Combined geochemical and geophysical studies of submarine groundwater discharge in Puget Sound, WA

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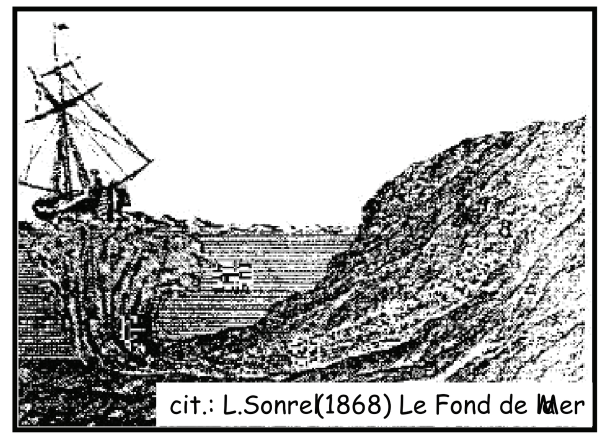
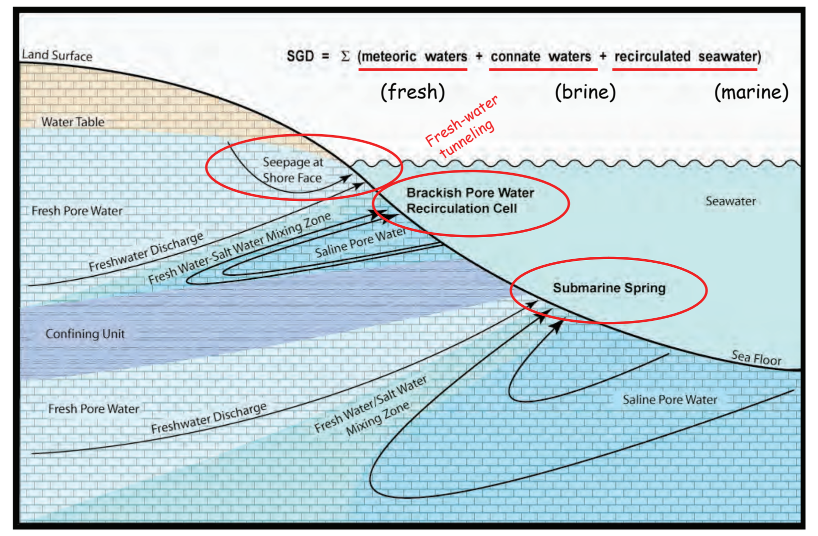
ABSTRACT

The discharge of groundwater into the ocean (submarine groundwater discharge, SGD) is recognized today as a major component in the exchange between land and sea. Submarine groundwater discharge can consist of both fresh water and recycled sea water, and this flow is expressed most often not through offshore spring vents, but as diffuse and ephemeral shore-proximal flow that is inherently difficult to quantify. The persistent discharge of coastal groundwater can be an important pathway for solute and contaminant transport from land to the coastal ocean. As a consequence, SGD and associated material loads should be taken into account in any calculation of water or constituent mass balance for coastal systems.

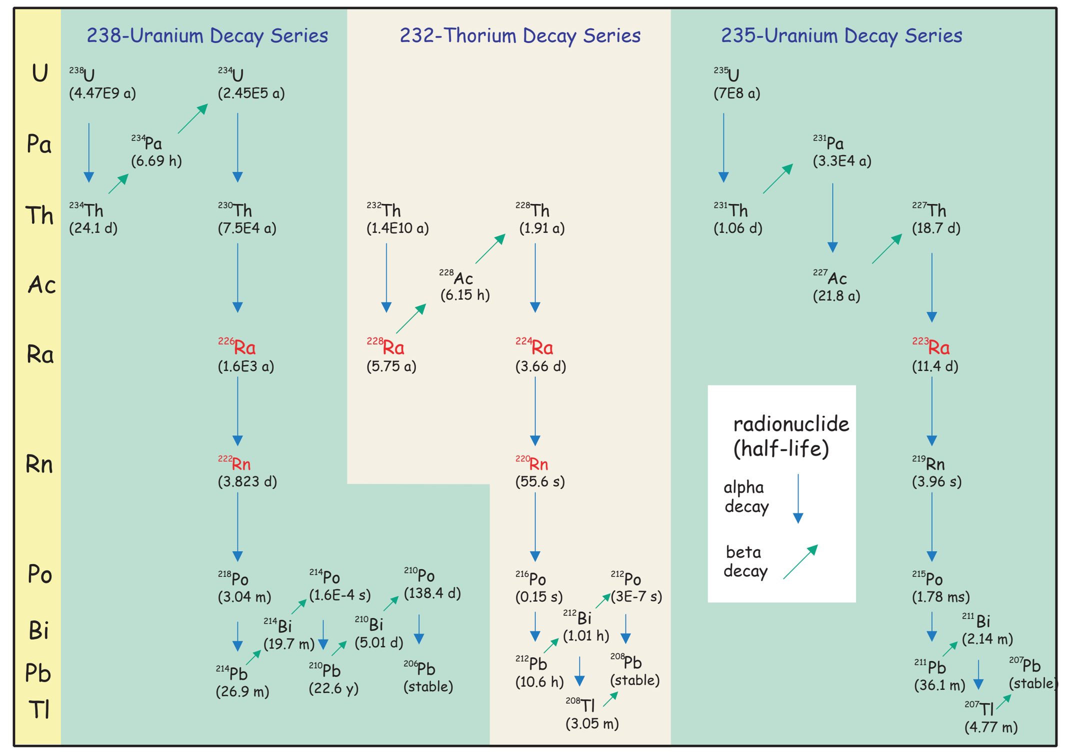
Ecological impacts of SGD are varied: elevated SGD-derived nutrient loads may serve to fuel biological activity, leading to possible coastal eutrophication or heightened algal bloom activity. Redox sensitive constituents may participate in tidally modulated oxidation-reduction reactions that can impact biological availability or toxicity. The coastal salinity regime may also be impacted by the discharge of fresher or saltier groundwater. Here we present geochemical and geophysical studies of SGD in select sites within Puget Sound (Hood Canal, Liberty Bay, and Skagit Bay) to evaluate the potential role of SGD in affecting the near-shore ecology.





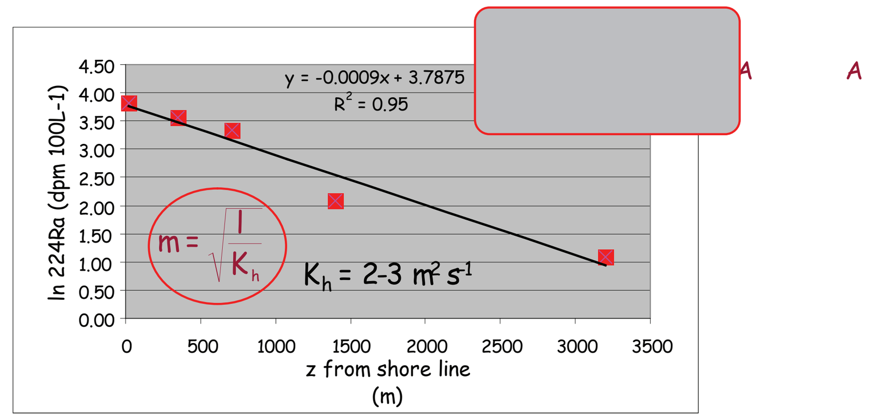
(1) Methods

Geochemcial Tracers

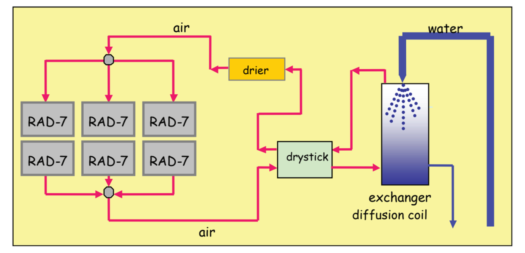


U/Th series radionuclides as submarine groundwater tracers

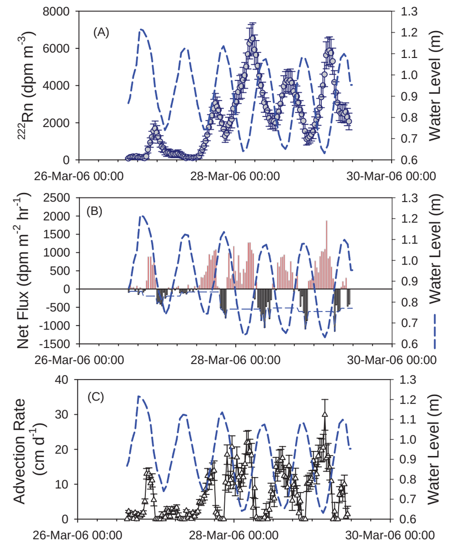
Mixing coefficient x 224Ra gradient = offshore flux must be balanced by coastal inputs as SGD. Divide by gw conc. for estimate of water flux



Short-lived Ra isotopes ($^{223,224}Ra$) as water mass mixing coefficients



Multiple 222Rn detectors plumbed in parallel for 'near' continuous coverage

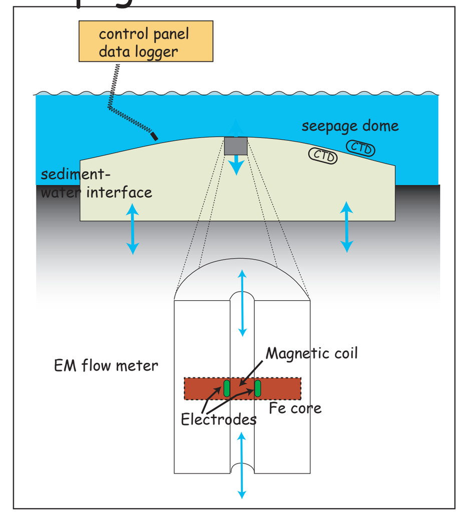


Mass balance of 222Rn to determine total (saline + fresh) SGD rate

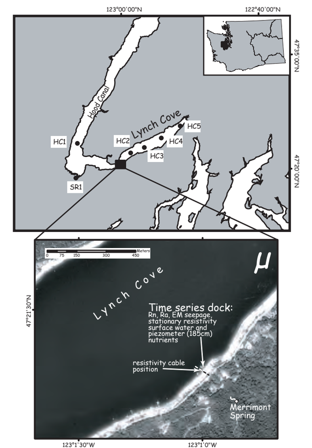
Geophysical Techniques

multi-electrode resistivity (res = elec cond^{-1})

electro-magnetic seepage meter



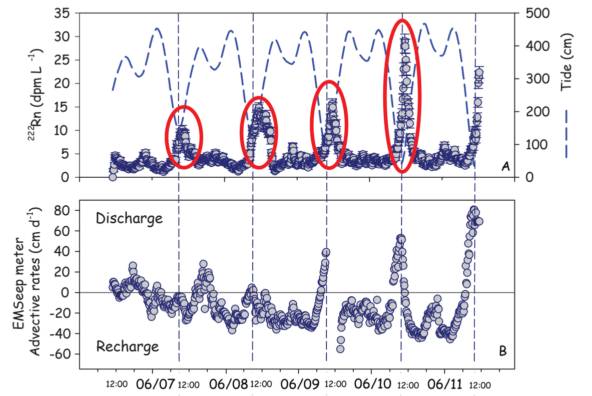
(2) Hood Canal



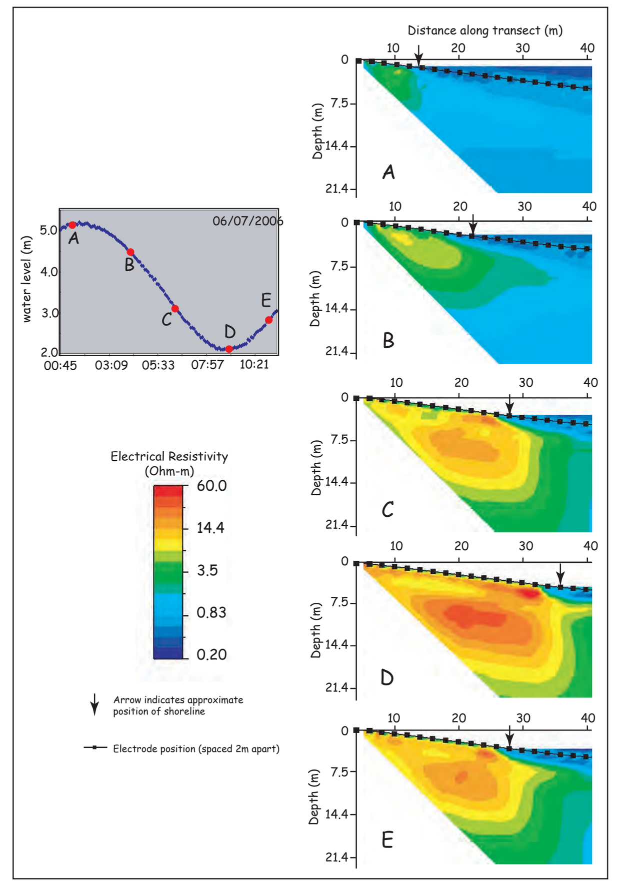
Is submarine groundwater discharge (SGD) important in a nutrient budget of Hood Canal?

If so, can we better quantify this 'missing' contribution?

Lynch Cove (Hood Canal) time series results



Shore-perpendicular time series resistivity

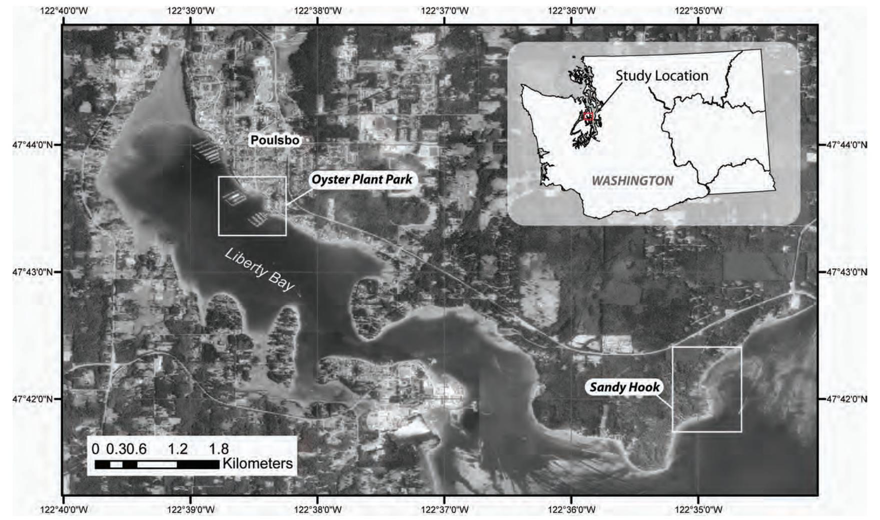


Lynch Cove (Hood Canal) SGD-derived nutrient loads

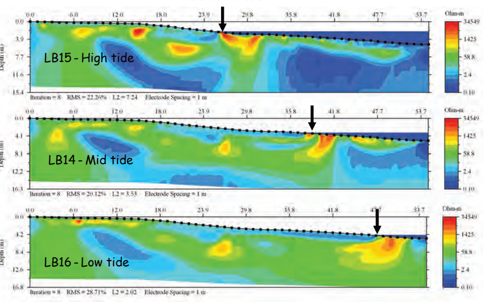
Approach	SGD $m^3 s^{-1}$	NH_4	Si	PO_4	NO_3+NO_2	DIN	DON	TDN
		mol d^{-1}						
Rn[a]	28	28	3.6×10^5	2.6×10^3	5.9×10^4	5.9×10^4	1.3×10^4	7.2×10^4
Ra[b]	24 (86%)[c]	24	3.0×10^5	2.2×10^3	5.0×10^4	5.0×10^4	1.1×10^4	6.0×10^4
Seep water[d]	28	240	4.2×10^5	1.1×10^4	1.7×10^4	1.7×10^4	1.9×10^4	3.6×10^4
Manual seepmeter[e]	3.4	28	5.0×10^4	1.3×10^3	2.0×10^3	2.0×10^3	2.3×10^3	4.3×10^3
Mass balance[f]	1.2[d]	--	--	--	--	4.2×10^3	--	--
Rivers/ Streams[g]	--	--	--	--	--	2.1×10^3	--	--
Atmospheric Deposition[g]	--	--	--	--	--	3.3×10^2	--	--

Summary:
SGD-derived nutrients are a significant component of the overall nutrient budget into Lynch Cove (Hood Canal)

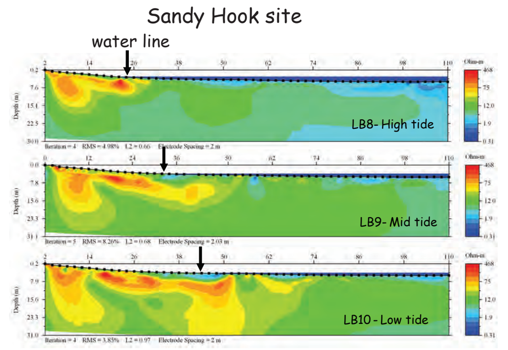
(3) Liberty Bay

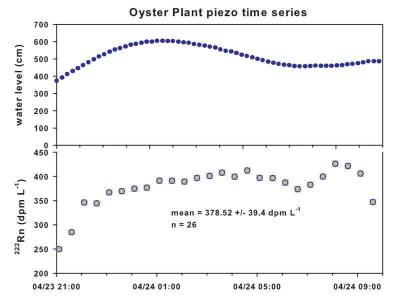


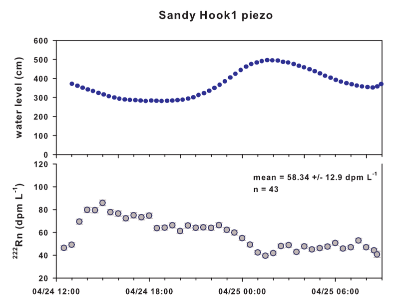
Oyster Plant site

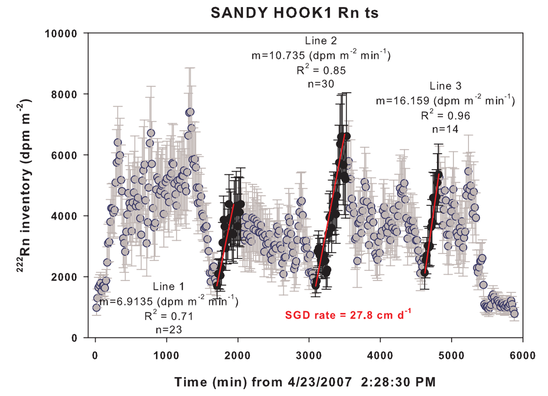


Sandy Hook site

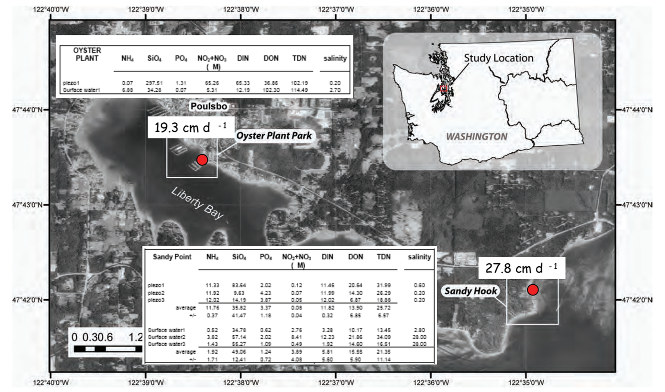








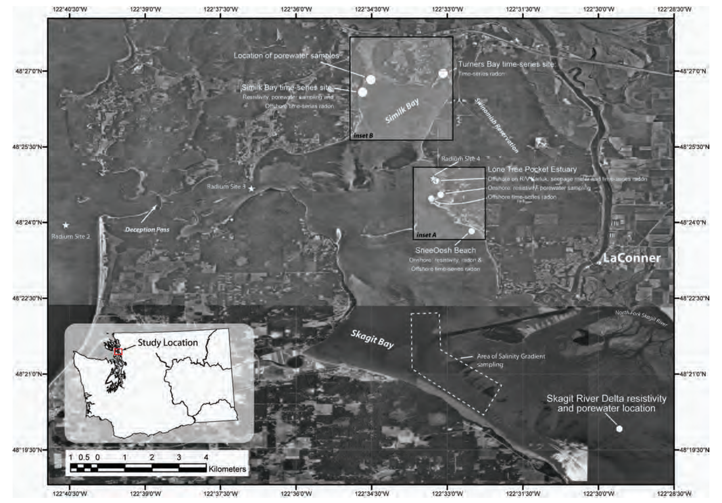
Liberty Bay: Rn-derived SGD rates



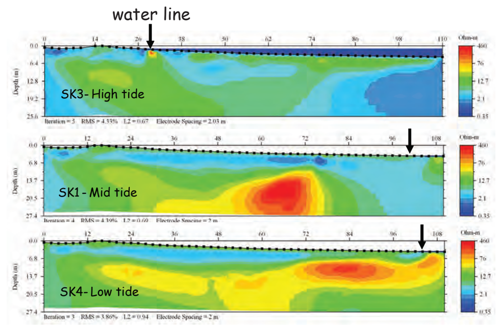
Liberty Bay: Rn-derived SGD nutrient loading estimates

	NH_4	SiO_4	PO_4	NO_2+NO_3	DIN	DON	TDN
	(mM m^{-2} d^{-1})						
Oyster Plant	0.0	57.4	0.3	12.6	12.6	7.1	19.7
Sandy Hook (EM)	2.3	2.7	0.7	0.0	2.3	1.3	3.6
Sandy Hook (Rn)	3.3	10.0	0.9	0.0	3.3	3.9	7.2

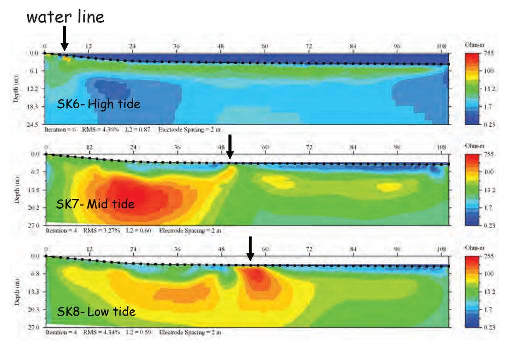
(4) Skagit Bay

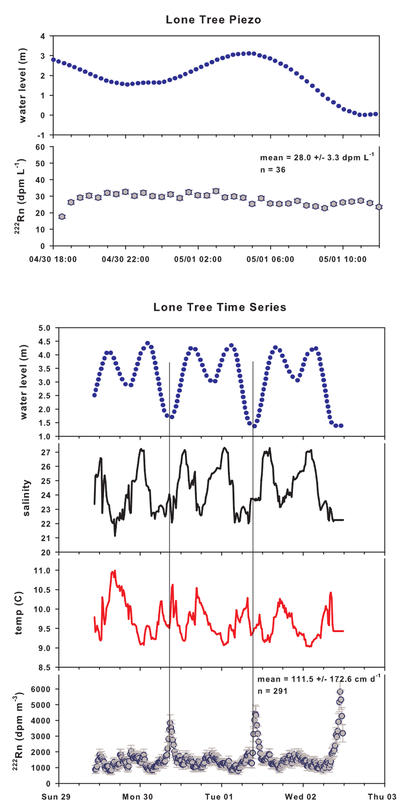


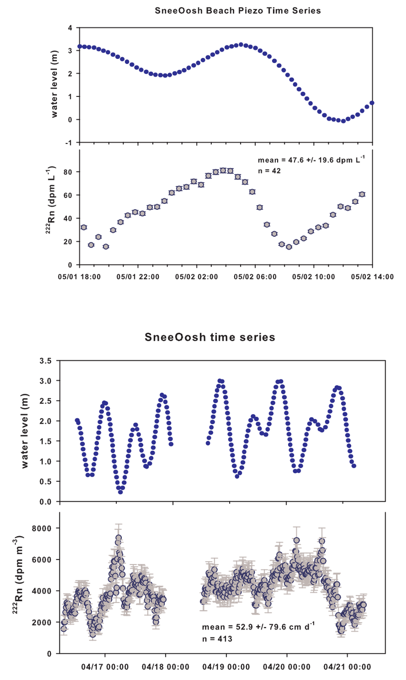
Lone Tree site (pocket estuary)



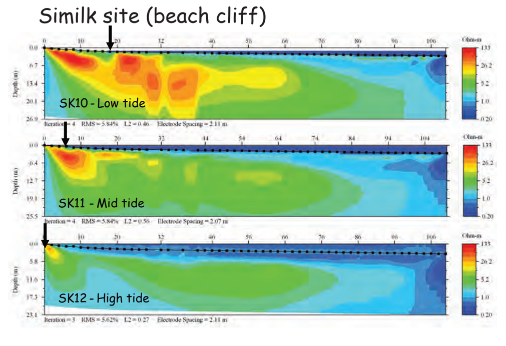
SneeOosh site (beach)



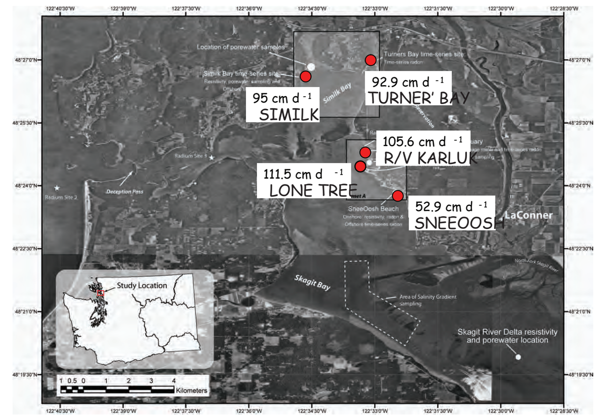




Similk site (beach cliff)



Skagit Bay: Rn-derived SGD rates



Skagit Bay: Rn-derived SGD nutrient loading estimates

	NH_4	SiO_4	PO_4	NO_2+NO_3	DIN	DON	TDN
	(mM m^{-2} d^{-1}))						
LT dingy	0.6	161.5	2.1	40.6	41.1	42.2	83.3
LT Karluk	0.5	152.9	2.0	38.4	38.9	39.9	78.9
Turner' Bay	0.5	134.5	1.7	33.8	34.3	35.1	69.4
SneeOosh	0.3	36.2	1.8	44.6	44.9	21.7	65.4
Similk	43.6	135.7	2.8	0.0	43.6	5.6	49.2

Summary:
Results of SGD rates and associated SGD-derived nutrient loads can be interpreted in terms of a coastal typology that may provide insights into broader scale SGD impacts on the coastal geomorphology and ecology.

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