Siting and Engineering Constraints of a New Dam in an Alpine Resort
Damon Miller¹ and Grant Jones²

¹ Dam Engineer, GHD¹; ² Principal Geoscientist, GHD²

Mt Buller Alpine Resort has significant constraints on its capacity to store and supply potable water during times of peak demand, which impacts the ability to sustain and grow visitation to the resort, limiting optimal functioning and future development of the resort.

A proposed new 100 megalitre dam would primarily supply the resident and visitor populations with a reliable potable water source while also maintaining through snowmaking, the Resort’s amenity and functionality during winter for skiing and snow-play.

Standard dam engineering criteria of technical feasibility and environmental impact influenced the site selection and design of the new off-stream storage whilst additional key drivers unique to an alpine resort, framed around impact to existing skiable terrain and resort functionality, were critical to satisfy the resort stakeholders. The need to minimise the visual impact of the dam and integrate with the resort environment was also of high importance.

Keywords: alpine resort, dam siting, constrained site, multi-criteria assessment, visual impact

Introduction

Mt Buller Alpine Resort is located approximately 230 km north-east of Melbourne and, together with adjacent Mt Stirling Resort, covers an area of 5,000 hectares. The Mt Buller Mt Stirling Alpine Resort Management Board (RMB) is responsible for the management of both resorts, which sit on Victorian public land.

Mt Buller Alpine Resort has significant constraints on its capacity to store and supply potable water during times of peak demand, which impacts their ability to sustain and grow visitation to the resort. The constraints on the existing water storage limit optimal functioning and future development of the resort.

The Mt Buller Sustainable Water Security Project encompasses a series of projects designed to assist the RMB’s obligation to provide a secure and reliable future water supply to the Resort. The project centrepiece is a new 100 megalitre (ML) dam to primarily supply the resident and visitor populations with potable water while also maintaining the Resort’s amenity and functionality during winter for skiing and snow-play, through snowmaking.

The off-stream embankment dam is currently entering detailed design stage and awaiting planning approvals for the preferred site selected following an options assessment process. This paper focuses on the challenges of siting and designing a dam where, rather than engineering considerations alone being the key driver, a location with minimal impact on the existing ski area, integration with existing infrastructure and environmental constraints were critical to the client and the alpine resort stakeholders. As such, engineers are tasked with designing the dam in a geotechnically and topographically challenging location.

As part of the concept design phase development, detailed mapping and geotechnical investigations were undertaken, which included drilling, test pitting and a seismic survey.

A complex ground model was identified, highlighted by the range of materials that will be excavated within the footprint and subsequently form the embankment. Basalt, granite, colluvium and alluvium deposits are encountered across the site, which is thought to be an ancient uplifted valley. The geological model presents design and construction challenges in excavation and material suitability for the embankment, along with a complex hydrogeological profile, which is not only critical for the dam design but also connection to downstream sensitive environmental communities. Construction constraints to contend with due to the variable material’s extensive stockpiling and mixing requirements, reinforce the difficulties of the site.

Water supply options assessment

A range of water supply options for Mt Buller was identified in a Water Supply Demand Strategy undertaken by GHD. The review included an assessment against a range of criteria. Water supply options considered included:

- Demand management (reduction of water demand/improved efficiency);
- On-Mountain and off-mountain storages;
- Increased surface water extractions;
- Use of alternative supplies such as stormwater, rainwater, and groundwater;
- A combination of the above; and
- Do nothing.
A new 100 ML on-mountain storage was identified as the most appropriate option as it provides the Resort with significant operational flexibility all year round, and allows it to balance raw water, potable and recycled water demands. This storage also provides an effective way to manage the inherent variability in climate and streamflow associated with the Mt Buller region. A storage of this size would allow the RMB to divert water during winter months only, in accordance with the condition of their extraction licence and would also provide an adequate, gravity fed (if appropriately sited) supply for firefighting.

The population of Mt Buller varies seasonally, with a large number of visitors to the Resort during the winter ski season. Therefore, the water demand for potable water use also varies seasonally, with higher water demand during winter months and lower water demand during summer months. The current annual average potable water demand at Mt Buller is around 167 ML/yr and varies between 5 and 36 ML/month depending upon seasonal visitation.

Identification of potential storage sites

The process of identifying and shortlisting potential sites for a 100 ML capacity water storage began with the review of previous investigation reports commissioned by RMB for potential water storage sites. Consultation and discussions to confirm potential sites were undertaken with RMB and Buller Ski Lifts (BSL) and likely issues / constraints were outlined and considered. GHD dams, geotechnical, planning and environmental personnel conducted site inspections to develop and confirm the shortlist of potential sites.

The outcome of this process was the identification of three potential storage sites within the Resort. The potential storage sites are known as ‘Tirol’, ‘Koflers’ and ‘Control Centre’. The location of the potential sites is presented in Figure Error! Reference source not found.1. Several options were considered for the storage layout on the Tirol and Control Centre sites.

![Figure 1: Location of the Tirol, Koflers and Control Centre sites](image)

Development and assessment of storage concepts

Following the identification and selection of the three potential dam sites, preliminary 100 ML concept designs were developed in order to evaluate how a dam of this size would function on each site. This included information on footprint area, site topography, embankment dimensions, excavation quantities and excavation depth.

The preliminary concept designs allowed initial investigations into potential visual and ecological impacts to be undertaken. They were also used to facilitate a series of discussions with the RMB and BSL on issues such as the potential impacts on Resort users, existing infrastructure and future operations.

Concepts were further developed with desktop studies and site walkovers to gather site-specific information on the geotechnical and environmental conditions of each site.
The Tirol site had previously been the subject of geotechnical, flora and fauna assessments. No similar assessments had been undertaken for the Koflers or Control Centre site. During the dam preliminary concept development process, assessments and investigations were undertaken on these sites to ensure sufficient information was available to input to the Multi-Criteria Assessment for the site selection process.

Multi-Criteria Assessment

A multi-criteria assessment (MCA) process was developed and employed on the three potential sites utilising a range of objectives and criteria sourced from relevant planning and strategy documents, and from RMB organisation-specific objectives. Assessment criteria (developed in conjunction with RMB and with input from BSL) included land use planning, environment, heritage, social, economic, ski resort utility, technical and engineering, construction, operational and bushfire management considerations.

Whilst all the criteria were considered important and relevant to the Project and to the consideration of siting options, four of these criteria were considered to be ‘key’ project drivers, specifically:

- Impact on native vegetation;
- Geotechnical suitability and risk;
- Impact on skiable terrain, connectivity and Resort functionality; and
- Construction cost.

The first stage of the process evaluated all three sites (Tirol, Koflers and Control Centre), and was informed from prior investigations, as well as limited site specific geotechnical and ecological investigations. This stage utilised the MCA. A number of important points emerged from the site investigations and comparisons which have been undertaken, namely:

- No ‘optimal’ site was identified – there are degrees of compromise, relatively ‘better’ or ‘worse’ depending upon the specific parameter being assessed; and
- There are different degrees and depth of information on each site based on previous assessments undertaken (for example geotechnical and ecological assessments). Therefore, it is not always possible to make a direct comparison between sites based on the same level of information.

One site (Koflers) was considered to be inferior due to site topography and impact on flora and fauna and was eliminated from the shortlist of potential sites. The Control Centre site was considered to have sufficient merit to be the preferred site, but additional information was required in order for this to be confirmed.

The second stage of the site selection process was undertaken following a series of more detailed geotechnical, hydrogeological and ecological investigations, in conjunction with the preliminary concept design process. This concept design considered a larger footprint than the first stage in order to take account of storage construction methodology, and the need to install and relocate ancillary infrastructure. Following these investigations, the MCA was reviewed to ensure that the preferred site was still scored as preferred in light of the additional information that had been gained.

A traffic light approach to assess the sites for each criterion was adopted in order to simplify the assessment process. An abbreviated summary of the MCA objectives is outlined in Error! Reference source not found..

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Criteria</th>
<th>Key Project Driver or Criteria</th>
<th>Tirol</th>
<th>Koflers</th>
<th>Control Centre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment &amp; Heritage</td>
<td>Impact on native vegetation</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td></td>
</tr>
<tr>
<td>Economic</td>
<td>Dam Construction Cost - embankment material availability</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dam Construction Cost - ripping and blasting required for rock cut</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dam Construction Cost - minimise earthworks volume</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td></td>
</tr>
<tr>
<td>Ski Resort Utility</td>
<td>Impact on existing skiable terrain, connectivity and Resort functionality</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td></td>
</tr>
<tr>
<td>Technical / Engineering</td>
<td>Capacity to adjust dimensions of the footprint during detailed design and construction</td>
<td>□</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Geotechnical feasibility</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Geotechnical risk to achieving 100 ML storage volume</td>
<td>✅</td>
<td>✅</td>
<td>✅</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dam Break Consequence Category</td>
<td>□</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 1: MCA assessment criteria and outcomes
Based on the results of the MCA, in particular relating to the key criteria, the Control Centre site emerged as the preferred concept for the off-stream storage.

Control Centre site description
The proposed Control Centre site location is within the Mt Buller Alpine Resort ski area, north of the final stretch of the unsealed Summit Road over the existing Boggy Creek ski lift alignment and extending north down the hillside to the Summit Nature Walk track. The site is located on a gently to moderately sloping plateau directly west of the Mt Buller summit. The site area slopes downhill to the north with the slopes steepening as they approach the valley below.

The area is typically vegetated with low lying alpine grasses, flowers and shrubs. Occasional rock outcrops and boulders of basalt are exposed towards the south-east corner of the site. The existing terrain and layout are presented in Figure 2.

Figure 2 – Existing terrain and layout of Control Centre site

Geotechnical investigations
The Warburton 1:250,000 geology map issued by the Geological Survey of Victoria was reviewed to assess the likely geology at the selected sites during the Concept Design phase. The 2010 Coffey Geotechnical Assessment of the Tirol site provided borehole data and mapping within the surrounding area.

The indicated geology at the site predominantly consists of a cap of Tertiary basalt overlying Devonian granite. The map indicated that the Mt Buller massif directly to the west of the site is made up of Devonian hornfels.

Fourteen boreholes were drilled across the proposed Control Centre dam site to a maximum depth of 26 m. Nine test pits were excavated up to 3.3 m depth.

Additionally, a geophysical seismic refraction survey was undertaken along five alignments dissecting and surrounding the project site.

Subsurface conditions
The subsurface intrusive and seismic investigations typically confirmed the regional mapping with granite rock being confirmed as the basement rock in the majority of investigation locations. The profile included basalt of varying depth and previously unmapped alluvium and colluvium deposits.

The granite was intruded during the Devonian Period with a subsequent period of uplift, exhumation and weathering. Eventually the granite formed a prehistoric land surface for an uncertain period of time. During this period the rock surface became deeply weathered and soil-like. With increasing depth beneath the project area, the granite becomes less weathered and more competent.

Since the early Tertiary Period, the granite has been overlain in places with a relatively complex lithological profile comprising several phases of deposition of sediments and volcanics. These materials filled a palaeovalley formed in the Devonian granite which still exists beneath the project area. The commencement of valley infilling began in the early Tertiary and was possibly related to the relatively rapid uplift of the area. A significant depth of colluvium was deposited into the base of the valley, with depths interpreted to over 20 m in thickness. These colluvial deposits comprise variable mixtures of matrix to clast supported cobbles and boulders. The cobbles and boulders are typically of high to very high strength meta-sandstone while the matrix is generally of sandy clays, gravels, sands and sandy silts. The sediments are interpreted to be ancient (Tertiary age) landslide deposits.
Subsequent volcanic activity released basalt of the Older Volcanics onto the valley floor. A period of deposition then commenced in a swampy environment potentially formed when lava flows and/or colluvial deposits dammed drainage lines allowing water to collect in the base of the valley. These swamp deposits formed organic rich carbonaceous clays and silts which have subsequently lithified to weak mudstones with minor impersistent coal seams. A second, later lava flow deposited an upper capping of basalt over the valley fill sediments. This basalt layer has protected the valley fill materials from erosion during the uplift of the area. This basalt layer is highly variable from extremely weathered to fresh due to the exposure of this rock at the surface for much of the last 30-40 million years. Outcrops of basalt in a fresh state have however been located in the south-east portion of the proposed storage area.

A layer of clay-rich residual soils exists across the site, derived from the basalt or granite. A layer of organic, sandy clay topsoil is present beneath most of the storage area.

A 3D site geological model was created from the interpreted borehole and test pit logs in Leapfrog Geo, a geological modelling program and is presented in Figure 3.

![Image of a 3D geological model](image_url)

**Figure 3 – Modelled Control Centre site geology profile with proposed dam embankment**

### Groundwater

All of the encountered lithologies, where saturated, represent aquifers to varying degrees. Both the granite and competent basalt (Older Volcanic map unit) represent fractured rock aquifers where groundwater is stored and transmitted by fractures, joints and other discontinuities within the rock mass. The alluvium tends to be fine grained and therefore it is likely to act like an aquitard, forming either a perching bed or confining layer for the underlying saturated granite. The colluvium comprises variable mixtures of both fine and coarse grained sediments. It is interpreted to behave as a porous media continuum where saturated. It appears that both the colluvium and alluvium follow the land contours across the top portion of the site.

The Mt Buller groundwater typically flows from the higher topographies to the lower topographies. The proposed storage is located close to a ridge line, where groundwater flow would radiate from the ridge. Based on bores screening the granite, the depth to groundwater in the granite becomes shallower relative to the ground level along flow lines and rises towards surface level at the northern end of the site.

Spring flow was observed downhill from the toe of the proposed main embankment in a boggy region, with obvious visual evidence of flows and saturated ground.

In general the granitic terrain forms a relatively complex aquifer system, with flow processes occurring in the deeper zones dominated by fracturing and secondary porosity, and flow in the weathered zones analogous to a porous media continuum. It is suspected that all the identified hydrogeological units are in variable hydraulic connection with each other, as supported by similar groundwater chemistries. Some localised perching may occur through:

- Retarding of vertical migration by the Carbonaceous Mudstone;
- Permeability contrasts within the granite, between granitic soils and weathered granite; and
- Local low permeability horizons, i.e. clay layers, within colluvium.

**Design and construction**

The Control Centre dam will be situated on a moderate slope and as such the proposed embankment varies in height and arrangement significantly across the layout. The southern side of the dam will be almost totally in cut, with a 1 V to 2.5 H embankment of over 10 m in height at the maximum section. The fill embankment is also designed for 1 V to 2.5 H upstream and downstream slopes, with a maximum height of 17 m on the downstream side.

The dam has been designed to provide excess cut, based on an assumed wastage rate from the required excavation. The excess in cut was targeted in the concept modelling due to the expected quantities of unsuitable material for use as embankment fill. Due to the variable nature of the cut material, significant stockpiling will be required to achieve consistency in the embankment. Embankments are to be constructed from a blend of the suitable cut materials, mixed during stockpiling works. Of these materials, the 10 % topsoil component plus approximately 20 % of other materials are unsuitable due to the organic content in the case of the topsoil and carbonaceous mudstones, and the oversize material in the case of the upper basalt and the colluvium. The topsoil and oversized rockfill material will be used in the site re-profiling and rehabilitation works upon completion of the dam construction.

Due to a lack of suitable clay material available from either the cut material or another local source, the dam will be fully lined with a high-density polyethylene (HDPE) liner to provide an impermeable barrier. The liner will be backed by full height filter protection incorporated into the cut and upstream embankments. This will protect against any flaw or leak in the liner and also provide a collection system for the groundwater pressures present in the cut embankment. The general arrangement of the dam is presented in Figure 4.

![Figure 4 – Control Centre site dam concept design general arrangement](image)

Cross-sections for stability modelling were taken through the permanent cut embankment and extended through the highest fill embankment section. The typical maximum cut and embankment cross-section along with the interpreted geological profile from the 3D model is presented in Figure 5. The strength parameters of each soil unit were estimated from correlations with infield test results, laboratory results, and engineering experience. Construction, steady state, rapid drawdown and seismic cases were analysed in SlopeW, with most cases meeting the minimum required factors of safety. Further investigation and laboratory testing of materials are scheduled during detailed design to confirm parameters for stability modelling and embankment compaction.
Environmental impact

Mt Buller is well known for its ecological significance as part of the Victorian Alps. The alpine climate and elevated topography present unique alpine and sub-alpine habitats that support a range of threatened species, including many that occur only at this altitude. Significant planning and environment overlays govern development in the region and due to the large footprint and impact of the proposed dam, an extensive flora and fauna assessment was undertaken at the project site.

The assessment incorporated the identification, mapping and evaluation of significant flora and fauna species and habitat within the project area. Direct and indirect impacts of the construction of the dam were identified and potential environment constraints outlined. Recommendations regarding the avoidance of significant ecological values and offset requirements were developed and included as part of the planning permit submission.

Landscape and visual impact

An assessment of the landscape and visual impacts of the proposed Control Centre dam was undertaken to investigate mitigation measures to avoid, reduce, remedy or offset undesirable landscape and visual impacts resulting from the project. The local landscape immediately surrounding the site is characterised by alpine meadow with managed recreational infrastructure in place. While not a highly trafficked recreational area by skiers and snowboards during winter, connections between lifts and ski areas are made by crossing the area of the proposed dam. A number of design opportunities were developed that will allow the new dam to not only visually integrate with the local landscape character but also integrate with the existing recreational uses surrounding the site.

Given this context, a new dam surrounded by recreational opportunities such as moguls, viewing structures, halfpipes and boulders should not appear out of place. The careful choice of materials and vegetation used in revegetation and alignment of fencing will help the new development visually blend in with the managed recreational landscape character.

Due to the nature of the project there will be a permanent impact on the visual landscape and amenity for some viewing locations within the project area and measures to minimise these impacts can be incorporated in the design. While there will be impacts during the construction phase, these will be temporary and not during the snow season.

With adoption of site specific mitigation measures for establishing new vegetation in combination with built form initiatives, the visual impacts of the dam are generally not expected to be significant and are manageable in the context of the locality and the landscape. The landscape and visual impact model is presented in Figure 6.
Figure 6 – Landscape and visual impact model of the proposed dam

Conclusions

Standard dam engineering criteria of technical feasibility and environmental impact influenced the site selection and design of the new off-stream storage at Mt Buller Alpine Resort. Additional key drivers unique to an alpine resort were critical to satisfy the resort stakeholders and were framed around potential impacts on existing skiable terrain and resort functionality. The need to minimise the visual impact of the dam and integrate with the resort environment was also of high importance.

The MCA process resulted in selecting the Control Centre site based on the preferred or acceptable results of key assessment criteria. The site was chosen despite a complex geological profile and challenging topography for the storage size required. These issues presented design challenges on embankment profiles and material selection.

Acknowledgements

The authors would like to thank Mt Buller Mt Stirling Resort Management Board and GHD for the permission and support provided for the presentation and publication of this paper. The senior author, in particular, appreciates the efforts of Grant Jones, Peter Buchanan, Dave Evan, Steve Dahl and Alistair Schofield for their work on the project which formed the topics of this case study.

References

- ANCOLD (2014), Regulation and Practice for the Environmental Management of Dams in Australia
- AECOM (2009), Mt Buller Water Storage - Concept Design Report
- Coffey Geotechnics (2010), Geotechnical Assessment – Proposed Water Storage, Summit Road, Mt Buller
- GHD (2014), Mt Buller Sustainable Water Security Project – Off Stream Storage, Preliminary Business Case
- GHD (2014), Mt Buller Sustainable Water Security Project – Off Stream Storage, Options Assessment Report
- GHD (2014), Mt Buller Sustainable Water Security Project – Off Stream Storage, Factual Geotechnical Report
- GHD (2014), Mt Buller Sustainable Water Security Project – Off Stream Storage, Preliminary Geotechnical Risk Assessment
• GHD (2014), Mt Buller Sustainable Water Security Project – Off Stream Storage, Concept Design Report
• GHD (2014), Mt Buller Sustainable Water Security Project – Off Stream Storage, Flora and Fauna Assessment
• GHD (2014), Mt Buller Sustainable Water Security Project – Off Stream Storage, Landscape and Visual Impact Assessment