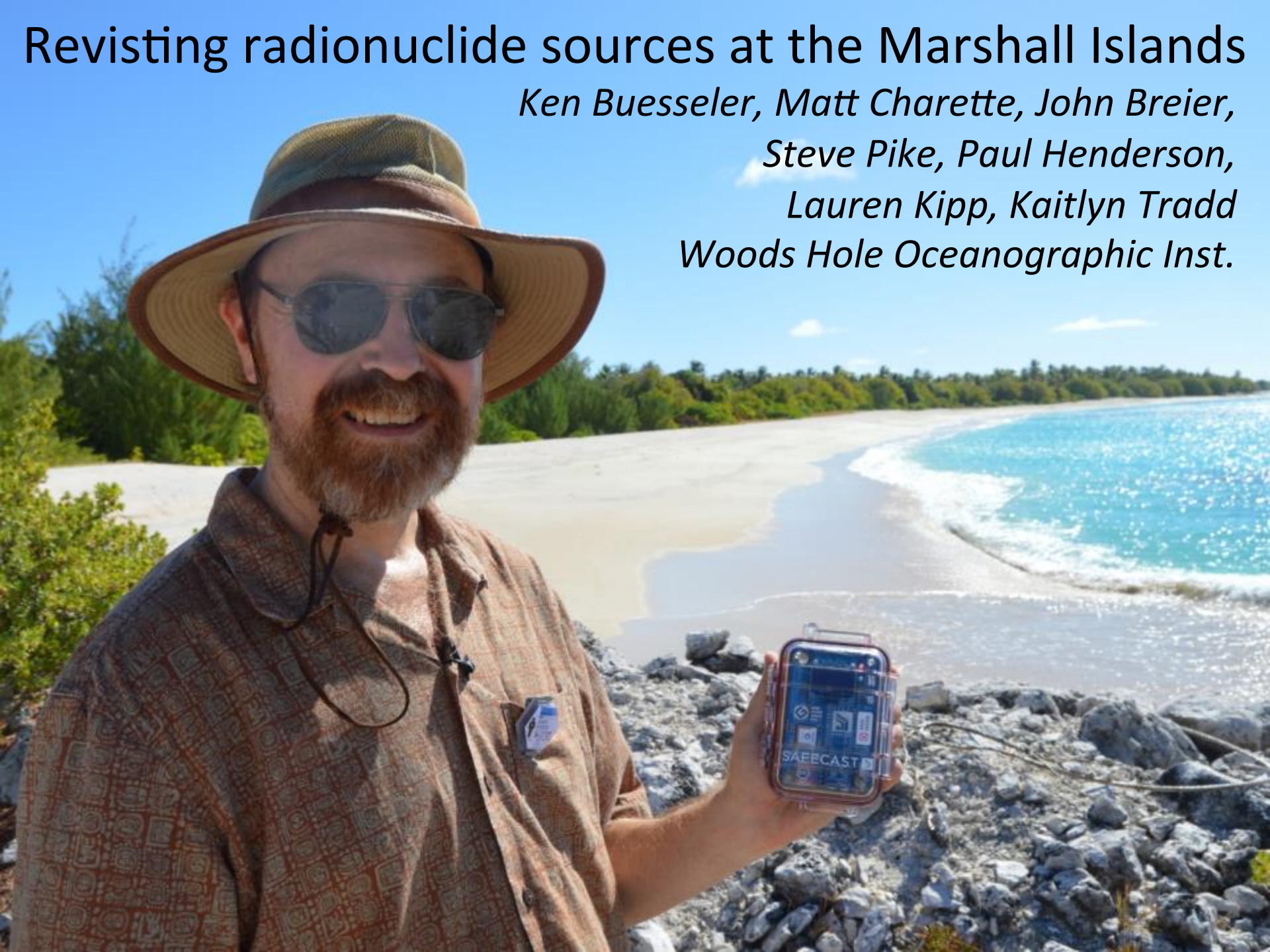
Revisting radionuclide sources at the Marshall Islands

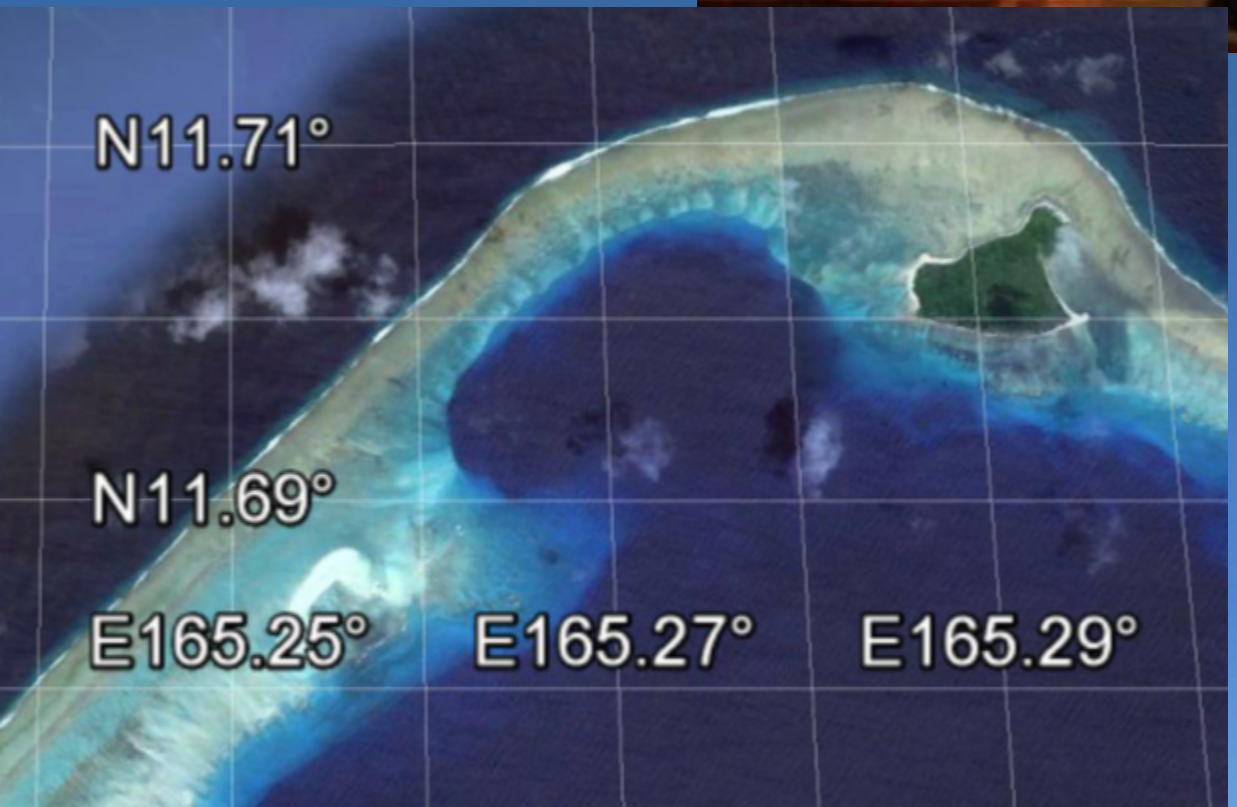
Ken Buesseler, Matt Charette, John Breier,
Steve Pike, Paul Henderson,
Lauren Kipp, Kaitlyn Tradd
Woods Hole Oceanographic Inst.



Marshall Islands- ground zero for US nuclear testing

Baker 1946

Bravo
First H bomb
Bikini 1954



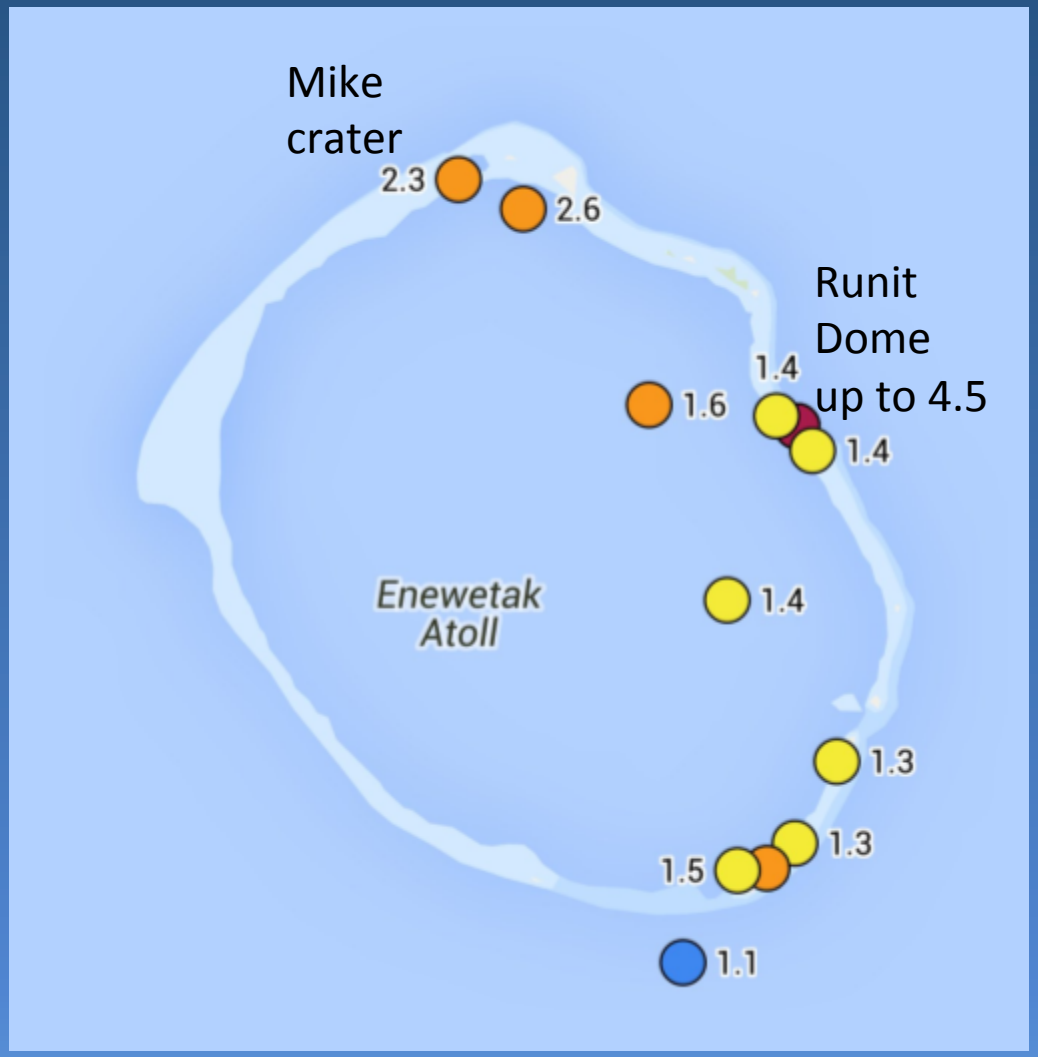
Bravo site
2015

Bikini- Bravo Crater

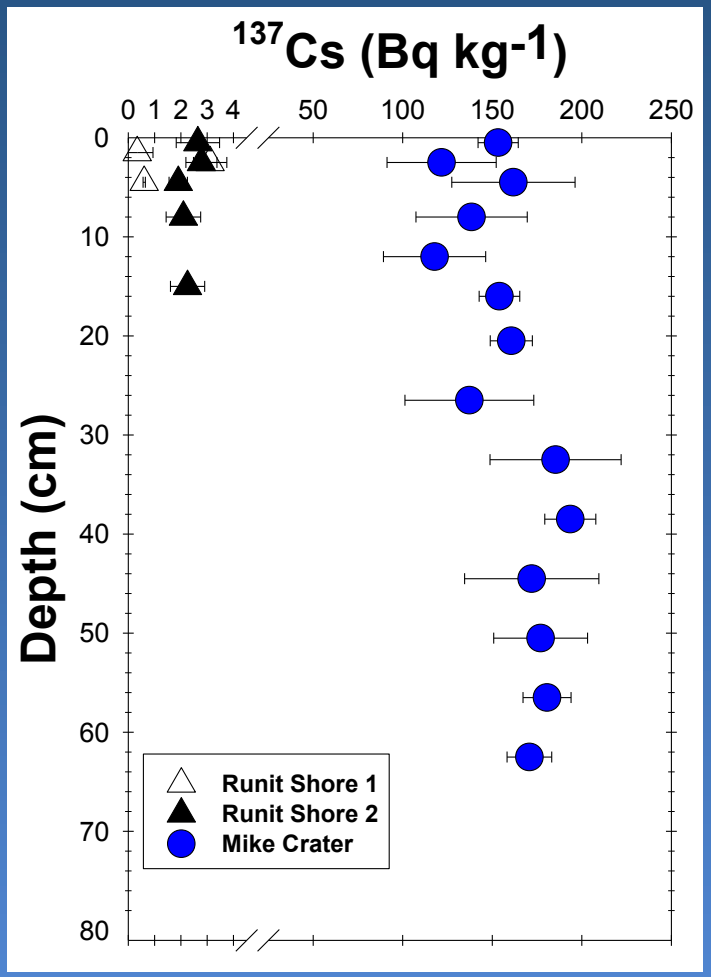
Enewetak-Runit dome

Enewetak Cesium-137

Water activities Bq m^{-3}



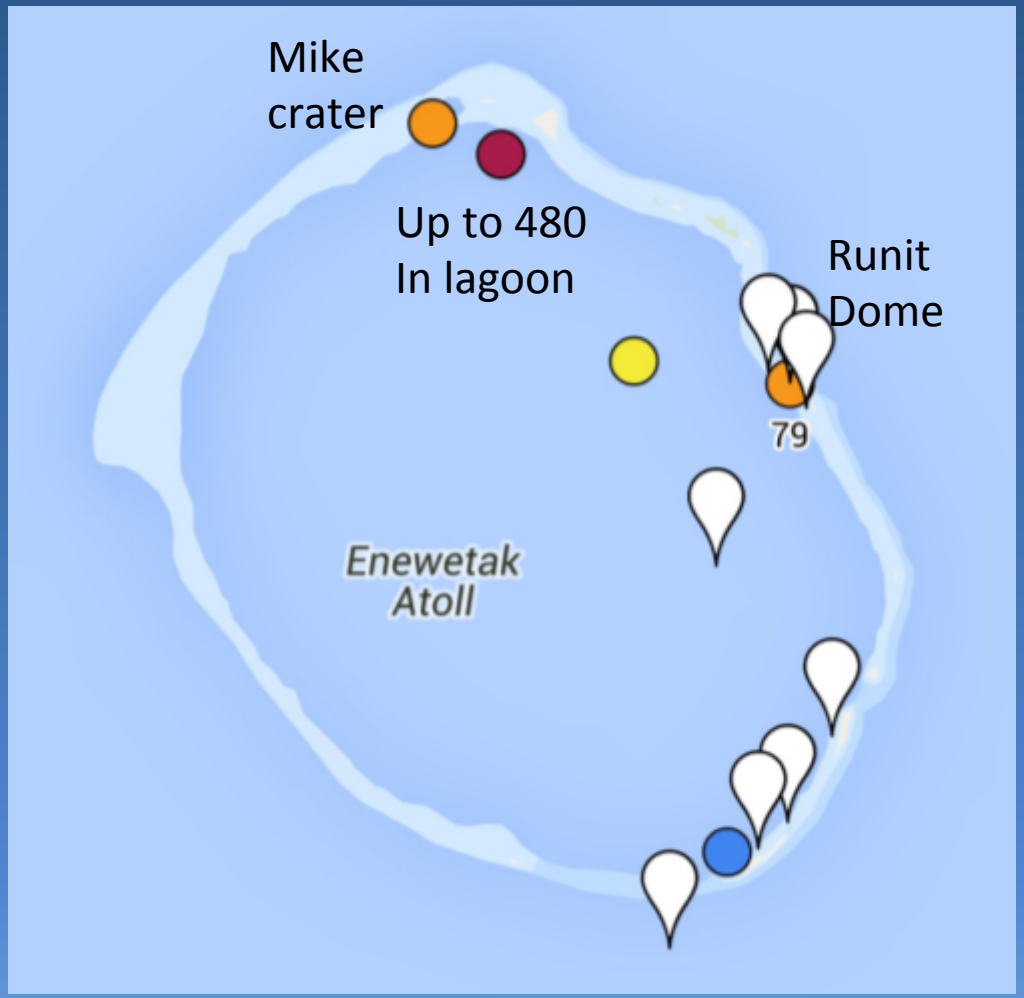
Sediment activities Bq kg^{-1}



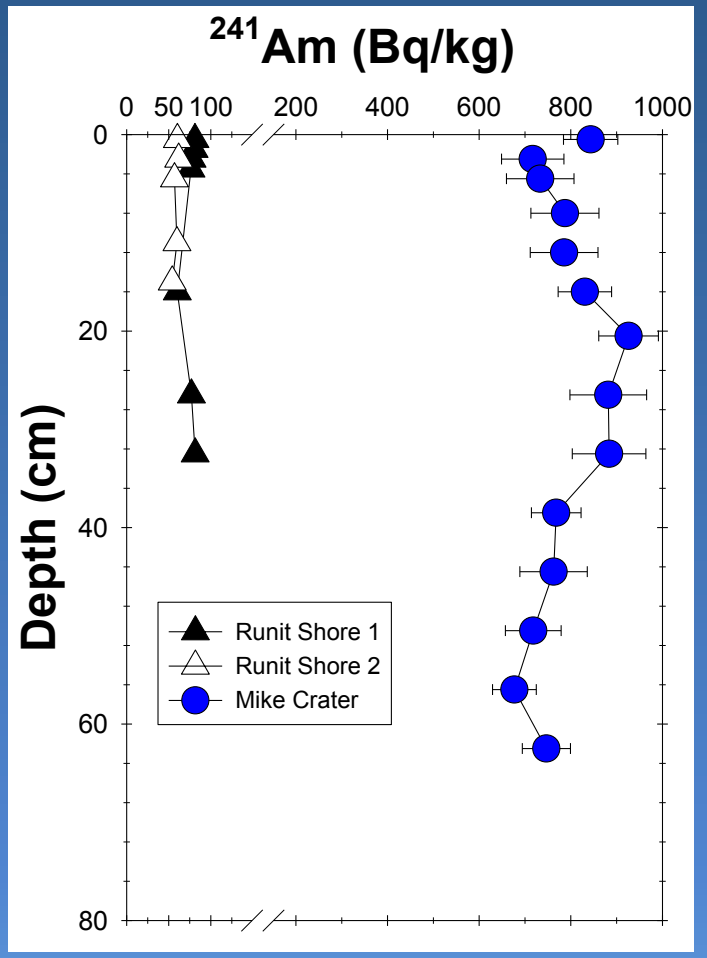
Enewetak Americium-241

(from decay of plutonum-241 t ½ = 14 yr)

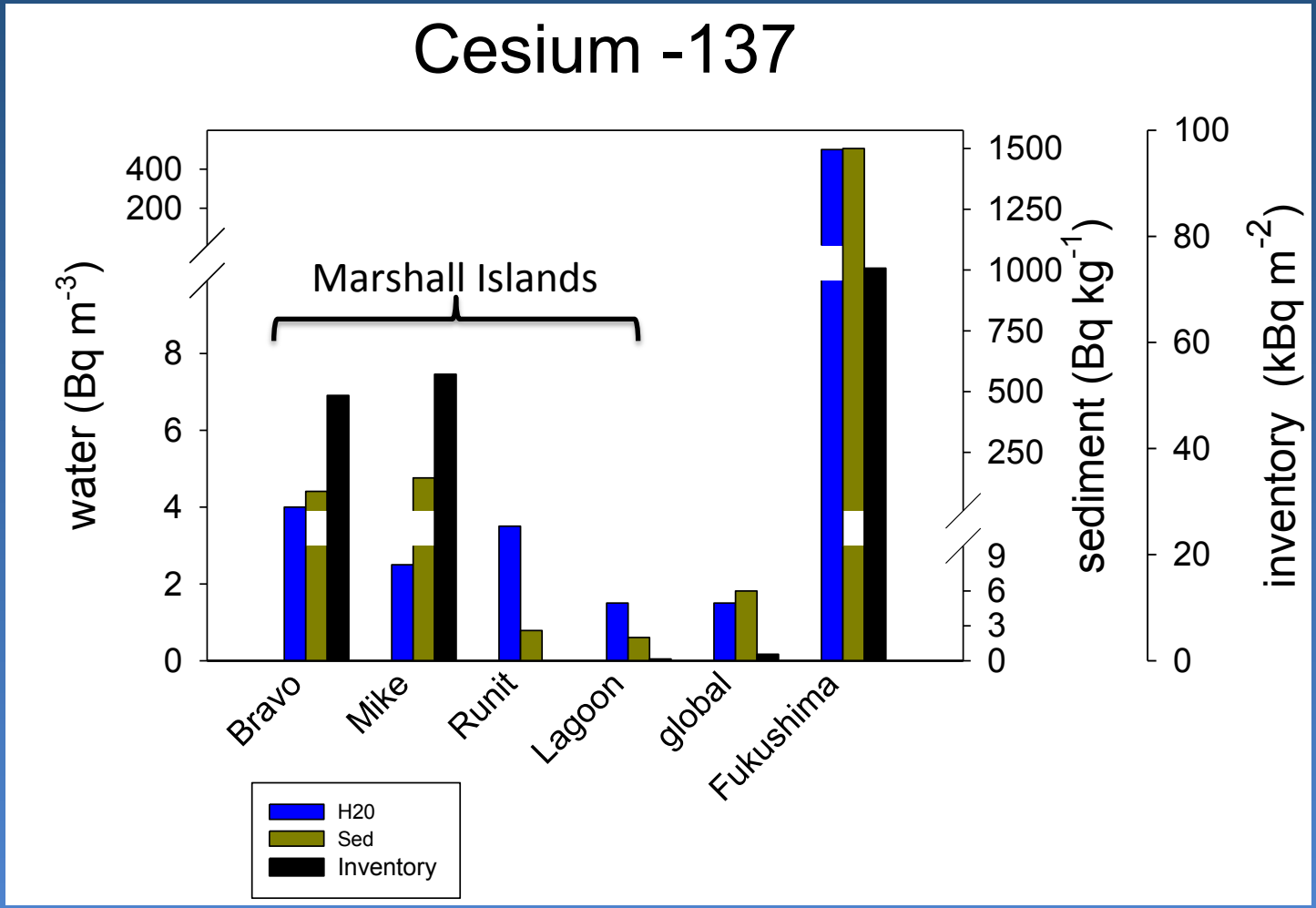
Water activities (est.) mBq m^{-3}



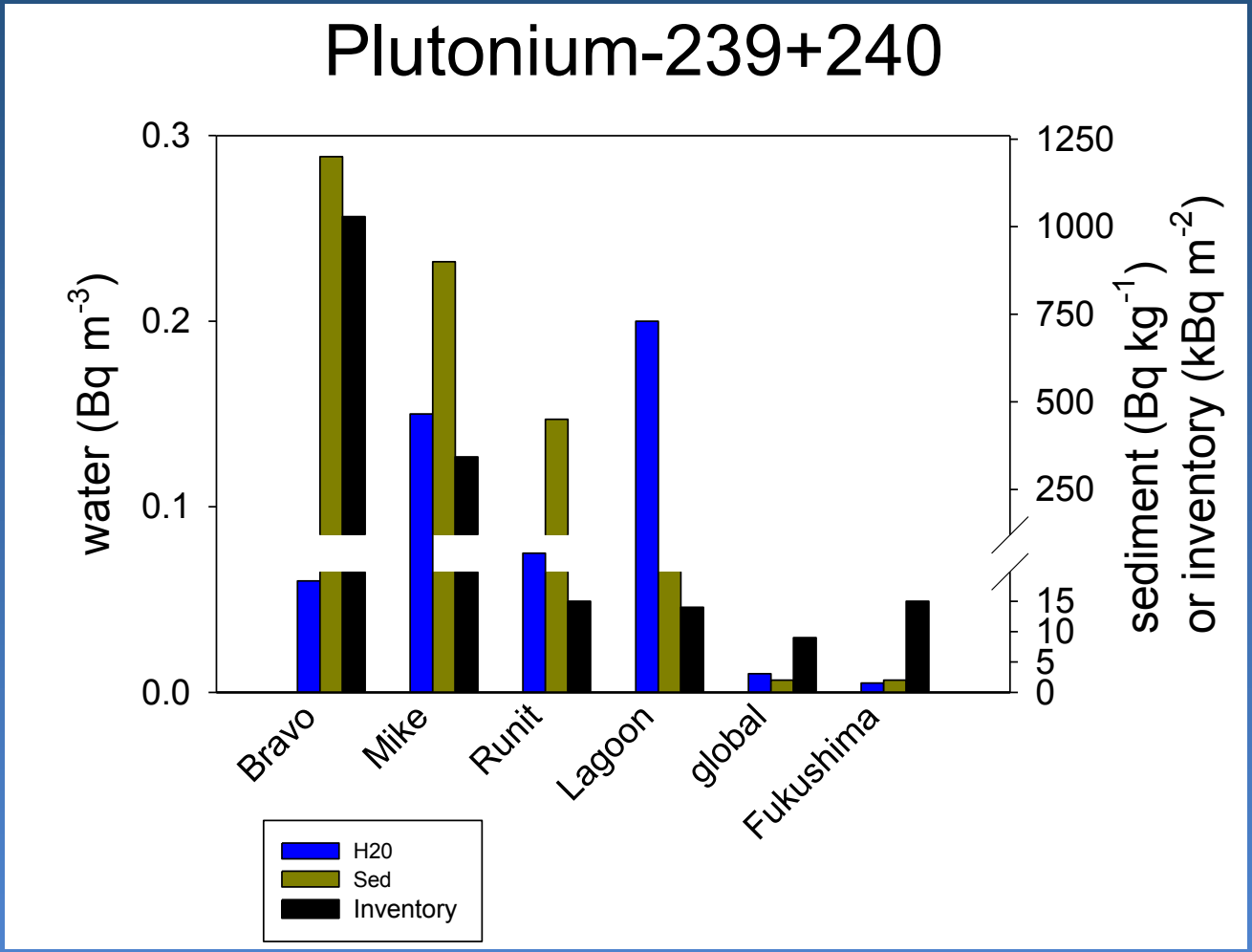
Sediment activities Bq kg^{-1}



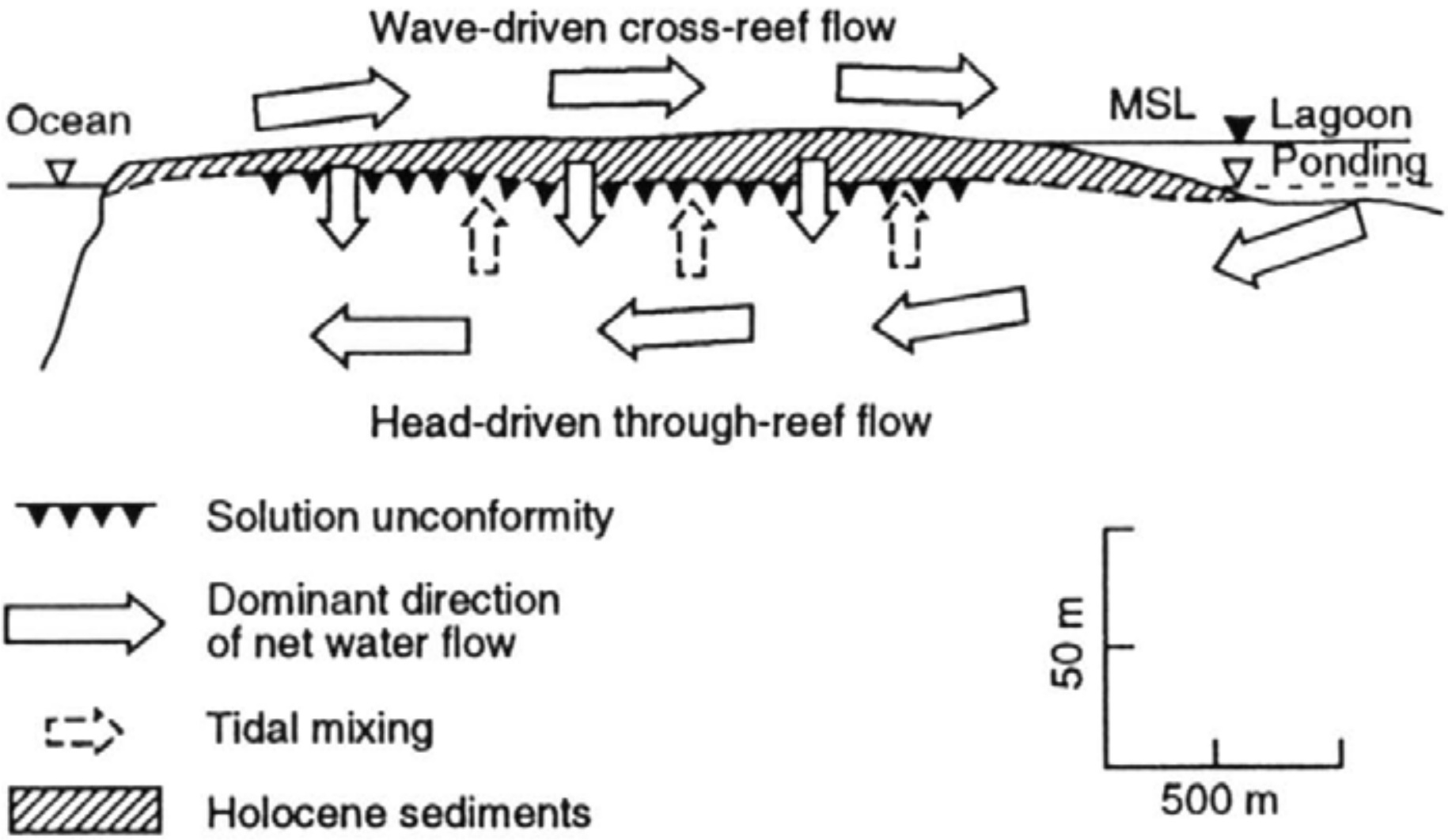
Marshall Islands- how does it compare?



Marshall Islands- how does it compare?



Hydrogeology of Enewetak Atoll



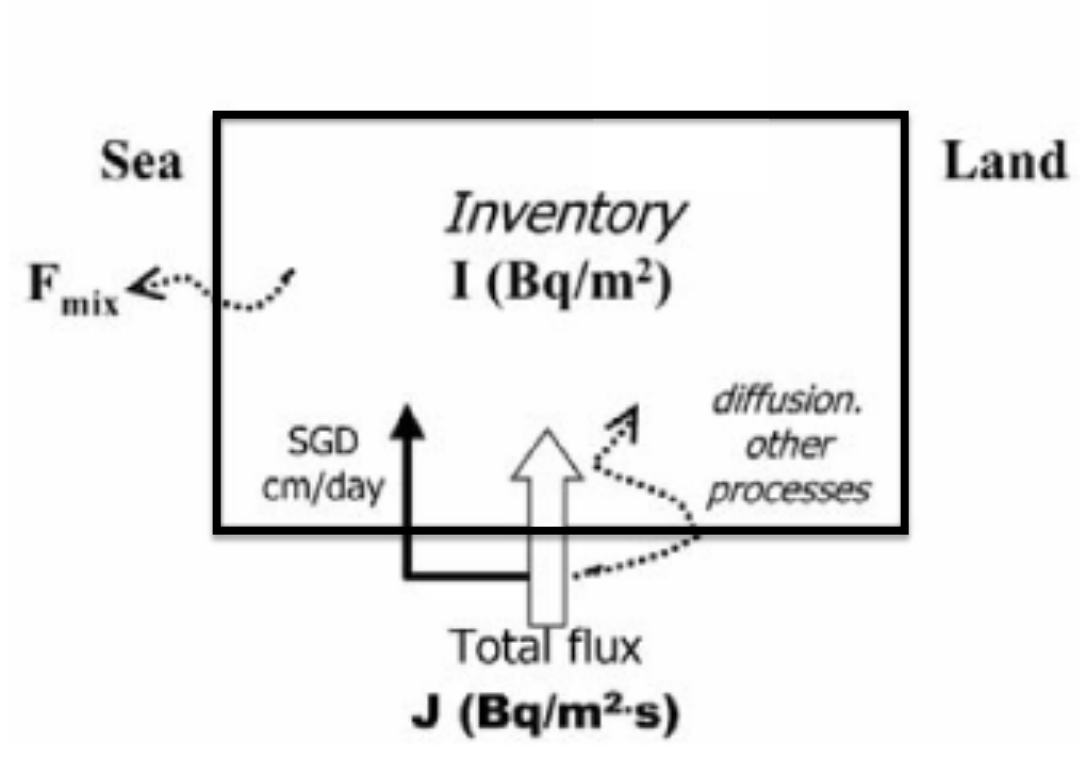
Lagoon Flushing Times (T_W)

Location	Flushing Time (d)	Method	Reference
Bikini Atoll	37 (Jan. 2015)	Ra isotopes	This study
	39 (winter) 80 (summer)	Field measurements-scale lab model	Von Arx (1948)
	17 (Jul. 1946)	Radioisotopes	Ford (1949)
Enewetak Atoll	16 (Jan. 2015)	Ra isotopes	This study
	28 (n/a)	Circulation box model	Atkinson et al. (1981)
Majuro Atoll	15	Tidal Current Model	

At steady-state, lagoon export fluxes for 137-Cs and 241-Am can be calculated as:

$$\text{Flux (Bq/d)} = (A_{lagoon} - A_{Pacific}) * V_{lagoon} / T_W$$

Submarine Groundwater Discharge using radium isotopes ($m^3/m^2/d$)



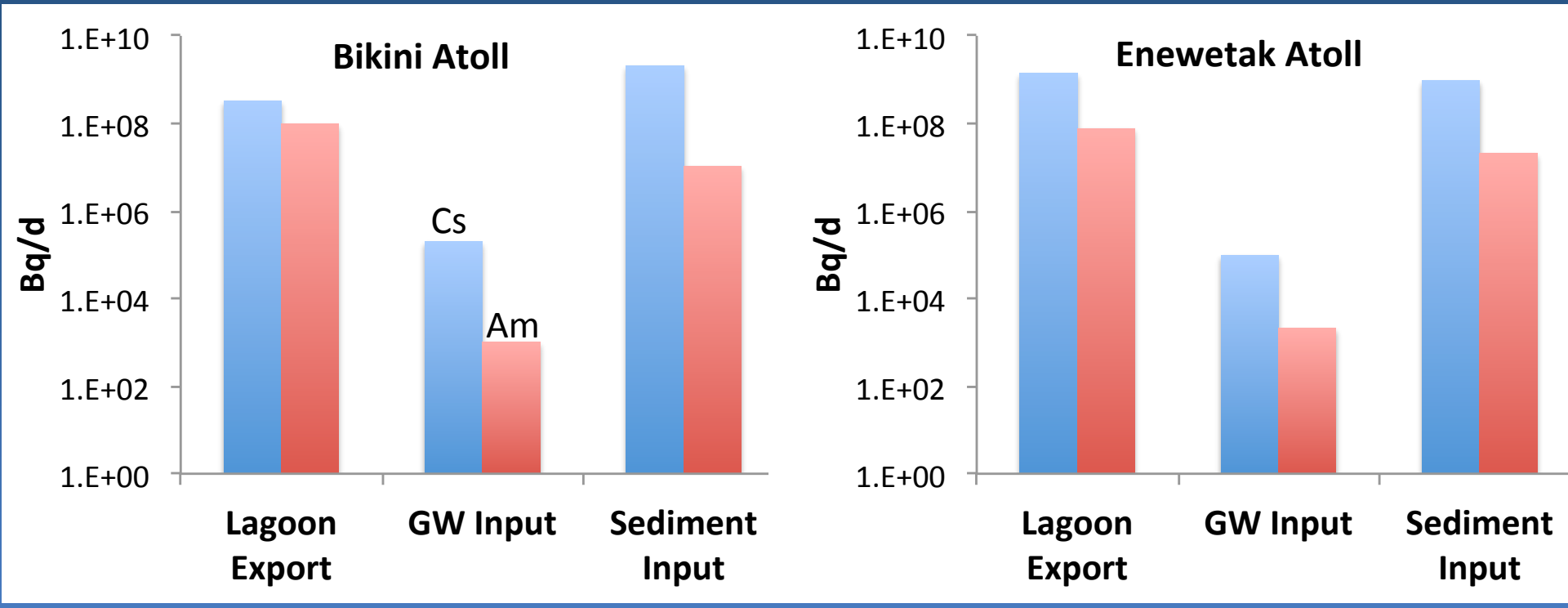
Credit: Burnett and Dulaiova (2003)

Lagoon groundwater 137-Cs and 241-Am inputs can be calculated as:

$$\text{SGD Flux (Bq/d)} = \text{SGD} * \text{Area}_{SGD} * A_{GW}$$

Location	^{224}Ra	^{223}Ra	^{226}Ra	Average
Bikini Atoll	5.6	3.1	1.2	3.3
Enewetak Atoll	1.1	2.7	2.1	2.0

Lagoon 137-Cs and 241-Am Sources and Sinks (Bq/d)



- Groundwater inputs too small to be main source of both ^{137}Cs and ^{241}Am
- Lagoon & crater sediments are likely source of water column Cs and Am (calculated here assuming Ra isotopes apply to entire lagoon)

Marshall Islands today

Ongoing source of radionuclides to the N. Pacific
- lagoon waters show elevated activities
- bigger source for Pu than Cs to N. Pacific
- Pu isotopes show ongoing long range transport from MI

Lagoon and crater sediments are likely source
- highest water column levels just above seafloor in craters

Seafloor sediments are largest radionuclide inventory
- well mixed to >80 cm (most prior inventories to 20-30 cm)

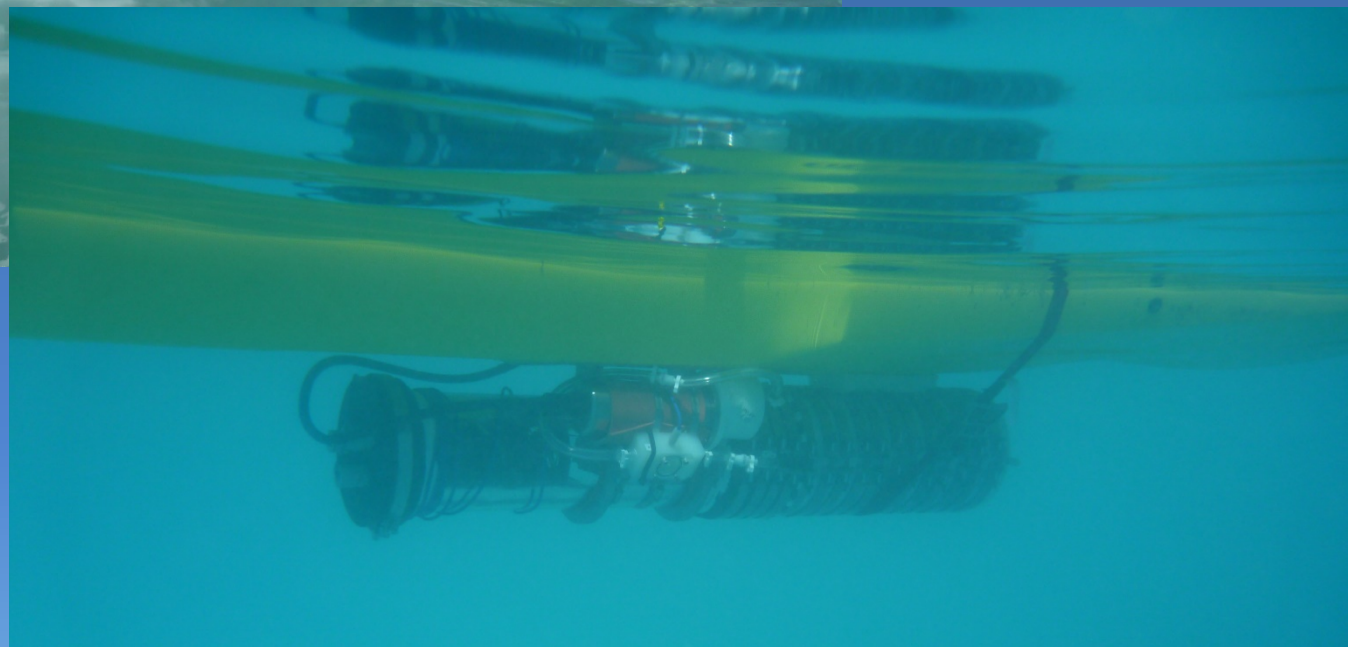
Groundwater inputs can be quantified with radium isotopes
- need more than single snap shot and limited locations
- GW levels of Cs, Am (and likely Pu) elevated

Plutonium isotopes will separate Runit Pu from other sources

Marshall Islands Future?

Jet-Yak

Autonomous cesium sampler

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Republic of the Marshall Islands
enewetak@ntamar.net

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Bikini - Cesium 137 in early 1970's

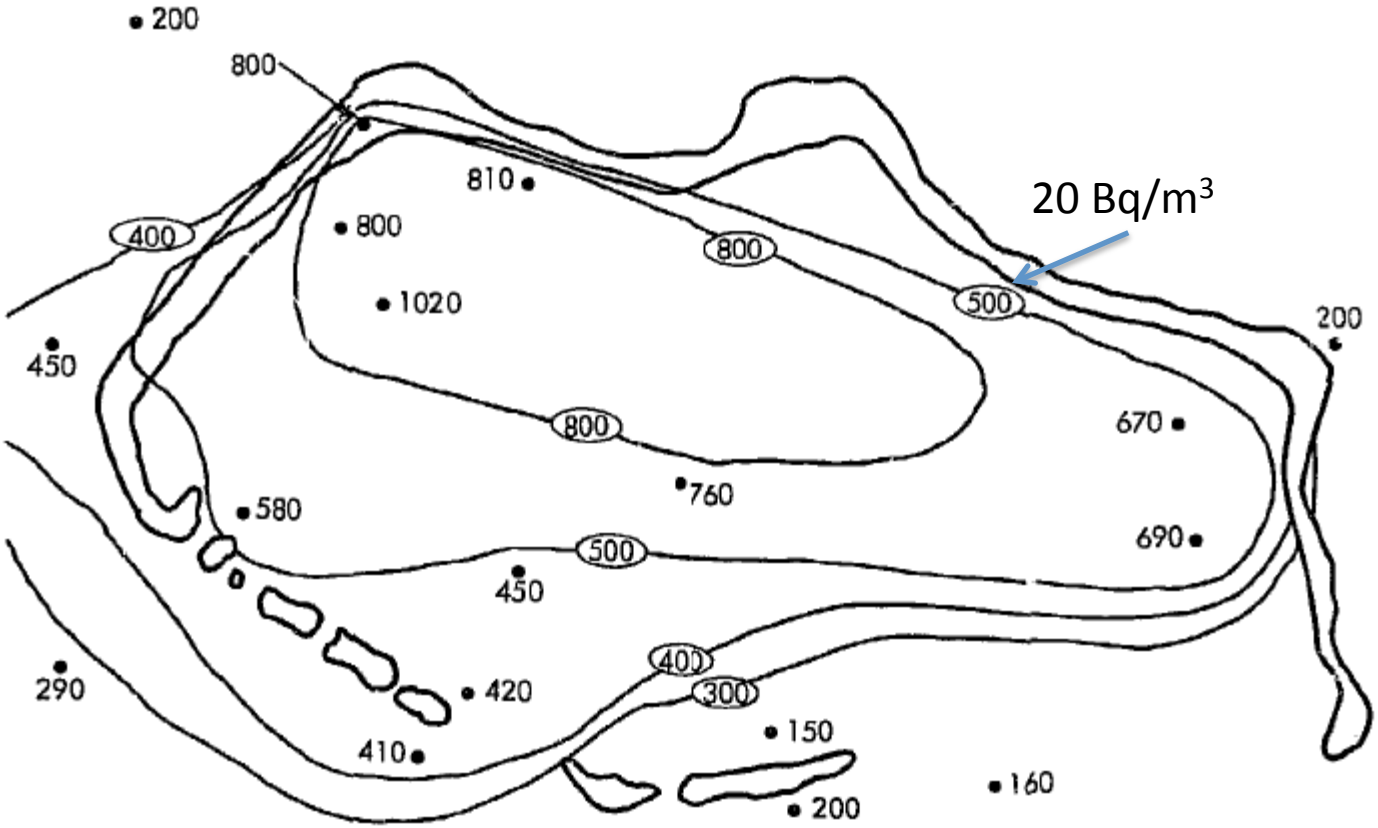

Fig. 12. Bikini lagoon: surface concentrations and isolines of $^{239,240}Pu$ (upper) and ^{137}Cs (lower). All values are in fCi/kg.

20 Bq/m^3 = more than 100 times less than US drinking water limit
= 10 times seawater in Woods Hole in 2015