contaminated site work. Fine grain limits were determined in a similar fashion, using clay contents >18% with saturation percentage values subjected to fine-grained lower threshold testing.

Results are shown in Table 3, and incorrectly identified soil textures are shaded in yellow based on 95% of the textures being correctly identified. A coarse soil saturation percentage threshold of ≤32% was identified, below which there is a 95% probability (as defined by the existing database) that the soil would be measured as coarse based on hydrometer analysis. A fine soil saturation percentage threshold of ≥42% was identified, above which there is a 95% probability (as defined by the existing database) that the soil would be measured as fine based on hydrometer analysis. Figure 13 shows the full distribution of saturation percentage and clay content data in relation to the final thresholds determined.

The available sample population with clay content <18% used to determine the coarse soil threshold (n=92) was relatively smaller than the dataset size used to determine the fine soil threshold (n=628), suggesting that the fine grained threshold may be a more confident indicator of fine grained texture. This is also suggested when comparing the 99th percentile thresholds generated from the same dataset.

Similar results could be produced by developing regressions between sand content and saturation percentage. However, the role of silt content is less clear. The relationship between saturation percentage and silt percentage did not demonstrate a significant correlation as shown in Figure 14. While it appears possible that the minimum saturation percentage for a given grouping of silt% is increasing, this may be the result of smaller dataset sizes at higher silt contents. While samples with saturation percentages between 32-43% fall into a grey area between the two defined thresholds (Figure 13), it was noted that soil samples in this range tended to be soils with higher silt contents and in some cases sand content. Soils within this threshold range should be analyzed for texture by hydrometer as the possibility exists that they may be defined as coarse soils by hydrometer.

Table 3. Summary of 95% threshold tests for coarse and fine-grained soil data

Coarse-grained Limits (<18% clay)			
Sat % threshold	# sat % over threshold	# Clay ≤18%	Percent passing
<40%	203	162	79.80
<35%	142	128	90.14
<34%	111	101	90.99
<33%	91	83	91.1
<32.5%	96	91	94.79
<32%	**92**	**88**	**95.65**
<30%	**70**	**69**	**98.5**
<27%	**38**	**38**	**100**
Fine-grained Limits (≥18% clay)			
Sat % threshold	# sat % over threshold	# Clay ≥18%	Percent passing
>59.5%	264	262	99.24
>59%	291	288	98.97
>55%	362	357	98.62
>52.5%	415	409	98.55
>52%	434	427	98.39
>51%	454	447	98.46
>50%	489	478	97.75
>45%	595	572	96.13
>43%	**628**	**600**	**95.54**
>42%	645	610	94.57

*Note: Threshold tests completed with accuracies of **approximately** 95% or greater highlighted in yellow.*

Figure 13. Coarse and fine-grained saturation percentage thresholds

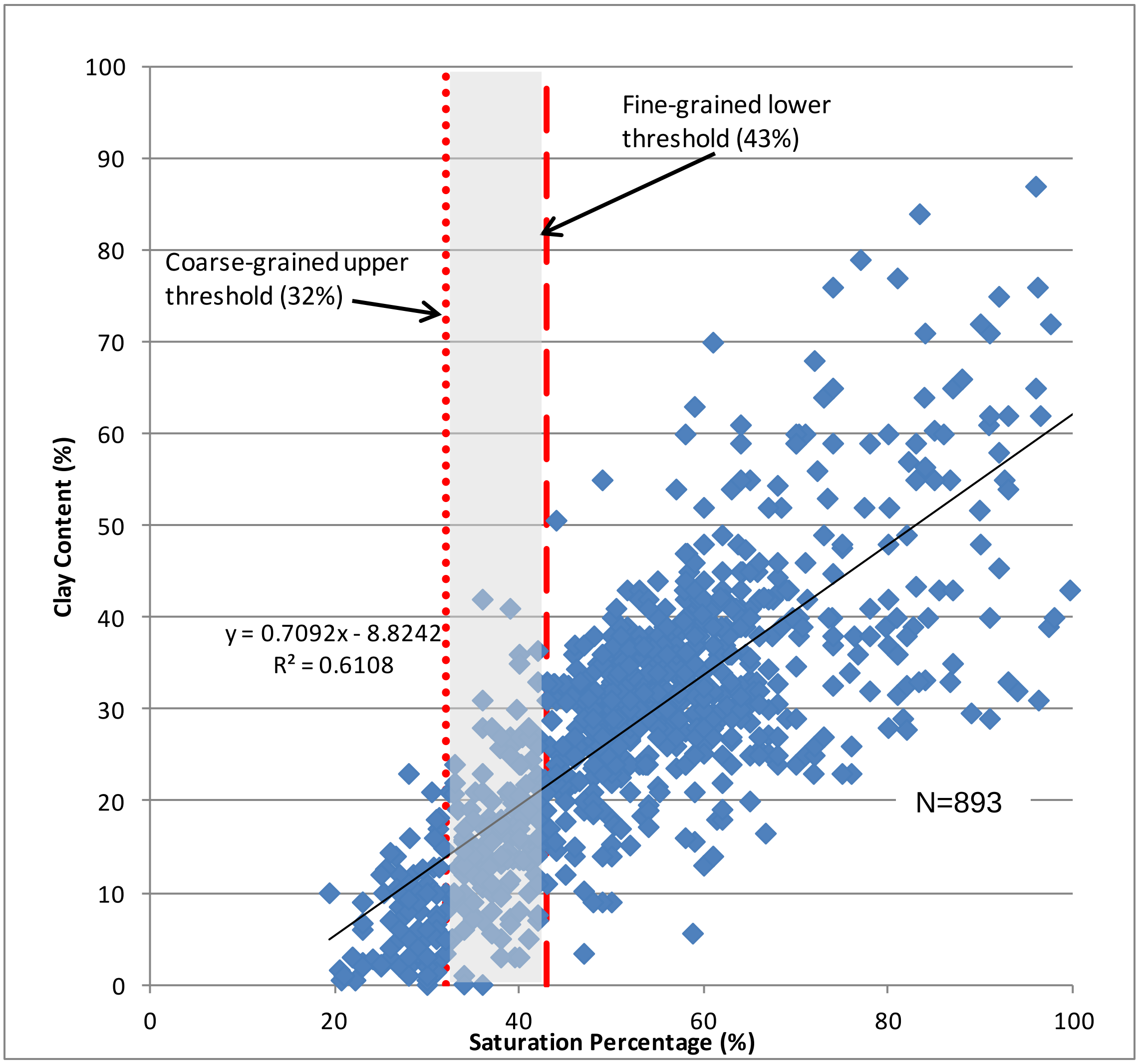


Figure 14. Saturation Percentage and Silt Content

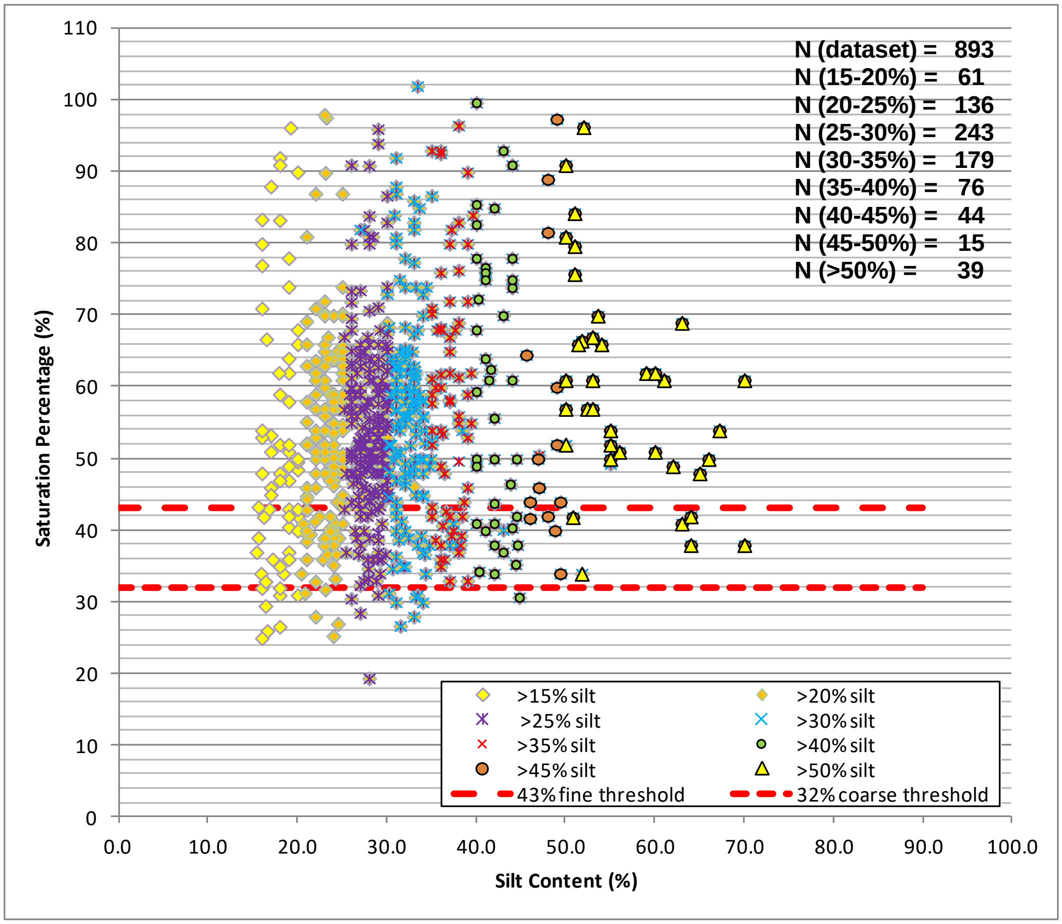


Table 4a. Texture by hydrometer data for saturation percentage (32-43%) population

Sand (%)	Silt (%)	Clay (%)	Saturation (%)
99.6	0.4	**0.1**	34.0
97.0	2.0	**1.0**	34.0
92.0	5.0	**3.0**	39.5
76.0	21.0	**3.0**	40.0
70.0	27.0	**3.0**	38.0
93.0	3.6	**3.4**	32.0
60.0	36.0	**4.0**	38.0
78.0	18.0	**4.9**	32.0
92.0	3.0	**5.0**	41.0
85.0	10.0	**5.0**	32.7
85.0	10.0	**5.0**	32.7
58.0	37.0	**5.0**	38.0
69.0	25.4	**5.6**	37.0
82.0	12.0	**6.0**	34.0
61.0	32.4	**6.6**	39.0
83.0	10.0	**7.0**	36.0
66.0	27.0	**7.0**	42.0
77.2	15.6	**7.2**	39.0
77.2	15.6	**7.2**	39.0
61.0	31.8	**7.2**	35.0
88.8	3.6	**7.6**	35.0
54.0	38.4	**7.6**	42.0
78.0	14.0	**8.0**	40.0
76.0	16.0	**8.0**	32.0
54.0	38.0	**8.0**	37.0
88.4	3.2	**8.4**	34.0
73.0	18.0	**9.0**	35.0
55.0	36.0	**9.0**	35.0
62.0	28.8	**9.2**	33.0
63.0	27.4	**9.6**	33.0
57.0	33.4	**9.6**	38.0
54.0	37.0	**9.9**	33.0
84.0	6.0	**10.0**	41.0
82.0	7.0	**10.0**	34.0
80.0	10.0	**10.0**	32.0
71.0	19.0	**10.0**	37.0
68.0	22.0	**10.0**	32.9
51.6	38.2	**10.2**	38.0
66.6	22.8	**10.6**	36.0
80.0	9.0	**11.0**	38.8
69.0	20.0	**11.0**	43.0
55.0	34.0	**11.0**	37.0
52.0	37.0	**11.0**	42.0
64.0	24.6	**11.4**	39.0
60.0	28.4	**11.6**	36.0
56.0	32.0	**12.0**	35.0
46.0	42.0	**12.0**	34.0
42.0	46.0	**12.0**	41.7
63.0	24.2	**12.8**	33.3
58.0	29.2	**12.8**	34.0
53.0	34.2	**12.8**	36.7
83.0	4.0	**13.0**	34.0
56.0	31.0	**13.0**	36.4
56.0	31.0	**13.0**	42.0
49.0	37.8	**13.2**	38.0
66.0	20.6	**13.4**	41.0
68.0	18.4	**13.6**	34.0
67.4	19.0	**13.6**	40.5
60.0	26.4	**13.6**	40.0
49.0	37.4	**13.6**	41.0

Sand (%)	Silt (%)	Clay (%)	Saturation (%)
42.4	44.0	**13.6**	40.4
42.4	44.0	**13.6**	40.4
63.0	23.3	**13.7**	36.7
55.0	31.3	**13.7**	38.7
48.0	38.3	**13.7**	39.3
77.0	9.0	**14.0**	35.0
72.0	14.0	**14.0**	38.0
69.8	16.2	**14.0**	41.9
62.0	24.0	**14.0**	38.0
16.0	70.0	**14.0**	38.0
35.0	50.8	**14.2**	41.9
68.3	17.2	**14.4**	36.0
56.0	29.4	**14.6**	36.0
50.0	35.4	**14.6**	38.7
49.0	36.4	**14.6**	36.0
41.0	44.4	**14.6**	35.3
41.0	44.4	**14.6**	35.3
33.6	51.8	**14.6**	34.0
76.0	8.0	**15.0**	34.4
66.0	19.0	**15.0**	42.0
60.6	24.2	**15.2**	41.0
56.8	27.8	**15.4**	42.0
54.0	30.6	**15.5**	34.7
69.0	15.4	**15.6**	37.0
64.0	20.4	**15.6**	34.0
70.0	14.3	**15.8**	40.0
60.0	24.3	**15.8**	36.7
50.0	34.3	**15.8**	34.0
50.0	34.3	**15.8**	34.0
44.0	40.3	**15.8**	34.3
44.0	40.3	**15.8**	34.3
74.0	10.0	**16.0**	39.0
35.2	48.8	**16.0**	40.0
21.0	64.0	**16.0**	42.0
68.0	15.9	**16.1**	34.0
59.0	24.0	**17.0**	40.0
33.6	49.4	**17.0**	34.0
19.0	64.0	**17.0**	38.0
55.0	27.8	**17.2**	36.0
53.0	29.8	**17.2**	36.7
49.0	33.8	**17.2**	39.3
48.0	34.7	**17.3**	38.0
38.0	44.6	**17.4**	38.0
55.0	27.4	**17.6**	40.0
68.0	14.0	**18.0**	35.0
62.0	20.0	**18.0**	40.0
59.0	23.0	**18.0**	38.0
59.0	23.0	**18.0**	38.0
45.0	37.0	**18.0**	42.0
55.0	26.8	18.2	36.7
55.0	26.8	18.2	36.7
60.0	21.0	19.0	39.5
60.0	21.0	19.0	42.9
18.0	63.0	19.0	41.0
59.0	21.9	19.1	41.3
53.0	27.9	19.1	33.3
53.0	27.9	19.1	33.3
53.0	27.9	19.1	34.7
53.0	27.9	19.1	34.7
51.0	29.4	19.6	41.0

Sand (%)	Silt (%)	Clay (%)	Saturation (%)
43.0	37.2	19.8	39.3
6.0	24.0	20.0	40.0
51.0	29.0	20.0	37.0
45.0	35.0	20.0	42.0
45.0	35.0	20.0	42.0
53.0	26.6	20.5	39.0
42.0	37.4	20.6	40.0
62.8	16.4	20.8	32.9
62.8	16.4	20.8	32.9
51.0	28.2	20.8	42.7
51.0	28.2	20.8	42.7
58.0	21.0	21.0	36.0
56.0	24.0	21.0	35.2
55.0	24.0	21.0	39.0
52.0	27.0	21.0	32.4
50.0	29.0	21.0	38.7
34.0	44.5	21.5	42.0
42.0	36.2	21.8	40.7
39.0	39.0	22.0	33.0
41.0	36.6	22.4	42.7
54.8	22.4	22.8	42.0
54.8	22.4	22.8	42.0
58.0	19.0	23.0	36.0
59.0	19.0	23.0	36.0
51.0	24.0	24.0	40.2
44.0	31.0	24.0	40.0
39.0	37.0	24.0	33.0
33.0	43.0	24.0	40.1
44.0	31.6	24.5	41.3
52.0	23.0	25.0	39.0
51.2	23.0	25.8	37.9
51.2	23.0	25.8	37.9
53.0	21.0	26.0	38.5
46.0	28.0	26.0	39.0
27.0	48.0	26.0	42.0
52.2	21.4	26.4	39.5
50.2	23.0	26.8	38.8
49.6	23.6	26.8	39.9
54.0	19.0	27.0	42.0
49.4	23.6	27.0	40.3
49.4	23.6	27.0	40.3
45.0	28.0	27.0	39.0
33.0	40.0	27.0	41.0
32.0	41.0	27.0	40.0
31.0	42.0	27.0	38.0
32.0	42.0	27.0	41.0
47.0	25.0	28.0	41.0
36.0	36.0	28.0	36.0
29.0	43.0	28.0	37.0
41.0	29.0	30.0	39.7
58.0	29.0	31.0	36.0
48.0	19.0	33.0	43.0
47.0	20.0	33.0	42.0
32.0	32.0	35.0	40.0
45.0	20.0	36.0	40.0
40.0	23.6	36.4	42.0
36.0	23.0	41.0	39.0
22.0	36.0	42.0	36.0

Table 4b. Texture by hydrometer data for saturation percentage (43-52%) population

Sand (%)	Silt (%)	Clay (%)	Saturation (%)
73.0	23.6	3.4	47
49.0	46.0	5.0	44
54.0	38.6	7.4	44
51.0	40.0	9.0	49
51.0	40.0	9.0	50
26.0	65.0	9.0	48
71.8	18.0	10.2	47
69.0	20.0	11.0	43
54.0	34.0	12.0	45.0
72.0	14.0	14.0	46.0
50.0	36.0	14.0	49
20	66	14.0	50
61.0	24.4	14.6	44
63.0	22.0	15.0	46
55.4	29.4	15.2	52
51.0	33.7	15.3	50
73.2	11.2	15.6	43.9
67.2	16.8	16.0	43.0
67.4	15.6	17.0	43.3
64.0	19.0	17.0	51.0
67.8	14.8	17.4	50.3
49.0	33.2	17.8	45.0
40.0	42.0	18.0	50
52.6	28.8	18.6	48
56.0	25.0	19.0	48
53.0	28.0	19.0	49
51.0	30.0	19.0	47
67.0	13.6	19.4	47.6
55.0	25.4	19.6	48
52.0	28.4	19.6	48
64.0	16.0	20.0	48
61.0	19.0	20.0	47.0
51.0	29.0	20.0	45.0
49.0	31.0	20.0	47.0
49.0	31.0	20.0	47.0
57.0	21.0	21.0	44.4
57.0	21.0	21.0	44.8
55.0	24.0	21.0	48.0
51.0	27.0	21.0	43.0
46.0	33.0	21.0	48
29.0	50.0	21.0	52
48.0	30.2	21.8	44.7
57.0	21.0	22.0	46.0
56.0	22.0	22.0	50.0
53.0	25.0	22.0	45.0
49.0	29.0	22.0	43
47.0	31.0	22.0	43.0
47.0	31.0	22.0	43.0
47.0	31.0	22.0	44.0
44.0	34.0	22.0	44.8
37.0	42.0	22.0	43.8
34.0	43.8	22.2	46.5
46.0	31.4	22.6	51
41.0	36.4	22.6	48.0
53.0	24.0	23.0	49
49.0	28.0	23.0	44.0
48.0	29.0	23.0	45
30.0	46.9	23.1	50.0
53.0	23.4	23.6	48
53.0	23.4	23.6	48.0
47.0	29.4	23.6	50
51.0	25.0	24.0	50.4
51.0	25.0	24.0	50.4
50.0	26.0	24.0	44.0
49.0	27.0	24.0	48.1
49.0	27.0	24.0	48.1
49.0	27.0	24.0	50.0
42.0	35.0	24.0	52.0
46.0	29.4	24.6	46.0
12.3	30.0	24.9	45.2
49.0	26.0	25.0	50
48.0	27.0	25.0	49.5
48.0	27.0	25.0	49.5
48.0	28.0	25.0	51.0
47.0	28.0	25.0	44.3
47.0	28.0	25.0	50.0
47.0	28.0	25.0	50
36.0	39.0	25.0	46.0
13.0	62.0	25.0	49.0
48.4	26.2	25.4	48.0
50.0	24.0	26.0	46.3
49.0	25.0	26.0	48.7
49.0	25.0	26.0	48.7
48.0	26.0	26.0	50.4
48.0	26.0	26.0	50.8
48.0	26.0	26.0	50.8
44.0	30.0	26.0	44.7
44.0	30.0	26.0	44.7
39.0	35.0	26.0	43.3
19.0	55.0	26.0	50.0
29.0	44.5	26.5	50.0
44.0	29.4	26.6	48
43.0	30.4	26.6	52
43.0	30.4	26.6	52.0
46.4	26.8	26.8	52.0
40.0	33.1	26.9	50.0
49.0	24.0	27.0	51.0
45.0	28.0	27.0	49
44.0	29.0	27.0	46.0
44.0	29.0	27.0	52.0
43.0	30.0	27.0	49.0
17.0	56.0	27.0	51.0
38.0	34.7	27.3	49
43.0	29.6	27.4	49.0
45.4	27.0	27.6	52
43.2	29.2	27.6	48.0
47.0	25.0	28.0	50
46.0	27.0	28.0	52
45.0	27.0	28.0	51
43.4	28.6	28.0	52.0
39.0	33.0	28.0	46.2
38.0	34.0	28.0	48.0
17.0	55.0	28.0	49.3
44.0	27.7	28.3	48.5
42.0	29.2	28.8	43.5
48.0	23.0	29.0	48
47.0	24.0	29.0	48.0
47.0	24.0	29.0	50.2
47.0	24.0	29.0	50.2
46.0	25.0	29.0	50.7
46.0	25.0	29.0	50.7
45.0	26.0	29.0	48
39.0	32.0	29.0	47.0
22.0	49.0	29.0	52.0
36.0	34.9	29.2	50.0
43.0	27.5	29.5	50.0
43.0	27.4	29.6	52
43.0	27.4	29.6	52.0
37.8	32.6	29.6	48.6
39.4	30.7	29.9	49.8
52.0	18.0	30.0	52.0
46.0	24.0	30.0	47.0
38.0	32.0	30.0	48.0
36.0	34.0	30.0	50.0
32.0	38.0	30.0	49.7
37.0	32.4	30.6	48
40.8	28.4	30.8	45.1
54.0	15.0	31.0	44
53.0	17.0	31.0	46.0
52.0	17.0	31.0	45.0
51.0	18.0	31.0	48.0
43.0	26.0	31.0	50
40	29.0	31	43
39.0	30.0	31.0	47.0
38.0	31.0	31.0	50.5
14.0	55.0	31.0	52
9.0	60.0	31.0	51.0
41.8	27.0	31.2	47.5
40.0	28.6	31.4	45.7
40.0	28.6	31.4	45.7
40.7	27.6	31.7	46.0
53.0	15.0	32.0	44.0
51.0	17.0	32.0	51.0
48.0	20.0	32.0	50.0
43.0	25.0	32.0	50
41.0	28.0	32.0	49.3
41.0	27.0	32.0	51.8
37.8	30.2	32.0	48.2
37.8	30.2	32.0	48.2
37.0	32.0	32.0	46.4
39.4	28.0	32.6	45.3
39.4	28.0	32.6	45.3
42.4	24.8	32.8	43.7
42.0	25.2	32.8	43.0
40.4	26.8	32.8	43.8
40.4	26.8	32.8	43.8
40.4	26.8	32.8	44.8
40.4	26.8	32.8	44.8
48.0	19.0	33.0	43.0
44.0	23.0	33.0	50
44.0	23.0	33.0	52
40.8	26.2	33.0	46.6
40.2	26.6	33.2	47.1
40.2	26.6	33.2	47.1
38.4	28.0	33.6	50.6
37.8	28.4	33.8	49.9
47.0	19.0	34.0	52.0
44.0	22.0	34.0	48.0
37.8	28.2	34.0	50.9
37.8	28.2	34.0	50.9
36.4	29.6	34.0	50.8
36.4	29.4	34.2	51.8
38.4	27.2	34.4	46.2

Sand (%)	Silt (%)	Clay (%)	Saturation (%)
32.6	32.6	34.8	51.9
46.0	19.0	35.0	49
45.0	20.0	35.0	48.5
41.0	24.0	35.0	52
39.0	26.0	35.0	51
33.0	32.0	35.0	49.4
35.4	29.4	35.2	51.2
44.0	20.0	36.0	49.6
38.0	26.0	36.0	51
34.0	30.0	36.0	45.9

Sand (%)	Silt (%)	Clay (%)	Saturation (%)
31.0	33.0	36.0	49.0
31.0	33.0	36.0	49
36.2	27.2	36.6	51.9
34.4	28.8	36.8	50.1
34.4	28.8	36.8	50.1
42.0	21.0	37.0	52
33.0	30.0	37.0	47.0
32.0	31.0	37.0	47
16.0	47.0	37.0	46.0
39.0	23.0	38.0	51

Sand (%)	Silt (%)	Clay (%)	Saturation (%)
33.0	29.0	38.0	48.1
39.0	22.0	39.0	51.0
34.0	27.0	39.0	51.7
32.0	28.0	40.0	50.1
12.0	47.0	41.0	50.5
26.0	30.0	43.0	51.7
0.5	49.4	50.6	44.0
33.0	12.0	55.0	49

Notes:
Sand content data >45% (soil texture limit for sandy clay, sandy clay loam) and silt content data >35% (from Figure 14) highlighted in yellow.
Clay content data <18% shown ***bolded***

3 CONCLUSIONS

Using saturation percentage and textural data by hydrometer, from Alberta subsoils (>1.5 m depth) that are not organic or impacted by produced water, empirical saturation percentage thresholds were established that could be used to determine with a 95% estimated accuracy of prediction (based on the underlying dataset) whether a soil was fine ($\geq$ 18% clay) or coarse (<18% clay) textured. The threshold for identifying a fine soil is a saturation percentage value $\geq$43%. This is reasonably similar to the coarse/fine threshold as defined by the USDA (1954). The threshold for identifying a coarse soil is a saturation percentage value $\leq$32%. This threshold was based on a smaller dataset compared to the fine soil threshold.

This algorithm was found to be strongest at the lower end of the clay content percentage range, where the correlation between clay content and saturation percentage was observed to be stronger, and silt content was relatively low (<35%). Subsoil samples with saturation percentage values falling between the two thresholds (32-43%) were found to have greater silt contents (>35%) and may have elevated sand contents – soils within this range should be analyzed for texture by hydrometer as they may be coarse soils.

The subset of the data known to have heavy clay (>60%, n=38) was considered unlikely to yield significant results, as the subset was both limited for deriving 95% accuracy for a threshold test, and highly scattered (R^2= 0.086, compared to R^2=0.6105 for the population as a whole). This limitation, at present, means that this analysis is limited to distinguishing fine from coarse-textured soils.

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