

# AUFEIS EFFECTS ON STREAM DISCHARGE AND MEASUREMENT IN SUBARCTIC BASINS

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## Introduction

A seasonal accumulation of ice which is superimposed on the frozen surface of a stream, river, or sector of landscape is generally termed aufeis (Grey and MacKay 1979), or simply "icing" (Carey 1973). Aufeis can result from continued winter-season groundwater discharge at springs (e.g. Veillette and Thomas 1979) or from open-system pingos (Åkerman 1982), from glacier-terminus water discharge (Åkerman 1982), and in valleys from out-of-channel streamflow (Kane and Carlson 1977). While some investigators prefer the Russian term "naled" (e.g., Åkerman 1982) for reference to such accumulations of extrusive ice, I will continue to utilize "aufeis" in the sense employed by Grey and MacKay (1979), as the designation for ice which forms over an existing ice cover on rivers and streams (and presumably over adjacent floodplains if the ice accumulation fills and overtops the stream channel). Although not restricted to high latitudes, aufeis is commonly associated with permafrost-dominated terrain and is more common in northern regions.

Comprehensive reviews of aufeis (or icing) have been provided by Carey (1973) and Grey and MacKay (1979). Kane et al. (1973), Kane and Carlson (1977), and Kane (1981) have summarized knowledge of mechanisms of the formation of aufeis. Carlson (1979), and Grey and MacKay (1979) speculated on the engineering consequences of aufeis formation. In Alaska, Sloan et al. (1975) observed and documented locations of aufeis activity along the entire route of the trans-Alaska pipeline. Slaughter (1982) documented recurrence of aufeis in an upland subarctic research catchment.

## Aufeis Processes

Aufeis generally forms when water in, or adjacent to, a stream channel rises above the level of an existing ice cover. Such water flows over existing ice, losing heat and gradually freezing (at a rate dependent on ambient air temperatures, rates of flow, and gradient of surface ice) to produce a thickened ice cover. In central Alaska, Carlson and Kane (1973) and Kane et al. (1973) monitored aufeis formation on small streams and demonstrated that episodes of aufeis formation occurred in response to restriction of available flow area in a stream course. Such restriction could be by freezing from top, bottom, and/or sides, development of anchor ice in the stream, and by surface-ice depression subsequent to increase in snowpack and/or aufeis. Such restriction leads to an increase in piezometric head or pore-water pressure of water flowing down-valley in the unfrozen channel and in the associated aquifer. As winter progresses, continued constriction of the available unfrozen channel and aquifer commonly results in continuing, episodic accumulation of aufeis. As the piezometric head exceeds the existing ice surface at a given site, unfrozen water will reach the ice surface through any available conduit. The course may be through vertical tension or contraction cracks which develop in the stream-ice cover, along narrow unfrozen zones around the stems of woody plants, or along lateral conduits leading water away from the stream channel and into the snowpack on the adjacent floodplain (Jenson 1978).