Sediment-Laden Ice: Is it a Serious Impediment to Subsurface Tidal Turbines in Minas Passage?

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The Ice Phenomena of the Bay of Fundy

Within and hour or so of the flood tide the estuary is seen to be full of masses of floating ice, mud-stained and some times, but not often, loaded with earth, stones, or pieces of marsh.

Henry Y. Hind, 1875.

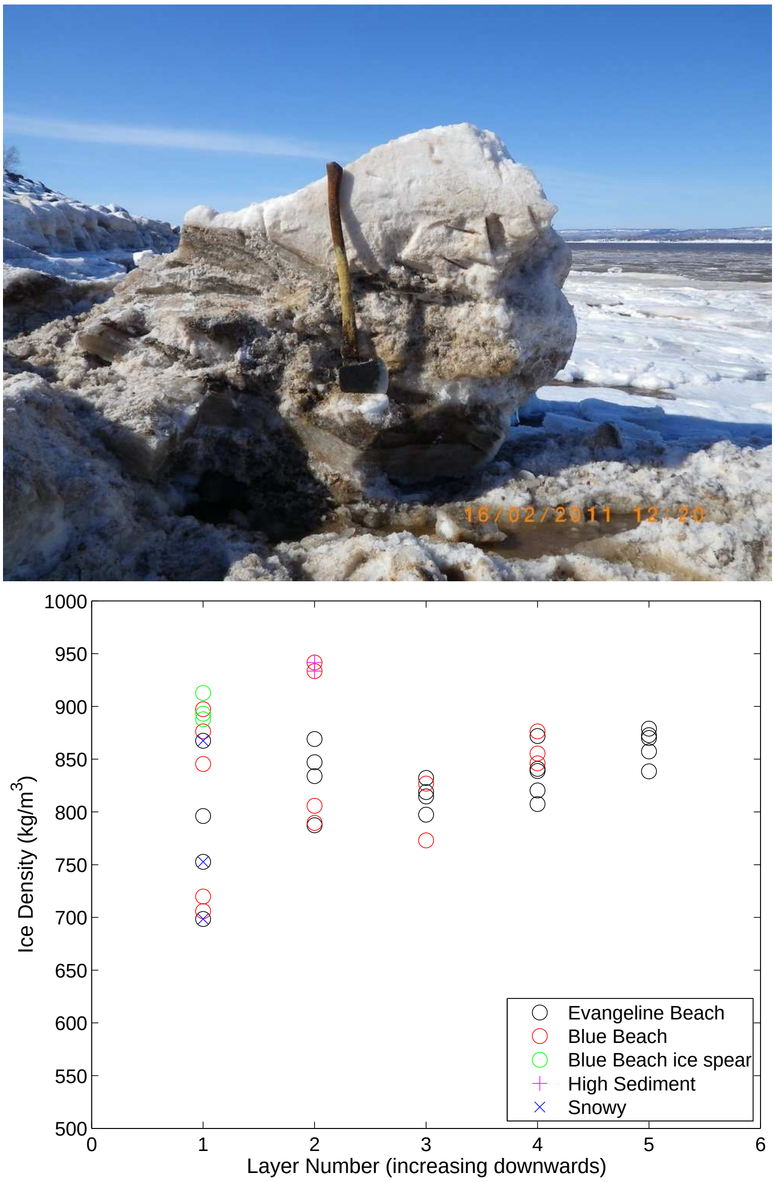

Figure 1: Ice cake 1 at Evangeline Beach (45.13834° N, 64.31901° W) on 16 February 2011. Winds onshore, average air temperature -9.3 °C, water temperature -1.5 °C. Sectioning and frazil-ice. Seawater density ≈ 1023 kg/m^3, **all samples float**.

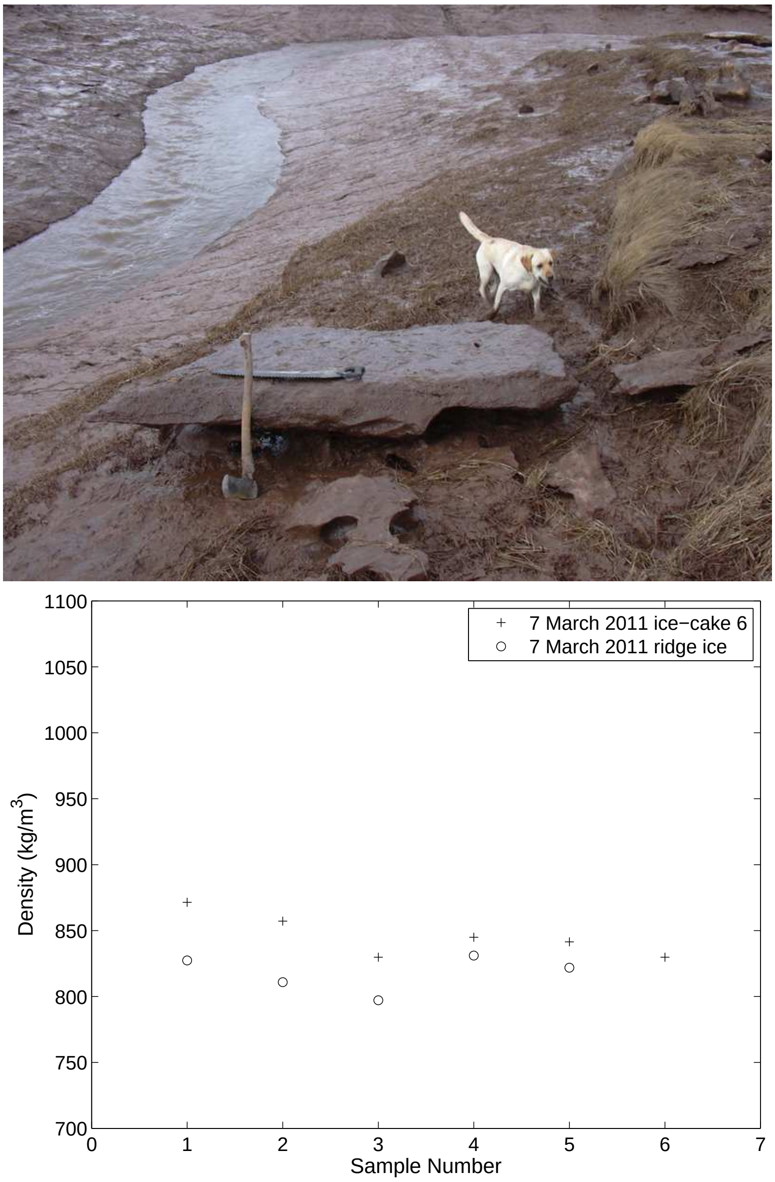

Figure 2: Ice cake 6 at Grand Pre, West Long Island Rd, on 7 March 2011. GPS 45.12154° N, 64.33353° W. Sediment stained ice cakes...

Figure 3: Locations.

Figure 4: Views from Block Wharf Rd, Summerville. **Top:** Stranded ice covers the beach on 18 February 2011. **Bottom:** Tides and wind have removed most ice from the beach by 22 February 2011.

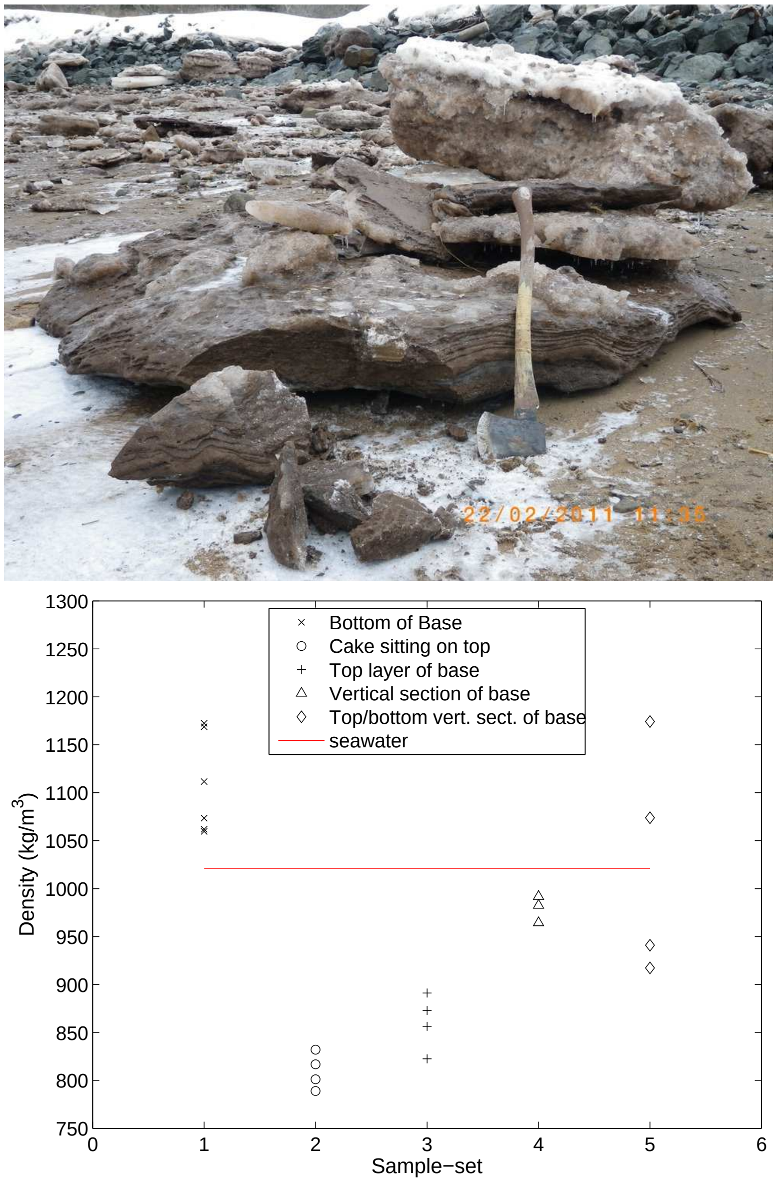

Figure 5: Ice cake 4 at Summerville, Block Wharf Rd, on 22 February 2011.

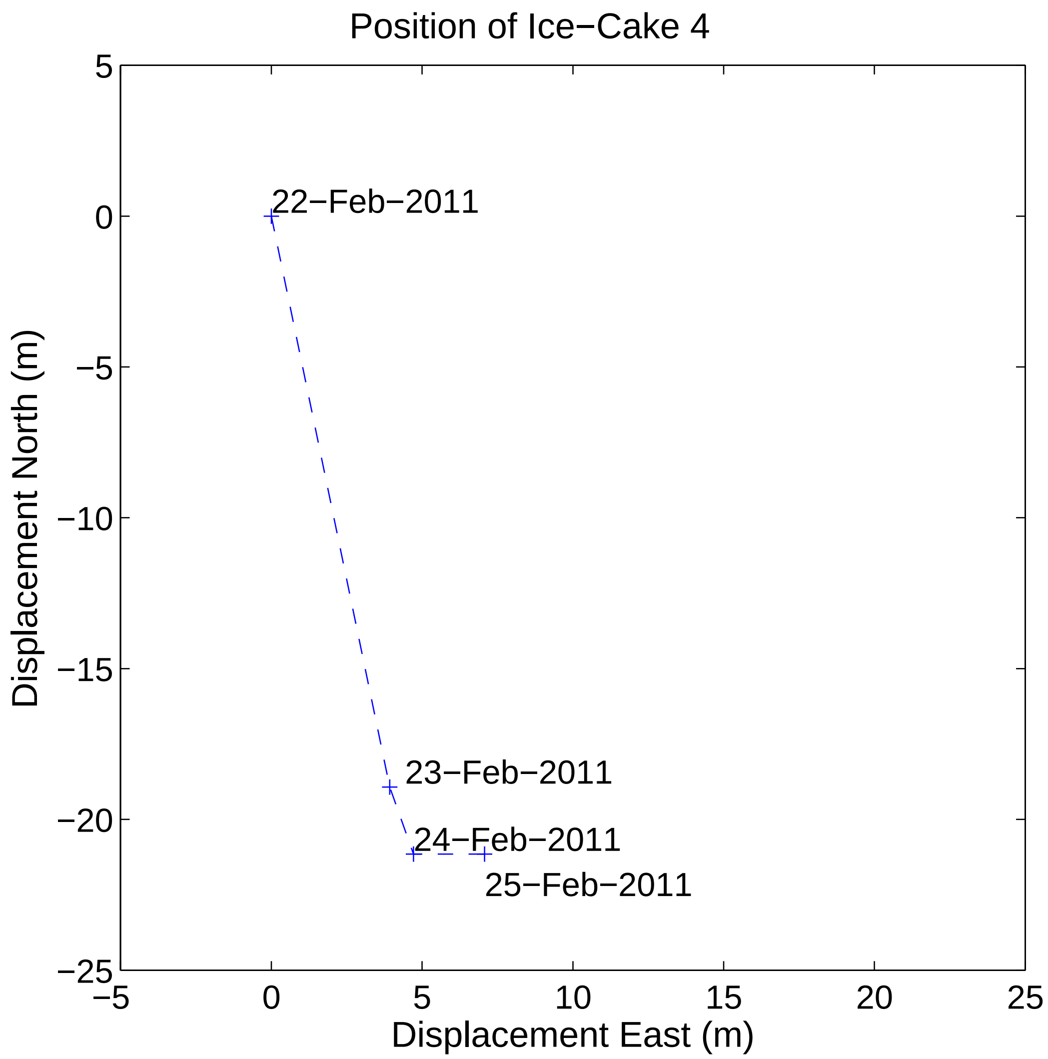

Figure 6: Positions of the negatively buoyant ice cake 4.

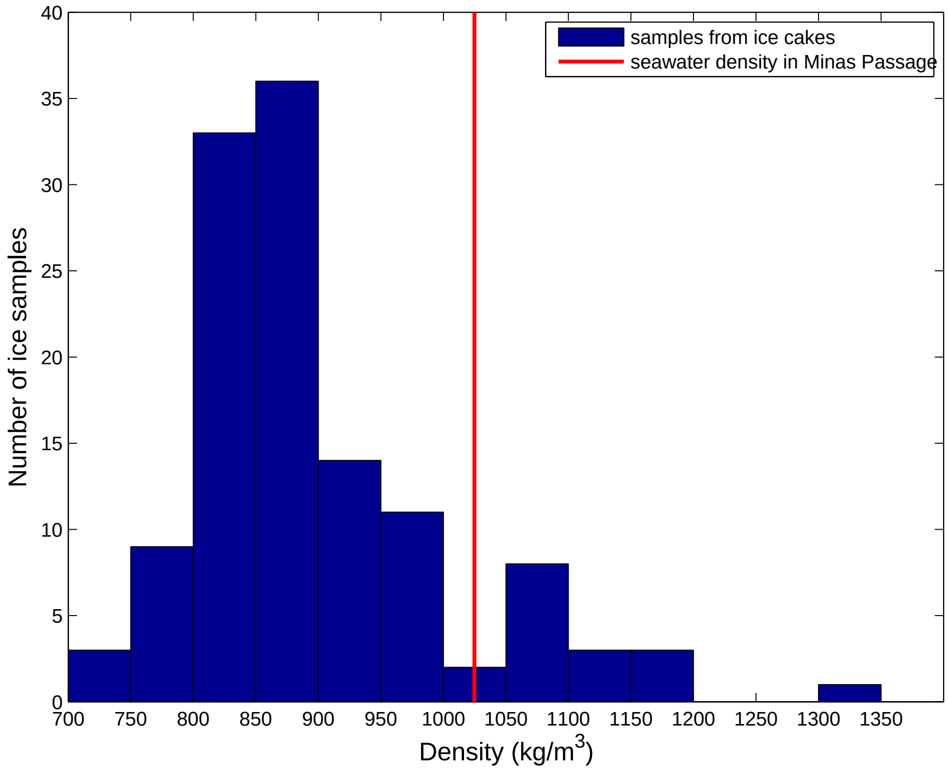

Figure 7: Histogram of density of samples from ice cakes, including samples from the ridge ice.

Table 1: An upper limit on density discrepancy $|\rho_{\text{seawater}} - \rho|$ of an ice cake with length scale L if that ice cake is to be dragged into mid water-column by turbulence resulting from 5 m/s tidal currents.

$\lvert\rho_{\text{seawater}} - \rho\rvert$ (kg/m^3)	L (m)	nominal ice-cake mass (kg)
130	0.1	1
26	0.5	130
13	1.0	1000
8.7	1.5	3500
6.5	2.0	8200
5.2	2.5	16000
4.3	3.0	28000

$$\frac{1}{2} C_d \rho_{\text{seawater}} A w_c^2 = g|\rho_{\text{seawater}} - \rho| V \tag{1}$$

Collision with a dangerously-large ice cake depends upon an irreducible sequence of events:

1. A much larger buoyant ice cake to form in the intertidal zone,
2. Adhere to dense, frozen sedimentary material,
3. Have sufficient buoyancy to break the frozen sediment free,
4. Resulting, buoyant ice cake is washed offshore,
5. While offshore, it must differentially melt or fracture, so less dense ice is lost preferentially to dense sedimentary material. **Opposite is observed!**
6. Remaining ice cake must be sufficiently large to be a danger.
7. Achieve an overall density that falls within a narrow range in order that turbulence can move it vertically through the water column.
8. Persist in that state for sufficiently long to have a significant collision cross-section with a turbine.

The probability of danger to tidal turbines is a multiplicative process, equal to the product of probabilities of processes in steps 1 through 8. This joint probability is akin to the "Drake Equation" and is similarly confounded by poorly known constituent probabilities and the lack of a single observation of the sought-after entity.