Probe Calibration Document 2: Unburned Soils

Organic Soil Calibration Algorithms for the Campbell Scientific handheld Hydrosense-I and II units

2017-2018 Unburned Soils of Boreal Alberta CA and Arctic Alaska USA

This document is supplementary to the previously distributed probe calibration document 1. The previously developed calibrations were based primarily on *fire-affected* organic soils of Northwest Territories and Alaska (collected by field teams of two ABoVE projects (Alaska PI Loboda and NWT PI Bourgeau-Chavez). The sites used for this document were *unburned* peatland and upland sites in Red Earth Creek Alberta and tundra sites in Sagwon, Alaska, collected under a SUSMAP grant (PI Bourgeau-Chavez).

The Campbell Scientific Hydrosense handheld soil moisture probes have built in calibration to a loam mineral soil. Organic soils of the Boreal-Arctic have characteristic low bulk density and the default loam calibration typically underestimates actual soil moisture condition. For that reason, we carefully harvested soil samples of 2.5 gallon size to use in a laboratory setting to develop gravimetric based calibration algorithms specific to the boreal and arctic organic soils (*after* Bourgeau-Chavez et al. 2010). A series of samples were collected in non-burned tundra types, boreal bog, fen, upland deciduous and conifer sites. The results of these calibrations are presented in this document.

This document has calibrations for 5 soils groups (A-E) with group C actually representing tussocks themselves, thus we now have a calibration for probing tundra tussocks. The best break down of these sampled soils for calibration of the probes was by ecotypes. See the last 2 pages of this document for plots of the laboratory data and fitted calibration curves.

Table 1. Description of soils and tundra tussocks grouped by ecotype for calibration

	Group	Boreal/Tundra Ecotypes	General guidelines
Boreal	A	Upland Deciduous (UD), *Feathermoss dominant* Lowland Conifer (CON) and Treed Fen (TF)	Feathermoss dominant < 7 cm Live/dead moss over 6-17+ cm duff or for deciduous sites lower duff and silty clay
	B	Sphagnum dominant Bog & Open Fen (OF)	Sphagnum dominant – > 7 cm live/dead moss over > 9 cm duff
Tundra	C	Tundra *Tussocks ONLY*	Calibration is for probing the *Tussocks* themselves and *not* the soil
	D	Tundra Tussock and Tundra Tussock Shrub sites	>8cm Live/dead moss and or upper duff over 12-24 cm lower duff
	E	Non-tussock Tundra: Sedge and Shrub Tundra	<2 cm live/dead moss over 7-20 cm lower duff over clay

Unfortunately, attempts to group samples based on soil profiles alone was not feasible. We provide a description of the soils in each group, which should help in deciding on which group best matches a new soil sampled with the hydrosense probes. We did also create a general algorithm (bottom of Table 3) for calibration of organic soils based on all ecotypes/soils. Table 2 lists characteristics of a subset of the samples used in the laboratory for algorithm development.

Table 2. Examples of harvested samples by ecotype and soil profiles with depths in cm that were used in the laboratory calibration. The measurements are based on the samples and do not describe the full soil profiles. A description of the four organic soil horizons (live moss, dead moss, upper duff, lower duff) is provided in Figure 1. NM – Not measured

	Group	Harvested Sample	Live Moss	Dead Moss	Upper Duff	Lower Duff	Organic Profile Depth to 20 cm	Mineral Soil
Boreal	A	Conifer 1-1	3	0	13	4+	20	-
		Deciduous Upland 2-8	0	2	-	8	10	Silty Clay
		Deciduous Upland 3-8	0	7	-	6	13	Silty Clay
		Treed Fen1-1	2	2	8	8+	20	-
	B	Bog 1-1	3	17+	NM	NM	20	-
		Bog 3-8	2	11	10+	NM	23	-
		Open Fen 1-7	0	12	0	9+	21	-
		Open Fen 3-8	2	5	9	7.5+	23.5	-
Tundra	C	Tussock 1	NA	NA	NA	NA	NA	-
		Tussock 2	NA	NA	NA	NA	NA	-
	D	Tundra Tussock 2A1	2	6	0	12	20	Clay
		Tundra Tussock Shrub 2A1	3	7	0	17	27	-
		Tundra Tussock Shrub3	0	0	17	7	24	-
	E	Tundra sedge 1	0	1	0	19	20	Clay
		Tundra Shrub 6A1	2	0	0	7	9	Clay/sand

Below are tables representing the organic soil calibration equations for different probes, probe lengths, and groups of ecosystem types. The values given in table 3 (a, b, c) are coefficients that should be used in the following equation where θ is the percent volumetric moisture content (% VMC) and τ is the probe period (ms for Hydrosense I and μs for Hydrosense II):

$$\theta = a\,\tau^2 + b\,\tau + c$$

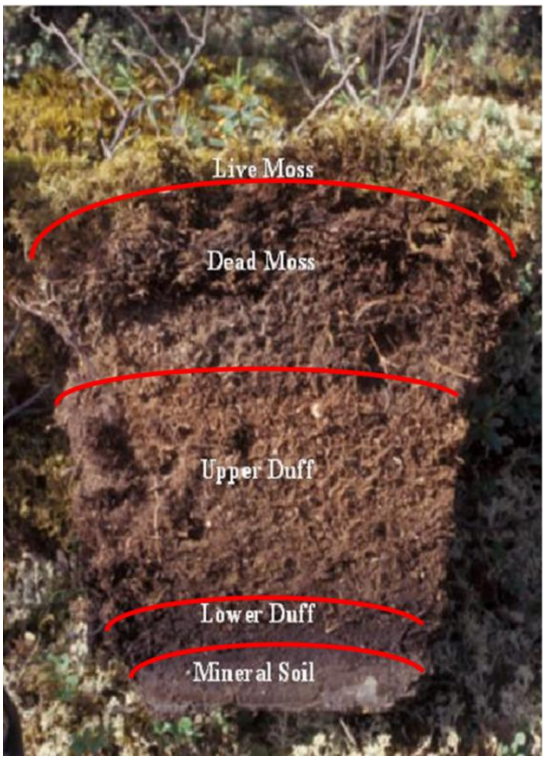
The probes supplied by ABoVE are Hydrosense II. The 6 cm probe depth refers to the 12 cm probe length inserted at a 30 degree angle to measure the top 6 cm of soil. 10 cm probe depth refers to the 20 cm probe length inserted at 30 degree angle to measure the top 10 cm of soil. 12 cm and 20 cm depths are the 12 and 20 cm probe lengths inserted vertically from the surface down into the soil layers.

Be sure to select the equation for the correct probe (Hydrosense I or II) and probe length/depth that was used in the field, as they are not generally interchangeable.

Table 3. Calibration coefficients for each group A to E for Hydrosense-1 (H-1) and Hydrosense-2 (H-2)

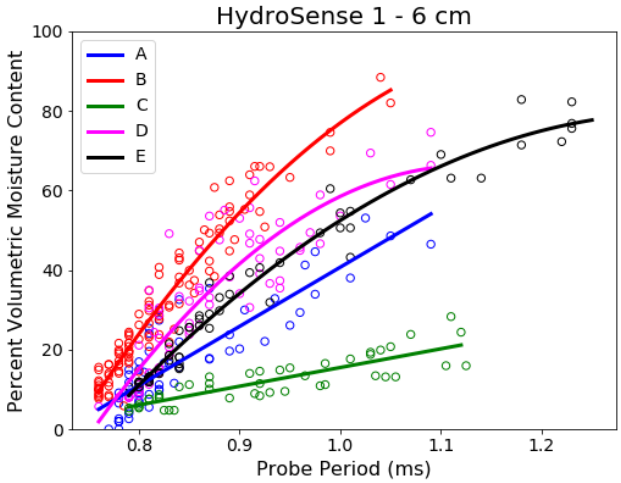
Sensor	Probe Length	Group Name	Group Description	a	b	c	R^2	p	n	S.E.
H-1	20 cm	Group A	Uplands & Treed Fens	0	112.461	-84.73	0.93	<0.05	128	4.53
H-1	12 cm	Group A	Uplands & Treed Fens	0	150.598	-116.3	0.84	<0.05	55	4.24
H-1	6 cm	Group A	Uplands & Treed Fens	0	148.732	-108.031	0.76	<0.05	59	6.46
H-2	20 cm	Group A	Uplands & Treed Fens	NA	NA	NA	NA	NA	NA	NA
H-2	12 cm	Group A	Uplands & Treed Fens	0	49.495	-53.487	0.79	<0.05	54	4.7
H-2	6 cm	Group A	Uplands & Treed Fens	0	59.992	-58.71	0.8	<0.05	59	5.86
H-1	20 cm	Group B	Bogs and Open Fens	0	124.428	-90.625	0.85	<0.05	81	6.21
H-1	12 cm	Group B	Bogs and Open Fens	-398.84	942.67	-478.37	0.91	<0.05	105	5.73
H-1	6 cm	Group B	Bogs and Open Fens	-399.62	984.45	-507.87	0.93	<0.05	105	4.92
H-2	20 cm	Group B	Bogs and Open Fens	0	38.574	-53.198	0.87	<0.05	81	5.81
H-2	12 cm	Group B	Bogs and Open Fens	0	83.743	-74.954	0.91	<0.05	104	5.64
H-2	6 cm	Group B	Bogs and Open Fens	0	98.346	-88.078	0.92	<0.05	104	5.51
H-1	20 cm	Group C	Just Tussocks (No Soil)	0	27.411	-17.002	0.78	<0.05	39	2.66
H-1	12 cm	Group C	Just Tussocks (No Soil)	0	41.599	-27.604	0.72	<0.05	45	3.02
H-1	6 cm	Group C	Just Tussocks (No Soil)	0	47.047	-31.563	0.72	<0.05	45	3.02
H-2	20 cm	Group C	Just Tussocks (No Soil)	0	9.645	-10.336	0.69	<0.05	39	3.15
H-2	12 cm	Group C	Just Tussocks (No Soil)	0	17.628	-14.678	0.66	<0.05	44	3.3
H-2	6 cm	Group C	Just Tussocks (No Soil)	0	18.188	-14.852	0.67	<0.05	44	3.24
H-1	20 cm	Group D	Tussock/Tussock Shrub Tundra	0	123.132	-94.883	0.95	<0.05	48	4.43
H-1	12 cm	Group D	Tussock/Tussock Shrub Tundra	-263.22	666.88	-356.05	0.87	<0.05	71	6.6
H-1	6 cm	Group D	Tussock/Tussock Shrub Tundra	-475.7	1073.1	-538.9	0.79	<0.05	71	8.33
H-2	20 cm	Group D	Tussock/Tussock Shrub Tundra	16.264	-31.061	16.084	0.97	<0.05	51	3.65
H-2	12 cm	Group D	Tussock/Tussock Shrub Tundra	0	77.147	-81.761	0.92	<0.05	74	5.39
H-2	6 cm	Group D	Tussock/Tussock Shrub Tundra	0	78.378	-74.436	0.73	<0.05	73	9.83
H-1	20 cm	Group E	Sedge/Shrub Tundra	-89.858	315.378	-191.869	0.99	<0.05	50	1.56
H-1	12 cm	Group E	Sedge/Shrub Tundra	-131	419.82	-240.16	0.98	<0.05	58	3.02
H-1	6 cm	Group E	Sedge/Shrub Tundra	-235.67	631.17	-343.05	0.97	<0.05	58	3.92
H-2	20 cm	Group E	Sedge/Shrub Tundra	-24.822	175.394	-229.601	0.99	<0.05	50	1.58
H-2	12 cm	Group E	Sedge/Shrub Tundra	-42.552	216.794	-185.246	0.98	<0.05	58	3.31
H-2	6 cm	Group E	Sedge/Shrub Tundra	-43.737	214.758	-178.697	0.98	<0.05	58	3.4
H-1	20 cm	General	Groups A, B, D, E	-62.29	250	-154.8	0.92	<0.05	179	5.29
H-1	12 cm	General	Groups A, B, D, E	-115.98	381.52	-216.74	0.74	<0.05	289	9.92
H-1	6 cm	General	Groups A, B, D, E	-302.97	744.79	-384.43	0.74	<0.05	293	9.83
H-2	20 cm	General	Groups A, B, D, E	0	43.3943	-63.8266	0.91	<0.05	182	5.64
H-2	12 cm	General	Groups A, B, D, E	0	68.352	-64.79	0.7	<0.05	290	10.72
H-2	6 cm	General	Groups A, B, D, E	-17.5	123.71	-101.1	0.74	<0.05	294	10.06

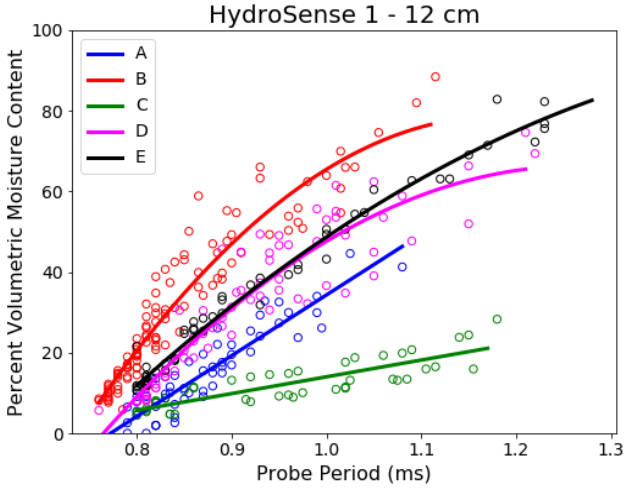
Soil Horizon Definitions



- **Live moss: living moss layer**
- **Dead Moss: undecomposed moss and other plant parts**
- **Upper Duff: fibric layer, partially decomposed moss/organic plant parts still visible**
- **Lower Duff: humic layer, decomposition more advanced, denser than fibric layer and plant parts are no longer visible**

Figure 1. Organic soil profile showing distinction of live moss, dead moss, upper duff and lower duff.


HydroSense 1 - 6 cm
Percent Volumetric Moisture Content
Probe Period (ms)
A
B
C
D
E
0
20
40
60
80
100
0.8
0.9
1.0
1.1
1.2


HydroSense 1 - 12 cm
Percent Volumetric Moisture Content
Probe Period (ms)
A
B
C
D
E
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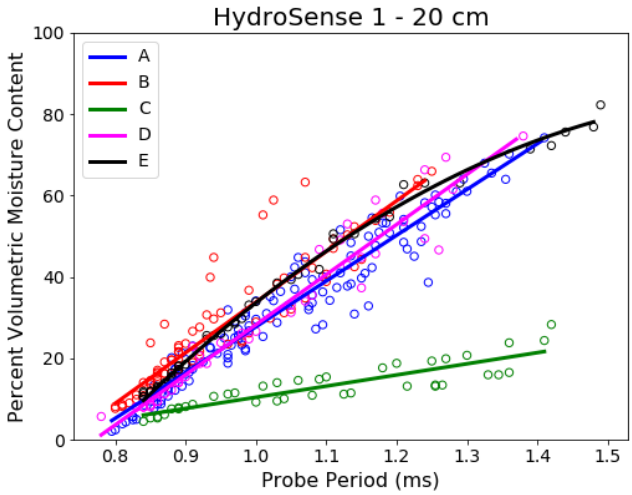
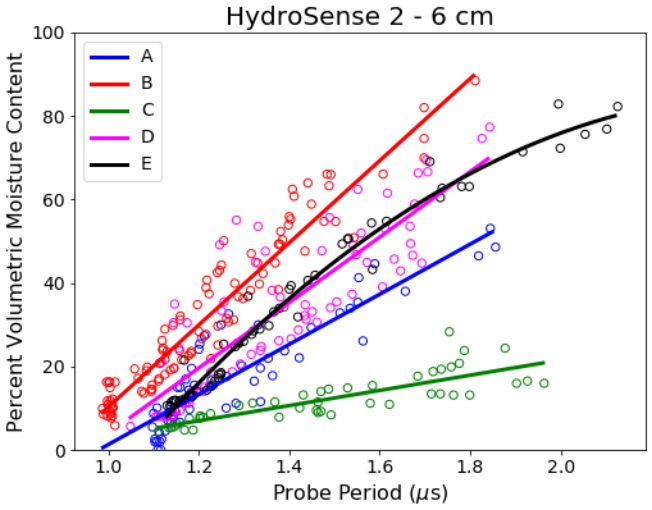
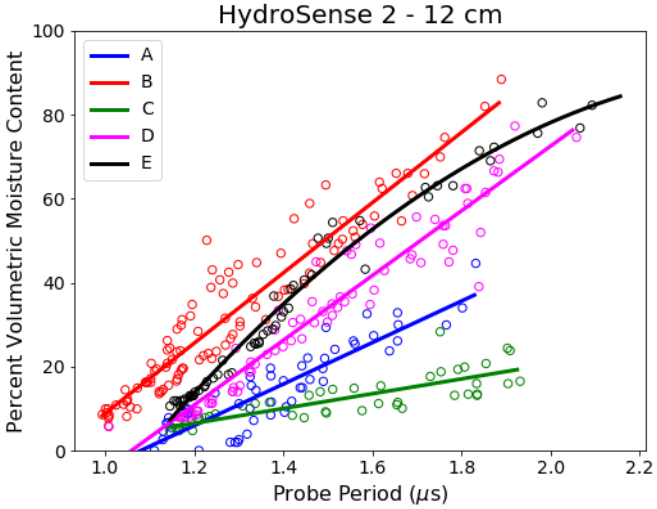
20
40
60
80
100
0.8
0.9
1.0
1.1
1.2
1.3


HydroSense 1 - 20 cm
Percent Volumetric Moisture Content
Probe Period (ms)
A
B
C
D
E
0
20
40
60
80
100
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5


HydroSense 2 - 6 cm
Percent Volumetric Moisture Content
Probe Period (μs)
A
B
C
D
E
0
20
40
60
80
100
1.0
1.2
1.4
1.6
1.8
2.0


HydroSense 2 - 12 cm
Percent Volumetric Moisture Content
Probe Period (μs)
A
B
C
D
E
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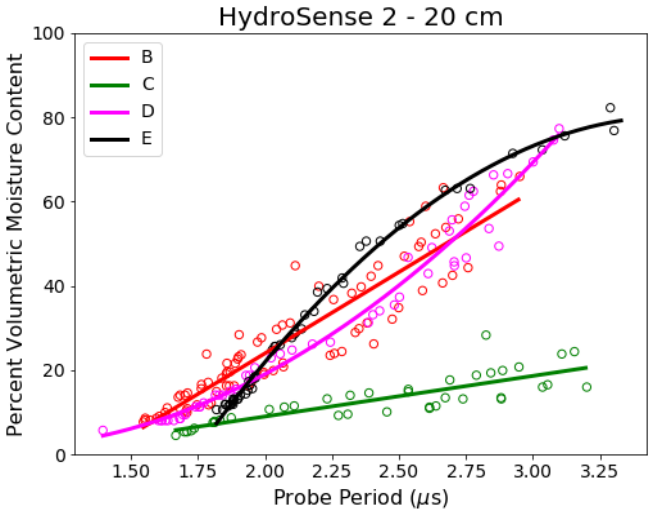
20
40
60
80
100
1.0
1.2
1.4
1.6
1.8
2.0
2.2


HydroSense 2 - 20 cm
Percent Volumetric Moisture Content
Probe Period (μs)
B
C
D
E
0
20
40
60
80
100
1.50
1.75
2.00
2.25
2.50
2.75
3.00
3.25