Before the Expert Panel appointed under the Fast-track Approvals Act 2024

Under	the Fast-track Approvals Act 2024
And	
In the Matter of	an application for approvals by NZSki Limited to upgrade existing infrastructure at the Remarkables Ski Area, including a new passenger transport lift, carparking areas, and expanding the ski field into the adjacent Doolans Basin

Statement of Evidence of **Nicolas James Cullen** on behalf of NZSki Limited in response to Section 53 Comments

Climate Change

Dated: 3 November 2026

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INTRODUCTION

Qualifications and Experience

1. My name is Professor Nicolas James Cullen.

2. I am a Professor in the School of Geography at the University of Otago, specialising in mountain and polar climate, seasonal snow and glaciers. My current research includes the use of field observations and physically based modelling to investigate snow accumulation, redistribution and melt, snowpack evolution and stability, avalanche hazard, and the impacts of climate variability and change on mountain environments.

3. I have extensive research experience in the Southern Alps of Aotearoa New Zealand, including modelling historical and future snow conditions and supervising postgraduate research on climate change impacts on seasonal snow and snow reliability. I also contributed to the assessment of seasonal snow and glaciers in the national climate change projections guidance prepared by Bodeker et al. (2022).

4. I am currently President of the Meteorological Society of New Zealand and previously served as Convenor of the New Zealand Snow and Avalanche Committee (**NZSAC**). My expertise in mountain climatology, snow processes and climate change provides the scientific basis for this independent assessment of climate resilience associated with the proposed Remarkables Ski Area Upgrades and Doolans Expansion Project.

5. This statement is given as part of NZSki Limited's (**NZSki**) response to comments on the Remarkables Ski Area Upgrade and Doolans Expansion (**Project**) made under Section 53 of the Fast-track Approvals Act 2024 (**FTA**). This statement responds to specific comments raised by:

   (a) Statement of Evidence of Dr Rowan Dixon for Kā Rūnaka.

   (b) Department of Conservation (**DOC**) s53 Comments Remarkables.

   (c) DOC s53 Comments Remarkables - Attachment 1 - DOC Expert Statement - Planning - J Macleod.

   (d) New Zealand Conservation Authority (**NZCA**).

6. While this is not an Environment Court hearing I have read and agree to comply with the Code of Conduct for Expert Witnesses in the Environment Court Practice Note 2023. This evidence is within my area of expertise, except where I state that I am

relying on material produced by another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

Purpose

7. NZSki Limited is seeking approvals under the Fast-track Approvals Act for the Remarkables Ski Area Upgrades and Doolans Expansion Project. The Project proposes upgrades to existing infrastructure within The Remarkables Ski Area and an expansion of lift-accessible skiable terrain by approximately 262 hectares into the adjacent Doolans Basin, accessed via a proposed gondola and associated ski trails.

8. Climate change is expected to reduce the availability and reliability of natural snow in New Zealand's mountain environments (Hendrikx et al., 2012; IPCC, 2021, 2022; Bodeker et al., 2022). However, the magnitude of these impacts varies with elevation, local climate and terrain characteristics. Advances in snowmaking technology may also influence how ski areas respond to changing conditions. Understanding these factors is therefore important when considering the potential long-term climate resilience of the proposed development.

9. *The purpose of this report is to provide an independent scientific assessment of the implications of climate change for the Project,* with particular emphasis on the following four considerations:

    (a) *Climate change projections*: Review current scientific literature on historical and projected changes in climate and seasonal snow in New Zealand, with particular relevance to the Southern Alps and including the research of Hendrikx and more recent physically based snow-modelling studies.

    (b) *Climate resilience of Doolans Basin*: Examine how the elevation, aspect and topographic characteristics of Doolans Basin may influence snow accumulation and persistence, drawing on preliminary historical snowpack modelling, and assess the potential advantages of these characteristics for maintaining natural snow reliability under a warming climate.

    (c) *Implications for the proposed development*: Evaluate the implications of projected climate change for the Project, drawing on the scientific literature and site-specific findings to assess the potential benefits of the proposed expansion for future snow reliability.

    (d) *Long-term resilience and snowmaking*: Consider the implications of climate change over the proposed 37-year concession period, including the

potential contribution and limitations of conventional snowmaking and recent technological advances as adaptation measures.

10. The assessment draws on published scientific research and available information about the proposed development. It distinguishes between established scientific findings, preliminary site-specific modelling results, interpretations of the physical characteristics of Doolans Basin and uncertainties that cannot be resolved using the available evidence. While preliminary site-specific snowpack simulations are considered, the assessment does not include comprehensive modelling of future snow conditions and is not an assessment of the Project's financial viability or its wider environmental effects.

CLIMATE CHANGE AND SEASONAL SNOW IN NEW ZEALAND

11. Mountain snow is particularly sensitive to climate warming because air temperature influences precipitation phase, snowmelt and the duration of seasonal snow cover. The IPCC projects continued reductions in mountain snow under future warming, with generally greater proportional losses at lower elevations (IPCC, 2021, 2022). International research similarly identifies declining natural snow reliability as a significant challenge for ski areas, with the magnitude of impacts influenced by elevation, local climate and adaptation measures (Steiger et al., 2019). New Zealand climate projections are consistent with these findings (Hendrikx et al., 2012; Bodeker et al., 2022).

12. An important distinction is how changes in seasonal snow are assessed. National climate projections have commonly used snow days, defined using temperature and precipitation conditions favourable for snowfall, as an indicator of future snow decline (Ministry for the Environment, 2018; Bodeker et al., 2022). While useful at broad spatial scales, this indicator does not directly represent snow accumulation, redistribution, melt or persistence. These processes are particularly important when assessing snow reliability at individual ski areas.

Projected Changes in Seasonal Snow

13. Hendrikx et al. (2012) provided an early assessment of projected changes in seasonal snow across New Zealand using a temperature-index snow model. This approach estimates snow accumulation and melt using simplified relationships with meteorological variables, rather than explicitly representing the physical energy and mass exchanges within the snowpack. Their results projected an upward shift of approximately 0–200 m by the 2040s and 150–450 m by the 2090s in the elevation supporting snow cover for more than three months annually (**Table 1**).

Table 1. Projected upward shifts in elevation thresholds for seasonal snow cover in New Zealand, relative to the respective historical reference periods.

Study / scenario	Mid-century upward shift	Late-century upward shift
Hendrikx et al. (2012)	0–200 m (2040s)	150–450 m (2090s)
Berg (2025), SSP1-2.6	+174 m	+170 m
Berg (2025), SSP2-4.5	+242 m	+443 m
Berg (2025), SSP3-7.0	+312 m	+661 m

14. More recent New Zealand research has applied the physically based Flexible Snow Model (FSM2), which explicitly represents snowpack energy and mass balances, including radiative and turbulent heat exchanges, snow accumulation, melt and refreezing (Essery, 2015; Essery et al., 2025). In simple terms, the model uses meteorological conditions, including temperature, precipitation, wind and radiation, to calculate how snow accumulates, changes and melts over time. This provides a more detailed representation of snowpack behaviour than models based primarily on temperature. Wright (2021) used FSM2 to investigate future seasonal snow conditions in the Upper Clutha/Mata-Au catchment, identifying reductions in snow accumulation and persistence under warming. Berg (2025) applied FSM2 to the Craigieburn Range, examining changes in seasonal snow under three greenhouse gas emissions pathways.

15. The three pathways represent different possible futures for global greenhouse gas emissions: SSP1-2.6 assumes substantial emissions reductions and strong climate change mitigation; SSP2-4.5 represents an intermediate pathway with more gradual emissions reductions; and SSP3-7.0 represents a high-emissions future with limited climate change mitigation and continued increases in emissions. These scenarios are used to examine how different emissions trajectories influence future climate conditions. They are not predictions of what will occur, and no specific likelihood is assigned to any individual pathway (IPCC, 2021; Bodeker et al., 2022).

16. For the Craigieburn Range, Berg (2025) found that the elevation supporting at least 90 snow-cover days annually increased from approximately 1,290 m for the historical reference period (1995–2014) to between 1,464 m and 1,602 m by mid-century (2041–2060), depending on the emissions pathway. This represents an upward shift of approximately 174–312 m. By late century (2080–2099), the projected elevation ranged from 1,460 m under SSP1-2.6 to 1,951 m under SSP3-7.0, corresponding to increases of approximately 170–661 m (Table 1).

17. *Importantly, Berg's results demonstrate that future greenhouse gas emissions strongly influence the magnitude of snowpack change* (**Figure 1**). While reductions in snow persistence occur across emissions pathways by mid-century, the projections diverge considerably thereafter. Under the lower-emissions pathway, the

elevation threshold stabilises towards the end of the century, whereas continued high emissions result in substantial additional losses of seasonal snow at progressively higher elevations.

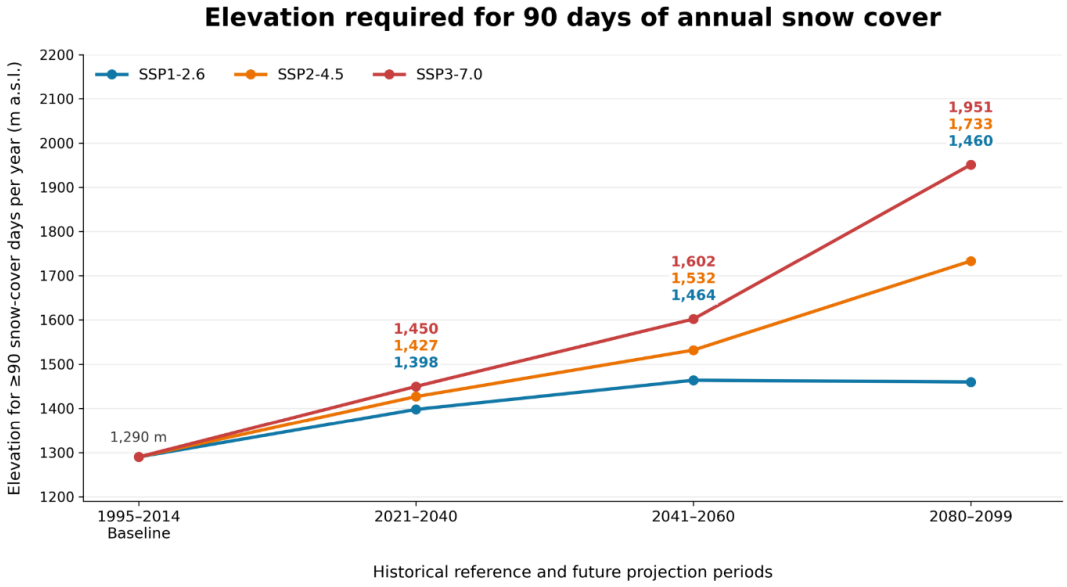


Figure 1. Elevation required to support at least 90 annual snow-cover days on the Craigieburn Range under historical and future emissions scenarios. Redrawn from Berg (2025, Section 4.4, Figure 4.16).

18. Hendrikx et al. (2012) examined projected changes in seasonal snow across New Zealand, whereas Berg (2025) focused specifically on the Craigieburn Range in the Southern Alps. The studies also differ in emissions scenarios, snow-model physics and definitions of snow cover. Their results should therefore be compared in terms of the direction and approximate magnitude of projected change, rather than interpreted as directly equivalent snow-cover elevation thresholds (Table 1). Berg's analysis provides an indicator of changes in seasonal snow persistence rather than a direct measure of future ski-season duration or operational reliability.

19. *Section 3 conclusion*: The scientific evidence consistently indicates declining natural snow accumulation and persistence under future warming, with generally greater impacts at lower elevations. The physically based modelling of Wright (2021) and Berg (2025) reinforces earlier projections of declining seasonal snow cover, while providing a more detailed representation of snow accumulation, melt and refreezing. Berg (2025) indicates that, even under the highest emissions pathway considered (SSP3-7.0), the elevation projected to support at least 90 annual snow-cover days in the Craigieburn Range is approximately 1,600 m by mid-century (2041–2060). However, the magnitude of future snow decline depends strongly on the emissions pathway, particularly beyond mid-century.

CLIMATE RESILIENCE OF DOOLANS BASIN

20. The proposed expansion into Doolans Basin will likely improve the relative climate resilience of The Remarkables Ski Area by increasing access to terrain with favourable natural snow conditions. The expansion extends from approximately 1,580 m to 1,921 m, encompassing elevations where snow accumulation and persistence are influenced by both temperature and local terrain characteristics. As discussed under the heading Climate Change and Seasonal Snow in New Zealand above, the effects of climate warming on seasonal snow are generally greater at lower elevations, although there is no single elevation threshold that defines these conditions across New Zealand's mountain environments. In addition to elevation, the southerly and southeasterly aspects of parts of Doolans Basin will favour snow retention through reduced incoming solar radiation and greater topographic shading. The following assessment examines these potential advantages using preliminary historical snowpack simulations.

Historical Snowpack Modelling and Local Terrain Influences

21. Preliminary historical snowpack simulations were undertaken using the physically based Flexible Snow Model (FSM2) as part of the MBIE-funded Smart Ideas research project, Better runoff and hazard predictions through national-scale snowmelt forecasting (MBIE, 2023). Model outputs from this project were made available for four representative locations across The Remarkables Ski Area and Doolans Basin. The simulations cover the period 1990–2018 and provide an assessment of seasonal snow accumulation, depth and persistence under historical climate conditions. The lower-elevation sites comprise the existing Base Building (1,595 m) and proposed Doolans Base (1,580 m), while the higher-elevation sites include the top of Curvey Basin (1,967 m) and the proposed top of Doolans Gondola (1,921 m). The modelling outputs are preliminary and have not undergone comprehensive site-specific validation. However, comparison with independent snow observations recorded by ski patrol and provided by NZSki offers useful context for evaluating the magnitude and seasonal evolution of the simulated snowpack.

22. The simulations indicate substantially greater natural snow accumulation at the proposed Doolans Base compared with the existing Base Building, despite their similar elevations (Figure 2). Peak modelled mean seasonal snow depth reaches approximately 110 cm at Doolans Base, compared with 57 cm at the Base Building. As the simulations do not explicitly represent wind-driven snow redistribution, this difference is consistent with the influence of slope aspect and topographic shading on incoming solar radiation. Reduced solar radiation can limit the energy available for snowmelt, allowing snow to accumulate and persist for longer, particularly during

periods when temperatures fluctuate around freezing. Comparison with ski patrol observations from the Alta weather plot (1,640 m) indicates that the simulated snow depths are broadly consistent with the range of conditions experienced at The Remarkables.

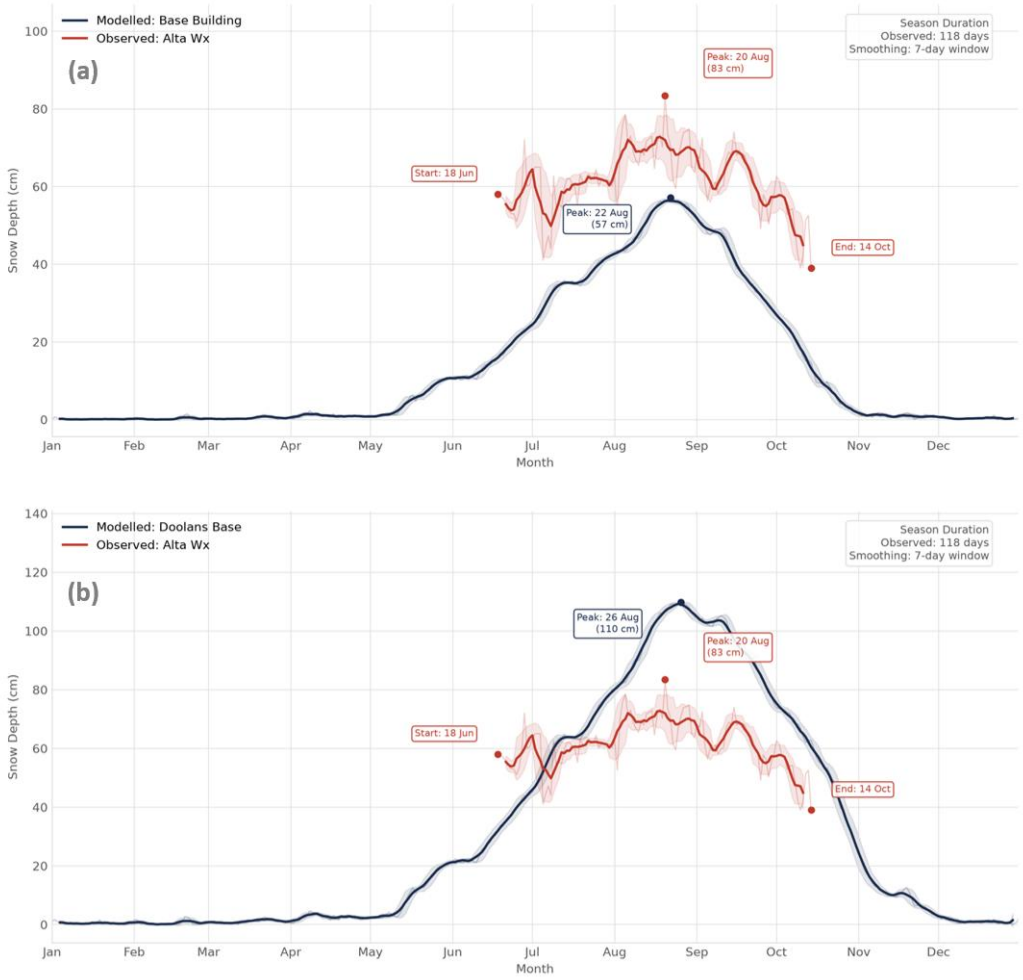


Figure 2. Comparison of seasonal snowpack cycles modelled using FSM2 (1990–2018) at (a) the existing Base Building (1,595 m) and (b) the proposed Doolans Base (1,580 m), with snow observations recorded by ski patrol at the Alta weather plot (1,640 m) during 2019–2023. Although the datasets cover different periods and elevations, the observations provide useful context for evaluating the magnitude and seasonal evolution of modelled snow depth. Source data: Preliminary FSM2 outputs from the MBIE Smart Ideas project (see Acknowledgements).

23. Elevation provides an additional and important control on snowpack accumulation and persistence. Lower temperatures at higher elevations generally increase the proportion of precipitation falling as snow, reduce the frequency of melt conditions and extend the duration of seasonal snow cover. These effects are evident in the historical FSM2 simulations, with substantially deeper and more persistent snowpacks at the higher-elevation locations (Figure 3). Peak modelled mean seasonal snow depths reach approximately 148 cm at the top of Curvey Basin

(1,967 m) and 136 cm at the proposed top of Doolans Gondola (1,921 m), with snow cover persisting into November and December. The slightly greater snow depth at Curvey Basin is consistent with its approximately 46 m higher elevation, although other local terrain influences may also contribute. Both locations demonstrate the relative advantages of higher-elevation terrain for natural snow reliability, consistent with international research identifying elevation as a key influence on ski-area sensitivity to climate change (Steiger et al., 2019). Comparison with ski patrol observations from the Sugar weather plot (1,860 m) provides additional context, with simulated snow depths and seasonal patterns broadly consistent with the range of conditions observed at The Remarkables.

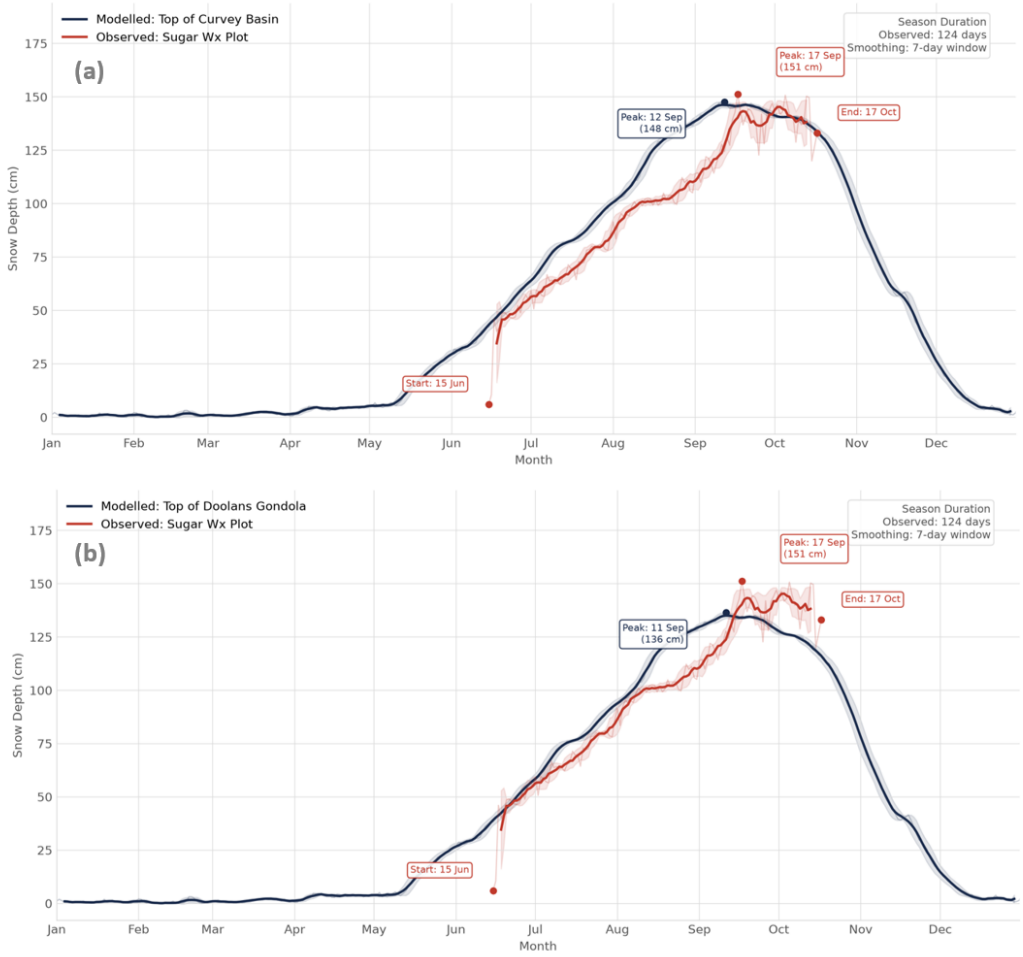


Figure 3. Comparison of seasonal snowpack cycles modelled using FSM2 (1990–2018) at (a) the top of Curvey Basin (1,967 m) and (b) the proposed top of Doolans Gondola (1,921 m), with snow observations recorded by ski patrol at the Sugar weather plot (1,860 m) during 2019–2026. Although the datasets cover different periods and elevations, the observations provide useful context for evaluating the magnitude and seasonal evolution of modelled snow depth. Source data: Preliminary FSM2 outputs from the MBIE Smart Ideas project (see Acknowledgements).

Decadal Changes in Seasonal Snow Conditions

24. The historical FSM2 simulations also indicate changes in seasonal snowpack characteristics between decades (Figure 4). Mean ski-season snow depth (June–October) decreases from the 1990s to the 2010s at all four locations, with substantially greater proportional reductions at lower elevations (approximately 30–35%) compared with higher elevations (less than 10%). Despite these reductions, Doolans Base consistently maintains a substantially deeper snowpack than the existing Base Building at a similar elevation, indicating that its relative snow-retention advantage persists across the three decades. These results highlight the greater reductions in mean snow depth at lower elevations and the importance of local terrain characteristics in influencing snow accumulation and persistence.

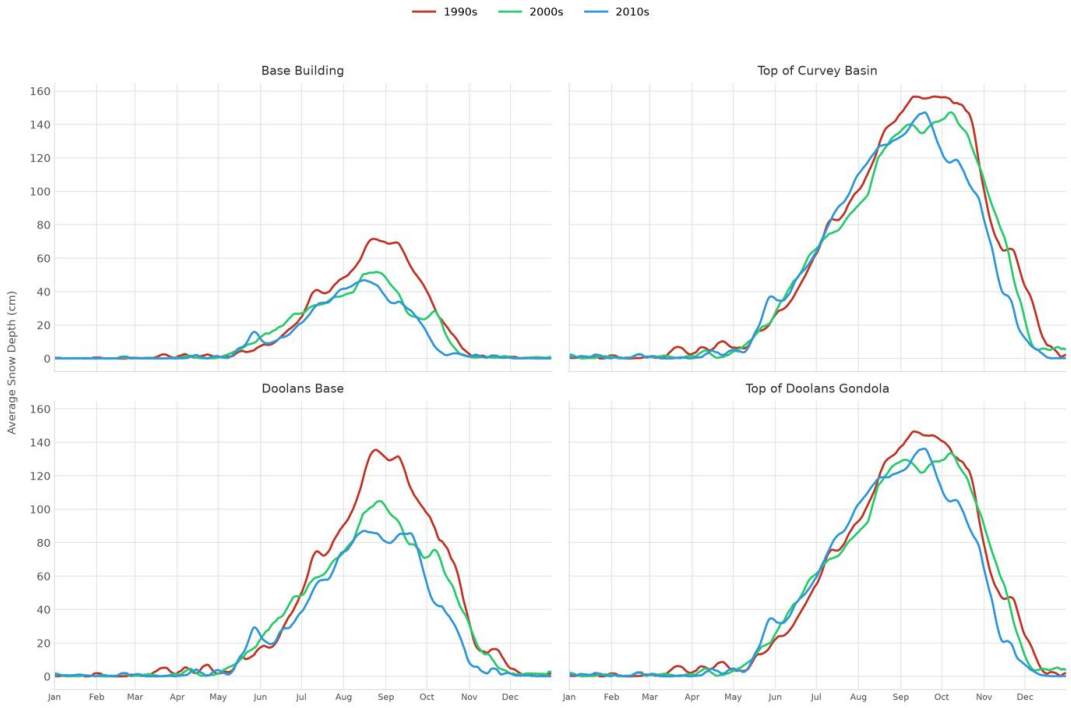


Figure 4. Decadal changes in modelled seasonal snow depth at four locations within The Remarkables Ski Area, based on FSM2 simulations for 1990–2018. Mean seasonal snow depth is shown for the 1990s, 2000s and 2010s (2010-2018) at the Base Building (1,595 m), Doolans Base (1,580 m), top of Curvey Basin (1,967 m) and top of Doolans Gondola (1,921 m). Source data: Preliminary FSM2 outputs from the MBIE Smart Ideas project (see Acknowledgements).

25. Despite a warming climate, historical snowfall records maintained by NZSki and discussed by Lawerence (2026) do not indicate a strong decline in annual snowfall at The Remarkables. Although the records exhibit considerable interannual variability, statistical analysis of annual snowfall totals for 1985–2025 identifies no significant trend using either linear regression ($p = 0.127$) or the Mann–Kendall test

($p = 0.096$). However, some uncertainty surrounds the consistency of the historical observations, particularly whether snowfall was recorded over comparable periods each season. These differences may influence the annual totals and limit the reliability of long-term trend estimates. Nevertheless, the available observations provide no clear evidence of a substantial decline in recorded snowfall over the historical period.

26. The contrast between the historical snowfall observations and FSM2 simulations is important: while the available observations do not indicate a strong decline in annual snowfall, modelled seasonal snow depth has decreased between decades. This highlights the importance of distinguishing snowfall from snowpack accumulation and persistence. Changes in precipitation phase, winter snowmelt and the balance between accumulation and ablation may contribute to thinner snowpacks even where annual snowfall remains relatively stable. International research demonstrates that warming can alter the timing and seasonal distribution of snowmelt (Musselman et al., 2017). However, the relative contributions of these processes have not been quantified in the present analysis, and the decadal comparisons should not be interpreted as a direct measure of long-term climate change.

27. Overall, the preliminary historical modelling comparing conditions from the 1990s to the 2010s demonstrate that both elevation and local terrain characteristics strongly influence snow accumulation and persistence at The Remarkables. Doolans Base maintains a substantially deeper snowpack than the existing Base Building at a similar elevation, while higher-elevation terrain supported deeper, longer-lasting snow cover and experienced smaller proportional reductions in mean snow depth than lower-elevation sites. These findings highlight the importance of elevation, aspect and topographic shading in influencing natural snow conditions within Doolans Basin.

IMPLICATIONS FOR THE PROPOSED DEVELOPMENT

28. Climate change is expected to progressively reduce the reliability of natural snow at The Remarkables Ski Area, although the magnitude of these changes will vary across the mountain. International research demonstrates that the sensitivity of ski areas to climate change depends strongly on elevation, regional climate and local terrain characteristics, with generally greater impacts at lower elevations (Steiger et al., 2019). Studies using physically based snowpack models have also highlighted the importance of resolving local snow accumulation and melt processes when assessing snow reliability (Spandre et al., 2019). These findings are consistent with the New Zealand research discussed above, particularly Hendrikx et al. (2012), Wright (2021) and Berg (2025).

29. The historical modelling presented under the heading Climate Resilience in the Doolans Basin above, provides site-specific evidence of the influence of elevation and local terrain characteristics on natural snow conditions at The Remarkables. Doolans Basin exhibits favourable conditions for snow accumulation and persistence associated with its elevation, aspect and topographic shading. The modelling also indicates that higher-elevation terrain experienced smaller proportional reductions in mean snow depth between the 1990s and 2010s. Together, these findings are consistent with the broader scientific understanding of the factors influencing snow reliability and provide a sound basis for assessing the climate resilience advantages of the proposed expansion.

30. Wind-driven snow redistribution may provide additional benefits in sheltered terrain within Doolans Basin, particularly where snow transported from exposed slopes accumulates in gullies and topographic depressions. However, this process is not explicitly represented in the preliminary FSM2 simulations, and its contribution to snow accumulation has not been quantified. The modelling results therefore provide evidence of favourable snow retention associated with local terrain characteristics, rather than a comprehensive assessment of all processes influencing snow distribution across the basin.

31. The advantages associated with elevation, aspect and topographic shading are expected to remain relevant under a warming climate, providing opportunities for comparatively favourable natural snow conditions as temperatures increase. Although the historical simulations do not establish how these advantages will evolve under future warming, they provide supporting evidence for the relative benefits of accessing terrain with these characteristics. The magnitude of future snowpack reductions will depend on greenhouse gas emissions and the response of local snowpack processes. International studies also demonstrate that natural snow reliability does not translate directly into ski-area operating conditions, which depend on snowmaking, grooming, terrain characteristics and other adaptation measures (Steiger et al., 2019).

32. Overall, the available scientific evidence supports the conclusion that the proposed expansion into Doolans Basin is likely to improve the relative climate resilience of The Remarkables Ski Area over the proposed 37-year concession period. The expansion provides access to additional terrain with favourable elevation, aspect and topographic characteristics that are expected to support natural snow accumulation and persistence under a warming climate, although the magnitude of future snowpack reductions within Doolans Basin has not been quantified.

LONG-TERM CLIMATE RESILIENCE AND THE ROLE OF SNOWMAKING

33. The long-term climate resilience of The Remarkables Ski Area must be considered over the proposed 37-year concession period. This section considers the scientific evidence on the role of snowmaking, including advances in snowmaking technology, in supporting ski-area climate resilience and its potential relevance to the proposed Doolans Basin expansion. It does not assess the specific water take requirements or proposed snowmaking operations associated with the Project.

34. As discussed under the section headed Climate Change and Seasonal Snow in New Zealand above, recent physically based snow modelling for the Craigieburn Range indicates that seasonal snow accumulation and persistence will decline through mid-century, with relatively modest differences between greenhouse gas emissions pathways over this period (Berg, 2025). Beyond mid-century, the projections diverge considerably, with seasonal snow conditions stabilising under lower emissions but continuing to deteriorate under higher emissions. Although these findings require further investigation across the Southern Alps, they suggest that a 37-year planning horizon is a reasonable timeframe for considering the potential climate resilience of the proposed development, particularly where favourable terrain characteristics and adaptation measures may help maintain snow reliability.

35. Hendrikx and Hreinsson (2012) considered the future role of snowmaking at ten New Zealand ski areas, including The Remarkables. Their simulations indicated that conventional snowmaking could offset some losses in natural snow days, although suitable snowmaking hours decreased with warming. Although these simulations reflected the snowmaking technology available at the time, more recent international research has further demonstrated the potential for snowmaking to improve ski-area resilience under climate change. Physically based modelling of ski areas in the French Alps and Pyrenees demonstrates that snowmaking can substantially improve snow reliability and is expected to remain an effective adaptation strategy for many ski areas through mid-century, although its effectiveness varies with elevation and regional climate (Spandre et al., 2019).

36. Snowmaking technology has advanced since 2012. Lawerence (2026) reports that modern snow guns can produce approximately 50% more snow than equipment used 15–20 years earlier, operate at wet-bulb temperatures near −1.5 °C rather than −2.5 °C, and consume approximately 15–20% less energy per cubic metre of snow produced. These technological improvements provide additional opportunities to maintain effective snowmaking under a warming climate, helping to offset some of the reduction in suitable snowmaking conditions.

37. Refrigeration-based snow factories offer an additional adaptation option because they can manufacture snow at outdoor temperatures unsuitable for conventional snow guns. Lawerence (2026) reports that NZSki's snow factory at Coronet Peak has improved early-season opening certainty and identifies commercial systems capable of producing up to approximately 1,000 m³ of snow per day. These technologies provide additional flexibility for maintaining snow cover during warmer conditions and may become increasingly valuable as conventional snowmaking opportunities decline under climate warming.

38. The strongest adaptation opportunity for Doolans Basin is therefore the combination of favourable natural snow-retention characteristics and targeted snowmaking, an approach consistent with international research demonstrating the importance of integrating local terrain conditions and snow management when assessing ski-area climate resilience (Spandre et al., 2019). Terrain that retains natural and manufactured snow more effectively may reduce the frequency and extent of snowmaking required, although this potential benefit has not been quantified. Snowmaking cannot reverse the regional climatic trend, but it may improve operational flexibility and help maintain access and continuity in selected areas, particularly during marginal early-season conditions.

39. The elevation, favourable aspects and snow-retention characteristics of Doolans Basin provide a strong foundation for maintaining snow reliability under a warming climate. When combined with advances in conventional snowmaking and refrigeration-based technologies, these characteristics offer significant opportunities to maintain snow reliability and operational flexibility over the proposed 37-year concession period. The available scientific evidence therefore indicates that the proposed expansion could contribute to a positive long-term adaptation strategy for The Remarkables Ski Area, providing access to terrain with favourable natural snow conditions and greater opportunities to manage the impacts of a warming climate.

OVERALL CONCLUSIONS

40. This assessment has considered the implications of climate change for the proposed Doolans Basin expansion at The Remarkables Ski Area, drawing on published New Zealand and international research, historical snowpack modelling, and recent advances in snowmaking technology. The principal findings are:

    (a) *Climate change projections*: Rising temperatures are expected to reduce natural snow accumulation and persistence across New Zealand's mountain environments, with generally greater impacts at lower elevations. Recent physically based snow modelling in parts of the Southern Alps reinforces these findings and demonstrates that the magnitude of future

snow decline depends strongly on the emissions pathway, particularly beyond mid-century.

(b) *Climate resilience of Doolans Basin*: Preliminary historical snowpack modelling comparing conditions from the 1990s to the 2010s demonstrates that both elevation and local terrain characteristics strongly influence snow accumulation and persistence at The Remarkables. Doolans Base maintains a substantially deeper snowpack than the existing Base Building at a similar elevation, while higher-elevation terrain across the existing ski area and proposed expansion supported deeper, longer-lasting snow cover. Higher-elevation sites also experienced smaller proportional reductions in mean snow depth between the 1990s and 2010s than lower-elevation sites. These findings highlight the importance of elevation, aspect and topographic shading in influencing natural snow conditions within Doolans Basin.

(c) *Implications for the proposed development*: The available scientific evidence, including historical snowpack modelling, supports the conclusion that the proposed expansion into Doolans Basin is likely to improve the relative climate resilience of The Remarkables Ski Area over the proposed 37-year concession period. Although natural snow reliability is expected to decline under continued warming, the advantages associated with elevation, aspect and topographic shading are likely to remain relevant. However, their effectiveness in maintaining snow cover under future climate conditions has not been quantified.

(d) *Long-term resilience and snowmaking*: The elevation, favourable aspects and snow-retention characteristics of Doolans Basin provide a strong foundation for maintaining snow reliability under a warming climate. Combined with advances in conventional snowmaking and refrigeration-based technologies, these characteristics offer significant opportunities to maintain snow reliability and operational flexibility over the proposed 37-year concession period.

41. Overall, the available scientific evidence supports the proposed Doolans Basin expansion as an important component of a long-term climate adaptation strategy for The Remarkables Ski Area. Historical snowpack modelling demonstrates that Doolans Basin has characteristics that favour natural snow accumulation and retention, providing opportunities to improve snow reliability and adapt to a warming climate. While the magnitude of future snowpack changes within Doolans Basin has not been quantified, the advantages associated with elevation, aspect and

topographic shading are likely to remain important, particularly when combined with advances in snowmaking technology.

Acknowledgements

42. The author acknowledges Dr Jono Conway from Earth Science New Zealand and the research team associated with the MBIE-funded Smart Ideas project, *Better runoff and hazard predictions through national-scale snowmelt forecasting*, for providing the preliminary FSM2 modelling outputs used in this assessment. The author also acknowledges Maya Berg, PhD candidate in the School of Geography at the University of Otago, for analysing these outputs and preparing Figures 2–4.

43. The author acknowledges the New Zealand Mountain Safety Council for facilitating access to the InfoEx database and The Remarkables ski patrol for recording the snow observations used in this assessment. These observations were obtained from the Sugar (1,860 m) and Alta (1,640 m) weather plots for the available ski seasons between 2019 and 2026. The observations were restricted to June–October and have not undergone comprehensive quality control; consequently, potential measurement errors and inconsistencies should be considered when interpreting comparisons with the modelled snowpack.



Professor Nicolas James Cullen

3 November 2026

References

Berg, M. G. (2025). *Ka Mua, Ka Muri: Simulating past and future snowpack dynamics on the Craigieburn Range in Aotearoa New Zealand* [Master of Science thesis, University of Otago]. https://hdl.handle.net/10523/48098

Bodeker, G., Cullen, N., Katurji, M., McDonald, A., Morgenstern, O., Noone, D., Renwick, J., Revell, L., & Tait, A. (2022). *Aotearoa New Zealand climate change projections guidance: Interpreting the latest IPCC WG1 report findings*. Report CR 501. Prepared for the Ministry for the Environment.

Department of Conservation. (2016). *Otago Conservation Management Strategy 2016–2026* (incorporating the 2022 partial review). Department of Conservation, New Zealand.

Essery, R. (2015). A factorial snowpack model (FSM 1.0). *Geoscientific Model Development, 8*, 3867–3876. https://doi.org/10.5194/gmd-8-3867-2015

Essery, R., Mazzotti, G., Barr, S., Jonas, T., Quaife, T., & Rutter, N. (2025). A Flexible Snow Model (FSM 2.1.1) including a forest canopy. *Geoscientific Model Development, 18*, 3583–3605. https://doi.org/10.5194/gmd-18-3583-2025

Hendrikx, J., Hreinsson, E. Ö., Clark, M. P., & Mullan, A. B. (2012). The potential impact of climate change on seasonal snow in New Zealand: Part I—An analysis using 12 GCMs. *Theoretical and Applied Climatology, 110*(4), 607–618. https://doi.org/10.1007/s00704-012-0711-1

Hendrikx, J., & Hreinsson, E. Ö. (2012). The potential impact of climate change on seasonal snow in New Zealand: Part II—Industry vulnerability and future snowmaking potential. *Theoretical and Applied Climatology, 110*(4), 619–630. https://doi.org/10.1007/s00704-012-0713-z

IPCC. (2021). *Climate change 2021: The physical science basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. https://doi.org/10.1017/9781009157896

IPCC. (2022). *Climate change 2022: Impacts, adaptation and vulnerability*. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. https://doi.org/10.1017/9781009325844

Lawerence, R. (2026). *Climate change resilience and the Remarkables Ski Area Upgrades and the Doolans Expansion Project*. Memorandum to the Environmental Protection Authority, NZSki Limited.

Ministry for the Environment. (2018). *Climate change projections for New Zealand: Atmosphere projections based on simulations from the IPCC Fifth Assessment* (2nd ed.). Ministry for the Environment, Wellington.

Musselman, K. N., Clark, M. P., Liu, C., Ikeda, K., & Rasmussen, R. (2017). Slower snowmelt in a warmer world. *Nature Climate Change, 7*, 214–219. https://doi.org/10.1038/nclimate3225

Spandre, P., François, H., Verfaillie, D., Pons, M., Vernay, M., Lafaysse, M., George, E., & Morin, S. (2019). Winter tourism under climate change in the Pyrenees and the French Alps: Relevance of snowmaking as a technical adaptation. *The Cryosphere, 13*, 1325–1347. https://doi.org/10.5194/tc-13-1325-2019

Steiger, R., Scott, D., Abegg, B., Pons, M., & Aall, C. (2019). A critical review of climate change risk for ski tourism. *Current Issues in Tourism, 22*(11), 1343–1379. https://doi.org/10.1080/13683500.2017.1410110

Wright, M. (2021). *The potential impact of climate change on seasonal snow in the Clutha/Mata-Au Catchment, New Zealand* [Master of Applied Science thesis, University of Otago].