Mount Buller Water Storage Project

Hydrological and Ecological Monitoring and Adaptive Management Program

Impact Year 1 Monitoring

DRAFT REPORT

Prepared for Mount Buller and Mount Stirling Alpine Resort Management Board

2 October 2020

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Contents

Tables

Figures

Photos

Summary

Background

In October 2019, the Mount Buller and Mount Stirling Alpine Resort Management Board (the RMB) started construction of a 100-megalitre off-stream water storage and ancillary infrastructure (the project) on Mount Buller within a 10.347-hectare Project Construction Footprint (PCF) between the summit and the village. As part of the project, the RMB is implementing a Hydrological and Ecological Monitoring and Adaptive Management Program (HEMAMP), with an objective of maintaining the extent and condition of Alpine Bogs that are downslope of the water storage.

Two years of baseline ecological monitoring data (Baseline Years 1 and 2) were collected as part of the HEMAMP in 2018 and 2019. This report summarises the ecological monitoring data collected in 2020 (Impact Year 1), compares the results of Impact Year 1 monitoring with baseline data and assesses these results against the HEMAMP's performance criteria.

The performance criteria are as follows:

- The 'extent' criterion – there will be no more than a 10% reduction in the total combined area of the impact sites, determined by on-ground or remote (aerial) monitoring and taking into account natural variation based on extent observations averaged across control sites.
- The 'composition' criterion – there will be no more than a 10% reduction in the total 'bog-dependent' native flora species richness of the impact sites, taking into account natural variation based on species richness observations averaged across control sites.
- The 'encroachment' criteria:
  - Atypical species – there will be no more than a 10% increase in the cover of 'non-bog-dependent' species within the impact sites, taking into account natural variation based on observations averaged across control sites.
  - Weeds – the total cover of weeds (naturalised exotic flora species) within the impact sites will not exceed 5%.
- The 'structure' criterion – there will be no more than a 10% reduction in the average cover of Peat Moss *Sphagnum* spp. within the impact sites, taking into account natural variation based on Peat Moss cover averaged across control sites.

Results

Criterion	Parameter	Threshold	Result*	Compliant?	Action Req'd?	Comments
Extent	Area of Alpine Bogs	-10.0%	-3.7%	Yes	Yes	Control weeds/deer, focussing on areas of sedimentation
Composition	Bog-dependent species richness	-10.0%	0%	Yes	No	
Encroachment by atypical species	Cover of non-bog-dependent native flora	+10.0%	+6.4%	Yes	Yes	Investigate possible hydrological changes at impact sites
Encroachment by weeds	Cover of weeds	5%	7.3%	No	Yes	Control weeds/deer, focussing on areas of sedimentation
Structure	Cover of Peat Moss	-10.0%	+14.0%	Yes	No	

*Note: The result for cover of weeds is expressed as an absolute percentage cover. All other results are expressed as a relative change from the Baseline Mean (BM) to Impact Year 1 (IY1).

Conclusion and recommendations

A number of new and pre-existing impacts on Alpine Bogs (at impact sites and control sites) were recorded in Impact Year 1, including the following:

- Deer activity, such as wallowing and trampling, continues to have impacts on control sites and impact sites, with three control sites (Bogs 4.1/5/7, 11.1 and S1) and two impact sites (Bogs 4.2 and 6) noticeably affected. Based on personal observations and a comparison of photographic evidence, the impact of deer appears to be worsening at control sites.
- The monitoring process has caused visible trampling of vegetation at some monitoring sites, particularly around the starts and ends of monitoring transects at shrubbier locations, such as the control sites at Mount Stirling.
- Construction of the project has resulted in sediment and at least seven boulders or large rocks entering impact sites. All impact sites have been affected by sedimentation. Control sites are mostly unaffected by sedimentation, except where the aqueduct occasionally discharges into a small part of Bog 11.1 (a control site), near Bogs 11.2 and 12 (both impact sites).
- Weed proliferation continues at all monitoring sites and is likely to be facilitated by the other impacts listed above, particularly deer activity and sedimentation. Localised but severe weed infestations occur at several control sites (Bogs 1, 2, 4.1/5/7, 11.1 and S1) and at one impact site (Bog 6). The overall cover of weeds has increased at impact sites relative to control sites, although this increase is not statistically significant.

Ultimately, these new and pre-existing impacts have contributed to one non-compliance (encroachment by weeds) and two potential future non-compliances (extent of Alpine Bogs and encroachment by non-bog-dependent species) in Impact Year 1.

As was predicted by baseline monitoring, there is currently non-compliance with the weed cover performance criterion because weed cover at impact sites exceeds 5%. However, it should be noted that weed cover at impact sites already exceeded 5% in Baseline Years 1 and 2. Limited weed control was undertaken in Baseline Years 1 and 2 to allow for collection of a representative baseline dataset. With sedimentation providing suitable conditions for further weed proliferation and an apparent increase in weed cover at impact sites in Impact Year 1, weed management actions commenced in Impact Year 1 immediately after monitoring was complete. Weed management should also be accompanied by deer control.

Although currently compliant, there is potential future non-compliance with the extent criterion. Impact sites have experienced a 3.7% reduction in area, relative to control sites, since construction of the water storage started. The relative reduction in area at impact sites is not statistically significant and control of weeds and deer, focussing on areas of sedimentation, should assist in reversing any apparent loss of bog extent.

Although currently compliant, there is also potential future non-compliance with one of the encroachment criteria. There has been a statistically significant 6.4% increase in the cover of non-bog-dependent species within impact sites, relative to control sites. The majority of this increase has been brought about by an increase in the cover of shrub and grass species that are not characteristic of Alpine Bogs. The reason for this change is unknown and should continue to be monitored closely. As part of the HEMAMP's hydrological monitoring, there should be an analysis of possible hydrological changes that may have occurred at impact sites. This will inform whether or not environmental watering may be needed.

The recommendations of this monitoring report are as follows:

1. The HEMAMP protocol should be updated to include Carpet Sedge *Carex jackiana*, Sweet Holy-grass *Hierochloe redolens* and Mountain Daisy-bush *Olearia algida* among the list of bog-dependent species.
2. The HEMAMP protocol for point intersection sampling along transects should be updated to make it clear that only species touching the pin are recorded and not species, such as Snow Gum *Eucalyptus pauciflora*, that may be directly above the pin.
3. The HEMAMP protocol should be updated to make note of the insurance pegs installed at the 5.5-metre mark of all transects at Bog 13.
4. The HEMAMP protocol should be updated to provide clarification of the treatment of Bidgee-widgee *Acaena novae-zelandiae*, Alpine Water-fern *Blechnum penna-marina* subsp. *alpina* and Tall Sedge *Carex appressa* during mapping of Alpine Bog boundaries.
5. The Baseline Year 1 area of Bog 6 should be treated as an outlier and, for the purposes of future area comparisons, replaced with the Baseline Year 2 area of Bog 6.
6. Steps should be taken to prevent further movement of sediment, rocks and boulders from the PCF into Alpine Bogs. This will require immediate and long-term implementation of the Ecological Rehabilitation Plan (Biosis 2020).
7. Sambar Deer *Cervus unicolor* should be controlled as soon as possible at Mount Buller with the aim of preventing this species from further damaging Alpine Bogs.
8. Analysis of aerial imagery (whether captured by unmanned aerial vehicle or satellite) should continue to be investigated as an alternative method of monitoring the extent and condition of Alpine Bogs, with the aim of reducing the impacts of annual on-ground monitoring.
9. Weed control should continue at all Alpine Bogs, prioritising areas of sedimentation, deer damage and the localised weed infestations within and on the margins of the Alpine Bogs (particularly at Bogs 1, 2, 4.1/5/7, 6, 11.1, 11.2 and S1). The following weed species should be targeted:
   - Milfoil *Achillea millefolium*
   - Brown-top Bent *Agrostis capillaris*

- Sweet Vernal-grass *Anthoxanthum odoratum*
- Spear Thistle *Cirsium vulgare*
- Musk Monkey-flower *Erythranthe moschata*
- Yorkshire Fog *Holcus lanatus*
- Jointed Rush *Juncus articulatus* subsp. *articulatus*
- Soft Rush *Juncus effusus* subsp. *effusus*
- Sword Rush *Juncus ensifolius*
- Apple *Malus pumila*
- Creeping Buttercup *Ranunculus repens*
- Blackberry *Rubus anglocandicans*.

10. The use of alternative weed control methods, such as heat, should be trialled to expand the window of time during which weed control can occur, to minimise the risk to Alpine Bogs from herbicide application and to ultimately improve the management of weeds in Alpine Bogs at Mount Buller and Mount Stirling.
11. The proportion of Peat Moss *Sphagnum cristatum* recorded as dead at impact sites relative to control sites should be reviewed again in IY2 to determine whether a protracted decline in Peat Moss is occurring at impact sites.

1. Introduction

1.1 Project background

Alpine Bogs are groundwater dependent ecosystems with a scattered distribution in alpine, sub-alpine and montane environments across the Australian Alps (Commonwealth of Australia 2009; FFG Act Scientific Advisory Committee 2013). They are generally characterised by the presence of Peat Moss *Sphagnum* spp. and are particularly susceptible to climate change, given that they have a fragmented distribution and are already at their environmental tolerance limit (Commonwealth of Australia 2009; Macdonald 2009). Approximately 3 hectares of Alpine Bog are known to exist at Mount Buller.

Alpine Bogs are listed as threatened ecological communities under Commonwealth and State legislation. The Alpine Sphagnum Bogs and Associated Fens (ASBAF) ecological community is listed as endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The Alpine Bog Community is listed as threatened under the Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act). Throughout this document, the term 'Alpine Bogs' refers to both ASBAF and the Alpine Bog Community.

In October 2019, the Mount Buller and Mount Stirling Alpine Resort Management Board (the RMB) started construction of a 100-megalitre off-stream water storage and ancillary infrastructure (the project) on Mount Buller between the summit and the village. Most of the known Alpine Bog community at Mount Buller is located downslope of the Project Construction Footprint (PCF) for the water storage and the project has the potential to affect the hydrology of these Alpine Bogs (Biosis and GHD 2016).

In accordance with approvals for the project (EPBC Act Approval 2014/7303 and Planning Permit PA1600138), the RMB is implementing a Hydrological and Ecological Monitoring and Adaptive Management Program (HEMAMP), with the objective of maintaining the extent and condition of Alpine Bogs that are downslope of the proposed water storage (Biosis 2019). Those Alpine Bogs whose catchment areas are affected by the water storage are known as impact sites and are monitored annually as part of the HEMAMP. The monitoring also includes control sites, which are Alpine Bogs whose catchment areas are unaffected by the water storage.

The HEMAMP aims to meet the following performance criteria:

- The 'extent' criterion – there will be no more than a 10% reduction in the total combined area of the impact sites, determined by on-ground or remote (aerial) monitoring and taking into account natural variation based on extent observations averaged across control sites.
- The 'composition' criterion – there will be no more than a 10% reduction in the total 'bog-dependent' native flora species richness of the impact sites, taking into account natural variation based on species richness observations averaged across control sites.
- The 'encroachment' criteria:
  - Atypical species – there will be no more than a 10% increase in the cover of 'non-bog-dependent' species within the impact sites, taking into account natural variation based on observations averaged across control sites.
  - Weeds – the total cover of weeds (naturalised exotic flora species) within the impact sites will not exceed 5%.

- The 'structure' criterion – there will be no more than a 10% reduction in the average cover of Peat Moss within the impact sites, taking into account natural variation based on Peat Moss cover averaged across control sites.

1.2 Scope of this report

The HEMAMP outlines a monitoring and management regime for selected Alpine Bogs on Mount Buller and Mount Stirling (Figure 1). Between 2014 and 2018, the RMB, assisted by GHD Pty Ltd (GHD), established climatological and hydrological monitoring infrastructure and commenced collecting climate, groundwater and surface water observations as part of the HEMAMP. In January and February 2018, the RMB commissioned Biosis Pty Ltd (Biosis) to establish the HEMAMP's ecological monitoring components and collect the first year of baseline ecological monitoring data (Baseline Year 1 or BY1). A second year of baseline climatological, hydrological and ecological data (Baseline Year 2 or BY2) was collected from June 2018 to May 2019. The first year of ecological data since construction began (Impact Year 1 or IY1) was collected from January 2020 to March 2020.

This monitoring report:

- Provides a summary of the ecological data collected in IY1 (climatological and hydrological data will be reported separately).
- Compares ecological data collected in IY1 with the baseline data collected over BY1 and BY2.
- Assesses these results against the HEMAMP's performance criteria and recommend appropriate management actions.

In order to remain adaptive, the HEMAMP will be updated as required and with approval from the Victorian Government Department of Environment, Land, Water and Planning (DELWP) and the Australian Government Department of Agriculture, Water and the Environment (DAWE). Numerous refinements were made to the HEMAMP protocol during the two baseline monitoring years. Recommendations for further refinements are made in this report and, along with management recommendations, are highlighted in text boxes as shown below.

Recommendations
All recommendations arising from IY1 monitoring are highlighted in this fashion throughout this monitoring report.

2. Methods

The ecological monitoring methods follow the HEMAMP protocol (Biosis 2019), except where specifically noted.

2.1 Monitoring effort, frequency and timing

The ecological monitoring components of the HEMAMP were successfully established in January and February 2018 (BY1) and ecological monitoring has since been conducted annually. Each year, transect monitoring has been undertaken from late January until mid-February, while mapping has been undertaken from late January until mid-March. Table 1 summarises the ecological monitoring effort undertaken each year at Mount Buller (Figure 2) and Mount Stirling (Figure 3). Table 2 summarises the timing of annual ecological monitoring. Slight differences in timing (particularly the monitoring end date) were generally associated with weather conditions and the need to maintain consistency in the quality of the data (e.g. DGPS mapping under clear skies). Slight differences in timing from year to year are unlikely to affect an assessment against the performance criteria.

Table 1 Annual ecological monitoring effort as part of the HEMAMP

Statistic	Impact sites	Control sites (Buller : Stirling)	Total
Number of sites* (Alpine Bogs)	6	7 (4 : 3)	13
Number of transects	24	23 (14 : 9)	47
Average length of transect (m)	18.5	21.6 (22.3 : 20.4)	20
Number of point intersections (20-cm intervals)	2196	2457 (1546 : 911)	4653
Number of quadrats	87	101 (64 : 37)	188
Number of photo points	48	46 (28 : 18)	94

*Note: The data presented in this table relate to the sites at which line and belt transects have been established and point intersection and quadrat monitoring is conducted. Additional sites are mapped but not subject to point intersection and quadrat monitoring.

Table 2 Timing of annual ecological monitoring

Monitoring year	Transect monitoring period	Mapping period
Baseline Year 1	26 January 2018 to 9 February 2018	26 January 2018 to 9 February 2018
Baseline Year 2	29 January 2019 to 14 February 2019	29 January 2019 to 23 February 2019
Impact Year 1	28 January 2020 to 20 February 2020	30 January 2020 to 14 March 2020

2.2 Species lists

2.2.1 Full flora species list for control and impact sites

The comprehensive list of all flora species observed at Alpine Bog monitoring sites is updated annually to reflect taxonomic name changes and to add any new observations, including incidental observations and observations made during transect monitoring. The full flora list is shown in Appendix 1 and uses Victorian Biodiversity Atlas (DELWP 2019) nomenclature.

While this flora list is comprehensive, there are a number of reasons why not all flora species will have been detected. For example, some flora species may not have been found or positively identified due to seasonal conditions, species dormancy and a lack of diagnostic material with which to identify specimens to species level. In addition, many bryophytes (liverworts and mosses) have not yet been identified to species level due to time limitations. A herbarium of flora samples, including many bryophyte samples, is being maintained and will assist in refining the flora species list over time.

2.2.2 Bog-dependent flora species list

From the full species list, a subset of species considered dependent on and characteristic of the Alpine Bogs at Mount Buller and Mount Stirling was determined in BY1. The list of bog-dependent flora species is presented in Appendix 1. The list draws heavily upon the diagnostic bog species outlined in the key to Alpine Bogs (Appendix 2; Commonwealth of Australia 2013) and the EPBC Act policy statement for Alpine Bogs (Commonwealth of Australia 2009).

Three species were added to the bog-dependent flora species list in IY1: Carpet Sedge *Carex jackiana*, Sweet Holy-grass *Hierochloe redolens* and Mountain Daisy-bush *Olearia algida*. At Mount Buller and Mount Stirling, these species are restricted to Alpine Bogs and should therefore be included among the list of diagnostic species for mapping purposes (Appendix 2) and the list of bog-dependent species for assessment against performance criteria (Appendix 1).

The inclusion of these additional species is supported by field observations at the monitoring sites, the EPBC Act policy statement for Alpine Bogs (Commonwealth of Australia 2009) and VicFlora (RBGV 2020). Mountain Daisy-bush is listed as a typical mainland Alpine Bog plant species in the EPBC Act policy statement for Alpine Bogs (Commonwealth of Australia 2009). VicFlora describes Carpet Sedge as locally common in alpine areas, usually within or bordering bog communities, and Sweet Holy-grass as occurring in Peat Moss beds throughout the Victorian Alps (RBGV 2020).

Carpet Sedge, Sweet Holy-grass and Mountain Daisy-bush have been treated as diagnostic species for mapping purposes since monitoring began in BY1. Their absence from the bog-dependent species list until now was an oversight. All data from BY1 and BY2 have been adjusted to reflect the status change to these three species and to ensure accurate comparisons between monitoring results in baseline and impact years.

Impact Year 1 – Recommendation 1
The HEMAMP protocol should be updated to include Carpet Sedge *Carex jackiana*, Sweet Holy-grass *Hierochloe redolens* and Mountain Daisy-bush *Olearia algida* among the list of bog-dependent species.

2.3 Monitoring parameters

Line transects, belt transects, photo points and on-ground mapping are used to collect data for the following ecological parameters in accordance with the HEMAMP:

- Bog extent:
  - Area of Alpine Bogs.
- Bog composition:
  - Richness of bog-dependent flora.
  - Cover of bog-dependent flora.
- Encroachment by weeds and other atypical species:
  - Cover of weeds.
  - Cover of non-bog-dependent flora.
- Bog structure:
  - Peat Moss *Sphagnum* spp. cover.

These parameters allow for the current extent and condition of the Alpine Bogs to be directly assessed against the HEMAMP's performance criteria. Additional parameters, such as the dimensions of the Alpine Bogs and cover of bare ground, are also examined in this monitoring report to provide a more detailed analysis of the outcomes of Alpine Bog management at Mount Buller and Mount Stirling.

2.3.1 Line transects (point intersections)

Fixed transects are used as line transects to collect data that can be used to infer bog extent, bog composition, weed encroachment and bog structure. At each transect, a measuring tape is extended from the start peg (designated as 0 centimetres) to the end peg. A 5-millimetre diameter steel pin (approximately 1 metre long) is inserted vertically into the vegetation at regular intervals along the tape. At each interval, the following observations are recorded:

- The ground condition at the base of the pin, categorised as follows:
  - Litter: dead or detached plant material.
  - Vegetation: living and attached vegetation (this category was used where the base of the pin rested on vegetation, such as the woody stem of a shrub or the rosette leaves of a herb, in which case the species to which the vegetation belonged was also recorded).
  - Rock: substrate comprising cobbles, boulders or bedrock i.e. anything with a particle size greater than 64 millimetres and therefore not easily erodible in an Alpine Bog context (EPA Victoria 2003).
  - Bare ground: substrate comprising silt, sand, gravel or pebbles i.e. anything with a particle size of 64 millimetres or less and therefore easily erodible in an Alpine Bog context (EPA Victoria 2003).
  - Water: running water (which is generally rare, except after rain) or a standing pool or puddle of water (which is generally more common).
- All species of flora touching the pin along any part of the pin's length. Note that only species in contact with the pin (not species above the pin) are recorded.

- The condition of each species touching the pin, categorised as follows:
  - Alive: where any living plant material belonging to the species in question is touching the pin, even if some of the material touching the pin is dead (living material is inferred by the presence of photosynthesising tissue i.e. 'green' tissue).
  - Dead: where all plant material belonging to the species in question and touching the pin is dead (inferred by a clear lack of photosynthesising tissue).

Impact Year 1 – Recommendation 2

The HEMAMP protocol for point intersection sampling along transects should be updated to make it clear that only species touching the pin are recorded and not species, such as Snow Gum *Eucalyptus pauciflora*, that may be directly above the pin.

At each line transect, the first point observation is made at a distance of 20 centimetres (0.2 metres) from the start peg. Point observations are made at 20-centimetre increments thereafter, moving towards the end of the transect, with the final observation being made at a point 20 centimetres from the end peg.

The types of species recorded (i.e. bog-dependent species or not) and the position at which they are recorded provides an indication of the extent of the Alpine Bog, by allowing the dimensions of the Alpine Bog to be estimated. Using the Diagnostic Key to Alpine Bogs (Appendix 2), the edge of the Alpine Bog is taken to be the point at which bog-dependent flora species richness is equal to non-bog-dependent flora species richness (similar to the on-ground boundary mapping, where the edge of the Alpine Bog is where Peat Moss no longer occurs and bog-dependent flora no longer make up 50% of vegetative cover).

The frequency at which species are recorded provides an indication of the structure of the Alpine Bogs and any encroachment of atypical or weed species. It allows for the cover of bog-dependent species, non-bog-dependent species, weeds and Peat Moss to be estimated and assessed against the relevant performance criteria. The frequency at which various ground conditions or dead plant specimens are recorded may also give an early indication of potential floristic or structural changes occurring within the Alpine Bogs.

Finally, it should be noted that a third middle peg was placed at the 5.5-metre mark (2.5 metres from the end peg) along all three transects at Bog 13 in IY1. Bog 13 is near the base of Grimus chairlift and the end pegs of Bog 13 transects are at the edge of the access road to the chairlift. The third pegs are insurance pegs, in case any future work on Grimus chairlift or the access road damages the end pegs of these transects.

Impact Year 1 – Recommendation 3

The HEMAMP protocol should be updated to make note of the insurance pegs installed at the 5.5-metre mark of all transects at Bog 13.

2.3.2 Belt transects (quadrats)

The fixed transects are used as belt transects to collect a comprehensive flora species list, estimate the species richness of bog-dependent flora and identify new atypical species that may be encroaching on the Alpine Bogs.

A 1x1 metre quadrat is placed at 4-metre intervals along each transect, starting and ending 4 metres from the ends of each transect. The centre of the quadrat is placed at the 4-metre interval mark. All flora species within the quadrat are recorded.

When combined with point intersection data, quadrat data provide a measure of the species richness of bog-dependent flora. Point intersection data capture the most dominant flora species. The inclusion of quadrat data increases the likelihood of detecting small or rare species, including any novel weed species that may need managing.

2.3.3 Photo points

The start and end pegs of each fixed transect are photo points from which photos are taken annually to allow for qualitative assessment of changes (if any) to the extent, composition, encroachment and structure of Alpine Bogs. The standard photo point requirements, including camera settings, are detailed in the HEMAMP protocol (Biosis 2019). Importantly, photos are labelled with a code that is a concatenation of the bog number (1, 2, 4.1, 4.2, 5, 6, 7, 8, 9, 10, 11.1, 11.2, 12, 13, S1, S2 or S3), transect letter (A, B, C, D or E) and peg position ('S' to denote 'start peg' or 'E' to denote 'end peg'). For example, the photo taken from the start peg of Transect C at Bog 8 is labelled '8CS'.

2.3.4 On-ground mapping

Each year, the boundary of each Alpine Bog (at impact and control sites) has been mapped on foot using a DGPS (Samsung Galaxy Tab A6 paired with a Trimble R1 GNSS receiver). In BY1 and BY2, this mapping was to an accuracy of 3 metres or better in most instances, but accuracy was reduced to up to 5 metres in some areas with an overhanging tree canopy, particularly at Mount Stirling. In IY1, improvements to DGPS technology (e.g. satellite availability and satellite-delivered correction services, particularly Trimble RTX) allowed for sub-2-metre accuracy in most instances (especially at Mount Buller sites) and generally no worse than 3-metre accuracy (e.g. at Mount Stirling sites with overhanging tree canopies). As much as possible, mapping in IY1 was conducted under clear skies because it was noticed that cloud cover adversely affected DGPS accuracy.

Alpine Bogs are mapped using the Diagnostic Key to Alpine Bogs (Appendix 2), as follows:

- Using the Diagnostic Key to Alpine Bogs, it is first determined whether an Alpine Bog occurred in the given area. Areas are considered to be Alpine Bog if one or more of the following criteria are met (Appendix 2):
  - Live, hummock-forming Peat Moss is present and abundant (at least 20% cover).
  - A peat substrate is present, Peat Moss is present but not abundant (less than 20% cover) and at least two bog-dependent flora species (diagnostic species) make up at least 50% of the cover of all other vegetation present.
  - A peat substrate is present, Peat Moss is absent but at least three bog-dependent flora species (diagnostic species) make up at least 50% of the vegetative cover.
- Once presence of an Alpine Bog is established, the boundary of the Alpine Bog is mapped at the point where bog-dependent flora are no longer dominant (i.e. bog-dependent flora no longer made up 50% of the vegetative cover). For the purpose of mapping Alpine Bog boundaries, the cover of Bidgee-widgee *Acaena novae-zelandiae,* Alpine Water-fern *Blechnum penna-marina* subsp. *alpina* and Tall Sedge *Carex appressa* are not included in total vegetation cover. These three species are regarded as 'neutral' when mapping Alpine Bog boundaries, although they are still considered to be non-bog-dependent for all other purposes. This approach is consistent with how mapping was conducted in BY1 and BY2 but the approach has not been clarified until now.

Impact Year 1 – Recommendation 4

The HEMAMP protocol should be updated to provide clarification of the treatment of Bidgee-widgee *Acaena novae-zelandiae*, Alpine Water-fern *Blechnum penna-marina* subsp. *alpina* and Tall Sedge *Carex appressa* during mapping of Alpine Bog boundaries.

2.4 Data management

In addition to a herbarium of plant samples, the following three datasets are being maintained:

- A database of all photo points taken to date.
- A spreadsheet of all observations from all transect monitoring conducted to date.
- Spatial data for Alpine Bog boundaries from each year and locations of photo points and transects.

2.5 Data analysis

The ecological monitoring program follows a 'Beyond BACI' (Before-After-Control-Impact) design and data analysis has been set up accordingly (Underwood 1992 and 1994). Linear Mixed-effects Models (LMMs) and Analysis of Variance (ANOVA) were used to test the statistical significance of the effect of the period (before/after) and treatment (control/impact) on a given response variable (e.g. area of Alpine Bogs or cover of weeds).

LMMs were fitted using the 'lme4' package in the R statistical and graphical environment (R Development Core Team 2020) using the Restricted Maximum Likelihood (REML) method and the Kenward-Roger approximation for degrees of freedom. The models were in the following form:

*Response ~ Period * Site Class + (1|Year) + (1|Sample)*

The various components of the models are explained as follows:

- Response:
  - The response variable is the ecological monitoring parameter of interest, such as the area of Alpine Bogs or cover of weeds, non-bog-dependent flora, bog-dependent flora or Peat Moss.
  - We are interested in detecting whether or not there has been a statistically significant change in the response variable at impact sites relative to control sites in the period after the impact commenced.
- Period and Site Class:
  - Period refers to the time before (i.e. BY1 and BY2) or after (i.e. IY1) the potential impact commenced (i.e. before or after construction of the water storage started).
  - Site Class refers to the 'treatment' that the Alpine Bogs have received. The Alpine Bogs belong to one of two Site Classes – control sites or impact sites.
  - Period and Site Class are the fixed effects in the model. They are the BACI effect that we are monitoring.

- 1|Year and 1|Sample:
  - The model also includes Year (BY1, BY2, IY1 etc.) and Sample (Bog 1, Bog 2, Bog 4.1/5/7 etc.) as random effects (i.e. random temporal and spatial variables).
  - The Sample-to-Sample variation represents localised spatial variability within each Site Class (e.g. the variation between Bog 1 and Bog 2 represents some of the random effect within Control sites).
  - The Year-to-Year variation represents temporal variability that applies to all Samples, regardless of Site Class (i.e. the random temporal effect that applies equally to Control and Impact sites, causing the same fluctuations at both Site Classes from year-to-year).

We are interested in determining whether or not there is a statistically significant interaction between Period and Site Class (sometimes called a BA*CI interaction or BACI contrast). If the coefficient for the BA*CI interaction is statistically significant, it suggests that there is a significant difference in the response of control and impact sites to the impact i.e. there is a statistically significant difference between the control and impact sites after the impact, compared with the control and impact sites before the impact. The statistical significance of this interaction was determined by ANOVA and analysis of Estimated Marginal Means (EMMs) using the 'lmerTest' and 'emmeans' packages in the R statistical and graphical environment (R Development Core Team 2020) and a 5% statistical significance threshold ($\alpha = 0.05$).

3. Results

Results are presented here for extent, composition, encroachment and structure, which are the ecological parameters that correspond to each of the HEMAMP performance criteria. Where relevant, the results tables that are presented here allow for results to be added at a later date for IY2, after which the HEMAMP will be independently reviewed in accordance with approval conditions for the water storage project.

3.1 Results for bog extent

The area of each Alpine Bog was mapped using DGPS. The results of this mapping are presented in Table 3 and Figure 4. The total combined area of all Alpine Bogs at impact sites decreased from a baseline mean of 1.3667 hectares to 1.3217 hectares in IY1 (a decrease of 0.0450 hectares or 3.3%). The total combined area of all Alpine Bogs at control sites increased from a baseline mean of 2.0812 hectares to 2.0904 hectares in IY1 (an increase of 0.0092 hectares or 0.4%). The relative change in the area of impact sites was therefore a decrease of 3.7%, although this change was not statistically significant (coefficient = 0.0088; standard error = 0.0140; F-statistic = 0.3959; degrees of freedom = 23; P = 0.5354).

The dimensions of each Alpine Bog were estimated using line transects and the Diagnostic Key to Alpine Bogs (Appendix 2). The results of these estimates are presented in Table 4. The sum of dimensions at impact sites increased from a baseline mean of 354.7 metres to 355.6 metres in IY1 (an increase of 0.9 metres or 0.3%), while the sum of dimensions at control sites decreased from a baseline mean of 438.8 metres to 438.6 metres in IY1 (a decrease of 0.2 metres, which is effectively 0.0%). The relative change in the dimensions of the impact sites was therefore an increase of 0.3%, although this change was not statistically significant (coefficient = -0.1790; standard error = 0.7410; F-statistic = 0.0581; degrees of freedom = 23; P =0.8117).

Line transects (point intersections) were also used to estimate the cover of bare ground. These estimates are displayed in Table 5. Both the impact sites and control sites experienced a considerable increase in bare ground in IY1. The cover of bare ground increased from a baseline mean of 1.0% to 5.4% in IY1 at impact sites and from a baseline mean of 0.6% to 4.8% in IY1 at control sites. Since the increase in bare ground was similar across impact and control sites in IY1, the increase in bare ground at impact sites relative to control sites was not statistically significant (coefficient = 0.0058; standard error = 0.0122; F-statistic = 0.2264; degrees of freedom = 23; P = 0.6387).

Table 3 Area of Alpine Bogs as determined by DGPS mapping

Site	Area (ha)				
	Baseline Year 1	Baseline Year 2	Baseline Mean	Impact Year 1	Impact Year 2
All Impact Sites	**1.3797***	**1.3536**	**1.3667**	**1.3217**	
Bog 4.2	0.4014	0.3842	0.3928	0.3912	
Bog 6	0.4914*	0.6723	0.6723*	0.6380	
Bog 8/9/10	0.0667	0.0718	0.0692	0.0704	
Bog 11.2	0.1195	0.1120	0.1157	0.1094	
Bog 12	0.1145	0.1071	0.1108	0.1076	
Bog 13	0.0051	0.0063	0.0057	0.0051	
All Control Sites	**2.1446**	**2.0178**	**2.0812**	**2.0904**	
Bog 1	0.1781	0.1620	0.1700	0.1491	
Bog 2	0.1516	0.1481	0.1499	0.1459	
Bog 4.1/5/7	0.5562	0.5457	0.5509	0.5480	
Bog 11.1	0.2798	0.2590	0.2694	0.2571	
Bog S1	0.5712	0.4584	0.5148	0.5129	
Bog S2	0.1805	0.1778	0.1791	0.1785	
Bog S3	0.2271	0.2669	0.2470	0.2989	

*Note: As discussed in Section 4 of this report, mapping of Bog 6 in BY1 is unlikely to have captured the full extent of the Bog 6 entity as recognised in subsequent years. The area recorded for Bog 6 in BY1 is therefore unreliable and has not contributed to the baseline mean area for Bog 6 or total area of all impact sites in BY1. The BY2 area has been used instead, given that the average change in area of all monitoring sites from BY1 to BY2 was negligible (mean change = 0.0022 hectares, standard deviation = 0.0609; median change = -0.0074 hectares, interquartile range = -0.0464 to 0.0329).

Table 4 Dimensions of Alpine Bogs as estimated by line transects

Site	Sum of dimensions (m)				
	Baseline Year 1	Baseline Year 2	Baseline Mean	Impact Year 1	Impact Year 2
All Impact Sites	**356.2**	**353.2**	**354.7**	**355.6**	
Bog 4.2	92.2	92.6	92.4	92.2	
Bog 6	79.6	75.8	77.7	77.4	
Bog 8/9/10	66.4	67.8	67.1	65.2	
Bog 11.2	67.2	66.4	66.8	66.8	
Bog 12	40.6	41.0	40.8	41.4	
Bog 13	10.2	9.6	9.9	12.6	
All Control Sites	**436.0**	**441.6**	**438.8**	**438.6**	
Bog 1	55.8	57.2	56.5	57.0	
Bog 2	78.8	79.6	79.2	77.2	
Bog 4.1/5/7	81.6	84.2	82.9	85.2	
Bog 11.1	48.6	48.4	48.5	48.0	
Bog S1	52.6	52.4	52.5	52.0	
Bog S2	57.4	58.2	57.8	58.2	
Bog S3	61.2	61.6	61.4	61.0	

Table 5 Cover of bare ground as estimated by line transects

Site	Cover of bare ground				
	Baseline Year 1	Baseline Year 2	Baseline Mean	Impact Year 1	Impact Year 2
All Impact Sites	**1.9%**	**0.1%**	**1.0%**	**5.4%**	
Bog 4.2	3.4%	0.0%	1.7%	5.8%	
Bog 6	3.8%	0.0%	1.9%	8.2%	
Bog 8/9/10	0.7%	0.0%	0.3%	6.0%	
Bog 11.2	0.0%	0.0%	0.0%	3.7%	
Bog 12	0.8%	0.8%	0.8%	3.1%	
Bog 13	0.0%	0.0%	0.0%	0.0%	
All Control Sites	**0.9%**	**0.2%**	**0.6%**	**4.8%**	
Bog 1	0.6%	0.0%	0.3%	3.5%	
Bog 2	1.1%	0.0%	0.6%	10.3%	
Bog 4.1/5/7	0.4%	0.0%	0.2%	0.8%	
Bog 11.1	0.7%	0.4%	0.5%	3.6%	
Bog S1	3.0%	0.3%	1.7%	2.4%	
Bog S2	0.0%	0.0%	0.0%	5.7%	
Bog S3	0.9%	0.9%	0.9%	7.9%	

3.2 Results for bog composition

Using line transects (point intersections) and belt transects (quadrats), a total of twelve bog-dependent flora species were recorded at impact and control sites across baseline years and IY1 collectively (Appendix 1). At impact sites, an average of 10.5 bog-dependent flora species were recorded during BY1 and BY2 and 11 bog-dependent flora species were recorded in IY1. Similarly, at control sites, an average of 10.5 bog-dependent flora species were recorded in BY1 and BY2 and 11 bog-dependent flora species were recorded in IY1. The results of species richness counts are presented in Table 6. Importantly, there was no statistically significant change in bog-dependent flora species richness at impact sites relative to control sites in IY1 (coefficient = -0.2740; standard error = 0.6100; F-statistic = 0.2017; degrees of freedom = 23; P = 0.6575).

Line transects (point intersections) were also used to estimate the cover of bog-dependent flora species. Table 7 shows these covers. The cover of bog-dependent flora species increased from a baseline mean of 78.2% to 79.7% in IY1 at impact sites and from a baseline mean of 87.9% to 88.3% in IY1 at control sites. While the increase in cover of bog-dependent species was greater at impact sites relative to control sites, the increase was not statistically significant (coefficient = -0.0259; standard error = 0.143; F-statistic = 3.2653; degrees of freedom = 23; P = 0.0839).

Table 6 Richness of bog-dependent flora species as determined by line and belt transects

Site	Number of bog-dependent flora species				
	Baseline Year 1	Baseline Year 2	Baseline Mean	Impact Year 1	Impact Year 2
All Impact Sites	**10**	**11**	**10.5**	**11**	
Bog 4.2	8	9	8.5	8	
Bog 6	8	8	8	9	
Bog 8/9/10	9	5	7	8	
Bog 11.2	6	6	6	6	
Bog 12	7	7	7	6	
Bog 13	3	5	4	6	
All Control Sites	**11**	**10**	**10.5**	**11**	
Bog 1	5	5	5	5	
Bog 2	6	6	6	5	
Bog 4.1/5/7	8	8	8	7	
Bog 11.1	8	7	7.5	8	
Bog S1	6	6	6	7	
Bog S2	6	6	6	6	
Bog S3	7	8	7.5	9	

Table 7 Cover of bog-dependent flora species as estimated by line transects

Site	Cover of bog-dependent flora species				
	Baseline Year 1	Baseline Year 2	Baseline Mean	Impact Year 1	Impact Year 2
All Impact Sites	**77.9%**	**78.5%**	**78.2%**	**79.7%**	
Bog 4.2	87.5%	87.3%	87.4%	87.3%	
Bog 6	72.2%	72.4%	72.3%	72.6%	
Bog 8/9/10	75.6%	75.6%	75.6%	77.5%	
Bog 11.2	88.1%	90.5%	89.3%	91.0%	
Bog 12	72.8%	72.4%	72.6%	73.5%	
Bog 13	43.6%	48.7%	46.2%	59.0%	
All Control Sites	**86.9%**	**88.8%**	**87.9%**	**88.3%**	
Bog 1	88.0%	90.5%	89.3%	90.2%	
Bog 2	89.0%	91.1%	90.0%	91.3%	
Bog 4.1/5/7	81.2%	83.9%	82.5%	83.7%	
Bog 11.1	87.4%	87.7%	87.5%	88.1%	
Bog S1	84.8%	86.9%	85.9%	86.9%	
Bog S2	97.0%	99.3%	98.1%	98.0%	
Bog S3	84.2%	85.2%	84.7%	82.3%	

3.3 Results for encroachment by weeds and other atypical species

Line transects (point intersections) were used to estimate the covers of native non-bog-dependent flora species and weeds. These estimates are displayed in Table 8 and Table 9 respectively.

The cover of native non-bog-dependent flora species increased from a baseline mean of 45.2% to 46.5% in IY1 at impact sites and decreased from a baseline mean of 45.1% to 43.5% in IY1 at control sites. This represents a relative increase of 6.4% in the cover of native non-bog-dependent flora species at impact sites in IY1 (relative to control sites). This relative increase is statistically significant (coefficient = -0.0422; standard error = 0.0164; F-statistic = 6.6416; degrees of freedom = 23; P = 0.0169).

The cover of weeds increased from a baseline mean of 5.9% to 7.3% in IY1 at impact sites and from a baseline mean of 4.3% to 5.0% in IY1 at control sites. However, the greater increase in weed cover at impact sites relative to control sites is not statistically significant (coefficient = -0.0112; standard error = 0.0116; F-statistic = 0.9220; degrees of freedom = 23; P = 0.3469).

Table 8 Cover of native non-bog-dependent flora species as estimated by line transects

Site	Cover of native non-bog-dependent flora species				
	Baseline Year 1	Baseline Year 2	Baseline Mean	Impact Year 1	Impact Year 2
All Impact Sites	**44.4%**	**46.1%**	**45.2%**	**46.5%**	
Bog 4.2	24.7%	26.9%	25.8%	27.1%	
Bog 6	62.5%	65.7%	64.1%	61.5%	
Bog 8/9/10	49.4%	51.7%	50.6%	53.3%	
Bog 11.2	24.9%	23.6%	24.3%	25.7%	
Bog 12	61.5%	61.5%	61.5%	63.4%	
Bog 13	66.7%	72.6%	69.7%	79.5%	
All Control Sites	**44.2%**	**46.1%**	**45.1%**	**43.5%**	
Bog 1	42.9%	44.2%	43.5%	45.4%	
Bog 2	41.6%	41.4%	41.5%	41.2%	
Bog 4.1/5/7	39.2%	42.3%	40.8%	39.8%	
Bog 11.1	41.2%	44.4%	42.8%	40.4%	
Bog S1	54.5%	57.9%	56.2%	46.8%	
Bog S2	32.3%	32.3%	32.3%	33.0%	
Bog S3	61.2%	63.7%	62.5%	60.6%	

Table 9 Cover of weed species as estimated by line transects

Site	Cover of weed species				
	Baseline Year 1	Baseline Year 2	Baseline Mean	Impact Year 1	Impact Year 2
All Impact Sites	**5.4%**	**6.3%**	**5.9%**	**7.3%**	
Bog 4.2	4.5%	4.7%	4.6%	4.3%	
Bog 6	4.4%	6.9%	5.7%	7.8%	
Bog 8/9/10	6.0%	9.0%	7.5%	11.0%	
Bog 11.2	0.0%	0.0%	0.0%	0.0%	
Bog 12	0.0%	0.4%	0.2%	0.8%	
Bog 13	40.2%	35.0%	37.6%	42.7%	
All Control Sites	**3.3%**	**5.3%**	**4.3%**	**5.0%**	
Bog 1	3.2%	3.5%	3.3%	3.5%	
Bog 2	3.9%	4.6%	4.2%	5.5%	
Bog 4.1/5/7	4.9%	7.6%	6.2%	5.4%	
Bog 11.1	1.4%	3.2%	2.3%	4.3%	
Bog S1	6.4%	7.4%	6.9%	6.7%	
Bog S2	0.0%	0.0%	0.0%	0.0%	
Bog S3	2.2%	9.5%	5.8%	8.5%	

3.4 Results for bog structure

Line transects (point intersections) were used to estimate the cover of Peat Moss *Sphagnum* spp. at impact sites and control sites. These estimates are displayed in Table 10. At impact sites, the cover of Peat Moss increased from a baseline mean of 5.4% to 6.0% in IY1. At control sites, the cover of Peat Moss decreased from a baseline mean of 16.4% to 15.9% in IY1. The increase in Peat Moss cover at impact sites relative to control sites is not statistically significant (coefficient = -0.0195; standard error = 0.0133; F-statistic = 2.1444; degrees of freedom = 23; P = 0.1566).

Table 10 Cover of Peat Moss *Sphagnum* spp. as estimated by line transects

Site	Cover of Peat Moss *Sphagnum* spp.				
	Baseline Year 1	Baseline Year 2	Baseline Mean	Impact Year 1	Impact Year 2
All Impact Sites	**5.4%**	**5.3%**	**5.4%**	**6.0%**	
Bog 4.2	15.9%	15.1%	15.5%	15.1%	
Bog 6	0.0%	0.0%	0.0%	0.0%	
Bog 8/9/10	0.0%	0.0%	0.0%	2.1%	
Bog 11.2	3.2%	2.7%	2.9%	2.1%	
Bog 12	0.0%	0.0%	0.0%	0.0%	
Bog 13	18.8%	22.2%	20.5%	28.2%	
All Control Sites	**15.5%**	**17.2%**	**16.4%**	**15.9%**	
Bog 1	0.0%	0.0%	0.0%	0.0%	
Bog 2	3.4%	3.0%	3.2%	2.1%	
Bog 4.1/5/7	0.0%	0.0%	0.0%	0.0%	
Bog 11.1	5.4%	11.9%	8.7%	7.6%	
Bog S1	33.7%	39.4%	36.5%	38.7%	
Bog S2	62.0%	65.0%	63.5%	59.3%	
Bog S3	21.1%	21.1%	21.1%	21.8%	

3.5 Summary of monitoring results

Table 11 summarises the results of the HEMAMP BY1, BY2 and IY1 monitoring in terms of the four performance criteria.

Table 11 Summary of ecological monitoring results in Baseline Years 1 and 2 and Impact Year 1

Parameter	Site	Baseline Mean (BM) ±Standard Deviation	IY1	Change (BM to IY1)	% Change (BM to IY1)
Extent					
Area (ha)	Impact sites	1.3667 ±0.0185	1.3217	-0.0450	-3.3%
	Control sites	2.0812 ±0.0897	2.0904	+0.0092	+0.4%
Sum of dimensions (m)	Impact sites	354.7 ±2.1	355.6	+0.9	+0.3%
	Control sites	438.8 ±4.0	438.6	-0.2	0%
Cover of bare ground (%)	Impact sites	1.0 ±1.3	5.4	+4.4	+448.8%
	Control sites	0.6 ±0.5	4.8	+4.2	+750.0%
Composition					
Bog-dependent species richness	Impact sites	10.5 ±0.7	11	+0.5	+4.8%
	Control sites	10.5 ±0.7	11	+0.5	+4.8%
Cover of bog-dependent flora (%)	Impact sites	78.2 ±0.4	79.7	+1.5	+1.9%
	Control sites	87.9 ±1.3	88.3	+0.4	+0.5%
Encroachment					
Cover of non-bog-dependent native flora (%)	Impact sites	45.2 ±1.2	46.5	+1.3	+2.9%
	Control sites	45.1 ±1.3	43.5	-1.6	-3.5%
Cover of weeds (%)	Impact sites	5.9 ±0.6	7.3	+1.4	N/A
	Control sites	4.3 ±1.4	5.0	+0.7	N/A
Structure					
Cover of Peat Moss (%)	Impact sites	5.4 ±0.1	6.0	+0.6	+11.0%
	Control sites	16.4 ±1.2	15.9	-0.5	-3.0%

4. Discussion

Construction of the water storage project started in October 2019. Since then, construction has had a visible impact on several downslope Alpine Bogs, particularly on impact sites but also, to a much lesser extent, on control sites at Mount Buller.

At least seven boulders and large rocks have entered the impact sites from the Project Construction Footprint (PCF). The failure of erosion controls within the PCF has resulted in sediment being washed into and through impact sites (Photo 1). To a limited extent, sediment has travelled laterally via the aqueduct and into a small part of one control site, Bog 11.1, near where it meets Bogs 11.2 and 12, both of which are impact sites.

The impact of sedimentation was particularly noticeable at Bogs 4.2, 6, 11.2 and 12 (all impact sites) and is discussed in more detail in the following sub-sections of this report. The hydrological monitoring component of the HEMAMP (reported separately) should provide additional data to gauge the intensity and duration of sedimentation that has occurred.

4.1 Bog extent

The extent criterion requires that there is no more than a 10% reduction in the total combined area of impact sites, relative to control sites. The extent of Alpine Bogs is estimated by on-ground mapping and by using the results of point intersection data to estimate dimensions of the Alpine Bogs. However, it is important to appreciate the limitations of both methods of estimating Alpine Bog extent. These limitations are outlined in Section 4.1.1 of this report.

In addition, assessment against the extent criterion is complicated by the fact that almost all Mount Buller monitoring sites (all control sites and all impact sites, except Bog 8/9/10) have decreased in area, while the Mount Stirling control sites have collectively increased in area. There are a multitude of potential causes for this, including the impacts of deer and weeds distributed unevenly across sites, sedimentation of impact sites, improvements in DGPS accuracy at Mount Stirling and/or a combination of these. The extent of bare ground across all Alpine Bogs was extracted from line transect data to assist in determining the effect that sedimentation may have had on the extent of Alpine Bogs. This is discussed further in Section 4.1.3 of this report.

4.1.1 The difference between area and dimensions

Using the point intersection data to estimate dimensions, Alpine Bogs are considered present where bog-dependent flora species richness is equal to or greater than non-bog-dependent flora species richness. Unlike on-ground mapping, dimension estimates do not consider the cover of bog-dependent species. This means that a given point along a transect may be mapped as Alpine Bog on the ground due to the dominance of Peat Moss or three other bog-dependent species but not recorded as being within the dimensions of the Alpine Bog using the point intersection sampling method because more non-bog-dependent species are touching the pin at that particular point.

In this respect, the point intersection data provides the floristic boundary of the Alpine Bogs based purely on species ratios. By contrast, on-ground mapping using the Diagnostic Key to Alpine Bogs (Appendix 2) provides an estimate of the functional boundary of the Alpine Bogs by considering species present (Peat Moss and other bog-dependent flora), their cover (whether bog-dependent species make up 50% or more of vegetative cover) and/or their substrate (whether peat is present).

On-ground mapping is likely to be more subjective than dimension calculations due to the visual method by which cover is estimated during mapping. This and the inherent inaccuracies associated with DGPS technology may make on-ground mapping more variable from year-to-year than dimension calculations (monitoring results so far would suggest this). Nevertheless, on-ground mapping provides a broader picture of changes that may be occurring over the entire Alpine Bog, rather than changes occurring across the sample of locations at which transects have been established.

A compromise between scale and objectivity could be achieved by regular capture and analysis of high resolution aerial imagery of the Alpine Bogs. Aerial image analysis could offer a more objective approach to monitoring Alpine Bogs at a broad scale, while also reducing the trampling of the Alpine Bogs that occurs during monitoring. On-ground mapping provides the opportunity to note and record particular management issues across each site, which may otherwise go undetected by transect monitoring and remote (aerial) mapping. However, on-ground mapping also contributes to the vegetation damage that has become noticeable at the Alpine Bogs as a result of annual monitoring. If aerial image analysis proves to be reliable, there may be scope to reduce the frequency of on-ground mapping and replace it with remote mapping.

Impact Year 1 – Recommendation 5
Analysis of aerial imagery (whether captured by unmanned aerial vehicle or satellite) should continue to be investigated as an alternative method of monitoring the extent and condition of Alpine Bogs, with the aim of reducing the impacts of annual on-ground monitoring.

4.1.2 Outliers

On average, the areas and dimensions of all Alpine Bogs showed little change from BY1 to BY2, before construction started. The mean and median changes in areas and dimensions of Alpine Bogs from BY1 to BY2 were close to zero (Figure 5). From BY1 to BY2, the mean change in area across all Alpine Bogs (n=13) was 0.0022 hectares (standard deviation = 0.0609 hectares) while the median change was -0.0074 hectares (interquartile range = -0.0167 to 0.0032 hectares). The mean change in dimensions across all Alpine Bogs (n=13) was 0.2 metres (standard deviation = 1.5 metres) and the median change was 0.4 metres (interquartile range = -2.7 to 3.4 metres), both of which are close to zero considering dimensions are measured in 0.2-metre increments.

As Figure 5 indicates, certain Alpine Bogs showed considerable variation in area from BY1 to BY2, most notably Bogs 6, S1 and S3. While the area of most Alpine Bogs remained relatively stable from BY1 to BY2, these three Alpine Bogs were potential outliers with respect to their change in area and Bog 6 was a potential outlier with respect to its change in dimensions. Bog 6 increased in area by 0.1809 hectares (a 36.8% increase) but decreased in dimensions by 3.8 metres (a 4.8% decrease). Bog S1 decreased in area by 0.1128 hectares (a 19.7% decrease) and Bog S3 increased in area by 0.0398 hectares (a 17.5% increase). The distance that these changes were from the interquartile range (IQR) of changes observed from BY1 to BY2 was more than 1.5 times the interquartile range itself (Figure 5). This is a common means of identifying potential outlier values in datasets. However, potential outlier results should not be excluded from a dataset without further justification.

Bog 6

Figure 4f shows that there was a large area at the north-western extent of Bog 6 that was not mapped in BY1, but mapped in BY2 and IY1. The area is large enough to explain most of the difference in area observed at Bog 6 from BY1 to BY2. There are a number of possible explanations for this difference in area, including the following:

- It is possible that operator error in BY1 contributed to the north-western extent being missed. This explanation is unlikely, given that the same assessor undertook the mapping in BY1 and BY2, at the same time of year, using the same equipment and applying the same Diagnostic Key to Alpine Bogs (Appendix 2). The species composition of Bog 6 at its current north-western extent is very similar to the species composition of the rest of the northern half of this Alpine Bog. The same characteristic species are dominant, namely Baeckea *Baeckea* spp., Spreading Rope-rush *Empodisma minus*, Swamp Heath *Epacris paludosa* and Candle Heath *Richea continentis*. It is therefore unlikely that misidentification of species or misapplication of the Diagnostic Key to Alpine Bogs would have contributed to the north-western extent of Bog 6 being missed in BY1.
- It is possible that the current north-western extent of Bog 6 did not meet the criteria outlined in the Diagnostic Key to Alpine Bogs in BY1 and was therefore not mapped as Alpine Bog. While it is possible or even likely that some of the area may not have satisfied the criteria (see next point), it seems unlikely that the entire area did not. In BY2 and IY1, the majority of the north-western extent clearly satisfied the criteria and was not marginal (i.e. the relative cover of bog-dependent flora far exceeded 50% across most of the north-western extent). In addition, comparison of photos from BY1 to IY1 (e.g. from Photo Point 6DS) and aerial imagery from 2015 to 2019, do not point to such an extensive floristic change having taken place over a 12-month period.
- Given that Alpine Bog mapping for the HEMAMP relies primarily on identifying the boundary at which bog-dependent flora are no longer dominant, the most probable explanation is that the north-western extent of Bog 6 was floristically fragmented or 'cut-off' from the main body of Bog 6 in BY1 and therefore not mapped as part of Bog 6 in BY1. The north-western extent of Bog 6 was most likely Alpine Bog but floristically separated from the rest of Bog 6 by the presence of non-bog-dependent species along the BY1 north-western boundary, such that the threshold for 50% relative cover of bog-dependent flora species was not met. There could be many reasons for the north-western extent of Bog 6 being separated in BY1 but subsequently combined into one larger Bog 6 in BY2 and IY1, including:
  - Changes in weed cover: Mapping in IY1 has shown the effect that the proliferation of weeds has had on fragmenting Alpine Bogs at Mount Buller. For example, as at IY1, Bog 6 now exists as two fragmented areas, a northern half and a southern half, due to weeds now dominating bog-dependent flora in the central area of Bog 6 (Figure 4f). It is possible that the north-western extent of Bog 6 was similarly fragmented in BY1. The status of Bog 6 is currently marginal in some places along the north-western boundary that was mapped in BY1 because weeds and other non-bog-dependent flora are close to being more dominant than bog-dependent flora species.
  - Fire recovery: Even before the effects of sedimentation in IY1, the northern half of Bog 6 and surrounding Sub-alpine Woodland were in a dynamic state of recovery following the 2006-2007 bushfires. Some patches of Snow Gum *Eucalyptus pauciflora* in this area were severely burnt and are still regrowing, while other patches were completely killed by the fire and have not regenerated (Photo 2). This differs from other Alpine Bogs on the northern slopes of Mount Buller, where Snow Gums were not burnt or have mostly recovered. An overhanging Snow Gum canopy offers shade and a microclimate that can be more conducive to bog-dependent flora, especially on slopes with a northerly aspect.
  - Herbivory and damage from deer: The damage caused by Sambar Deer *Cervus unicolor* wallowing, trampling and browsing is readily apparent in the northern half of Bog 6 (Photo 3). This may have contributed to the state of flux observed in the northern half of Bog 6 since BY1.
  - Changes to hydrology: In BY1, it was noted that the predominant water source for what is now the north-western extent of Bog 6 appeared to be from the south-west, along a rocky drainage

line coming off the north-eastern branch of Bog 4.1/5/7 (a control site). Lateral surface water flows from the south-east, originating from the narrow central area of Bog 6, were not apparent. However, these surface water flows appeared to have reversed the following year. In BY2 and IY1, it was noted that there was very little flow through the rocky drainage line from the south-west (Bog 4.1/5/7) and most surface water appeared to be arriving laterally from the south-east (the central area of Bog 6).

- Post-winter growth: Low-growing plants in this area are typically flattened by snow in winter. The way in which they recover and regain their shape will vary from year-to-year, which may have contributed to the north-western extent of Bog 6 not being contiguous with the remainder of Bog 6 in BY1.

- Vegetation management: The condition, extent and integrity of Alpine Bogs near ski runs is likely to be improving since implementation of the Mount Buller Ski Field Vegetation Management Plan began in 2013-2014 (Biosis 2013). Ski field grooming now avoids Alpine Bogs.

- A combination of the above.

Since the north-western extent of Bog 6 was not included in the BY1 mapping of this site, even as an isolated fragment, there is justification to exclude the BY1 area of Bog 6 as an outlier. For the purpose of area comparisons, the BY2 area of Bog 6 has been used instead, on the basis that the mean and median change in all other Alpine Bogs from BY1 to BY2 was close to zero.

Impact Year 1 – Recommendation 6
The BY1 area of Bog 6 should be treated as an outlier and, for the purposes of future area comparisons, replaced with the BY2 area of Bog 6.

Alternatively, the north-western extent of Bog 6 could be excluded from all future area comparisons by drawing an arbitrary line through the northern half of Bog 6. However, this would not allow for long-term monitoring of a large part of the northern half of Bog 6, which we now know is in a state of flux. Indeed, bog dimension calculations suggest that Bog 6 is in a greater state of flux than all other monitoring sites.

Bog 6 is a potential outlier with respect to its change in dimensions from BY1 to BY2 (Figure 5). The sum of the dimensions of Bog 6 decreased by 3.8 metres from BY1 to BY2, which is more than double the change observed at any other Alpine Bog over the same period. However, there does not appear to be any justification for excluding this observation as an outlier. On the contrary, bog dimensions support the observations made at Bog 6 during transect monitoring and boundary mapping that the proliferation of weeds is fragmenting and reducing the extent of Bog 6. For example, the greatest dimensional change from BY1 to BY2 was 4.6 metres and occurred at Transect 6C (Photo 4), where on-ground mapping has also recorded a narrowing of the bog width due to weed encroachment since BY1 and approximately 27 metres upslope of where Bog 6 has now become fragmented due to weed encroachment.

Therefore, while there is justification to remove and replace the BY1 area for Bog 6 as an outlier, there is no justification to do the same for BY1 dimensions for Bog 6, despite Figure 5 suggesting that BY1 dimensions may be an outlier.

Bogs S1 and S3

Like Bog 6, Bogs S1 and S3 are also identified in Figure 5 as potential outliers with respect to their change in area from BY1 to BY2. Bogs S1 and S3 are also recovering after the 2006-2007 bushfires. In particular, Mountain Tea-tree *Leptospermum grandifolium* is regenerating in some areas at the edges of these Alpine Bogs, after the parent trees were killed by fire.

However, in contrast with Bog 6, there is no single location where the majority of the change in area has been observed at Bogs S1 and S3 (Figure 4). Changes observed at Bogs S1 and S3 are less extreme than at Bog 6 and are more likely attributable to improvements in DGPS accuracy over the past three years. Finally, the changes observed at Bogs S1 and S3, one a reduction and the other an increase in area, nullify each other to some extent. In this respect, sample replication has served its purpose and there is no justification for removing any of the BY1 or BY2 areas for Bogs S1 and S3 as outliers.

4.1.3 Impacts on bog extent

Results from IY1 suggest that the floristic boundaries of the Alpine Bogs (as represented by the sum of dimensions) has remained relatively close to their baseline mean (Table 11). Dimensions increased by 0.9 metres (0.3%) at impact sites and decreased by 0.2 metres (0.0%) at control sites. On the other hand, areas of some Alpine Bogs have changed more substantially. The area of impact sites decreased by 0.0450 hectares (3.3%) while the area of control site increased by 0.0092 hectares (0.4%) (Table 11).

Although the collective area of control sites has remained relatively constant, closer examination of control sites indicates that Mount Buller control sites decreased in area by 0.0402 hectares (3.5%), while Mount Stirling control sites increased in area by 0.0494 hectares (5.2%) (Table 12). In total, Mount Buller monitoring sites (impact and control sites) have therefore decreased from a baseline mean area of 2.5069 hectares to 2.4218 hectares in IY1, a loss of 0.0851 hectares or 3.4% from the baseline mean. This equates to an 8.6% relative loss in area of Alpine Bogs at Mount Buller, relative to Mount Stirling sites.

Table 12 Change in Alpine Bog extent from baseline mean to Impact Year 1

Site	Area (ha)			Sum of Dimensions (m)		
	Baseline Mean (BM)	Impact Year 1	Change (BM to IY1)	Baseline Mean (BM)	Impact Year 1	Change (BM to IY1)
All Impact Sites	**1.3666**	**1.3217**	**-0.0449 ha -3.3%**	**354.7**	**355.6**	**+0.9 m +0.3%**
All Control Sites	**2.0812**	**2.0904**	**+0.0092 ha +0.4%**	**438.8**	**438.6**	**-0.2 m +0.0%**
Mount Buller Control Sites	1.1403	1.1001	-0.0402 ha -3.5%	267.1	267.4	+0.3 m +0.1%
Mount Stirling Control Sites	0.9410	0.9903	+0.0494 +5.2%	171.7	171.2	-0.5 m -0.3%

The performance criterion related to bog extent requires that there be no more than a 10% reduction in the total combined area of impact sites, relative to control sites. Further to this, Condition 2b of EPBC Act Approval 2014/7303 requires that collectively no more than 0.0900 hectares of indirectly affected areas of Alpine Bog be lost, relative to control sites. The approval defines indirectly affected areas of Alpine Bog as Bogs 4.2, 6, 8, 9, 10, 11.2 and 12 (i.e. all impact sites except Bog 13), being the Alpine Bogs occurring in the catchment area that may be indirectly impacted by the water storage.

However, assessment of performance against the extent criterion is complicated by the fact that all Mount Buller control sites have decreased in area. The fact that Mount Stirling control sites have collectively increased in area while Mount Buller impact and control sites have decreased in area suggests that there may have been localised impacts on Alpine Bogs at Mount Buller.

Empirical observations recorded during on-ground mapping and transect monitoring suggest that the impact of sedimentation on Mount Buller monitoring sites has been primarily limited to impact sites. Sedimentation was observed in a small area of Bog 11.1 (a control site), but the extent of sedimentation at Bog 11.1 was not extensive (in the order of 10 square metres) and not where monitoring transects have been established. Bog 11.1 is discussed in more detail below. While sedimentation and weed proliferation have likely contributed to the loss of bog extent at impact sites, deer and localised hydrological changes (drying soils) appear to be the primary drivers of a loss of bog extent at Mount Buller control sites (particularly Bogs 1, 2, 4.1/5/7, 11.1).

Although the relative changes in bog extent in IY1 are not statistically significant, the primary aim of monitoring is to assess results against the performance criteria (and over-reliance on statistical significance in the context of BACI monitoring should be avoided). The changes in extent of Alpine Bogs in IY1 point to potential future non-compliance and therefore merit further discussion below.

Mount Buller impact sites

The impact of sedimentation is likely to be the main reason for the increase in bare ground and loss of bog extent observed at Mount Buller impact sites. While localised deer damage was observed in the northern half of Bog 6 and along the south-western boundary of Bog 4.2, the damage is unlikely to be the primary reason for the widespread increase in bare ground and loss of bog extent across impact sites. The extent of bare ground at impact sites increased from a baseline mean of 1.0% to 5.4% in IY1, with all impact sites recording an increase in bare ground except Bog 13 (which is furthest from the PCF). The greatest increase in bare ground occurred at Bog 6, from a baseline mean of 1.9% to 8.2% in IY1, which is consistent with the sedimentation and consequent reduction in bog extent observed at Bog 6 during mapping in IY1.

Sediment, primarily from the dam embankment, appears to have washed downhill and into the impact sites. Some sediment has been collected by the aqueduct, which is situated east-west through the middle of the Alpine Bogs (compare Photo 5 and Photo 6). While the aqueduct has trapped some sediment, it has also redistributed it laterally to other areas. For example, the aqueduct mostly discharges surface water (and therefore sediment) into the south-western corner of Bog 6. This appears to be associated with a loss of bog extent in the south-west and central areas of Bog 6 (Photo 4 and Photo 7). Bog 6 has recorded the greatest increase in bare ground (from a baseline mean of 1.9% to 8.2% in IY1), experienced the greatest loss of bog extent (a loss of 0.0343 hectares or 5.1%) and is perhaps the worst affected by sedimentation (with an increase in bare ground from a baseline mean of 1.9% to 8.2% in IY1).

Evidence of sedimentation was recorded at all impact sites except Bog 13, which is presumably too far downslope and too small to have received bulk sediment loads. In the most affected locations, sediment was 10-20 centimetres deep and had buried low-growing Alpine Bog vegetation, such as Peat Moss and Carpet Sedge (Photo 7). Elsewhere, taller Alpine Bog vegetation had been left with a film of sediment covering photosynthetic tissue. It is expected that rain and snow will remove most of this film over time but the response of Alpine Bog vegetation in areas that are more heavily buried is uncertain.

Already, some areas that are buried in 10-20 centimetres of sediment have been colonised by weeds, resulting in loss of Alpine Bog extent (e.g. along the northern boundary of Bog 4.2 and south-west and central areas of Bog 6). Sedimentation has assisted in the proliferation stoloniferous and rhizomatous weed species, such as Brown-top Bent *Agrostis capillaris* and Musk Monkey-flower *Erythranthe moschata.* These species are able to actively and rapidly grow through the sediment. Other weed species, such as Yorkshire Fog *Holcus lanatus*, Creeping Fescue *Festuca rubra* and Soft Rush *Juncus effusus*, may or may not be stoloniferous or rhizomatous, but are tall enough to persist through the sediment layer, unlike many shorter bog-dependent flora species, such as Peat Moss and Carpet Sedge.

There is a risk that these weeds will become permanently established on new bare ground caused by sedimentation, resulting in a permanent loss of bog extent. In most cases, attempting to remove sediment and boulders from the Alpine Bogs cannot be easily achieved without causing further damage and disturbance to the Alpine Bogs. Steps should be taken to implement the Ecological Rehabilitation Plan (Biosis 2020), to ensure that no more sediment, rocks or boulders enter the Alpine Bogs and to prioritise control of weeds establishing on new areas of bare ground. Weeds are discussed further in Section 4.3.1 of this report.

Impact Year 1 – Recommendation 7
Steps should be taken to prevent further movement of sediment, rocks and boulders from the PCF into Alpine Bogs. This will require immediate and long-term implementation of the Ecological Rehabilitation Plan (Biosis 2020).

Mount Buller control sites

The impact of deer and a drying substrate, rather than sedimentation, are likely to be the main reasons for the increase in bare ground and loss of bog extent observed at all Mount Buller control sites. Sedimentation at Mount Buller control sites was only observed at the north-western extent of Bog 11.1 (a control site), near Bogs 11.2 and 12 (both impact sites) and where the aqueduct occasionally discharges surface water during periods of high rainfall. On the other hand, deer damage, drying soils and an associated proliferation of weeds were recorded at all Mount Buller control sites in IY1.

Deer activity (wallowing, trampling and browsing) has been recorded at Mount Buller control sites since BY1 but appeared to have intensified in IY1. Deer have actively removed Alpine Bog vegetation, facilitated the spread of weeds and consequently caused a loss of bog extent at Mount Buller control sites, particularly Bogs 4.1/5/7 and 11.1 (Photo 8 and Photo 9). These Alpine Bogs are now fragmented by weeds, such as Musk Monkey-flower, Soft Rush and Sword Rush *Juncus ensifolius* (Photo 10; Figure 4). Weeds that were already present within and around the Alpine Bogs, particularly in the vicinity of the aqueduct, have colonised the bare ground that has been made available by deer. Over time, this bare ground may also be colonised by seed-dispersed weed species from elsewhere and deer may act as the vector that introduces these novel weeds.

Impact Year 1 – Recommendation 8
Sambar Deer *Cervus unicolor* should be controlled as soon as possible at Mount Buller with the aim of preventing this species from further damaging Alpine Bogs.

In addition to deer, drying soils appear to have contributed to a loss of bog extent at Bogs 1 and 4.1/5/7 and possibly at Bog 2. The loss of bog extent at Bog 1 in IY1 has mostly occurred at its eastern end, where soils appear to have dried, perhaps due to changes to the release of water from the water treatment hut approximately 20 metres south (Photo 11 and Photo 12). It may be that less water was discharged in IY1 or that the water discharge pipe was moved, thereby contributing to the drying soils observed at the eastern end of Bog 1 in IY1. This may have also contributed to the slight (0.0040-hectare) contraction of Bog 2, immediately downslope, in IY1. Similarly, a gradual drying of soils has been observed at the north-eastern arm of Bog 4.1/5/7 since BY1, which has materialised as a progressive reduction in bog extent at this location (Photo 13). The cause for this drying is uncertain but is consistent with the suspected reduction in surface water flows from Bog 4.1/5/7 to the north-western extent of Bog 6 (see discussion about change in hydrology at Bog 6 at Section 4.1.2 of this report). Other hydrological changes may have occurred in IY1 and will be reported separately as part of the HEMAMP's hydrological monitoring.

Although drying of soils likely explains the reduction in bog extent observed at Bogs 1 and 2 in IY1, it seems unlikely that it would have caused the magnitude of increase in bare ground that has also been recorded at these sites. Of the Mount Buller control sites, Bogs 1 and 2 recorded the greatest increases in bare ground in IY1 (Table 5). Closer examination reveals that the increased bare ground was primarily recorded at Transects 1B and 2C, which are immediately upslope and downslope of each other. It is possible that very localised erosion or sediment run-off from a haulage track immediately upslope within the PCF may have contributed to these increases in bare ground at Bogs 1 and 2 (Photo 14). Further investigation would be needed to determine this. In any case, the localised nature of this bare ground and the fact that it does not coincide with the areas of lost bog extent suggest that drying soils are the more likely explanation for loss of bog extent at Bogs 1 and 2.

Mount Stirling control sites

In IY1, a similar increase in bare ground was recorded at Mount Stirling control sites as at Mount Buller monitoring sites (Table 13). However, unlike Mount Buller monitoring sites, Mount Stirling sites actually increased in area. Unsurprisingly, no sedimentation was observed at Mount Stirling monitoring sites. Deer activity was observed at the western end of Bog S1, near Transects S1A and the end of Transect S1B, and in the middle of Bog S3, halfway along Transect S3B, but these were not the transects at which elevated bare ground was recorded. Elevated bare ground was recorded along Transects S2A, S3A and S3C, locations where sedimentation, deer activity or drying soils were not noted.

Table 13 Change in cover of bare ground from baseline mean to Impact Year 1

Site	Cover (%) of Bare Ground		
	Baseline Mean (BM)	Impact Year 1	Change (BM to IY1)
All Impact Sites	**0.98**	**5.37**	**+4.39**
All Control Sites	**0.57**	**4.84**	**+4.27**
Mount Buller Control Sites	0.39	4.53	+4.14
Mount Stirling Control Sites	0.88	5.38	+4.50

It is therefore unclear what may have caused the increase in cover of bare ground at Mount Stirling monitoring sites, without causing any reduction in the area of these Alpine Bogs. The additional 4.50% of bare ground observed at Mount Stirling corresponds almost exactly with the reduction observed in two other ground conditions: litter, which reduced by 2.47%, and vegetation, which reduced by 2.25%. This suggests two possible explanations for the observations at Mount Stirling control sites, both of which are linked to the shrubbier nature of these sites (as opposed to Mount Buller monitoring sites):

- Heavy rainfall immediately prior to transect monitoring at Mount Stirling may have washed away fine leaf litter from below the relatively tall shrub layer. Climatological monitoring may support this explanation. Much of the litter present at Mount Stirling monitoring sites comprises the small leaves of Baeckea and Swamp Heath, which are easily transported by water. Along the transects at which elevated bare ground was recorded (Transects S2A, S3A and S3C), there is also less of a tangled sub-shrub layer (e.g. Spreading Rope-rush and Candle Heath), which would normally trap litter and which is common along other transects, particularly at Mount Buller.

- Trampling from two previous years of monitoring along these transects may have reduced the frequency at which vegetation was recorded as the ground condition. Transect monitoring has caused noticeable trampling of Alpine Bogs, particularly along transects at shrubbier sites (i.e. at Mount Stirling). Vegetation is recorded as the ground condition when the base of the monitoring pin rests on vegetation, such as the woody stem of a shrub or the rosette leaves of a herb, in which case the species to which the vegetation belongs is also recorded. Trampling during monitoring has broken the woody stems of shrubs and disturbed the sub-shrub layer. Below a layer of tall Baeckea and Swamp Heath, the sub-shrub layer along Transects S2A, S3A and S3C is relatively dark, sparse and sensitive to disturbance, comprising small scattered herbs (e.g. Willow Herb *Epilobium* spp.), graminoids (e.g. Club Sedge *Isolepis* spp.), ferns (e.g. Alpine Water-fern *Blechnum penna-marina* subsp. *alpina*) and bryophyte mats (e.g. Feather Moss *Brachythecium* spp.). Indeed, along these transects in IY1, there was a 25% decrease in the incidence of these species compared with the baseline mean.

4.2 Bog composition

The performance criterion relating to the composition of the Alpine Bogs is expressed in terms of bog-dependent species richness (i.e. number of bog-dependent species). It requires that there be no more than a 10% reduction in the total bog-dependent native flora species richness of the impact sites, taking into account natural variation based on species richness observations averaged across control sites. In Section 3.2, results are presented for both richness and cover of bog-dependent species because species cover provides some explanation for changes that may be observed in species richness.

There was no appreciable change to the composition of impact and control sites in IY1. There was no change to the richness of bog-dependent flora and no reduction in the cover of bog-dependent flora at impact sites relative to control sites. Although three additions were made to the list of bog-dependent flora in IY1 (Carpet Sedge, Sweet Holy-grass and Mountain Daisy-bush), these additions were not the reason for no change in bog composition being observed. The same results would have been obtained without the addition of these species to the list of bog-dependent flora.

However, it should be noted that the addition of three species (which should have occurred during baseline monitoring but was overlooked) has the effect of reducing the sensitivity of the composition criterion. Previously, with a total of nine bog-dependent species being recorded across all monitoring sites combined (eight species at control sites and eight species at impact sites), the net loss of just one bog-dependent species from impact sites relative to control sites would have resulted in a reduction in bog-dependent species richness of more than 10% and the composition criterion being breached. As highlighted in BY2, this made the criterion highly sensitive and susceptible to false positives due to the misidentification of similar species in the field (e.g. Subalpine Baeckea *latifolia* and Mountain Baeckea *Baeckea utilis s.s.*).

The addition of Carpet Sedge, Sweet Holy-grass and Mountain Daisy-bush to the bog-dependent species list means that a total of 12 bog-dependent species were recorded across all control and impact sites combined (11 species at control sites and 11 species at impact sites). This means that there would now need to be a net loss of two bog-dependent species from impact sites relative to control sites for more than a 10% reduction in bog-dependent species richness to be recorded and for the composition criterion to be breached. Although the loss of only one bog-dependent species will no longer breach the performance criterion, it should still trigger further investigation into the underlying cause for any net decline in bog-dependent species richness at impact sites. This will allow proactive management actions and interventions to be undertaken, if necessary.

4.3 Encroachment by weeds and other atypical species

4.3.1 Encroachment by weeds

In 2013/2014, Mount Buller's Alpine Bogs were recorded as having low (less than 5%) weed cover (Biosis and GHD 2016). As a result, the HEMAMP's performance criteria require that the total weed cover at impact sites does not exceed 5% (Biosis 2019).

The total weed cover at impact sites was 5.4% in BY1, 6.3% in BY2 and 7.3% in IY1. In contrast, total weed cover at control sites was 3.3% in BY1, 5.3% in BY2 and 5.0% in IY1 (Figure 6). Even before construction began, the criterion for maximum weed cover was already exceeded at impact sites. Limited weed management occurred at the Alpine Bogs during BY1 and BY2 to allow for a robust and representative baseline dataset to be collected. Consequently, weed cover at impact sites still exceeds 5% as at IY1.

In addition, weed cover appears to have increased at impact sites in IY1, relative to control sites, where weed cover appears to be stable or decreasing. While the apparent trend in weed cover is not statistically significant (possibly because only one year of post-impact monitoring has been conducted), it is nevertheless concerning and may reflect the novel impact (i.e. sedimentation) that has occurred at impact sites. Control sites fluctuated about a mean weed cover of 4.3% in BY1 and BY2 and, with a current weed cover of 5.0%, are on the allowable threshold set by the performance criteria. At impact sites, however, there appears to be the beginning of a trend towards increasing weed cover, increasing by approximately 1% cover per year (Figure 6).

The increase in weed cover observed at impact sites in IY1 is likely to have been facilitated by disturbance from sediment, rock and boulders from the PCF. As outlined in Section 4.3.1 of this report, sedimentation has assisted in the proliferation stoloniferous and rhizomatous weed species. Unlike bog-dependent flora species, these weeds are rapid colonisers of bare ground and readily grow through the sediment. Disturbance caused by deer has resulted in an observed increase in weed cover (e.g. at Transect 5A, part of the Bog 4.1/5/7 control site at Mount Buller). However, one would assume that deer impacts would be relatively evenly distributed across impact and control sites (at least at impact and control sites at Mount Buller, which are in close proximity to each other). Indeed, at Mount Buller sites, wallowing and trampling by deer was recorded at two impact sites and two control sites in IY1.

Proliferation of weeds, whether facilitated by sedimentation or deer, is the major reason for areas formerly mapped as Alpine Bog no longer meeting the criteria outlined in the Diagnostic Key to Alpine Bogs (Appendix 2). At Mount Buller and Mount Stirling monitoring sites, the spread of weeds has resulted in the fragmentation of Alpine Bogs (e.g. Bogs 4.1/5/7, 6, 11.1 and S1). At Mount Buller, it has resulted in the overall reduction in extent of all monitoring sites. Without immediate efforts to control weeds, there is a risk that they will proliferate further, become permanently established on bare ground caused by sedimentation and/or deer and result in further losses to the extent of Alpine Bogs.

Impact Year 1 – Recommendation 9

Weed control should be implemented as soon as possible, prioritising areas of sedimentation and deer damage (particularly at Bogs 1, 2, 4.1/5/7, 6, 11.1, 11.2 and S1). The following weed species should be targeted:

- Milfoil *Achillea millefolium*
- Brown-top Bent *Agrostis capillaris*
- Sweet Vernal-grass *Anthoxanthum odoratum*
- Spear Thistle *Cirsium vulgare*
- Musk Monkey-flower *Erythranthe moschata*
- Yorkshire Fog *Holcus lanatus*
- Jointed Rush *Juncus articulatus* subsp. *articulatus*
- Soft Rush *Juncus effusus* subsp. *effusus*
- Sword Rush *Juncus ensifolius*
- Apple *Malus pumila*
- Creeping Buttercup *Ranunculus repens*
- Blackberry *Rubus anglocandicans*

Impact Year 1 – Recommendation 10

The use of alternative weed control methods, such as heat, should be trialled to expand the window of time during which weed control can occur, to minimise the risk to Alpine Bogs from herbicide application and to ultimately improve the management of weeds in Alpine Bogs at Mount Buller and Mount Stirling.

4.3.2 Encroachment by native non-bog-dependent species

The performance criterion for atypical species requires that there be no more than a 10% increase in the cover of non-bog-dependent species at impact sites, relative to control sites. When compared with the baseline mean, there has been a 2.9% increase in the cover of non-bog-dependent species at impact sites and a 3.5% reduction at control sites (Table 11). This represents a statistically significant 6.4% relative increase in the cover of non-bog-dependent species at impact sites, which is more than halfway towards the 10% threshold for this performance criterion. This reason for this increase in non-bog-dependent species is unclear, but the result somewhat mirrors the results for bog extent, in that observations are similar at Mount Buller monitoring sites (both impact and control sites) but differ from observations at Mount Stirling.

Several non-bog-dependent species have increased in cover at all Mount Buller monitoring sites but not at Mount Stirling monitoring sites. The main non-bog-dependent species that have increased in cover at Mount Buller are shrub species that typically surround Alpine bogs (e.g. Alpine Leionema *Leionema phylicifolium*, Kerosene Bush *Ozothamnus cupressoides* and Alpine Podolobium *Podolobium alpestre*) and Snow Grasses *Poa* spp. (e.g. Soft Snow-grass *Poa hiemata*). It may be that these species have increased in cover because they better tolerate disturbance (e.g. from sedimentation or deer). The increase in the cover of these species at Mount Buller control sites has been offset by a reduction in cover of Tall Sedge (Table 14). Indeed, curiously, the cover of Tall Sedge has decreased at all but two monitoring sites across Mount Buller and Mount Stirling (it has remained relatively stable at Bogs 8/9/10 and 13). The considerable reduction in cover of Tall Sedge at Mount Stirling control sites may explain the elevated cover of bare ground observed at Mount Stirling control sites (Table 11).

Table 14 Change in key non-bog-dependent species cover from baseline mean to Impact Year 1

Site	Collective Cover (%) of Alpine Leionema, Kerosene Bush, Alpine Podolobium and Snow Grasses			Cover (%) of Tall Sedge		
	Baseline Mean (BM)	Impact Year 1	Change (BM to IY1)	Baseline Mean (BM)	Impact Year 1	Change (BM to IY1)
All Impact Sites	**30.4**	**35.3**	**+4.9**	**12.0**	**11.2**	**-0.8**
All Control Sites	**26.8**	**28.4**	**+1.6**	**14.9**	**11.3**	**-3.6**
Mount Buller Control Sites	22.4	24.4	+2.0	10.5	8.4	-2.1
Mount Stirling Control Sites	7.7	7.4	-0.3	22.4	16.1	-6.3

4.4 Bog structure

The structure criterion requires that there be no more than a 10% reduction in the average cover of Peat Moss at impact sites, relative to control sites. The cover of Peat Moss was relatively stable at impact sites over the two years of baseline monitoring. In IY1, Peat Moss cover increased from a baseline mean of 5.4% to 6.0% at impact sites but decreased from a baseline mean of 16.4% to 15.9% at control sites. This represents a relative increase of 14.0% in Peat Moss cover at impact sites (Table 11), although this is not statistically significant.

The increase in Peat Moss cover at impact sites can be attributed to Bog 8 (an increase from a baseline mean of 0.0% to 2.1% in IY1) and Bog 13 (an increase from a baseline mean of 20.5% to 28.2% in IY1) (Table 10). However, two third off the Peat Moss cover recorded at Bog 8 in IY1 was dead. Indeed, the proportion of Peat Moss recorded as dead at impact sites increased considerably in IY1 (Figure 7). The proportion of dead Peat Moss at control sites has been decreasing since BY1, when 2.6% was recorded as dead, to a point where 1.5% was recorded as dead in IY1. While the proportion of dead Peat Moss at impact sites remained relatively constant in the baseline years, at 0.8% in BY1 and 0.9% in BY2, it increased to 8.4% in IY1.

The reason for the increase in dead Peat Moss at impact sites in IY1 is unknown. It may be that Peat Moss (e.g. at Bog 8) underwent a period of growth, colonised new areas under favourable conditions and then died back by the time monitoring was repeated in IY1. Alternatively, the increase in dead Peat Moss may be attributable to sedimentation of impact sites in IY1 or it may simply be a random stochastic event. The increase in dead Peat Moss may signal a future decline in Peat Moss cover at impact sites and, since the cause for the observed increase is unknown, it should be assessed again in IY2.

Impact Year 1 – Recommendation 11

The proportion of Peat Moss *Sphagnum cristatum* recorded as dead at impact sites relative to control sites should be reviewed again in IY2 to determine whether a protracted decline in Peat Moss is occurring at impact sites.

4.5 Key observations at each monitoring site

Table 15 summarises the key observations made at each monitoring site in IY1 and indicates management actions that may be required.

Table 15 Observations made at monitoring sites in IY1 and management priorities

Bog	Observations in IY1	Priority
Control Sites		
Bog 1	The south-eastern corner of Bog 1 appears to be drying, perhaps due to changes to the way water is released from the water treatment hut 20 m south (Photo 11 and Photo 12). The extent of Bog 1 has therefore decreased. Soft Rush appears to be spreading along the northern boundary of this site, along the edge of the Summer Nature Walk.	Moderate priority for weed control.
Bog 2	The eastern boundary of Bog 2, near Transect 2A, is subject to severe weed pressures due to historic disturbances to the east of this monitoring site. The cover of weeds (especially Milfoil) along Transect 2A has nearly doubled, from a baseline mean of 13.1% to 22.3% in IY1.	Moderate priority for weed control.
Bog 3	Soft Rush and Musk Monkey-flower are spreading in Bog 3, particularly along its western side, resulting in the Alpine Bog reducing in size (Photo 15).	Moderate priority for weed control.
Bog 4.1/5/7	This Alpine Bog complex is now fragmented due to the proliferation of weeds along the aqueduct and now north of the aqueduct. In order of priority, the main weeds of concern are Sword Rush, Musk Monkey-flower, Soft Rush and Apple. In addition, there is an expanding deer wallow at Transect 5A (Photo 8).	High priority for weed and deer control.
Bog 11.1	Proliferation of weeds (mainly Soft Rush), damage from deer and, to a lesser extent, sediment delivered from the aqueduct has resulted in fragmentation of this control site at its western end (Photo 9). Milfoil has recently colonised the relatively undisturbed vegetation at the eastern end of this Alpine Bog.	High priority for weed and deer control.
Bog S1	The north-western end of this Alpine Bog (near Transect S1A) appears to have dried out, perhaps due to water flow becoming more channelised. The impact of deer and horses is also evident near Stirling Trail. As a result, weedy grasses and Musk Monkey-flower have been spreading and the bog is contracting at this end. Blocking of the main channel (e.g. with rice straw bales) may benefit some of this area and allow for recolonisation by bog-dependent species, like Peat Moss. In addition, there is an expanding Blackberry infestation in the centre of this bog, about halfway upslope (Photo 16).	High priority for weed and deer control.
Bog S2	Although no weeds have been recorded by line (point) or belt (quadrat) transects at this monitoring site since BY1, incidental observations suggest that Musk Monkey-flower may be increasing in cover. This weed currently exists as a few isolated occurrences in the north-western half.	Moderate to high priority for weed control.

Bog	Observations in IY1	Priority
Bog S3	Weed cover, especially Musk Monkey-flower, is increasing at the southern edge of this Alpine Bog (along Transect S3C), mainly associated with Wombat Drop Track, which passes through the site. Along Transect S3C, weed cover has increased from a baseline mean of 15.8% to 25.2% in IY1.	Moderate priority for weed control.
Impact Sites		
Bog 4.2	Sediment has been deposited along the northern boundary (at the aqueduct). This area should be monitored for establishing weeds and treated accordingly. A small deer wallow is also present at the south-west boundary of this Alpine Bog but has not yet resulted in significant weed invasion in this area.	Moderate priority for weed and deer control.
Bog 6	Sedimentation is particularly evident in the south-west and west of this site, where the aqueduct spills over into the Alpine Bog. Bog-dependent species have been buried and weeds (e.g. Brown-top Bent, Yorkshire Fog and Soft Rush) are proliferating. In addition, this Alpine Bog has been fragmented approximately 70-100 metres downslope of the aqueduct due to sedimentation burying bog-dependent species, proliferation of weeds (e.g. Sweet Vernal-grass, Soft Rush and Musk Monkey-flower) and, to a lesser extent, trampling by deer. Without treatment, weeds will become permanently established.	High priority for weed and deer control.
Bog 8/9/10	The covers of bare ground (due to sedimentation) and weeds (e.g. Milfoil and Brown-top Bent) have increased considerably at this Alpine Bog complex in IY1, but the area of the Alpine Bog complex has so far remained stable.	Moderate priority for weed control.
Bog 11.2 and 12	These bogs are immediately upslope/downslope of each other and have similar management issues. Sedimentation is evident in these Alpine Bogs and there will need to be an effort to ensure that weeds do not colonise the new bare ground.	High priority for weed control.
Bog 13	Since BY1, this bog has been surrounded by predominantly introduced vegetation, particularly weedy grasses (e.g. Brown-top Bent and Sweet Vernal-grass). Weed cover at this Alpine Bog appears to be stable.	Moderate priority for weed control.

5. Conclusion and recommendations

Three years of ecological monitoring in accordance with the HEMAMP protocol have now been completed, including two years of baseline monitoring and one year of post-impact monitoring. The monitoring results presented here allow for an assessment against the HEMAMP's performance criteria. Table 16 presents the results of the compliance assessment as at IY1.

Table 16 Compliance with the HEMAMP performance criteria

Performance criterion	Compliant?	Action required?	Comments
Extent			
No more than a 10% reduction in the total combined area of impact sites, relative to control sites.	Yes	Yes	Potential for future non-compliance with a 3.7% reduction in the total combined area of impact sites, relative to control sites. Control weeds/deer, focussing on areas of sedimentation.
Composition			
No more than a 10% reduction in the total 'bog-dependent' native flora species richness of impact sites, relative to control sites.	Yes	No	No change in the total bog-dependent native flora species richness of impact sites, relative to control sites.
Encroachment			
No more than a 10% increase in the cover of 'non-bog-dependent' species within impact sites, relative to control sites.	Yes	Yes	Potential for future non-compliance with a relative 6.4% increase in cover of non-bog-dependent species at impact sites. Investigate possible hydrological changes at impact sites and adapt management accordingly.
Weed cover not to exceed 5%.	No	Yes	Weed cover at impact sites is 7.3% and appears to be increasing. Control weeds/deer, focussing on areas of sedimentation.
Structure			
No more than a 10% reduction in the average cover of Peat Moss within impact sites, relative to control sites.	Yes	No	Average cover of Peat Moss within impact sites, relative to control sites, increased by 14.0% in IY1.

As was predicted by baseline monitoring prior to construction commencing, there is currently non-compliance with the weed cover performance criterion because weed cover at impact sites exceeds 5% (recorded to be 7.3% in IY1 and it appears to be increasing). Weed management commenced at impact and control sites immediately after the preliminary IY1 monitoring results were known. Weed management should continue, focussing especially on areas affected by sedimentation, and should be accompanied by deer control.

Although currently compliant, there is potential future non-compliance with the extent criterion. Impact sites have experienced a 3.7% reduction in area, relative to control sites, since construction of the water storage started. Control of weeds and deer, focussing on areas of sedimentation, should assist in reversing any apparent loss of bog extent.

Although currently compliant, there is also potential future non-compliance with one of the encroachment criteria. There has been a 6.4% increase in the cover of non-bog-dependent species within impact sites, relative to control sites. As part of the HEMAMP's hydrological monitoring, there should be an analysis of possible hydrological changes that may have occurred at impact sites. This will inform whether or not environmental watering may be needed.

The recommendations of this monitoring report are as follows:

1. The HEMAMP protocol should be updated to include Carpet Sedge *Carex jackiana*, Sweet Holy-grass *Hierochloe redolens* and Mountain Daisy-bush *Olearia algida* among the list of bog-dependent species.
2. The HEMAMP protocol for point intersection sampling along transects should be updated to make it clear that only species touching the pin are recorded and not species, such as Snow Gum *Eucalyptus pauciflora*, that may be directly above the pin.
3. The HEMAMP protocol should be updated to make note of the insurance pegs installed at the 5.5-metre mark of all transects at Bog 13.
4. The HEMAMP protocol should be updated to provide clarification of the treatment of Bidgee-widgee *Acaena novae-zelandiae*, Alpine Water-fern *Blechnum penna-marina* subsp. *alpina* and Tall Sedge *Carex appressa* during mapping of Alpine Bog boundaries.
5. The BY1 area of Bog 6 should be treated as an outlier and, for the purposes of future area comparisons, replaced with the BY2 area of Bog 6.
6. Steps should be taken to prevent further movement of sediment, rocks and boulders from the PCF into Alpine Bogs. This will require immediate and long-term implementation of the Ecological Rehabilitation Plan (Biosis 2020).
7. Sambar Deer *Cervus unicolor* should be controlled as soon as possible at Mount Buller with the aim of preventing this species from further damaging Alpine Bogs.
8. Analysis of aerial imagery (whether captured by unmanned aerial vehicle or satellite) should continue to be investigated as an alternative method of monitoring the extent and condition of Alpine Bogs, with the aim of reducing the impacts of annual on-ground monitoring.
9. Weed control should be implemented as soon as possible, prioritising areas of sedimentation and deer damage (particularly at Bogs 1, 2, 4.1/5/7, 6, 11.1, 11.2 and S1). The following weed species should be targeted:
   - Milfoil *Achillea millefolium*
   - Brown-top Bent *Agrostis capillaris*
   - Sweet Vernal-grass *Anthoxanthum odoratum*
   - Spear Thistle *Cirsium vulgare*
   - Musk Monkey-flower *Erythranthe moschata*
   - Yorkshire Fog *Holcus lanatus*
   - Jointed Rush *Juncus articulatus* subsp. *articulatus*
   - Soft Rush *Juncus effusus* subsp. *effusus*

- Sword Rush *Juncus ensifolius*
- Apple *Malus pumila*
- Creeping Buttercup *Ranunculus repens*
- Blackberry *Rubus anglocandicans*.

10. The use of alternative weed control methods, such as heat, should be trialled to expand the window of time during which weed control can occur, to minimise the risk to Alpine Bogs from herbicide application and to ultimately improve the management of weeds in Alpine Bogs at Mount Buller and Mount Stirling.
11. The proportion of Peat Moss *Sphagnum cristatum* recorded as dead at impact sites relative to control sites should be reviewed again in IY2 to determine whether a protracted decline in Peat Moss is occurring at impact sites.

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Figures

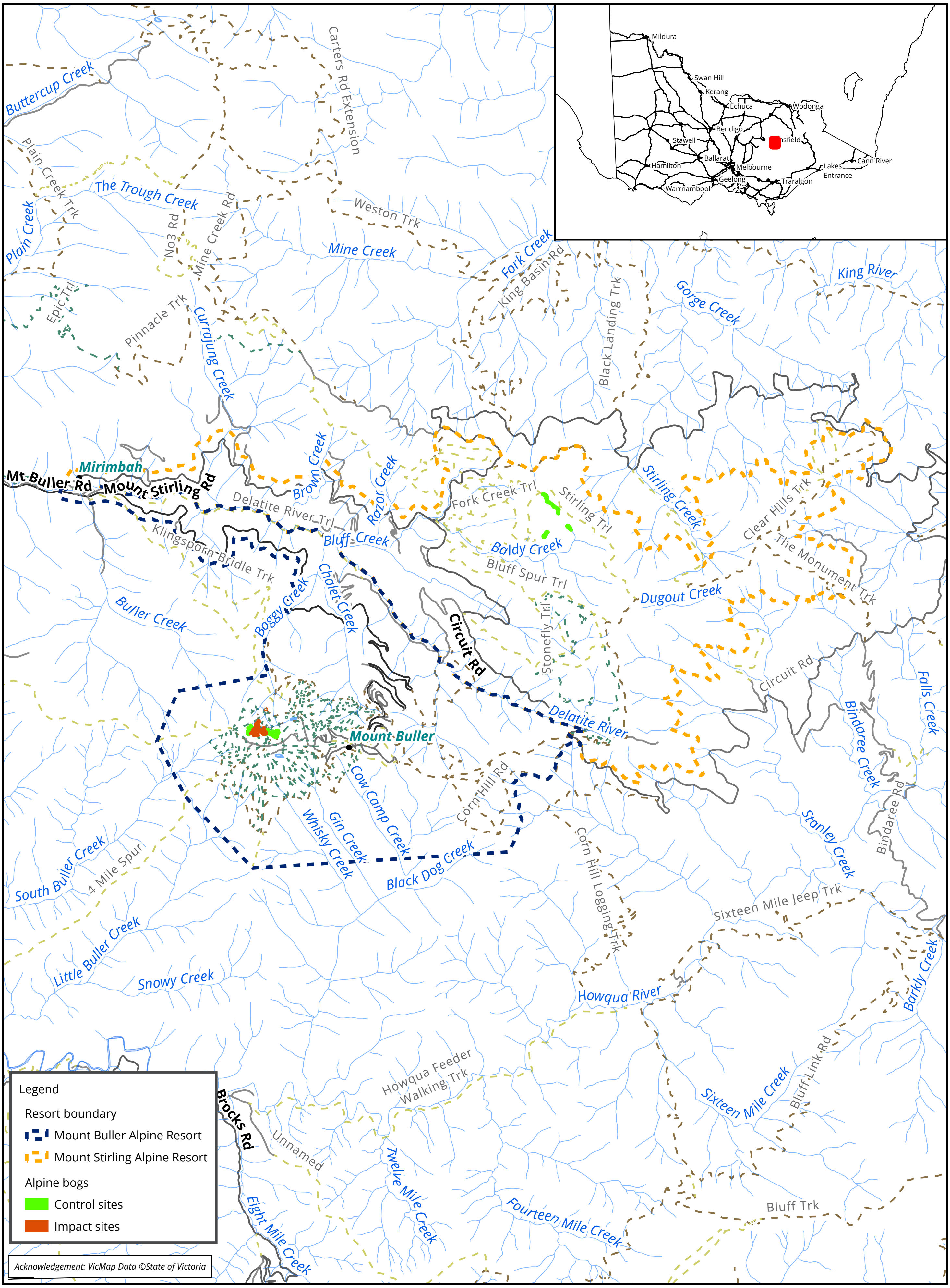

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Figure 1: Location of the Mount Buller and Mount Stirling Alpine Resorts, Victoria

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Date: 28 March 2018,
Checked by: MG, Drawn by: SSK, Last edited by: skumar
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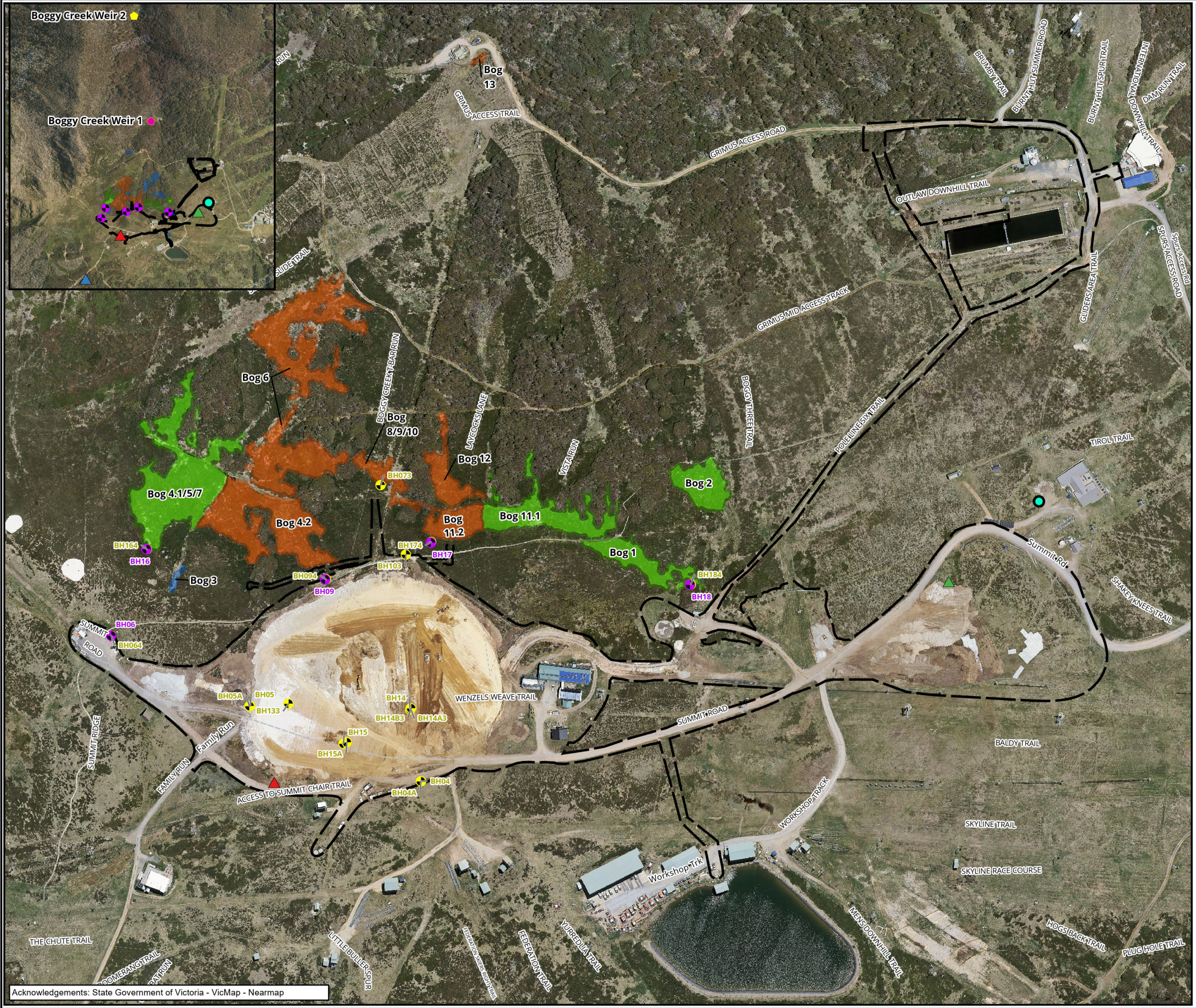

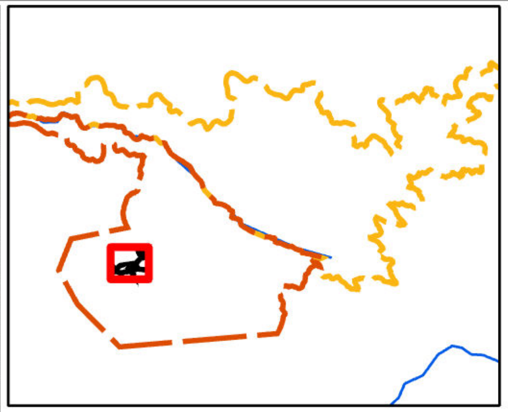

Legend

- Project Construction Footprint

Alpine Bogs

- Control sites (2020)
- Impact sites (2020)
- Other sites (2020)
- Groundwater bore
- BoM Station
- Other groundwater boreholes
- Boggy Creek Snow Gauge
- Family Run Snow Gauge
- Tirol Snow Gauge

Figure 2: Location of Alpine Bogs subject to monitoring at Mount Buller Alpine Resort

0 30 60 90 120 150

Metres

Scale: 1:3000 @ A3

Coordinate System:

PCS: GDA 1994 MGA Zone 55

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Date: 28 January 2020,

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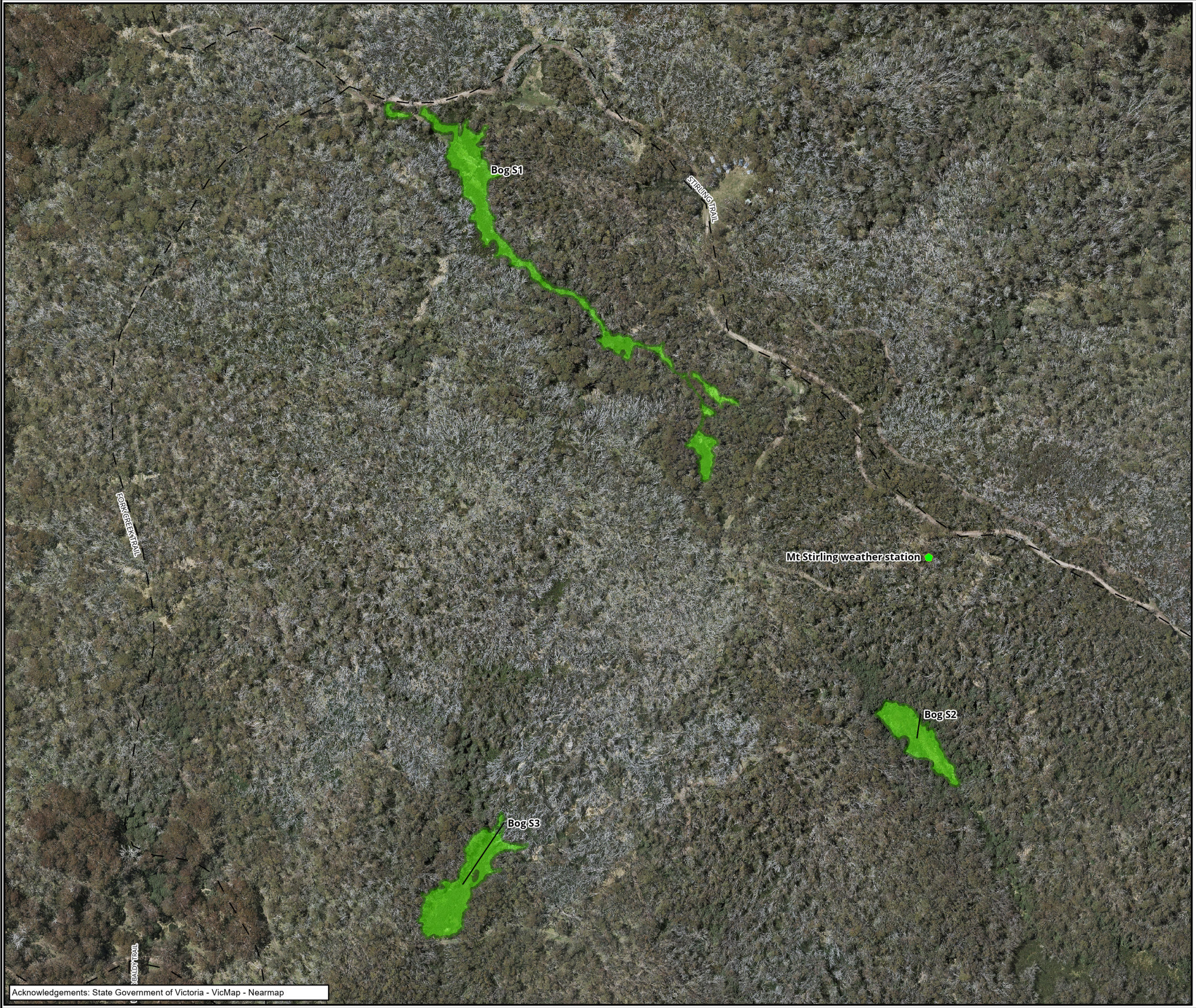

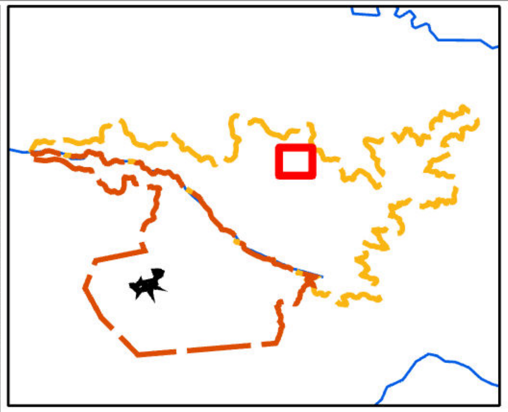

Legend

- Control sites (2020)
- Mt Stirling weather station

Figure 3: Location of Alpine Bogs subject to monitoring at Mount Stirling Alpine Resort

0 30 60 90 120 150

Metres

Scale: 1:3000 @ A3

Coordinate System:

PCS: GDA 1994 MGA Zone 55

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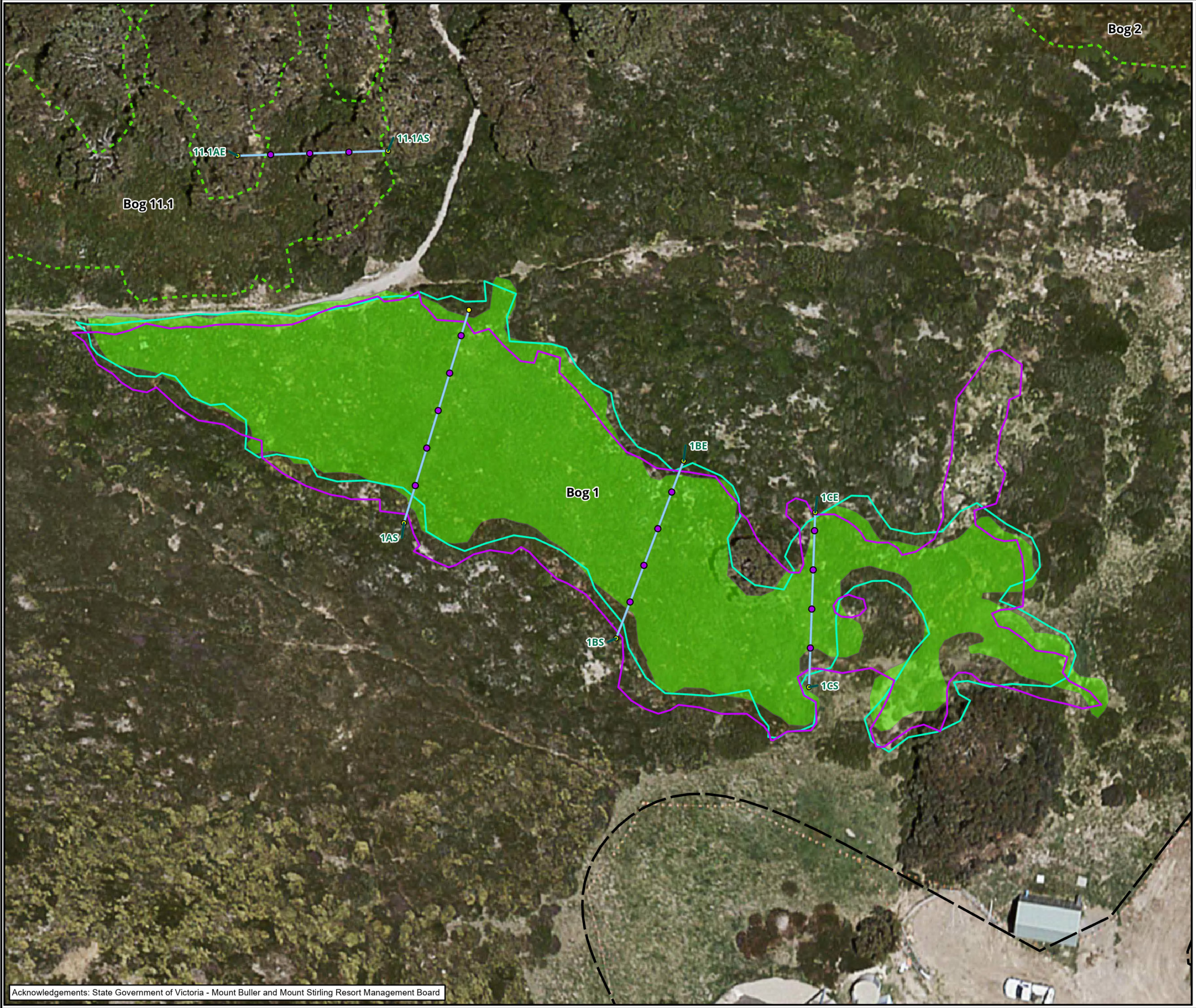
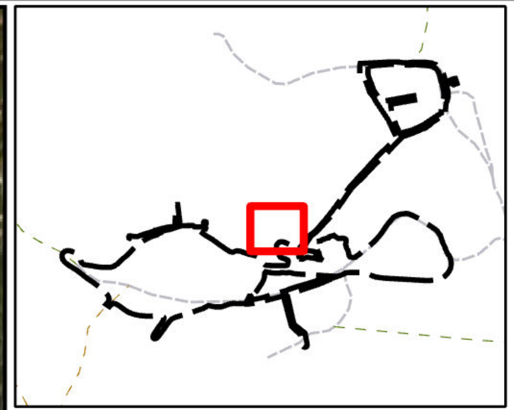


Acknowledgements: State Government of Victoria - Mount Buller and Mount Stirling Resort Management Board



Legend

- Project Construction Footprint
- Transects
- Quadrats
- Photo points
- Control site (2020)
- Baseline year 1
- Baseline year 2

Figure 4a: Bog 1 (control site)

0 3.5 7 10.5 14 17.5

Metres

Scale 1:360 @ A3

Coordinate System:

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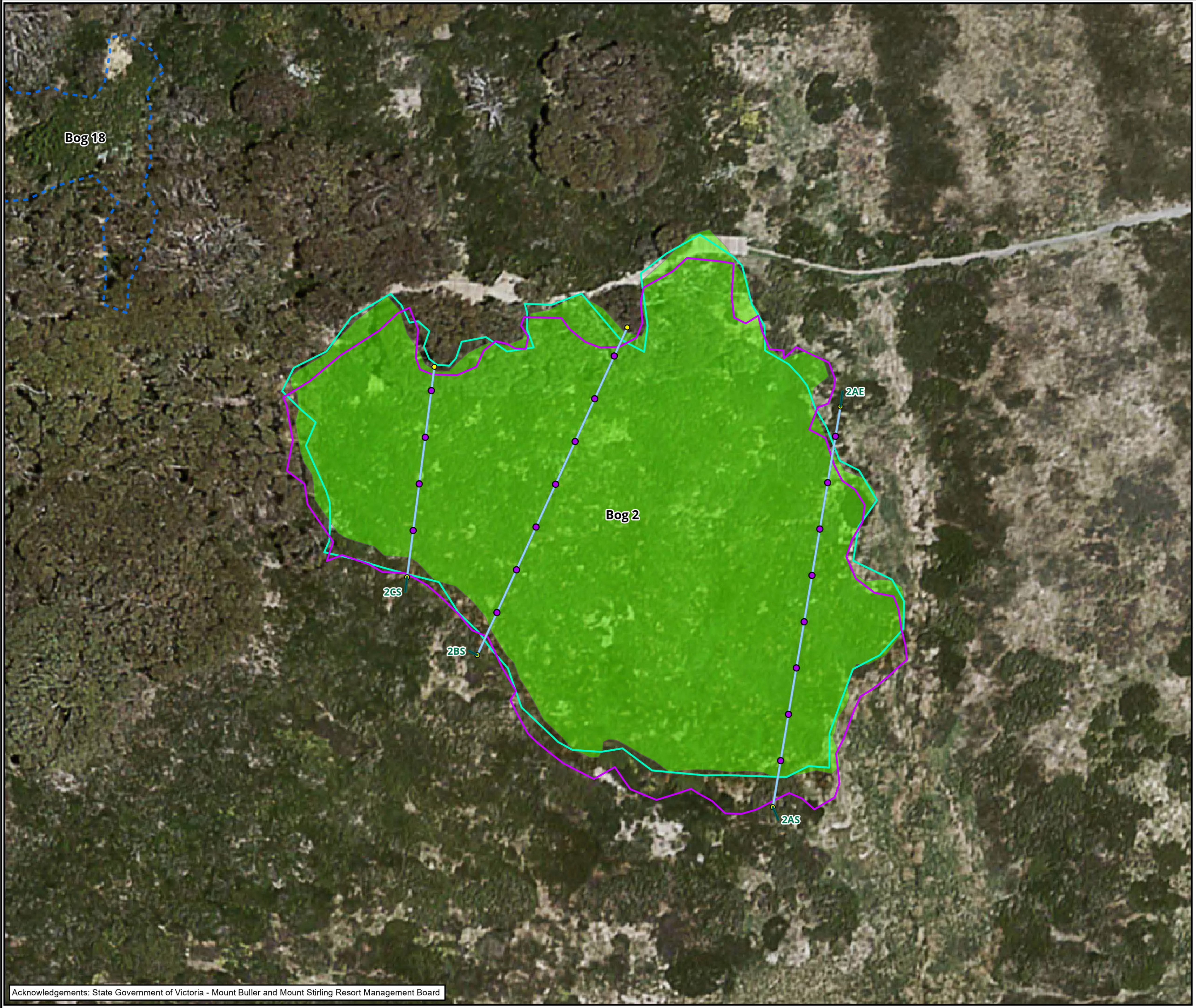

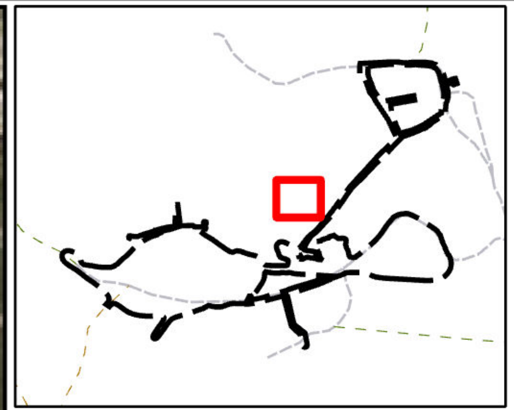

Legend

- Transects
- Quadrats
- Photo points
- Control site (2020)
- Baseline year 1
- Baseline year 2

Figure 4b: Bog 2 (control site)

0 3 6 9 12 15

Metres

Scale 1:300 @ A3

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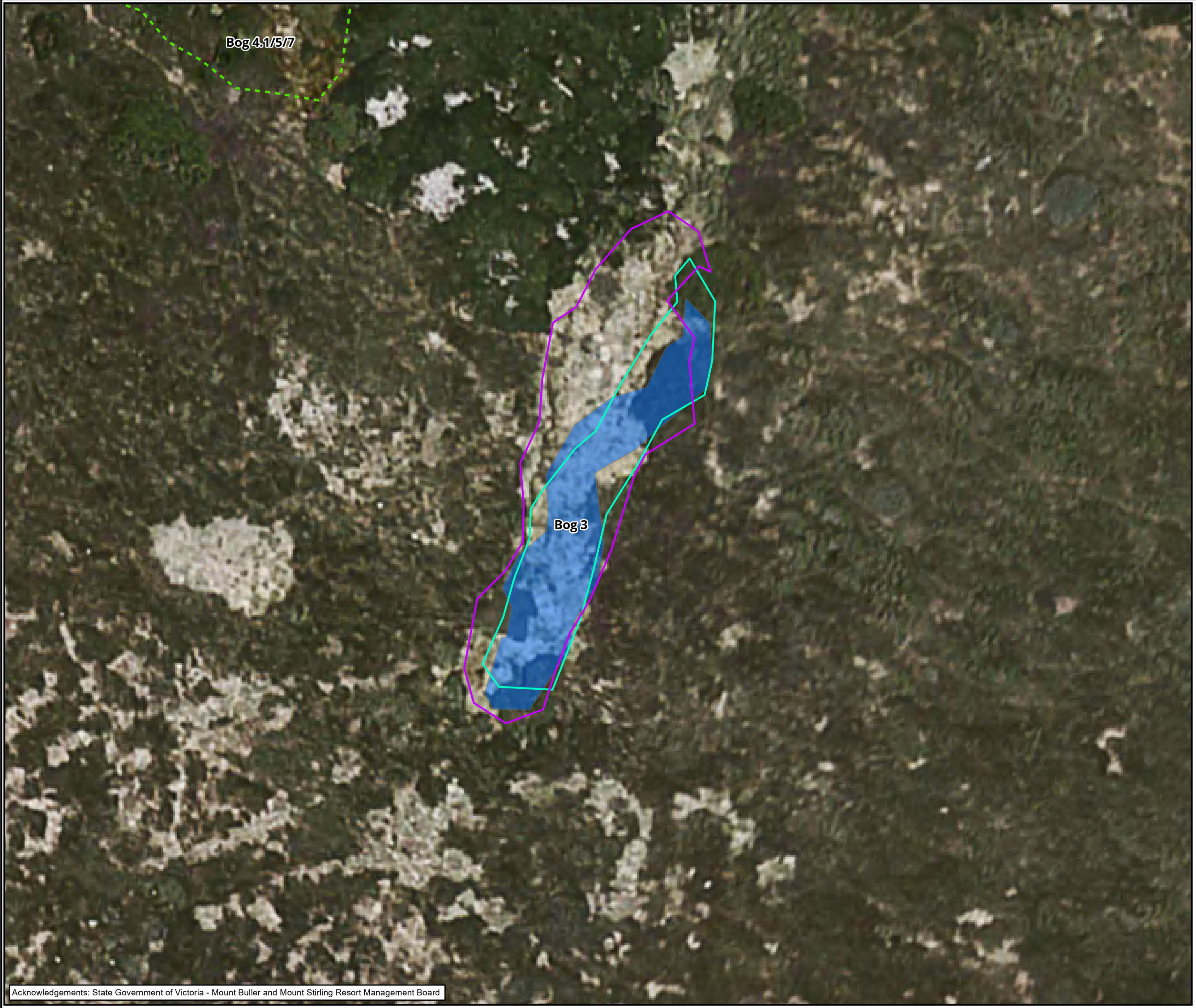

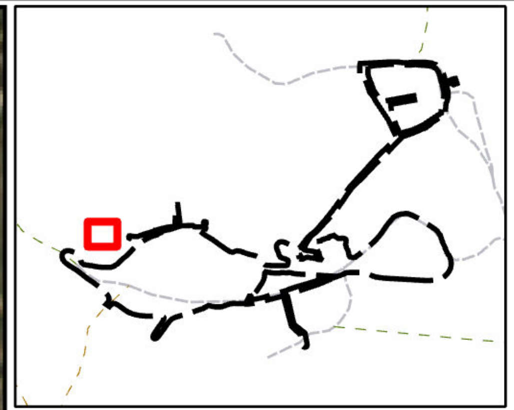

Legend

- Other site (2020)
- Baseline year 1
- Baseline year 2

Figure 4c: Bog 3 (other site)

0 2 4 6 8 10

Metres

Scale 1:200 @ A3

Coordinate System:

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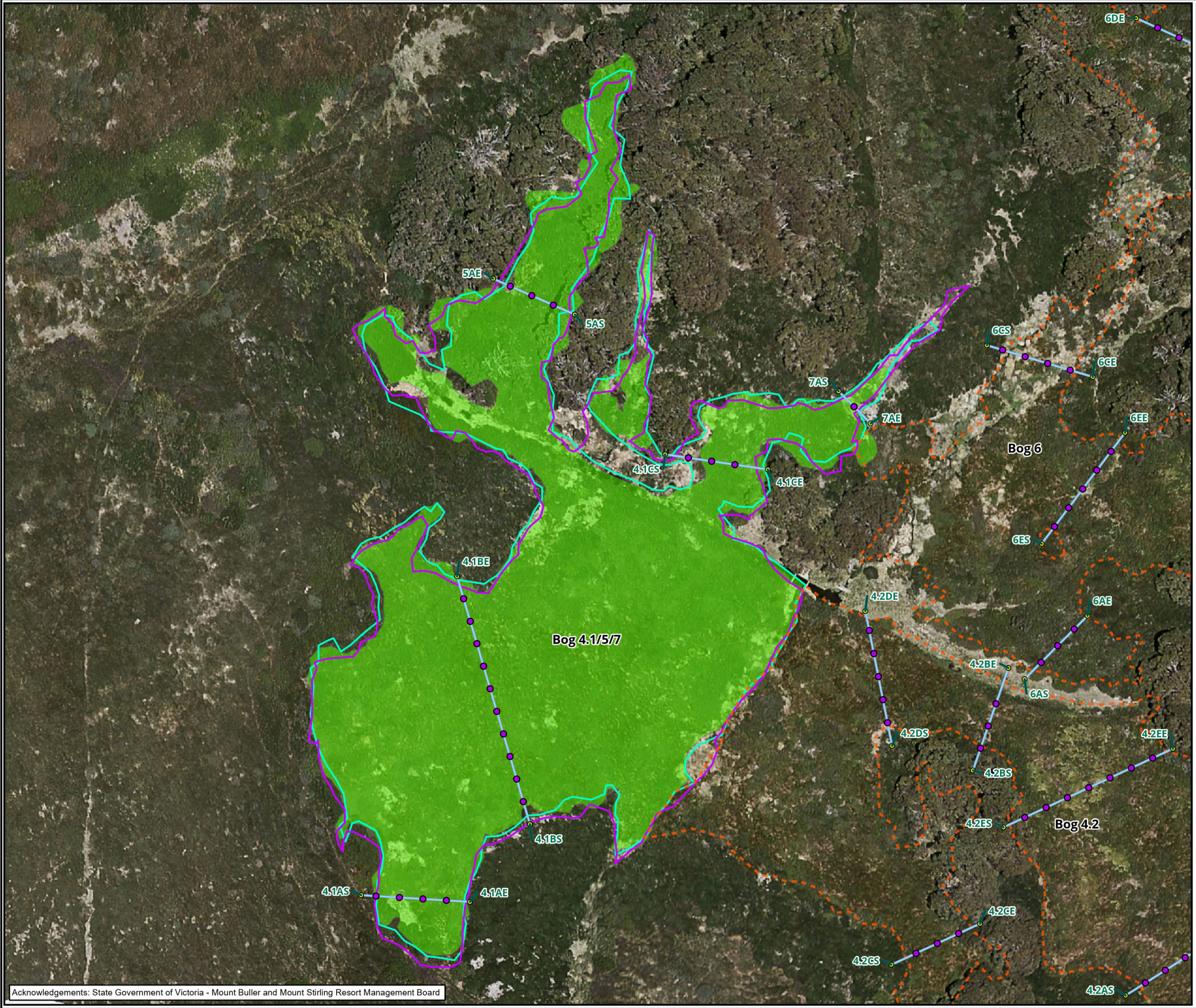

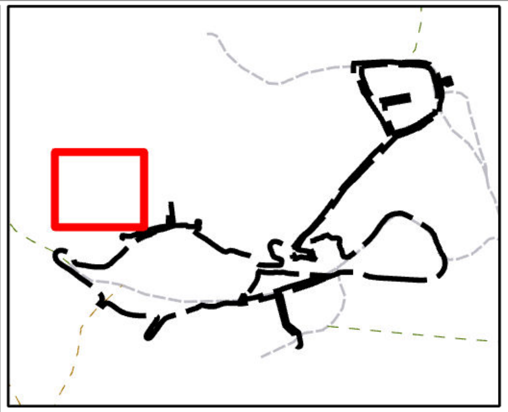

Legend

- Transects
- Quadrats
- Photo points
- Control site (2020)
- Baseline year 1
- Baseline year 2

Figure 4d: Bog 4.1/5/7 (control site)

0 6 12 18 24 30

Metres

Scale 1:600 @ A3

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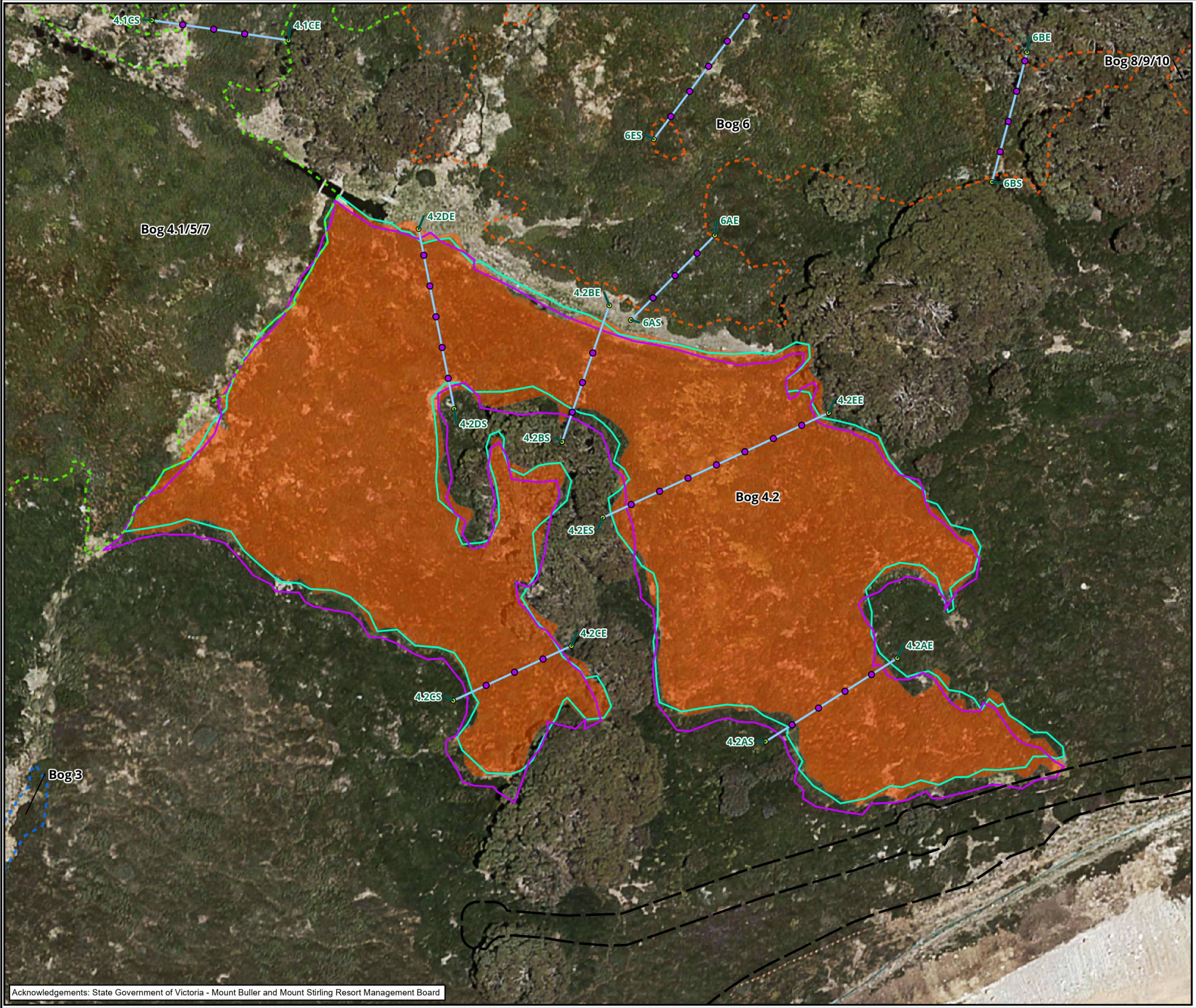

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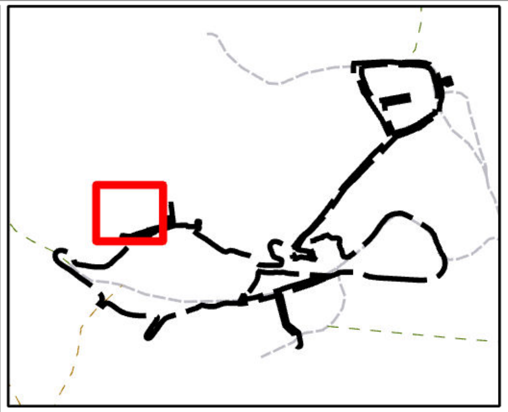

Legend

- Project Construction Footprint
- Transects
- Quadrats
- Photo points
- Impact site (2020)
- Baseline year 1
- Baseline year 2

Figure 4e: Bog 4.2 (impact site)

0 4.5 9 13.5 18 22.5

Metres

Scale 1:450 @ A3

Coordinate System:

PCS: GDA 1994 MGA Zone 55

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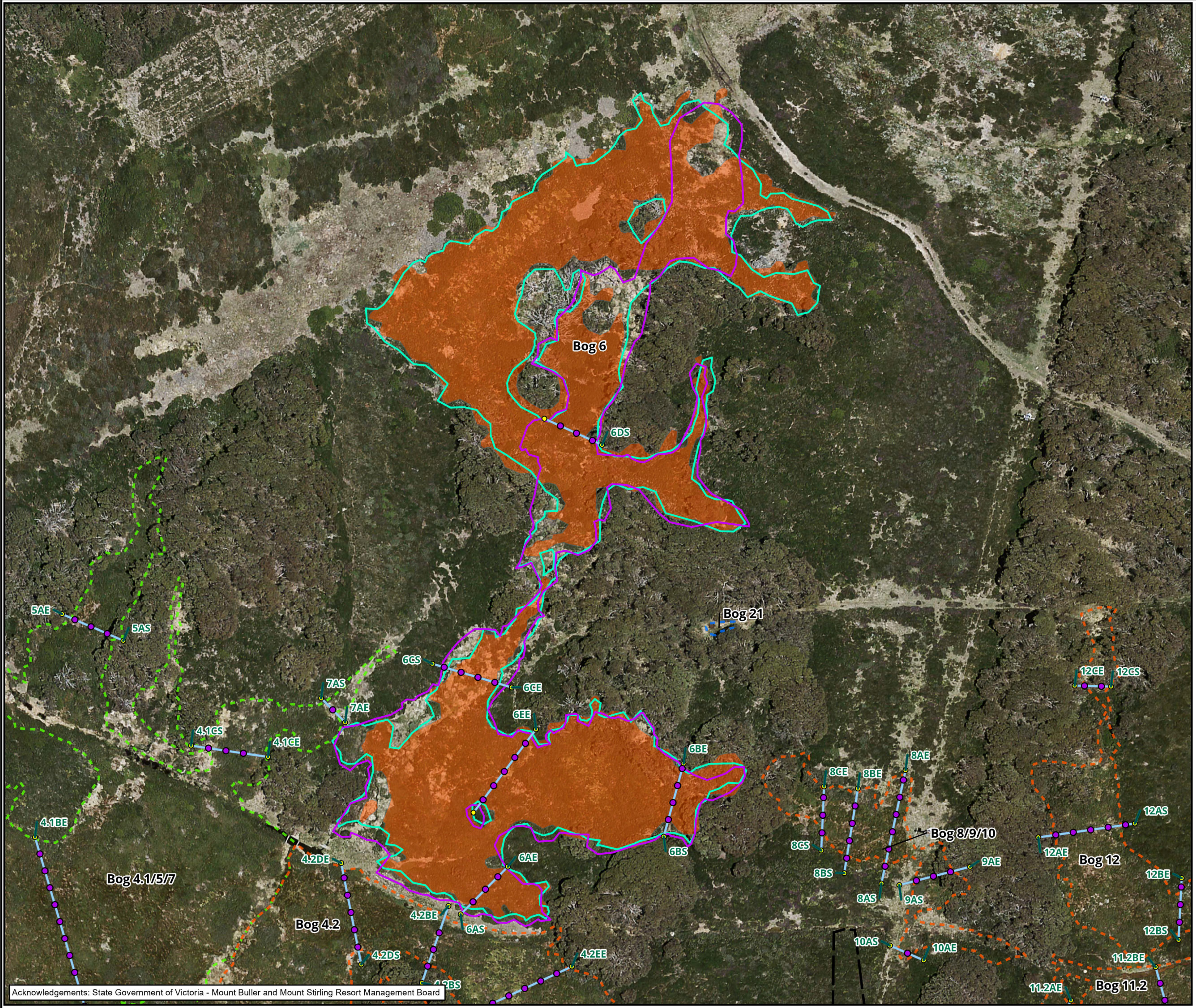

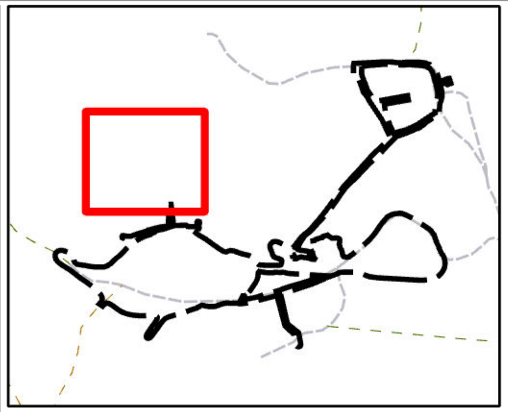

Legend

- Project Construction Footprint
- Transects
- Quadrats
- Photo points
- Impact site (2020)
- Baseline year 1
- Baseline year 2

Figure 4f: Bog 6 (impact site)

0 8 16 24 32 40

Metres

Scale 1:800 @ A3

Coordinate System: PCS: GDA 1994 MGA Zone 55

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Matter: 26702
Date: 15 April 2020,
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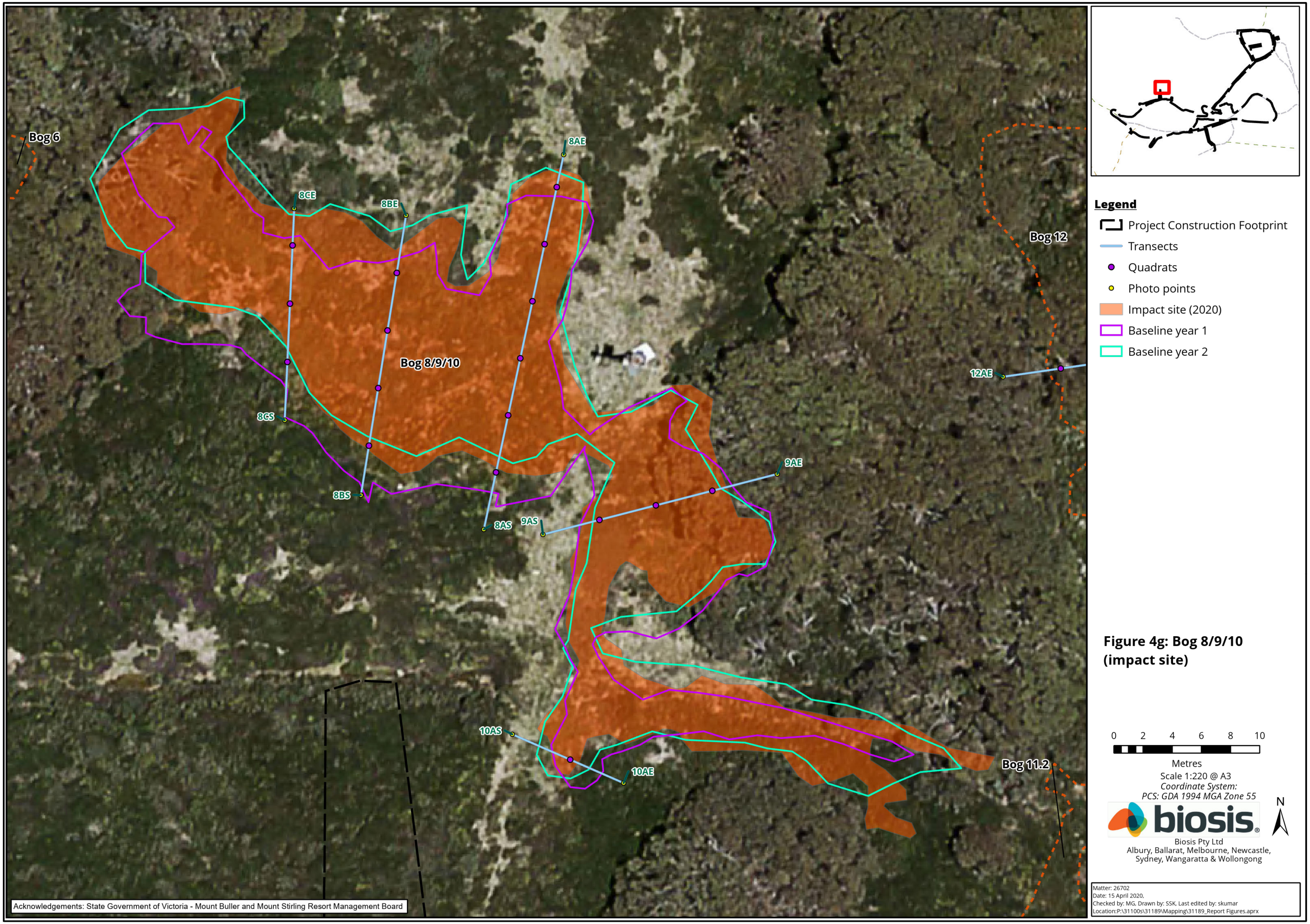
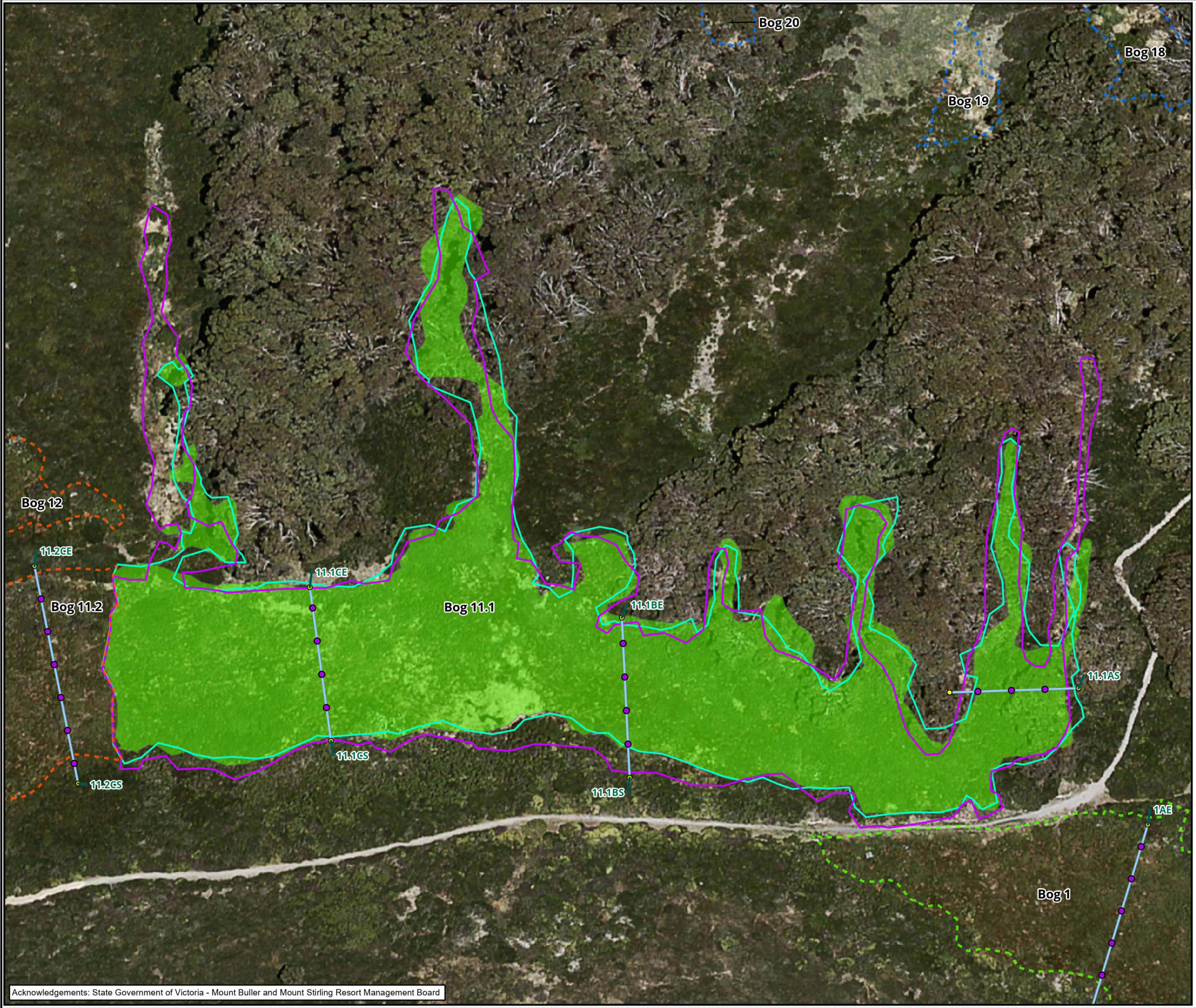
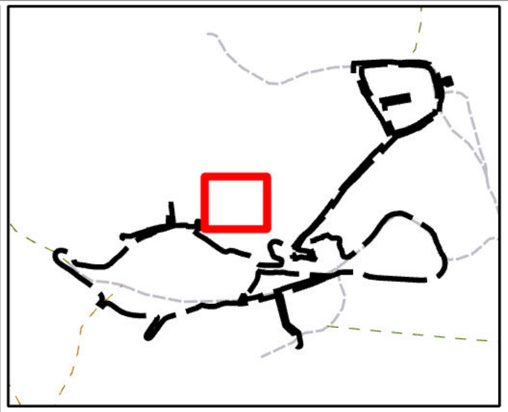


Figure 4g: Bog 8/9/10 (impact site)





Legend

- Transects
- Quadrats
- Photo points
- Control site (2020)
- Baseline year 1
- Baseline year 2

Figure 4h: Bog 11.1 (control site)

0 4 8 12 16 20

Metres

Scale 1:420 @ A3

Coordinate System:

PCS: GDA 1994 MGA Zone 55

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Date: 15 April 2020,
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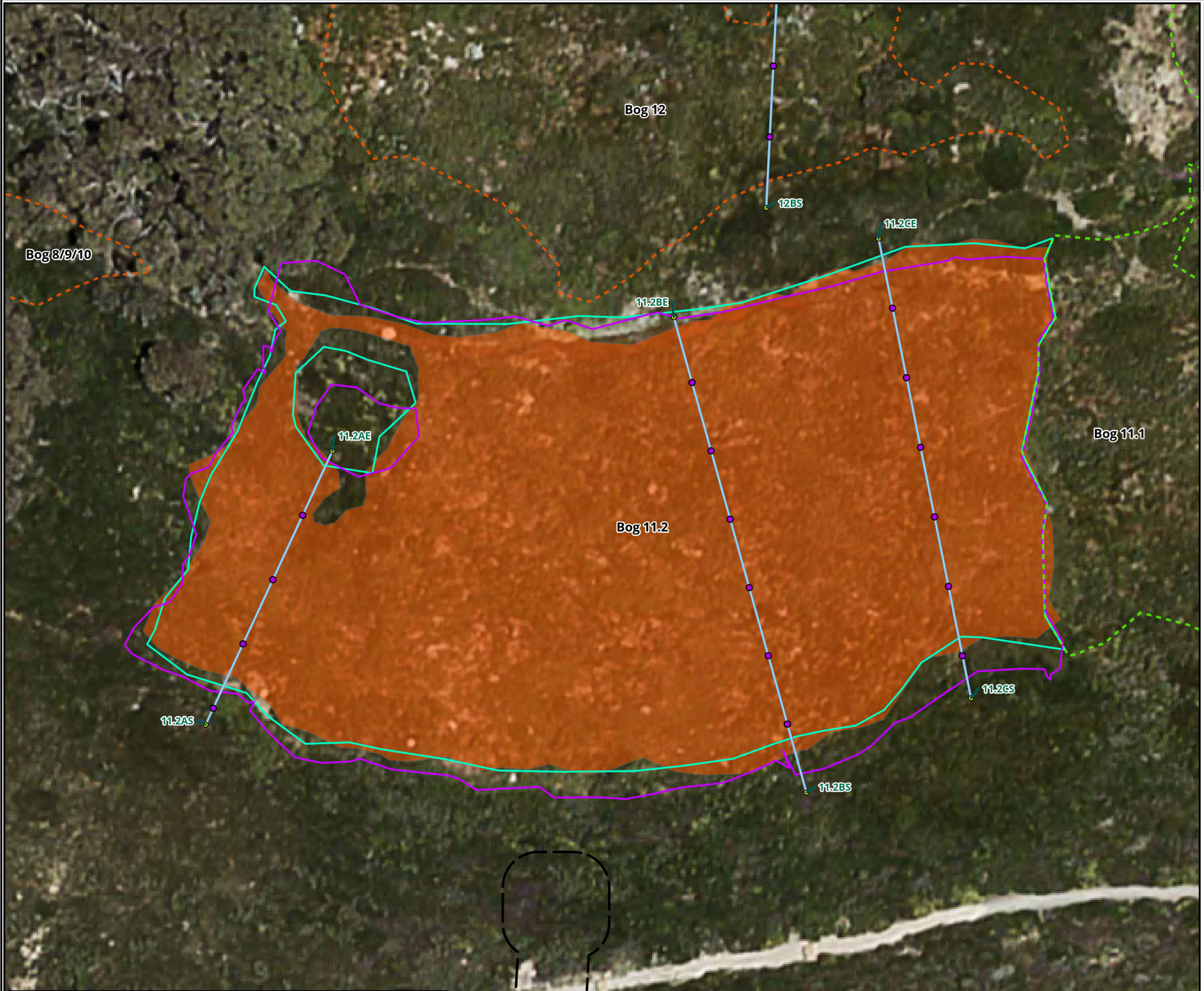
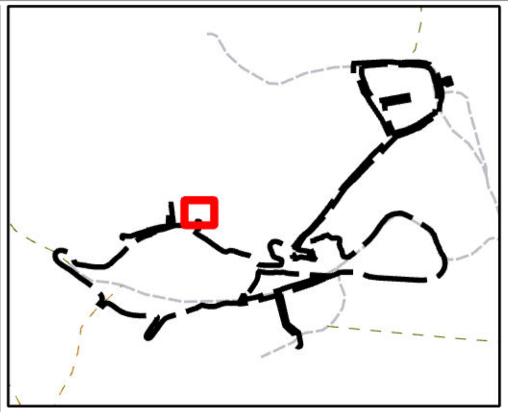


Acknowledgements: State Government of Victoria - Mount Buller and Mount Stirling Resort Management Board



Legend

- Project Construction Footprint
- Transects
- Quadrats
- Photo points
- Impact site (2020)
- Baseline year 1
- Baseline year 2

Figure 4i: Bog 11.2 (impact site)

0 2 4 6 8 10

Metres

Scale 1:200 @ A3

Coordinate System:
PCS: GDA 1994 MGA Zone 55

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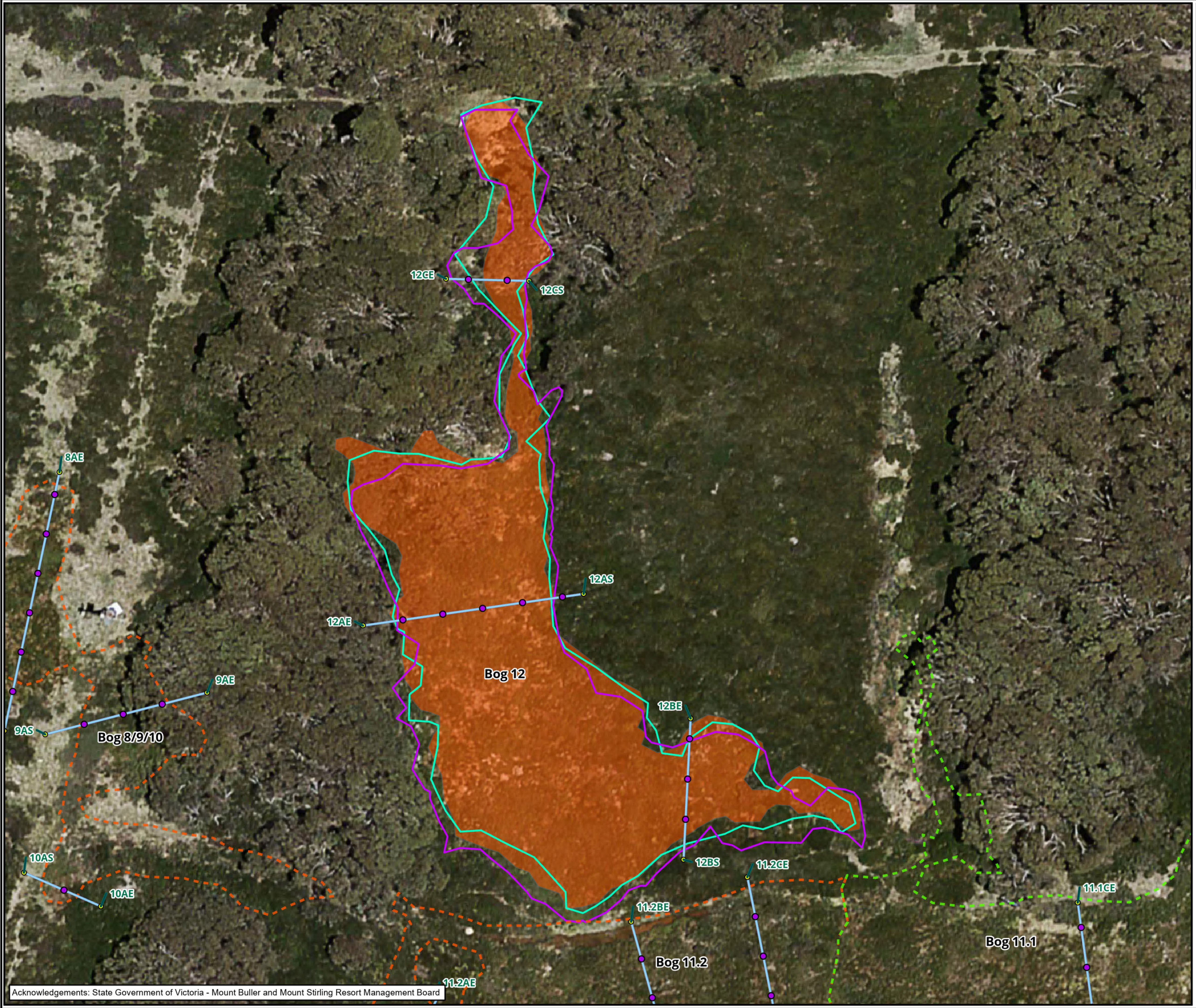

Acknowledgements: State Government of Victoria - Mount Buller and Mount Stirling Resort Management Board

Legend

- Transects
- Quadrats
- Photo points
- Impact site (2020)
- Baseline year 1
- Baseline year 2

Figure 4j: Bog 12 (impact site)

Scale 1:350 @ A3
Coordinate System:
PCS: GDA 1994 MGA Zone 55

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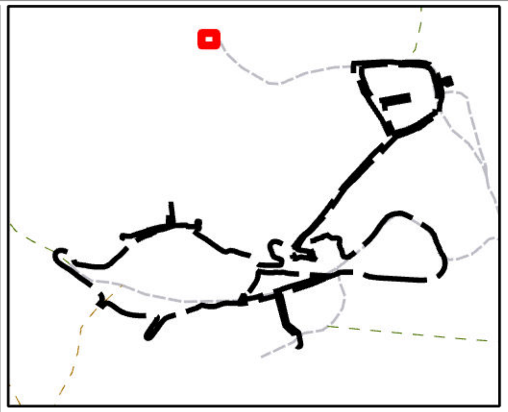

Legend

- Transects
- Quadrats
- Photo points
- Impact site (2020)
- Baseline year 1
- Baseline year 2

Figure 4k: Bog 13 (impact site)

0 1 2 3 4 5

Metres

Scale 1:100 @ A3

Coordinate System:

PCS: GDA 1994 MGA Zone 55

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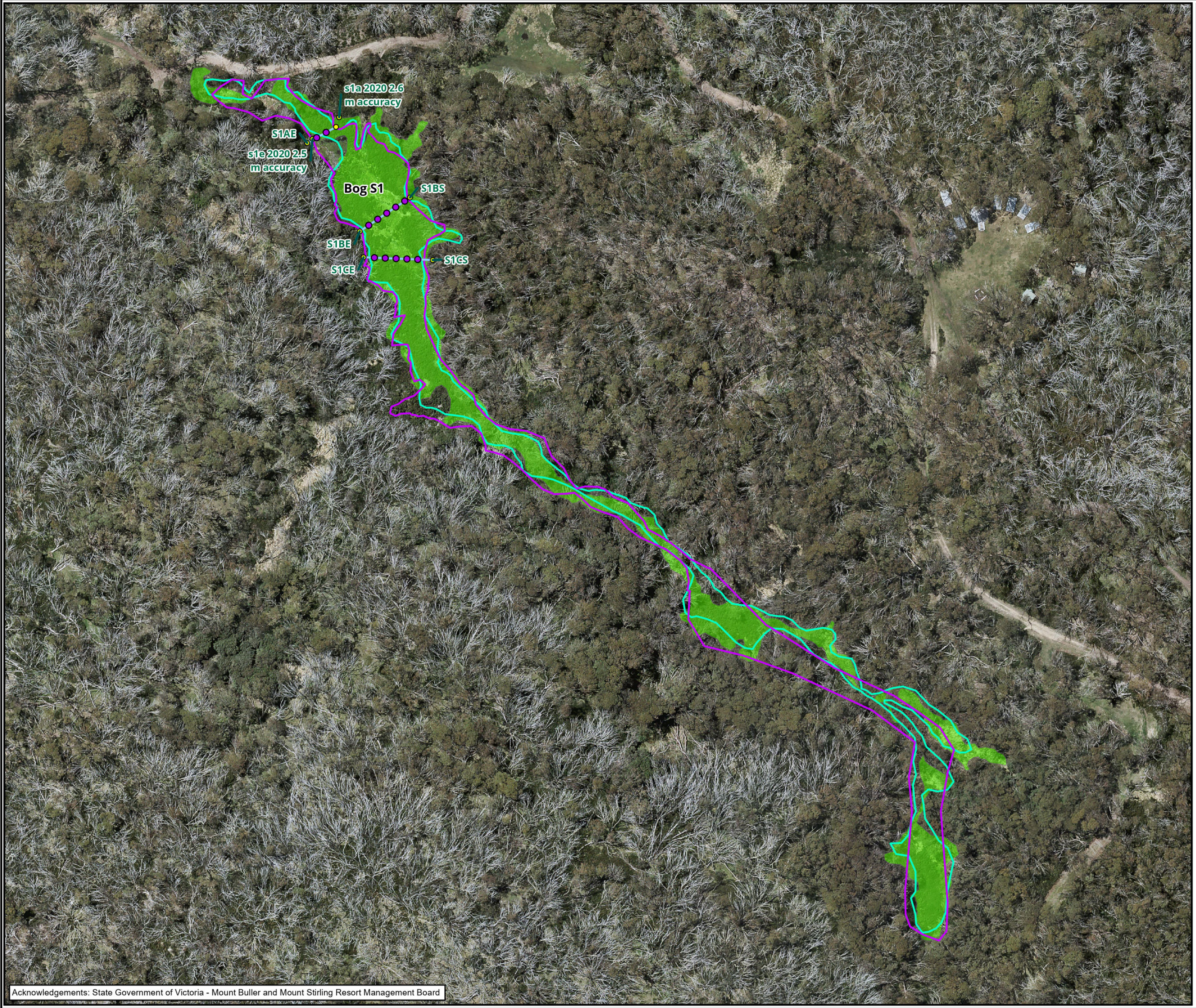

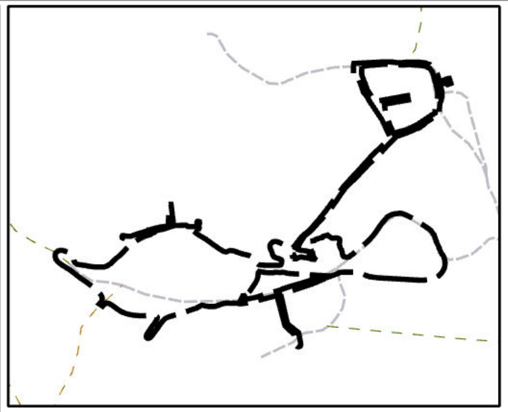

Legend

- Transects
- Quadrats
- Photo points
- Control site (2020)
- Baseline year 1
- Baseline year 2

Figure 4l: Bog S1 (control site)

0 10 20 30 40 50

Metres

Scale 1:1,300 @ A3

Coordinate System:
PCS: GDA 1994 MGA Zone 55

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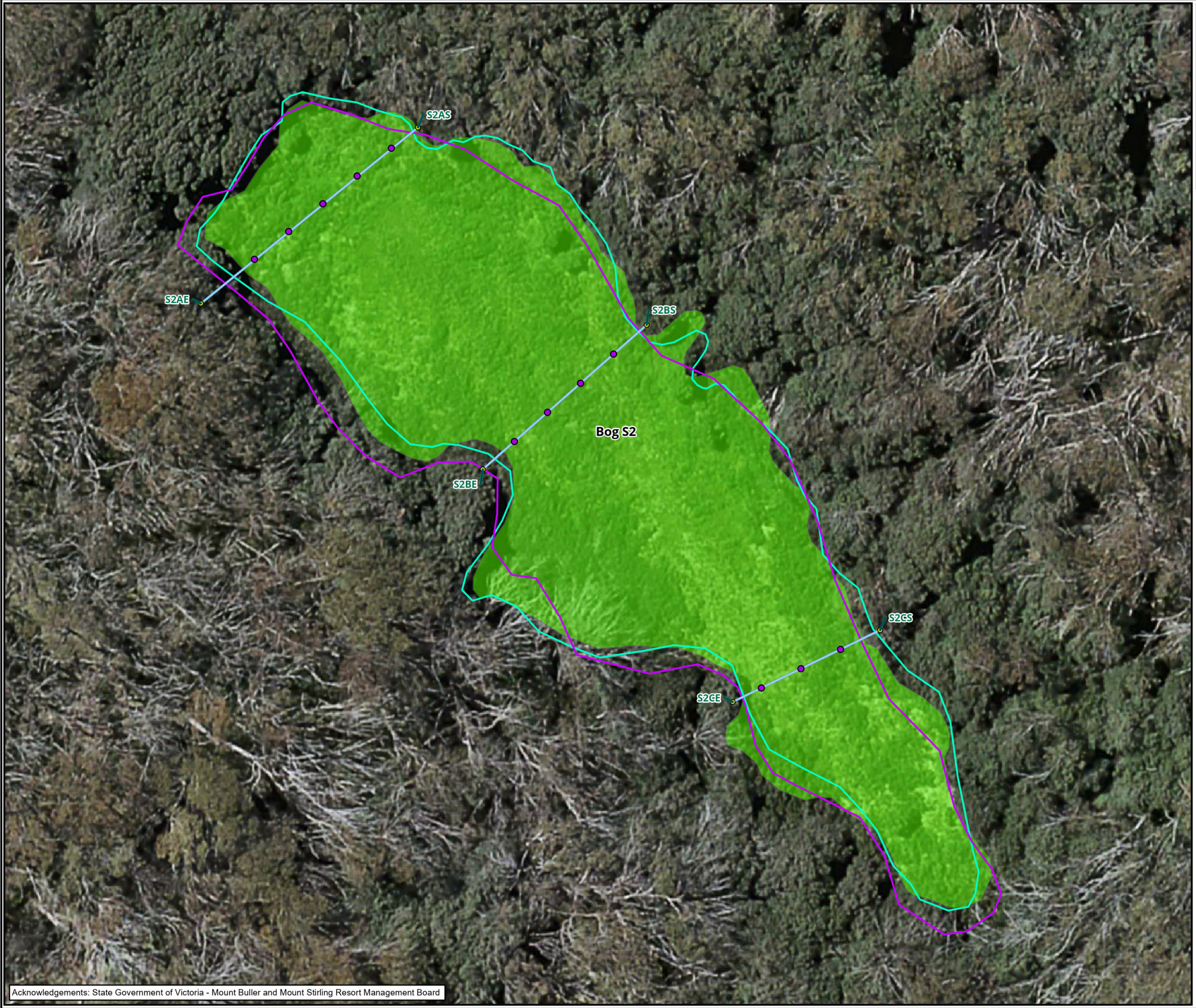

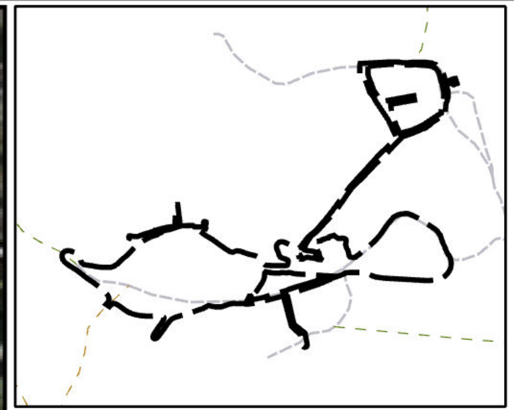

Legend

- Transects
- Quadrats
- Photo points
- Control site (2020)
- Baseline year 1
- Baseline year 2

Figure 4m: Bog S2 (control site)

0 3 6 9 12 15

Metres

Scale 1:320 @ A3

Coordinate System:

PCS: GDA 1994 MGA Zone 55

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Date: 15 April 2020,

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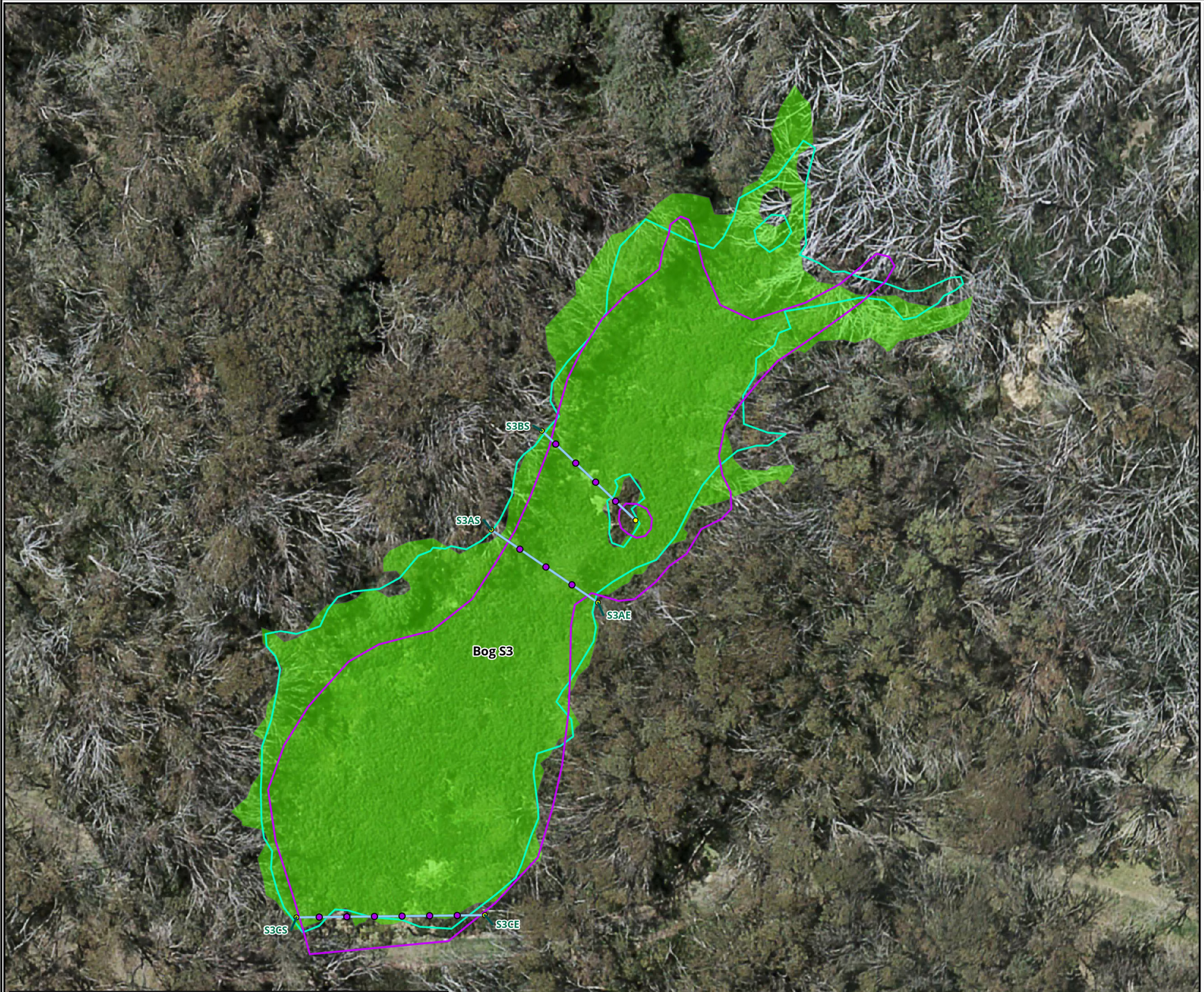
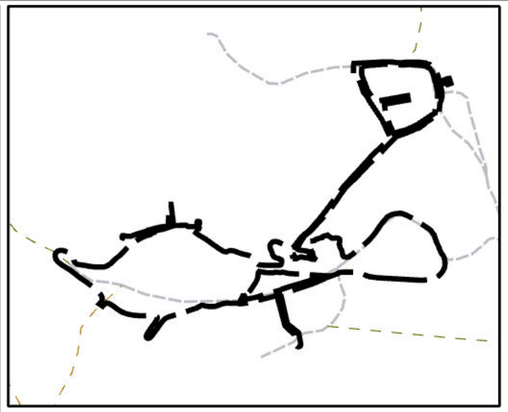


Acknowledgements: State Government of Victoria - Mount Buller and Mount Stirling Resort Management Board



Legend

- Transects
- Quadrats
- Photo points
- Control site (2020)
- Baseline year 1
- Baseline year 2

Figure 4n: Bog S3 (control site)

0 4.5 9 13.5 18 22.5

Metres

Scale 1:450 @ A3

Coordinate System:

PCS: GDA 1994 MGA Zone 55

N

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Matter: 26702

Date: 15 April 2020,

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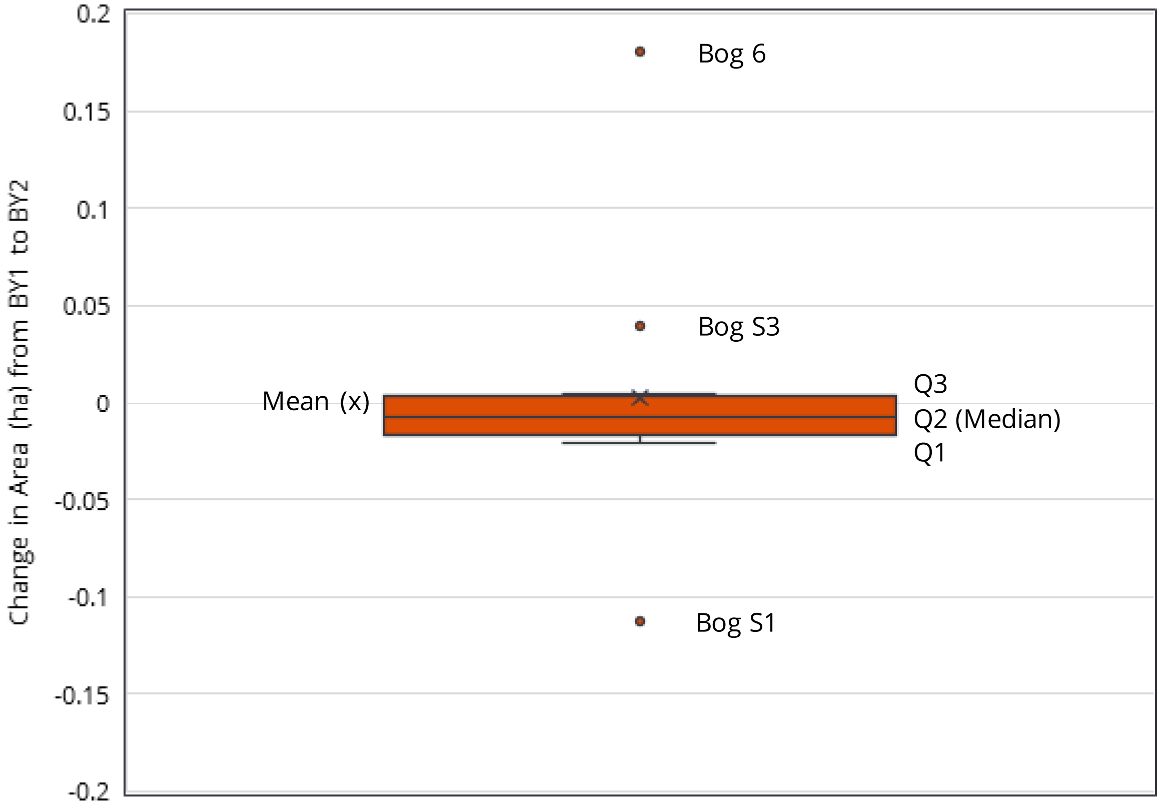

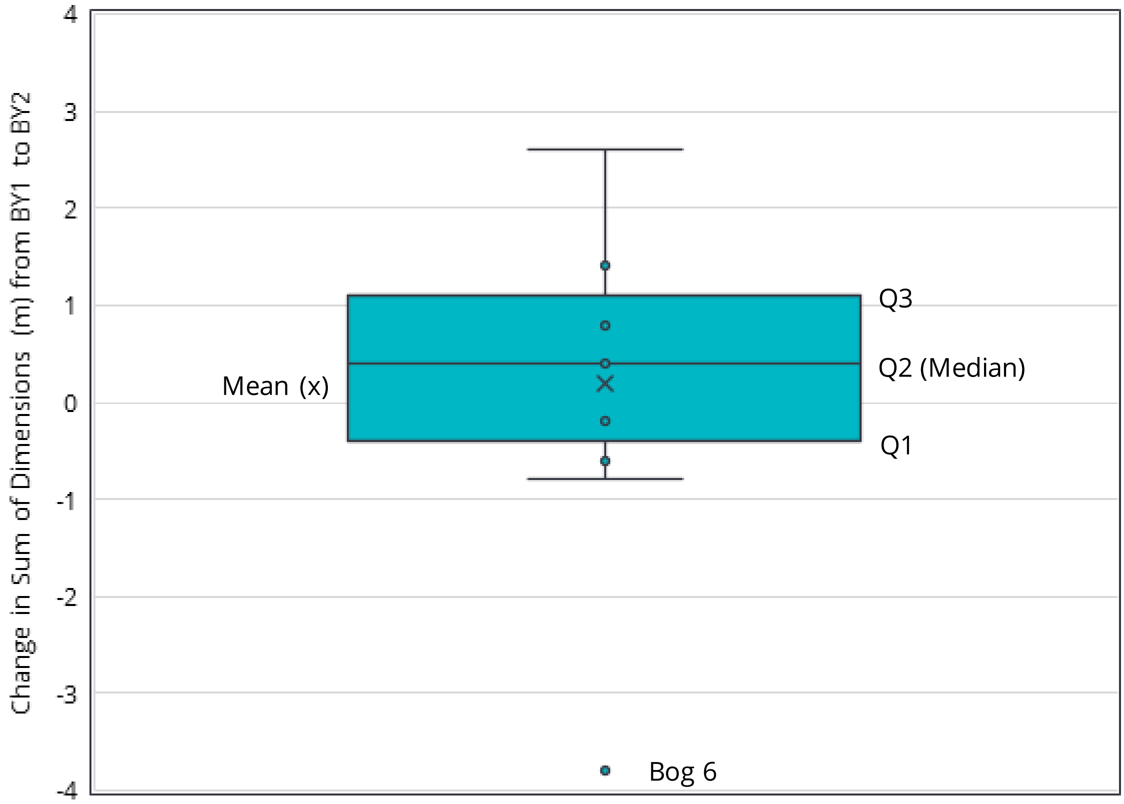

Figure 5 Box plots showing the change in area and dimensions of Alpine Bogs from BY1 to BY2

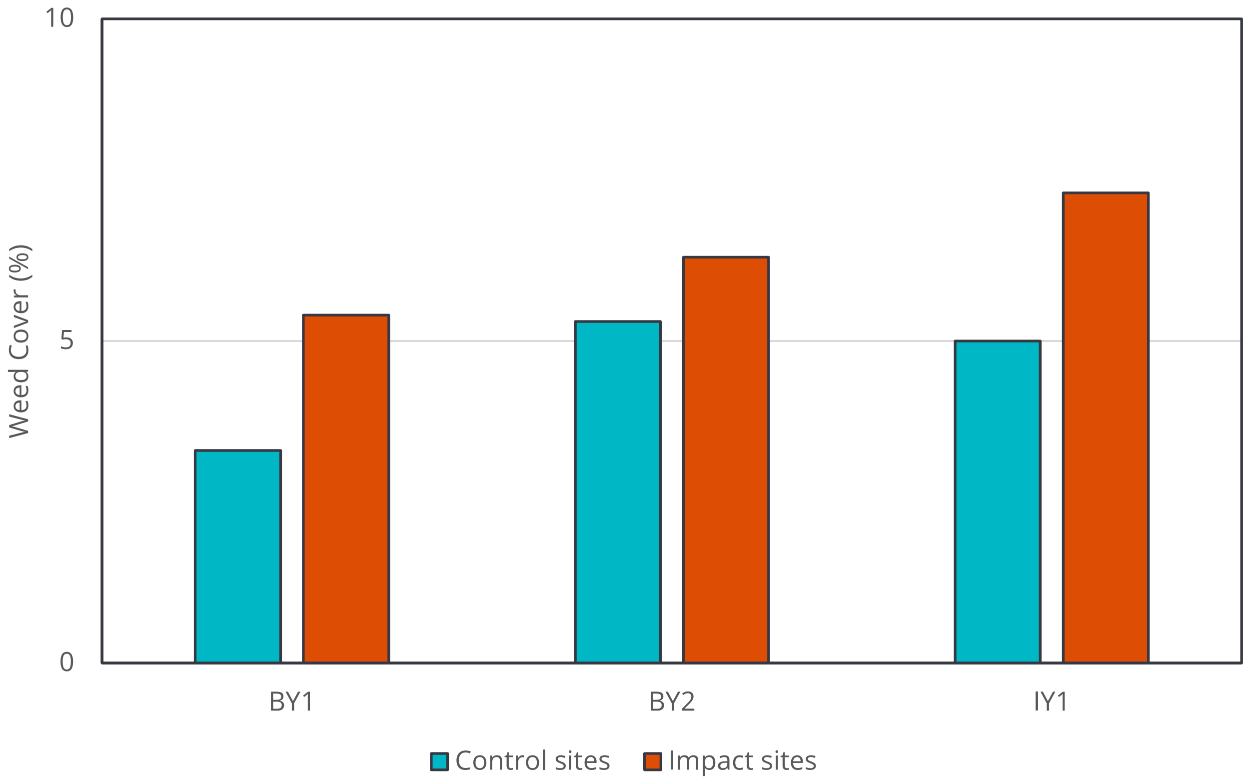

Figure 6 Percentage weed cover at impact and control sites from BY1 to IY1

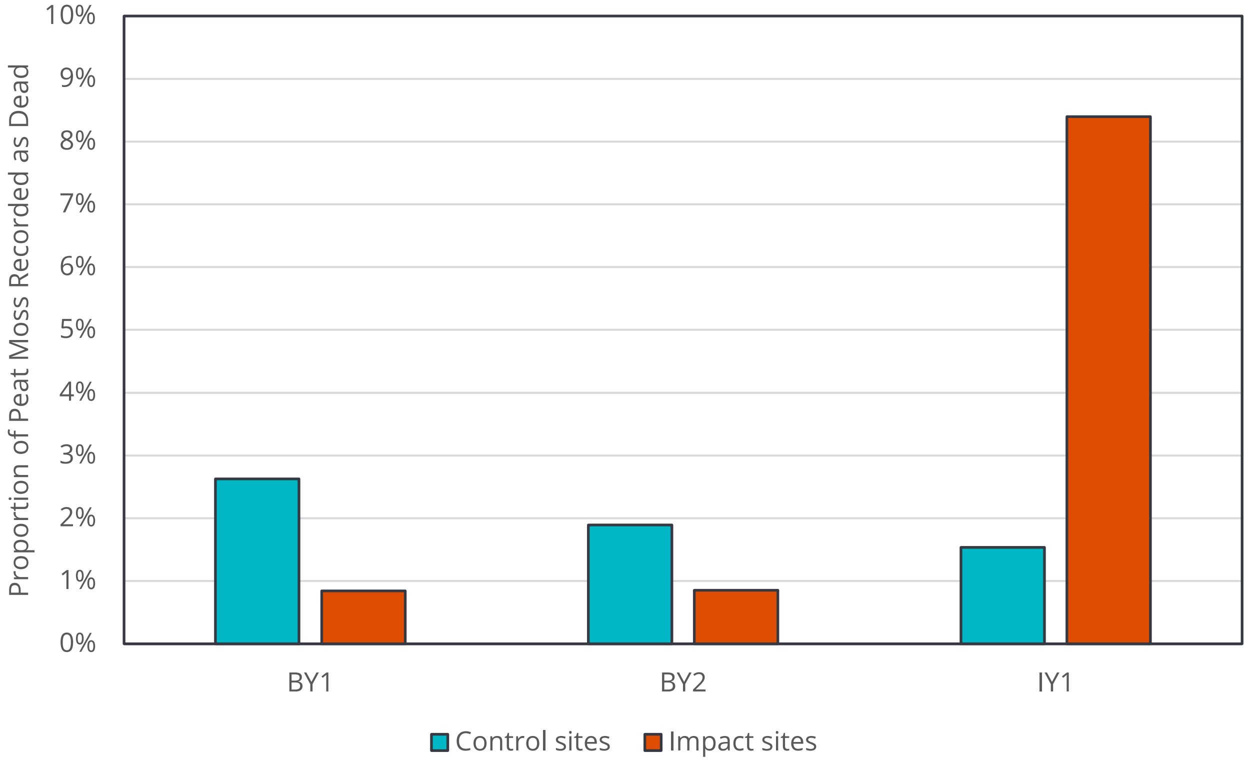

Figure 7 Proportion of Peat Moss recorded as dead at control and impact sites

Photos

Photo 1 Source of sediment at the base of the dam embankment and upslope of Alpine Bogs.

Photo 2 Snow Gums killed by the 2006-2007 bushfire at the northern half of Bog 6.

Photo 3 Damage caused by Sambar Deer at the northern half of Bog 6.

Photo 4 Sedimentation and weed proliferation along Transect 6C.

Photo 5 **Aqueduct between Bog 11.2 (right) and Bog 12 (left), facing east (BY1; 27 January 2018, before sedimentation).**

Photo 6 **Aqueduct between Bog 11.2 (right) and Bog 12 (left), facing east (IY1; 6 February 2020, after sedimentation).**

Photo 7 Sediment burying Alpine Bog vegetation at the south-western extent of Bog 6.

Photo 8 Impact of deer on Bog 4.1/5/7, near Transect 5A.

Photo 9 Impact of deer on Bog 11.1, between Transects 11.1B and 11.1C.

Photo 10 Sword Rush infestation near the aqueduct at Bog 4.1/5/7.

Photo 11 Drying soils at the eastern end of Bog 1.

Photo 12 Location of water treatment hut and discharge pipe upslope of Bog 1 (right).

Photo 13 Drying of the north-eastern arm of Bog 4.1/5/7.

Photo 14 Haulage road that may be the source of localised sedimentation in Bogs 1 and 2.

Photo 15 Soft Rush infestation on the western edge of Bog 3.

Photo 16 Blackberry infestation in the middle of Bog S1.

Appendices

Appendix 1 Flora species lists

The following status codes are used in this Appendix:

Code	Meaning	Notes
National significance (EPBC Act)		
CR	Critically endangered	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)
EN	Endangered	
VU	Vulnerable	
State significance (FFG Act and AL)		
L	Listed as threatened	Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act)
P	Protected species (public land only)	
x	Extinct	DELWP's Advisory List (AL) of Rare or Threatened Plants in Victoria (DEPI 2014)
e	Endangered	
v	Vulnerable	
r	Rare	
Noxious weed status (CaLP Act)		
SP	State prohibited species	Victorian *Catchment and Land Protection Act 1994* (CaLP Act) Goulburn Broken/North East Catchment Management Authorities
RP	Regionally prohibited species	
RC	Regionally controlled species	
R	Restricted species	
Other		
#	Native species outside its natural range	Assessed using VBA (DELWP 2019) and VicFlora (RBGV 2020)
^	Bog-dependent species	Refer to Diagnostic Key to Alpine Bogs (Appendix 2)

A2.1 Flora species list for all Alpine Bogs

Status	Scientific Name	Common Name
Indigenous species		
	Acaena novae-zelandiae	Bidgee-widgee
r P	*Aciphylla glacialis*	Snow Aciphyll
r P	*Acrothamnus montanus*	Snow Beard-heath
	Andreaea spp.	Lantern Moss
	Agrostis parviflora	Hair Bent
	Anthosachne scabra s.s.	Common Wheat-grass
P	*Asperula conferta*	Common Woodruff
P	*Asperula gunnii*	Mountain Woodruff
^	*Astelia alpina* var. *novae-hollandiae*	Silver Astelia
	Asterella spp.	Star Liverwort
^ P	*Baeckea gunniana*	Alpine Baeckea
^ r P	*Baeckea latifolia*	Subalpine Baeckea
^ P	*Baeckea utilis s.s.*	Mountain Baeckea
P	*Blechnum penna-marina* subsp. *alpina*	Alpine Water-fern
P	*Brachyscome scapigera*	Tufted Daisy
	Brachythecium spp.	Feather Moss
	Breutelia pendula	Mountain Breutelia
	Bryophyta spp.	Unidentified Moss
^	*Callistemon pityoides*	Alpine Bottlebrush
	Carex appressa	Tall Sedge
	Carex austroflaccida	Mountain Hook-sedge
	Carex breviculmis	Common Grass-sedge
^ r	*Carex jackiana*	Carpet Sedge
r P	*Celmisia latifolia*	Victorian Snow-daisy
P	*Celmisia* spp.	Snow Daisy
r P	*Celmisia tomentella*	Silver Snow-daisy
P	*Chiloglottis cornuta*	Green Bird-orchid
P	*Chiloglottis* spp.	Bird Orchid
	Clematis aristata	Mountain Clematis
P	*Coronidium monticola*	Mountain Everlasting
P	*Cotula alpina*	Alpine Cotula
r P	*Craspedia adenophora*	Sticky Billy-buttons
P	*Craspedia aurantia s.l.*	Orange/Green Billy-buttons
P	*Craspedia* spp.	Billy Buttons
	Ditrichum spp.	Ditrichum
^	*Empodisma minus*	Spreading Rope-rush
^ P	*Epacris paludosa*	Swamp Heath
	Epilobium billardiereanum subsp. *billardiereanum*	Smooth Willow-herb
	Epilobium billardiereanum subsp. *hydrophilum*	Robust Willow-herb
r	*Epilobium sarmentaceum*	Mountain Willow-herb
	Epilobium spp.	Willow Herb
	Eucalyptus pauciflora	Snow Gum
P	*Euchiton involucratus s.s.*	Star Cudweed

Status	Scientific Name	Common Name
P	*Euchiton sphaericus*	Annual Cudweed
P	*Euchiton* spp.	Cudweed
k	*Gentianella cunninghamii* subsp. *major*	Tall Snow-gentian
r	*Gentianella muelleriana* subsp. *willisiana*	Mount Buller Snow-gentian
k	*Geranium potentilloides* var. 1	Soft Crane's-bill
k	*Geranium* sp. 7	Alpine Swamp Crane's-bill
	Gonocarpus micranthus	Creeping Raspwort
	Gonocarpus montanus	Mat Raspwort
	Gonocarpus tetragynus	Common Raspwort
	Goodenia hederacea	Ivy Goodenia
P	*Grevillea australis*	Alpine Grevillea
^	*Hierochloe redolens*	Sweet Holy-grass
	Hovea montana	Alpine Rusty-pods
r P	*Huperzia australiana*	Fir Clubmoss
	Hydrocotyle hirta	Hairy Pennywort
	Hypericum japonicum	Matted St John's Wort
	Hypnodendron spp.	Palm Moss
	Isolepis aucklandica	New Zealand Club-sedge
	Isolepis habra	Wispy Club-sedge
r	*Isolepis montivaga*	Fog Club-sedge
	Isolepis spp.	Club Sedge
	Isolepis subtilissima	Mountain Club-sedge
P	*Lagenophora montana*	Mountain Bottle-daisy
P	*Lagenophora stipitata*	Common Bottle-daisy
	Leionema phylicifolium	Alpine Leionema
	Leptospermum grandifolium	Mountain Tea-tree
	Libertia pulchella	Pretty Grass-flag
	Luzula modesta	Southern Woodrush
P	*Lycopodium fastigiatum*	Mountain Clubmoss
r P	*Lycopodium scariosum*	Spreading Clubmoss
	Marchantiales spp.	Unidentified Liverwort
	Melicytus sp. aff. *dentatus* (Snowfields variant)	Alpine Shrub-violet
	Mentha laxiflora	Forest Mint
P	*Microseris lanceolata*	Alpine Yam-daisy
^ P	*Olearia algida*	Mountain Daisy-bush
r P	*Olearia phlogopappa* subsp. *flavescens*	Dusty Daisy-bush
	Oreobolus distichus	Fan Tuft-rush
	Oreomyrrhis eriopoda	Australian Caraway
	Orites lancifolius	Alpine Orites
P	*Ozothamnus cupressoides*	Kerosene Bush
r	*Phebalium squamulosum* subsp. *alpinum*	Alpine Phebalium
	Philonotis spp.	Apple Moss
P	*Picris angustifolia* subsp. *merxmuelleri*	Highland Picris
	Pimelea alpina	Alpine Rice-flower
	Pimelea ligustrina	Tall Rice-flower

Status	Scientific Name	Common Name
	Pimelea spp.	Rice Flower
	Plantago euryphylla	Broad Plantain
	Poa costiniana	Bog Snow-grass
	Poa ensiformis	Sword Tussock-grass
	Poa fawcettiae	Horny Snow-grass
	Poa hiemata	Soft Snow-grass
	Poa hothamensis	Ledge Grass
	Poaceae spp.	Unidentified Grass
	Podocarpus lawrencei	Mountain Plum-pine
P	*Podolepis robusta*	Alpine Podolepis
P	*Podolepis* spp.	Podolepis
	Podolobium alpestre	Alpine Podolobium
P	*Polystichum proliferum*	Mother Shield-fern
	Polytrichum spp.	Haircap
P	*Prasophyllum* spp.	Leek Orchid
	Ranunculus graniticola	Granite Buttercup
r	*Ranunculus gunnianus*	Gunn's Alpine Buttercup
	Ranunculus lappaceus	Australian Buttercup
	Ranunculus pimpinellifolius	Bog Buttercup
	Ranunculus spp.	Buttercup
^ P	*Richea continentis*	Candle Heath
	Rubus parvifolius	Small-leaf Bramble
	Rumex brownii	Slender Dock
	Rytidosperma penicillatum	Weeping Wallaby-grass
	Schoenus calyptratus	Alpine Bog-sedge
r	*Scleranthus brockiei*	Brock Knawel
P	*Senecio gunnii*	Mountain Fireweed
r P	*Senecio pinnatifolius* var. *alpinus*	Snowfield Groundsel
^ P	*Sphagnum cristatum*	Peat Moss
	Stellaria pungens	Prickly Starwort
P	*Stylidium armeria* subsp. *armeria*	Common Triggerplant
r P	*Stylidium montanum*	Alpine Triggerplant
P	*Stylidium* spp.	Trigger Plant
	Tasmannia xerophila subsp. xerophila	Alpine Pepper
	Tayloria spp.	Dung Moss
P	*Thelymitra* spp.	Sun Orchid
	Veronica serpyllifolia	Thyme Speedwell
	Viola betonicifolia	Showy Violet
	Wahlenbergia ceracea	Waxy Bluebell
	Wahlenbergia gloriosa	Royal Bluebell
P	*Xerochrysum subundulatum*	Orange Everlasting
Introduced species		
	Acetosella vulgaris	Sheep Sorrel
	Achillea millefolium	Milfoil
	Agrostis capillaris	Brown-top Bent

Status	Scientific Name	Common Name
	Anthoxanthum odoratum	Sweet Vernal-grass
	Cerastium glomeratum s.s.	Sticky Mouse-ear Chickweed
	Cerastium spp.	Mouse-ear Chickweed
	Cerastium vulgare	Common Mouse-ear Chickweed
R/RC	*Cirsium vulgare*	Spear Thistle
	Dactylis glomerata	Cocksfoot
	Erythranthe moschata	Musk Monkey-flower
	Festuca rubra s.s.	Creeping Fescue
	Holcus lanatus	Yorkshire Fog
	Hypochaeris radicata	Flatweed
	Juncus articulatus subsp. *articulatus*	Jointed Rush
	Juncus effusus subsp. *effusus*	Soft Rush
	Juncus ensifolius	Sword Rush
	Malus pumila	Apple
	Phleum pratense	Timothy Grass
	Ranunculus repens	Creeping Buttercup
RC/RC	*Rubus anglocandicans*	Blackberry
	Sonchus asper	Rough Sow-thistle
	Taraxacum officinale spp. agg.	Garden Dandelion
	Trifolium repens var. *repens*	White Clover
	Viola arvensis	Field Pansy

A2.2 Bog-dependent flora species list

Status	Scientific Name	Common Name
^	*Astelia alpina var. novae-hollandiae*	Silver Astelia
^ P	*Baeckea gunniana*	Alpine Baeckea
^ r P	*Baeckea latifolia*	Subalpine Baeckea
^ P	*Baeckea utilis s.s.*	Mountain Baeckea
^	*Callistemon pityoides*	Alpine Bottlebrush
^ r	*Carex jackiana*	Carpet Sedge
^	*Empodisma minus*	Spreading Rope-rush
^ P	*Epacris paludosa*	Swamp Heath
^	*Hierochloe redolens*	Sweet Holy-grass
^ P	*Olearia algida*	Mountain Daisy-bush
^ P	*Richea continentis*	Candle Heath
^ P	*Sphagnum cristatum*	Peat Moss

Appendix 2 Diagnostic Key to Alpine Bogs

This diagnostic key has been reproduced from the key to the EPBC Act listed ecological community (ASBAF), produced by the Commonwealth of Australia (2013). The key appeared in early draft versions of the National Recovery Plan but does not appear in the final version (Commonwealth of Australia 2015; A. Tolsma, ARI, pers. comm., February 2019).

Key to the listed Alpine *Sphagnum* bogs and Associated Fens ecological community on the Australian mainland

The listed ecological community comprises two main components, *Sphagnum* bogs and their associated fens. Fens, or fen pools, are species-poor communities typically linked to bogs. They are dominated by sedges and frequently inundated. The bogs which surround or link to fens generally display greater species diversity, and it is this diversity which in part guides the following key.

1. Are you above 1000m in elevation and in the Australian Alps bioregion?
Yes – go to 2 | No – Unlikely to be the listed community

2. Is live, hummock-forming *Sphagnum* present and abundant, or if burnt[1], can abundant pre-fire *Sphagnum* be inferred from burnt remnants?
Yes – Is the listed community | No, *Sphagnum* is minor or absent – go to 3

3. Does the site have a peat substrate evident?
Yes, or unsure – go to 4 | No – Unlikely to be the listed community

4. Is *Sphagnum* present?
Yes – go to 5 | No – go to 6

5. Is most of the non-*Sphagnum* vegetation cover composed of two or more of the diagnostic species listed below?
Yes – Is the listed community. | No – Not the listed community, but may be transitional or a degraded version[2]

6. Is most of the vegetation cover composed of 3 or more of the diagnostic species?
Yes – Is the listed community, possibly degraded. | No – Not the listed community, but may be transitional or a degraded version[2]

<u>Diagnostic species other than *Sphagnum*:</u>

- *Empodisma minus*
- *Epacris* spp (usually *E. paludosa, E. glacialis, E. celata or E. breviflora*)
- *Richea* spp (*R. continentis or R. victoriana*)
- *Baeckea* spp (usually *B. gunniana, B. latifolia or B.utilis*)
- *Astelia alpina*
- *Carpha nivicola*
- *Baloskion australe*
- *Carex gaudichaudiana*
- *Callistemon pityoides*
- *Hakea microcarpa*
- *Carex jackiana*[3]
- *Hierochloe redolens*[3]
- *Olearia algida*[3]

[1] If a site has been recently and severely burnt, *Sphagnum* and other key diagnostic species may be temporarily absent (live hummock-forming *Sphagnum* would normally comprise at least 20-30% cover).In this case, assessment of the site for the listed community should be delayed for at least 24 months. However, the presence of burnt hummocks over peat indicates the community is present.

[2] Clarification: no need to refer.

[3] This key originally appeared in a draft version of the National Recovery Plan for the Alpine Sphagnum Bogs and Associated Fens. The key has been left unchanged except for the addition of these three species and this footnote. These species have been added by Biosis for the purposes of monitoring Alpine Bogs at Mount Buller and Mount Stirling, Victoria. At these locations, Carex jackiana, Hierochloe redolens and Olearia algida are restricted to Alpine Bogs and are therefore amongst the diagnostic species.

Appendix 3 Photo points

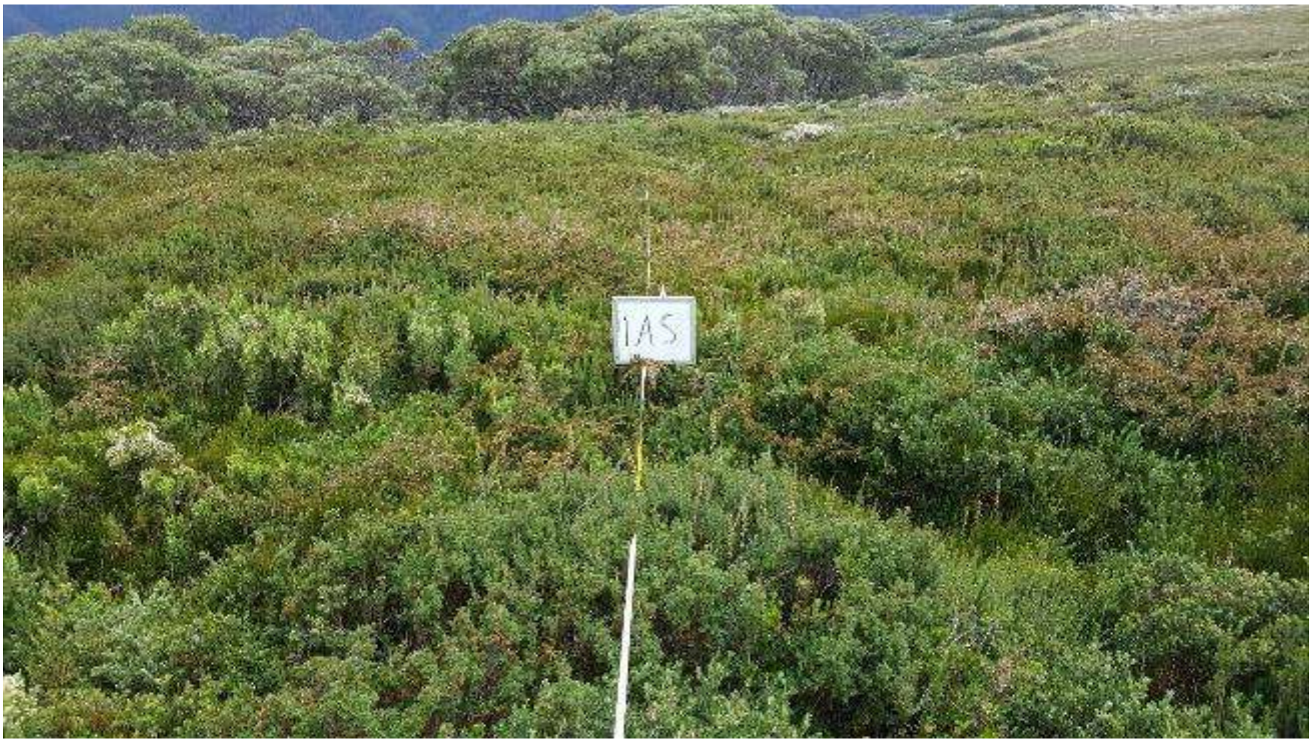

Photo Point 1AS, Bog 1 (Control), Baseline Year 1, 9 February 2018

Photo Point 1AS, Bog 1 (Control), Baseline Year 2, 31 January 2019

Photo Point 1AS, Bog 1 (Control), Impact Year 1, 31 January 2020

Photo Point 1AE, Bog 1 (Control), Baseline Year 1, 9 February 2018

Photo Point 1AE, Bog 1 (Control), Baseline Year 2, 31 January 2019

Photo Point 1AE, Bog 1 (Control), Impact Year 1, 31 January 2020

Photo Point 1BS, Bog 1 (Control), Baseline Year 1, 9 February 2018

Photo Point 1BS, Bog 1 (Control), Baseline Year 2, 31 January 2019

Photo Point 1BS, Bog 1 (Control), Impact Year 1, 31 January 2020

Photo Point 1BE, Bog 1 (Control), Baseline Year 1, 9 February 2018

Photo Point 1BE, Bog 1 (Control), Baseline Year 2, 31 January 2019

Photo Point 1BE, Bog 1 (Control), Impact Year 1, 31 January 2020

Photo Point 1CS, Bog 1 (Control), Baseline Year 1, 9 February 2018

Photo Point 1CS, Bog 1 (Control), Baseline Year 2, 31 January 2019

Photo Point 1CS, Bog 1 (Control), Impact Year 1, 31 January 2020

Photo Point 1CE, Bog 1 (Control), Baseline Year 1, 9 February 2018

Photo Point 1CE, Bog 1 (Control), Baseline Year 2, 31 January 2019

Photo Point 1CE, Bog 1 (Control), Impact Year 1, 31 January 2020

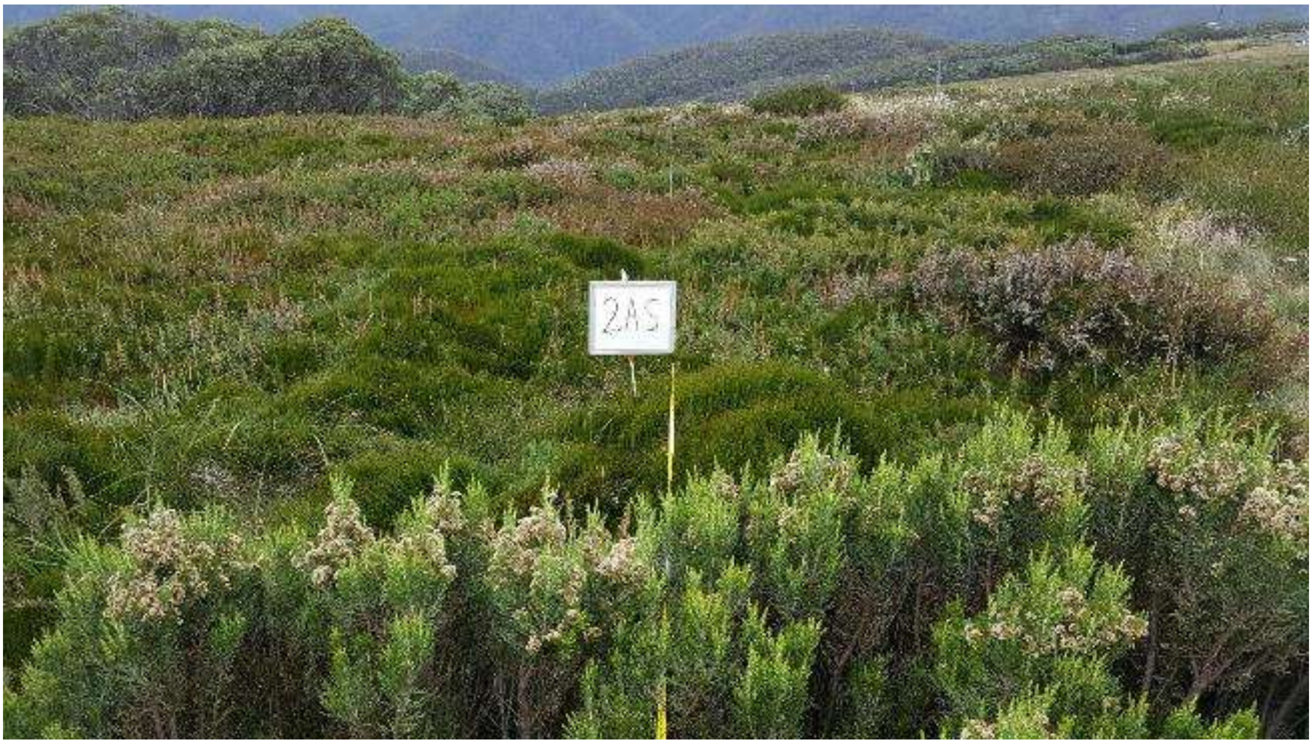

Photo Point 2AS, Bog 2 (Control), Baseline Year 1, 9 February 2018

Photo Point 2AS, Bog 2 (Control), Baseline Year 2, 31 January 2019

Photo Point 2AS, Bog 2 (Control), Impact Year 1, 3 February 2020

Photo Point 2AE, Bog 2 (Control), Baseline Year 1, 9 February 2018

Photo Point 2AE, Bog 2 (Control), Baseline Year 2, 31 January 2019

Photo Point 2AE, Bog 2 (Control), Impact Year 1, 3 February 2020

Photo Point 2BS, Bog 2 (Control), Baseline Year 1, 9 February 2018

Photo Point 2BS, Bog 2 (Control), Baseline Year 2, 1 February 2019

Photo Point 2BS, Bog 2 (Control), Impact Year 1, 3 February 2020

Photo Point 2BE, Bog 2 (Control), Baseline Year 1, 9 February 2018

Photo Point 2BE, Bog 2 (Control), Baseline Year 2, 1 February 2019

Photo Point 2BE, Bog 2 (Control), Impact Year 1, 3 February 2020

Photo Point 2CS, Bog 2 (Control), Baseline Year 1, 9 February 2018

Photo Point 2CS, Bog 2 (Control), Baseline Year 2, 1 February 2019

Photo Point 2CS, Bog 2 (Control), Impact Year 1, 3 February 2020

Photo Point 2CE, Bog 2 (Control), Baseline Year 1, 9 February 2018

Photo Point 2CE, Bog 2 (Control), Baseline Year 2, 1 February 2019

Photo Point 2CE, Bog 2 (Control), Impact Year 1, 3 February 2020

Photo Point 4.1AS, Bog 4.1/5/7 (Control), Baseline Year 1, 8 February 2018

Photo Point 4.1AS, Bog 4.1/5/7 (Control), Baseline Year 2, 14 February 2019

Photo Point 4.1AS, Bog 4.1/5/7 (Control), Impact Year 1, 4 February 2020

Photo Point 4.1AE, Bog 4.1/5/7 (Control), Baseline Year 1, 8 February 2018

Photo Point 4.1AE, Bog 4.1/5/7 (Control), Baseline Year 2, 14 February 2019

Photo Point 4.1AE, Bog 4.1/5/7 (Control), Impact Year 1, 4 February 2020

Photo Point 4.1BS, Bog 4.1/5/7 (Control), Baseline Year 1, 8 February 2018

Photo Point 4.1BS, Bog 4.1/5/7 (Control), Baseline Year 2, 14 February 2019

Photo Point 4.1BS, Bog 4.1/5/7 (Control), Impact Year 1, 4 February 2020

Photo Point 4.1BE, Bog 4.1/5/7 (Control), Baseline Year 1, 8 February 2018

Photo Point 4.1BE, Bog 4.1/5/7 (Control), Baseline Year 2, 14 February 2019

Photo Point 4.1BE, Bog 4.1/5/7 (Control), Impact Year 1, 4 February 2020

Photo Point 4.1CS, Bog 4.1/5/7 (Control), Baseline Year 1, 8 February 2018

Photo Point 4.1CS, Bog 4.1/5/7 (Control), Baseline Year 2, 14 February 2019

Photo Point 4.1CS, Bog 4.1/5/7 (Control), Impact Year 1, 5 February 2020

Photo Point 4.1CE, Bog 4.1/5/7 (Control), Baseline Year 1, 8 February 2018

Photo Point 4.1CE, Bog 4.1/5/7 (Control), Baseline Year 2, 14 February 2019

Photo Point 4.1CE, Bog 4.1/5/7 (Control), Impact Year 1, 5 February 2020

Photo Point 4.2AS, Bog 4.2 (Impact), Baseline Year 1, 30 January 2018

Photo Point 4.2AS, Bog 4.2 (Impact), Baseline Year 2, 1 February 2019

Photo Point 4.2AS, Bog 4.2 (Impact), Impact Year 1, 5 February 2020

Photo Point 4.2AE, Bog 4.2 (Impact), Baseline Year 1, 30 January 2018

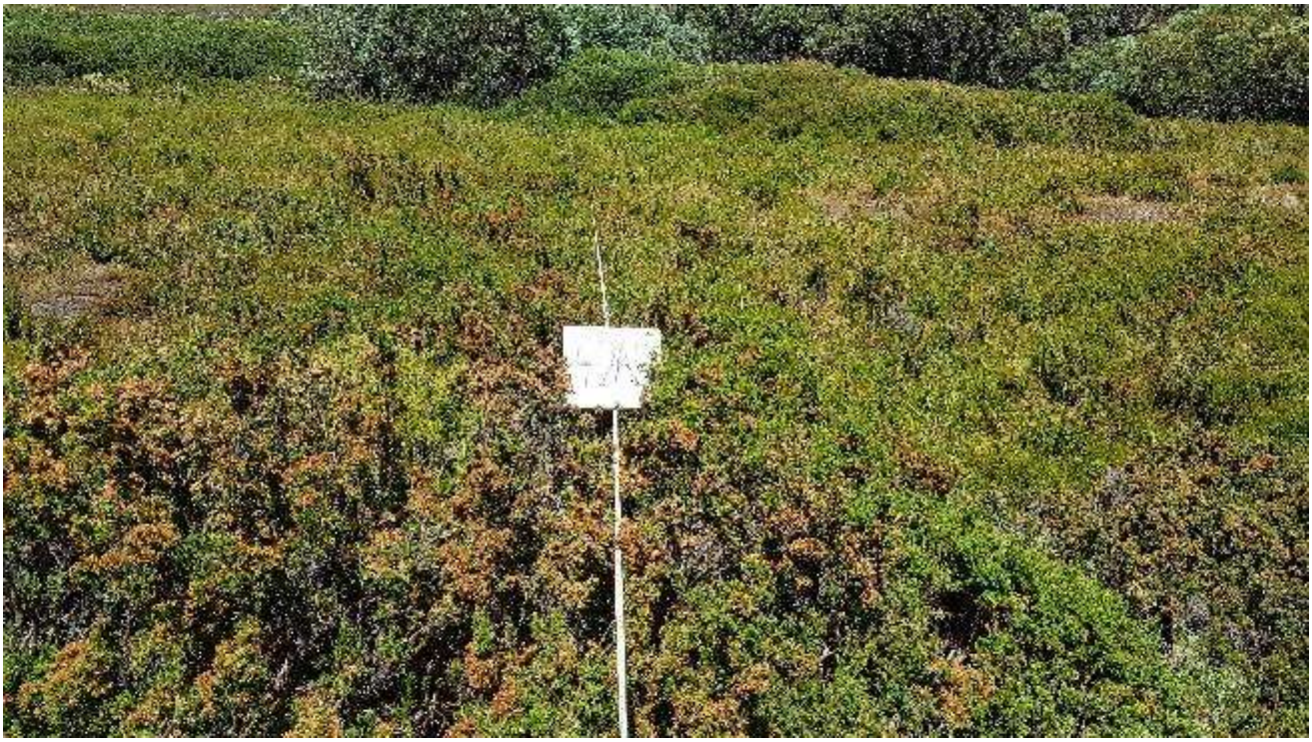

Photo Point 4.2AE, Bog 4.2 (Impact), Baseline Year 2, 1 February 2019

Photo Point 4.2AE, Bog 4.2 (Impact), Impact Year 1, 5 February 2020

Photo Point 4.2BS, Bog 4.2 (Impact), Baseline Year 1, 30 January 2018

Photo Point 4.2BS, Bog 4.2 (Impact), Baseline Year 2, 1 February 2019

Photo Point 4.2BS, Bog 4.2 (Impact), Impact Year 1, 4 February 2020

Photo Point 4.2BE, Bog 4.2 (Impact), Baseline Year 1, 30 January 2018

Photo Point 4.2BE, Bog 4.2 (Impact), Baseline Year 2, 1 February 2019

Photo Point 4.2BE, Bog 4.2 (Impact), Impact Year 1, 4 February 2020

Photo Point 4.2CS, Bog 4.2 (Impact), Baseline Year 1, 31 January 2018

Photo Point 4.2CS, Bog 4.2 (Impact), Baseline Year 2, 1 February 2019

Photo Point 4.2CS, Bog 4.2 (Impact), Impact Year 1, 4 February 2020

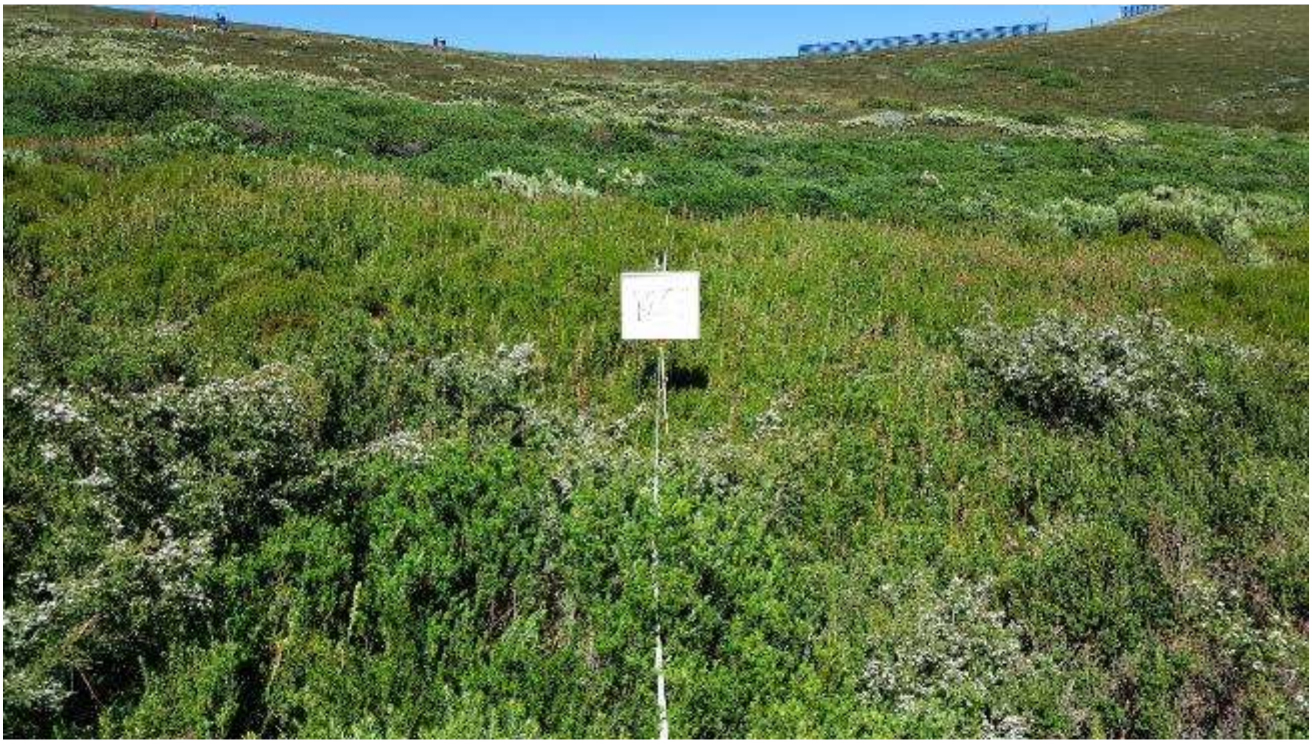

Photo Point 4.2CE, Bog 4.2 (Impact), Baseline Year 1, 31 January 2018

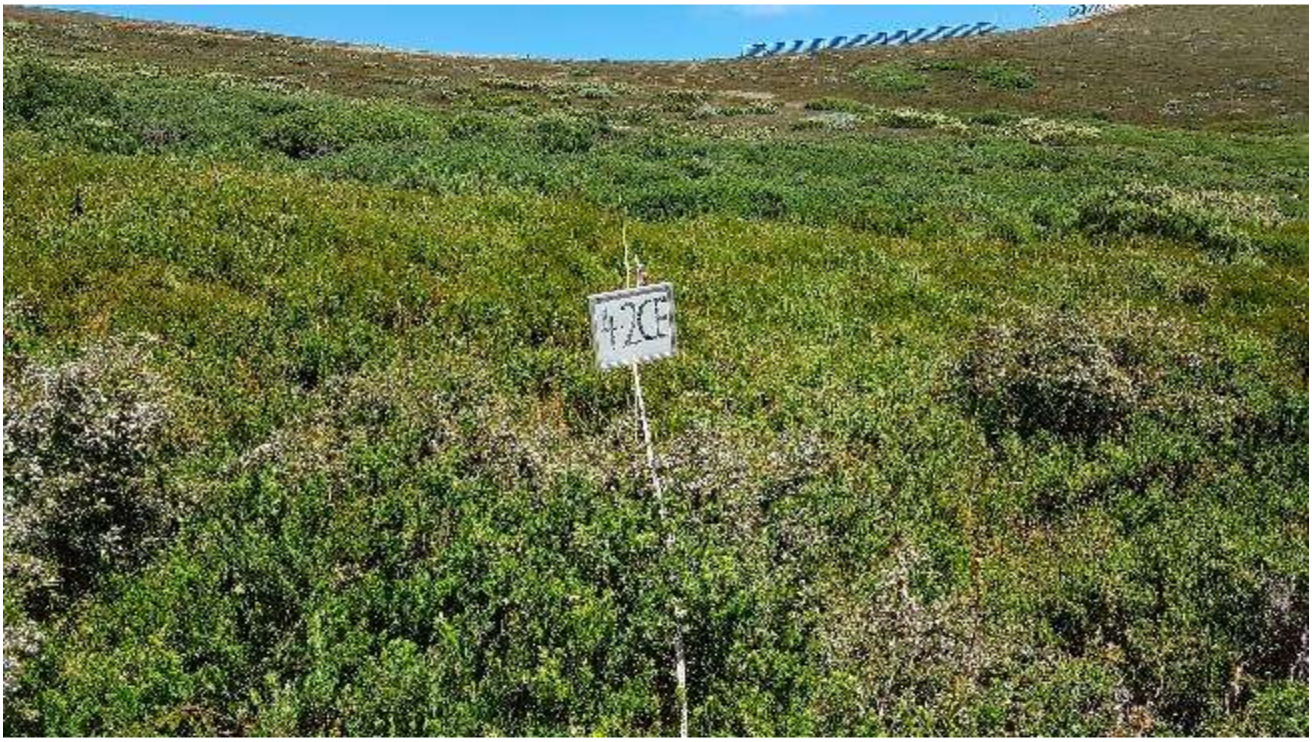

Photo Point 4.2CE, Bog 4.2 (Impact), Baseline Year 2, 1 February 2019

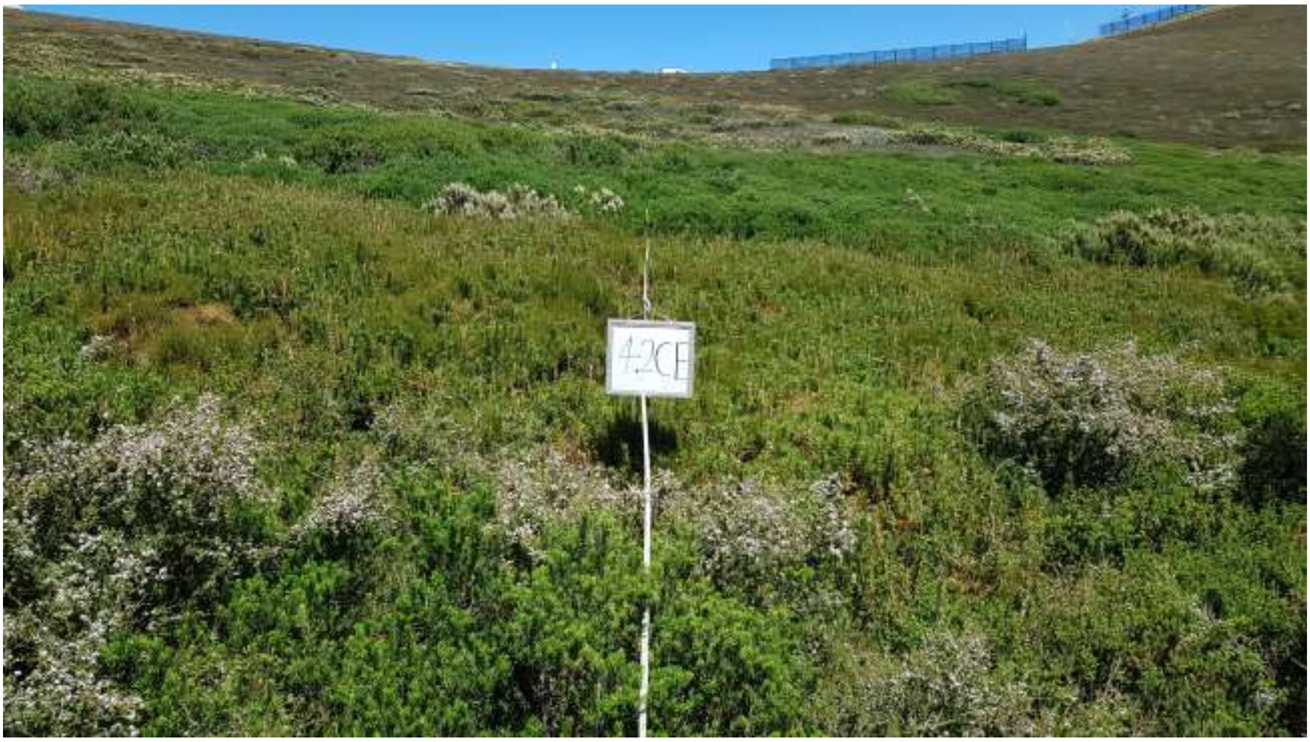

Photo Point 4.2CE, Bog 4.2 (Impact), Impact Year 1, 4 February 2020

Photo Point 4.2DS, Bog 4.2 (Impact), Baseline Year 1, 31 January 2018

Photo Point 4.2DS, Bog 4.2 (Impact), Baseline Year 2, 1 February 2019

Photo Point 4.2DS, Bog 4.2 (Impact), Impact Year 1, 4 February 2020

Photo Point 4.2DE, Bog 4.2 (Impact), Baseline Year 1, 31 January 2018

Photo Point 4.2DE, Bog 4.2 (Impact), Baseline Year 2, 1 February 2019

Photo Point 4.2DE, Bog 4.2 (Impact), Impact Year 1, 4 February 2020

Photo Point 4.2ES, Bog 4.2 (Impact), Baseline Year 1, 31 January 2018

Photo Point 4.2ES, Bog 4.2 (Impact), Baseline Year 2, 1 February 2019

Photo Point 4.2ES, Bog 4.2 (Impact), Impact Year 1, 4 February 2020

Photo Point 4.2EE, Bog 4.2 (Impact), Baseline Year 1, 31 January 2018

Photo Point 4.2EE, Bog 4.2 (Impact), Baseline Year 2, 1 February 2019

Photo Point 4.2EE, Bog 4.2 (Impact), Impact Year 1, 4 February 2020

Photo Point 5AS, Bog 4.1/5/7 (Control), Baseline Year 1, 8 February 2018

Photo Point 5AS, Bog 4.1/5/7 (Control), Baseline Year 2, 14 February 2019

Photo Point 5AS, Bog 4.1/5/7 (Control), Impact Year 1, 6 February 2020

Photo Point 5AE, Bog 4.1/5/7 (Control), Baseline Year 1, 8 February 2018

Photo Point 5AE, Bog 4.1/5/7 (Control), Baseline Year 2, 14 February 2019

Photo Point 5AE, Bog 4.1/5/7 (Control), Impact Year 1, 6 February 2020

Photo Point 6AS, Bog 6 (Impact), Baseline Year 1, 31 January 2018

Photo Point 6AS, Bog 6 (Impact), Baseline Year 2, 1 February 2019

Photo Point 6AS, Bog 6 (Impact), Impact Year 1, 5 February 2020

Photo Point 6AE, Bog 6 (Impact), Baseline Year 1, 31 January 2018

Photo Point 6AE, Bog 6 (Impact), Baseline Year 2, 1 February 2019

Photo Point 6AE, Bog 6 (Impact), Impact Year 1, 5 February 2020

Photo Point 6BS, Bog 6 (Impact), Baseline Year 1, 31 January 2018

Photo Point 6BS, Bog 6 (Impact), Baseline Year 2, 14 February 2019

Photo Point 6BS, Bog 6 (Impact), Impact Year 1, 5 February 2020

Photo Point 6BE, Bog 6 (Impact), Baseline Year 1, 31 January 2018

Photo Point 6BE, Bog 6 (Impact), Baseline Year 2, 14 February 2019

Photo Point 6BE, Bog 6 (Impact), Impact Year 1, 5 February 2020

Photo Point 6CS, Bog 6 (Impact), Baseline Year 1, 1 February 2018

Photo Point 6CS, Bog 6 (Impact), Baseline Year 2, 11 February 2019

Photo Point 6CS, Bog 6 (Impact), Impact Year 1, 5 February 2020

Photo Point 6CE, Bog 6 (Impact), Baseline Year 1, 1 February 2018

Photo Point 6CE, Bog 6 (Impact), Baseline Year 2, 11 February 2019

Photo Point 6CE, Bog 6 (Impact), Impact Year 1, 5 February 2020

Photo Point 6DS, Bog 6 (Impact), Baseline Year 1, 1 February 2018

Photo Point 6DS, Bog 6 (Impact), Baseline Year 2, 11 February 2019

Photo Point 6DS, Bog 6 (Impact), Impact Year 1, 5 February 2020

Photo Point 6DE, Bog 6 (Impact), Baseline Year 1, 1 February 2018

Photo Point 6DE, Bog 6 (Impact), Baseline Year 2, 11 February 2019

Photo Point 6DE, Bog 6 (Impact), Impact Year 1, 5 February 2020

Photo Point 6ES, Bog 6 (Impact), Baseline Year 1, 1 February 2018

Photo Point 6ES, Bog 6 (Impact), Baseline Year 2, 11 February 2019

Photo Point 6ES, Bog 6 (Impact), Impact Year 1, 5 February 2020

Photo Point 6EE, Bog 6 (Impact), Baseline Year 1, 1 February 2018

Photo Point 6EE, Bog 6 (Impact), Baseline Year 2, 11 February 2019

Photo Point 6EE, Bog 6 (Impact), Impact Year 1, 5 February 2020

Photo Point 7AS, Bog 4.1/5/7 (Control), Baseline Year 1, 1 February 2018

Photo Point 7AS, Bog 4.1/5/7 (Control), Baseline Year 2, 11 February 2019

Photo Point 7AS, Bog 4.1/5/7 (Control), Impact Year 1, 5 February 2020

Photo Point 7AE, Bog 4.1/5/7 (Control), Baseline Year 1, 1 February 2018

Photo Point 7AE, Bog 4.1/5/7 (Control), Baseline Year 2, 11 February 2019

Photo Point 7AE, Bog 4.1/5/7 (Control), Impact Year 1, 5 February 2020

Photo Point 8AS, Bog 8/9/10 (Impact), Baseline Year 1, 26 January 2018

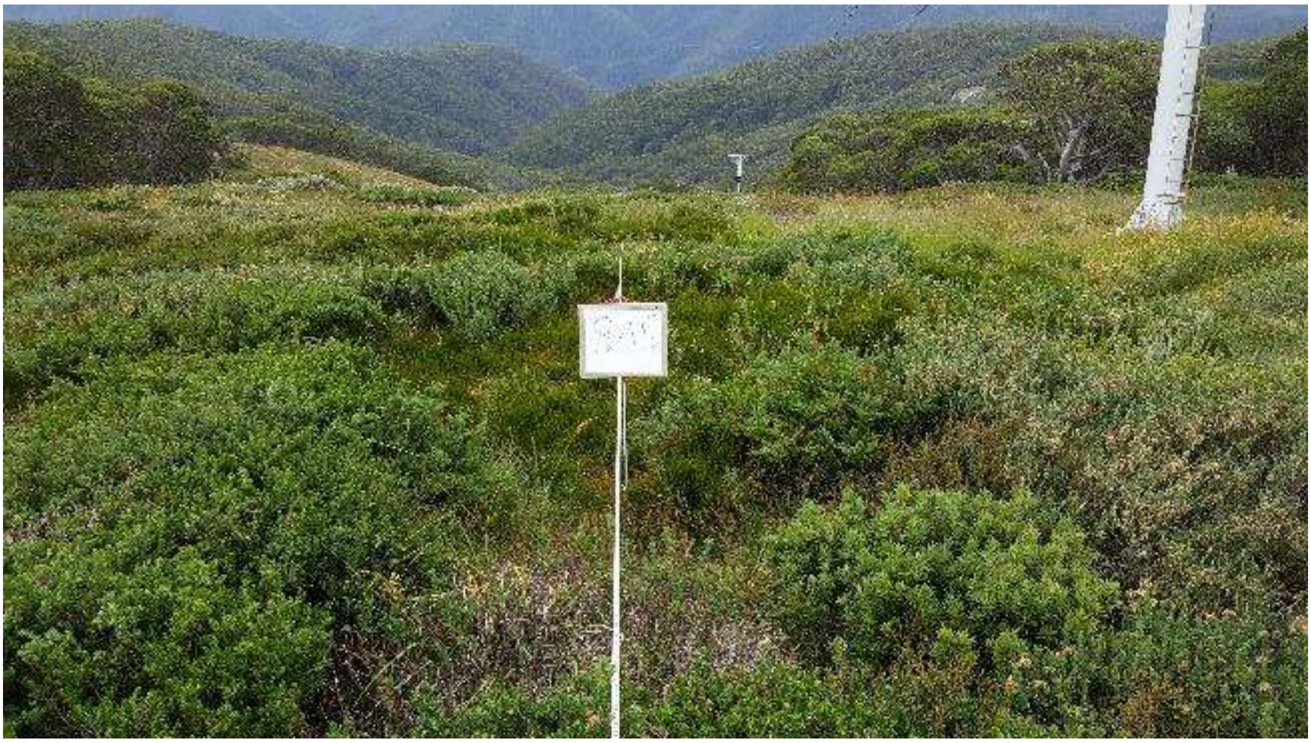

Photo Point 8AS, Bog 8/9/10 (Impact), Baseline Year 2, 29 January 2019

Photo Point 8AS, Bog 8/9/10 (Impact), Impact Year 1, 18 February 2020

Photo Point 8AE, Bog 8/9/10 (Impact), Baseline Year 1, 26 January 2018

Photo Point 8AE, Bog 8/9/10 (Impact), Baseline Year 2, 29 January 2019

Photo Point 8AE, Bog 8/9/10 (Impact), Impact Year 1, 18 February 2020

Photo Point 8BS, Bog 8/9/10 (Impact), Baseline Year 1, 26 January 2018

Photo Point 8BS, Bog 8/9/10 (Impact), Baseline Year 2, 29 January 2019

Photo Point 8BS, Bog 8/9/10 (Impact), Impact Year 1, 18 February 2020

Photo Point 8BE, Bog 8/9/10 (Impact), Baseline Year 1, 26 January 2018

Photo Point 8BE, Bog 8/9/10 (Impact), Baseline Year 2, 29 January 2019

Photo Point 8BE, Bog 8/9/10 (Impact), Impact Year 1, 18 February 2020

Photo Point 8CS, Bog 8/9/10 (Impact), Baseline Year 1, 26 January 2018

Photo Point 8CS, Bog 8/9/10 (Impact), Baseline Year 2, 30 January 2019

Photo Point 8CS, Bog 8/9/10 (Impact), Impact Year 1, 20 February 2020

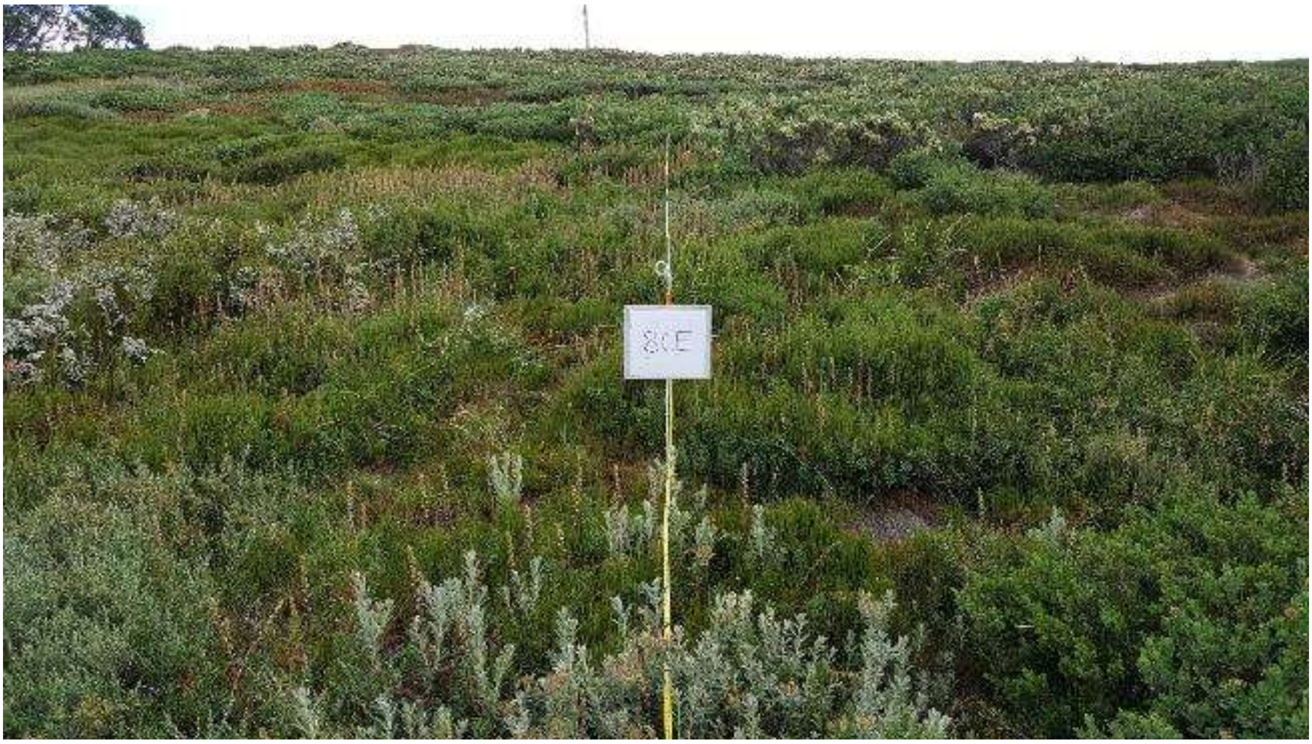

Photo Point 8CE, Bog 8/9/10 (Impact), Baseline Year 1, 26 January 2018

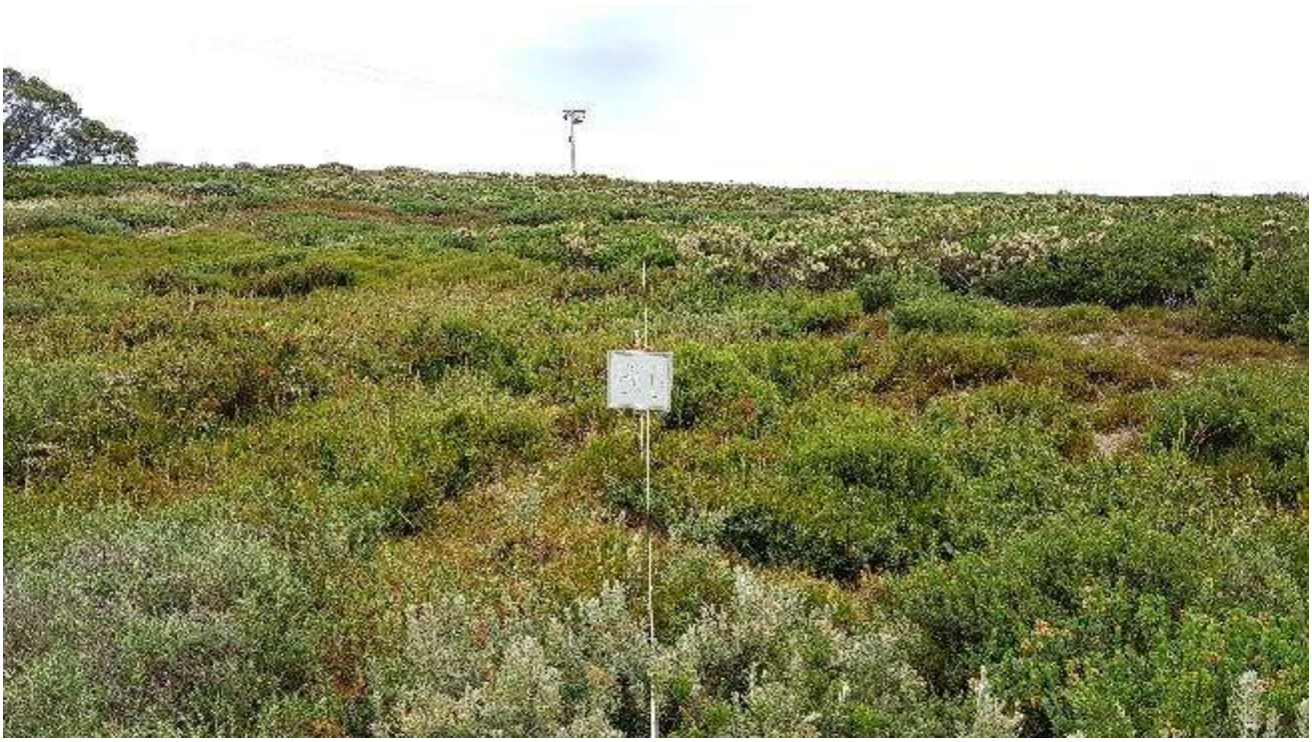

Photo Point 8CE, Bog 8/9/10 (Impact), Baseline Year 2, 30 January 2019

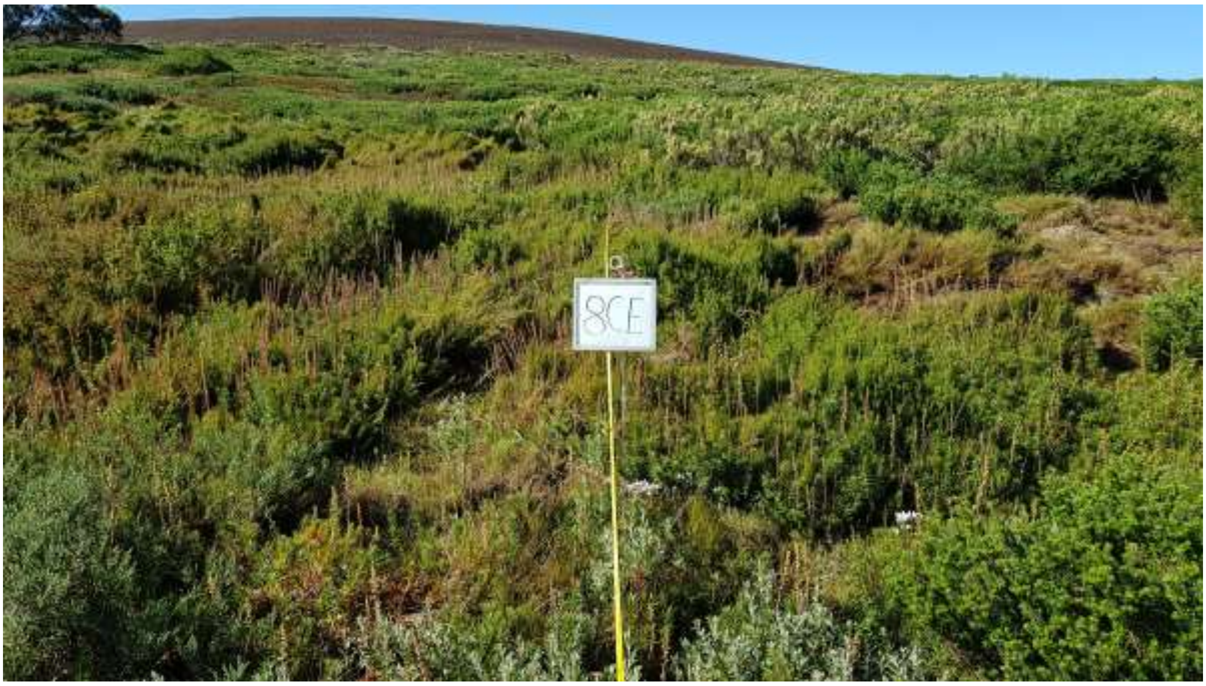

Photo Point 8CE, Bog 8/9/10 (Impact), Impact Year 1, 20 February 2020

Photo Point 9AS, Bog 8/9/10 (Impact), Baseline Year 1, 27 January 2018

Photo Point 9AS, Bog 8/9/10 (Impact), Baseline Year 2, 30 January 2019

Photo Point 9AS, Bog 8/9/10 (Impact), Impact Year 1, 7 February 2020

Photo Point 9AE, Bog 8/9/10 (Impact), Baseline Year 1, 27 January 2018

Photo Point 9AE, Bog 8/9/10 (Impact), Baseline Year 2, 30 January 2019

Photo Point 9AE, Bog 8/9/10 (Impact), Impact Year 1, 7 February 2020

Photo Point 10AS, Bog 8/9/10 (Impact), Baseline Year 1, 27 January 2018

Photo Point 10AS, Bog 8/9/10 (Impact), Baseline Year 2, 30 January 2019

Photo Point 10AS, Bog 8/9/10 (Impact), Impact Year 1, 7 February 2020

Photo Point 10AE, Bog 8/9/10 (Impact), Baseline Year 1, 27 January 2018

Photo Point 10AE, Bog 8/9/10 (Impact), Baseline Year 2, 30 January 2019

Photo Point 10AE, Bog 8/9/10 (Impact), Impact Year 1, 7 February 2020

Photo Point 11.1AS, Bog 11.1 (Control), Baseline Year 1, 8 February 2018

Photo Point 11.1AS, Bog 11.1 (Control), Baseline Year 2, 31 January 2019

Photo Point 11.1AS, Bog 11.1 (Control), Impact Year 1, 3 February 2020

Photo Point 11.1AE, Bog 11.1 (Control), Baseline Year 1, 8 February 2018

Photo Point 11.1AE, Bog 11.1 (Control), Baseline Year 2, 31 January 2019

Photo Point 11.1AE, Bog 11.1 (Control), Impact Year 1, 3 February 2020

Photo Point 11.1BS, Bog 11.1 (Control), Baseline Year 1, 8 February 2018

Photo Point 11.1BS, Bog 11.1 (Control), Baseline Year 2, 31 January 2019

Photo Point 11.1BS, Bog 11.1 (Control), Impact Year 1, 3 February 2020

Photo Point 11.1BE, Bog 11.1 (Control), Baseline Year 1, 8 February 2018

Photo Point 11.1BE, Bog 11.1 (Control), Baseline Year 2, 31 January 2019

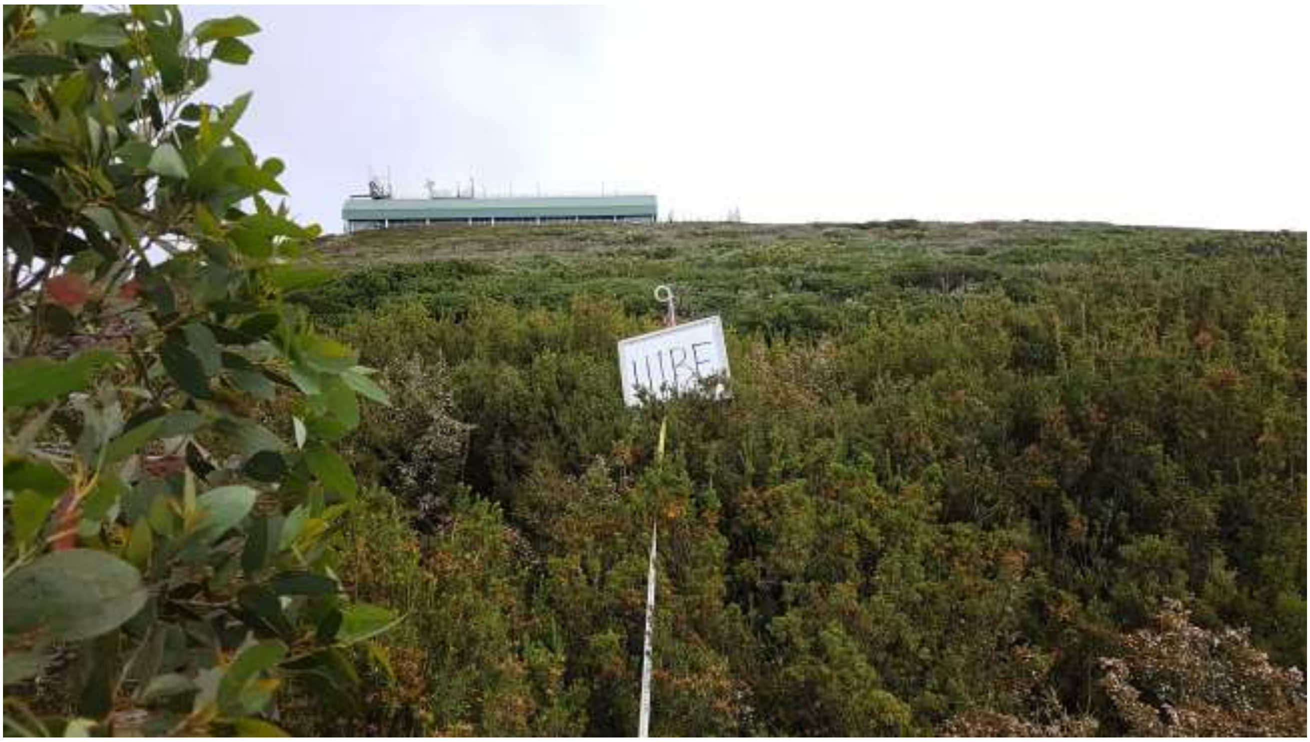

Photo Point 11.1BE, Bog 11.1 (Control), Impact Year 1, 3 February 2020

Photo Point 11.1CS, Bog 11.1 (Control), Baseline Year 1, 8 February 2018

Photo Point 11.1CS, Bog 11.1 (Control), Baseline Year 2, 31 January 2019

Photo Point 11.1CS, Bog 11.1 (Control), Impact Year 1, 4 February 2020

Photo Point 11.1CE, Bog 11.1 (Control), Baseline Year 1, 8 February 2018

Photo Point 11.1CE, Bog 11.1 (Control), Baseline Year 2, 31 January 2019

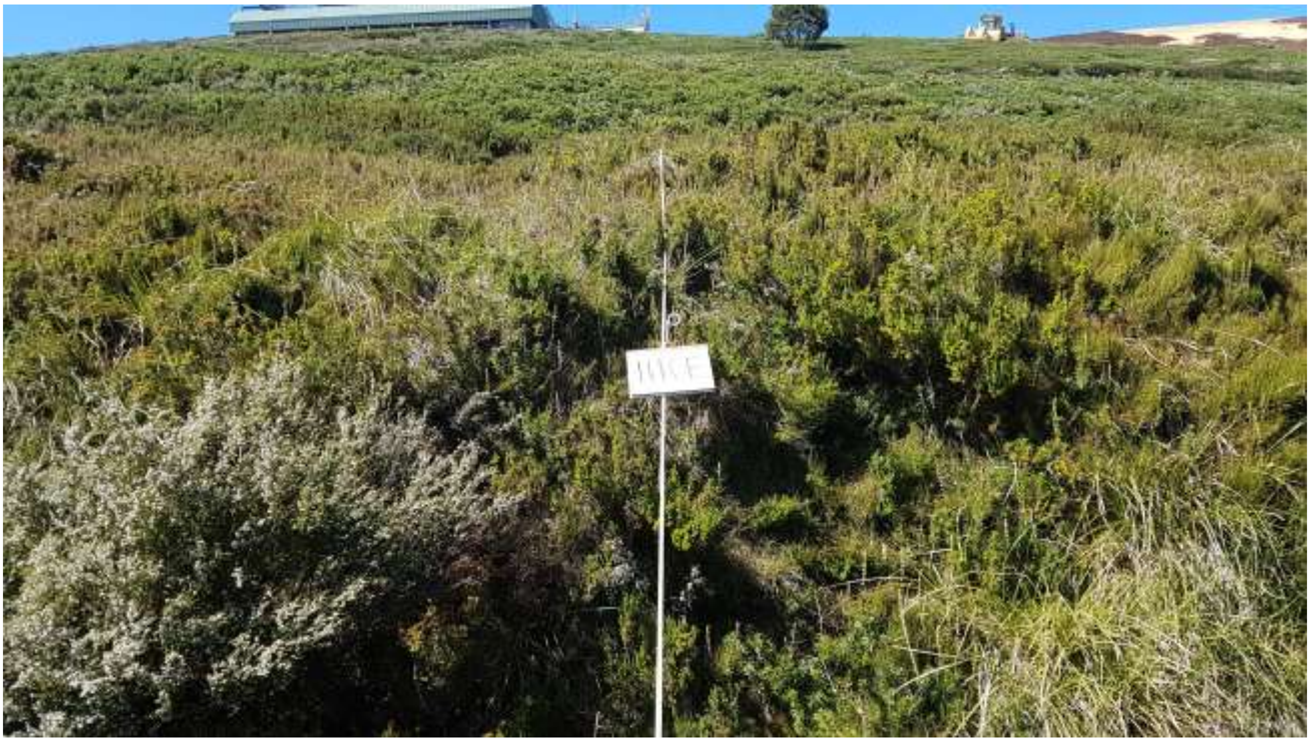

Photo Point 11.1CE, Bog 11.1 (Control), Impact Year 1, 4 February 2020

Photo Point 11.2AS, Bog 11.2 (Impact), Baseline Year 1, 28 January 2018

Photo Point 11.2AS, Bog 11.2 (Impact), Baseline Year 2, 31 January 2019

Photo Point 11.2AS, Bog 11.2 (Impact), Impact Year 1, 7 February 2020

Photo Point 11.2AE, Bog 11.2 (Impact), Baseline Year 1, 28 January 2018

Photo Point 11.2AE, Bog 11.2 (Impact), Baseline Year 2, 31 January 2019

Photo Point 11.2AE, Bog 11.2 (Impact), Impact Year 1, 7 February 2020

Photo Point 11.2BS, Bog 11.2 (Impact), Baseline Year 1, 28 January 2018

Photo Point 11.2BS, Bog 11.2 (Impact), Baseline Year 2, 31 January 2019

Photo Point 11.2BS, Bog 11.2 (Impact), Impact Year 1, 20 February 2020

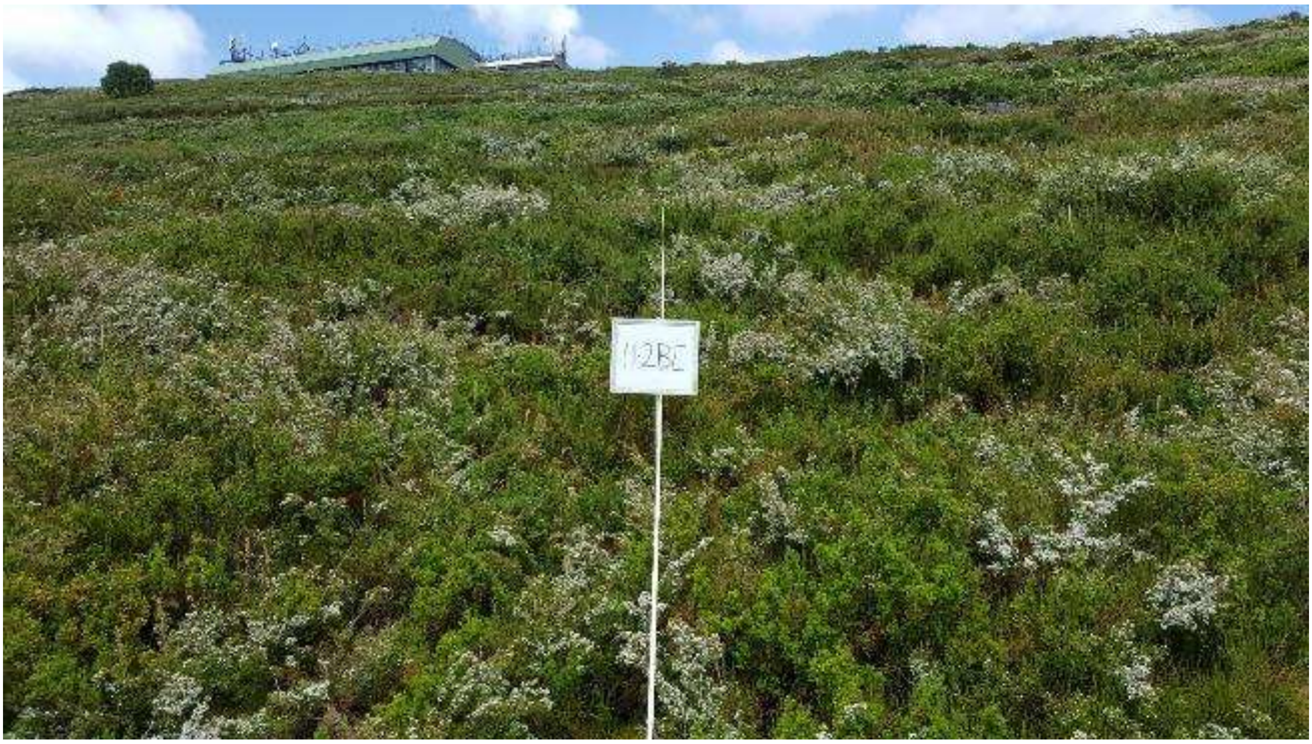

Photo Point 11.2BE, Bog 11.2 (Impact), Baseline Year 1, 28 January 2018

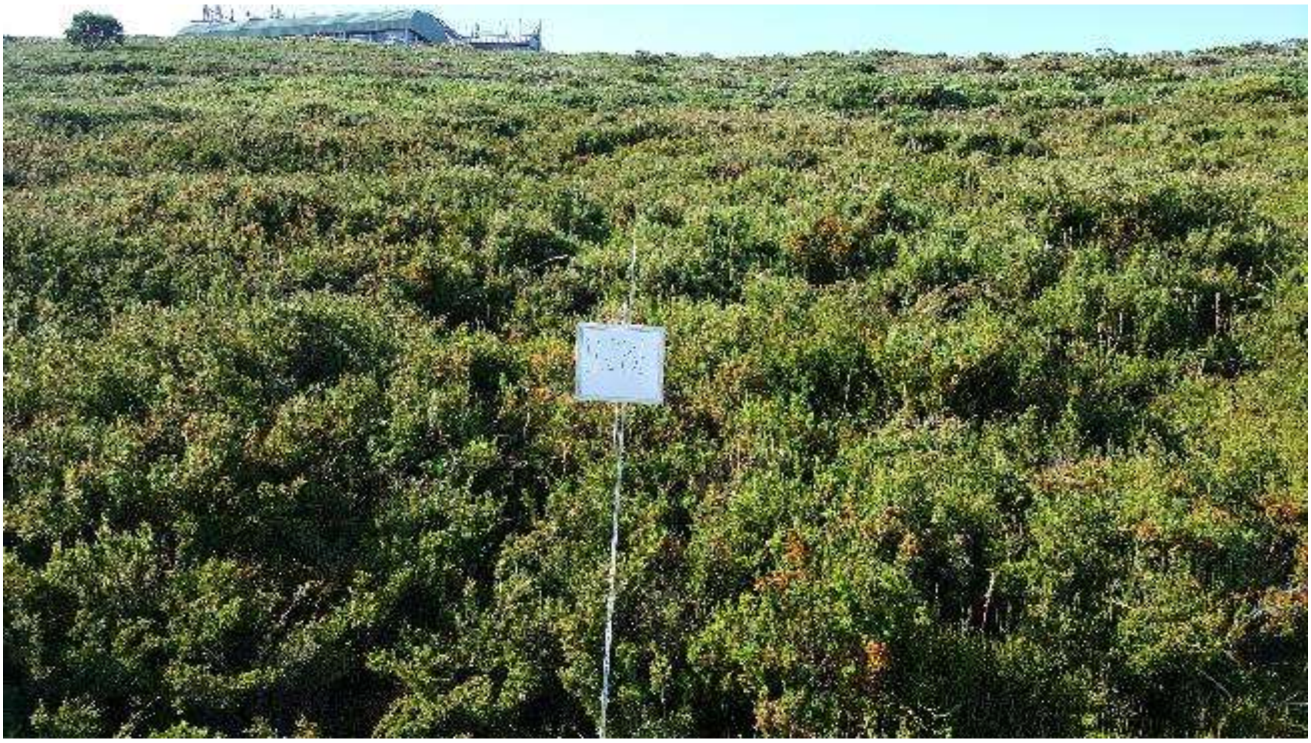

Photo Point 11.2BE, Bog 11.2 (Impact), Baseline Year 2, 31 January 2019

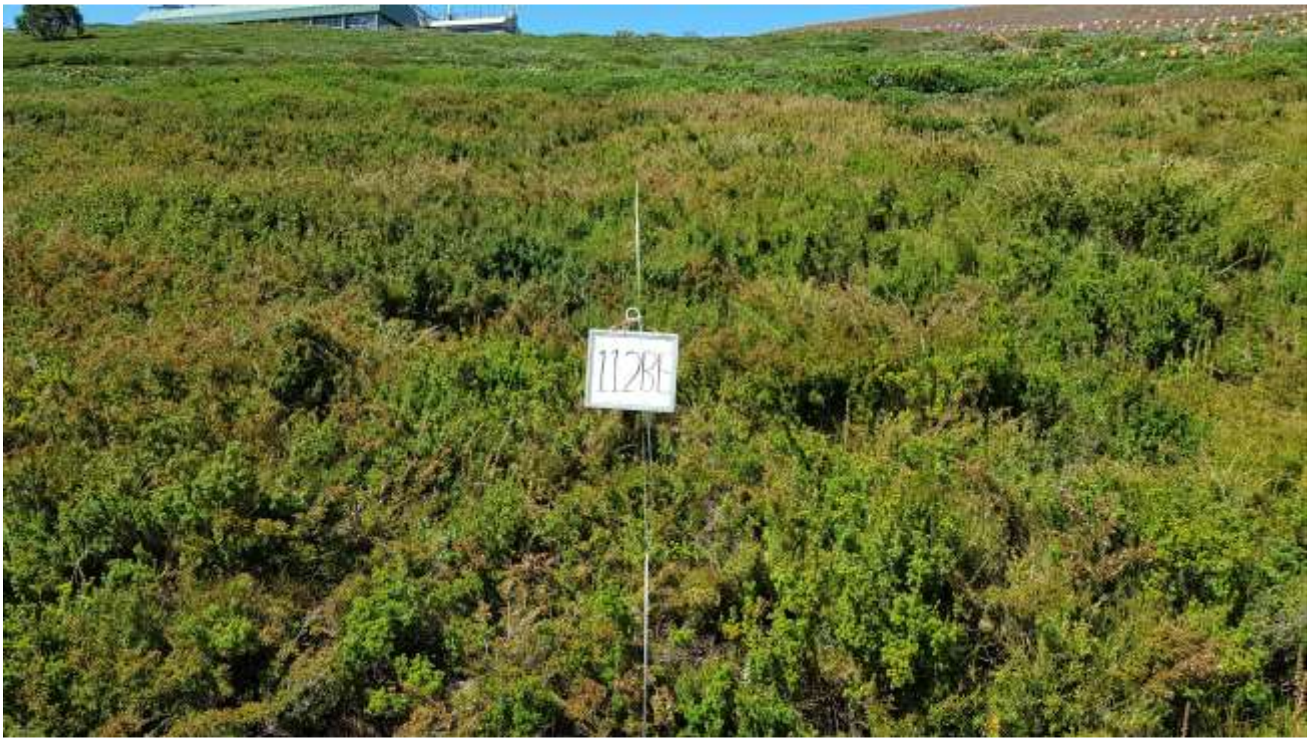

Photo Point 11.2BE, Bog 11.2 (Impact), Impact Year 1, 20 February 2020

Photo Point 11.2CS, Bog 11.2 (Impact), Baseline Year 1, 28 January 2018

Photo Point 11.2CS, Bog 11.2 (Impact), Baseline Year 2, 31 January 2019

Photo Point 11.2CS, Bog 11.2 (Impact), Impact Year 1, 6 February 2020

Photo Point 11.2CE, Bog 11.2 (Impact), Baseline Year 1, 28 January 2018

Photo Point 11.2CE, Bog 11.2 (Impact), Baseline Year 2, 31 January 2019

Photo Point 11.2CE, Bog 11.2 (Impact), Impact Year 1, 6 February 2020

Photo Point 12AS, Bog 12 (Impact), Baseline Year 1, 27 January 2018

Photo Point 12AS, Bog 12 (Impact), Baseline Year 2, 30 January 2019

Photo Point 12AS, Bog 12 (Impact), Impact Year 1, 7 February 2020

Photo Point 12AE, Bog 12 (Impact), Baseline Year 1, 27 January 2018

Photo Point 12AE, Bog 12 (Impact), Baseline Year 2, 30 January 2019

Photo Point 12AE, Bog 12 (Impact), Impact Year 1, 7 February 2020

Photo Point 12BS, Bog 12 (Impact), Baseline Year 1, 29 January 2018

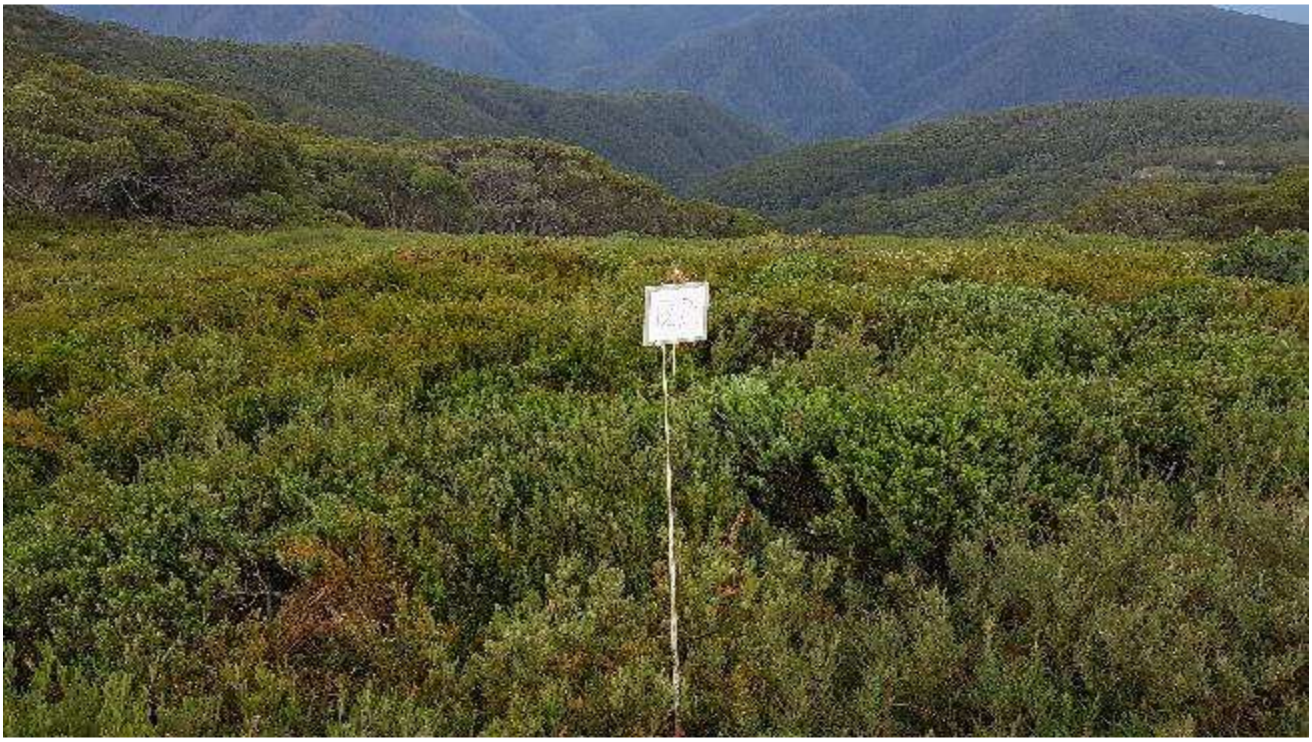

Photo Point 12BS, Bog 12 (Impact), Baseline Year 2, 30 January 2019

Photo Point 12BS, Bog 12 (Impact), Impact Year 1, 6 February 2020

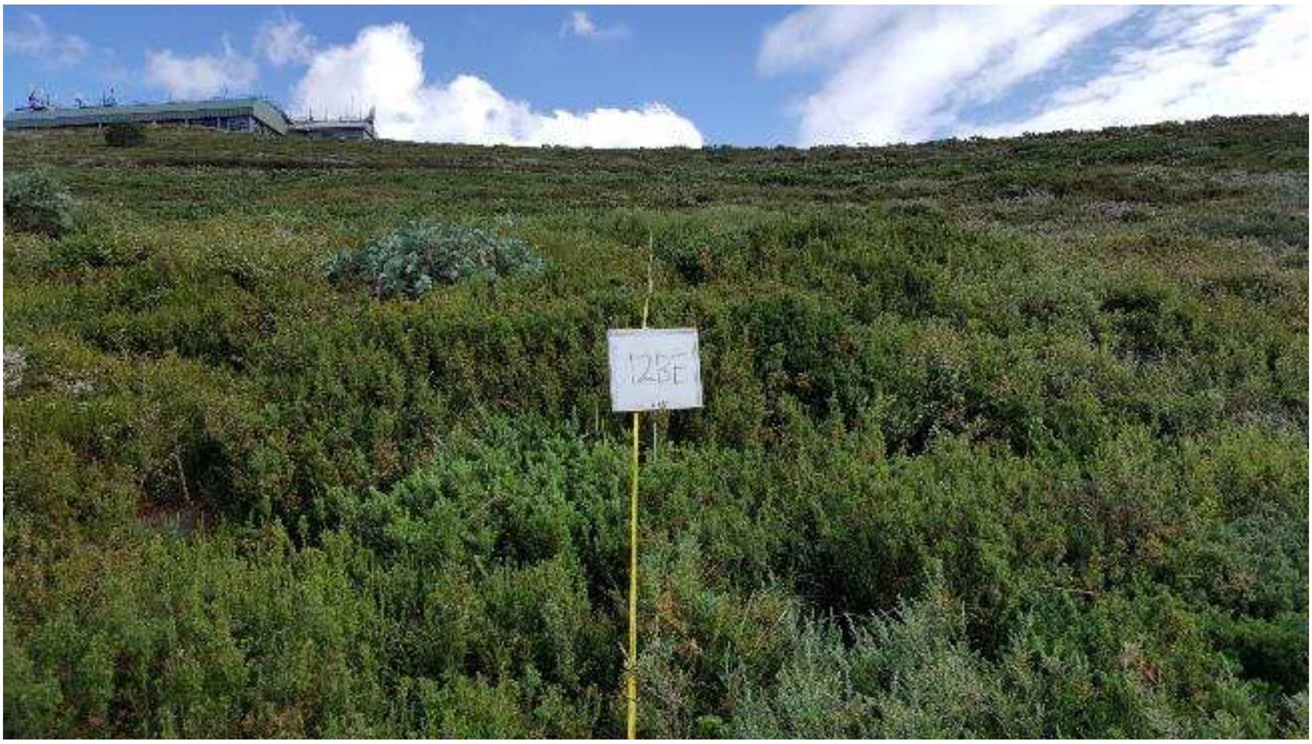

Photo Point 12BE, Bog 12 (Impact), Baseline Year 1, 29 January 2018

Photo Point 12BE, Bog 12 (Impact), Baseline Year 2, 30 January 2019

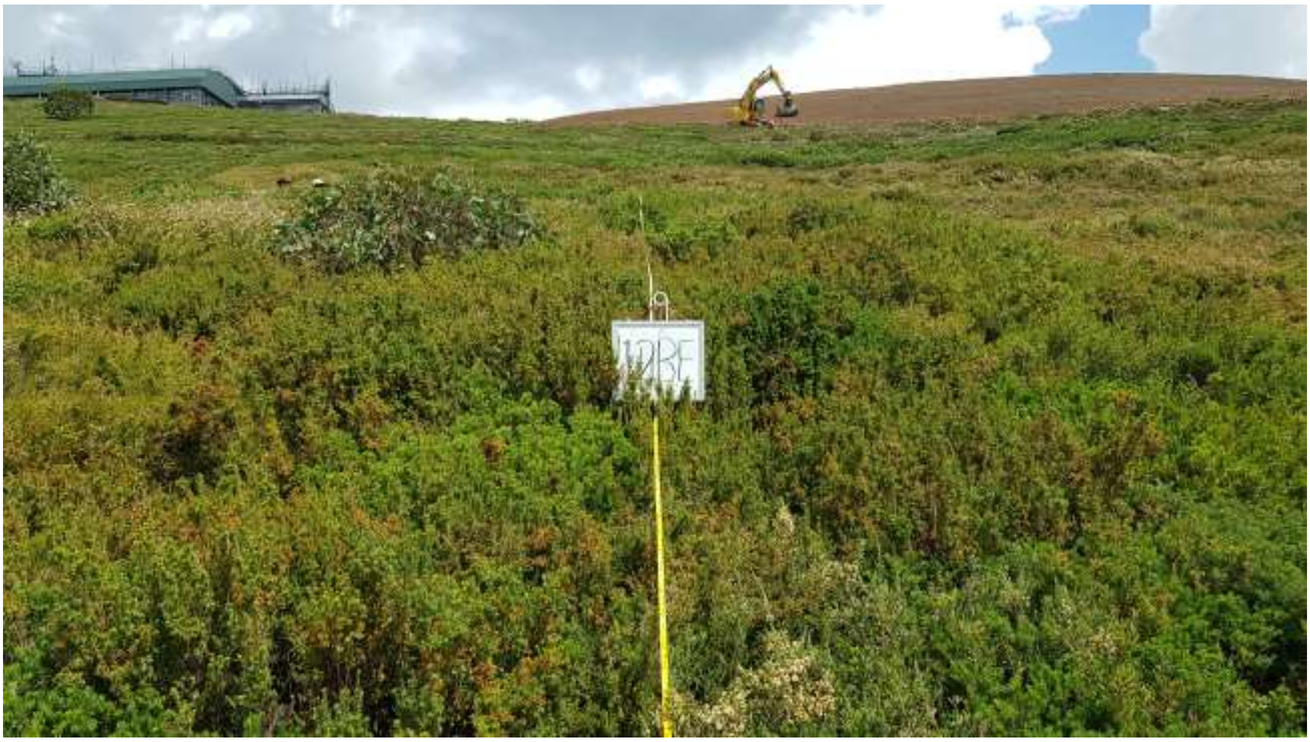

Photo Point 12BE, Bog 12 (Impact), Impact Year 1, 6 February 2020

Photo Point 12CS, Bog 12 (Impact), Baseline Year 1, 29 January 2018

Photo Point 12CS, Bog 12 (Impact), Baseline Year 2, 30 January 2019

Photo Point 12CS, Bog 12 (Impact), Impact Year 1, 7 February 2020

Photo Point 12CE, Bog 12 (Impact), Baseline Year 1, 29 January 2018

Photo Point 12CE, Bog 12 (Impact), Baseline Year 2, 30 January 2019

Photo Point 12CE, Bog 12 (Impact), Impact Year 1, 7 February 2020

Photo Point 13AS, Bog 13 (Impact), Baseline Year 1, 2 February 2018

Photo Point 13AS, Bog 13 (Impact), Baseline Year 2, 14 February 2019

Photo Point 13AS, Bog 13 (Impact), Impact Year 1, 31 January 2020

Photo Point 13AE, Bog 13 (Impact), Baseline Year 1, 2 February 2018

Photo Point 13AE, Bog 13 (Impact), Baseline Year 2, 14 February 2019

Photo Point 13AE, Bog 13 (Impact), Impact Year 1, 31 January 2020

Photo Point 13BS, Bog 13 (Impact), Baseline Year 1, 2 February 2018

Photo Point 13BS, Bog 13 (Impact), Baseline Year 2, 14 February 2019

Photo Point 13BS, Bog 13 (Impact), Impact Year 1, 31 January 2020

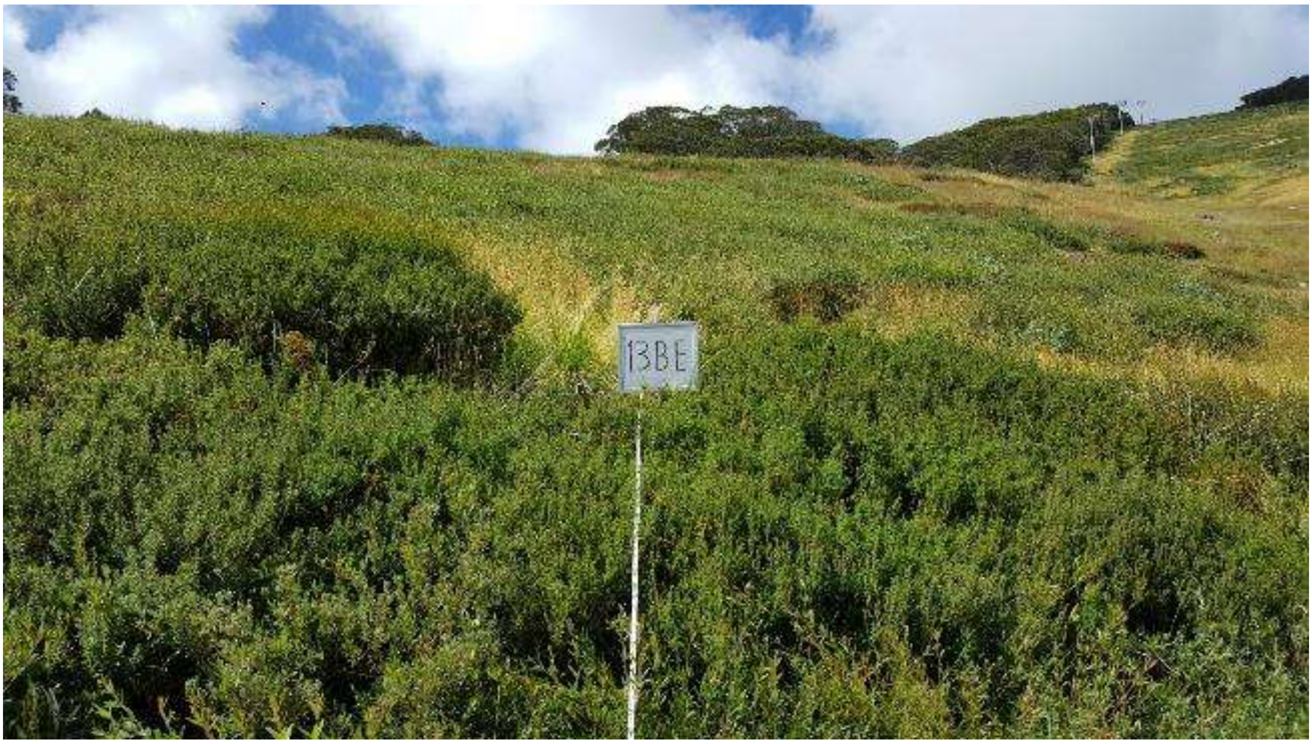

Photo Point 13BE, Bog 13 (Impact), Baseline Year 1, 2 February 2018

Photo Point 13BE, Bog 13 (Impact), Baseline Year 2, 14 February 2019

Photo Point 13BE, Bog 13 (Impact), Impact Year 1, 31 January 2020

Photo Point 13CS, Bog 13 (Impact), Baseline Year 1, 2 February 2018

Photo Point 13CS, Bog 13 (Impact), Baseline Year 2, 14 February 2019

Photo Point 13CS, Bog 13 (Impact), Impact Year 1, 31 January 2020

Photo Point 13CE, Bog 13 (Impact), Baseline Year 1, 2 February 2018

Photo Point 13CE, Bog 13 (Impact), Baseline Year 2, 14 February 2019

Photo Point 13CE, Bog 13 (Impact), Impact Year 1, 31 January 2020

Photo Point S1AS, Bog S1 (Control), Baseline Year 1, 6 February 2018

Photo Point S1AS, Bog S1 (Control), Baseline Year 2, 13 February 2019

Photo Point S1AS, Bog S1 (Control), Impact Year 1, 28 January 2020

Photo Point S1AE, Bog S1 (Control), Baseline Year 1, 6 February 2018

Photo Point S1AE, Bog S1 (Control), Baseline Year 2, 13 February 2019

Photo Point S1AE, Bog S1 (Control), Impact Year 1, 28 January 2020

Photo Point S1BS, Bog S1 (Control), Baseline Year 1, 6 February 2018

Photo Point S1BS, Bog S1 (Control), Baseline Year 2, 13 February 2019

Photo Point S1BS, Bog S1 (Control), Impact Year 1, 28 January 2020

Photo Point S1BE, Bog S1 (Control), Baseline Year 1, 6 February 2018

Photo Point S1BE, Bog S1 (Control), Baseline Year 2, 13 February 2019

Photo Point S1BE, Bog S1 (Control), Impact Year 1, 28 January 2020

Photo Point S1CS, Bog S1 (Control), Baseline Year 1, 6 February 2018

Photo Point S1CS, Bog S1 (Control), Baseline Year 2, 13 February 2019

Photo Point S1CS, Bog S1 (Control), Impact Year 1, 28 January 2020

Photo Point S1CE, Bog S1 (Control), Baseline Year 1, 6 February 2018

Photo Point S1CE, Bog S1 (Control), Baseline Year 2, 13 February 2019

Photo Point S1CE, Bog S1 (Control), Impact Year 1, 28 January 2020

Photo Point S2AS, Bog S2 (Control), Baseline Year 1, 6 February 2018

Photo Point S2AS, Bog S2 (Control), Baseline Year 2, 13 February 2019

Photo Point S2AS, Bog S2 (Control), Impact Year 1, 29 January 2020

Photo Point S2AE, Bog S2 (Control), Baseline Year 1, 6 February 2018

Photo Point S2AE, Bog S2 (Control), Baseline Year 2, 13 February 2019

Photo Point S2AE, Bog S2 (Control), Impact Year 1, 29 January 2020

Photo Point S2BS, Bog S2 (Control), Baseline Year 1, 7 February 2018

Photo Point S2BS, Bog S2 (Control), Baseline Year 2, 13 February 2019

Photo Point S2BS, Bog S2 (Control), Impact Year 1, 29 January 2020

Photo Point S2BE, Bog S2 (Control), Baseline Year 1, 7 February 2018

Photo Point S2BE, Bog S2 (Control), Baseline Year 2, 13 February 2019

Photo Point S2BE, Bog S2 (Control), Impact Year 1, 29 January 2020

Photo Point S2CS, Bog S2 (Control), Baseline Year 1, 7 February 2018

Photo Point S2CS, Bog S2 (Control), Baseline Year 2, 13 February 2019

Photo Point S2CS, Bog S2 (Control), Impact Year 1, 30 January 2020

Photo Point S2CE, Bog S2 (Control), Baseline Year 1, 7 February 2018

Photo Point S2CE, Bog S2 (Control), Baseline Year 2, 13 February 2019

Photo Point S2CE, Bog S2 (Control), Impact Year 1, 30 January 2020

Photo Point S3AS, Bog S3 (Control), Baseline Year 1, 7 February 2018

Photo Point S3AS, Bog S3 (Control), Baseline Year 2, 12 February 2019

Photo Point S3AS, Bog S3 (Control), Impact Year 1 29 January 2020

Photo Point S3AE, Bog S3 (Control), Baseline Year 1, 7 February 2018

Photo Point S3AE, Bog S3 (Control), Baseline Year 2, 12 February 2019

Photo Point S3AE, Bog S3 (Control), Impact Year 1, 29 January 2020

Photo Point S3BS, Bog S3 (Control), Baseline Year 1, 7 February 2018

Photo Point S3BS, Bog S3 (Control), Baseline Year 2, 12 February 2019

Photo Point S3BS, Bog S3 (Control), Impact Year 1, 29 January 2020

Photo Point S3BE, Bog S3 (Control), Baseline Year 1, 7 February 2018

Photo Point S3BE, Bog S3 (Control), Baseline Year 2, 12 February 2019

Photo Point S3BE, Bog S3 (Control), Impact Year 1, 29 January 2020

Photo Point S3CS, Bog S3 (Control), Baseline Year 1, 7 February 2018

Photo Point S3CS, Bog S3 (Control), Baseline Year 2, 12 February 2019

Photo Point S3CS, Bog S3 (Control), Impact Year 1, 29 January 2020

Photo Point S3CE, Bog S3 (Control), Baseline Year 1, 7 February 2018

Photo Point S3CE, Bog S3 (Control), Baseline Year 2, 12 February 2019

Photo Point S3CE, Bog S3 (Control), Impact Year 1, 29 January 2020