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

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| **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 **Alexandra Macdonald Badenhop** on behalf of NZSki Limited in response to Section 53 Comments

Hydrology

Dated: 3 November 2026

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# INTRODUCTION

1. My name is Alexandra Macdonald Badenhop.

2. I am employed by e3Scientific Limited as the Technical Director for Water & Environmental Management, based in Arrowtown. I hold a Bachelor of Engineering (Environmental) (Hons) (1999) from the University of New South Wales (UNSW) and a Masters of Engineering Science (Groundwater Studies) from UNSW in 2008. The subjects completed for my masters also fulfilled criteria for Master of Engineering Science (Water Quality).

3. I have over 20 years of experience working in the water industry in Australia and New Zealand. My experience has encompassed a range of engineering studies including hydrogeology, hydrogeochemistry and water quality assessments, groundwater-surface water interactions and investigations to characterise site hydrology, and assessments of environmental effect for take and discharge consents across Otago and Southland.

4. I have acted as an Expert Witness in consent hearings in New Zealand for the past ten years and am a member of the New Zealand Hydrological Society and the International Association of Hydrogeologists.

5. I am working on the following Fast Track applications:

    a) FTAA-2507-1089 Bendigo-Ophir Gold Project for Otago Regional Council

    b) FTAA-2608-1288 Macraes Phase 4 (MP4) Project for Otago Regional Council

    c) This FTAA 2605-1236 Remarkables Ski Area Upgrade and Doolans Expansion for the applicant.

6. 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) Dr Michael John Crawshaw Greer's Surface Water Quality and Ecology Specialist Response, included as Appendix 2 of the Otago Regional Council s53 response;

    b) Charlotte Lockyer, Surface Water Hydrology Specialist Response included as Appendix 3 of the Otago Regional Council s53 response;

c) Dr Christopher Kavazos's Statement of Evidence, included as Appendix B to the Department of Conservation S51 concessions and approvals document and S53 comments;

d) Dr Andrew Rossaak Wetland and Tarn Specialist Response, included as Appendix 1 of the Otago Regional Council s53 response;

e) Matthew John Dale in his Statement of Evidence on behalf of Te Rūnanga o Moeraki, Kāti Huirapa Rūnaka ki Puketeraki, Te Rūnanga o Ōtākou, Hokonui Rūnanga, Waihōpai Rūnanga, Te Rūnanga o Awarua, Te Rūnanga o Ōtaka Aparima, Te Ao Marama Incorporated and Aukaha (1997) Limited.

7. My original findings are provided in full in the following reports lodged as Part B Technical Reports and Drawings

a) B-08 Remarkables Ski Area Upgrade and Doolans Expansion – Doolans Creek Water Take

b) B-14 Remarkables Ski Area Upgrade and Doolans Expansion – Tracks, Crossings, Stormwater Freshwater Ecological and Hydrological Impact Assessment.

8. These reports should be read in conjunction with the below reports as they interrelate: B-09 relates to freshwater ecological impacts of B-08 Doolans Creek Water take. B-12 relates to B-14 and covers wetland aspects of Doolans Basin. A-10 and B-16 relates to B14 with regard to stormwater aspects. A-10 Substantive Application Report Section 3 Project Description Updated 3 September 2026

a) B-09 Remarkables Ski Area Upgrade and Doolans Expansion – Freshwater Ecological Impact Assessment.

b) B-12 Remarkables Ski Area Upgrade and Doolans Expansion – Terrestrial Ecological Impact Assessment.

c) B-16 Remarkables Ski Area Upgrade and Doolans Expansion – Stormwater Concept Report.

d) Response to ORC re B.14 Tracks Crossings Stormwater Freshwater Ecological and Hydrological Impact Assessment 27 Aug 26.

e) Response to DOC re B-08 Doolans Creek Water Take 26 Aug 26.

f) Response to ORC re B-08 Doolans Creek Water Take 26 Aug 26.

9. Although this is not an Environment Court proceeding my confirmation of compliance with the Code of Conduct for Expert Witnesses in the Environment Court Practice Note 2023 is included in B-08 Remarkables Ski Area Upgrade and Doolans Expansion – Doolans Creek Water Take submitted as part of the substantive application.

10. I refer to the evidence of Dr Richard Allibone for tarn and Doolans Creek water take ecological matters; Mr Mark Hamer for other freshwater ecological matters; Mr Liam Salemink-Waldron, and Ms Rebecca Teele for wetland ecological matters.

## SPECIFIC RESPONSE TO COMMENTS

### Water Take

#### *Effects on Flows*

11. Dr Kavazos, (paragraph 20) states that the water take from the Doolans Creek can be managed to a low level of effect if there is a residual flow of 33.5 L/s and telemetered recording. I agree with this statement and the requirement for a residual flow is included in conditions WAT12 and WAT13. Whilst it was stated in updated Section 6.2.5 of B-08 that flow would continue to be monitored at DC3 to ensure the residual flow is maintained, it has not yet been included in consent conditions. I agree with the recommendation as per paragraph 92 of his evidence, that a consent condition requiring real time telemetered flow monitoring of Doolans Creek (right branch) is appropriate to ensure that the residual flow is maintained.

12. Ms Lockyer agrees that based on the available hydrological information, the proposed residual flow and the requested abstraction volume, the effects of the proposal on the hydrology and natural character of the stream are expected to be low. Dr Greer also agrees that all of the issues pertaining to the water takes effects on aquatic ecology have been resolved.

13. Mr Dale (paragraph 15) states that “the available assessment does not adequately quantify site-specific changes in wetted habitat or test the combined effects of abstraction and plausible future changes in snowmelt and seasonal low flows over the proposed 35-year consent period”. Site-specific changes in wetted habitat have been addressed by Dr Allibone. I consider that whilst there maybe changes in natural flows over the 35 year take period, the consent conditions limiting the rate of take and providing for residual flow will be protective of the stream hydrology.

#### *Flow Monitoring*

14. Dr Greer (page 18) has specified a preference for Consent Condition WAT.14 to measure cumulative water take and report the cumulative volume at 15-minute

intervals. At this stage the flow meter for the site has not been selected, however all measurement and reporting will be required to meet the Resource Management (Measurement and Reporting of Water Takes) Amendment Regulations 2020.

### *Climate Change*

15. Dr Kavazos discusses the effect of climate change on streamflow in paragraphs 199 – 203, in particular "Projected warming and changes in precipitation phase result in less water being stored as seasonal snow, more winter precipitation falling as rain, earlier runoff, increased winter flows and reduced summer flows. In the Kawarau catchment, projected ensemble-mean summer runoff reductions of approximately 10% by the 2050s and 24% by the 2090s, alongside a shift in the historic snowmelt-driven flow peak to earlier in spring." He states that further climate change advice is required to consider "The expected reduction in natural snowpack depth and potential increase in water abstraction and storage required to make snow." (Paragraph 203 c)". Mr Dale shares similar concerns and discusses the need for further climate change assessment of the proposed abstraction in Paragraphs 39-43 of his evidence.

16. In my opinion, the proposed consent conditions (WAT12 and WAT13) which require the maintenance of a residual flow of 33.5L/s, and the specified maximum rate of take of 30 L/s (WAT.11) protect against any additional stream impacts that could occur as a result of climate change. The residual flow proposed is currently 50% of Mean Annual Low Flow (MALF). If the MALF decreases due to climate change, the residual flow will be greater than 50% of MALF, and will prevent any further reduction in flow. The maximum rate of take and annual volumes specified in the consent conditions prevent any further taking of water to make additional snow. If climate change effects were such that the applicant required additional water, these consent conditions would need to be altered by a further consenting process that would require the assessment of any additional effects.

17. As stated in Mr Dale's evidence (paragraph 37), "climate modelling indicates that increasing temperature will affect snow accumulation, snow-cover duration and the proportion of precipitation falling as snow, with consequent changes to the timing and magnitude of snowmelt-derived runoff". Snow-melt is expected to occur earlier in spring than previously. This would increase the flows in Doolans Creek during the snow-making period. The low flow periods within the current record have occurred in late summer/early autumn after snowmelt has occurred. The flows during this season then are not likely to be decreased further, though the duration of low flow may be extended. Regardless, a reduction in the MALF will not change the residual flow that is required to be maintained, nor the overall volumes of water that are to be taken under the proposed consent conditions.

### *Alternatives Assessment - Lake Alta Water Abstraction*

18. ORC's view that further assessment is required to discount the use of Lake Alta within the currently consented limits as source of water for the Doolans expansion, including "the extent to which consent conditions constrain abstraction throughout the ski season (including lake level restrictions), and whether the available water could reduce or avoid the need for the proposed Doolans Basin storage reservoir" (ORC Comments Letter at Para 58).

19. Dr Kavazos expresses a similar opinion and, (paragraph 23, 119 - 126) considers that avoidance of the loss of Tarn 3 has not been adequately addressed by using an alternative water source such as Lake Alta. He states that "The proposed take is conservatively estimated by me at about 2.2% of the volume of Lake Alta and the applicant has not compared the ecological effects of the two options." Firstly, it is important to note that it is not the storage volume of the lake that is pertinent to the sustainable take of water from Lake Alta, but the annual lake recharge and outflows to the Rastus Burn and downstream wetlands that should be considered.

20. To address the concerns of both ORC and DOC, a hydrological assessment of the use of Lake Alta as an alternative to the Doolans water take is included as **Appendix A** to this statement of evidence. This assessment reviews the historical water use, and site water demand and finds that the water demand for the Remarkables Upgrade and Doolans Expansion is less than the currently consented annual take volumes from Lake Alta. However, to service the snowmaking needs of the ski area, the take would have to operate at a much higher instantaneous rate of take than is currently consented (347 L/s compared to 125 L/s),

21. A water balance model was prepared for Lake Alta based on historical water level data, pumping data, known groundwater losses and modelled Rastus Burn outflows. The model was run using 2025 data for three scenarios. Results indicate that full snow-making capacity will be significantly restricted by the lake level drawdown limits currently imposed on the consent. The additional take results in the lake level recovering weeks later than it otherwise would have, and hence later recommencement of flows into the Rastus Burn. However, flows had recommenced before the end of October for all scenarios.

22. To be able to operate the proposed expanded snowmaking system to produce the required amount of snow during available snowmaking weather windows, the lake level drawdown limit would need to be changed, as would the consented maximum rate of take. Should the additional drawdown of Lake Alta be considered to be an acceptable alternative to a new water take from Doolans Creek, a further environmental effects assessment would be required including (but not limited to) assessment of effects as a result of:

(a) the lowered lake levels;

(b) the installation and operation of the additional infrastructure; and

(c) downstream effects including on the potable water take and wastewater dilution and further more detailed modelling should be completed for additional years before a decision is taken.

**Hydrological Connectivity of Tarn 3 and Intermittent Stream to Groundwater**

23. Dr Kavazos states (paragraph 155) that "a constructed armoured swale is not an ecological substitute for an intermittent alpine stream channel. The two differ in substrate, in hydraulic and thermal behaviour, and in biological function. An intermittent alpine channel retains interstitial habitat within natural bed material, supports a specialised invertebrate and floral assemblages adapted to intermittent wetting, and exchanges water with the surrounding shallow subsurface across its length. A riprap lined swale designed for hydraulic conveyance and scour resistance does none of those things."

24. Similarly, Mr Rossaak has stated "The applicant also dismisses the hydrological connectivity of the tarn to ground water and the intermittent stream that feeds it. The tarn may lose water to groundwater without being fed by it. The proposed liner removes the groundwater pathway, and no water balance has been provided. The intermittent stream feeding the tarn is proposed to be reclaimed, and swales created around the lined reservoir to prevent inflow".

25. Both of the statements from Dr Kavazos and Mr Rossaak are in error regarding the swale design. I consider it likely that this error has stemmed from the mapping that labels the features as Armoured Swales, included Attachment G of the proposed consent conditions. However, the entirety of the swale is not proposed to be armoured. The primary design for the channel around the reservoir is described in Section 4.2.1 of B-16 Remarkables Ski Area Upgrade and Doolans Expansion – Stormwater Concept Report.

26. The only sections that are proposed to be lined with rock and geotextile are the inlet (~3 m length) and discharge points (2-3 discharge points of 2.5 – 3 m) to reduce scour and erosion. Whilst the ecological and biological functioning are outside of my expertise, it is my opinion that the swale will function in a similar manner hydrologically, in that the swale will receive the same intermittent inflows as the intermittent stream and therefore will be intermittently wet and will exchange water with the surrounding shallow subsurface across its length. Lower flows would be likely to be lost to ground along on a shorter extent of the swale whilst higher flows may persist further along the length of the swale.

27. The reports provided do not, as Mr Rossaak asserted, "dismiss the hydrological connectivity of the tarn to ground water and the intermittent stream that feeds it", rather they present a simple conceptual model of site hydrology As stated in Section 6.6 of B-08, "The reservoir is to be constructed in the location of an existing tarn. The flow into the tarn is to be diverted into an armoured swale around the northern side of the tarn which will also prevent any upgradient flows directly entering the reservoir. This will allow the water that previously fed the tarn to infiltrate to ground in close proximity to the existing tarn." In hydrogeological terms, the tarn is most likely to be disconnected and losing to groundwater, rather than connected and gaining or connected and losing.

28. Mr Rossaak has also stated that "The applicant concludes there will be no effect on downgradient wetlands but has not provided a water balance for the tarn catchment." As stated in Section 6 of B-08, the nearest downgradient wetlands are ~260 m from the tarn, and are therefore outside of the 100 m buffer required for assessment under the National Environmental Standards for Freshwater (NES-F). The conceptual model for the tarn water balance is expanded further in the following statements, with additional evidence supplied in Appendix B.

29. The tarn catchment is approximately 91,055 m2, of which the reservoir will be ~4450 $m^2$. This sub-catchment is situated within a larger sub-catchment of the Doolans Creek (Right Branch), which is 437,000 m2. It is this larger catchment that is likely the water source for the closest wetland to the tarn. The reservoir area is therefore ~5% of the tarn subcatchment, and 1% of the larger sub-catchment area. These catchments are shown in Appendix B. Currently, rain falling in the tarn sub-catchment either enters soil moisture storage and may subsequently recharge groundwater, or accumulates as runoff flowing into the intermittent stream and subsequently into the tarn, sheetflows directly into the tarn, or falls directly onto the tarn footprint. Some of the rainfall is lost via evaporation/evapotranspiration within the catchment. Of the runoff that enters the tarn, some will be lost from tarn storage via evaporation and some will be lost to groundwater.

30. After the tarn is converted to a reservoir, the runoff that formerly flowed into the tarn either via the intermittent stream or via sheetflow will be diverted into swales. This water will continue to either be lost via evaporation/evapotranspiration in the swales or be lost to groundwater. The water that formerly entered the tarn storage will not be diverted out of the tarn sub-catchment; it will continue to lose to groundwater adjacent to the tarn. This volume of water infiltrating is not expected to change significantly, however there may be some minor difference in the timing of the infiltration. The main difference in terms of water balance will be that the precipitation that falls directly onto the reservoir will no longer infiltrate to groundwater as the reservoir will be lined. This means that ~1% of the water falling in the larger catchment can no longer infiltrate to groundwater (noting that a component of this percentage will be lost to evaporation as it was previously). This difference in losses to groundwater is highly unlikely to have any effect on downgradient wetlands, and would be within the natural water balance variation.

## Streams and Crossings Effects on Hydrology

### *Service trench construction*

31. Dr Kavazos (Paragraph 135) and Mr Rossaak (Section 3.3) recommend that precast concrete bulkheads be used to avoid the adverse effects from pouring concrete in-situ (i.e. highly alkaline leachate). I note that the priority is to avoid preferential pathways within the wetland that divert water away from the wetland therefore the site-specific sizing of the bulkheads will be vital to achieve this aim, and a precast bulkhead might not achieve that. As an alternative, I recommend the use of a bentonite impregnated synthetic felt that will still provide the low conductivity barrier to flow without the risk of alkaline leachate from concrete. Mr Rossack (Section 3.3) and Dr Kavazos (paragraph 135) states that the use of bulkheads and permeable tracks in alpine peat remains unproven. Mr Rossacks recommends changing consent condition EW.6 to include “precast bulkheads upstream and downstream of trenches and backfill material no more permeable than the surrounding material”. I note that while the use of bulkheads and permeable tracks is unproven in alpine peat, the hydrological principles informing the recommendation of these crossings are well known. The flow of water is dictated by the hydraulic gradient and the hydraulic conductivity of the medium; mediums of lower permeability will reduce flow whereas higher permeability will increase flow. In the case of the services trench and the associated permeable crossings, the use of a material around the trenches and crossings “no more permeable than the surrounding material” would allow for the use of materials that reduce or present a barrier to the flow of water through the crossing and to the downgradient wetland, altering the hydrology of the wetland. Reduction in hydrological flow to the downgradient wetland is undesirable and we do not recommend this statement is adopted. Similarly, while the use of the concrete bulkhead is not proven, the intent is to provide a low conductivity barrier to flow in

the services trench, which can be achieved with a barrier several orders of magnitude lower than peat and native soils. As discussed in the previous paragraph, this could be achieved with a bentonite impregnated synthetic felt. Stormwater Management

32. Paragraph 137-138 of Dr Kavazos statement expresses concerns regarding the sedimentation of wetlands from a bare earthed track during construction and operation. It should be noted that stormwater controls are in place throughout the operation of the tracks, not only within the construction phase.

***Stream and Wetland Crossing Alternatives***

33. ORC (paragraph 60) states “Mr Rossaak also identifies concerns with the extent to which alternative track alignments, crossing locations and infrastructure configurations have been investigated to avoid or minimise effects on high-value wetlands.” The track alignment has been informed by mapping of wetland areas alongside slope assessment to reduce wetland loss, cut and fill for the track and therefore overall environmental impact. Alternative track alignments were not reviewed because the track has already been designed to minimise effects on wetlands. Similarly alternative crossing locations were not reviewed because crossings were largely dictated by the track alignment i.e. designed to minimise loss of wetland extent. Infrastructure configurations were reviewed with Stantec and the three main categories of infrastructure for crossings were decided on as follows:

(a) A splash crossing is the preferred crossing type because it maintains stream hydrology and minimises loss of stream habitat.

(b) Where a splash crossing is not appropriate, due to the gradient of approach angles, the stream itself or expected flow rates within the stream, then a culvert has been recommended because it is able to convey a larger flow while allowing for passage over the stream.

(c) Permeable crossings are used where the track passes through wetlands to ensure wetland hydrology is maintained.

34. e3s summarised all stream and wetland crossings associated with the proposed Remarkables ski area upgrade and Doolans expansion (e3s, 2026). A comparison of crossing options at each location was not undertaken, instead the characteristics of the crossings were assessed to demonstrate that the category of crossing listed above was able to maintain natural hydrology and minimise the loss of stream or wetland extent.

35. Dr Kavazos, (paragraph 153) states that a bridge crossing would be more appropriate than a culvert at proposed Culvert H, avoiding adverse effects given the

steep banks at the site. Dr Kavazos changes terms, referring to both a culvert and a splash crossing being recommended at this location. For clarification, a culvert has been recommended for this location not a splash crossing. The report by e3s (2026) assesses this crossing and notes that there is no wetland present at this location, the culvert has been sized appropriately for the catchment runoff potential and to maintain flow characteristics as much as possible. The report states that there will be loss of stream extent around culverts: upgradient of the culvert due to changes to flow as water enters the culvert, for the length of the culvert and downgradient where scour protection has been installed at the pipe outlet until it returns to natural stream bed. Erosion and sediment controls will be bespoke to each crossing however the general principles outlined in the Erosion and Sediment Control Plan are that during construction of a culvert clean water will be diverted around the area using a pipe drop structure to avoid it flowing over exposed earth. The overall freshwater ecological effect associated with the loss of stream habitat and sedimentation from the construction of culverts was assessed in e3s (2026) as low. While the ecological value of the streams are high there is a small scale of permanent loss and the erosion and sediment controls, alongside recommended monitoring, are considered appropriate to mitigate effects.

### *Ongoing Monitoring of Wetlands Associated with Stream Crossings – DOC*

36. Ongoing monitoring of wetlands is recommended by Dr Kavazos (paragraph 150) to ensure that effects are managed. Ongoing monitoring is addressed in condition ECO. 35 which recommends “Monitoring must be undertaken on an annual basis for 3 years and then biennially for a further 4 years”. This is further addressed in paragraph 167 where he recommends “b) measurable hydrological performance outcomes that maintain existing surface and shallow subsurface flow along with long-term performance monitoring established from pre-construction baseline states”. While I agree that existing surface and shallow sub-surface flow should be maintained, monitoring should be conducted in a manner that minimises intrusion to the wetland, which was the intent of the monitoring that has been recommend for condition 35. Dr Kavazos has not provided any further specific recommendations as to either what the performance outcomes should be or how they should be measured.

37. Mr Rossaak proposes the following changes to ECO.35:

    (a) At least one season of pre-works baseline.

    (b) Piezometers at representative seepage, cushion bog and string mire crossings.

    (c) Matched control sites.

(d) Quantified triggers for “loss or altered hydrological condition”.

(e) Extend to wetlands within 100 m downgradient.

(f) Any area showing hydrological change is counted as wetland loss under the ECO.6 cap, with compensation adjusted.

38. These recommendations are noted. I recommend that the photographic and quadrat monitoring proposed in ECO. 35 is carried out bi-monthly across spring and summer prior to construction commencing to provide a range in the baseline moisture conditions assessed. Monitoring should be at locations up and down gradient of the proposed works with the upgradient monitoring locations then becoming the control locations. Installation of piezometers could result in additional disturbance to the wetland areas. An alternative would be assessing soil moisture conditions alongside baseline monitoring using a handheld soil moisture meter. Soil moisture readings at the up and downgradient locations can then be taken after works are completed at the time intervals outlined in ECO.35. If soil moisture measured at the downgradient locations decreases below comparable baseline conditions and quadrat assessments show impacts on vegetation then a review of the crossing would need to be undertaken to identify and implement any physical changes required to ensure the crossing functions as intended. The above is considered a high-level recommendation and specific detail around how to assess hydrological condition and triggers for loss or altered hydrological condition should be included in the Terrestrial Ecology Management Plan.

39. Mr Rossack (condition WAT.25) suggests the condition be reworded to require pre-construction delineation of the riparian wetland to stream transition around Armoured Swale A. I agree with this update to condition WAT. 25.



**Alexandra Macdonald Badenhop**

**3 November 2026**

## Appendix A - Hydrological assessment of the use of Lake Alta as an alternative to the Doolans water take

# MEMO

| | | | |
|---|---|---|---|
| To: | NZSki | Ref: | 25047G |
| Cc: | Mitchell Daysh | | |
| From: | Alexandra Badenhop | | |
| Date: | 31.10.26 | | |
| Subject: | Lake Alta Water Take Option Assessment | | |

## 1 Introduction

The Doolans Creek Water Take Assessment of Effects (e3scientific, 2026a) (Water Take AEE) forms part of the NZSki fast track application to expand the existing Remarkables ski operation into the Doolans. The application requests a water take of 30 L/s totalling 38,872 $m^3$/month and 41,240 $m^3$/year from the Doolans Creek for snow making and potable water combined. NZSki has received feedback that due to the indirect effects of the take (1.5 km track building to the water take and use of Tarn 3 as a reservoir) that the alternative of taking additional water from Lake Alta should be further investigated due to the view that Lake Alta currently holds a large volume of water and NZSki have existing water take permissions.

### 1.1 Background

Within the Water Take AEE and request for information responses, the following reasons were provided as to why taking of additional water from Lake Alta or the Rastus Burn was not considered viable:

- Rastas Burn catchment overallocated
- Catchment less than half that of Doolans Creek above DC3 hence lower MALF
- Water level within Lake Alta cannot be maintained above required consented level and meet snowmaking needs of Remarkables and Doolans Expansion.

- Transferring water between Kawarau River and Nevis River catchments may be considered culturally inappropriate, however further input from manu whenua would be required to confirm.

NZSki currently holds three consents to abstract water within the Rastus Burn catchment, as summarised in Table 1. Both the snowmaking consents require abstraction from Lake Alta to cease when the lake water level is at or below 1799.4 m asl, and maintenance of a residual flow of 15 L/s within the Rastus Burn at the Rastus Burn location of take. These conditions (rather than the total consented volume) constrain snowmaking within the Remarkables ski field.

**Table 1: Current Consents held by NZSki within the Rastus Burn Catchment**

| Consent | Purpose | Take Location | Rate of Take (L/s) | Total Annual Take ($m^3$) | Minimum Lake Level |
|---|---|---|---|---|---|
| **RM11.368.03** | Primary Allocation for snowmaking | Rastus Burn and Lake Alta | 74 | 400,000 | 1799.4 m asl |
| **RM11.368.04** | Supplementary allocation for snowmaking | Rastus Burn and Lake Alta | 51 | | |
| **RM16.115.01** | Constant flow water supply* | Rastus Burn | 5.2 | 151,200 | n/a |

RM16.115.01 includes potable supply and flushing flows to ensure wastewater treatment systems remain operational in the alpine conditions.

Given that snow-making in the Remarkables Ski Area is already constrained by the existing consent conditions, it was not considered viable to increase the currently consented takes to provide snow-making in the Doolans Expansion Area, and therefore this option had not been subjected to a detailed investigation.

## 1.2 Scope of Work

This memo has been prepared to provide further assessment of the potential for taking additional water from Lake Alta. This includes the following scope of work:

- A review of the Remarkables Ski Area Water Demand and snow-making constraints
- Development of a basic water balance model for Lake Alta
- A water balance assessment of the effects of the required take on Lake Alta and flow into the Rastus Burn

# 2 Site Context

Lake Alta is located at the base of Double Cone in the Remarkables Range at an altitude of 1800 m.a.s.l. and has a catchment area of 110 ha. The alpine lake freezes over and is covered in ice and snow in winter and is open in summer. The lake sits on Department of Conservation (DOC) land within an area managed as the Remarkables Ski Area by NZSki. In summer, Lake Alta is a popular destination for recreational walking and swimming. The 13 hectare lake is approximately 34.45 m deep (Figure 1) (Clarke Fortune McDonald & Associates., 2011). The lake drains from an outlet at 1799.97 mASL to the Rastus Burn, which ultimately discharges to the Kawarau River and on to the Clutha River.

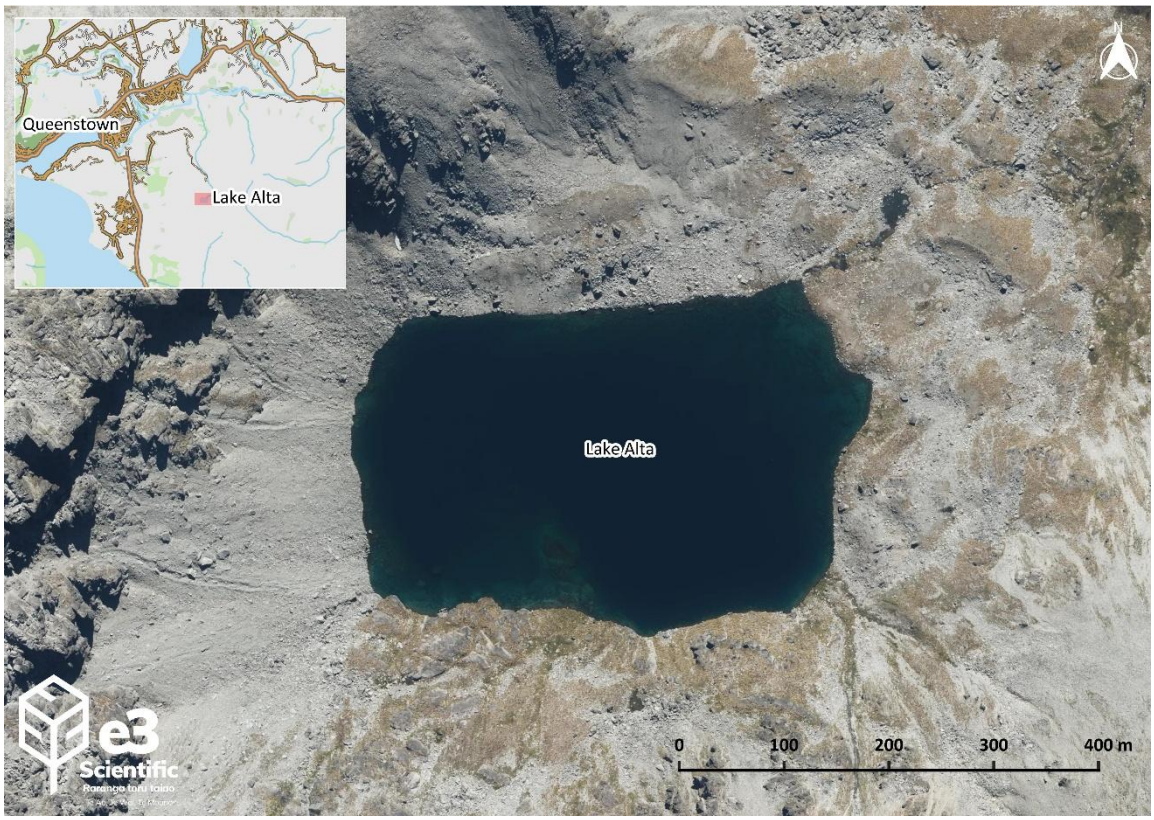



**Figure 1: Lake Alta.**

The water abstraction site is located 4 m below the water surface at the northwestern edge of the lake near the lake outlet. The pumps for the existing snowmaking water abstraction are flown and placed into the Lake for the winter season and removed over the summer months. They connect to a pipeline that runs from the Lake Alta abstraction site to the Lake Alta pumphouse. This pipeline was trenched and buried under consent RM11.368.02.

## 2.1 Climate

There are no permanent rainfall gauges in the Remarkables Ski Area. NZ Ski record rainfall (and snow depth) during the months the ski field is in operation. Rain Effects Ltd estimated the rainfall in the Lake Alta catchment in their (2003) study[i]. This is consistent with the rainfall medians predicted on the ORC Grow Otago map of 1250-1500 mm[ii].

## 2.2 Rastus Burn Flows

The Rastus Burn is not currently gauged; however water level monitoring and flow gauging events are currently being conducted adjacent to the wastewater infiltration basin to support the wastewater discharge consent. NZ River Maps presents the modelled MALF at this location is 31 L/s[iii], and the median flow as 54 L/s.

Flows were measured along the Rastus Burn between Lake Alta and the base building by e3Scientific staff on 5th May 2025 at the locations shown in Figure 2. Flows from Lake Alta into the Rastus Burn were 23 L/s before decreasing in a losing reach to 15 L/s and increasing to 33 L/s within the wetland area. Further losses and gains along the reach resulted in flows fluctuating within this range (15-33 L/s). The current take within the catchment is possible due to the large buffering volume of Lake Alta, however Otago Regional Council lists the Rastus Burn as an overallocated catchment.

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[i] Rainfall was estimated by applying a correction factor to the Queenstown Airport rainfall data to account for elevation. The elevation correction factor was informed by a study by the New Zealand Land Settlement Board (1977). This study referenced the expected rainfall at high altitudes in the Hector Mountains as 1525 mm/annum. Rain Effects Ltd therefore assumed that the rainfall at the Remarkables base building (at an elevation of 1630 m) would be roughly twice the rainfall recorded at the Queenstown Airport rain gauge. based on the assumption of a straight-line relationship between the elevation and rainfall at the Queenstown Airport rain gauge (726 mm/yr at 357 m elevation) and the rainfall at the top of the Remarks which resulted in an annual average rainfall estimation of 1720 mm/yr at 2320 m.

[ii] https://maps.orc.govt.nz/OtagoViewer232/?map=a3d75c9e135142e68f4e02b6fb64eaf7, accessed 29/10/2026

[iii] (NZ River Maps: https://shiny.niwa.co.nz/nzrivermaps/, accessed 28/07/26)

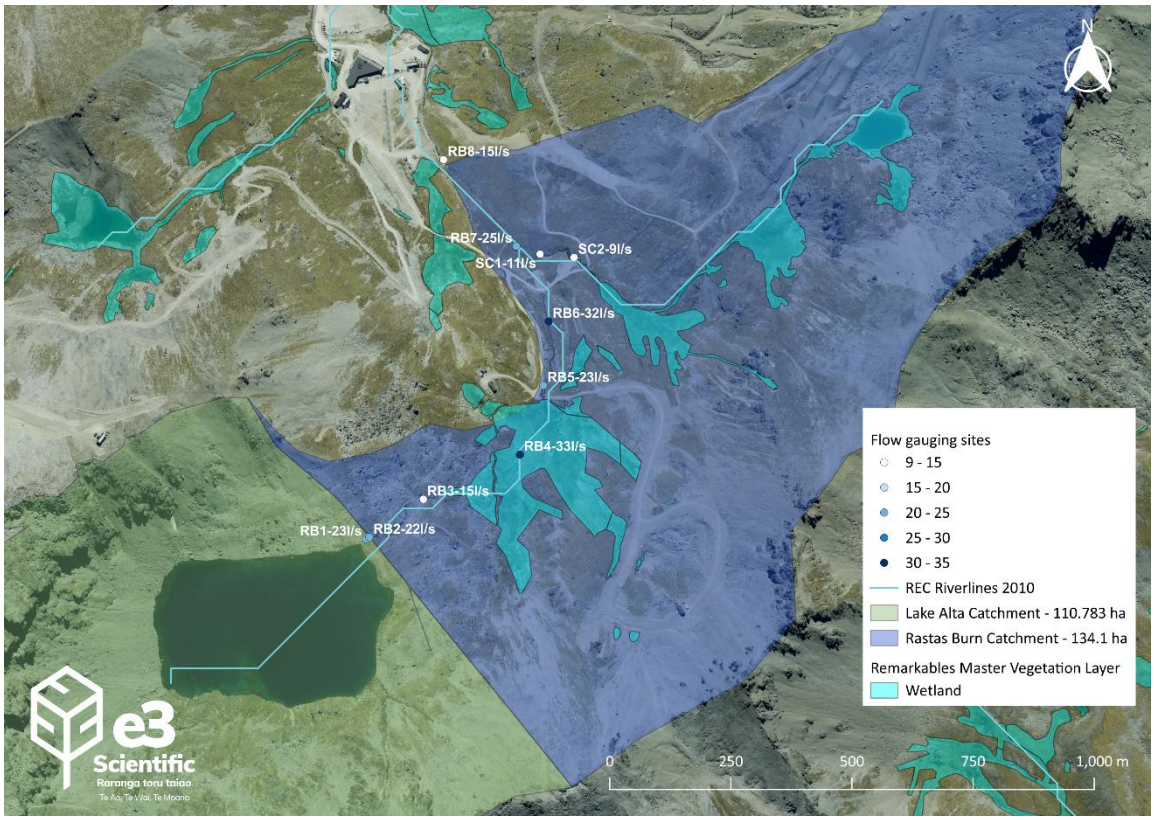



**Figure 2: Flows measured 5th May, 2025 and wetlands in Rastus Burn catchment[iv]**

## 2.3 Wetlands

Wetland areas are present approximately 250 m downslope of Lake Alta at breaks in slope and along riparian margins. Wetlands in the study area have been mapped by e3Scientific (Figure 2) and are further described (e3Scientific, Remarkables Ski Area Upgrade and Doolans Expansion - Terrestrial Ecological Impact Assessment. May 2026, 2026c) . The existing pipeline from the Lake to the pumphouse is trenched through these wetlands.

# 3 Water Demand

## 3.1 Snow-making Considerations

An explanation for the amount of water necessary for the Doolans Expansion was provided in Section 6.3 of the updated Water Take AEE with respect to the needs for potable water supply, snow-making, fire-fighting and balancing storage and rates of take.

[iv] Rastas Burn sub-catchment mapped is that above the potable water take, not the entire catchment.

Snow can be made faster at colder temperatures. The systems at the Remarkables are designed to make snow at around -4°C. The rate of take recognises that the optimum window for snow-making may not persist for an extended period and therefore is based on the need to generate a snow base within a certain number of hours given the right weather window..

## 3.2 Climate Change

The Climate Projections Map produced by the Ministry for the Environment[v] has been generated to a 5 km resolution across the country. The proposed development site fell under the Central Otago District and had a comparison base period of 1986-2005 under a climate change scenario of SSP1 – 2.6 and a future period of 2021-2040 looking at annual variables.

Under the above climate change scenario, average daily air temperature is expected to increase by +0.6°C, average daily minimum temperature increases of +0.5°C, total rainfall to increase by +2.2%, the number of rainy days <1mm to decrease -0.8 days, while number of rainy days >25mm set to change +0.5 days. Wind is expected to increase on average by +1.6%, and the number of windy days >10m/s increase by 5.7 days. Potential Evapotranspiration Deficit (PED) was used to estimate drought exposure, with this set to increase by approximately 17.9 mm.

In terms of snow-making, the availability of water for snow making is not expected to decrease in this scenario due to the total rainfall days not reducing, however the cold temperature windows for snow-making may become shorter; there may be more marginal temperature windows where snow-making is challenging and production is reduced, and there is expected to be increased warm weather windows where snowmaking is not feasible, and rainfall/warm weather events resulting in loss of snow pack during the ski season may become more frequent. This means that in this scenario the skifields need to have access to more water, and to be able to take and use the water to make the snow-pack more rapidly whilst the appropriate temperature window persists.

[v] https://map.climatedata.environment.govt.nz/, accessed 11/03/26

## 3.3 Historic Snow-making Water Use for the Remarkables Ski Field

Historic water use collated from water metering of the take from Lake Alta over the past ten years is provided in Table 2.

**Table 2: Historic Snow-Making Water Use**

| Year | No. Days Pumping | Average Daily Volume ($m^3$) | Max Daily Volume ($m^3$) | Total Volume ($m^3$) |
|---|---|---|---|---|
| **2017** | 83 | 1,802 | 8,512 | 149,531 |
| **2018** | 53 | 1,837 | 5,544 | 97,342 |
| **2019** | 59 | 2,052 | 9,021 | 121,045 |
| **2020** | 56 | 2,481 | 8,899 | 138,950 |
| **2021** | 53 | 2,877 | 9,577 | 152,488 |
| **2022** | 56 | 2,221 | 6,772 | 124,375 |
| **2023** | 46 | 2,634 | 6,983 | 121,151 |
| **2024** | 58 | 2,139 | 7,927 | 124,064 |
| **2025** | 81 | 2,303 | 7,530 | 186,570 |
| **2026** | 81 | 1,749 | 6,530 | 141,680 |

Whilst the highest volume taken to date is much less than the consent allocation of 400,000 $m^3$/year (186,570 $m^3$ in 2025), it is important to note that snow-making has been limited by both the consent conditions (maximum rate of take and lake level limits) and the available infrastructure. Snow-making has been severely limited by the available flow rates in the Rastusburn, resulting in a 3 stage approach requiring 500-700 hrs of pumping to cover key ski trails. This is significantly more time than other ski areas around NZ.

When reviewing the historic snow-making water use, it is important to note the following:

- The ski area has been constrained by power on how fast NZSki can make snow. Currently, given power supply constraints, they are unable to snowmake across all areas concurrently & run the lifts and deck heating- which means that they have historically used less water than was required for optimum snow-making within the snowmaking windows. The proposed expansion will upgrade the power supply, which will mean that snowmaking within the existing system and existing consents will be less constrained and should occur more often and over longer durations, given the available weather windows. This is expected to increase the total volume used (within the current consented limits).
- Snow-making demand has also changed over time due to ski area upgrades as follows:

- Since 2019, over 18 new snowmaking guns and 5 new lances have been added predominately across the new Sugar bowl trails in 2020 and 2021; and
- Since mid season 2024, snow-making commenced in Shadow Basin as part of the chairlift replacement project, with 18 new TT10 snowmaking fan-guns and 3 land (manual air/water) guns;

- During 2026, the water use was lower than expected due to limited snowmaking weather windows (warmer and windier weather in general, less calm colder periods ) and significant parts of the system were down for unplanned repairs and maintenance at various periods.

## 3.4 Snow-making Water Demand for Remarkables Upgrade and Doolans Expansion

Snow making water demand is calculated based on the water required to make a certain depth of snow. The calculations are based on snow having a density of ~400 kg/m$^3$ and therefore the volume of snow produced is 2.5 times the volume of water used to make the snow. The snow-making calculations allow for 15% losses via wind transport and evaporation at the time of snow-making. The calculated snow-making water demands for both the Remarkables Upgrade and Doolans Expansion, and the existing trails are shown in Table 3.

Of note are the following points:

- The snow-making regime in the existing area was designed based on producing only 0.4 m base over 80 hours, whereas the design for the upgrade and expansion area is designed to create 0.5 m base over 50 hours. The change to the design recognises the changing climate, i.e. that the temperature window in which to make snow to allow the ski areas to open and operate is likely to be shorter.
- Ideally, the ski area would have one main snowmaking campaign to create the base supplemented by natural snowfall and then top up whenever conditions allow for snowmaking (conditioning). This would continue until the end of August, at which time snowmaking would cease if the snow base was adequate. However, the amount of snow made June - August depends on natural snowfall, snowmaking climate conditions and on any warm or rainy periods that may have accelerated snow loss in the season.

- Sometimes, (not often, *but possibly becoming more frequent with climate change*) NZSki needs to make snow on trails with zero/little natural snow at the beginning of the season, which can then be completely lost by a warm/rainy period and the process needs to start again.
- Loss during the season can vary greatly. Snow isn't distributed evenly and more is required in higher traffic or more exposed areas and less in more protected areas or lee slopes.

The proposed Doolans power upgrade will enable snow to be made concurrently across all the slopes when the weather windows allow, and more often including during the day. This will allow more trails to be opened earlier in the season to provide an improved skiing experience and for them to be maintained with manmade snow. The increased snow-making for the Doolans expansion will result in higher water use at a higher instantaneous rate of take than is currently consented. The overall annualallocation is still expected to be within current consent limits in an average weather year (assuming no substantial rebuild campaigns are required due to severe snowpack loss in season)

**Table 3: Snow-making Water Demand**

| | Doolans Expansion & Remarkables Upgrade | | | | Rastas Burn (Existing) | | | Sub-totals | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Trails** | **Main Trail Doolans** | **Learners Slope** | **Main Trail to Sugar** | **Trail to Curvey** | **Sugar** | **Shadow** | **Curvey** | **Expansion** | **Existing** | **TOTAL** |
| Width | 30 | 40 | 7 | 15 | | | | | | |
| Trail | 2550 | 160 | 1100 | 480 | | | | | | |
| Area (m2) | 76,500 | 6,400 | 7,700 | 7,200 | 174,000 | 62,000 | 154,000 | 97,800 | 390,000 | 487,800 |
| Height of snow base (m) | 0.5 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | | | |
| Amount of snow for base (m3) | 43,988 | 3,680 | 4,428 | 4,140 | 80,040 | 28,520 | 70,840 | | | |
| Amount of water for base (m3) | 17,595 | 1,472 | 1,771 | 1,656 | 32,016 | 11,408 | 28,336 | 22,494 | 71,760 | 94,254 |
| Height of snow conditioning (m) | 0.5 | 0.5 | 0.5 | 0.5 | 1.1 | 1.1 | 1.1 | | | |
| Amount of snow for conditioning (m3) | 43,988 | 3,680 | 4,428 | 4,140 | 220,110 | 78,430 | 194,810 | | | |
| Amount of water for conditioning (m3) | 17,595 | 1,472 | 1,771 | 1,656 | 88,044 | 31,372 | 77,924 | 22,494 | 197,340 | 219,834 |
| **Total Water (base + conditioning) (m3)** | **35,190** | **2,944** | **3,542** | **3,312** | **120,060** | **42,780** | **106,260** | **44,988** | **269,100** | **314,088** |
| Design time for snowmaking base | 50 | 50 | 50 | 50 | 80 | 80 | 80 | | | |
| Flow rate (m3/hour) | 351.9 | 29.4 | 35.4 | 33.1 | 400.2 | 142.6 | 354.2 | 450 | 897 | 1,347 |
| **Flow rate (L/s)** | **97.8** | **8.2** | **9.8** | **9.2** | **111.2** | **39.6** | **98.4** | **125** | **249** | **374** |

# 4 Lake Alta Water Balance Modelling

To determine the effects of taking water for snow-making to fulfil the calculated water demand described in Section 3.4, water balance modelling was completed. Firstly, a basic annual calculation of water availability compared to water demand was completed to sense check the investigation in Section 4.1, followed by a daily timestep model described in the remainder of the section.

## 4.1 Basic Water Balance

The inflows into Lake Alta come from rainfall over the 110 ha catchment, and may enter the lake either by direct precipitation, runoff or groundwater inflows. Water is lost from the lake catchment via evaporation/evapotranspiration, groundwater losses and outflows to the Rastus Burn. Net recharge to the lake system was calculated by subtracting the outflows of groundwater and PET from the annual volume of precipitation falling on the catchment. This is the water that is available to refill the lake and overflow into the Rastus Burn. As a first pass sense check of the viability of the take, the water demand was compared to the net recharge to ensure it does not exceed 50% of net recharge to the lake (see Table 4). This indicates that under most conditions, there would be sufficient water available on an annual basis within the system to fulfil the snow-making water demands.

**Table 4: Basic Annual Water Balance**

| Scenario | Rainfall* (mm) | PET* (mm) | Groundwater Loss ($m^3$)# | Inflows ($m^3$) | Outflows ($m^3$) | Net Recharge ($m^3$) | 50% Recharge ($m^3$) | Water Demand ($m^3$) |
|---|---|---|---|---|---|---|---|---|
| **Median** | 1520 | 396 | 315,360 | 1,672,000 | 750,960 | 921,040 | 460,520 | 314,088 |
| **Dry year** | 1250 | 396 | 315,360 | 1,375,000 | 750,960 | 624,040 | 312,020 | 314,088 |

*Rainfall and PET sourced from Grow Otago mapping[vi]

# Groundwater loss values discussed in Section 4.2.1

## 4.2 Daily Timestep Model Setup

A daily timestep spreadsheet water balance model was setup in Microsoft Excel to assess the effect of increasing the take from Lake Alta on lake levels and Rastus Burn outflows. Model Inputs are summarised in Table 5.

[vi] https://maps.orc.govt.nz/OtagoViewer232/?map=a3d75c9e135142e68f4e02b6fb64eaf7, accessed 29/10/2026

**Table 5: Daily Timestep Water Balance Model Inputs**

| Parameter | Value | Source |
|---|---|---|
| **Catchment area (ha)** | 110,783 ha | GIS mapping |
| **Stage-Volume Relationship** | Lake Level (m amsl)= (-1.2169)*(lake volume in megalitres)$^2$ + 12.556*(lake volume in megalitres) + 1779.25 ($R^2$ =1) | Rain Effects Ltd (2012) 2011 survey and associated level-area-volume calculations by Clarke Fortune McDonald & Associates. Survey allowed depth contours to be drawn to calculate lake volume at various levels. |
| **Abstraction Flows** | Measured at five minute intervals and aggregated into daily volumes | NZSki water take flow metering |
| **Groundwater Losses** | 10 L/s | Flow gauging and calculations from lake level measurements, described further in Section 4.2.1 |
| **Lake level** | Measured at 15 minute intervals. Daily average extracted | NZ ski data logging for existing consents |
| **Rastus Burn Outlet** | <1799.97 m asl | Rain Effects Lts (2012), when lake level <1799.97 m no flow into the Rastas Burn. |
| **Rastus Burn Outflows** | Determined by lake level | Calculated using open channel flow equation based on lake level relative to outlet level. |
| **Net Inflows** | | Values calculated based water balance. Net inflows represent Rainfall +Runoff - Evaporation |

### 4.2.1 Groundwater losses

Groundwater losses have been calculated from lake level when it is <1799.97 m asl therefore no losses are occurring to the Rastus Burn. Lake level during summer (when it is not affected by potential snow melt) and when no rainfall has occurred, is converted to a volume. It has been assumed that there is no daily evapotranspiration loss as this data was too unreliable. The difference in daily lake level was converted to a volume and the maximum, minimum and average of these values are presented in Tables 2 and 3. The maximum value from Table 2 of 883 $m^3$/day is taken to be the maximum possible loss to groundwater. This is supported by the flow measurements taken in the Rastus Burn during the site visit by e3s on the 5$^{th}$ of May 2025 which showed that the difference in flow rate in the Rastus Burn between the Lake Alta outlet and just prior to the downslope wetlands was 10 l/s (assumed to be losses to groundwater) which equates to 864 $m^3$ per day.

### 4.2.2 Lake Level Data

Lake water level is recorded every 15 minutes and was downloaded for the years from 2014-2026.

Lake level data was processed as follows:

- To reduce the noise in the data daily median values were extracted.
- Lake levels between 2018 – March 2025 were adjusted by 0.5 m to account for a calibration error identified in March 2025 that has now been resolved
- Data greater than 1801 and less than 1798 m.a.s.l was considered in error and removed.

The available data set is presented in Figure 3. There are numerous gaps in the lake level record, however the records for the 2025 and 2026 ski seasons are complete.

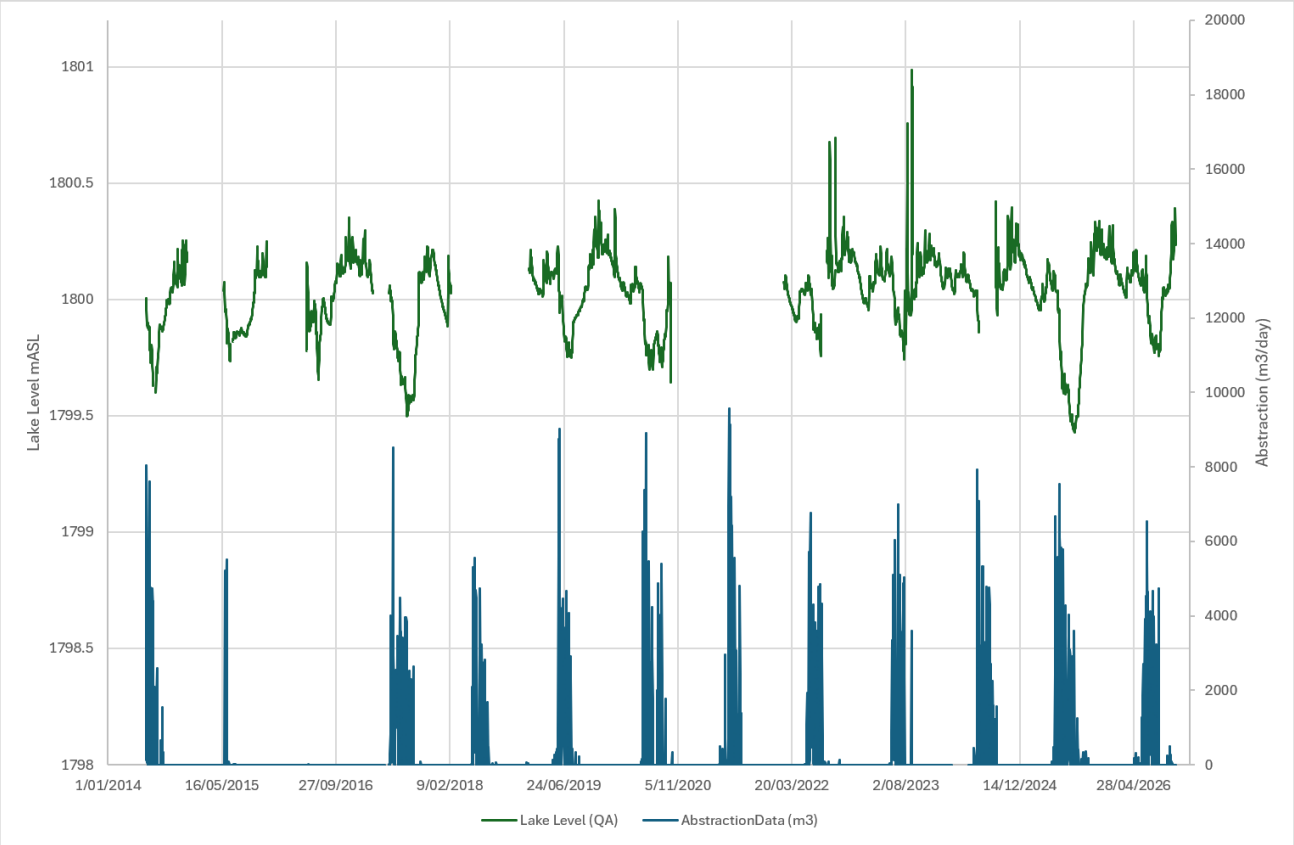



**Figure 3: Lake Alta Water Level Record and Abstraction Data**

### 4.2.3 Rastus Burn outflow

The outflow, Q, to the Rastus Burn was calculated using Manning's equation for open channel flow:

$$Q = \frac{1}{n} A R^{2/3} S^{1/2}$$

Where,

n = Manning's n roughness coefficient, 0.07 – considered the upper limit for a mountains streams with cobbles and boulders

A = Wetted area. Assumed trapezoidal channel with base of 0.4 m and side slope of 1:5, based on measurements made during flow gauging 5th May, 2025

P = wetted perimeter

R = A/P

S = slope, 0.03, based on GIS assessment and adjusted for flow gauging measurements

Note that the lake outlet is not actually a uniform channel and consists of large schist boulders that partially choke the outlet, as seen in Plate 1.



**Plate 1: Lake Alta Outlet**

The only flow measurement that could be used for calibration was the flow measurement on 5th May, 2025 of 23 L/s at the outlet, which matched well with modelled flow of 22 L/s.

Recent flow measurements in the Rastus Burn at the wastewater infiltration site (RB US) were also used to sense check the results, as the flow from the outlet should always be less than the measured flow downstream. These measured flows and calculated flows are compared in Table 6. Note that the table is sorted in order of lake level at the time of gauging, and the magnitude of gauged flows at RB US isn't correlated with the lake level. This is likely because the lake level had only just recovered past the outlet height at the lake in September, and therefore the outlet flows were a much lower proportion of the flows at the RB US site. The modelled flows at the outlet were always less than the measured flow at the RB US downstream site, which indicates the model is reasonable.

**Table 6: Measured vs. Modelled Flows**

| Location | Date | Time | Flow (L/s) | Uncertainty (L/s) | Lake Level | Calculated Flow at Outlet (L/s) |
|---|---|---|---|---|---|---|
| **RB US** | 1/09/2026 | 1:50:00 PM | 85 | 6.4 | 1800.008 | 5 |
| **RB US** | 24/09/2026 | 11:30:00 AM | 67 | 7.0 | 1800.036 | 15 |
| **RB US** | 1/10/2026 | 1:30:00 PM | 124 | 6.7 | 1800.044 | 19 |
| **RB US** | 9/03/2026 | 11:30:00 AM | 64 | 3.1 | 1800.070 | 35 |
| **RB US** | 28/10/2026 | 12:40:00 PM | 511 | 74.6 | 1800.275 | 441 |
| **RB Outlet** | 5/05/2025 | 10:05:00 AM | 23 | 0.8 | 1800.050 | 22 |

### 4.2.4 Net inflows

Net inflows (precipitation + runoff + groundwater inflows – evaporation/evapotranspiration) were calculated for the historical lake level record using the following equations:

$$\Delta s = V_{t2} - V_{t1}$$

Where,

$\Delta s$ = Change in lake storage ($m^3$)

$V_{t1}$ = Lake volume at timestep 1 (determined from stage-volume relationship)

$$\text{Net inflows} = \Delta s + Q_{gw} + Q_{RB} + Q_P$$

Where,

$Q_{gw}$ = Groundwater Loss (10 L/s)

$Q_{RB}$ = Rastas Burn Outflow

$Q_P$ = Abstraction volume

## 4.3 Future Scenarios

Future scenarios were run for the 2025 year, which was considered to be a low flow year, as discussed in e3scientific (2026a), as it had a complete pumping and lake level data set, as show in Figure 4. It was also the year with the highest recorded abstraction of 186,570 $m^3$.

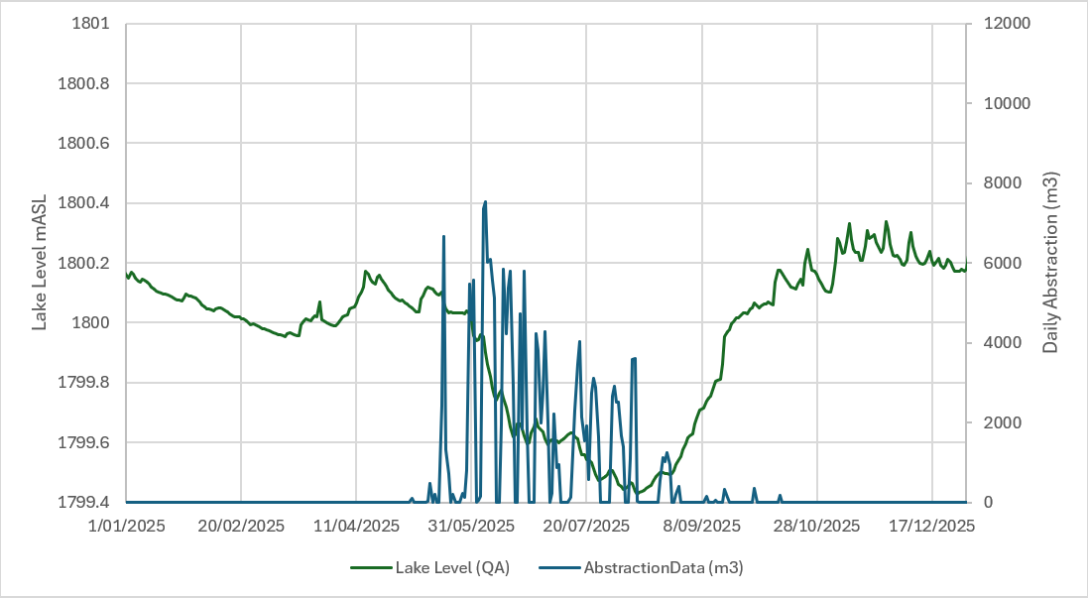



**Figure 4: Lake level and Pumping Data, 2025**

For the future scenarios, pumping occurred for the same number of hours that was recorded on each day of 2025. This was considered to give a reasonable representation of snow-making windows, however given that snow-making was still constrained by power, it may be an underestimate of the available snow-making hours that would otherwise have been available.

For each scenario, the pumping rate was increased to the desired rate of 374 L/s. The following three scenarios were modelled:

A. No lake level limit. Pumping only stops when the proposed abstraction volume is reached
B. Lake level drawdown limit of 1799.4 mASL
C. Lake level drawdown limit of 1799.0 mASL

## 4.4 Results

The modelled lake levels and Rastus Burn outflows for each scenario are compared with the historic measured water levels and modelled Rastus Burn flows for 2025 in Figure 5 to Figure 7. These results indicate that if the pumping regime was altered for 2025 the lake level would likely recover and the flow in the Rastas Burn recommence before the end of October for each scenario, which is up to almost a month longer than it took in 2025. However, only Scenario A which allowed uncontrolled drawdown of Lake Alta enabled the required snow-making volumes to be taken, and resulted in a lake level drawn down over 1.5m below the current consented limit.

| Scenario | Snow-making Volume* ($m^3$/year) | Minimum Lake Level m.ASL | Rastus Burn Flow Resumes |
|---|---|---|---|
| **Historic 2025** | 186,570 | 1799.433 | 20/09/2025 |
| **A. No lake level limit. Pumping only stops when the proposed abstraction volume is reached** | 324,819 | 1797.88 | 16/10/2025 |
| **B. Lake level drawdown limit of 1799.4 mASL** | <235,732 | 1799.4* | 5/10/2025 |
| **C. Lake level drawdown limit of 1799.0 mASL** | <285,100 | 1799.0* | 12/10/2025 |

Note that the model setup using the daily timestep results means that the water level may be drawn down further than the limit during the day or enable additional abstraction of water beyond the limit within that timestep before abstraction stops. For this reason the volume is shown as less than the volume the model has recorded.

Note that after the Rastus Burn outlet begins to spill there are some unrealistic fluctuations that occur due to the daily timestep used in the model. i.e. the Rastus Burn flows out at the one rate for the entire 24 hours based on the lake level at the beginning of the timestep which means the water level can drop lower than it would in reality. This does not affect the results in terms of the time it would take for the lake level to recover to the outlet height or the overall amount of drawdown in the lake.

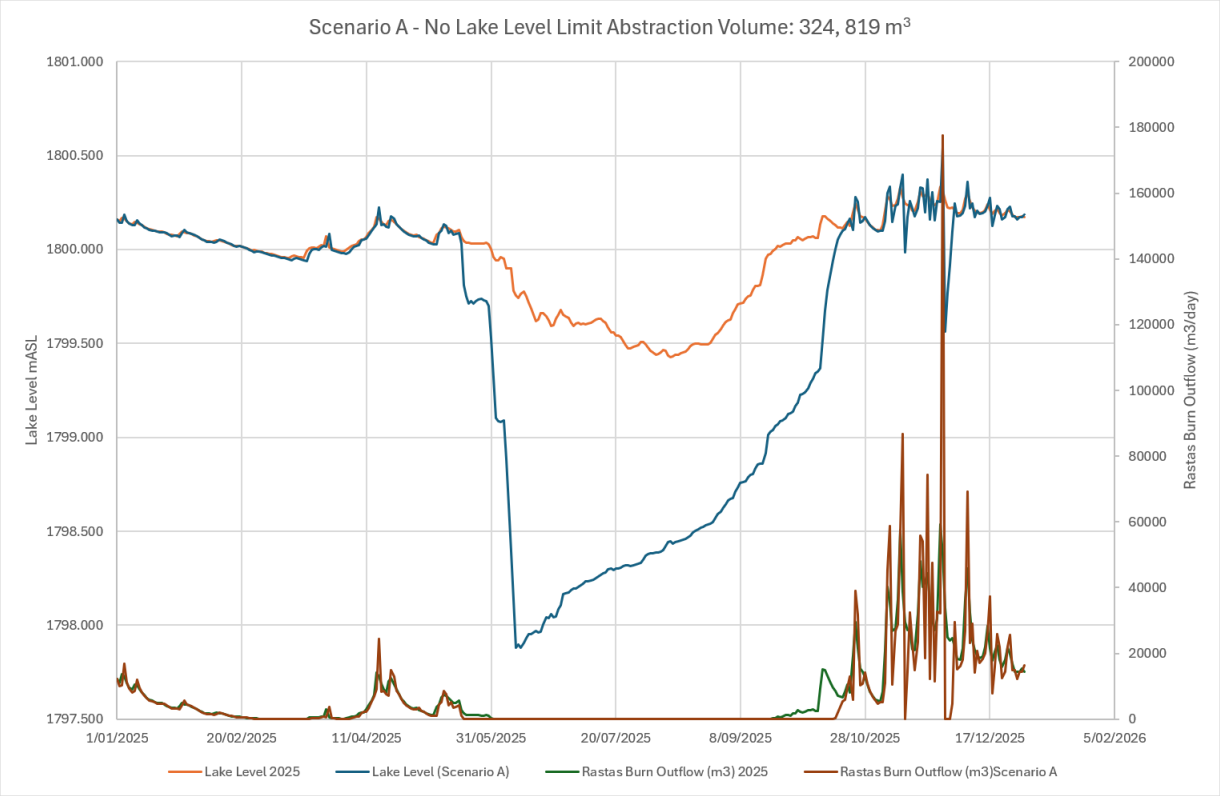



**Figure 5: Scenario A Lake Levels and Rastus Burn Outflows**

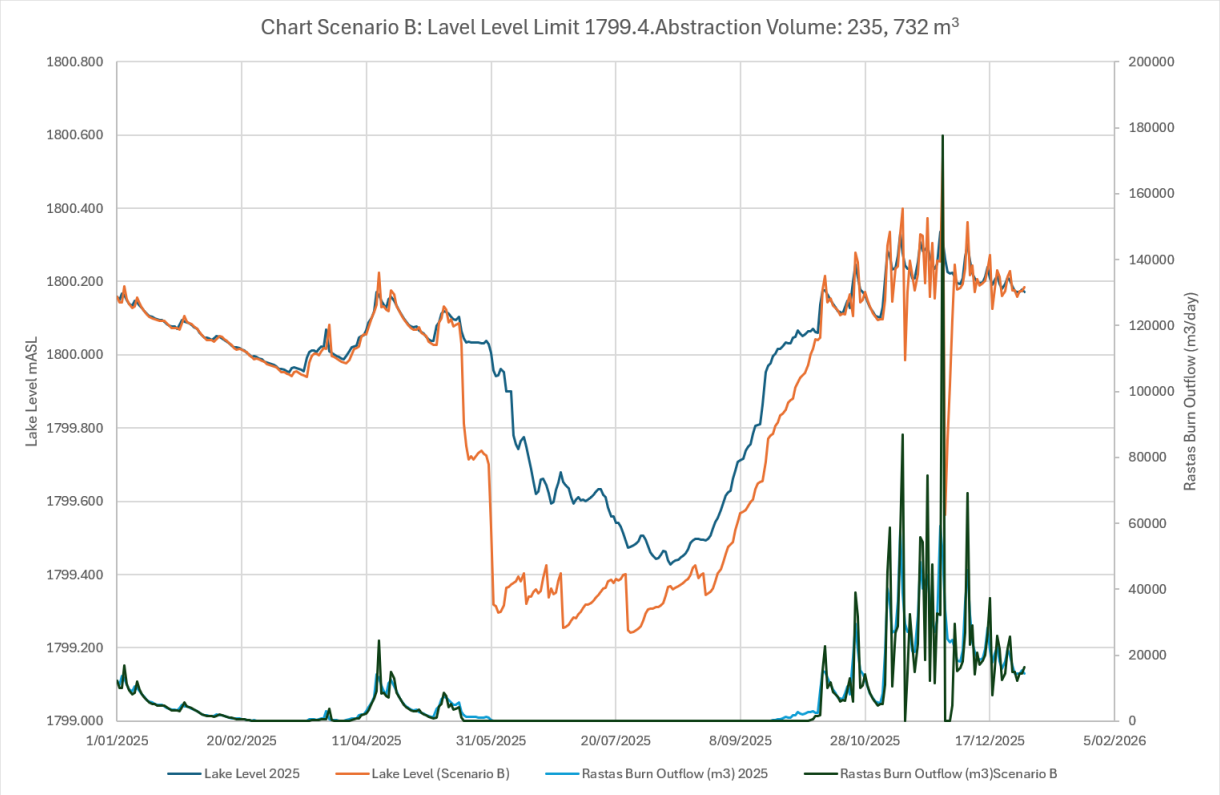



**Figure 6: Scenario B Lake Levels and Rastus Burn Outflows**

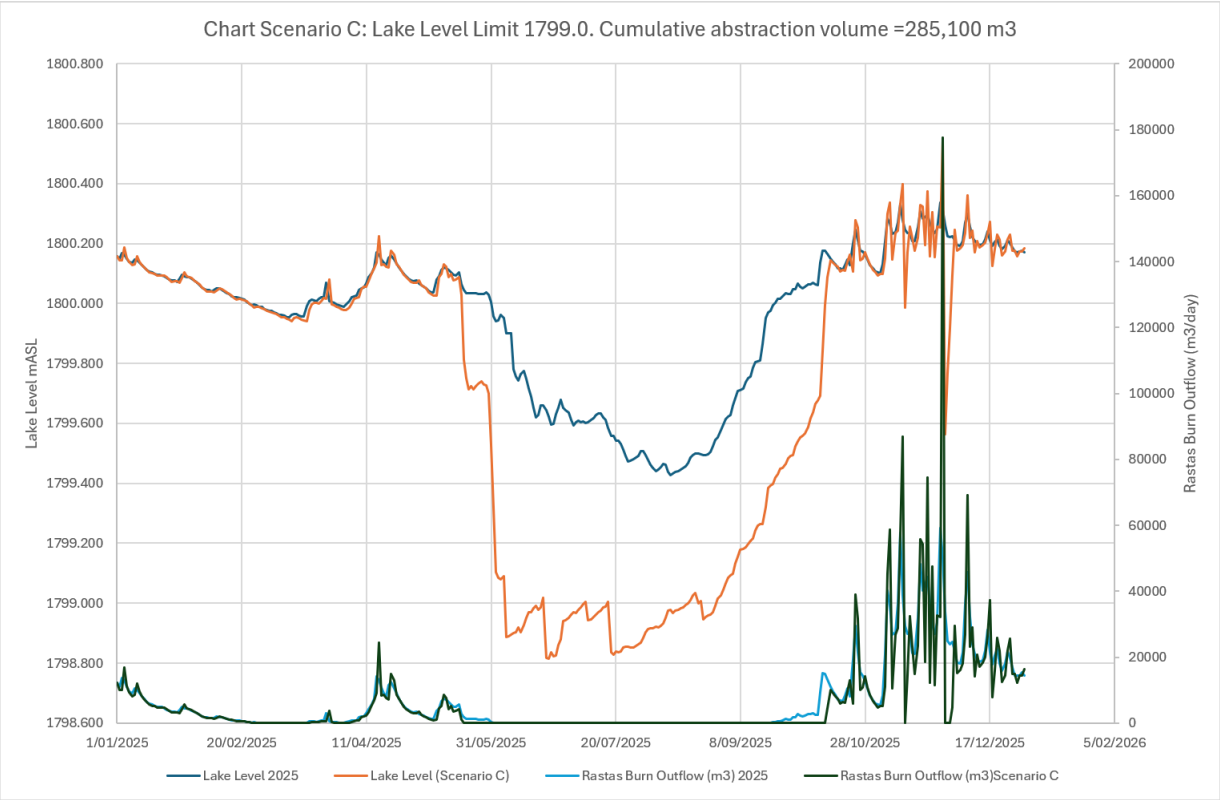



**Figure 7: Scenario C Lake Levels and Rastus Burn Outflows**

# 5 Conclusions & Recommendations

The review of snow-making water demand established the potential water requirement of 314,088 $m^3$/year for the Remarkables upgrade and Doolans expansion. This is within the currently consented annual take volumes from Lake Alta, however the instantaneous rate of take required is 374 L/s to allow snow-making across the expanded ski area when the appropriate snow-making weather window occurs. This is much higher than the currently consented rate of 125 L/s.

A water balance model was prepared for Lake Alta based on historical water level data, pumping data, known groundwater losses and modelled Rastus Burn outflows. The model was run using 2025 data for three scenarios. Results indicate that full snow-making capacity will be significantly restricted by the lake level drawdown limits currently imposed on the consent.The additional take results in the lake level recovering weeks later than it otherwise would have, and hence later recommencement of flows into the Rastus Burn. However, flows had recommenced before the end of October for all scenarios.

To be able to operate the proposed expanded snowmaking system to produce the required amount of snow during available snowmaking weather windows, the lake

level drawdown limit would need to be changed. Should the additional drawdown of Lake Alta be considered to be an acceptable alternative to a new water take from Doolans Creek, a further environmental effects assessment will be required including (but not limited to) assessment of effects as a result of: the lowered lake levels; the installation and operation of the additional infrastructure; and downstream effects including on the potable water take and wastewater dilution and further more detailed modelling should be completed for additional years before a decision is taken.

# 6 References

e3scientific. (2026a). *Doolans Creek Water Take Assessmentof Effects.* Arrowtown: e3scientific Ltd.

e3Scientific. (2026b). *Remarkables Ski Area Upgrade and Doolans Expansion - Doolans Basin Weir, Water Take and Reservoir Freshwater Ecological Impact Assessment. May 2026.*

e3Scientific. (2026c). *Remarkables Ski Area Upgrade and Doolans Expansion - Terrestrial Ecological Impact Assessment. May 2026.*

## Appendix B – Tarn 3 supporting evidence

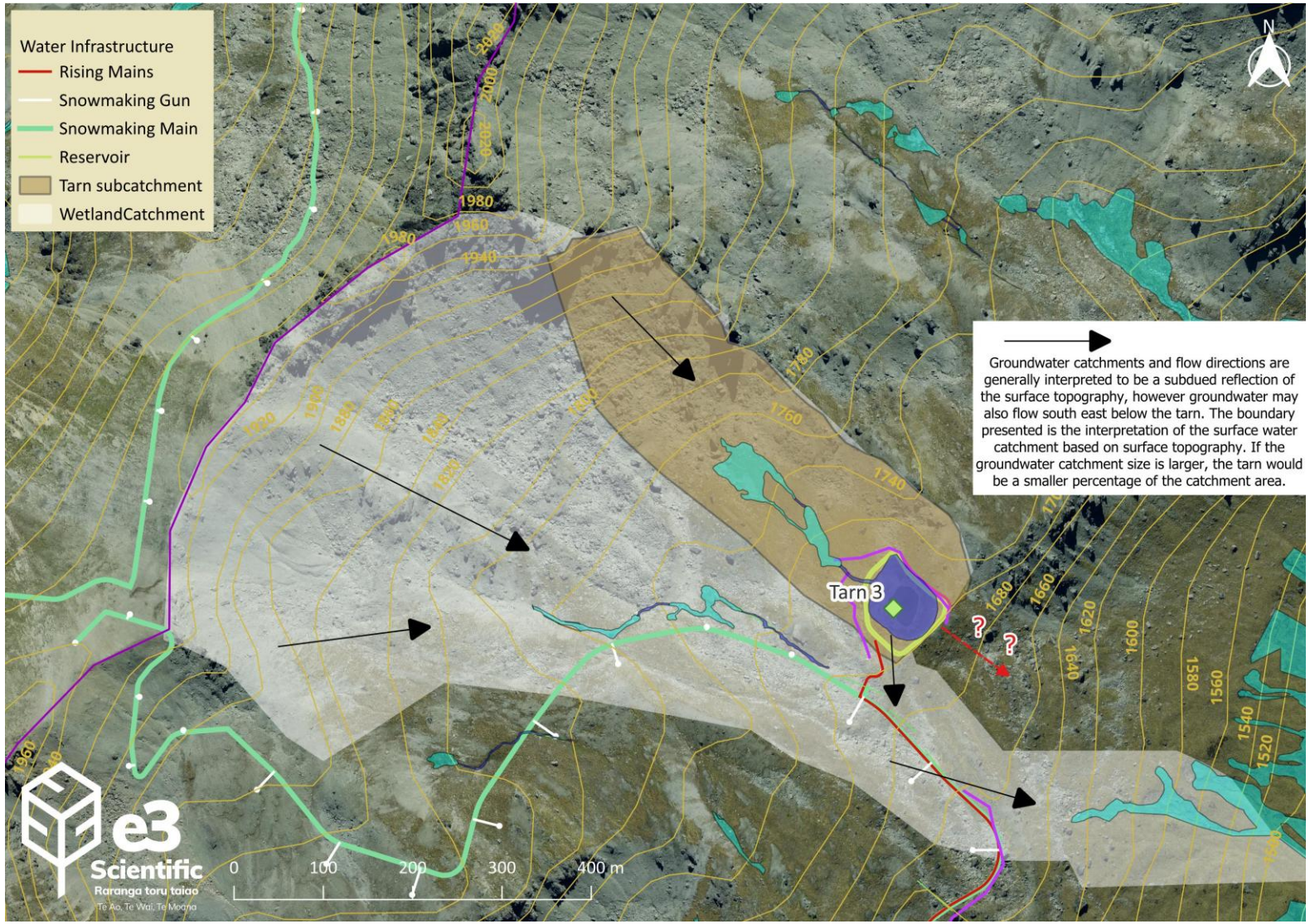



**Figure 1: Surface Water Catchments and Likely Groundwater Flow Directions**



**Above: Photo taken from the eastern edge of Tarn 3 facing ESE downgradient.**



**Above: Photo taken from the eastern edge of Tarn 3 facing SSE with the moraine visible in the middle ground.**

The photos in the photo plate above demonstrate that there are no wetlands visible on the terrace directly below Tarn 3. There is no obvious surface flow path from the outlet of Tarn 3 towards the terrace below. If there was groundwater flow to the east beneath the tarn, wetlands would likely be present at the break of slope in this location.