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ICEBERG PRODUCTION IN THE PRINCE WILLIAM SOUND AREA

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The fiords of the Gulf of Alaska and Prince William Sound and the associated coastal ranges of Alaska and the Yukon contain more glaciers than any other North American region, excluding the Arctic Islands of Canada. Many of the valley glaciers, feeding from a variety of ice sheets and upland icecaps, flow to levels lower than sea level and form tidewater glaciers. Tidewater glaciers calve icebergs into the coastal waters of the fiords. This calving and iceberg forming results in a glacial cycle of advance and retreat that differs greatly from the cycle of land glaciers. This cycle is called the tidewater glacier cycle.

Tidewater glacial cycles are controlled by depth of water at the glacier front; retreating rapidly when the front floats or rests in deep water and advancing slowly when the terminus builds a platform of protective end moraine on which the glacier terminus rests. The production of icebergs fluctuates with the glacial advance/retreat cycle. More icebergs calve during a rapid retreat stage of the cycle. The Columbia Glacier is an example of a tidewater glacier that remained stable for several decades and recently (1984) began a rapid recession due to glacial thinning and subsequent retreat from the protective end moraine and shallow water. The current dramatic retreat has caused many and large icebergs (for Alaska - not Antarctica) to be formed, some have been estimated to weigh 1 million tons. Most of the icebergs float behind abandoned end moraines where they melt rapidly from the relatively warm sea water.

Fifty-two Alaskan tidewater glaciers have been documented in the Alaska Marine Ice Atlas; the easternmost being the LeConte Glacier in LeConte Bay (near Petersburg) and the westernmost; the Dinglestadt Glacier in McCarty Fiord on the Kenai Peninsula. These glaciers produce icebergs that float for a short period of time in the tidal waters of the fiord. The icebergs in eight of the Alaskan fiords have attracted innovative entrepreneurs to develop techniques for harvesting and marketing glacial ice. Requests for iceberg harvesting have been submitted to the Department of Natural Resources for using ice from Aialik Bay, Harris Bay, Blackstone Bay Icy Bay (Kenai Peninsula), Harriman Fiord, College Fiord, Columbia Bay, and Icy Bay (near Yakutat).

Certain characteristics of the glaciers of the Alaskan coastal mountains are important related to considerations of iceberg production, and harvest.

Age of Glacier Ice

Calculation based on assumption of glacier length and ice velocities indicate that a particle of snow falling on the uppermost part of a coastal Alaskan glacier will reach the terminus within 60 to 80 years. Smaller glaciers flow more slowly and larger glaciers more rapidly so the ice in icebergs is approximately 70 years old. This also means that a glacier totally replaces itself about every 70 years (the average lifetime of people).

Glacier ice, therefore, is a renewable resource, replacing itself and wasting itself away constantly. Removal of ice from the cycle, especially removal of ice from the final stages of the glacial ice cycle causes nearly no effects on the system. The coastal Alaskan glaciers are in a coastal geographic setting receiving extreme amounts of precipitation. The highest measured snow accumulations in the world have been measured on the icefields of these glaciers. The ice accumulates rapidly and flows at relatively high speed to areas lower in elevation and higher in temperature where ice melts rapidly. Due to the

high energy resulting from the high precipitation, warm climate, and steep terrain the ice "rushes" through the glacier. Some of the glaciers actually reach the sea, which is a very hostile environment for glacial ice. These glaciers calve icebergs into the fiords of relatively warm water.

Duration of Icebergs

Once calved from the glacial terminus, glacier ice melts rapidly, especially in the relatively warm waters of the Gulf of Alaska. Observers report that the life of an iceberg in Prince William Sound is a few hours for most bergs and a few days for the larger icebergs. Therefore, icebergs will disappear from the bay within a few days if not replenished by continued calving from the glacier terminus. The presence of icebergs in a bay indicates that a glacier is actively calving; creating icebergs at a rate that normally is far greater than a few ships can remove.

Floating glacier ice is classified as follows:

Brash Ice	Accumulations of floating ice fragments smaller than 6 ft across
Growler	Smaller than bergy bits, greenish color, greater than 6 ft across and less than 3 ft above water
Bergy bits	A piece of floating ice about the size of a small house, showing 3 ft to 15 ft above the water
Iceberg	Large pieces of glacier ice showing more than 15 ft above the water

Most of the floating ice in the Prince William Sound area is classified as brash ice or growler ice. A few icebergs and bergy bits are produced, especially from glaciers experiencing drastic retreat.

Rates of Iceberg Formation

The amount of ice reaching the terminus of Alaska's tidewater glaciers has been calculated for a few of the most important glaciers. The Hubbard Glacier, in the slow advancing phase of the marine-glacier cycle, has been predicted to dam Russell Fiord causing a very large lake and a new Situk River to be formed. The water produced each year from the Hubbard Glacier is calculated at 6.8 cubic kilometers of which 95 percent is calved as icebergs (6.5 cu. km.). The Columbia Glacier, famous and investigated due to its recent rapid retreat and increased iceberg production, produces about 3 cu. km. of icebergs per year.

Effect of Iceberg Harvesting at 2000 tons per week

If 2000 tons per week (104,000 tons per year) were taken from the bay in front of the Columbia Glacier, the percentage loss represented by the yearly harvest would be 0.004 percent for a year. If the year's harvest were taken in one week, it would represent 0.2 percent of the weekly production of icebergs, or 1.0 percent of the daily production. (That is if all the year's ice were taken on a single day it would be 1.0 percent of the ice produced that day.) These calculations are far from accurate but they indicate that the amount of ice harvest is very small compared to available iceberg ice.

Iceberg production from eight bays in the Gulf of Alaska/Prince William Sound area have been calculated and data are shown in Table 1. Most of the glaciers for which ice harvest applications have been submitted are not well studied so that assumptions must be made as to the depth and velocity of the ice. The surface area and length have been measured from maps. A matrix showing the volume of ice and the estimated iceberg production from thirteen glaciers in eight bays has been calculated. These estimates are based on assumptions of glacier dimensions so they are only general estimates. For the final column it is assumed that 2000 tons of icebergs are harvested each week. The percentage of total icebergs available represented by 2000 tons/per week (104,000 ton per year) for a year is shown in the final column of Table 1. For example, Aialik Glacier is estimated to produce 25,000,000 tons of icebergs per year. Harvesting 2000 tons/week equals 104,000 tons/year, which represents 0.4 percent of the yearly iceberg production. Aailik's average daily production of icebergs is 25,000,000 tons/365 or 68,000 tons per day.

Conclusions

Tidewater glaciers of the Gulf of Alaska area are very dynamic glacier systems because of high precipitation and warm climate. Great volumes of ice move from the accumulation areas to the sea. Several glaciers flowing to sea level in Alaskan fiords calve large amounts of ice into relatively warm sea water to create icebergs. An iceberg exists only a few hours to a few days.

Iceberg harvesting removes far less than 1 percent of the ice from the glacial system, and the harvesting occurs at the final phase of the glacial system. If not harvested, the ice would melt and disappear within a few days.

The model used to calculate percentages uses very conservative estimates as few actual data exist for iceberg production. Many glaciers calve more than 50 percent of their ice into the sea. The model for Table 1 assumes a 50 percent calving rate and ice age of 100 years. The age of 100 years is also higher than most calculations of glacier ice age, which is about 70 years.

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Table 1. Estimated Iceberg Production from Prince Willaim Sound Glaciers

Location	Glacier Name	Length (km)	Area (sq km)	Estimated Vol. (cub km)	Life (years)	Bergs (%)	Estimated Annual Bergs (cub km)	(cub yd)	(tons)	Permitted % (2000ton/wk)	Terminous
AIALIK BAY	Aialik	11.0	17.0	5.1	100	50%	0.026	33,000,000	24,000,000	0.43%	stable
	Holgate	13.0	69.0	20.7	100	50%	0.104	135,000,000	99,000,000	0.11%	receding
HARRIS BAY	Northwestern	14.0	87.0	43.5	100	50%	0.218	285,000,000	210,000,000	0.05%	receding
BLACKSTONE BAY	Blackstone	11.0	80.0	40.0	100	50%	0.200	262,000,000	193,000,000	0.05%	slow receding
ICY BAY (PWS)	Tiger	11.0	51.0	15.3	100	50%	0.077	100,000,000	74,000,000	0.14%	slow receding
HARRIMAN FJORD	Barry	15.0	29.0	8.7	100	50%	0.044	57,000,000	42,000,000	0.25%	receding
	Harriman	13.0	49.0	14.7	100	50%	0.074	96,000,000	71,000,000	0.15%	advancing
	Suspence	13.0	66.0	19.8	100	50%	0.099	130,000,000	96,000,000	0.11%	slow advance
COLLEGE FJORD	Yale	35.0	220.0	110.0	100	50%	0.550	719,000,000	529,000,000	0.02%	slow receding
	Harvard	39.0	500.0	250.0	100	50%	1.250	1,635,000,000	1,203,000,000	0.01%	slow advance
COLUMBIA BAY	Columbia	66.0	1370.0	795.0	100	50%	3.975	5,200,000,000	3,827,000,000	0.003%	strong receding
ICY BAY (nr Yakutat)	Tyndel	35.0	-	-	-	-	0.700	916,000,000	674,000,000	0.02%	receding
	Yahtse	65.0	-	-	-	-	5.000	6,541,000,000	4,814,000,000	0.002%	receding
	Guyot	30.0	-	-	-	-	0.600	785,000,000	578,000,000	0.02%	receding