Using estuarine cores to assess historical changes to sedimentation and contamination in New River Estuary

Danielle J. Brown[1]*, Nick Ward[2], Tim Ellis[2], Clint Rissmann[3] and Matthew I. Leybourne[1,4]

[1]Harquail School of Earth Sciences, Laurentian University, Sudbury, CA (*dbrown@laurentian.ca); [2]Environment Southland, Invercargill, NZ; [3]e3 Scientific, Invercargill, NZ; QFIR, Geological Sciences and Geological Engineering, Queen's University, Kingston, CA

New River Estuary (NRE)

Increased sedimentation in NRE (Fig. 1) is a problem as fine-sediment has negative ecological impacts and can transport heavy metals and nutrients. High concentrations of heavy metals, N, and P decrease water quality and can lead to estuarine contamination and eutrophication.

Shallow (25 cm) and deep (40-100 cm) cores were collected by hand at low and high tide from the two main depositional sites in the NRE: the Lower Waihopai Arm (LW) and East Daffodil Bay (DE). The intensity of fine-sediment accumulation decreases from the upper to lower Waihopai Arm and again to Daffodil Bay.

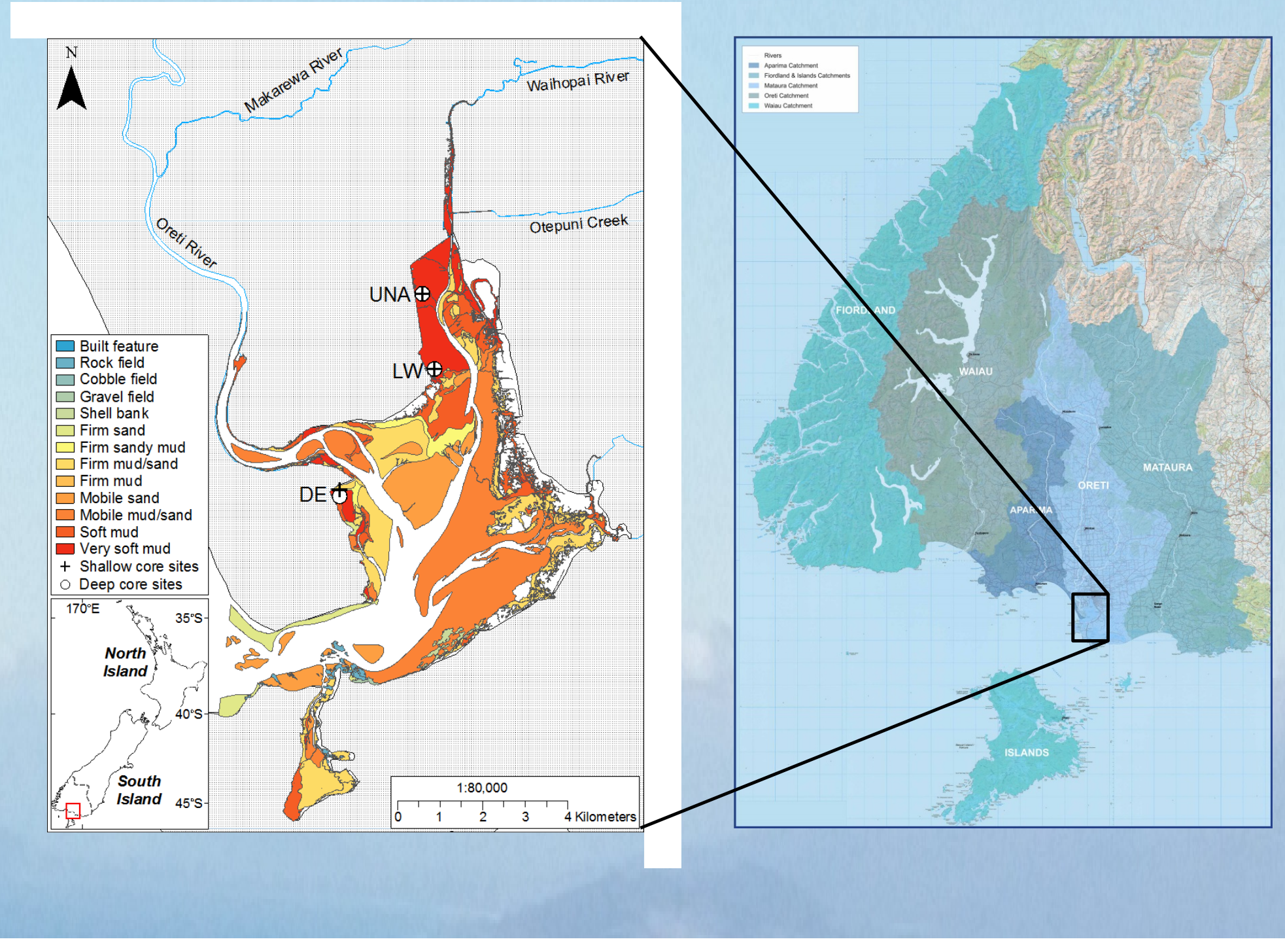

Figure 1. Sediment core sampling sites in NRE: Upper North Arm (UNA), named after a previous study[f], Lower Waihopai Arm (LW), and East Daffodil Bay (DE). Overlaying the location map is the broad-scale classification of surface substrate[g].

Change in chemistry and sedimentation rate

Sedimentation rate (S) is calculated using Pb-radioisotope dates (t) and uncompacted depths (d) from a horizon (x):

$$S = (d_x - d_0) / t_{x\text{-}0}$$

Average sedimentation rate increases up-core from:

- UNA - 7.3-13.3 mm/yr (11-77 cm) → 22.4 mm/yr (0-11 cm)
- LW - 5.9 mm/yr (12-23 cm) → 17.5 mm/yr (0-12 cm)
- DE - 5.5-7.0 mm/yr (13-73 cm) → 10.3 mm/yr (0-13 cm)

High Pb values (Fig. 2) date sediment to between 1975 and 1986, when leaded petroleum use was at its peak[e]. In this period, bioavailable Ni (partial fraction) increases significantly above the trigger value in UNA at 38 cm and in LW at 18 cm.

Increases in Cu and Zn and a decrease in Ca (Fig. 3) highlight a transition from a marine-dominated (higher concentration of shells, high Ca) sediment signature to a terrestrial-dominated signature:

UNA → 38-60 cm, at 38 cm (1975-1986) the sediment source remains unchanged to the top of the core

LW → 18-30 cm, at 18 cm (1975-1986) the sediment source remains unchanged to the top of the core

DE → 0-65 cm, the constant terrestrial signature visible in the other two cores is not apparent, likely because Daffodil Bay is not as well-developed in fine-grained sedimentation as the Waihopai Arm.

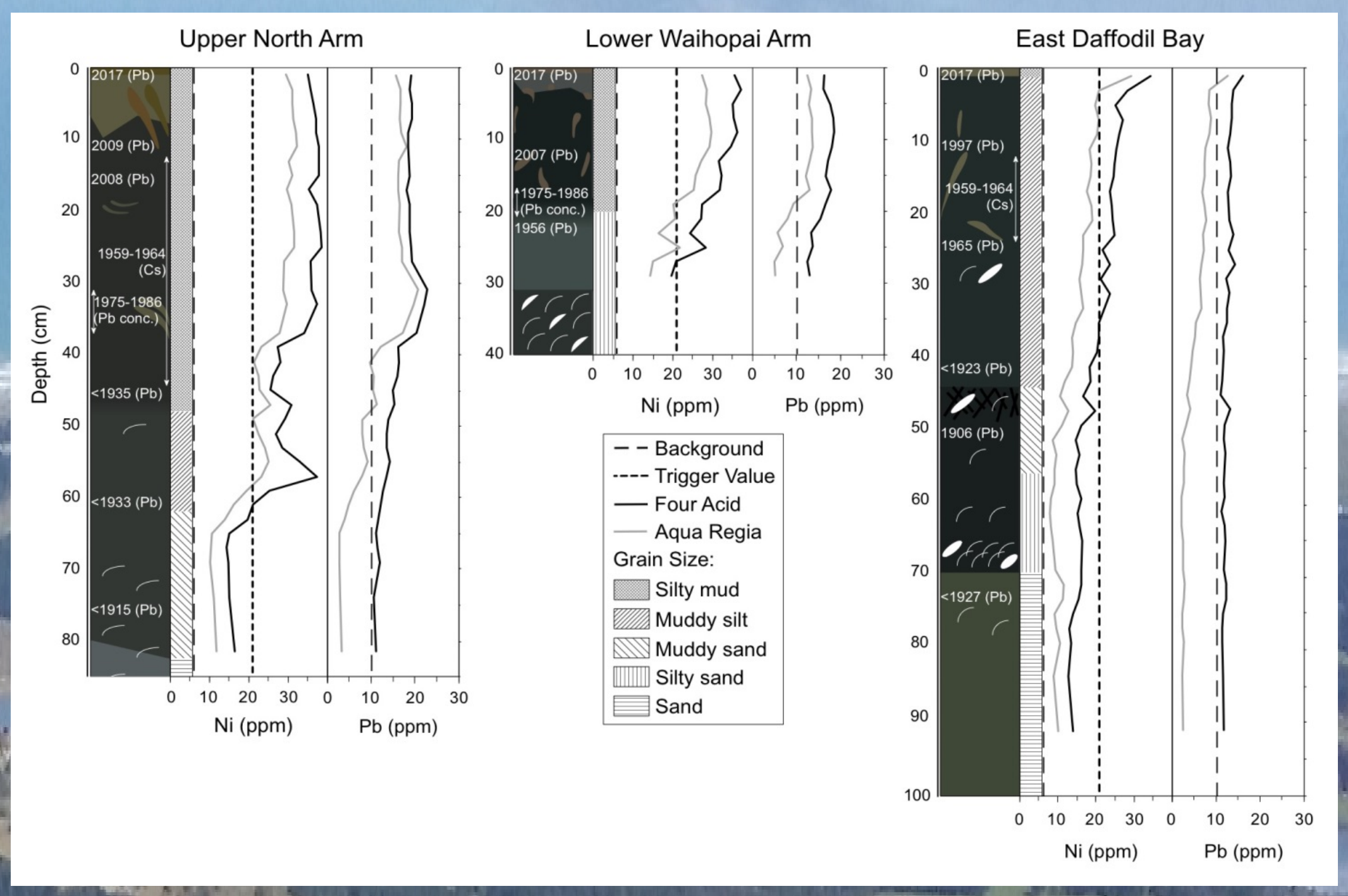

Figure 2. Down-core decreases in Ni and Pb concentrations of total (four acid) and partial (aqua regia) sediment fractions, showing the trigger value of Ni[b] and Ni and Pb background concentrations[c]. The core cartoons highlight down-core changes in colour, grain size, material present (shells, organic matter, burrow traces), and calculated ages (^{210}Pb and ^{137}Cs radioisotopes and Pb concentration).

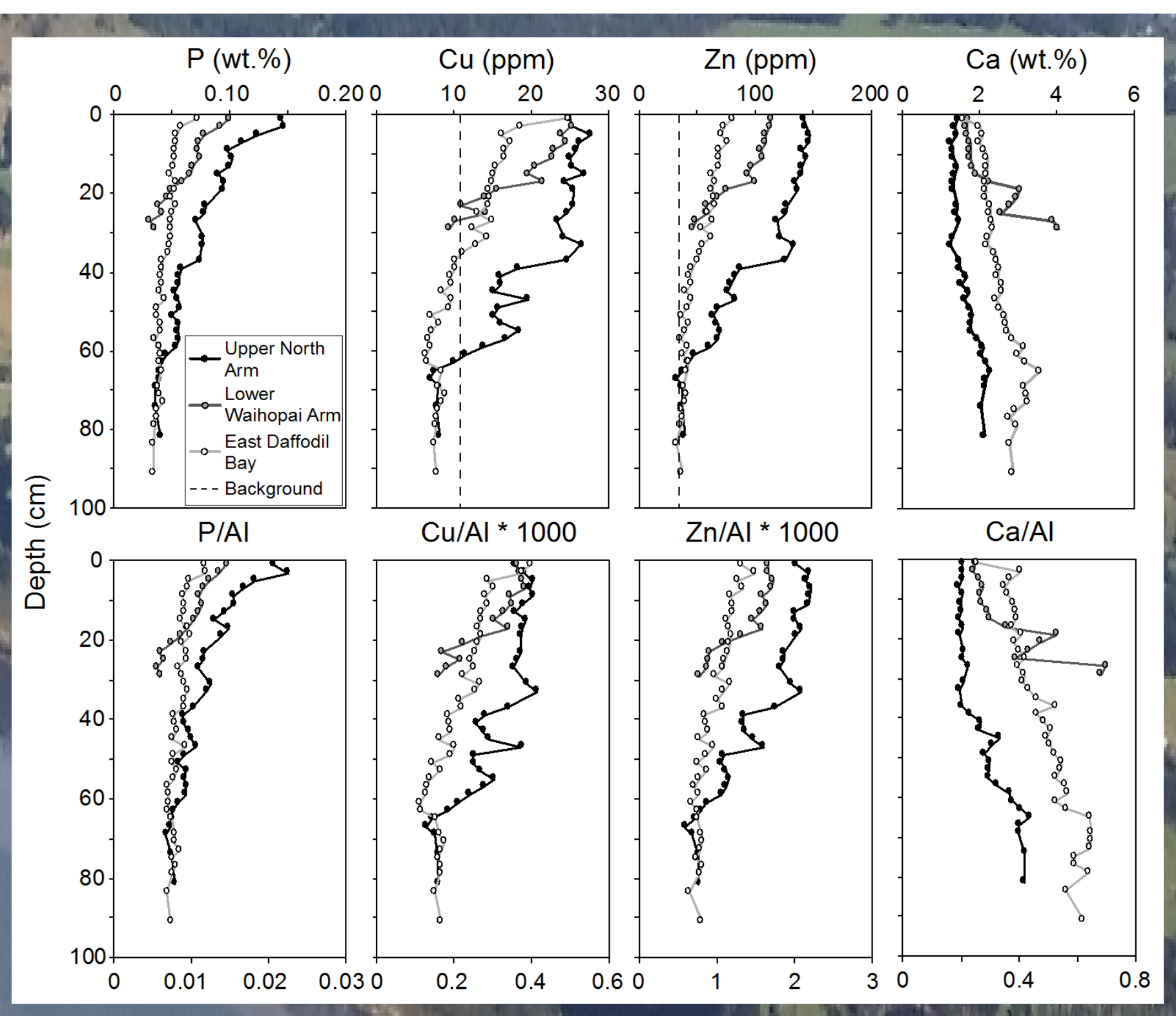

Figure 3. Total down-core concentrations with background values of Cu and Zn. Elements are normalised to Al to show "true" down-core trends by eliminating the effect of grain size variability.

Change in erosional process

Fallout radionuclides can identify the primary erosional processes that mobilise sediment into waterways[d]. The UNA and LW shallow cores and upper deep cores have 25-75% of sediment sourced from surface soil erosion, likely pasture soil (Fig. 4). Conversely, the lower deep UNA and LW cores have 50-75% sediment sourced from channel bank collapse. The upper DE deep core has up to 30% sediment sourced from surface soil erosion. ^{7}Be concentrations suggest minimal subsoil sources.

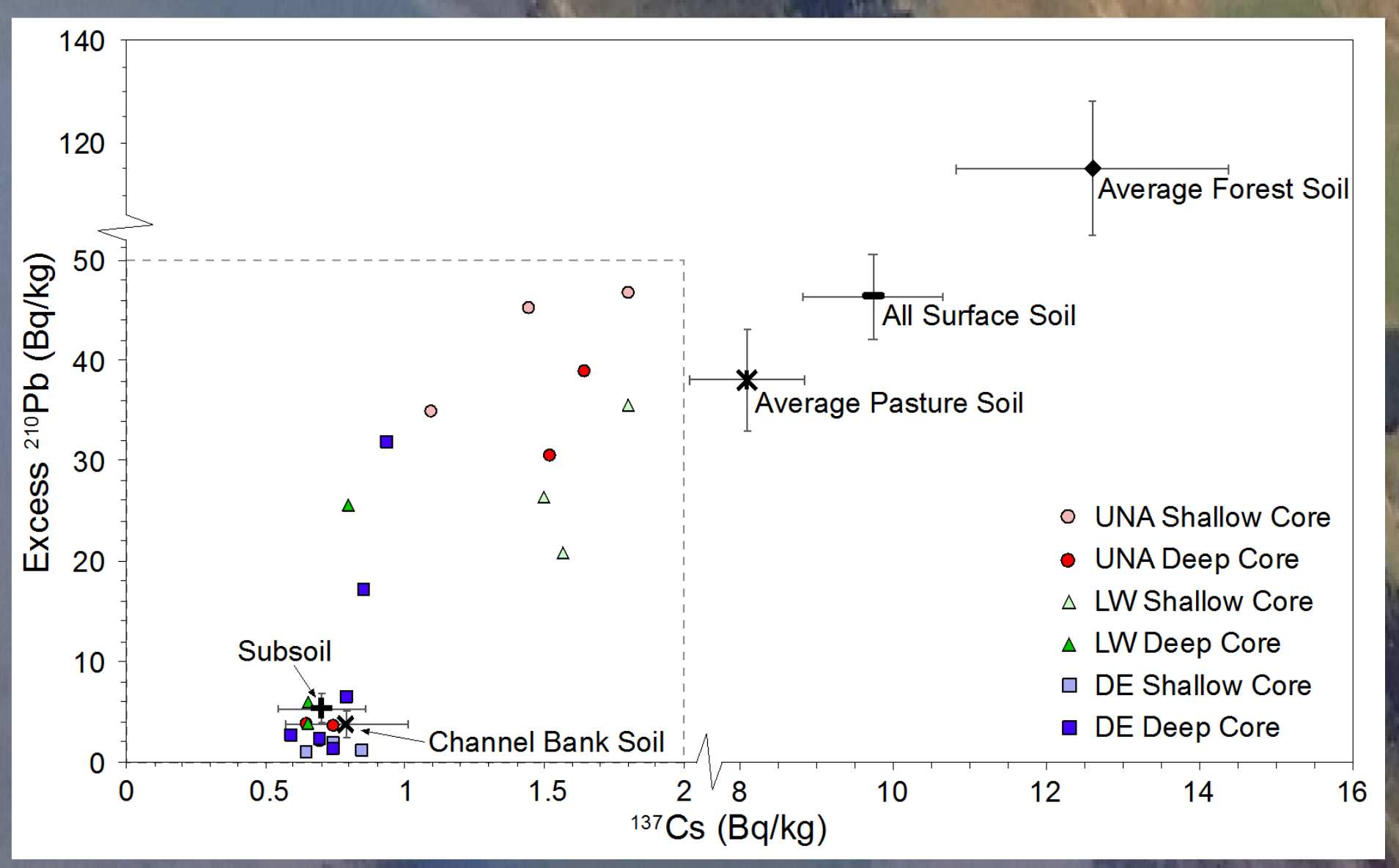

Figure 4. Plot of ^{137}Cs versus excess ^{210}Pb concentrations in sampled horizons and average reference materials that represent sheet erosion of surface soil, gully erosion of subsoil, and channel bank collapse[d].

Carbon stable isotopes

Terrestrial δ^{13}C → -28‰[a]

Marine δ^{13}C → -21‰ to -22‰[a]

Up-core decreases in δ^{13}C emphasize a transition from a marine-dominated source of organic-C to a terrestrial-dominated source. Between 1975-1986 (35 cm: UNA, 17 cm: LW), carbon becomes primarily terrestrial-sourced, irrespective of the consistent up-core increase in organic-C.

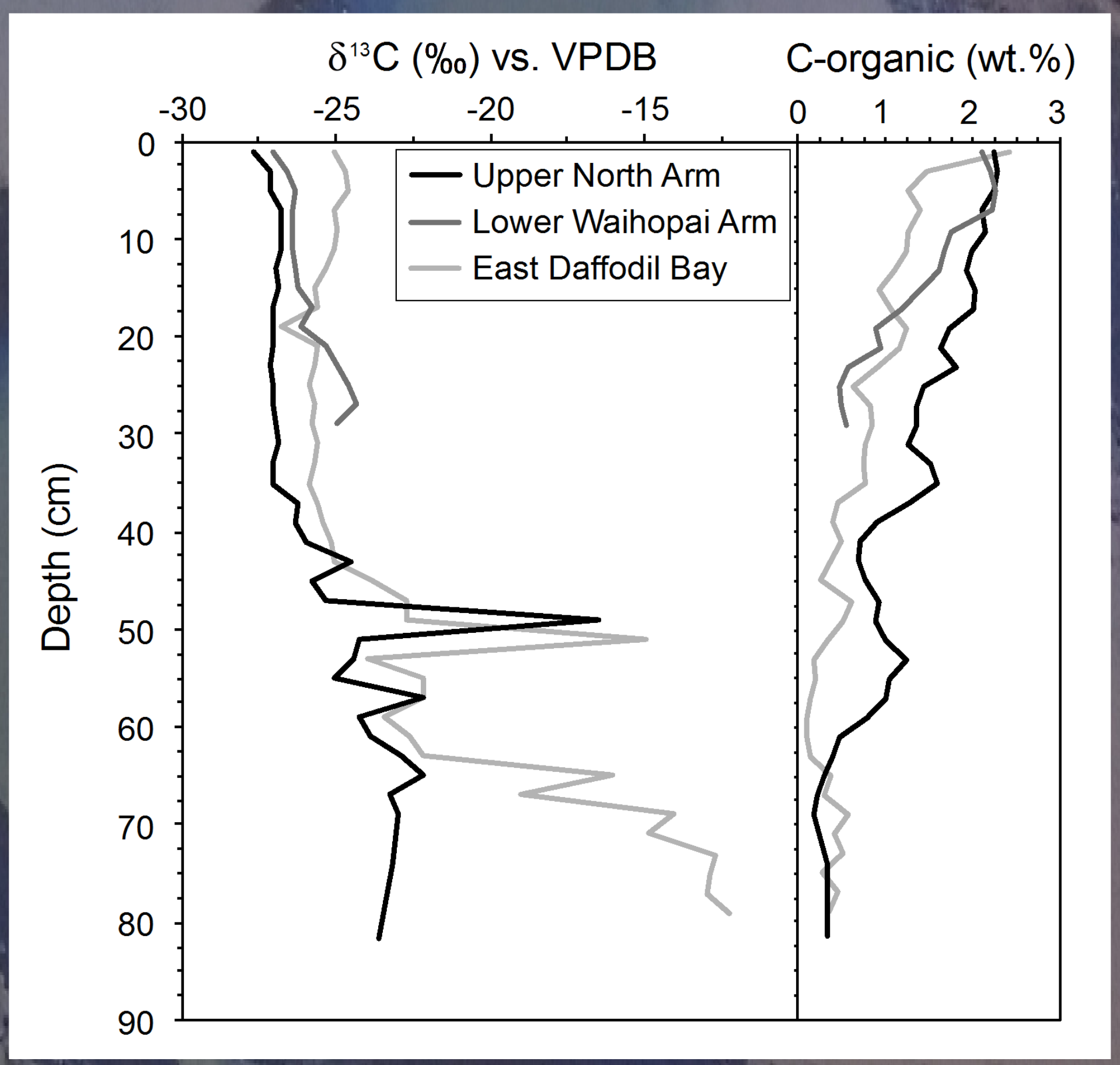

Figure 5. Down-core stable-C isotopic signatures and organic-C content.

Conclusions

1. Increased rate of fine-sediment accumulation up-core
2. Increased concentration of heavy metals and nutrients up-core
3. Change in dominant sediment sources from subsoil sources (historical) to surface sources (present)
4. Change from marine-dominated to terrestrial-dominated sources of sediment, especially after 1975-1986

References

[a] Alling, V., Humborg, C., Morth, C., Rahm, L., and Pollehne, F. 2008. Tracing terrestrial organic matter by S and C stable isotope signatures in a subarctic estuary. *Limnol. Oceanogr.* 53, 6: 2594-2602

[b] ANZECC and ARMCANZ. 2000. Australian and New Zealand guidelines for fresh and marine water quality. *National Water Quality Management Strategy*

[c] Cavanagh, J.E., McNeill, S., Arienti, C., and Rattenbury, M. 2015. Background soil concentrations of selected trace elements and organic contaminants in New Zealand. *Landcare Research Report 2440*

[d] Hancock, G. and Caitcheon, G. 2010. Sediment sources and transport to the Logan-Albert River estuary during the January 2008 flood event. *CSIRO: National Research Flagship*

[e] Pearson, L.K., Hendy, C.H., Hamilton, D.P., and Pickett, R.C. 2010. Natural and anthropogenic lead in sediments of the Rotorua lakes, New Zealand. *Earth and Planetary Science Letters*. 297: 536-544

[f] Robertson, B.M. and Stevens, L.M. 2007. New River Estuary 2007: Broad scale habitat mapping and sedimentation rate. *Wriggle Coastal Management Report*

[g] Robertson, B.M., Stevens, L.M., and Robertson, B.P. 2016. Nutrient/sediment loads and condition of Southland's shallow, intertidal dominated estuaries. *Wriggle Coastal Management Report*