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KMP SO$_2$ EEM Program – Technical Memo S06

Long-term Soil Monitoring Plots
Plot Establishment: 2017 Update
(Update to 2016 Technical Memo S04)

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1   Overview

Under the Environmental Effects Monitoring (EEM) Program, long-term soil monitoring plots will address the observation-based KPI: 'observed change in base cation pool over time' through repeat sampling and analysis of soils for exchangeable base cations every five years (ESSA et al., 2014).

During October–December 2015 and June–July 2016, long-term soil monitoring plots were established at Coho Flats and at Lakelse Lake, Kitimat Valley, and the reference (background) plots were established at Kemano (far from the smelter emissions plume). This memo describes the establishment of the plots (i.e., plot locations and layout of plot design), the initial collection of soil, and processing of samples (i.e., drying and sieving) during 2015 and 2016. The monitoring plots were re-visited for soil bulk density sampling, and mapping of tree locations during June–July 2016. In addition, the background (control or reference) plots were established at Kemano. Chemical extraction (for exchangeable base cations and exchangeable acidity) was also carried out during 2016.

This memo (S06) updates the March 2016 'Long-term Soil Monitoring Plots— Plot Establishment' memo (S04), with the new information on field sampling and soil analysis carried out during 2016, including the collection of soil bulk density samples, and mapping of tree locations at Coho Flats and Lakelse Lake, and the establishment (i.e., select locations and layout plot design) of the background (control or reference) plots at Kemano (including the initial collection of soil, bulk density samples, and mapping of tree locations).

2   Objective and Rationale

The objective of the long-term soil plots is to monitor changes in soil base cation pools over time through repeated sampling and analysis (every five years). The monitoring plots provide a framework for replicate random sampling of soils, allowing for the statistical assessment of changes between sampling campaigns.

Under the EEM Program, long-term soil monitoring plots will be established in near-field and far-field locations with respect to smelter emissions. In addition a background or reference plot will be established (remote from emissions sources outside the Kitimat Valley) to assess whether a change soil base cation pools (if observed) is causally related to the Kitimat Modernisation Project (KMP). Changes in soil exchangeable base cations will initially evaluated in the upper mineral soil (0–5 cm) between sampling periods. If a statistical change is detected, analysis will be carried out down the soil profile.

3   Plot Location and Design

During October–December 2015, near-field and far-field plots were established at Coho Flats (latitude: 54.07660, longitude: –128.65117) and Lakelse Lake (latitude: 54.37827, longitude: –128.57990), respectively, to reflect the gradient in atmospheric deposition, and during 2016 reference (or background) plots were established at Kemano (latitude: 53.53032, longitude: –127.97384; see Figure 1). The plots in the Kitimat Valley are located in close proximity to, or co-located with, the NADP atmospheric deposition monitoring stations at Haul Road and Lakelse Lake. At each location, primary and secondary (backup) plots were established within forest stands dominated by western Hemlock; secondary plots (located generally within 500 m of the primary

plot) provide a backup or replacement to the primary plot if disturbed or destroyed within the lifetime of the monitoring program.

Each long-term soil plot is 32 m by 30 m in size and composed of twenty 8 m by 6 m sub-plots lettered A to T; the A sub-plot is oriented to the north-west corner of each plot (Figure 2). Each sub-plot is further divided into twelve 2 m by 2 m sampling grids (numbered 1 to 12); one numbered grid was randomly sampled from each lettered sub-plot at five depths: litter-fibric (LF), humic (H), and 0–5 cm, 5–15 cm, and 15–30 cm depths in the mineral soil (yielding a total of 100 soil samples for each plot, i.e., 5 soil samples by depth within each of the 20 lettered sub-plots). Every five years one numbered grid within each lettered sub-plot will be randomly sampled (note: individual numbered grids are sampled only once), allowing for a total of twelve sampling campaigns. During the twelve sampling campaigns, each numbered grids is sampled only once. The re-sampling of the primary plots at Coho Flats and Lakelse Lake are scheduled for summer 2018.
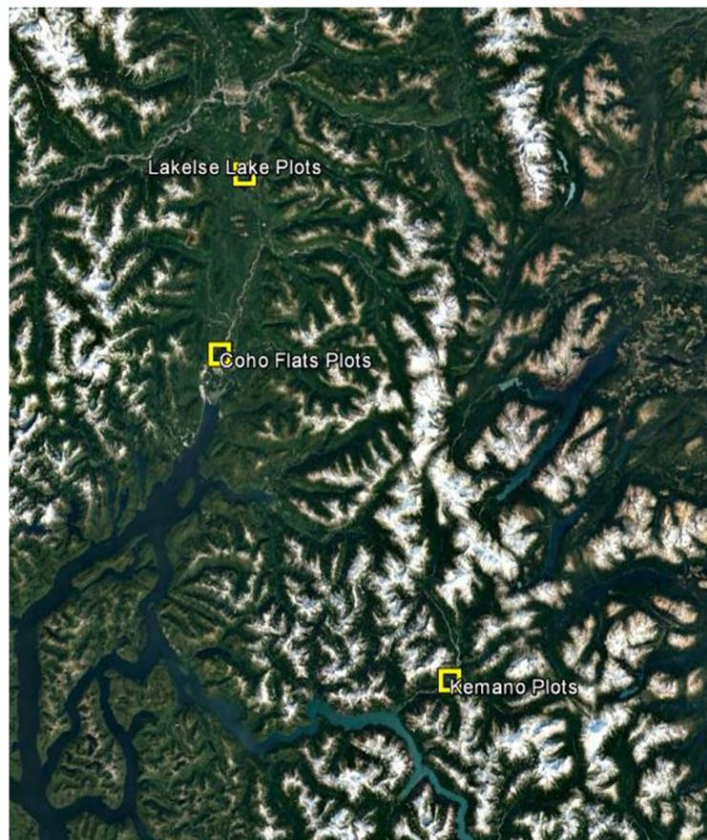

Figure 1. Location of long-term soil monitoring plots at Coho Flats (near-field) and Lakelse Lake (far-field), in the Kitimat Valley, and Kemano (reference). Note: primary and secondary [backup] plots were established at all three locations.
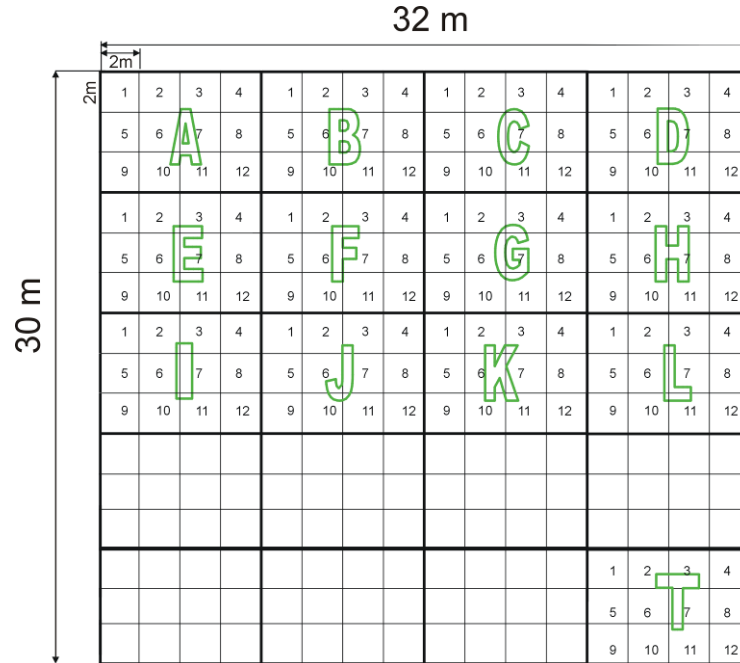
Figure 2. Long-term soil monitoring plot; the plot is divided into twenty 8 m by 6 m sub-plots, lettered A to T; each sub-plot is further divided into twelve 2 m by 2 m sampling grids, numbered 1 to 12. One numbered grid within each lettered sub-plot is randomly selected for sampling during each campaign, allowing for a total of 12 sampling events, with 20 samples per depth.

4 Plot Sampling and Analysis

During October–December 2015, long-term soil monitoring plots (primary and secondary) were established in forest stands dominated by Western Hemlock at Coho Flats and Lakelse Lake, Kitimat Valley (Figure 3). During June–July 2016, the reference long-term soil monitoring plots (primary and secondary) were established at Kemano (Figure 3). Within each plot, one numbered grid was randomly sampled from each lettered sub-plot (see Appendix A for a list of sample grids). In total ~360 mineral soil samples were collected during 2015 and 2016 (6 plots × 20 sub-plots × 3 soil depths). In addition, soil bulk density sampling and tree mapping were carried out at Kemano, and the plots at Lakelse Lake and Coho Flats were revisited to also collect soil samples for bulk density determination, and to map out tree species across all plots. In total ~360 bulk density soil core samples were collected during 2016 (6 plots × 20 sub-plots × 3 soil depths).

Soil samples from the first (2015) and second (2016) sampling campaign have been dried, sieved to < 2 mm and analysed for pH, organic matter content (estimated as % loss on ignition) and bulk density (Figure 4 and Table 1). There is a noticeable difference in organic matter content between depths in the mineral soil (i.e., there is a statistically significant decrease in organic matter between the 0–5 cm and the lower depths at Lakelse Lake, Figure 4) but not between primary and secondary plots (i.e., there is no statistical difference between the 0–5 cm at Lakelse Lake primary compared with the same depth in Lakelse Lake secondary). In contrast, there is no significnat differnce (decreases) in organic matter with depth at the Coho Flats primary plot (see Figure 4 and Table 1)

Tree species were mapped for all plots during 2016 (Figure 5). All primary plots are dominated by Western Hemlock (61% of plot DBH at Kemano, 44% at Lakelse Lake and 96% at Coho Flats;

Figure 5). The total number of trees (> 10 cm DBH) ranged from 47 (Coho Flats), 69 (Kemano) to 108 (Lakelse Lake).

During 2017, the 0–5 cm depth soil samples at the primary plots will be analyzed for exchangeable base cations, and exchangeable acidity (note: laboratory extractions were carried out during 2016, soils are awaiting analysis), and all soils (from the primary and secondary plots) will be archived.
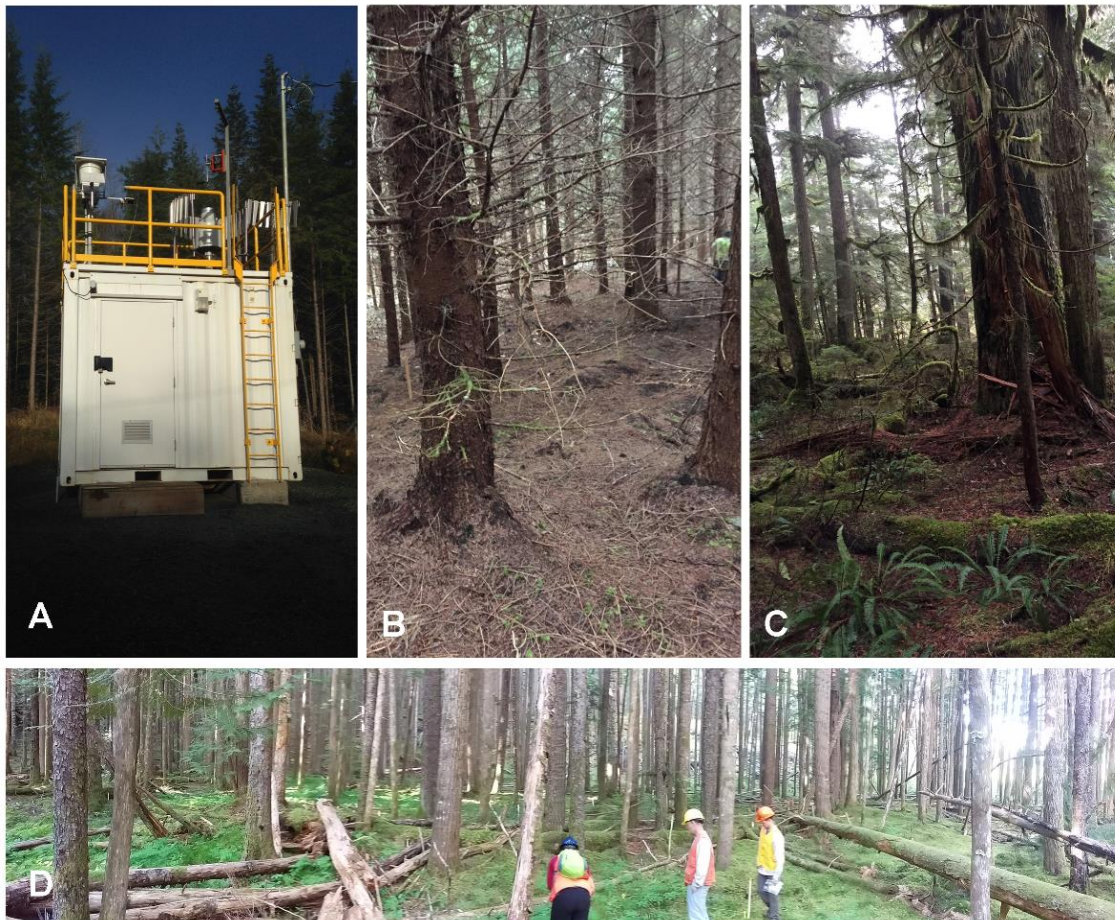

Figure 3. The long-term soil monitoring plots are located at Lakelse Lake beside the NADP monitoring station (A), in a western Hemlock stand (primary plot is shown in B), and east of the Coho Flats Trail, Kitimat (primary plot is shown in C). The reference (or background) plot is located in Kemano (primary plot at Seekwyakin camp is shown in D).
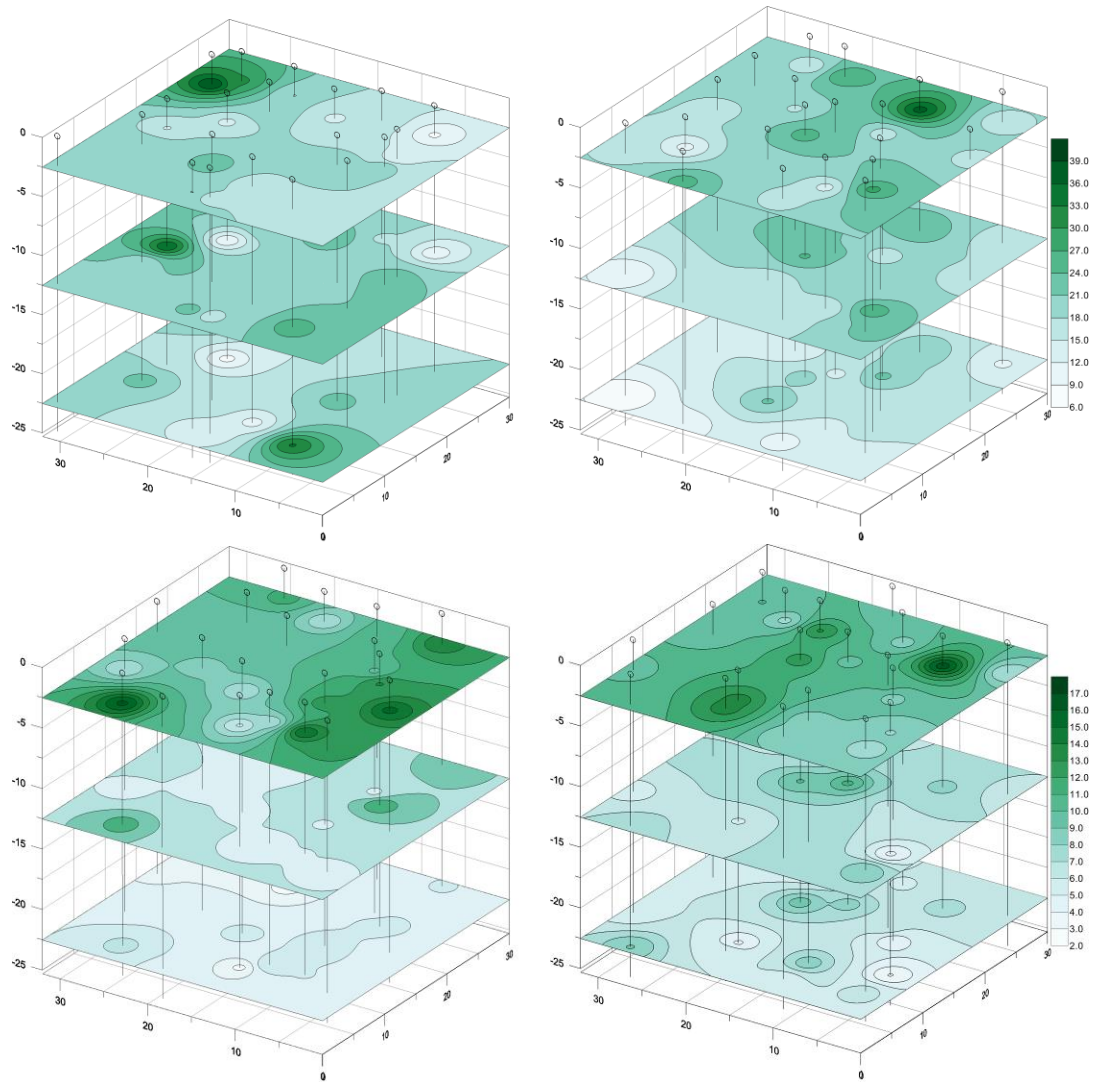
Figure 4. Three-dimensional representation of soil organic matter content (%) in the 0–5 cm, 5–15 cm, and 15–30 cm (mineral) soil depths at the primary (left) and secondary (right) long-term soil monitoring plots at Coho Flats (upper) and Lakelse Lake (lower). The vertical lines indicate the location of the soil sampling pits (n = 20 per plot, with soil sampling at three depths).

Table 1. Average soil data (n = 20 per soil depth) for primary and secondary plots at Coho Flats, Lakelse Lake and Kemano.

Soil Variable	Depth (cm)	Coho Flats Primary	Secondary	Lakelse Lake Primary	Secondary	Kemano Primary	Secondary[$]
Organic	0–5	19.04	20.36	10.59	10.07	12.05	3.40
matter	5–15	20.33	18.62	6.52	6.11	10.88	2.79
(%)	15–30	17.93	14.79	4.50	5.08	10.40	2.03
pH	0–5	4.56	4.62	5.13	4.97	4.95	5.70
	5–15	5.07	4.73	5.41	5.38	5.01	5.73
	15–30	5.33	4.97	5.50	5.49	5.11	5.75
Bulk	0–5	0.664	0.708	0.738	0.828	0.952	1.189
density	5–15	0.646	0.708	0.922	0.905	0.906	.
(g cm^{-3})	15–30	0.849	0.664	1.066	0.911	0.814	.
Coarse	0–5	34.87	30.86	.	.	5.05	3.50
fragment	5–15	39.32	34.26	.	.	9.84	2.66
(%w)	15–30	50.62	35.64	.	.	10.95	2.86
Field	0–5	46.11	41.43	34.09	29.92	15.60	23.19
moisture	5–15	43.46	38.94	32.83	32.02	18.09	.
(%v)	15–30	40.39	39.00	32.90	33.00	15.82	.

[$] this is a very sandy site, making collection of bulk density difficult, as such bulk density was only collected from one depth (which was assumed representative of all depths).
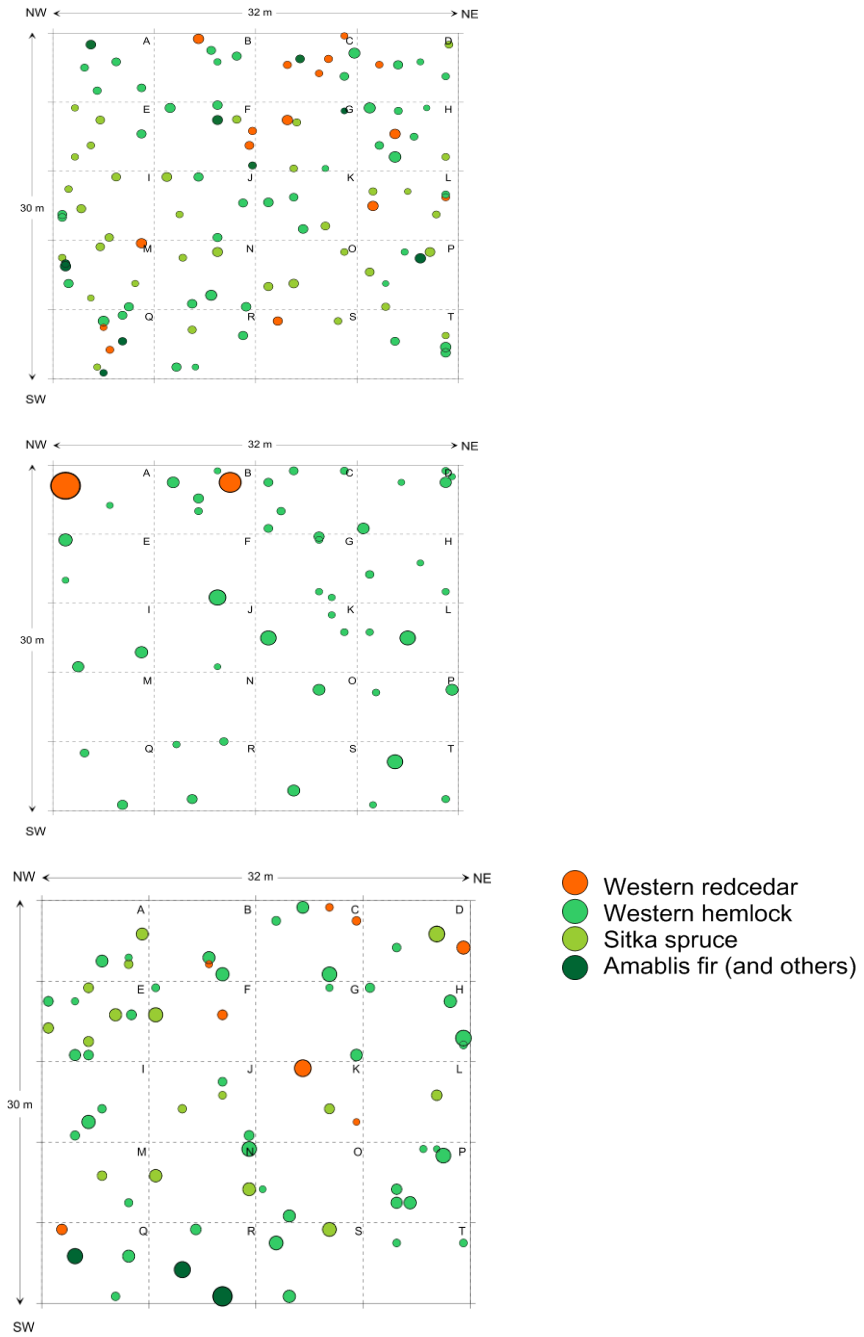
Figure 5. Layout of the primary long-term soil monitoring plots at Lakelse Lake (upper), Coho Flats (middle), and Kemano (lower) showing the location and relative size of each tree species.

5 Literature Cited

ESSA Technologies, J. Laurence, Limnotek, Risk Sciences International, Rio Tinto Alcan, Trent University, Trinity Consultants and University of Illinois. 2013. Sulphur Dioxide Technical Assessment Report in Support of the 2013 Application to Amend the P2-00001 Multimedia Permit for the Kitimat Modernization Project. Vol.2: Final Technical Report. Prepared for RTA, Kitimat, BC. 450 pp.

ESSA Technologies, J. Laurence, Risk Sciences International, Trent University, and Trinity Consultants. 2014. Kitimat Airshed Emissions Effects Assessment. Report prepared for BC Ministry of Environment, Smithers, BC. 205 pp. + appendices.

6   Appendix A

Table A1. Soil plot grids sampled (at five depths) during 2015 within the primary and secondary plots located at Coho Flats and Lakelse Lake (see Figure 1). Grids are identified by the sub-plot letter and grid number (see Figure 2). Grid locations for the primary plots are also shown in Figure A1.

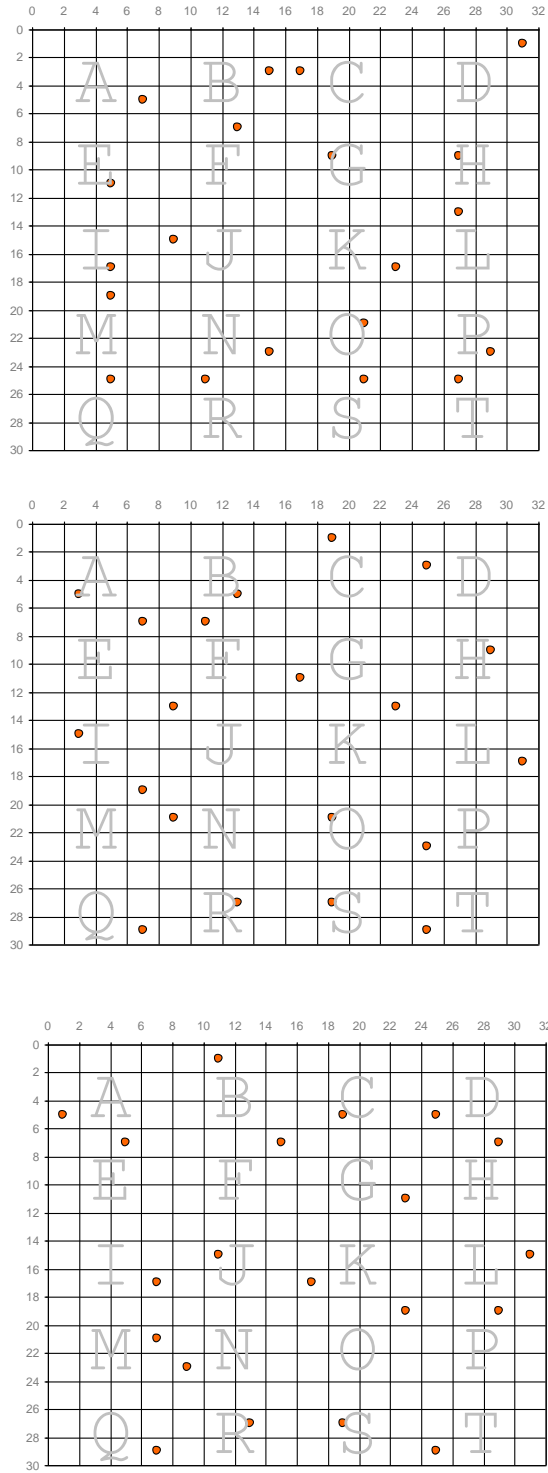| #	Coho Flats		Lakelse Lake		Kemano	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
1	A12	A10	A10	A10	A09	A08
2	B08	B06	B11	B06	B02	B12
3	C05	C03	C02	C10	C10	C03
4	D04	D07	D05	D02	D09	D12
5	E11	E07	E04	E06	E03	E04
6	F03	F01	F02	F02	F04	F07
7	G06	G05	G09	G02	G12	G06
8	H06	H01	H07	H04	H03	H11
9	I11	I04	I06	I08	I12	I09
10	J05	J12	J01	J09	J06	J01
11	K12	K05	K04	K10	K09	K09
12	L02	L06	L12	L11	L08	L06
13	M03	M01	M04	M12	M08	M02
14	N12	N02	N05	N04	N09	N04
15	O07	O03	O06	O11	O04	O11
16	P11	P06	P09	P09	P03	P07
17	Q03	Q06	Q12	Q01	Q12	Q02
18	R02	R02	R07	R03	R07	R04
19	S03	S07	S06	S09	S06	S10
20	T02	T05	T09	T03	T09	T04

Figure A1. Location of soil sampling grids within letter sub-plots at the primary plots at Coho Flats (upper), Lakelse Lake (middle) and Kemano (lower).