

SIGNIFICANT ERROR IN THE STAKE APPROACH FOR MEASURING WHITE ICE GROWTH

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It has long been recognized that there is a need for non-destructive techniques for monitoring white ice growth over an entire lake surface (Adams 1977, Andrews 1962). This measurement is important because it is an indicator of the whole winter snow loading to the lake surface. The most common technique used in continuous whole lake surveys is that of stakes with growth reference marks (Adams and Shaw 1966). This technique has been used on both subarctic (Jones 1969) and temperate winter lake covers (Prowse 1978). Adams and Prowse (1980) suggest the stake technique could be used in conjunction with a mechanical non-slushing ice device.

The theory behind the stake approach is quite simple. Early in the winter after 15 cm of black ice growth holes are drilled through the ice cover. Stakes are then placed in the drill holes. Snow is packed around the stakes to ensure the stake remains perpendicular to the ice surface. It is critical that the air temperature is cold enough to produce rapid freezing of the slush packed around the stake. At this point a reference line is placed on the stake one meter above the black ice surface. If there has been previous white ice development this line is placed one meter above the black ice/white ice interface (Figure 1). For future reference this line will be referred to as the OML and the height will be called h_1 .

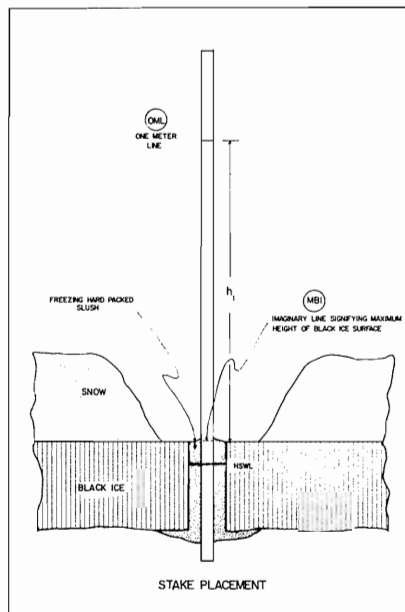


Figure 1. The placement of the cedar stake.

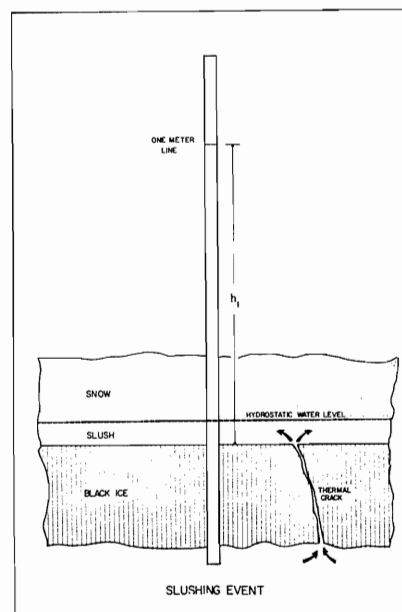


Figure 2. A simplified slushing event.

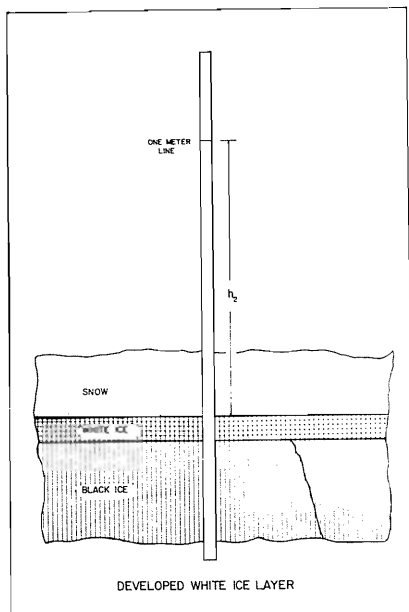


Figure 3. Developed white ice layer.

When a slushing event occurs (Figure 2) water rises through cracks caused by thermal expansion. The water saturates the lower layers of the snowcover to the height of the hydrostatic water level. This implies of course that there is a positive hydrostatic head. The water in fact rises above the hydrostatic water level due to capillary draw.

This layer of slush then freezes downward to the black ice surface. Once completely frozen this layer is called white ice (Adams 1976). The height of the reference mark is now measured from the ice surface and is less than a meter (Figure 3). This height will be referred to as h_2 . The difference between h_1 and h_2 is the thickness of white ice.

In the first week of November 1979, 126 cedar stakes (5cmx5cmx180cm) were frozen in the Elizabeth Lake (Labrador) ice cover in a stratified random sample. Growth reference lines were placed on the stakes at the one meter height. At the time of placement there was a patchy snowcover and the hydrostatic water level was negative at all stake sites.

In the last week of February 1980 the lake surface was drilled near each stake site to check the stake derived white ice depth against the actual white ice depth. The statistical results of this test are shown in the following table.

Type of Measurement	Mean	Std Deviation	Variation (%)	Std Error	Range	Maximum	Minimum
Drilled	17.4	18.0	103.0	3.5	66.0	66.0	0.0
Staked	23.0	50.0	217.0	9.8	104.0	102.0	-2.0

The error in the white ice depth derived from the stakes was large and unacceptable. The mean difference between drilled and staked white ice depths was 4.1 ± 11.4 cm. This implies a minimum error of 25 percent using the stake approach.

A Student t-test was performed on the two types of white ice measurements and it was found they could not be described as being from the same sample population. Regression analysis was undertaken to see if the stakes were consistently in error, however this proved insignificant.

The stakes were subsequently recalibrated and over the rest of the winter no error greater than 2.5cm was found between randomly selected drilled and staked derived white ice depths.

There appears to be three possible explanations for the errors. Stake slippage could have resulted from either insufficient freezing at the time of stake placement or due to radiation meltout around the stakes. Finally there could have been secondary superficial black ice growth.

If stake slippage occurred the result would be the moving of the reference line (OML) closer to the black ice surface. This results in a h_2 measurement of less than one meter indicating white ice growth, when in fact none has occurred (Figure 4). Stake slippage at the time of stake placement is the most likely cause of this error. Radiation meltout is

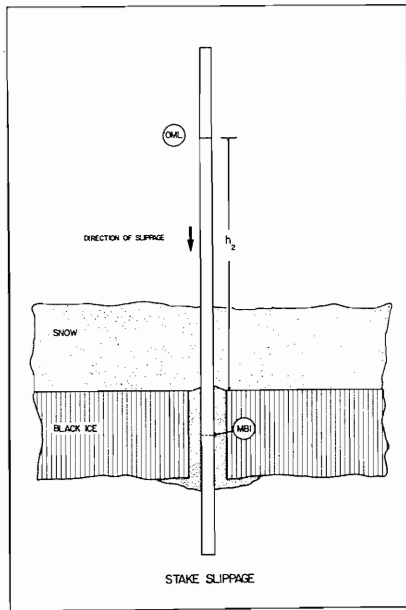


Figure 4. Stake slippage.

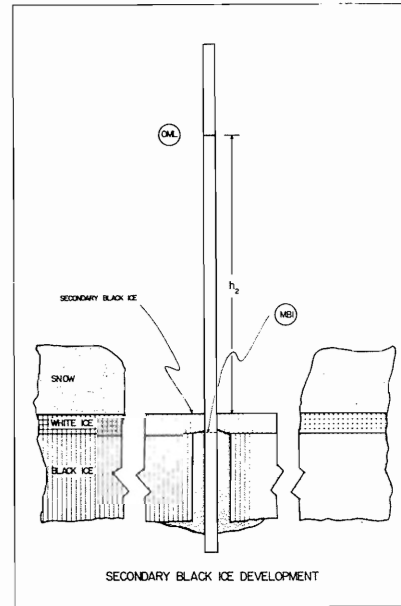


Figure 5. Secondary superficial black ice growth.

known to cause slippage in the spring but it is unlikely to be a factor in mid-winter.

Secondary superficial black ice growth is also a possible source of error. If the snow loading around a clear section of the lake ice cover was sufficient to depress the ice sheet and thermal cracking were to occur, clear lake water would freeze on the surface of the original black ice. The stake approach would indicate this as white ice growth, while in a drill hole this would appear as black ice (Figure 5).

While these problems have definitely produced large errors in this study it is still believed that with the correct precautions the stake approach can be used for large whole lake samples of white ice growth and development. At the time of stake placement it must be sufficiently cold to freeze the stakes into the surface. A survey should be conducted soon after stake placement to correct any errors that occur as a result of slippage. It is important that there should be negative hydrostatic water levels throughout this survey or it defeats the purpose of a non-destructive sampling technique. The surface of the ice should be checked for ice type when white ice development is indicated on the stake. Finally it is suggested that if any radiation melt is evident around the base of the stakes the stake approach should be abandoned.

Acknowledgments

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