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1 Chapter summary

This chapter details the physical assets proposed to be constructed for the Project (the Facilities) and provides a historical context for the design process.

1.1 Introduction

Snowy Hydro undertook a program of site visits and third-party engagement to develop the engineering design to operating requirements. Given the Project's challenging performance requirements, prospective contractors (tenderers) were involved early through an Early Contractor Consultation (**ECC**) process in developing and proofing design concepts and clarifying requirements, including Research & Development (**R&D**) and modelling.

The above process resulted in the Employer's Requirements, formalising Snowy Hydro requirements from a contractual perspective and were issued to Civil and Electrical/Mechanical (***E&M***) contractors in a formal tender process.

The Employer's Requirements are arranged hierarchically and embody a number of key principles and drivers for operating performance.

Snowy Hydro undertook a staged design process, which, as at Final Investment Decision (***FID***), has resulted in the submission (and ongoing evaluation) of both Civil and E&M tender designs.

The design of the Facilities as it stands as at FID is described in detail.

1.2 Activities undertaken

The following ongoing activities were central to developing the engineering design of the Project to its FID state:

1. Site visits;
2. Engagement of specialist advisors;
3. Collaboration with contractors;
4. Development of Reference Design; and
5. Technical assurance program.

The Project began with research and collation of existing relevant worldwide experience. Sites of special interests were visited and various specialist advisors engaged. A Request for Information (***RFI***) process was undertaken with the E&M suppliers to support early development and reference checking.

Snowy Hydro engaged SMEC Australia Pty Ltd (***SMEC***) in 2017 to:

1. Undertake engineering design and geotechnical investigation management for the Feasibility Study; and

2. Develop the feasibility design into a Reference Design to support the tender process for the Main Works (see *Supporting Chapter Two - Procurement* for the tender process).

The Main Works Project contract structure is an Engineer-Procure-Construct (***EPC***) contract based on the International Federation of Consulting Engineers' (***FIDIC***) Silver Book as detailed in Supporting *Chapter Three - Contracts and legal*. A key component of this contract is the Employer's Requirements. Fundamentally these are performance and functional requirements that the Employer (Snowy Hydro) requires for the Project to meet its objectives. As an example, the Reference Design is an interpretation of the Employer's Requirements. It represents one way in which the Project could be developed and serves as a basis for tender evaluation.

A collaborative process utilising SMEC's internal expertise, review by Snowy Hydro external advisors and finally pressure testing from the Contractors, has refined the Employer's Requirements to a position which reflects Snowy Hydro's performance and functional output requirements for the Facilities. The Project has been running a collaborative, or ECC process, with both the Civil and E&M Contractors since mid-2017 (see *Supporting Chapter Two*).

Given the proposed scale, complexity, and 'world-first' nature of the proposed Facilities, the Project undertook a technical assurance program. This included the following parties:

1. **SMEC (as Owner's Engineer)** - engineering design and quality assurance;
2. **Snowy Hydro's engineering, asset management and operations team** - operational advice and direction on design and construction elements;
3. **Owner's Advisors** - key organisations and individuals with experience in similar projects; and
4. **Technical Reference Group (*TRG*)** - Snowy Hydro senior leaders' group.

The Project team undertook a program of visiting pumped-hydro projects, experts and manufacturing locations around the world.

The Project hydraulic design is extremely challenging, due to the power output, high head and long tunnels. The Contractors have limited prototype experience with such a challenging hydraulic design and are pushing the boundaries of their present operational experience. Therefore all E&M tenderers were required to perform R&D and design works in critical areas and to make this visible to Snowy Hydro prior to submission of tenders.

Each E&M Contractor completed a pump-turbine model test of the proposed Project variable-speed pump-turbine as close to full homology as time permitted, with the performance of this model witnessed by Snowy Hydro.

1.3 Functional and performance requirements

The documents comprising the Employer's Requirements are a key input into the Main Works contract structure. These documents specify Snowy Hydro's key performance and functional requirements.

The Employer's Requirements are structured in a 'pyramid' formation, with the key overarching performance and functional requirements at the top. The key elements of the Employer's Requirements are:

1. 3.01 - Performance requirements - Purpose, key principles, functional and performance requirements;
2. 3.02 - Key Project elements - Key Project elements and milestones, the division of responsibility;
3. Specifications:[1]
    a. 3.04 - Particular functional and performance requirements;
    b. 3.05 - Standard technical requirements;
    c. 3.06 - Construction requirements.
4. 4 - Plans and management processes - processes by which the Contractors will complete the Project.
5. A number of key principles were outlined in the Employer's Requirements:
    a. Safety management;
    b. Zero harm;
    c. Snowy Hydro values;
    d. Operability and maintainability;
    e. Quality; and
    f. Life cycle cost.
6. The Employer's Requirements included a number of design-specific key drivers:
    a. High round-trip efficiency (***RTE***) across the operating range;
    b. High availability and reliability;
    c. Fast generation and pump start-up times;
    d. Wide operational load bands;
    e. Low vibration and noise;
    f. Low arc flash energy, low electric and magnetic fields and low circulating currents;
    g. Ease of maintenance;
    h. Long asset life; and
    i. Ability to undertake all future operation and maintenance activities efficiently and safely.

The Project is required to achieve a generation and pumping capacity of 2,000 MW at a 0.9 power factor leading and lagging for the full design life.

Dynamic capability, or the ability to operate up to 10% over the rated capacity, is required for all generating units individually.

The Facilities shall be required to operate over the:

1. Full generation range when Tantangara is between maximum flood level conditions and minimum operating level (***MOL***) and Talbingo operating between MOL and full supply level (***FSL***);
2. Full pumping range when Talbingo is at maximum flood level conditions and MOL and with Tantangara operating between MOL and FSL; and

[1] Note: There is no section 3.03.

3. Full range of extreme climate conditions prevalent at the Site in the Kosciuszko National Park (***KNP***).

The Facilities must be designed to meet changing future market demands (see *Supporting Chapter Six - Market modelling*), and as such have been specified to operate in a way that allows for this flexibility going forward.

Snowy Hydro has current assets in its fleet that are close to 70 years old and are still functioning as they were designed. The Facilities need to have a similar long design life to ensure that the most commercial value can be derived from the assets. The operational life for key structural elements of the Facilities is thus 100 years, with other elements of the Facilities requiring shorter operating lives.

The Scheme's high reliability and availability are among Snowy Hydro's key pillars to operational success. They depend on strong maintenance and monitoring practices.

Key drivers for maintenance include:

1. Prescriptive and condition-based;
2. Non-invasive;
3. Short-duration outages;
4. Remote monitoring;
5. Low ambient noise; and
6. Minimise manual handling.

Key drivers for monitoring include:

1. Digital twin;
2. Real-time, self-monitoring; and
3. Video.

The Facilities must meet specified efficiency and head loss targets.

The E&M Contractor must meet requirements in respect of National Electricity Rules (***NER***), including:

1. Access standards and performance requirements;
2. Information to confirm compliance; and
3. Requests for additional information.

The E&M tenders were received on 12 October 2018, and the Civil Contractors received on 09 November 2018. They included a number of alternative options and departures from the Employer's Requirements. These are detailed in the body of the chapter.

1.4 Design approach

Snowy Hydro's guiding principles for the design and the Employer's Requirements for the Project evolved from the objective of meeting the needs of the National Electricity Market (***NEM***) as variable intermittent generation is expected to supply a large portion of the NEM's energy.

To meet this goal, the Facilities must:

1. Provide a safe and robust operation, meeting international design standards;
2. Comply with the requirements of Australian regulatory bodies;
3. Have high operational reliability and flexibility; and
4. Require low operating and maintenance costs.

The design process went through the following stages:

1. Feasibility design:
    a. Development of a Technical Requirements Document (***TRD***);
    b. Exploration of options; and
    c. Development of base case feasibility design.
2. Reference Design - basis for tender documents;
3. Geotechnical investigations - preparation of Geotechnical Baseline Report (***GBR***) (see *Supporting Chapter Three*) from outputs of geotechnical investigation campaigns;
4. Contractors' design proposals - received and being evaluated as at FID.

Further design reviews will occur following contract award and commencement of the Contractors' formal design activities.

1.5 Key project elements

1.5.1 Overview

The main features of the Facilities comprise:

1. Power Waterway;
2. Power Station Complex;
3. Access Tunnels; and
4. Project-wide services and systems.

1.5.2 Power Waterway

The Power Waterway conveys water between the two reservoirs and comprises:

1. **Tantangara Intake** - the point of entry/exit to the Power Waterway for water entering/leaving Tantangara Reservoir. The Tantangara intake structure will be located towards the southern end of Tantangara Reservoir, on its western shore, about 1 km northwest of Tantangara Dam;
2. **Headrace Tunnel** - links the Tantangara Intake to the Distributor Tunnels;
3. **Distributor Tunnels** - the division of the single waterway (headrace) into three waterways so that separate waterways can service a pair of machine units;
4. **Headrace Surge Tanks** - Provide free surface as close as possible to the turbine to attenuate transient pressures;
5. **Pressure Shaft Structure** - conveys the water vertically from the end of the Distributor Tunnel to the start of the Pressure Tunnels;

6. **Pressure Tunnels** - connect the bottom of the Pressure Shaft Structure to six Penstock Tunnels;
7. **Penstock Tunnels** - provide individual water supply to the six pump-turbines;
8. **Draft Tube Tunnels** - connect the draft tube elbow below the pump-turbines to the Collector Tunnels;
9. **Collector Tunnels** - combine flow from the Draft Tube Tunnels upstream of the Tailrace Surge Tank;
10. **Tailrace Surge Tank** - operates similarly to the Headrace Surge Tanks;
11. **Tailrace Tunnel** - links the Tailrace Surge Tank, to the Talbingo Intake; and
12. **Talbingo Intake** - the point of entry/exit to the Power Waterway for water entering/leaving Talbingo Reservoir. The Talbingo Intake Structure is situated near the upstream end of Talbingo Reservoir on its eastern side, about 17 km south of Talbingo Dam, where the Yarrangobilly River and Middle Creek flow into the storage.

1.5.3 Power Station Complex

The Power Station Complex is a drained, underground facility comprising:

1. **Machine Hall** - a machine hall cavern housing six pump-turbine units. Each unit consists of a 340 MW Francis pump-turbine and a 375/425 MVA motor-generator and their ancillary systems. Three of the units are variable-speed (asynchronous) and three are fixed-speed (synchronous), arranged in a way that the three pressure tunnels are connected to one variable-speed and one fixed-speed unit. The Machine Hall includes various control rooms and space for communication and power equipment, amenities and drainage and dewatering equipment;
2. **Transformer Hall** - a transformer hall cavern housing six transformers. The Transformer Hall contains the main transformers with one three-phase transformer per unit provided in the Reference Design; and
3. **Gas-Insulated Switchgear (*GIS*) cavern** - a cavern for housing GIS will be incorporated into the Power Station Complex. The Reference Design has located the GIS into an extension of the Transformer Hall, however placing the GIS directly over the main transformers has not been specifically precluded.

1.5.4 Access Tunnels

The access tunnels provide efficient and safe access to permanent infrastructure. The access tunnels comprise:

1. **Main Access Tunnel (*MAT*)** - primary access conduit to the Power Station Complex during operation;
2. **Emergency Egress, Cable and Ventilation Tunnel (*ECVT*)** - provides a conduit for power evacuation, an alternative to the MAT for egress in emergency situations, and a ventilation and dewatering conduit. A 330 kV outdoor cable yard will be provided at the ECVT portal for termination of the 330 kV cables from underground GIS and interconnection with the transmission line connecting to the TransGrid transmission system;

3. **Penstock Guard Valve (*PGV*) Chamber Access Tunnel** - provides permanent access to the PGV and Pressure Shaft Inspection Chamber;
4. **Pressure Shaft Inspection Chamber Access Tunnel** - connects the PGV Chamber Access Tunnel with the Pressure Shaft Inspection Chamber;
5. **Tailrace Surge Tank Access Tunnel** - provides construction and permanent access to the top of the Tailrace Surge Tank from the MAT; and
6. **Draft Tube Valve (*DTV*) Gallery Access Tunnel** - connects the MAT to the bottom of the transformer hall cavern to facilitate the installation, operation and maintenance of the DTVs.

1.5.5 Project-wide systems and services

Project-wide services and systems provided in the Reference Design include:

1. An integrated security system with a closed-circuit television system (***CCTV***) and access control system;
2. An overall fibre-optic cable-based communication system;
3. DC systems, lighting and small power;
4. Outlying areas Medium Voltage (***MV***) and Low Voltage (***LV***) distribution system;
5. Control and measurement system; and
6. Protection system.

1.6 Contractors' design

Contractors' submissions included key differences between the Reference Design and the proposed Civil and E&M designs.

Major areas of difference include:

1. Access roads - grade separation between light and heavy vehicles and reducing the grade of some roads by changing the alignment;
2. Power waterway:
    a. Headrace and tailrace - Secondary cast in situ lining, length of headrace;
    b. Surge tanks - one surge tank instead of three;
    c. Pressure shafts - differing downstream waterway layouts.
3. Power station complex - no significant changes; and
4. Access tunnels - Exploratory Tunnel alignment based on ECVT rather than MAT.

2 Activities undertaken

2.1 Overview

The following section outlines the activities undertaken during the development of the Facilities design for the Project. This involved development of the

Reference Design, Employer's Requirements, an engaged Contractor input and review process and Snowy Hydro's technical review assurance program.

An early part of the Project's development process was to research and collate existing worldwide experience with similar developments. Essentially, to learn as much as possible from past experiences and then leverage them to develop the Project. This included incorporating existing Snowy Hydro knowledge and experience.

A number of special interest sites were identified together with the already known and new specialist area experts that could assist in the development and verification of the Facilities design. The sites of interest were visited for inspection and detailed discussions with the owners and many of the identified experts were engaged as Owner's Advisors.

An RFI process was formally commenced with all four E&M Contractors to complete early development and reference checking works. This included:

1. Design calculation to show that the Project could be developed from proven existing designs;
2. Development and testing on pump-turbine models to provide a sound basis from which to tender;
3. Nomination of appropriate reference sites for inspection;
4. Discussions with their owners and operational tests on their machines; and
5. Nomination and inspections of the proposed motor/generator and pump-turbine component manufacturing locations.

This was completed and documented for all four tenderers. Selected international experts together with Owner's Team personnel were used to assess this work.

2.2 Development of Reference Design

Snowy Hydro engaged SMEC Australia Pty Ltd (***SMEC***) in 2017. SMEC was engaged to undertake the engineering and some of the geotechnical investigation work for the Feasibility Study. This was completed in November 2017.

Subsequently, SMEC in conjunction with Snowy Hydro developed the feasibility study design further. This development was based on a greater understanding of ground conditions as more information was obtained. Options that remained within the Feasibility Study were optimised and design developed until options were either adopted or eliminated from being viable. This was developed into the Reference Design for the Project. This activity was completed by mid-2018.

This is further described in the *Design Approach* section below.

2.3 Development of Employer's Requirements

The Main Works Project contract structure is an EPC contract as detailed in *Supporting Chapter Three - Contracts and legal*. A key component of this contract is the Employer's Requirements. Fundamentally these are performance and functional requirements that the Employer (Snowy Hydro) requires for the Project to meet its objectives. As an example, the Reference Design is an interpretation of the Employer's Requirements. It represents one way in which the Project could be developed.

A key focus of the Project team has therefore been the development of these Employer's Requirements. The following list outlines how this process was undertaken for the technical requirements:

1. Development of draft Employer's Requirements by SMEC;
2. Review of Employer's Requirements by Snowy Hydro by internal business operations and engineering experts;
3. Review of Employer's Requirements by Snowy Hydro Owner's Advisors;
4. Collaborative review of feedback between SMEC and Snowy Hydro engineers, and adoption of proposed changes or inclusions where required;
5. Review of Employer's Requirements by E&M Contractors with a particular focus on the top 10 issues;
6. Review of Employer's Requirements by Civil Contractors with a particular focus on the top 10 issues;
7. Review by Project team of proposed changes, and adoption where considered suitable in the interests of Snowy Hydro; and
8. Updating the Employer's Requirements based on additional information as the Project has developed or areas have required clarification.

A collaborative process utilising SMEC's internal expertise, review by Snowy Hydro external advisors and finally pressure testing from the Contractors, has refined the Employer's Requirements to a position which reflects Snowy Hydro's performance and functional output for the Facilities.

2.4 Collaborative process with Contractors

The Project has been running a collaborative process, or ECC process with both the Civil and E&M Contractors since mid-2017. While this has occupied a significant portion of time for both Snowy Hydro and the Contractors, it is believed that the time commitment is minor in regards to the significant benefits that the process delivers for the final outcomes.

A key component of the optimisation of the Reference Design and finalisation of the Employer's Requirements has been the review and challenge process with the Contractors. This was an important element of the process as it allowed Snowy Hydro to understand where the Employer's Requirements were positioned within the market and how constructable the Reference Design was, and to be challenged on what is technically constructable. The output of the process also left scope for the Contractors to still input innovation and further optimisation into their final tender designs.

The key activities undertaken in this process were:

1. Review of the Reference Design and optimisation by the Contractors;
2. Review of the Employer's Requirements by the Contractors;
3. Issuing of clarifications of the Employer's Requirements to Snowy Hydro through an RFI process;
4. Submission of targeted preliminary study and design reports by the E&M Contractors;
5. The supply of initial information to feed the NER connection process;
6. Development of pump-turbine models by the E&Ms and completing of associated witness tests;
7. Face-to-face collaborative workshops between Snowy Hydro and the Contractors to enhance understanding of all aspects of the Project, eg: Employer's Requirements, approvals, safety expectations, environmental requirements and development of the Contractor's design;
8. Weekly 'coordination meetings' with both the E&M and Civil Contractors and Snowy Hydro to provide a frequent mechanism for discussion of new information, update on design and any key issues and/or challenges;
9. Weekly steering meetings with the two Civil Contractors to discuss all elements of the Project; and
10. Fortnightly steering meetings with the four E&M Contractors.

One of the main reasons for these key activities was to achieve a best-for-project outcome by creating an engaged relationship between the Employer, Snowy Hydro and the Contractors. This meant that whenever issues presented themselves, they could be quickly and openly discussed and resolved. By investing significant time in this tender development phase, a significant amount of risk has been removed and managed from the tender submissions. The outcome has been greatly improved.

2.5 Technical assurance

2.5.1 Overview

The extent and complexity of the Project are greater than Snowy Hydro has seen since the original construction of the Snowy Mountains Scheme. Snowy Hydro does not have the internal expertise and resources to cover all areas to the level needed. The proposed Facilities have a number of 'world firsts for a pumped-hydro energy storage (***PHES***) scheme', such as the combination of high head, long power waterway tunnels, high generation output, variable-speed technology and all within an area of complex geology.

In order for the Project Team to be assured that the Reference Design, Employer's Requirements and proposed Contractor designs were technically feasible, constructible and will provide a fit-for-purpose end product, the team undertook a technical assurance program. As there is no one company that has all the required knowledge alone for the development of the Project, this involved a number of companies and specialist individuals.

2.5.2 Owner's Engineer

Snowy Hydro engaged SMEC at the very beginning of the feasibility study. SMEC, as a professional engineering organisation with origins that date back to the original Scheme, has appropriate technical excellence and in-house knowledge. The SMEC team of designers, construction experts, environmental advisors and project managers form a large part of the Project team.

In order for SMEC to provide quality assurance, a quality system was implemented that provided assurance that the services provided comply with Snowy Hydro's requirements. The technical design management system had internal controls to manage the quality of design outputs in accordance with the requirements of *ISO AS/NZS 9001*, requiring the documentation of compliance to the Engineering Management Plan against this standard.

2.5.3 Snowy Hydro Engineering and Operations

Snowy Hydro's engineering, asset management and operations team played a significant role in the development of the Facilities. This primarily related to the input into the development of the Employer's Requirements, and design review activities of the Reference Design. Facilitated by the Project team, the following individuals and teams provided valuable operational advice and direction on design and construction elements:

1. Principal Engineers Civil, Mechanical and Electrical;
2. Project Engineering;
3. Reliability and Asset Integrity;
4. Asset Technology, particularly protection;
5. Engineering Systems and Support, in particular, Building Information Management (***BIM***);
6. ICS Infrastructure and Operations, particularly focused on communications;
7. Production and Operations; and
8. Generation Operations.

2.5.4 Owner's Advisors

The technical assurance program identified key organisations and individuals who had undertaken similar projects or parts thereof overseas and within Australia that could fill gaps of knowledge within the Project team and also provide multiple levels of verification in critical areas. These 'Owner's Advisors' were specifically identified based on their knowledge and experience. They were tasked with reviewing specific areas of Owner's Requirements and Reference Design, providing relevant information unique to their field of expertise and experience and to provide additional verification of critical areas. This process has enhanced quality and reduced risk.

Some of the key areas targeted included the following:

1. Experience with variable-speed technology;
2. Model testing of high head reversible Francis pump-turbines;

3. Segmental tunnel lining;
4. High-pressure concrete and steel-lined pressure shafts;
5. Construction of long pressure shafts with raise boring or inclined TBM;
6. Transient analysis;
7. Design and construction of ultra-large or multi-surge tank configurations;
8. Geology and geotechnical, as well as geotechnical risk sharing;
9. Power station ventilation design; and
10. Excavated material disposal and management.

Table 1 lists the Owner's Advisors and their scope.

Area	Organisation	Role
Geotechnical	Jacobs	Peer review geotechnical content
Geotechnical	Golders Associates	Review of GBR
Transients	Power Vision Engineering	Review and advise on transient analysis
Technical Components	Landsvirkjun Power	General review and advisor based on experience building very similar stations
Model tests	EPFL (École Polytechnique Fédérale de Lausanne)	Pump-turbine Model testing - input into requirements and evaluation
Tunnelling	VIGL Consult	Provide tunnel advice and expertise
Employer's Requirements	AF Consult	Provide review of components and input into Employer's Requirements
Tunnelling	JM Rock Consulting	Tunnel Risk share, TBM selection
Employer's Requirements	TU Graz	Input and advise into Employer's Requirements, particularly surge tank
Tunnelling	Neuenschwander Consulting Engineers	Tunnel Risk share, Payment clauses
Construction	CB&HR Consulting Pty Ltd	General internal advisor with significant construction experience
Excavated material	Royal Haskoning DHV	Excavated material disposal within reservoir investigation and advise
Excavated material	CSIRO	Assisting Royal Haskoning with geochemical analysis of rock
Electrical	Machine Monitor	Employer's Requirements advise and review
Electrical	Safearth	Employer's Requirements advise and review
Life safety/Ventilation	Stacey Agnew	Employer's Requirements advise and review of designs from a life safety and ventilation perspective
Electrical	EDF (Électricité de France)	Employer's Requirements advise and review
Electrical	Power systems engineers	Employer's Requirements advise and review
Electrical	Generator and motor engineering consultants	Employer's Requirements advise and review
Dam Hydrology	Hydrology & Risk Consulting Pty Ltd	Updated dam hydrology of reservoirs

Table 1: Owner's advisors

2.5.5 Technical Reference Group

Snowy Hydro established a TRG in mid-2018. The objective of the TRG is to represent the interests of Snowy Hydro by ensuring the best technical Project outcome for high impact and critical issues.

The TRG was established with senior leaders from the Snowy Hydro business from the following areas, providing a forum with significant business understanding:

1. Asset Management and Engineering;
2. Operations and Production;
3. Trading and Market Operations; and
4. Information and Communication Systems.

The TRG was then tasked with the following key deliverables:

1. Ensure key stakeholders are consulted prior to agreeing on the resolution of high impact or critical issues;
2. Prioritise and provide guidance on high impact and critical issues (cross-functional - project impacts and escalation point for issues experienced in the Project team);
3. Recommend issues that should be taken to the Project Governance Committee (see *Supporting Chapter Twenty - Governance*);
4. Represent the needs of the business;
5. Liaise with the business, including engineering and operational teams; and
6. Verify quality and functionality.

By involving key leaders from within the Business, the Project team were able to get assistance when challenging technical or operational decisions were required to be made.

2.6 Site Visits

The complex technical nature of the Project, in general, resulted in the need to rapidly invest in the development of people and business learning. This process was not dissimilar to that during the development of the original Scheme. In the early stages, the Snowy Mountains Authority sought extensive overseas assistance and training from the United States Bureau of Reclamation for over 100 engineers.

The Project team undertook a program of visiting pumped-hydro projects, experts and manufacturing locations around the world.

The program of site visits has been categorised as follows:

1. **Identify and Establish Contact** - The first phase was targeted at identifying reference sites for high head pumped-hydro stations, both complete and under construction, and identifying and establishing contact with experts that could possibly support the Project;

2. **Investigate and Interrogate** - The second phase investigated the bidders' reference projects and started the detailed interrogation with the panel of experts, 'Owner's Advisors'. The reference projects were investigated and interrogated from the perspectives of planning, construction, operation and maintenance. The machines were witnessed in operation as well as, where available, during maintenance. During this stage the team evaluated the strengths and weaknesses of each of the bidders and used the knowledge of the panel of experts to improve the quality of the Employer's Requirements; and
3. **Embed and Assure** - The third phase of the program comprised a series of factory visits in China, India and Europe and the turbine model tests for each of the Electrical and Mechanical bidders with a focus on assuring the quality of the Project is fit for purpose.

The key themes and practices that emerged from the program were:

1. **Awareness** - By experiencing firsthand the positives and negatives of completed pumped storage projects and those under construction, the team and the documented Employer's Requirements were enhanced in areas with which Snowy Hydro previously had limited technical knowledge;
2. **The A-Team** - The program identified a pool of expert contacts in high head hydro projects that Snowy Hydro has been able to call on for input and advice;
3. **Personal Development** - Exposure to the world's best is the foundation for ensuring that Snowy Hydro's needs are met when dealing with the Contractors;
4. **Assurance** - The review team identified a number of the key technical shortfalls of recently completed pumped storage projects that could be extremely costly for Snowy Hydro as a business. This will ultimately form the basis of quality assurance programs that can ensure a fit-for-purpose Project. In critical areas, concepts and analysis have been able to be challenged and multi-level checking has been performed;
5. **Relationships** - The team has started to develop strong relationships with suppliers and panels of experts that can ultimately prevent or rapidly resolve problems as they arise on the long project journey; and
6. **Diligence** - Having detailed knowledge of the bidders' reference projects and manufacturing facilities informs the tender and evaluation process for contractor selection.

Figure 1 outlines where and when the site visits were undertaken.

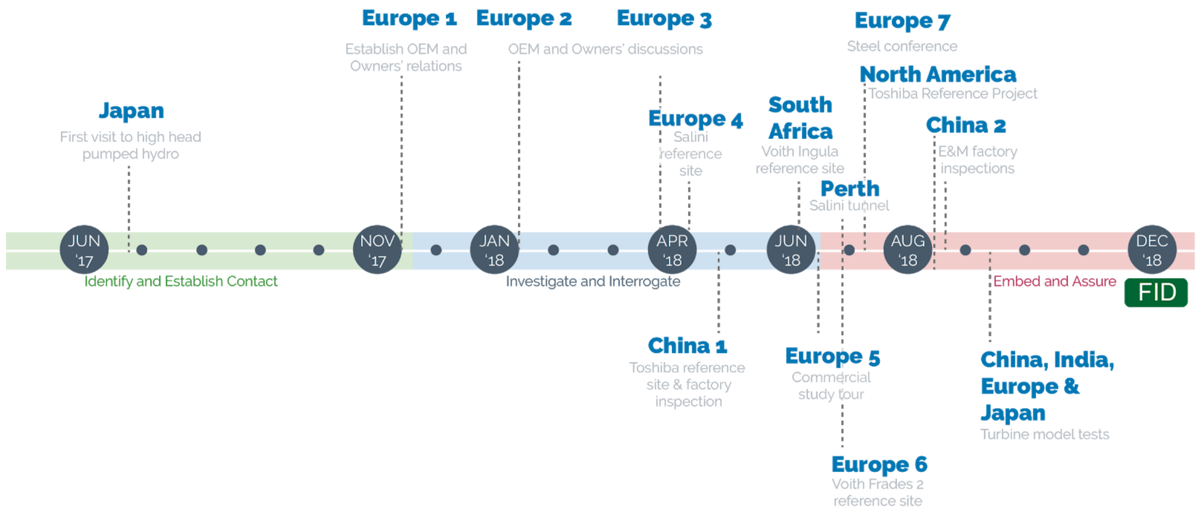

Figure 1: Site visit timeline

2.7 Model Tests

The Project hydraulic design is extremely challenging, due to the power output, high head and long tunnels. The Tenderers have limited prototype experience with such a challenging hydraulic design and are pushing the boundaries or their present operational experience. To narrow the gap, an early works package of E&M work was initiated in April 2018 requiring all tenderers to perform R&D and design works in critical areas and to make this visible to Snowy Hydro prior to the submission of tenders by the E&M Contractors.

The process included the requirement for each E&M Contractor to complete a pump-turbine model test of the proposed Project variable-speed pump-turbine as close to full homology as time permitted and for the performance of this model to be witnessed by Snowy Hydro. These preliminary model tests have no associated contractual guarantees but have been part of the basis for the Tenderers to set their tendered guarantees.

The witness of the resulting model performance was completed between 10 September 2018 and 05 October 2018, for one week in each of the tenderer's hydraulic laboratories. This also provided the opportunity for the Project team to spend time with each of the tenderers' design personnel to build relationships and assess working together.

3 Functional and performance requirements

3.1 Overview

As outlined below, one of the key inputs into the EPC contract is the set of documents comprising the Employer's Requirements, a defined term in the selected form of contract (see *Supporting Chapter Three*).

These documents specify Snowy Hydro's key performance and functional requirements, to which the Contractors, both E&M and Civil, are required to deliver. These requirements are to ensure Snowy Hydro is delivered a Project that meets its business and operational needs.

The following section summarises these key requirements.

3.2 Structure

The Employer's Requirements are structured in a 'pyramid' formation, with the key overarching performance and functional requirements at the top as can be seen in Figure 2 below. These requirements apply to both the Civil and E&M Contractor.

At the top level are the key performance requirements. These are 3*.01 Key project functional and performance requirements* which outline the most important areas for Snowy Hydro. These are the requirements that, when met, will provide Snowy Hydro with the Facilities that meet its operating and market requirements.

Sitting below is 3*.02 Key project elements* which outlines at a macro level, the key assets that are required as part of the Project. An example of a key project element is three pressure shafts in order to ensure appropriate redundancy in the system to ensure 2,000 MW is not suddenly withdrawn from the NEM at one instantaneous moment if a guard valve (at the top of the pressure shaft) were to trip. Having three means that if one is forced to close, a maximum of 666 MW would be taken off the grid.

Below these two key areas are the remaining Employer's Requirements. This is where the majority of the technical content lies. For each piece of equipment, plant or asset, there is a corresponding specification that outlines the key requirements that the Contractor must ensure are designed, constructed and/or provided. These requirements are broken into three main areas:[2]

1. **3.04** - Particular functional and performance requirements, which are broken into a civil, E&M and hydro-mechanical sections;
2. **3.05** - Standard technical requirements, consisting of four key requirements: R1 General, R2 Electrical, R3 Mechanical and R4 Civil which all underpin the 3.04 particular functional and performance requirements; and
3. **3.06** - Construction Requirements: a Civil Contractor document that outlines requirements relating to the construction of the Facilities to ensure quality and meet any environmental requirements. See *Chapter Fifteen - Contractor's Execution Approach* for details of the Construction Requirements.

[2] Note: there is no section 3.03.

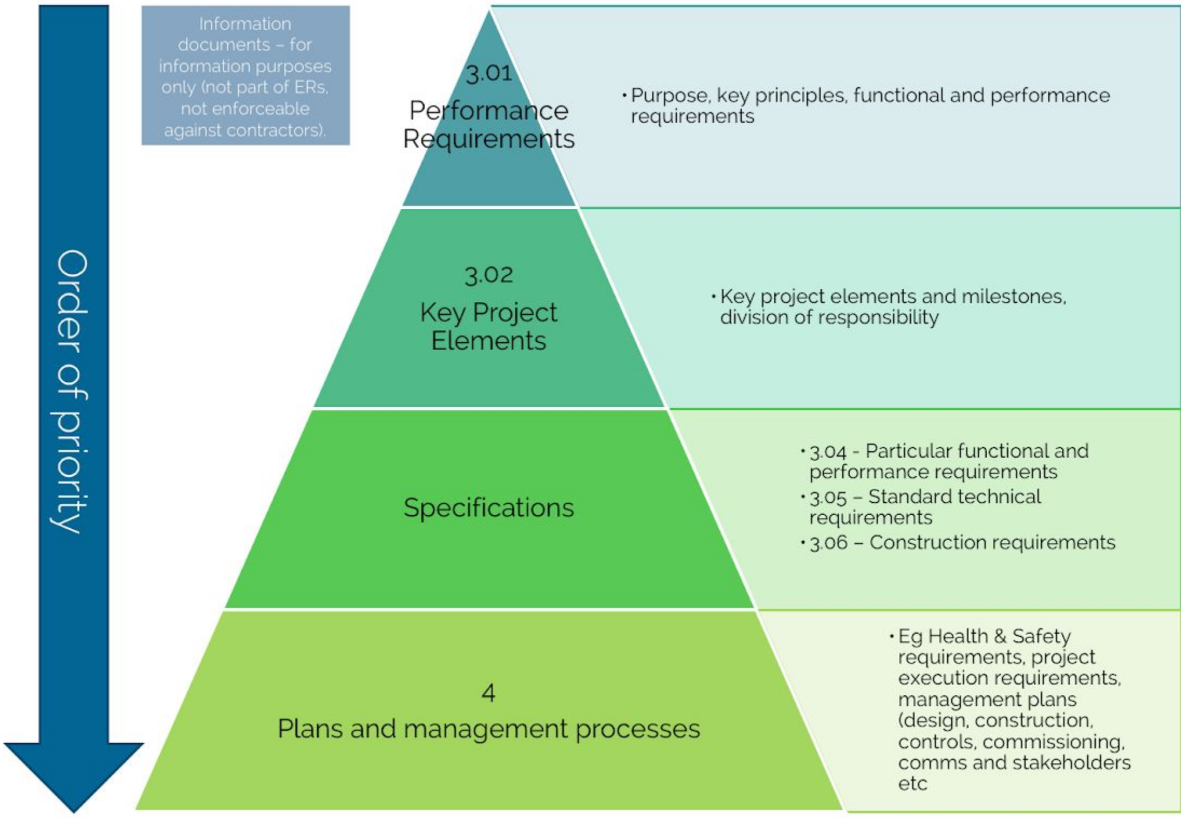

Figure 2: Employer's Requirements hierarchy

Where a discrepancy exists between two requirements, the higher requirement prevails. That way, if the Contractor can provide a solution that meets Snowy Hydro's key performance and functional requirements outlined in 3.01, that is different to the detailed requirements outlined in 3.04, then Snowy Hydro still is provided with a solution that meets its business and operational needs.

At the more detailed level in 3.04, 3.05 and 3.06, a division of responsibility document was developed in order to identify the responsibilities of requirements for each E&M and Civil Contractor.

At the bottom of the pyramid are all the management plans that the Contractors will provide. These cover areas from Health & Safety, project execution and design plans, all the way through to commissioning plans. These explain the processes by which the Contractors will complete the Project.

Each of the following sections outlines key areas of the Employer's Requirements.

3.3 Key principles & performance outcomes

A number of key principles were outlined in the Employer's Requirements. These outline key expectations of Snowy Hydro in both the design, construction and operation phases of the Project. These key principles are:

1. **Safety management** - Ensure the management of safety during the planning and carrying out of the Works is of the highest priority;
2. **Zero harm** - The Project can be completed with zero harm to people and the environment;
3. **Snowy Hydro values** - The basis of all behaviours, choices, decisions and interactions shall be the Employer's principal values of safety, teamwork, ownership, agility, decency and courage;
4. **Operability and maintainability** - The Project shall be designed and constructed in accordance with Industry Best Practice and in a manner that will facilitate the ability of the Employer to successfully operate and maintain the Project;
5. **Quality** - High level of quality in the design and construction of all aspects of the Works to be performed by the Contractor; and
6. **Life cycle cost** - The Contractor shall consider both life cycle costs and construction schedule and costs in its design and construction of the Works.

In the same light, a series of design-specific key drivers were outlined that shall drive the priorities of the Contractors during their design phase. These are outlined below:

1. High round-trip efficiency across the operating range;
2. High availability and reliability;
3. Fast generation and pump start-up times;
4. Wide operational load bands;
5. Low vibration and noise;
6. Low arc flash energy, low electric and magnetic fields and low circulating currents;
7. Ease of maintenance;
8. Long asset life; and
9. Ability to undertake all future operation and maintenance activities efficiently and safely.

3.4 Capacity and duty cycle performance

The Project is required to achieve a generation and pumping capacity of 2,000 MW at a 0.9 power factor leading and lagging for the full design life.

Dynamic capability, or the ability to operate up to 10% over the rated capacity, is required for all generating units individually. In other words, the generating units will be designed for dynamic capability, however dynamic capability will not be required for the entire station at the same time (eg 2,200 MW). This allows the Snowy Hydro operations and trading team enhanced flexibility to cover the lost capacity of one unit if it is out of service, by increasing the generating capacity of the other remaining units within hydraulic limits without materially affecting safety and the long-term asset health.

The duty cycle or the average per day operation of the equipment has been specified as a minimum in the requirements. The numbers outlined below are key inputs into duty cycle performance, as well as design life. It should be noted though that as at FID these numbers are still being negotiated with the E&M suppliers and are subject to change:

1. Five hours generation;
2. Five hours pumping;
3. Four hours synchronous condensing;
4. Ten start/stop cycles (to and from a standstill); and
5. Ten mode changes (between any mode of generating, synchronous condenser generating, pumping and synchronous condenser pumping).

Other important operating requirements for the Facilities are outlined in Table 2 below.

Item	Requirement
Dynamic capability	200 hours total per generating unit per year.
Operation between 1. 0% and 40% Load for synchronous speed 2. 0% and 30% Load for asynchronous speed	500 hours total per generating unit per year. This does not include time involved in starting, stopping and ramping the assets.
Spinning Reserve synchronised at no-load	250 hours per generating unit per year.
Load rejection	Generating unit shall be designed to withstand at least two load rejections in generation and pumping at maximum rated capacity per generating unit per year, excluding the commissioning phase.
Full speed runaway	Generating unit shall be designed to withstand at least two full speed runaway events per generating unit per 100 years.

Table 2: Operating requirements

3.5 Operating conditions, modes and performance

3.5.1 Operating conditions

It is important to specify the operating conditions under which the Facilities will be required to operate, to ensure that even under adverse operating conditions at Tantangara or Talbingo Reservoirs, the system can be operated safely and the required commercial output can be achieved.

The Facilities shall be required to operate over the:

1. Full generation range when Tantangara is between maximum flood level conditions and MOL and Talbingo operating between MOL and FSL; and

2. Full pumping range when Talbingo is at maximum flood level conditions and MOL and with Tantangara operating between MOL and FSL.

The Facilities shall be capable of continuously operating under the full range of extreme climate conditions prevalent at the Site in the KNP. The potential of future adverse changes to the climate and weather conditions at the Site must be allowed for in the design undertaken by the Contractors. The definition of extreme climate conditions is 3-sigma from the maximum January temperature and 3-sigma from the minimum July temperature. A climate trend increase of 0.1-0.2˚C per decade should also be considered. See Supporting *Chapter Eighteen - Hydrology* for further discussion of climate change trends.

3.5.2 Operating modes and performance

Snowy Hydro has had the benefit of owning and operating a 4,100 MW hydro electric scheme very successfully over a long period of time. As such, Snowy Hydro understands the operating modes and range of performance requirements that the facility needs to achieve to fit into the current generating portfolio. It is important to note though that the Facilities have been designed to meet the changing future market demands, and as such has been specified to operate in a way that allows for this flexibility going forward.

3.6 Design life and operation

Snowy Hydro has current assets in its fleet that are close to 70 years old and are still functioning as they were designed for. As such, the Facilities need to have a similar long design life to ensure that the most commercial value can be derived from the assets. For the following areas of the Facilities, therefore, the operational life requirement is 100 years:

1. Intakes;
2. Tunnels;
3. Pressure shafts;
4. Power station complex; and
5. Any embedded components.

The following design life applies for the main E&M plant:

1. Motor/generator stator and rotor windings: 50 years;
2. Transformer windings: 50 years;
3. Turbine runners/pump impellers: 50 years;
4. There shall be at least 40 years of reliable service life before the need for refurbishment and dismantling of the pump-turbines, PGVs, Main Inlet Valves (***MIV***) and DTVs; and
5. Trashracks: 50 years.

Snowy Hydro has challenged the Civil and E&M Contractors with some of these design life expectations and there may be changes going forward. The key message though is that the Facilities, like the current Snowy Hydro hydroelectric scheme, need to be designed and constructed to the highest quality standards, to ensure that in 100 years, the Facilities are still operable as they were designed for.

3.7 Maintenance and monitoring

Snowy Hydro has a strong asset management and engineering arm of the business that ensures the equipment and assets are monitored and maintained at the appropriate time and required frequency to ensure the high reliability and availability, one of Snowy Hydro's key pillars to operational success.

The Facilities to be constructed are no different. The way the Facilities are designed and the quality of the workmanship all will feed into the type, frequency and duration of the maintenance program once the Project is completed. The following are therefore key drivers for how maintenance and monitoring shall be considered in the design of the Facilities:

3.7.1 Maintenance

1. **Prescriptive and condition-based** - Maintenance shall be based on fit for purpose Industry Best Practice reliability and risk principles to achieve a prescriptive and condition-based outcome, rather than calendar fixed time and manual based inspections;
2. **Non-invasive** - Maintenance activities shall be designed around non-invasive tasks while limiting as practically as possible any physically opening, modifying or disassembly of equipment;
3. **Short-duration outages** - Where significant physical maintenance is required that requires an outage, that maintenance should be able to be undertaken during multiple short-duration outages and minor isolation and recall time outages as opposed to a lesser number of longer duration outages;
4. **Remote monitoring** - Routine monitoring shall be possible by Remotely Operated Vehicles (***ROV***) in tunnels (ie no dewatering of any tunnel shall be required for inspection activities);
5. **Low ambient noise** - Hearing protection shall not be required when performing maintenance with adjacent generating units operating under all operating conditions; and
6. **Minimise manual handling** - All Project areas shall have permanently installed mechanical handling equipment, where appropriate, to facilitate safe operations and maintenance.

3.7.2 Monitoring

1. **Digital twin** - Online measurement and monitoring of all systems shall be installed to allow the creation of a digital twin of the entire Facilities, incorporating asset condition/status and prescriptive maintenance analytics;
2. **Real-time, self-monitoring** - Safety critical and business critical system status shall be self-monitoring, known and locally and remotely displayed in real-time; and

3. **Video** - All areas within the Facilities shall be viewable via video cameras (and such video camera systems must be selected, designed and installed in accordance with Industry Best Practice). The cameras shall have movement detection and shall be provided with remote zoom and directional control capability.

3.8 NER Requirements

Under the NER, technical performance standards (access standards) are imposed on all connecting generators and loads. These standards are critical to maintaining power system security and as such must be agreed with the connecting Network Service Provider (***NSP***) and the Australian Energy Market Operator (***AEMO***) before an offer to connect can be made, and a Connection Agreement can be completed.

Compliance with the NER in respect of technical performance standards is therefore critical to the connection of the Facilities to the NEM, and its commissioning and future commercial operation including its ability to operate in accordance with the Project requirements.

To ensure the equipment provided by the E&M contractor is suitable for connection to the NEM, the E&M Contractor shall comply with the following statement as included in the Employers Requirements:

1. **Access standards and performance requirements** - The pump-generating units and systems provided by the E&M Contractor shall individually and in combination comply with the automatic access standards and performance requirements as described in or referenced by the NER, as in force at the Contract date and as established for each generating unit in accordance with clause 5.3.4 of Chapter 5 of the NER, unless otherwise agreed in writing by the Employer;
2. **Information to confirm compliance** - The E&M Contractor shall as part of its design provide to the Employer information, designs, calculations, models and model-based simulations, test programmes, testing and commissioning results, and other information sufficient to confirm compliance of the pump-generating systems with the requirements of the NER and those relevant codes, guidelines and standards referenced by the NER and/or produced by AEMO to support the NER; and
3. **Requests for additional information** - The E&M Contractor shall comply with requests for additional information and tests (including retests) made by the Employer, AEMO and/or the local NSP in respect of its engineering design, commissioning and verification tests such that the Employer will fulfil its obligations under the NER.

3.9 Material deviations as at FID in Employer's Requirements

As outlined in the *Activities undertaken* section, a highly collaborative process was sought with the development of the Employer's Requirements. This involved reviews and feedback from internal Snowy Hydro operational leaders, Owner's Advisors and the Contractors tendering for the Project. As such, feedback on the

Employer's Requirements was obtained, outlining the challenges and opportunities with the requirements and importantly where value may be obtained by relaxing or adjusting the requirements.

Some alternative options and departures from the Employer's Requirements were received with the E&M and Civil tenders. These deviations will be negotiated and either adopted and Employer's Requirements updated, or rejected. Prior to contract signing a complete set of agreed Employer's Requirements will be finalised.

4 Design approach

4.1 Guiding design principles and Project objectives

Snowy Hydro's expectations and guiding principles for the design for the Project evolved from the objective of future-proofing the NEM, at the least possible cost, against the intermittency of the primary renewable technologies (wind and solar) that are expected to supply a large portion of the NEM's energy. This guiding principle continued into the development of the Reference Design and the Employer's Requirements.

To meet this goal, the design must support Facilities that:

1. Provide safe and robust operation, meeting international design standards;
2. Comply with the requirements of Australian regulatory bodies;
3. Have high operational reliability and flexibility; and
4. Require low operating and maintenance costs.

The general approach adopted for the design of the Project was to develop a design which is robust to ensure reliable performance of the civil works under all operating conditions for the expected life of the Facilities.

It is based on good engineering practices and internationally-accepted design principles, guidelines and standards and optimised in accordance with Snowy Hydro's key objectives. This is achieved by harmonising the design of the civil works with the requirements of the E&M works while:

1. Meeting or exceeding the expected applicable environmental requirements of the relevant governmental regulators;
2. Meeting the obligations to local communities; and
3. Meeting Snowy Hydro's health and safety policies.

4.2 Design process

4.2.1 Feasibility Design

The feasibility design was developed following the principles set out in the TRD issued by Snowy Hydro. This document required a number of options to be explored as part of the design process. This was advanced by SMEC in collaboration with Snowy Hydro and the selected global industry experts. Throughout the design development, this constant process of optioneering was conducted as additional site information became available which considered the safety, environmental constraints, performance, costs, constructability, operation and maintenance of each design option to best achieve the project objectives.

4.2.2 Reference Design

Following approval by Snowy Hydro, the feasibility design was then progressed to the Reference Design which formed the basis for the tender documents. The key objectives of the Reference Design were to develop a design that:

1. Enhances the operational safety and reliability of Snowy Hydro's power generation system;
2. Optimises hydraulic performance and efficiency of the power waterway and plant;
3. Minimises construction costs;
4. Minimises construction time; and
5. Minimises operation and maintenance cost incurred during the life of the Project.

The Reference Design is a base design from which tenders, both Civil and E&M, could develop their own design for the Project.

The Reference Design illustrates Snowy Hydro's design intent with regards to the standard of quality, functionality and performance expected to be provided in the tender submissions prepared by the tenderers and is further enshrined in the Employer's Project Execution Requirements, Particular and Functional Performance Requirements and Employer's Construction Requirements. However, the Contractors were not required to adopt the design but encouraged to propose optimised designs provided that their designs meet the Employer's Requirements.

4.3 Geotechnical investigations

The availability of geotechnical information was limited during the feasibility design due to the Geotechnical Investigation Program (***GIP***) being undertaken in parallel with the Feasibility Study, with the results not being available in time to be incorporated.

With the completion of the GIP stage one in mid-2017, two geotechnical investigation campaigns were carried out by the design team during 2017 and 2018. The information obtained from these geotechnical investigations was incorporated into the Reference Design, allowing the design to be significantly advanced from what had been available during the Feasibility Study stage.

This geotechnical information was provided to tenderers in two documents, firstly as a Geotechnical Factual Report (***GFR***), which details all the factual data collected in the investigation. The second is the Geotechnical Interpretive Report (***GIR***) which includes the geotechnical consultant's interpretation of the factual data. The GFR was developed by GHD, and the GIR developed by SMEC.

Both the GFR and GIR led to the preparation of the GBR, which forms the basis for the risk sharing arrangement of the geological conditions between Snowy Hydro and the Civil Contractor.

4.4 Preliminary design and Contractor's proposal

In the tender submissions, the E&M and Civil Contractors have provided a tender design based upon Snowy Hydro's Employer's Requirements. The E&M also assumed the hydraulics layout as per the Reference Design for the basis of tendering. The quality of the design formed a key part of the tender evaluation.

The Contractors' tender design will be the basis for the preparation of the formal detailed design produced during the execution of the main contract. The tender design shows what the Contractor proposes to produce as the eventual asset that Snowy Hydro will own and operate. Snowy Hydro expects to have substantial input into key parameters of the tender design as the design is advanced by the Contractors to the final design.

4.5 Next steps

4.5.1 Design review

Under an EPC contract delivery model, the contractor is broadly responsible for the design of the Facilities. Through the contracting instrument, Snowy Hydro will establish appropriate review and sign-off points for the Owner's Team to ensure that key operational aspects of the design are consistent with the Employer's Requirements.

It is required that the Contractor undertake various studies in the course of the design. (eg functional safety, Hazard and Operability (***HAZOP***), and Reliability, Availability, Maintainability, Buildability, Operability (***RAMBO***)). The Owner's Team intends to be involved in such studies to ensure that the Owner's Requirements are fully met.

A formal HAZOP and functional safety assessment will be required in future stages of design development. Critical hazardous activities or conditions which have been identified in the HAZOP assessment requiring further consideration include:

1. Electrical faults of hydro-mechanical and electro-mechanical plant and equipment;
2. Hydraulic transients initiated by pump-turbine events.
3. Fire in the machine hall, isolated-phase busduct (***IPB***) galleries or in the transformer hall of the power station complex;
4. Flooding of the power station due to pipe or pressure vessel bursts or malfunctioning of valves, gates or drainage pumps;
5. Structural failure of concrete or steel structures due to overloading, material fatigue or scouring;
6. Oil spills and other forms of contamination; and

7. Plant or equipment outages due to material failure or human error leading to operational malfunctioning or operational failure.

The potential impact of each of these hazards will need to be assessed and mitigating measures included in the future stages of design development by adopting appropriate factors of safety and providing redundancy in plant, or alternative modes of operation, where applicable.

Wherever practical and possible, design features were incorporated in the Reference Design to enhance health and safety conditions for the operating personnel. These features include emergency escape routes, provision of stairs instead of ladders, and mechanical lifting devices instead of manual handling.

5 Key project elements

5.1 Overview

The main features of the Facilities, as developed for the Reference Design, are listed in Table 3. The final arrangement may differ in some aspects depending on the alternative design options offered by the successful tenderer. A general arrangement of the scheme is presented in Figure 3.

Description			Unit	Reference Design
General	Installed capacity (generation)		MW	2,000
	Installed capacity (pumping)		MW	2,000
	Max gross head (Tantangara Reservoir at FSL, Talbingo Reservoir at MOL)		m	694.4
	Min gross head (Tantangara Reservoir at MOL, Talbingo Reservoir at FSL)		m	662.6
	Design flow at design capacity		m^3/s	380
Tantangara Reservoir	FSL		ELm	1,228.693
	MOL		ELm	1,205.833
	Maximum flood level (dam crest level)		ELm	1,233.600
Talbingo Reservoir	FSL		ELm	543.193
	MOL		ELm	534.353
	Maximum flood level (dam crest level)		ELm	551.000
Power Waterway	Tantangara intake structure	Sill level	ELm	1,184.700
		Number of bays	No.	4
		Trash rack area	m^2	209
		Number of isolating gates	No.	1
		Number of stoplog sets	No.	1
	Headrace tunnel	Length	km	16.804
		Internal diameter	m	10.0
		Type of lining	concrete	
	Headrace surge tank	Number	No	3
		Type	Vertical circular atmospheric shaft with expansion chamber	
		Height	m	225.0
		Internal diameter	m	12.4 / 5.4
	Headrace surge tank lower expansion chamber	Number	No	3
		Type	Concrete lined D-shaped circular tunnel	
		Internal diameter	m	8
		Range	ELm	1150.000 to 1180.000
		Length	m	546.8
	Headrace surge tank upper expansion chamber	Type	Surface Pond	
		Internal diameter	m	17.5
		Invert level	ELm	1,300.000
		height	m	25.0

	PGV Chamber	Type	D-shaped Semi-Circular Cavern	
		Type of control	3. Nos. butterfly valves, ID 4.60 m	
	Pressure shaft Inspection Chamber	Type	D-shaped Semi-Circular cavern	
		Height	m	11.0
	Pressure shaft	Number	No.	3
		Shaft height	m	557.4
		Internal diameter	m	5.4 (concrete)
	Pressure Tunnels	Length	m	1,020.0 (total) 909.3 (concrete) 110.7 (steel)
		Internal diameter	m	5.4 (concrete) 4.8(steel)
	Penstock tunnels	Number	No.	6
		Length	m	93.0
		Internal diameter	m	2.7 to 2.2
		Type of lining	Steel	
	Draft tube tunnels	Number	No.	6
		Internal diameter	m	3.5
		Type of lining	Steel	
	Collector tunnels	Number	No.	3
		Internal diameter	m	5.4
	Tailrace Surge tank	Type	Vertical circular atmospheric shaft with expansion chamber	
		Height	m	160.0
		Internal diameter	m	23.4
	Tailrace Surge Tank Cavern	Height	m	17.0
		Width	m	26.5
		Length	m	40.0
	Tailrace Surge Expansion Chamber	Type	D-shaped Tunnel (concrete lined)	
		Length	m	830.0
		Internal Diameter	m	8.0
		Range	ELm	560.000 to 580.000
	Tailrace tunnel	Length	km	6.994
		Internal diameter	m	10.0
		Type of lining	Concrete	
		Number of isolating gates	No.	1
		Number of stoplog sets	No.	1
		Gate height	m	10.0
		Gate width	m	7.0
	Talbingo intake structure	Sill level	ELm	515.000
		Number of bays	No.	4
		Trash rack area	m^2	209
		Trash rack bar clearance	mm	90
Power station complex	Machine hall	Span	m	29.4 (crown arch) 32.8 (max width)
		Length	m	238.0
		Height	m	50.4 55.4 (max height)
		Unit spacing	m	18.0
	IPB galleries	Number	No.	6.0
		Span	m	10.0
		Length	m	50.0
		Height	m	17.0
	Transformer hall	Span	m	19.0
		Length	m	205.2
		Height	m	45.0
	GIS Hall	Span	m	19.0
		Length	m	90.1
		Height	m	25.0
	DTV gallery	Span	m	10.0
		Length	m	176.3
		Height	m	17.8
		Type of valve	Butterfly	
Access Tunnels	MAT	Width	m	8.3
		Height	m	8.0
		Length	m	3,069.7
	MAT 2	Width	m	8.3

		Height	m	8.0
		Length	m	368.8
	ECVT	Width	m	8.5
		Height	m	9.5
		Length	m	3,550
	PGV Chamber Access Tunnel	Width	m	6.0
		Height	m	6.6
		Length	m	994.7
	Tailrace Surge Tank Access Tunnel	Width	m	6.0
		Height	m	6.6
		Length	m	771.6
	Pressure Shaft Inspection Chamber Access Tunnel	Width	m	7.0
		Height	m	7.0
		Length	m	136.7
	DTV Gallery Access Tunnel	Width	m	6.0
		Height	m	6.6
		Length	m	543.4
	Cooling Water Tunnel	Width	m	8.0
		Height	m	8.0
		Length	m	97.0
Construction Adits	Tantangara Construction Adit	Internal Diameter	m	10.7
		Length	m	893.2
	Talbingo Construction Adit	Internal Diameter	m	10.7
		Length	m	902.1
	Marica Construction Adit	Internal Diameter	m	7.0
		Length	m	392.2
	Machine Hall Access Tunnel	Width	m	8.3
		Height	m	8.0
		Length	m	50.0
	Machine Hall Access Tunnel 2	Width	m	8.3
		Height	m	8.0
		Length	m	50.0
	Machine Hall Construction Adit	Internal Diameter	m	6.0
		Length	m	213.7
	Machine Hall Construction Adit 2	Internal Diameter	m	6.0
		Length	m	210.1
	Penstock Construction Adit	Internal Diameter	m	7.0
		Length	m	643.0
	Collector Tunnel Construction Adit	Internal Diameter	m	7.0
		Length	m	237.9
	Headrace Surge Tank Expansion Chamber Construction Adit	Internal Diameter	m	7.0
		Length	m	670.9

Table 3: Key project elements

5.2 Exploratory Works

Exploratory Works involves the construction of an exploratory tunnel to enable exploratory drilling and provide a greater understanding of the underground conditions at the power station complex location. Several supporting elements are also required to facilitate the construction of the exploratory tunnel.

The key elements of Exploratory Works include:

1. An exploratory tunnel about 3.1 km long to the site of the underground power station;
2. A portal construction pad for the exploratory tunnel;
3. An accommodation camp for the Exploratory Works construction workforce;

4. Road works and upgrades to enable access and haulage routes during Exploratory Works;
5. Barge access infrastructure to enable access and transport by barge on Talbingo Reservoir;
6. Excavated rock management, including subaqueous placement within Talbingo Reservoir and temporary on land placement; and
7. Services infrastructure such as diesel-generated power, water and communication.

Horizontal and other test drilling, investigations and analysis is also proposed for the above elements to inform Project viability and detailed design. All elements of Exploratory Works align with components of the proposed main works for the Project. However, if the Project is not approved or does not progress, the impacted areas will be rehabilitated, and project elements decommissioned in consultation with NSW National Parks and Wildlife Service (***NPWS***) requirements.

See Supporting *Chapter Thirteen - Early and exploratory works* for more details.

5.3 Main Works

5.3.1 Access Roads

Temporary roads

Provision for temporary road infrastructure required for the construction of the Works was based on the construction methodology and staging assumed in the Reference Design. These roads may be optimised, roads removed or additional roads added by the successful civil tenderer to suit their construction methodology subject to the required approvals. The roads outlined in Table 4 are new roads, or upgrades to existing roads expected to be required to support construction.

All construction roads will need to be handed back to the Employer in a condition appropriate for operation. Roads which will no longer be required will need to be rehabilitated to a state equal to or better than was previously found.

Road	Reason new road /road upgrade required for construction
Tantangara Road East	Access to potential quarry and or excavated rock sites from KNP
Tantangara Camp Road	Access to Tantangara Accommodation camp
Tantangara Road	Access to construct Tantangara Intake and Tantangara Causeway
Quarry Trail	Access to construct Tantangara Intake
Marica Trail	Access to the Snowy Mountains Highway from the surge shaft and to link Gooandra Adit to Talbingo Reservoir
Marica West Trail	Access to the surge shaft construction area
Mine Trail	Access to construct the MAT and ECVT
Ravine Road	Access from Link Road to Lobs Hole Road and Mine Trail, to construct Talbingo Intake, MAT, ECVT etc.
Lobs Hole Road	Access from Ravine Road to construct Talbingo Intake and access from the Middle Bay boat ramp to construct the MAT, ECVT
Wharf Road	Access from Ravine Road to construct Talbingo Intake and access from the Middle Bay boat ramp to construct the MAT, ECVT
Camp Road	Access to the Lobs Hole accommodation camp
Pipeline Road	Access to the construction water intake structure
Talbingo Intake Road	Access to construct Talbingo Intake
Spillway Road	Access to the Cascade Bay boat ramp to provide alternate construction access to Ravine Road.

Table 4: New roads and upgrades to existing roads required for construction[3]

Permanent Infrastructure

Permanent road infrastructure will be required post-construction of the Project to provide access to the new and existing facilities. The permanent infrastructure will be required by:

1. Snowy Hydro to access the new infrastructure;
2. NPWS and, where appropriate, the public, to maintain access to the KNP; and
3. Transgrid to access new and existing infrastructure.

All existing tracks/roads will need to be maintained and returned to their existing condition post-construction. The roads outlined in Table 5 are new roads, or upgrades to existing roads required to support operation of the Project.

[3] *Note: Where permanent roads are also required for construction, the Reference Design was developed for the worst case, construction traffic. The detailed design may require two designs for permanent access roads which are utilised during construction to reflect the vastly different uses.

Road	New road/road upgrade required for	Reason new road/road upgrade required for operation	Maintenance/Operati on
Ravine Road	Snowy Hydro	Access from Link Road to the MAT	Operation & maintenance
Mine Trail	Snowy Hydro	Access from Link Road to the MAT	Operation & maintenance
Tantangara Road	Snowy Hydro	Access from Snowy Mountains Highway to Tantangara Intake Structure	Maintenance
Quarry Trail	Snowy Hydro	Access from Tantangara Road to Tantangara Intake Structure	Maintenance
Lobs Hole Road	Snowy Hydro	Access from Ravine Road to Talbingo Intake Structure	Maintenance
Wharf Road	Snowy Hydro	Access from Ravine Road to Talbingo Intake Structure	Maintenance
Talbingo Intake Road	Snowy Hydro	Access from Ravine Road to Talbingo Intake Structure	Maintenance
Marica West Trail	Snowy Hydro	Access from Mine Trail to the surge shaft	Maintenance

Table 5: New roads and upgrades to existing roads required for operation

5.3.2 Power Waterway

The Reference Design provides for the power waterway to convey water between the two reservoirs and consists of the project elements as shown in plan and section on Figure 3:

1. Tantangara Intake;
2. Headrace Tunnel;
3. Distributor Tunnels;
4. Headrace Surge Tanks including expansion chambers;
5. Pressure Shafts;
6. Pressure Tunnels;
7. Penstock Tunnels;
8. Draft Tube Tunnels;
9. Collector Tunnels;
10. Tailrace Surge Tank including expansion chamber;
11. Tailrace Tunnel; and
12. Talbingo Intake.

These elements are described in more detail below. The final Facilities arrangement may differ slightly from the Reference Design, subject to Snowy Hydro's acceptance of alternative design options offered by the successful tenderer.

The waterway shall be required to operate in accordance with the Employer's Requirements and the inherent design philosophy for transient events which is primarily to enforce a safe hydraulic design of the Facilities while providing the required operational performance and flexibility.

The Contractor's design must ensure that all requirements in regards to transient modelling and design shall consider the most unfavourable mass oscillation events that excite the water mass. This shall include subsequent operation modes in resonance with loading, unloading, reloading and load rejection with emergency closing at most unfavourable times. The simulations shall include most unfavourable pump start-up with subsequent trip with emergency closing at the most unfavourable time point in regard to the water mass in the tunnels. All design load cases shall be checked for mass oscillation and water hammer behaviour.

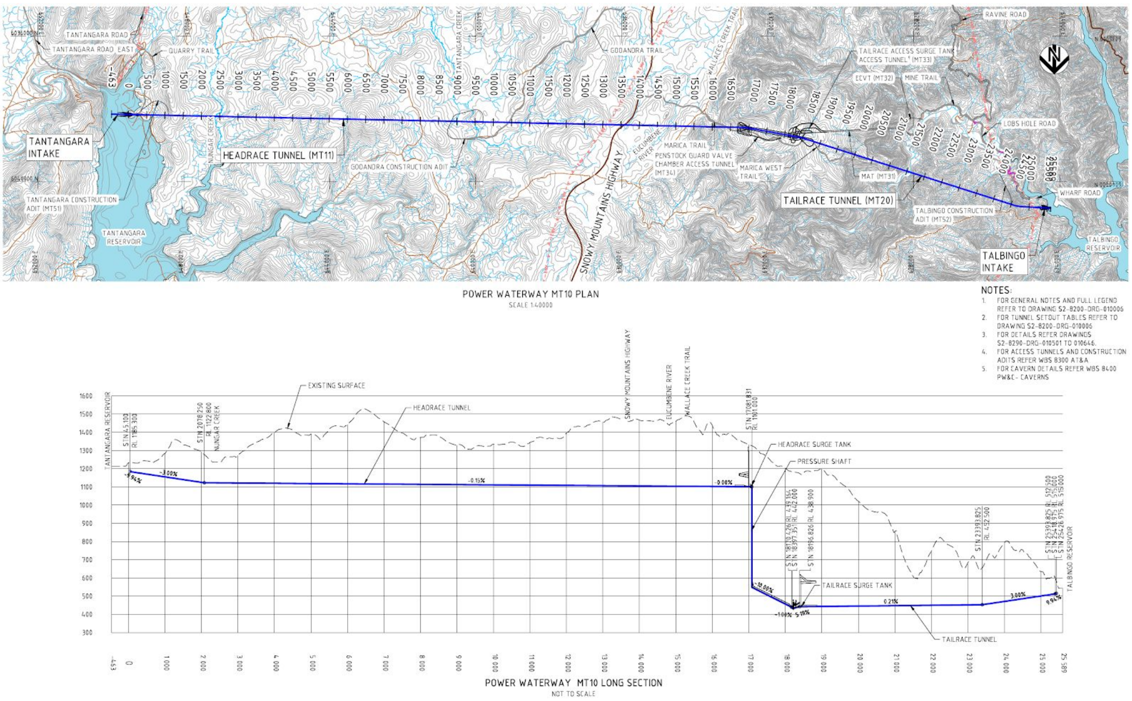

Figure 3: Plan (top) and Long Section (bottom) of the Power Waterway

Tantangara Intake

The intake structure is where water enters the power waterway from Tantangara Reservoir. The Tantangara intake structure will be located towards the southern end of Tantangara Reservoir, on its western shore, about 1 km northwest of Tantangara Dam, as shown on the surface view of Figure 4 and in isometric view on Figure 5.

Key Employer's Requirements for the intake structures shall be:

1. The intake structures shall be located and arranged so as to minimise their visual impact while meeting all technical objectives;
2. Trashracks shall limit the size and quantity of trash and foreign objects entering the power waterway and subsequently the pump-turbines. The trashrack slots must also be capable of accepting stoplogs if maintenance is required on the section of the conduit between this structure and the intake gate.. The trashrack slots must also be capable of accepting

stoplogs if maintenance is required on the section of the conduit between this structure and the intake gate;

3. Intake gates shall be capable of closing into maximum forward flow and shall provide emergency isolation of the waterways in the event of a tunnel leak or failure of other control items in the system as well as providing the capability for isolation for tunnel draining if required as well as providing the capability for isolation for tunnel draining if required;
4. The velocity through the track rack shall not exceed 2 m/s under the most adverse operating condition;
5. Stoplogs shall be used to isolate the intake gates from the reservoir for maintenance purposes;
6. Deployment of a ROV through the ROV shaft shall be provided in the intake gate structure; and
7. The design shall include the ability to lower equipment through the intake shaft to the power waterway tunnel for inspections.

The transition structure consists of a reinforced concrete diffuser structure, which provides the transition from the reservoir to the headrace tunnel. The 66 m long structure is located in an excavation adjacent to the reservoir and comprise:

1. Four bays, each 4.5 m wide by 11.5 m high at the entrance, converging to a square-shaped waterway equal to the tunnel diameter (10.0 m) at the entrance to the power waterway;
2. Diffuser vanes, which separate each bay with the vanes extending along much of the length of the structure and tapering in width; and
3. Trash racks at the upstream end of the structure.

The closure gate for the intake is located within an intake gate structure situated approximately 100 m west of the transition structure. The gate shaft incorporates:

1. A 7.0 m wide and 9.0 m high isolating gate;
2. Provision for installation of stoplogs ‘upstream’ (Tantangara Reservoir side) of the isolating gate;
3. A shaft 3.0 m wide and 7.0 m long, located ‘downstream’ of the shaft (slot) for the isolating gate, for lowering an ROV into the tunnel;
4. A gate chamber at the top of the shaft, with associated equipment for the operation and maintenance of the isolating gate and stoplogs;
5. A storage facility for the stoplogs; and
6. An overflow facility towards the top of the ROV shaft, to provide for surge discharge of water when the gate is lowered into flow.

Figure 4: Surface View of Tantangara intake and intake gate structure after construction

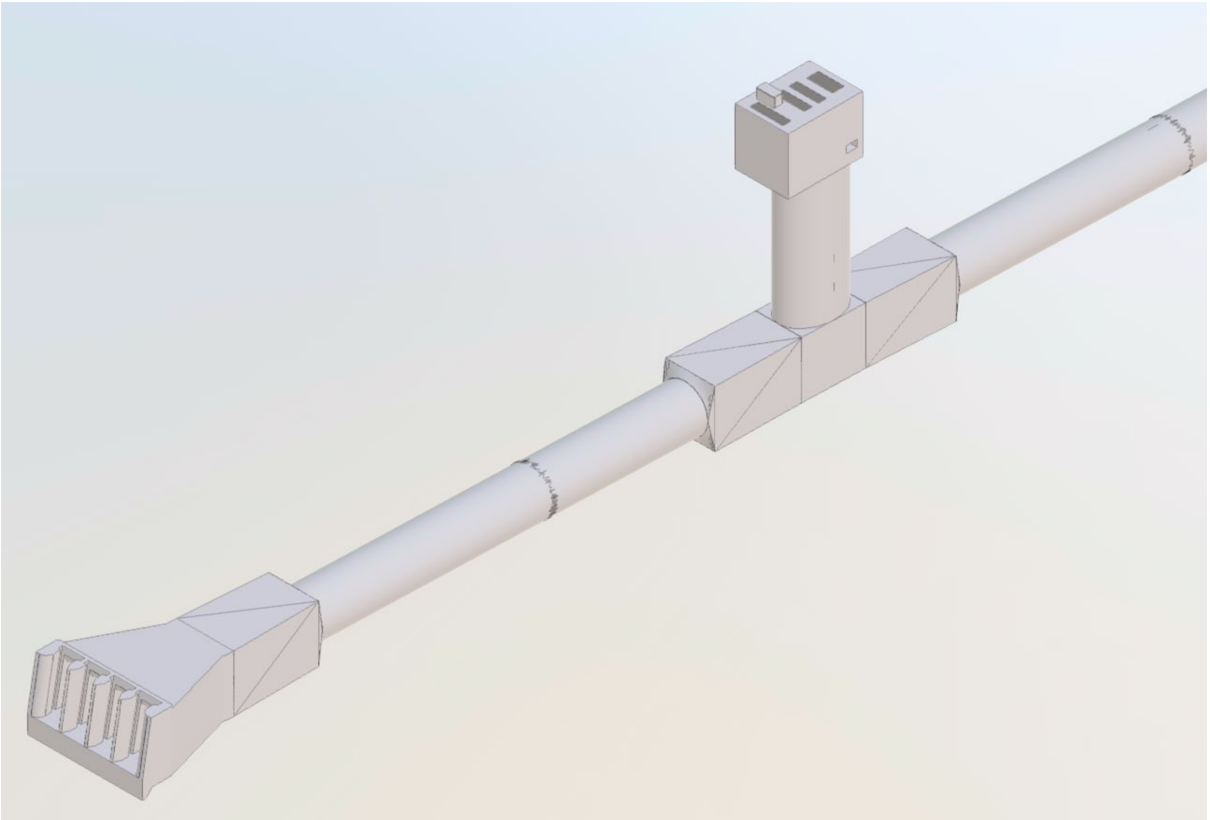

Figure 5: Tantangara intake and intake gate structure

Headrace Tunnel

The Headrace Tunnel links the Tantangara Intake to the Headrace Surge Tank located to the west. The horizontal alignment is predominantly straight. The vertical alignment has a 3% decline for the first 2 km to increase pressure within the headrace tunnel for hydraulic purposes. The remainder of the Headrace Tunnel has a 0.15% slope.

The alignment traverses a number of geological units and associated contacts as well as some identified geological features. The most significant feature is the Long Plain Fault.

A summary of the arrangement is provided in Table 6.

Feature	Value
Internal Diameter	10.0 m minimum
Extent	Ch. 78 to Ch. 16873
Total length	16.8 km
Bearing	Typically, 271˚
Gradient	0.15% and 3%
Depth range (to crown)	50 m to 410 m
Lining	Segmental Precast Concrete and/or Cast in situ Concrete

Table 6: Headrace tunnel geometric features

Distributor Tunnels

The single waterway (headrace) needs to split into three waterways so that separate waterways can service a pair of machine units. This also reduces the size of the high-pressure sections of the waterway to a diameter that is reasonable with consideration to hydraulics and constructability including steel lining thickness.

Separate Headrace Surge Tanks service each Distributor Tunnel. The three Distributor Tunnels connect the Headrace Tunnel, Headrace Surge Tanks and the Pressure Shafts through the PGV Chamber.

Figure 6 shows an isometric view of the arrangement of the Headrace Surge Shafts, Distributor Tunnels and PGV Chamber of the Power Waterway, as adopted in the Reference Design. Alternative arrangements may be proposed by tenderers and accepted by Snowy Hydro during the tender negotiations.

The PGVs being located within an open excavation that crosses all three Distributor Tunnels. In order to reduce leakage from the Distributor Tunnels a portion of the tunnels upstream and downstream of the valve chamber needs to be steel lined (approximately 50 m each side of the valve) to meet the acceptable hydraulic gradient leakage requirements. Downstream of the PGV Chamber, the three Distributor Tunnels continue to the top of the Pressure Shafts.

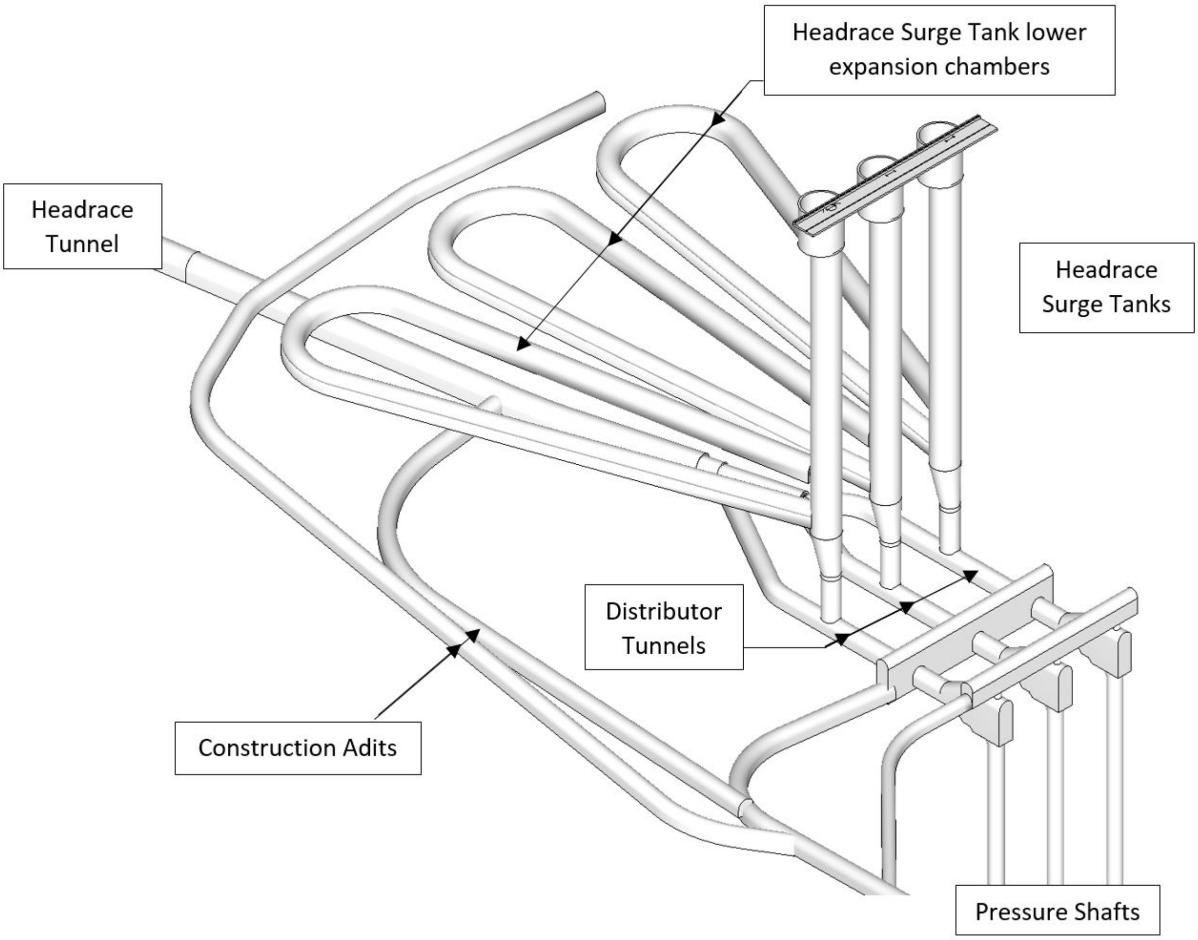

Figure 6: Headrace Surge Tank area, lower expansion chamber tunnels and construction adits are not shown for clarity.

The internal shape of the tunnel is generally circular, however a square to circular transition upstream and downstream of the intersection with the Headrace Surge Tanks are required as the bulkhead gate opening in the surge tank is rectangular.

The Distributor Tunnels vary in length and have a relatively flat grade at approximately EL1100.0. A summary of the arrangement is provided in Table 7.

Feature	Value
Internal Diameters	8.0 m, 6.0 m, 5.4 m
Total length	40.0 m, 274 m, 300 m (614 m total)
Bearing	Typically 280˚ arrow
Gradient	~0%, there will be a slight grade for drainage purposes.
Lining	Cast in situ concrete and steel

Table 7: Distributor tunnel geometric features

Headrace Surge Tank

The Reference Design has three headrace surge tanks, each serviced by a distributor tunnel. The purpose of the surge tanks is to provide a free surface as close as possible to the turbine to attenuate transient pressures caused by operational changes and in emergency rapid shut-downs. During the Reference Design there were concerns with low confining stresses and therefore the design was changed to a design where each paired waterway had its own surge shaft, lower expansion chamber and upper expansion pond. The Feasibility Study design consisted of a single large shaft servicing all units.

For the Reference Design option, a lower expansion chamber for each surge tank is required and provided in the form of an 8.0 m internal diameter tunnel which loops back onto the Headrace Surge Tank at an incline of 4.02% to allow the chamber to drain and vent with a total length of 546.8 m. These lower expansion chambers service the elevations EL1150.0 to EL1180.0.

The Surge Tanks also incorporate a bulkhead gate on the downstream side for isolation of a penstock and its guard valve.

A platform is provided at the top of the shaft of the Headrace Surge Tanks to allow for the operation and maintenance of the mechanical equipment. The platform includes a gantry crane for operating and maintaining the bulkhead gates in each of the surge tanks. The remaining part of the shaft collar forms part of the upper surge expansion ponds to accommodate the extreme upsurges. The ponds have a diameter of 17.5 m and are located between EL1300.0 to EL1320.0. An inspection ROV can also be launched from the pond area.

A summary of the arrangement is provided in Table 8.

Feature	Value
No.	3
Type	Vertical atmospheric orifice cylindrical surge shaft with upper expansion chamber and lower expansion chamber tunnel
Internal Diameter	12.4 m
Invert	EL1100.0
Height	225.0
Lower Expansion Tunnel Size	ID 8.0
Lower Expansion Tunnel Length	546.8 m
Lower Expansion Tunnel Vertical Range	EL1150.0 to EL1180.0
Upper Expansion Chamber Shaft Diameter	17.5 m
Upper Expansion Chamber Range	EL1300 to EL1325.0
Operating Platform Level	EL1325.2
Lining	Cast in situ concrete

Table 8: Headrace surge tank geometric features

Penstock Bulkhead Gate

The Reference Design incorporates the penstock bulkhead gate into the upstream wall of the surge tanks to allow the isolation of one PGV at a time from the surge tanks for inspection and maintenance. Installation of the gate will therefore take two units out of service. Alternative arrangements may be proposed by tenderers and accepted by Snowy Hydro during the tender negotiations.

One bulkhead gate is to be provided together with three sets of embedded parts. The penstock bulkhead gates are at the downstream side of the three individual surge tank orifices. The three surge chambers have been aligned so that the three gates are in a straight line.

A platform above the downstream side of the three surge chambers supports a gantry crane used for the installation and removal of the gates. A summary of the arrangement is provided in Table 9.

Feature	Value
Clear width of opening	4.3 m
Clear height opening	5.4 m
Sill level	EL1,100.000 m
Operating deck level	EL1,320.200 m
Design head	230 m
Estimated weight	72 t
Seal arrangement	Downstream sealing – double stem music note seal

Table 9: Penstock Bulkhead Gate geometric features

PGV Chamber

Waterway isolation valves are located downstream of the Headrace Surge Tank in the PGV Chamber. This isolation location is relatively close to the Power Station Complex so the volume of water between the valve chamber and the power station is relatively small which minimises the duration to dewater and fill the pressure shafts allowing shorter unit outages during machine maintenance. The PGV Chamber is in the low-pressure section of the Power Waterway which means the water pressure design loads acting on bulkhead gates and valves only need to cater for the lower pressures, leading to a more economical design.

The valves are lattice type butterfly valves with a nominal diameter of 4.6 m and a design head of 230 m. The valves provide:

1. Emergency closing into maximum flow for protection; and
2. Dewatering of each pressure shaft for maintenance of the turbine's MIVs, offtakes upstream of the MIVs and maintenance where

required on the pressure shaft. maintenance where required on the pressure shaft.

The valves are capable of being opened by hydraulic oil pressure and counterweight closed to ensure the valve can be closed without power supply. Valve closing will be initiated automatically by detection of penstock over-velocity or in the case of flooding of the Power Station Remote closing via the station control system will also be possible, Valve opening will only be possible in from the valve chamber in local manual mode.

A summary of the arrangement is provided in Table 10.

Feature	Value
Number of valves	3
Type	Lattice butterfly
Inner valve diameter	4.6 m
Capacity	The system shall be capable of two complete open/close cycles without power supply to the pumps.

Table 10: PGV geometric features

High-pressure Shafts

The pressure shafts convey the water vertically from the end of the Distributor Tunnel to the start of the high-pressure tunnels. Key Employer's Requirements for the pressure shaft structures are:

1. A minimum of three pressure shafts shall be provided to ensure that the maximum loss of generation capability in the event of a guard valve actuation is one third of installed capacity;
2. The pressure shafts shall be accessible from the top by:
    a. platform to facilitate dewatered inspection and maintenance by personnel; and
    b. Unmanned underwater vehicle to undertake inspections when the pressure shafts are filled with water.

An isometric view of the pressure shaft arrangement adopted for the Reference Design is shown on Figure 7. The top of the shaft is located at EL1105.4 (invert at the top is EL1100 and the bottom of the shaft is located at EL548.0. The Pressure Shafts are approximately 560 m high and are vertical. Inclined shafts were explored but were abandoned for the Reference Design due to constructability and expected geological conditions. The Contractor may propose an alternative arrangement with inclined shafts if geological conditions are favourable or offer cost savings. A Pressure Shaft Inspection Chamber is provided over the elbow at the top of the Pressure Shaft to allow for a man cage to be lowered for inspections and minor repairs.

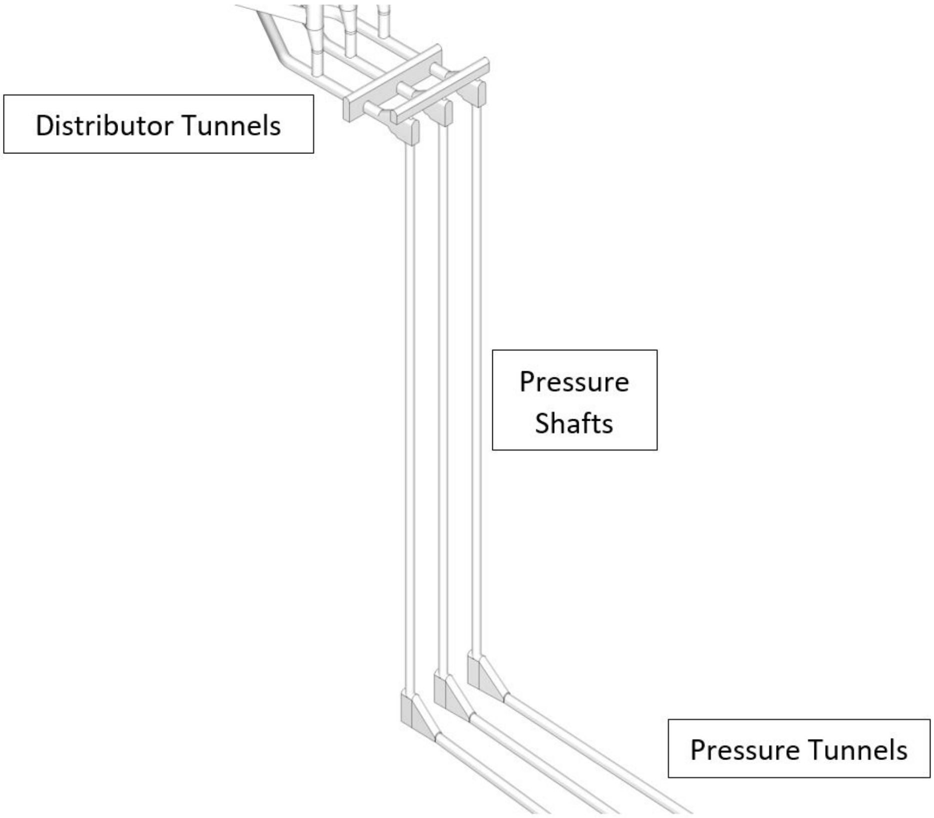

Figure 7: Pressure Shafts

A summary of the arrangement is provided in Table 11.

Feature	Value
No.	3
Internal Diameter	5.4 m
Total Height	557.4 m
Top of Shaft	EL1105.4
Bottom of Shaft	EL548
Inclination	90˚
Lining	Cast in situ concrete (top bend will be steel)

Table 11: Pressure Shaft geometric features

Pressure Tunnels and Penstocks tunnels

The three High-Pressure Tunnels, shown in the isometric view of Figure 8, connect the bottom of the three Pressure Shafts to six Penstock Tunnels through three bifurcations. The Pressure Tunnels are predominantly concrete lined with part of the Pressure Tunnel and Penstock Tunnels steel lined to minimise the risk of leakage from the waterway into the Power Station Complex and prevent hydrojacking. This has been controlled by ensuring there is an acceptable hydraulic gradient between the upstream end of the steel liner and any permanent open excavation (ie Power Station Complex and Access Tunnels).

The steel wye bifurcates split the flows in each of the Pressure Tunnels to two Penstock Tunnels of 2.7 m internal diameter. A taper to diameter 2.2 m is provided just upstream of the Machine Hall to transition to the final inlet pipe and MIV diameter. The High-Pressure and Penstock Tunnels are graded at 10% down towards the Power Station Complex for drainage purposes and to reduce the height of the Pressure Shafts.

The Pressure Tunnels have increased in length compared to the Feasibility Study due to the change in the location of the Power Station Complex. This increase in length has been offset by a shortening of the MAT, ECVT and Tailrace Tunnel.

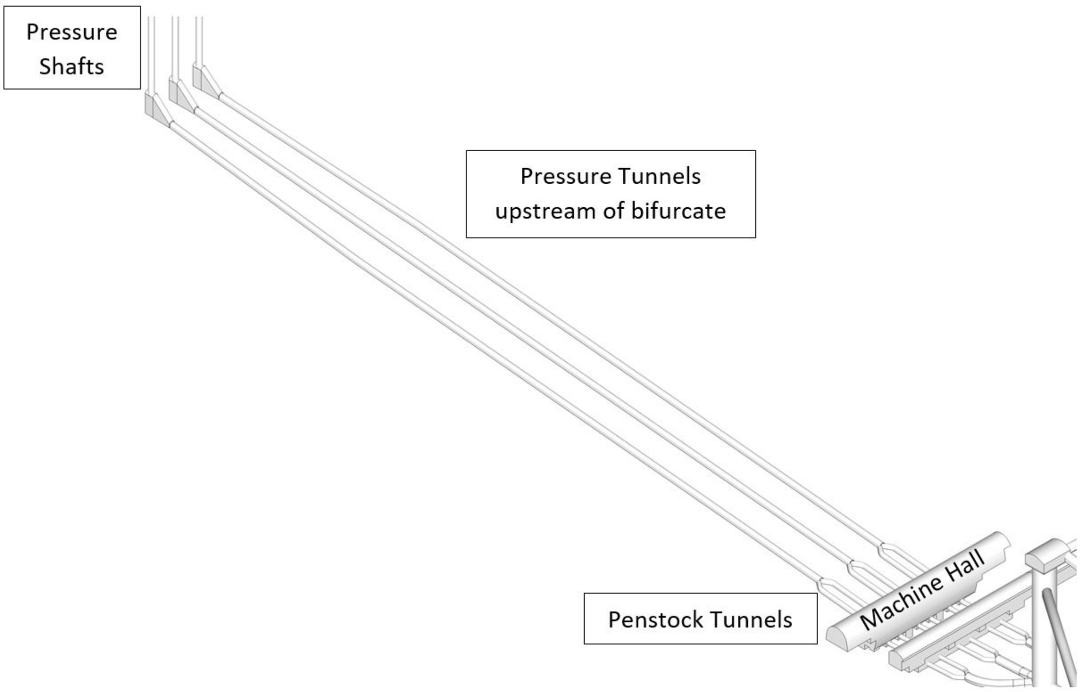

Figure 8: Pressure Tunnels and Penstock Tunnels

A summary of the Pressure Tunnels and Penstock Tunnels arrangement is provided in Table 12 and in Table 13, respectively.

Feature	Value
No.	3
Internal Diameters	5.4 m (conc.) 4.8 m (steel)
Length (each)	909.3 m (conc.) 110.7 m (steel)
Bearing	280
Inclination	-10%
Lining	Cast in situ concrete and steel

Table 12: Pressure tunnel geometric features

Feature	Value
No.	3
Internal Diameters	2.7 m transitioning to 2.1 m (steel)
Length (each)	93 m (steel)
Bearing	280
Inclination	-10%
Lining	Steel

Table 13: Penstock tunnel geometric features

Draft tube tunnels and collector tunnels

The six Draft Tube Tunnels connect the draft tube elbow below the pump-turbines to the downstream bifurcates upstream of the Tailrace Surge Tank. The Draft Tube Tunnels pass through the DTV Gallery at the bottom of the Transformer Hall Draft Tube Gallery. The Draft Tube Tunnels have an internal diameter of 3.5 m and are steel lined. Figure 9 shows an isometric view of the Draft Tube and Collector Tunnel arrangement developed in the Reference Design.

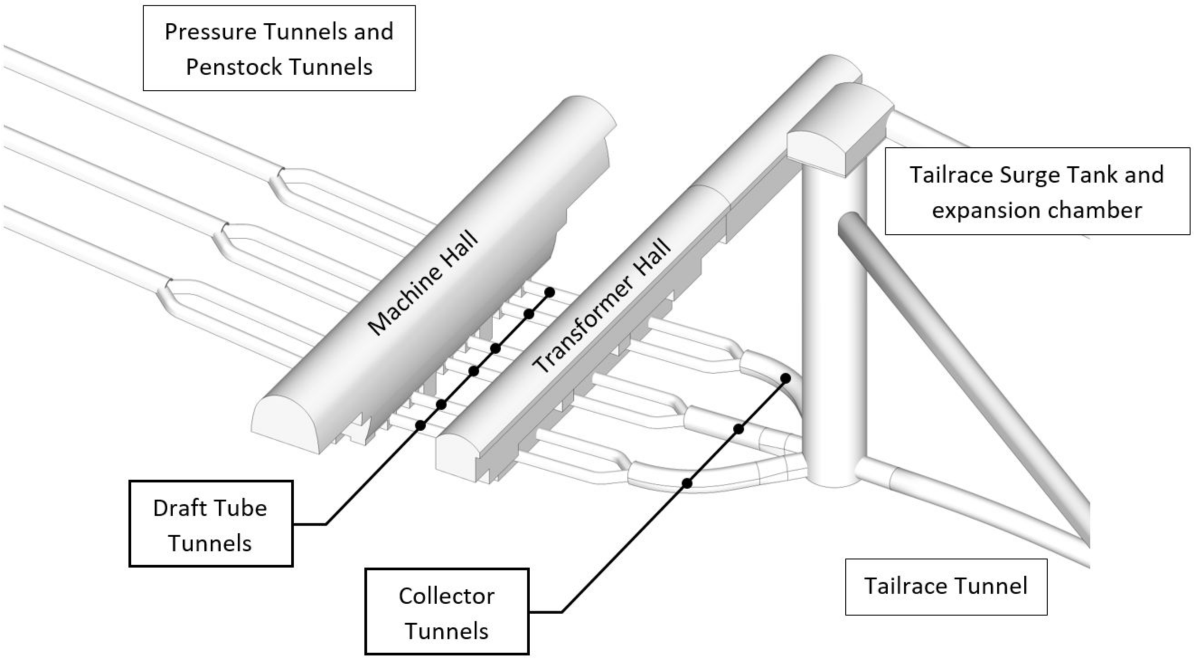

Figure 9: Draft Tube Tunnels and Collector Tunnels

A summary of Draft Tube Tunnel arrangement is provided in Table 14.

Feature	Value
No.	6
Internal Diameters	3.5 m
Length (each)	127 m to bifurcate (inclusive of DTV gallery)
Bearing	Predominant 280˚
Inclination	5%
Lining	Steel

Table 14: Draft tube tunnel geometric features

The Collector Tunnels convey the water from the six DTVs and then into three Large Collector Tunnels which then connect to the base of the Tailrace Surge Tank. The Collector Tunnels, including the bifurcate, are concrete lined and sized to limit velocities to minimise risk of concrete lining being scoured (ie velocities less than 6.0 m/s).

A summary of the Collector Tunnel arrangement is provided in Table 15.

Feature	Value
No.	3
Internal Diameter	5.4 m
Length	56.2 m (U3/4), 73.5 (U1/2, U5/6)
Bearing	Varies
Gradient	6.3% (U3/4), 5% (U1/2, U5/6)
Lining	Concrete

Table 15: Collector tunnel geometric features

Tailrace surge tank

A Tailrace Surge Tank is located downstream of the DTV Gallery. It provides a free surface close to the turbine to minimise the transient pressures due to machine operation (ie load acceptance and load rejection), and therefore reduce the internal pressures experienced by the Tailrace Tunnel lining and regulate pressure fluctuations in the tailrace.

The base of the Tailrace Surge Tank acts as a trifurcation as it receives the three upstream collector tunnels and converges them into the downstream Tailrace Tunnel. This junction is connected vertically to the Tailrace Surge Tank above through orifices at the diaphragm floor level at EL467.3.

A summary of the arrangement is provided in Table 16. The Tailrace Surge Tank is shown in Figure 9.

Feature	Value
No.	1
Type	Vertical atmospheric orifice cylindrical surge shaft with upper expansion chamber tunnel
Internal Diameter	23.4 m
Invert	EL442.0
Height	159.0
Expansion Tunnel Size	ID 8.0
Expansion Tunnel Length	830 m
Expansion Tunnel Vertical Range	EL560.0 to EL580.0
Operating Platform Level	EL601.0
Lining	Cast in situ Concrete

Table 16: Tailrace surge tank geometric features

A Collector Tunnel Bulkhead Gate on the upstream side of the Tailrace Surge Tank will allow isolation of one Collector Tunnel and two DTVs for maintenance and inspection at a time. The selected gate is a slide gate which can be operated in balanced conditions.

A summary of the arrangement is provided in Table 17.

Feature	Value
Clear width of opening	5.4 m
Clear height opening	5.4 m
Sill level	431.3 m
Operating deck level	600 m
Design head	180 m
Seal arrangement	Upstream (power station side) sealing – double stem seal

Table 17: Collector Tunnel Bulkhead Gate geometric features

Tailrace Tunnel

The Tailrace Tunnel alignment links the Tailrace Surge Tank, located downstream of the Power Station Complex, to the Talbingo Intake. The horizontal and vertical alignments are predominantly straight. A summary of the Tailrace Tunnel arrangement is provided in Table 18.

The Reference Design Tailrace Tunnel length is significantly shorter than Feasibility Study due to the relocation of the Power Station Complex and shifting of the Talbingo Intake to the Middle Bay location.

Feature	Value
Internal Diameter	10.0 m
Extent	Ch. 18397 to Ch. 25393
Total length	7.0 km
Bearing	Typically, 288 degrees
Gradient	0.06% to 3.0%
Lining	Segmental Precast Concrete and Cast in situ Concrete

Table 18: Geometric features of tailrace tunnel

Talbingo Intake

The Talbingo Intake Structure is situated near the upstream end of Talbingo Reservoir on its eastern side, about 17 km south of Talbingo Dam, where the Yarrangobilly River and Middle Creek flow into the storage.

Key relevant Employer's Requirements are provided in the *Tantangara Intake* section.

A relatively short approach channel of about 100 m length is required. The layout and features of Talbingo Intake Structure and Intake Gate Structure is as for the Tantangara Intake Structure except that the shaft is appreciably longer due to the steep topography, rising to an elevation of EL595.0 or about 50 m above FSL. Figure 8 shows a birdseye view of the Talbingo Intake Structure and Intake Gate Shaft. An isometric view with the topography omitted is shown in Figure 11.

Figure 10: Surface View of Talbingo intake and intake gate structure

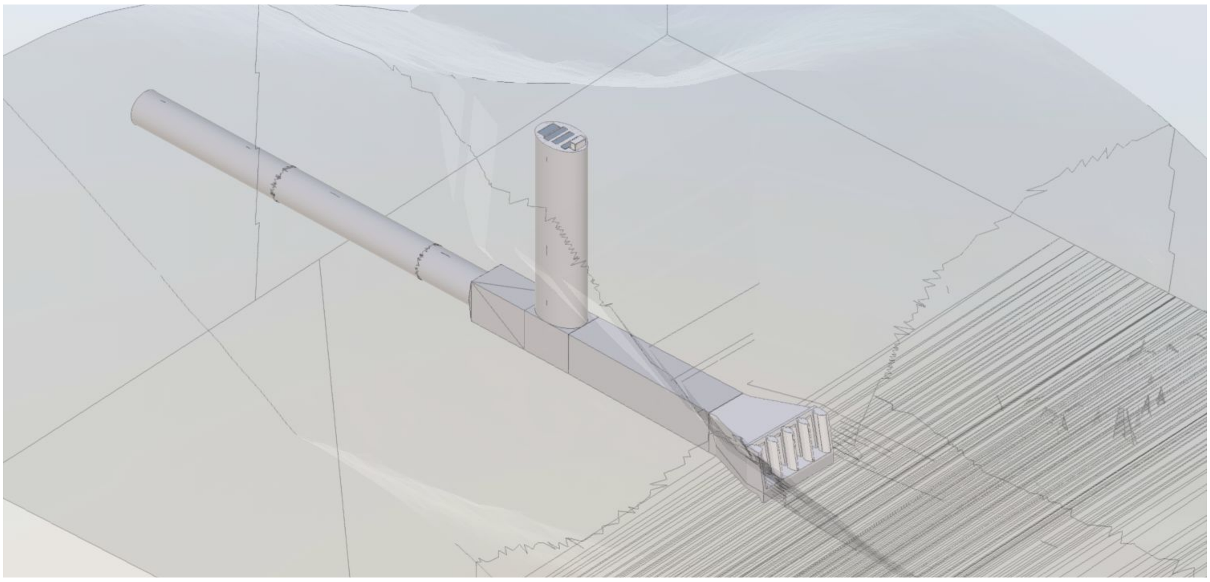

Figure 11: Isometric view of Talbingo intake and intake gate structure

Figure 12: Cross-sectional view of Talbingo intake and intake gate structure

As for the Tantangara Intake Structure, the Talbingo Intake Structure is fitted with trash racks which limit the size and quantity of trash and foreign objects entering the power waterway and pump-turbines. Attached to the trash racks are slots to install stoplogs if maintenance is required on the conduit section between the trashracks and intake gate and also provide slots to install stoplogs if maintenance is required on the conduit section between the trashracks and intake gate.

An Intake Gate is provided in the Intake Gate Structure which is capable of closing into maximum flow and provide an emergency isolation of the waterways in the event of a tunnel leak or failure of other control item in the system and provides to capability to isolate the tunnel for draining if needed and provides to capability to isolate the tunnel for draining if needed. Stop logs are also provided downstream of the Intake Gate to isolate the tunnels from the reservoir for maintenance of the gate.

5.3.3 Access Tunnels

The key objective of the access tunnels is to provide efficient and safe access to permanent infrastructure. For construction adits, the objective was to provide a safe temporary access to allow for the construction of the permanent infrastructure. A plan of the MAT and ECVT is shown in Figure 13.

Access Tunnel	Size (w × h, m)	Length (m)	Grade (%)
MAT (main access to station)	8.25 × 8.0	3070	Generally 6
MAT 2 (access to other end of station, from MAT)	8.25 × 8.0	369	3
ECVT	8.5 × 9.5	3550	<6
PGV Chamber Access Tunnel	6.0 × 6.6	995	11.5
Pressure Shaft Inspection Chamber Access Tunnel	7.0 × 7.0	137	0.44
Tailrace Surge Tank Access Tunnel	6.0 × 6.6	780	14.7
DTV Gallery Access Tunnel	8.0 × 8.0	543	12.1

Table 19: Summary of Access Tunnels

Main Access Tunnel

The MAT is the primary access conduit to the Power Station Complex during operation. As per the Employer's Requirements it shall be sized to cater for all construction, operation and maintenance activities and must be capable of accomodating:

1. All equipment and plant required to enter the station; and
2. Services including water pipework, lighting and ventilation ducts.

The development of the MAT follows the principles of optimising tunnel length to minimise cost, programme and maintenance.

With the Power Station Complex located at Ravine West, the Reference Design MAT grade is generally 6% with some sections of 1% for braking bays and flat approaches to the portal and Power Station Complex. The Reference Design MAT is 3,070 m long and intersects the Transformer Hall at operating floor level at EL457.0. The cross-section of the MAT is expected to be a D-shape, 8.25 m wide by 8.0 m high.

As the MAT approaches the cavern it branches into two tunnels so as to permit vehicular access to both assembly bays. Both tunnels are sized to facilitate the removal of all items of plant and equipment.

During the Feasibility Study, Snowy Hydro required access to the Power Station Complex from the Snowy Mountains Highway. To achieve this, the MAT portal was located along Marica Track at approximately EL1200.0. This arrangement resulted in a long declining access tunnel some 6.5 km long. After the Feasibility Study, Snowy Hydro reassessed this requirement and decided that a MAT located in the Ravine area, around the Yarrangobilly and Stable Creek confluence, would be acceptable.

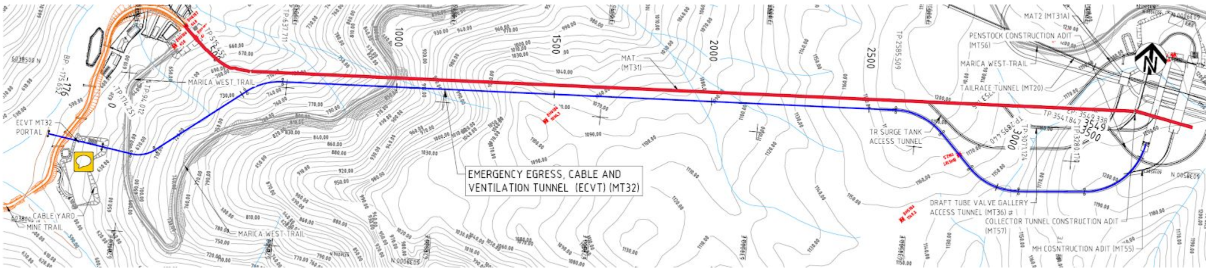

Figure 13: Plan of MAT (red) and ECVT (blue).

As per the Employer's Requirements, the portal of the MAT also accommodates a building complex and other infrastructure that services the Power Station Complex, water tanks and a water treatment plant.

Emergency Egress, Cable & Ventilation Tunnel

As per the Employer's Requirements, the ECVT is sized to be sufficient for all construction activities. Permanent equipment such as high voltage cables must be capable of accommodating any equipment or plant only able to enter the station via this route. Permanent power station equipment and plant need to be able to be routed through the MAT.

The ECVT also serves the following particular functions:

1. Conduit for power evacuation;
2. Alternative to MAT for egress in emergency situations;
3. Ventilation conduit; and
4. Dewatering conduit.

The ECVT portal is located near the confluence of the Yarrangobilly River and Stable Creek. This location was selected due to ease of power evacuation from this location. The location has been coordinated with TransGrid and is therefore fixed, regardless of the remaining scheme arrangement.

The ECVT portal platform is located at EL601.5 and is above the major Yarrangobilly flood levels. From there the ECVT Portal heads in an easterly direction and after 100 m turns left (to the North) towards the MAT alignment. At approximately CH 600.0 the alignment turns to the right and heads in an easterly direction and is parallel, both horizontally and vertically, to the MAT. At approximately CH 2650 the ECVT turns away from the MAT before turning back to meet the top of the GIS hall squarely at EL467.0. The ECVT is approximately 3,550 m long. The cross-section of the ECVT selected in the Reference Design is a D-shape, 8.5 m wide by 9.5 m high. The maximum gradient of the ECVT does not exceed 10%.

During the Reference Design, the ECVT alignment was parallel to the MAT to assist with constructability (flexibility of additional tunnel, second tunnel can be excavated quickly) and operability (fire and life safety zoning of the tunnels, optimised drainage).

As per the Employer's Requirements, equipment supporting the Power Station Complex is located at the tunnel portal including ventilation equipment, security, and emergency power generators and fuel.

Other Access Tunnels

PGV Chamber Access Tunnel

The PGV Chamber Access Tunnel provides permanent access to the PGV and Pressure Shaft Inspection Chamber. The Marica construction adit is also connected to the PGV Chamber Access Tunnel to provide construction access to the downstream end of the Headrace Tunnel, Distributor Tunnels and bottom of the Headrace Surge Tanks.

Pressure Shaft Inspection Chamber Access Tunnel

The Pressure Shaft Inspection Chamber Access Tunnel connects the PGV Chamber Access Tunnel with the Pressure Shaft Inspection Chamber. It starts at approximately CH 800.0 on the PGV Chamber Access Tunnel at an invert elevation of EL1119.4 and heads in a southerly direction to meet the Pressure Shaft Inspection Chamber end squarely at EL1120. It is approximately 137.0 m long and graded slightly upwards towards the inspection chamber at 0.44% to allow for gravity drainage of the Pressure Shaft Inspection Chamber excavation. The cross-section of the Pressure Shaft Inspection Chamber Access Tunnel shown on the Reference Design is 7.0 m wide by 7.0 m high.

Tailrace Surge Tank Access Tunnel

The Tailrace Surge Tank Access Tunnel provides construction and permanent access to the top of the Tailrace Surge Tank from the MAT. The tunnel starts at approximately CH 2510.0 on the MAT at EL491.0 and heads in a southerly-easterly direction. After 150 m, it turns to the left and heads in a westerly direction followed by an approximately 250 m long straight length of tunnel before sweeping up over the MAT to the Tailrace Surge Tank to meet the chamber end squarely at EL600.0. It is approximately 780 m long and graded upwards towards the Tailrace Surge Tank Chamber at 14.7%. Although relatively steep, this is considered appropriate given the relatively short length and the likely operational use of the equipment in the Tailrace Surge Tank. The cross-section of the Tailrace Surge Tank Chamber Access Tunnel of the Reference Design is 6.0 m wide by 6.6 m high.

DTV Gallery Access Tunnel

The DTV Gallery Access Tunnel connects the MAT to the bottom of the transformer hall cavern to facilitate the installation, operation and maintenance of the DTVs. This tunnel starts at CH2752.0 at EL479.1 on the MAT and slopes down to the DTV gallery at approximately to 12.1% to EL431.44. The tunnel is 543.4 m long. This length may be increased to flatten out the slope of the tunnel if found to be unsatisfactory through further design development. However, clearances below the penstock construction adit needs to be considered. During the construction phase, this tunnel will be important in the construction of all low level areas of the Power Station Complex, the upstream end of the Tailrace Tunnel and the Tailrace Surge Tank. The cross section of the DTV Gallery Access

Tunnel is expected to be D-shaped, 8.0 m wide by 8.0 m high to suit meet the construction requirements. The tunnel cross section dimensions may be reduced downstream of the intersection with the Collector Tunnel construction adit to maximise the cover between the tunnel crown the Transformer Hall.

5.3.4 Power Station Complex

General

As per the Employer's Requirements the Power Station Complex shall be a drained, underground facility comprising:

1. A machine hall cavern housing six pump-turbine units;
2. A transformer hall cavern housing six transformers; and
3. A cavern for housing GIS.

The complex shall manage water ingress to ensure that all areas are maintained in a dry state. The complex shall include adequate space and be designed to enable the upgrading of synchronous units to asynchronous units at a later date.

Location Layout

During the Feasibility Study, two power station location options were investigated: the Ravine Base Case and the Plateau Option. The Plateau Option was ruled out in the early phases of the Reference Design for a number of reasons including:

1. Long access tunnels – the MAT was 7.53 km long and the ECVT was 8.65 km long for the Plateau Option, thus considerably longer than the same tunnels for Ravine and Ravine West.;
2. Increased construction time due to the length of the access tunnel;
3. Increased construction cost due to access tunnel lengths (excavation, ventilation, HV cables, lighting);
4. Increased operational cost due to longer tunnels (ventilation, seepage inflows, increased drainage pumping effort);
5. Reduced safety both during construction and operation due to longer access tunnels;
6. Additional geological investigations for both Ravine and Ravine West indicated rock conditions which are not less favourable than for the Plateau Option;
7. Access Shaft required for the construction of the Plateau Option would be slow, expensive and would be required to be plugged after construction. Also increased risk of undesirable additional seepage inflow; and
8. MAT, ECVT and waterway (tailrace tunnel) also need to cross the Long Plain Fault. Ravine and Ravine West only have the power waterway (headrace tunnel).

	FS Ravine (with MAT from Ravine)	Plateau
MAT Length	4.6 km	7.53 km
ECVT Length	4.25 km	8.65 km

Table 20: Comparison of access tunnel lengths between Feasibility Study Design and Plateau

The Plateau option was therefore abandoned for the Reference Design.

Ravine West was considered as an option during the Feasibility Study. The purpose of investigating Ravine West as an option was to reduce the construction programme critical path which encompasses the Power Station Complex. By shifting the Ravine base case power station complex westward and with both MAT and ECVT portals in the Ravine area, from a Power Station Complex perspective, the length of the Access Tunnels reduces significantly. By reducing the lengths of the Access Tunnels, a direct reduction of the construction programme was achieved due to shorter access tunnel lengths and allowing the construction of the Power Station Complex to start earlier. The Headrace Surge Tank location remained unchanged due to it being constrained by topography.

The extent to which the Power Station Complex can be shifted westward is dependent on:

1. Power Station Complex and adjoining Power Waterway Tunnel confinement and safety from hydrojacking; and
2. Adequate management of hydraulic transients in the power waterway; and
3. Adequate management of hydraulic transients and associated effects on facility designs and performance.

The Ravine West option was adopted for the Reference Design.

A number of changes to the overall Power Station Complex arrangement have been implemented since the completion of the Feasibility Study. These changes included::

1. MAT approaching from the downstream direction;
2. Provision of two MATs into the Transformer Hall and Machine Hall;
3. Paired machine units; and
4. End assembly bays (instead of assembly bays in the centre of the Machine Hall).

	FS Ravine (with MAT from Ravine)	Ravine West
MAT Length	4.6 km	3.07 km
ECVT Length	4.25 km	3.55 km

Table 21: Comparison of access tunnel lengths between Feasibility Study Design and Ravine West

Layout

As per the Employer's Requirements, the adopted layout shall be subject to a space-proofing assessment undertaken in conjunction with the E&M Contractor to demonstrate to the Employer that the following requirements have been achieved:

1. Adequate space for all mechanical and electrical equipment;
2. No single points of failure;

3. Maintenance of plant can be undertaken without requiring the disassembly of non-associated generation equipment;
4. All plant is provided with access that will facilitate periodic inspection, maintenance and testing; and
5. All machine bays are provided with access hatches to allow equipment to be moved by the main station overhead crane through all levels of the station.

An isometric of the Power Station Complex showing the main structural elements is shown in Figure 14.

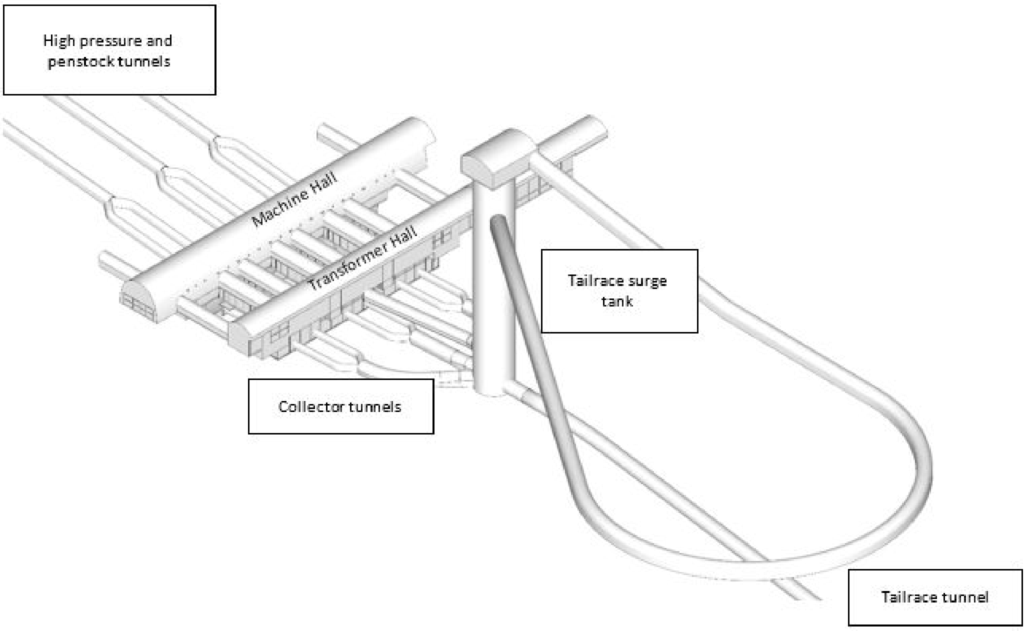

Figure 14: Isometric view of Power Station Complex

Machine Hall

General

The Machine Hall houses the six pump-turbine and motor-generator units. Each unit consists of a 340 MW Francis pump-turbine and a 375/425 MVA motor-generator and their ancillary systems. Three of the units are variable-speed (asynchronous) and three are fixed-speed (synchronous), arranged in a way that the three pressure tunnels are connected to one variable-speed and one fixed-speed unit. During generation, water enters the Machine Hall via the upstream Penstock Tunnels and exits through the downstream Draft Tube Tunnels (vice-versa for pumping mode). MIVs are provided on the six upstream Penstock Tunnels within the Machine Hall. Isolating valves are located in the downstream Draft Tube Tunnels beneath the Transformer Hall. The Machine Hall includes various control rooms and space for communication and power equipment, amenities and drainage and dewatering equipment.

The Machine Hall structure is primarily made of reinforced concrete, mass concrete and structural steel. Access into the Machine Hall is primarily through the MAT which is connected to end unloading bays on the downstream side of the Machine Hall.

Longitudinally, the Machine Hall structure comprises 14 distinct bays, two unloading bays, two assembly bays, six machine bays and four service bays (two end and two central). The Machine Hall is a maximum length of 248.0 m at the crown of the Machine Hall and generally 152.0 m long below the operating floor.

The Machine Hall cavern has a maximum width of 32.8 m and measures 26.5 m between the main station crane beams.

Vertically, the Machine Hall structure comprises seven floors. The overall height of the Machine Hall may vary dependending on the final cavern geometry to suit the geological rock conditions, The current arrangement of the Reference Design has a maximum cavern height of 55.4 m.

The entire Machine Hall is serviced by the main station crane to assist with the installation and maintenance of plant. The 2 x 280 t electric overhead travelling (***EOHT***) crane consists of two bogies and a hook clearance to the operating floor of about 10 m.

As per the Employer's Requirements, the Machine Hall shall:

1. Be able to be accessed at both ends from either branch of the MAT;
2. Incorporate assembly bays at each end with the access tunnel aligned along the edge furthest from the generating plant;
3. Provide a hydraulic layout of the plant that is symmetric; and
4. Provide a unitised arrangement whereby all associated auxiliary equipment is located within the same bay.

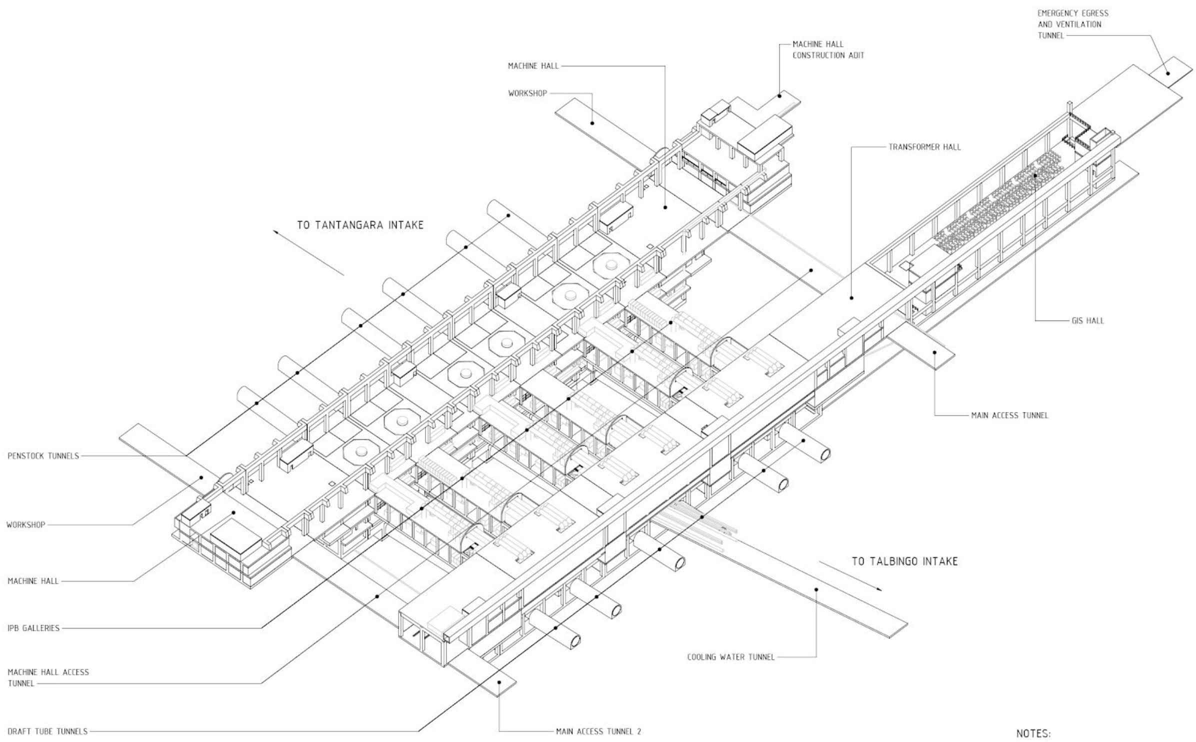

Figure 15: Isometric view of Power Station Complex structure

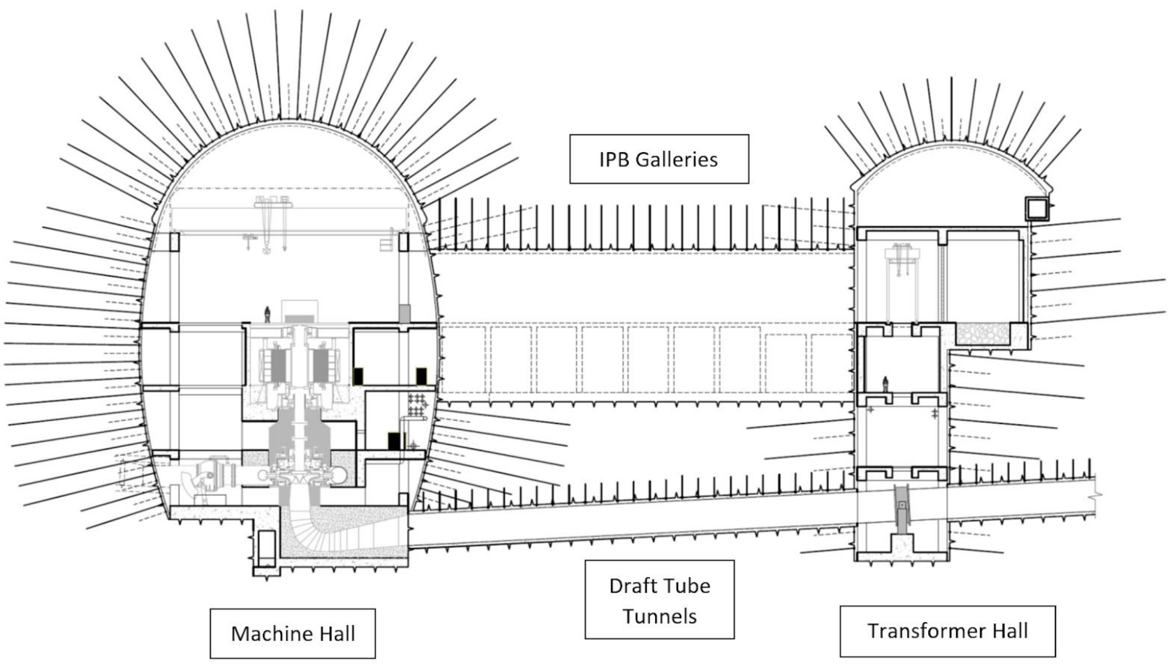

Figure 16: Cross Section of Power Station Complex

Pump-turbine units

A station configuration with three synchronous and three variable-speed units was adopted from the Feasibility Study. This combination provides the benefit of the variable-speed units for pumping mode and allows the full range of loads to be accommodated for pumping mode to allow maximum flexibility to utilise any available load in the power grid for pumping.

Three units were chosen as the most cost-effective way of accessing the flexibility of the variable-speed units. However, to allow flexibility for the synchronous units to be upgraded in the future to asynchronous units, the embedded parts of the turbines are to be identical.

Turbine governors

Six sets of automatic governor systems will be supplied for the units. The system is to be controlled by a PLC-based Digital Electronic Governor (***DEG***) which is integrated into the unit control system.

The digital processor will have Proportional Integral Derivative (***PID***) functionality for regulation of either power or frequency, as well as for control of start and stop routines.

For the synchronous units, the Snowy Hydro standard governor control logic will be implemented. For the asynchronous machines, a derivative of the Snowy Hydro standard governor logic shall be implemented. The DEG and Optimiser for the asynchronous units in generation mode will automatically adjust the speed set-point so that the unit is operated at maximum efficiency for a specific power output.

Main inlet valves

One spherical MIV will be provided for each unit. The MIV will operate as part of the normal start-up and shutdown sequence and during mode changes to and from synchronous condenser mode.

Design pressure will be approximately 1,100 m, the diameter is specified to be DN 2200, and mean flow velocity across the valve will be about 18 m/s at maximum turbine discharge of 68 m^3/s.

The MIV will be opened by hydraulic oil pressure actuated servo motor or servo motors and closed by counterweight. The hydraulic oil system will be a high-pressure system with nitrogen/oil piston accumulators to maintain sufficient pressure oil for two full opening strokes of the MIV without operation of the hydraulic pumps. The MIV will be capable of closing in an emergency into free discharge under maximum head.

Motor-generators

Variable-speed motor-generators

Three, vertical shaft, variable-speed (asynchronous) motor-generators will be provided for the Project. The motor-generators would be directly connected to the turbine pump via an intermediate shaft.

The variable-speed motor-generators would consist of a Doubly-fed Induction Motor-generator (***DFIM***) with a conventional stator and a set of three-phase slip rings supplying alternating current (***AC***) to a wound rotor.

The motor-generators will be totally enclosed, self-ventilated, with air–water heat exchangers. It is expected that the variable-speed motor-generator rotor will be supported by a combined lower guide / thrust bearing and an upper guide bearing, however, the arrangement of bearings will be finalised in coordination with the motor-generator supplier.

A summary of the variable-speed motor-generator features is provided in Table 22.

Feature	Value
Rated output at generator terminals	375 MVA
Overload capacity as generator	As specified for Pump-Turbine
Rate pump shaft power (maximum speed)	362 MW
Rated power factor in pumping and generating mode	0.9
Rated voltage	18 kV (assumed for the rating of the unit)
Rated frequency	50 Hz
Rotor lifting weight	525 t

Table 22: variable-speed motor-generator features

Fixed-speed motor-generators

Three, vertical shaft, fixed-speed (synchronous) motor-generators will be provided for the Project. The motor-generators will be salient pole, single-speed machines directly connected to the pump-turbine. Each motor-generator will be capable of the following operating modes:

1. Synchronous generator mode;
2. Synchronous condenser mode in generator rotational direction;
3. Synchronous motor mode; and
4. Synchronous condenser mode in motor rotational direction.

The motor-generators will be totally enclosed, self-ventilated, with air–water heat exchangers. It is expected that the motor-generator rotor will be supported by a combined lower guide/thrust bearing and an upper guide bearing, however, the arrangement of bearings will be finalised in coordination with the motor-generator supplier.

It is considered advantageous that the stator for the synchronous motor-generator and the variable-speed motor-generator is the same to enable future replacement of fixed-speed unit to variable-speed unit.

Three, static frequency converters (***SFC***), one per motor-generator, will be provided for the synchronous motor-generators for starting the machines in motor mode.

A summary of the variable-speed motor-generator features is provided in Table 23.

Feature	Value

Rated output at generator terminals	375 MVA
Overload capacity as generator	As specified for Pump-Turbine
Rate pump shaft power (maximum speed)	362 MW
Rated power factor in pumping and generating mode	0.9
Rated voltage	18 kV (assumed for the rating of the unit)
Rated frequency	50 Hz
Rotor lifting weight	500 t

Table 23: Synchronous motor-generator features

Isolated-phase Busduct Galleries

General

The IPB Galleries connect the Machine Hall to the Transformer Hall and contain electrical equipment required between the motor-generators and the main transformers.

The IPB galleries consist of two floors generally aligned with the machine hall generator floor and operating floor. Six IPB galleries are provided, one for each unit. The 10 m wide and 17.8 m high galleries are aligned in a straight line between the Machine Hall and Transformer Hall and perpendicular to the hall alignments.

The IPB galleries are accessed from the Machine Hall on the operating and generator floors and from the Transformer Hall from an access gallery below the main transformers. Provision for pedestrian access between the two halls is made in the IPB Galleries.

Generator Voltage Equipment

Generator voltage equipment for all motor-generator units will consist of the IPB assemblies, including the following:

1. Main IPB connections;
2. Generator circuit breakers and isolators;
3. AC excitation input side circuit breakers (asynchronous units only);
4. Phase reversal switches;
5. Stator short-circuiting equipment; and
6. Unit auxiliary and excitation transformers.

Transformer & GIS Hall

The Transformer Hall layout is primarily dependent on the arrangement of the main transformers with one three-phase transformer per unit provided in the Reference Design. After the Feasibility Study, Snowy Hydro decided that GIS will be incorporated into the Power Station Complex. The Reference Design has located the GIS into an extension of the Transformer Hall, however placing the GIS directly over the main transformers has not been specifically precluded.

The bottom of the Transformer Hall incorporates the DTV gallery. This area houses the draft tube butterfly valves, which are the primary point of isolation of the Machine Hall from the tailwater of Talbingo Reservoir.

Access to the Transformer Hall is via the MAT which approaches from the downstream side. The MAT splits into two tunnels as it approaches the Transformer Hall, to provide access at both ends. These two MAT tunnels then continue through the Transformer Hall towards the Machine Hall.

The Transformer Hall cavern is 19.0 m wide, 45.0 m high and 205.2 m long.

The GIS Hall is 19.0 m wide, 90.1 m long and approximately 24.0 m high.

As per the Employer's Requirements the Transformer Hall shall:

1. Be accessible at both ends from either branch of the MAT. Each path shall be capable of accommodating the loading and unloading of a main transformer from the transport vehicle; and
2. Accommodate six three-phase transformers (the main transformers) in individual fire-separated enclosures with a removable and re-constructable front wall to facilitate maintenance and removal.

Draft Tube Valves

One DTV will be installed downstream of each unit to enable dewatering of the pump-turbine for maintenance and to enable isolation of the draft tubes in case of a leak or break of a draft tube off-take. The DTV will be a lattice butterfly valve, the design pressure will be about 250 m and the nominal diameter will be 3.5 m.

The valve will be opened by one or two hydraulic cylinders and closed by counterweight. The hydraulic oil system will be a high-pressure system with nitrogen/oil piston accumulators to maintain sufficient pressure oil for two full opening strokes of the DTV without operation of the hydraulic pumps.

The DTV will normally remain open and be closed manually. If power station flooding is detected, the DTVs will close automatically after shutdown of the associated unit.

The DTVs will be installed and maintained by a gantry crane operating on the operating floor level of the Transformer Hall.

Main Transformers

General

Each motor-generator unit will be connected to a dedicated three-phase, step-up main transformer located underground in the Transformer Hall. The LV winding of the main transformer will be connected to the motor-generator via the isolated-phase bus duct and the high voltage winding will be connected to the GIS via 330 kV single-core cables.

Each main transformer and its auxiliaries will be located in a separate semi-enclosed cell inside the Transformer Hall. The main transformers will be rail mounted with facilities to hard-bolt the transformers to the concrete foundations to withstand seismic forces.

Water-based fire protection will be provided for each main transformer.

A summary of the main transformer features is provided in Table 24.

Feature	Value
Type of construction	Three-phase, two winding
Installation	Underground
Winding cooling medium	Mineral oil immersed
Rated frequency	50 Hz
Rated voltages at no-load (Ur)	330 kV
Transformer rated power	415 MVA
Type of cooling	Oil-directed water-forced (ODWF)
Maximum noise level	80 dB(A) (sound pressure)

Table 24: Variable-speed motor-generator features

Extra High Voltage GIS

An indoor, extra high voltage (***EHV***) SF_6 GIS switching station will be provided. The GIS will have single-phase encapsulation, in a one-and-a-half breaker configuration taking six incoming circuits into four outgoing circuits. The GIS will include the following circuits:

1. Six motor-generator bays connecting the main transformers to the GIS via EHV cable systems; and
2. Four outgoing transmission feeder bays connecting the GIS with the transmission system via EHV cable systems.

The GIS will be located in a dedicated GIS cavern. In the Reference Design, the GIS cavern has been located next to the Transformer Hall. However, it is a possibility that the Contractor may propose that the GIS cavern be located above the Transformer Hall.

A summary of the GIS features is provided in Table 25.

Feature	Value
Type	Single-phase encapsulated switchgear
Number of phases	Three
Bus bar arrangement	Breaker and a half scheme
Installation	Indoor
Nominal system operating voltage	330 kV
Highest system voltage	362 kV
Rated voltage (kV rms)	≥362 kV
Rated frequency	50 Hz

Table 25: GIS features

Extra High Voltage Cables

Extra high voltage cable connections will be provided between the:

1. Main transformers and the GIS; and
2. The GIS and the EHV cable sealing ends located in the outdoor cable yard.

The following sets of EHV cables will be provided:

1. Six sets of EHV cable systems between the main transformers and the GIS equipment including cable sealing ends at both ends of the cable; and
2. Four sets of EHV cable systems between the GIS equipment and the cable yard including cable sealing ends at both ends of the cable.

The EHV cables will be single-core, cross-linked polyethylene (***XLPE***)-insulated. The longest circuit length between the main transformer and GIS equipment is estimated to be approximately 300 m. The length of EHV cables between the GIS outgoing feeder bays and the outdoor cable yard is estimated to be approximately 4,300 m.

5.3.5 Balance of Plant

Mechanical

Auxiliaries

Several mechanical auxiliary systems are required for the operation of the power station plant.

Two separate cooling water systems are required:

1. Unitised cooling water (***UCW***) system, six sets - each pump-turbine generating unit has one unit cooling water system; and
2. A common station cooling water (***SCW***) system - to service common and station heat exchangers.

Two compressed air systems will be required:

1. Turbine dewatering air system – to supply air to dewater the turbines during synchronous condenser operation and pump starting; and
2. Operating air system – to provide compresses air to the generator brakes system and isolated-phase bus overpressure system.

Mobile oil handling and purification systems will be used for oil filling, draining of bearings, governor and valve oil tanks.

Drainage and dewatering system

A drainage and dewatering system is required for the dewatering of the turbines and associated waterways as well as for collecting and disposing of power station leakage and wastewater (other than sanitary water). The system will include:

1. Pressure shaft and spiral case drains;
2. Draft tube drains;
3. Dewatering pits (two);

4. Transfer pits (two); and
5. Dewatering and transfer pumps..

Fire fighting system

A power station fire fighting system will be provided that will typically include:

1. Fire alarm and detection system;
2. Fire protection water supply system, including;
3. Fire protection water storage tank;
4. Fire protection water supply pumps and filters;
5. Fire water pressure mains network; and
6. Transformer water-based fire protection systems (either traditional deluge or water mist systems).

The Power Station Complex and MAT portal buildings are unmanned facilities. Initial response would be from the Snowy Mountains Control Centre (***SMCC***) in Cooma. Snowy Hydro fire and rescue squads would then be mobilised to site to control the response.

Potable water

A potable water system will be provided for personnel working in the power station. A raw water system will also be provided for fire protection and water requirements in the Power Station Complex. The system will include:

1. Water treatment plant;
2. Raw water storage tank;
3. Potable water tanks; and
4. Reticulation system, including raw and potable water outlets.

Station cranes

The Reference Design includes power station main cranes and maintenance cranes. The power station main cranes are top-running bridge cranes and will be used to install and maintain major plant items within the coverage of the common power station main crane runway. Maintenance cranes are provided for the areas where frequent handling activities are expected. Fixed monorails are provided as necessary to facilitate maintenance of heavy equipment anywhere within the permanent facilities and monorail chain hoists for use with the monorails.

Heating, ventilating and air conditioning

Heating, ventilating and air conditioning systems (***HVAC***) is required for the underground facilities (eg Machine Hall, Transformer Hall, ECVT and MAT). The purpose of the HVAC systems of the Power Station Complex is to cater for the:

1. Removal of the plant heat loads;
2. Maintenance of an environment suitable for reliable operation of equipment especially with respect to dust, humidity, temperature and corrosive contaminants;
3. Prevention of condensation on the equipment;
4. Maintenance of a healthy working environment for personnel; and

5. Fulfilment of fire and emergency escape requirements.

The ventilation system is designed so that during normal operation and for all fires scenarios within the Power Station Complex, air is drawn into the power station along both the MAT and the ECVT. This ensures that there is fresh air in the tunnels so that they can be used as primary escape routes.

Following a discussion between HVAC and fire consultants Stacey Agnew and SMEC, the concept of cross passages between MAT and ECVT was introduced to address the problem of flow reversal in the tunnels, fire zoning for fires in the MAT and possible fogging occurring in the MAT under certain atmospheric conditions (ie hot air in the tunnel condenses to form clouds during winter).

The concept of the Reference Design is based on air entering through the MAT but being extracted prior to entering the power station cavern. The main air supply for the power station is through the ECVT.

Other

Flow and water level measuring systems are provided to interface with the plant control and protection system and together with the turbine instrumentation.

The Reference Design shows four station lifts servicing the Power Station Complex. They are all located on the upstream side of the Machine Hall.

Several station workshops and store rooms service the power station. The workshops are equipped with workshop machines, equipment and tools for carrying out maintenance of plant and equipment in the power station.

Electrical

Power Station MV and LV distribution systems

MV and LV distribution systems will be provided in the power station. Power supply sources will include:

1. Auxiliary power from motor-generator units 1, 3 and 5 (unit power supplies);
2. 11 kV power supply fed from the distribution NSP (***DNSP***) TransGrid's 330/33 kV Ravine substation; and
3. Emergency diesel generators.

The 11 kV and emergency diesel generator power supplies will be brought into the power station from the surface via independent routes in the ECVT and MAT.

The power station power distribution system will include:

1. 11 kV Emergency services switchboards;
2. 11 kV Main services switchboards;
3. Station service transformers;
4. 400 V Common services switchboards;
5. 400 V Emergency services switchboards; and
6. Other 400 V power station auxiliary switchboards as required.

DC Systems

DC systems will be provided throughout the Facilities for monitoring, control, protection and lighting functions. DC systems will include duplicated battery banks, duplicated battery chargers and duplicated switchboards.

DC systems will be provided for:

1. The motor-generator units, unit auxiliaries, unit excitation systems, main transformers monitoring, control and protection functions, power station auxiliaries;
2. Lighting services;
3. Monitoring, control and protection functions of the GIS; and
4. Monitoring, control and protection functions in the cable yard, MAT portal area, PGV chamber, headrace surge shaft tank, Talbingo intake structure and Talbingo intake structure.

Lighting and small power

All areas in the Facilities will require lighting and small power. All lighting facilities will be supplied from dedicated distribution and control system boards and will have automatic control systems. Emergency lighting will be installed to provide safe egress in the event of a power failure. Emergency lighting will be provided by self-contained battery-backed luminaries. Switch-and-plug sockets will also be provided throughout all areas of the Facilities.

Outlying areas MV and LV Distribution system

A MV and LV distribution system is required at the following outlying areas:

1. **Tantangara Intake Gate Structure** - supply provided by the local DNSP (Essential Energy) via 33 kV underground cable. The power supply system includes a backup diesel generator and switchboard;
2. **Talbingo Intake Gate Structure** - supply provided by via an underground 33 kV power cable from the TransGrid 330/33 kV Ravine substation. The power supply system includes a backup diesel generator and switchboard.
3. **PGV Chamber** - supply provided via an underground 33 kV power cable from a 33 kV supply point located at the MAT portal. The system includes a backup diesel generator and switchboard.
4. **Headrace Surge Tank** - supply provided via an underground 33 kV power cable from a 33 kV supply point located at the PGV chamber The system includes only a distribution board.

Control and Measurement System

An overall control and monitoring system is provided for the Project. The power station will normally be controlled remotely from the SMCC through Snowy Hydro's Supervisory control and data acquisition (**SCADA**) system, and the power station will not normally be manned. However, the Reference Design provides two workstations in the power station for local control.

Protection system

An overall protection system is provided for the Project. Each part of the Project will be protected by protection relays operating such that only the affected plant is taken out of service in the event of fault without damage to the system. Duplicated protection systems, that are fully redundant and segregated, will be provided. The system includes:

1. Motor-generator unit protection, with separate electrical trip and mechanical trip functions;
2. Main transformer protection;
3. 330 kV GIS busbar protection;
4. Line circuit to TransGrid;
5. Interzone protection;
6. Station and outlying works protection;
7. 33/11 kV substation electrical protection;
8. 11 kV standby diesel generators protection; and
9. Outlying works substations protection.

Project-wide services and systems

Project-wide services and systems provided in the Reference Design include:

1. An integrated security system with a closed-circuit television system (***CCTV***) and access control system; and
2. An overall fibre-optic cable-based communication system with two communications rooms in the power station, IT networks, IT WAN services, fixed voice services, satellite phone in the power station control room, internal mobile radio, and time signalling.

5.3.6 Cableyard

A 330 kV outdoor cable yard will be provided at the ECVT portal for termination of the 330 kV cables from underground GIS and interconnection with the transmission line connecting to the TransGrid transmission system. The cable yard will include 330 kV cable sealing ends and surge arresters. The cable yard will also include electrical building housing the diesel generator set and 33/11 kV power supply system.

See *Supporting Chapter Sixteen - Transmission* for more details.

6 Definitions and abbreviations

AC	Alternating current
AEMO	Australian Energy Market Operator
DEG	Digital Electronic Governor
DFIM	Doubly-fed Induction Motor-generator
DTV	Draft Tube Valve
E&M	Electrical/Mechanical
ECC	Early Contractor Consultation
ECVT	Egress, Cable and Ventilation Tunnel
EHV	Extra high voltage
EOHT	Electric overhead travelling
EPC	Engineer-Procure-Construct

FID	Final Investment Decision
FSL	Full supply level
GBR	Geotechnical Baseline Report
GFR	Geotechnical Factual Report
GIP	Geotechnical Investigation Program
GIR	Geotechnical Interpretive Report
GIS	Gas-Insulated Switchgear
HAZOP	Hazard and Operability
HVAC	Heating, ventilating and air conditioning
IPB	Isolated-phase busduct
KNP	Kosciuszko National Park
LV	Low Voltage
MAT	Main Access Tunnel
MIV	Main Inlet Valves
MOL	Minimum operating level
MV	Medium Voltage
NEM	National Electricity Market
NER	National Electricity Rules
NPWS	National Parks and Wildlife Service
NSP	Network Service Provider
ODWF	Oil-directed water-forced
PGV	Penstock Guard Valve
PHES	Pumped-hydro energy storage
PID	Proportional Integral Derivative
R&D	Research & Development
RFI	Request for Information
ROV	Remotely Operated Vehicles
RTE	Round-trip efficiency
SCADA	Supervisory control and data acquisition
SCW	Station cooling water
SFC	Static frequency converters
SMCC	Snowy Mountains Control Centre
TRD	Technical Requirements Document
TRG	Technical Reference Group
UCW	Unitised cooling water

9 Bibliography

There is no bibliography for this chapter.