# **Temporal evolution of the termini and subaqueous morphologies of lake-calving glaciers in *Aoraki*/Mount Cook National Park, New Zealand**

A thesis presented in partial fulfilment of the requirements
for the degree of
Doctor of Philosophy in Geography
at Massey University, Palmerston North, New Zealand.

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This is for you Dad. I wish you were here to see it.

# Abstract

The potential impact that subaqueous mass loss may have on glacier mass balance and volume reduction is unclear, primarily due to a lack of quantitative data. Therefore, in order to fully understand the potential contribution subaqueous calving and melting may make to glacier mass loss, it is important to understand how submerged extensions of glacier fronts ("ice ramps") are created and maintained. This study improves the understanding of the controls on subaqueous ice ramp development and evolution at debris-covered, lake-calving margins by investigating the temporal evolution and subaqueous morphology of the termini of lake-calving glaciers in *Aoraki*/Mount Cook National Park, New Zealand. These glaciers are in close proximity to each other, yet each represents different stages on the glacier retreat-proglacial lake development continuum. Through a combination of field-based data collection and remote sensing, the calving margins of Mueller, Hooker, Tasman, Murchison, Classen, Grey, Maud and Godley glaciers were examined over a variety of time scales (days to years). This research indicates that the evolution of subaqueous ice ramps is intrinsically linked to subaerial retreat and that temporal changes in subaqueous morphologies are driven by subaerial calving, subsequent subaqueous calving, and sedimentation. The study highlighted that it is vital to understand the subaqueous morphologies of glaciers, how these evolve over time and what controls this evolution. In addition, when predicting glacier retreat it is important to consider subaqueous morphologies, through the incorporation of quantitative data and waterline melt rates, in order to more accurately predict retreat and hence mass loss from a glacier. Glacier retreat and concurrent proglacial lake expansion were also found to vary significantly within a single mountain belt. The identification of subaqueous ice ramps extending from lake-calving debris-covered glaciers, along with the examination of controls on ice ramp development and evolution, contributes significantly to the understanding of subaqueous morphologies and potential mass loss from these sections of the glacier. These results also lead to a better understanding of how subaqueous sections influence overall glacier retreat.

# Thesis structure and note on authorship

This thesis consists of traditional thesis-style chapters (chapters 1, 2 and 7) and manuscripts written for publication in scientific journals (chapters 3-6). As a result, there is some repetition in chapters 1 to 6, particularly in the introduction, methods and study area sections. Some journal specific restrictions, such as abstract length and key words, are retained in the thesis.

I completed all the field work at *Aoraki*/Mount Cook National Park, analysed data and wrote all the text in this thesis. Manuscripts are however co-authored to acknowledge the input of others into the PhD, as appropriate. My supervisors, Martin Brook, Ian Fuller, Douglas Benn, and Kat Holt, contributed to developing the project concept, editing manuscripts and providing general advice. Statements (Doctoral Research Committee form 16) regarding the contribution made by myself to chapters 3-6 and consent of the co-authors to include their work in the thesis are contained in the Appendices.

Clare Robertson

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