EnergyAustralia & Arup

Cultana Pumped Hydro Energy Storage Project

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Cultana SPHES

ARENA Knowledge Sharing Report

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Acknowledgements

Traditional Owners – Barngarla People

EnergyAustralia and Arup would like to acknowledge that this report is with regard to a project that was planned to be constructed on the Country of the Barngarla people, on the hills of the eastern shores of the Eyre Peninsula extending to the waters of the upper Spencer Gulf under the broad skies of South Australia, and we pay our respect to Elders both past and present.

ARENA

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Government of South Australia

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EnergyAustralia and Arup

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Abbreviations

Table 1 – Abbreviations

Abbreviation	Term
ADWG	Australian Drinking Water Guidelines
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AEP	Annual Exceedance Probability
AFC	Acceptable Flood Capacity
AGM	Annual General Meeting
AHMP	Aboriginal Heritage Management Plan
ANCOLD	Australian National Committee on Large Dams
ARENA	Australian Renewable Energy Agency
ARP	Advanced Renewable Program
ARPFA	Advancing Renewables Program Funding Agreement
AUD	Australian Dollars
BDAC	Barngarla Determination Aboriginal Corporation
BESS	Battery Energy Storage System
BoP	Balance of Plant
BOTN	Battery of the Nation
Capex	Capital expenditure
CFSM	Converter-Fed Synchronous Machine
CIP	Clean-In-Place
CTA	Cultana Training Area
DEM	Department of Energy and Mining
DFIM	Doubly Fed Induction Machine
DoD	Department of Defence
DoEE	Department of Environment and Energy
DP	Development Plan
DPTI	Department of Planning, Transport and Infrastructure
EA	Energy Australia
ECI	Early Contractor Involvement
EPBC	Environment Protection and Biodiversity Conservation
EPC	Engineering, Procurement and Construction
ESCOSA	Essential Services Commission of South Australia
EV	Electric Vehicles
FCAS	Frequency Control Ancillary Services
FEED	Front-End Engineering Design

FIA	Flood Impact Analysis
FID	Final Investment Decision
FTE	Full time equivalent
GL	Giga Litres
GPS	Generator Performance Standard
GRP	Glass Reinforced Plastic
GSSF	Grid Scale Storage Fund
GWh	Giga-watt hours
HV	High Voltage
HVAC	Heating, ventilation and air conditioning
Hz	Hertz
ILUA	Indigenous Land Use Agreement
INOG	Intake Operating Gates
IPBs	Isolated Phase Busducts
IPO	Indicative Pricing Offer
IRR	Internal Rate of Return
km	Kilometres
km2	Kilometres Squared
KSR	Knowledge Sharing Report
kV	Kilovolt
LRD	Lined Rock-Filled Dam
LV	Low Voltage
m	Meters
m3/s	Meters Cubed Per Second
mg/l	Milligrams Per Litre
MIV	Main Isolator Valve
mm	Millimetres
MNES	Matters of national environmental significance
MP	Marine Parks
MVA	Mega Volt-Ampere
MW	Mega Watt
MWe	Mega Watts Electric
MWh	Mega Watt Hour
NCAS	Network Support and Control Ancillary Services
NEM	National Electricity Market
NPV	Net Present Value
NSW	New South Wales
O&M	Operation and Maintenance

OEM	Original Equipment Manufacturer
Opex	Operational expenditure
OTR	Office of Technical Regulator
PDI	Planning, Development and Infrastructure
PHES	Pumped Hydro Electric Storage
PMP	Probable Maximum Precipitation
PTUs	Pump Turbine Units
PV	Photovoltaic
Rd	Road
RO	Reverse Osmosis
rpm	Revolutions Per Minute
SA	South Australia
SARDI	South Australian Research and Development Institute
SEB	Significant Environmental Benefit
SFC	Static Frequency Converter
SPHES	Seawater Pumped Hydro Electric Storage
SRAS	System Restart Ancillary Services
TDS	Total Dissolved Solids
TP	Test Pits
UN	United Nations
UNSDG	United Nations Sustainable Development Goals
TNSP	Transmission Network Service Provider

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1 Executive Summary

1.1 Project background

EnergyAustralia and Arup have completed phase 2 of development for the proposed Cultana Seawater Pumped Hydro Energy Storage (SPHES) Project in South Australia (SA). Building on the pre-feasibility work completed in 2017 the partners completed a Front End Engineering Design (FEED) program, produced a Reference Design, sourced experienced hydro project construction contractors, progressed land access, environmental approvals and completed market and business case studies to support the making of a Financial Investment Decision (FID) by December 2019.

The purpose of the project was to complete the development and seek an FID for the proposed construction a 225MW, 8-hour SPHES system to provide GWh scale energy storage services to the national electricity grid in South Australia.

1.2 Negative investment decision

In light of higher-than-expected capital cost, revenue uncertainty, uncertainty around energy technology development, reducing costs of grid-scale battery technology and development approvals time frame, EnergyAustralia took a negative FID in November 2019.

The negative FID was the result of evaluation of financial and market modelling and risks under scenarios including increased renewables penetration, interstate interconnectors and introduction of other large PHES into the NEM. With all factors and risks considered the Cultana SPHES did not present a sufficiently compelling business case for EnergyAustralia.

Arup under its rights in the co-development agreement exercised a Development Transfer and remain as holders of the Project IP and initially continued as proponent for subsequent phase works.

However, Arup was informed in August 2020 that the landowner, Department of Defence (DoD), was unable to lease the land for the project therefore effectively ending the project.

The FID outcome, and termination of the project, while less satisfying than a positive decision, nevertheless allowed this Knowledge Sharing Report (KSR) to be prepared.

1.3 Department of Defence (land)

Although early negotiations and discussions with the Department of Defence (DoD) throughout 2018 and 2019 were positive, DoD confirmed in August 2020 that a land lease was unable to be provided. The change in stance for the DoD came about due to the direction in the 2020 Defence Strategic Update and the 2020 Defence Force Structure Plan issued on 1 July 2020.

1.4 Engagement and approvals

Stakeholder engagement with traditional owners, the Barngarla people, and other local community members including private property owners on the coastal strip progressed to plan with practical working relationships and good understanding of the project established. Grid connection design work with ElectraNet produced a detailed design for the Hannah Dam Substation and 275kV connection transmission line to tie in the facility to the existing eastern Davenport to Cultana circuit. A Technical Certificate was issued by OTR and DEM granted Crown Sponsorship to support the development approvals process under the PDI Act (2016).

1.5 Scope of phase 2 works

Building from the pre-feasibility study completed in 2017, the second phase development plan included completing all required FEED program work, environmental and planning approvals, land access, grid connection, contractor sourcing and business case inputs to enable an FID for construction of the 225MW x 8-hour energy storage facility.

1.6 Australian hydropower industry experience

Until recently, expertise in the Australian hydro power sector has been concentrated in State owned generating companies in Tasmania and News South Wales. The field of new PHES developments provides an opportunity for a wide range of Australian industry participants (energy companies, engineering consultants, sub-contractors, large Engineering, Procurement and Construction (EPC) contractors, and lawyers) to build a broader capability in hydro power.

As the new entrants mature in their delivery capability, competitiveness will increase and risk margins will decrease, both of which should improve development efficiency and economics of future PHES projects.

1.7 The roles of pumped hydro in the market

The Cultana SPHES was designed to provide gigawatt-hour scale energy storage infrastructure configured for safety and reliability with capacity each day to shift

1800 MWh of energy from times of high availability to periods of high demand. By displacing expensive fossil fuelled peaking plants during peak demand, the overall wholesale cost of power would be reduced, improving electricity affordability.

Utilising proven hydropower technology implementation of the proposed project could have improved reliability and security of grid supply for all electricity consumers in SA by:

- drawing up to 250MW from the network for approximately 10 hours per day, adding significant synchronous load, 'real inertia' and banking renewable energy for later use.
- providing 250MW of demand response with the ability to rapidly shed pumping load.

Demand response in this instance could provide the equivalent of peaking capacity while also easing network power flows, rather than adding power flow as the case if peaking capacity were simply added.

While in pumping mode during high renewables periods the 'real inertia' and local load to Davenport could have relieved potential curtailments of renewables during periods when the system could not accept high levels of non-synchronous generation. This would enable a higher capacity of wind and solar generation to be dispatched in SA reducing the need to rely on Victorian base load or gas fired generation capacity for system security purposes in SA. Having pumped the renewable energy into the upper reservoir the Project could have 'time shifted' that renewable capacity for availability in low renewables 'still and dark' periods.

In generating mode, the proposed facility could have had the capability to provide peaking capacity, delivering back to the network additional renewable energy on short notice at any peak demand period with 'real inertia' and reactive power as the network may require, reducing the reliance on gas fired generation for peaking service.

Through these robust and flexible operations, the Cultana SPHES if constructed could have been an enabling technology for the increased utilisation of intermittent renewables while also improving network security and reliability. Only pumped hydro can provide the combination of dispatchability and all-encompassing ancillary services capabilities, particularly physical inertia, that would otherwise reduce as thermal generation retires.

1.8 Design development

Arup completed the Front-End Engineering & Design (FEED) program including detailed site investigation studies, which informed the selection of a two-reservoir scheme utilising Reverse Osmosis (RO) treated seawater as the working fluid. This configuration offered low risk construction, robust long-life design and best social and environmental outcomes with least visual amenity impacts. Mindful of the long life of PHES assets the Cultana SPHES configuration was designed for sustainability and decades of reliable utility.

With the configuration defined to achieve the social, environmental and market performance described above, Arup produced the detailed Reference Design. The Reference Design included sufficient preliminary engineering to provide a sure technical basis for development approval and tender purposes.

1.9 Saltwater vs freshwater

The proposed Cultana project could have utilised either saltwater (seawater) or freshwater (desalinated seawater or potable/fresh water). Much investigation was undertaken for both approaches to arrive at a preferred option.

The largest drawcard for a seawater PHES is the opportunity to eliminate the lower reservoir, saving capital cost. This cost saving must be balanced against the increased cost and risk of exposing the system to corrosive seawater. Most suppliers suggested the repairs and maintenance requirements, including downtime for routine maintenance, would be twice that as compared with a freshwater PHES.

For the Cultana SPHES project it was found that the Spencer Gulf marine environment was not suitable for regular seawater exchange due to the lack of mixing with unused seawater. For this reason, it was necessary to have a more typical two-reservoir configuration and based on this freshwater was deemed to be the most cost-effective choice. The freshwater would be sourced by desalination of Spencer Gulf seawater.

1.10 Tendering for PHES

In May 2019 an Invitation to Tender was issued by EnergyAustralia to selected pre-qualified international hydro-power construction consortia. Tenderers were invited to add their own optimisations to bring about further efficiencies as part of the competitive sourcing. In October 2019 when bids closed, three full form, time and performance guaranteed, lump sum turnkey EPC proposals were received. This was the first time in Australia a fully market competitive sourcing program had been conducted to ascertain true market pricing for any PHES project.

1.11 High EPC tender prices

The tender responses achieved the technical and delivery standards requested, however the EPC prices for those proposals were higher than expected.

The Tenderer's proposals remain confidential and the tenderers own their IP therefore no tender response information is included in this report. However, re-adjustment of the EnergyAustralia projected full execution cost estimates resulted in a projected EPC cost of $700m before contingency, and a total project capex of approximately $790.5m including contingency and all owner's costs.

At this level of capex and a net capacity of 225MW the project exhibits a specific cost of approximately $3.4m/MW. This exceeded other similar scale PHES projects estimated costs of <$2m/MW.

The project team believes the Reference Design as tendered contained value engineering opportunities which if realised would likely lead to reduced capital cost.

1.12 Development approval delays

Unfortunately delays in determining the development approval pathways between the State and Commonwealth agencies for the DoD site also delayed lodgement of the Development Application. More than 12 months passed before the submission requirements for the Department of Environment and Energy (DoEE) Environment Protection and Biodiversity Conservation (EPBC) Act assessment were advised. This pushed the required time frame to achieve Development Approval well beyond the FID target date of December 2019.

1.13 Impact of proposed new interconnector

The advancing approvals for the EnergyConnect 800MW interconnector resulted in energy market modelling, which indicated narrower arbitrage opportunities in the SA energy market for at least the near term.

1.14 Development conclusion

EnergyAustralia and Arup completed the second phase development of the Cultana Seawater Pumped Hydro Energy Storage project over the 18 month period from June 2018 to December 2019. The development work, reference design and competitive market tendering process determined a specific cost for the proposed Cultana SPHES of $3.4m/MW. The high capex cost and energy market uncertainty resulted in EnergyAustralia taking a negative FID.

2 Introduction

The Cultana seawater Pumped Hydropower Energy Storage (PHES) Project was a grid scale electricity storage solution proposed to be located near Port Augusta in South Australia (SA). The proposed project site was on the north-eastern edge of the Department of Defence Cultana Training Area (CTA) near the 'El Alamein' Army Base on the shores of the Spencer Gulf. This report describes the development of the proposed facility with an electrical generation capacity of 225MW and a storage time of up to 8 hours. The plant if built would have supplied dispatchable electricity to the National Electricity Market (NEM) in SA, as well as providing a range of grid support and ancillary services.

The project received development funding from ARENA provided under the Advancing Renewables Program. As part of the ARENA funding requirements, this Knowledge Sharing Report (KSR) has been produced.

The project also received development funding from the South Australian Government Renewable Technology Fund.

The project, originally initiated by Arup and the University of Melbourne Energy Institute (MEI), was co-developed by EnergyAustralia and Arup in two phases beginning in 2017. In September 2017, EnergyAustralia and Arup issued a knowledge sharing report on completion of the initial feasibility stage of the project[1]. This report leads on from the initial feasibility stage, through the phase 2 development process to the Final Investment Decision (FID). The structure of this report is based on the requirements of the ARENA funding agreement and includes the following primary sections:

- Chapter 3 – PHES vs Seawater PHES – Sets out the viability of PHES in SA, addresses the key considerations associated with seawater PHES and provides an overview of objectives and key learnings from the project
- Chapter 4 – Technical Design – Describes the final technical design of the Cultana SPHES project
- Chapter 5 – Financial Viability – Describes the financial viability of the project and the commercial assumptions used
- Chapter 6 – Regulatory, Market and System Development Issues – Describes the regulatory, market and system constraints to development
- Chapter 7 – Land Access – Summary of land ownership, native title and stakeholders engaged
- Chapter 8 – Land Use Planning and Environmental – Describes the various agreements, permits and approvals that were required for the project and the process of each

[1] https://arena.gov.au/assets/2017/09/Cultana-Pumped-Hydro-Project-_Public-FINAL-150917.pdf

- Chapter 9 – Grid Connection – Status update on the grid connection studies and remaining activities.

Figure 1 – Proposed Cultana SPHES location and view to Spencer Gulf

3 PHES and Seawater PHES

3.1 Viability of PHES in South Australia

There is an increasing opportunity for bulk, grid scale energy storage within SA to complement the State's drive to 100 per cent renewable by 2030. Since 2017, it has been widely considered that the energy storage requirements could be met by at least one pumped hydro project.

Since the first Cultana SPHES KSR report in 2017, there have been five potential PHES projects within SA that were in contention to be the first to reach a positive FID. These included Cultana SPHES, Goat Hill PHES, Baroota PHES, Middleback PHES and Kanmantoo PHES.

Through the development of Cultana SPHES, the project team identified that the viability of the project largely comes down to overcoming commercial challenges associated with demonstrating a viable development. These can be identified in three areas:

1. capital costs associated with construction
2. forecast revenue modelling through operation
3. technical complexity of large, multidisciplinary systems

3.1.1 Capital Costs

Through various conference presentations some PHES proponents have published estimated project specific capex figures typically less than $2m/MW. The sourcing process conducted by EnergyAustralia with inclusion of owner's costs and contingency produced an all inclusive capex cost of $790.5m for the Cultana SPHES equivalent to $3.4m/MW.

Following the tender phase for the Cultana SPHES project it became clear that the supply cost of main equipment and associated civil and installation works within Australia are greater than generally anticipated, although it is noted that more recently other PHES projects have stated higher than anticipated costs.

Capex costs for Cultana were higher than expected due to configuration and site specific factors mostly related to the cost of the penstock and major civil structures of reservoirs and powerhouse. These were driven by site conditions with the low head available on the site requiring increased volume of all water storage and conveyance structures, and non-ideal type of site materials available for forming reservoir embankments, and the need for reservoir liners. The EnergyAustralia capex number also includes all owner related project costs and contingency. The location of the proposed facility within a DoD active training site also added significant security and access requirements which were also factored into the anticipated EPC costs.

In general, given the large capital costs required for these systems, hydro and pumped hydro projects have been heavily supported by Federal or State Governments. A Government could support pumped hydro through further incentivising a scheme which would reduce the capital cost risks and/or alleviate some of the operational risk associated with PHES project reliance on wholesale electricity price arbitrage as the principal source of revenue.

3.1.2 Revenue Modelling

Operationally, a PHES system within the NEM will likely participate in the wholesale, Frequency Control Ancillary Services (FCAS), Network Support and Control Ancillary Services (NSCAS) or System Restart Ancillary Services (SRAS) markets.

Currently, there is significant revenue risk associated with forecasting power pricing within Australia and understanding revenue from ancillary services. This risk is largely due to rapid increase in renewable energy penetration, support for additional interstate transmission interconnectors, other emerging technologies such as grid-scale battery storage, volatile power pricing and changing energy and climate policy development across Australia to respond to an evolving grid.

Given the large capital expenditure required for a pumped hydro scheme, the volatile revenue risk provides on-going difficulties to achieving a robust business case to support proving commercial viability of PHES.

Government policy and regulatory reform such as moving from a 30-minute averaging spot market settlement period to a 5-minute settlement period could greatly benefit fast responding generation and storage such as pumped hydro and batteries. However, the current market mechanisms were largely designed around the traditional generation mix, predominantly baseload power from fossil-fuel powered steam cycle generation plants. Recognition of the market benefits of GWh scale storage for the emerging generation technologies in the NEM could greatly improve the prospects of storage technologies such as pumped hydro to achieve commercial viability and realisation of storage projects.

3.1.3 Site and Technical complexity

The technical viability of a pumped hydro scheme is closely linked to the natural environment and underlying geology of the proposed location. The land for the proposed Cultana SPHES project is predominantly owned by the Department of Defence.

At the surface, topography conducive to siting large water storages with sufficient vertical separation yet horizontally proximity, with an available water supply and the nearby grid infrastructure for connection presents an initial suite of difficult requirements.

The intrusive civil works associated with the construction of powerhouse, penstock and reservoirs requires favourable geotechnical and environmental conditions.

Collecting the data required to confidently design and respond to the natural elements within the site parameters imposes program and commercial strain on the development phase of the project. However, without the required detailed technical information, the residual technical risk inherent within the project can result in a significant capital premium in the construction phase.

To improve the potential viability of a PHES project, it is strongly suggested that comprehensive site selection due diligence followed by adequate on-site testing prior to design development are undertaken.

3.1.4 Resultant Market Direction

During the past two years, the market has seen an increase in large scale battery energy storage systems (BESS) being installed or proposed within the South Australian network.

The barrier to entry for a battery project is considerably less than that of a pumped hydro system both environmentally and commercially. While batteries do not offer the same operational life or bulk energy storage capacity, they are compact with simple siting requirements and short installation time, able to provide very useful ancillary services and some participation in the wholesale market.

While it might appear that PHES and BESS are competing technologies, they are in fact complimentary with BESS demonstrating huge capacity for supporting grid stability with PHES to support the longer quantum of bulk GWh. There is a potential that without additional Government support, through funding or market mechanism to value capacity and inertia, the viability of PHES systems to provide larger scale and longer-term storage as a complement to BESS will not be realised.

Figure 2 – Davenport to Cultana Transmission Line

3.2 Seawater PHES and Implications of Use

PHES systems require large amounts of water for first fill of the reservoirs prior to operation and on-going top up through operation due to losses caused by evaporation and seepage. Given Australia's continual water security challenges, especially through recent droughts, access to freshwater for working fluid is highly contentious in some areas.

Projects that utilise freshwater for working fluid potentially restrict the use elsewhere within the local water network. While the water is either lost back to the environment through seepage or evaporated due to losses and returned to the water cycle, locally, the use of freshwater represents a potential reduction in water security. This could be viewed negatively for any project which could result in unwanted community concern or restricted access to water through extreme droughts. Operationally, this could be a significant risk depending on the natural environment of the PHES system. Within the Spencer Gulf region of SA, water security is a significant community concern and reduced impact to the water supply should be prioritised.

Utilising seawater as the working fluid for a PHES system presents an on-going opportunity. Through the development of the proposed Cultana SPHES, the project group has identified challenges associated with the use of seawater for PHES. These can be summarised into technical, regulatory and commercial aspects.

3.2.1 Technical

Technically, utilising seawater systems represents an interesting challenge. Largely the viability of utilising seawater for PHES comes down to the chloride concentration of the water and potential rate of corrosion of associated equipment which influences material selection and operational life. The Cultana SPHES project determined that there are two viable options for utilising seawater;

1. utilise seawater directly as the working fluid,
2. pre-treat the seawater utilising reverse osmosis process to provide desalinated water to the facility.

To overcome the operational risk associated with corrosion, Cultana SPHES project opted to pre-treat the seawater prior to filling the lower reservoir. The technical design and decision process for this is outlined in Section 4.1. Without pre-treatment of the seawater the project would have incurred additional risk associated with the operational life and performance of the Pump Turbine Units, penstock, reservoirs and associated Balance of Plant (BoP).

The project group viewed the additional operational risk of utilising seawater directly as too great and therefore opted for a first pass Reverse Osmosis (RO) treatment process prior to filling the reservoir.

3.2.2 Commercial

Commercially, the use of seawater adds additional costs to a PHES project compared with a freshwater solution. Depending on if the system pre-treats the water prior to filling the reservoir, the additional costs are either through costs associated with higher grade materials that can withstand higher concentrations of corrosive chloride or with the additional capital and operating costs required for a water treatment process plant.

Through the options assessment of Cultana SPHES, the additional capital costs for either treatment or no-treatment options were comparable, with neither option providing significant capital costs savings. Currently there is limited incentive to provide a seawater solution for PHES operation, as water utilities do not charge additional premiums to supply freshwater to new projects that may have a material impact on water security.

Utilising seawater without desalinating was found to directly result in greater operational costs compared with pre-treatment. This is largely due to the additional on-going maintenance inspections required and potential for greater replacement of critical items such as the turbine runner, penstock lining and associated equipment. There is also additional risk associated with rates of corrosion due to the direct use of seawater which is difficult to quantify prior to operation. Comparatively, the additional costs associated with maintaining and running the RO plant are less and some of the risk is mitigated.

As such, the project group viewed the additional operational requirements for direct seawater as too high and opted for pre-treatment of the working fluid. Further details of this design decision can be found in Section 4.1.

3.2.3 Regulatory

The use of seawater for a PHES project would need to comply with relevant State and Commonwealth legislation. To meet these requirements, impacts on the receiving environment (during construction, operation and maintenance) need to be sufficiently understood and addressed.

Potential impacts were identified as:

- impacts to local coastal processes and marine water quality
- impacts to marine ecology, including state and commonwealth listed species
- impacts to surface water or groundwater water quality from seepage of saline water from the reservoirs
- impacts to community amenity and values.

The statutory approvals, permits and licences required for the use of seawater in the PHES are outlines in Table 2.

Table 2 – Statutory approvals, permits and licences.

Legislation	Requirement
Planning, Development and Infrastructure Act 2016 (PDI Act)	The use of seawater (and the associated impacts, as outlined above) is to be included in the approval required under Section 131 of the PDI Act for construction, operation, and maintenance of the project.
Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)	Separate approval is required under the EPBC Act for any impacts from the use of seawater (and any associated discharge) to Matters of National Environmental Significance (MNES) and Commonwealth land (Defence land) during construction, operation, and maintenance of the project.
Marine Parks Act 2007 (MP Act)	A permit is required under Section 19 of the MP Act for carrying out works in the General Managed Use Marine Park Zone, including for construction of the seawater supply support structure and intake and outfall pipes.
Environment Protection Act 1993 (EP Act)	A licence is required under Schedule 1 Section 8(6a) of the EP Act for operation of a plant that produces more than 200kL of desalinated water per day.
	A licence is required under Section 8 (7) of the EP Act may be required for discharges to marine or inland waters where: the discharges raise the temperature of the receiving waters by more than 2 degrees Celsius at any time at a distance of 10

	metres or more from the point of discharge; or contain antibiotic or chemical water treatments, and the total volume of the discharges exceeds 50 kilolitres per day. (This licence is only required for the untreated seawater option and excludes for a desalination plant)
	Approval may be required under Schedule 1 Section 8(4) of the EP Act for the removal of solid matter from the bed of any marine waters or inland waters by any digging or suction apparatus. This may be required for construction of the seawater supply support structure and intake and outfall pipes.
	Under section 25 of the EPA Act, a person must not undertake an activity that pollutes, or might pollute, the environment unless the person takes all reasonable and practicable measures to prevent or minimise any resulting environmental harm. Environmental harm, in relation to water quality, is defined in the Environmental Protection (Water Quality) Policy 2015 as: loss of seagrass or other native aquatic vegetation from the waters: - a reduction in numbers of any native species of aquatic animal or insect in or in the vicinity of the waters - an increase in numbers of any non-native species of aquatic animal or insect in or in the vicinity of the waters - a reduction in numbers of aquatic organisms necessary to maintain the health of the ecosystem of the waters - an increase in algal or aquatic plant growth in the waters - the waters becoming toxic to vegetation on land - the waters becoming harmful or offensive to humans, livestock or native animals - an increase in turbidity or sediment levels of the waters. Impacts of the use of seawater on the above would need to be considered in the in the approval required under Section 131 of the PDI Act for construction, operation, and maintenance of the project.

3.2.4 Further Discussion

The stage 2 Cultana SPHES project development work crystalized some important factors with respect to the viability of using seawater as the PHES working fluid which was not identified in the KSR from September 2017.

‘Height is might’

Despite the positive conclusions of the earlier KSR, the topography of the Cultana site does not present sufficient vertical elevation difference, coupled with too much horizontal distance from coast to upper reservoir location for a viable one reservoir seawater system, therefore a two reservoir system was selected.

At its essence the penstock height to length ratio is too low for a one reservoir system. With an elevation of 260m and horizontal distance of 3300m the penstock elevation to length ratio is 0.078, equivalent to 4.5° degrees slope. As a comparison the Yanbaru penstock elevation to length ratio is 3x higher at 154m on 585m equals 0.263, equivalent to 14.7° degrees slope. Accordingly, for Cultana to match the Yanbaru project the distance from ridge top to shoreline would need to be no more than 990m.

The long and large diameter penstock for a one reservoir system at Cultana presents an uneconomic arrangement when using seawater where higher cost corrosion resistant materials are required.

There may be other Australian coastal locations where an upper reservoir could be sited with a sufficiently high penstock elevation to length ratio to present a viable opportunity for a single-reservoir seawater system, however these are also likely to be local areas of high natural beauty with planning approval challenges.

‘Avoiding biota impacts’

A viable single-reservoir seawater pumped hydro system needs to be located where it can draw seawater and return it from open ocean and/or with sufficient current and tidal exchange to ensure there is not just a continuous recycling of the same seawater compounding impacts on marine biota.

This criterion was achieved at Yanbaru but is not met at Cultana due to the volume and flow characteristics of the Spencer Gulf marine environment.

‘Fresh vs saltwater’

The business case for a seawater system is significantly less attractive if the option for a single reservoir is not available. Comparing two-reservoir alternatives, freshwater is likely both lower cost and lower risk even when accounting for the added cost of RO treatment to convert seawater to freshwater.

Given the proven technology utilised for a freshwater system with RO seawater treatment it is most likely developers will choose fresh rather than salty.

3.3 Role of PHES in the NEM and South Australia

With a progression of coal plant retirements slated between 2023 and 2042 in the eastern states and increasing renewables build out the obvious need for a huge NEM wide capacity for energy storage would seem to be inevitable. Government has recognised in its support for Snowy 2.0 and Battery of the Nation (BOTN) that PHES as a technology class has attractive attributes, including:

- multi-hour storage duration

- long asset life with lack of capacity degradation
- fast starting dispatchable generation and load.

However, PHES also has significant development challenges compared to other technologies, including:

- site identification, qualification and selection is long and expensive, with compromises often required across key attributes such as access to water, elevation/head, geology and location to transmission
- capital costs are high, and published estimates were found to be low, perhaps due to significant execution risk in delivering such large scale projects
- PHES is a mature technology with commodity materials and civil works comprising a large portion of overall costs, yielding little prospect of significant future capex reductions through technology development and scale meaning that value engineering on a project by project basis is critical
- PHES has long lead times, which increases the development risk compared to more agile modular technologies such as batteries.

PHES also faces unique commercial/market challenges including:

- batteries are on a declining cost curve; they are already the most economical solution for short duration storage which will reduce arbitrage value and impact PHES economics
- behind the meter battery uptake is also a competitive threat to PHES economics, and the uptake is very uncertain. Some of the higher projections represent this as a material threat to PHES
- the long lead time for development of a PHES project and the long asset life required to deliver a return increases the threat from emerging technologies
- many PHES projects will be reliant on securing a long-term offtake contract from a credit worthy counter party in order to reach FID. It is challenging for retailers to contemplate taking 100 per cent of the market risk on a long-term basis given the inherent technology, market and regulatory uncertainty.

Across the NEM rapid market change is opening the role for PHES but the very same change is increasing uncertainty and inherent investment risk.

It should however be understood that different investors and proponents will have differing views on acceptableness of risk, financing package and market assumptions. Additionally, different project designs and locations will attract different capital costs. This changes the business case on a party-by-party basis particularly for large scale infrastructure projects like PHES.

3.3.1 South Australia

While the significant renewables penetration presents a unique opportunity, there are other South Australian specific considerations that increase difficulty making an investment case for PHES.

SA is a relatively small market. It is challenging for an off taker to take on the volume of a single PHES project and have confidence that they will have long-term channels to market to be able to monetise the output. This issue remains until the interstate interconnectors provide access to a wider customer base; however better interconnectors also bring additional market forces that in the short-term work against the business case for PHES.

The proposed EnergyConnect SA to New South Wales (NSW) interconnector at 800MW capacity is expected to reduce arbitrage and capacity value in SA. With SA total demand typically cycling daily between 1200MW and 2500MW, the EnergyConnect capacity will have an impact on market dynamics.

After EnergyConnect has been in service for a few years and eastern state proposed REZ zones have come online, and/or more coal plant retirements have occurred then arbitrage will again widen across the whole NEM re-opening opportunities for PHES not just in SA.

3.4 Biofouling in Seawater PHES

Biofouling, or the build-up of biological matter such as algae and other organisms, can occur on the submerged surfaces of piping and equipment in a marine environment. This can cause issues with operability and performance if left unaddressed.

Ultimately, biofouling was deemed a high risk to the operation of the Cultana SPHES facility, with expensive management and unpredictable component lifetime if seawater was directly used from the Spencer Gulf. Therefore, management of biofouling was part of the decision to switch to utilisation of a RO plant to provide desalinated water. Biofouling must however still be dealt with in the marine intake, the marine side pipework and the RO plant.

3.5 Delivery Models and Financing Options

At inception the Cultana SPHES project was anticipated to utilise an ECI (Early Contractor Involvement) approach during the development phase to result in a negotiated EPC Contract for the delivery of execution of the project. However, for the reasons detailed in Section 5.1 EnergyAustralia revised the development plan to enable a competitive EPC tender process as part of development. Arriving at a full EPC wrap for the delivery of the project was the only execution model contemplated by EnergyAustralia as the obligation for meeting time, cost and performance obligations is carried by the party best able to manage all three factors to ensure a successful project outcome.

3.6 EnergyAustralia and Arup Co-Development Objectives

EnergyAustralia and Arup are both committed to assisting the transition from fossil fuel-based energy generation towards renewable energy. Pumped Hydro Energy Storage is seen to be key to enabling broader and larger development of renewable energy systems. To that end, EnergyAustralia and Arup had a vision to co-develop the Cultana SPHES that could uniquely provide energy storage to the grid, in a sustainable and affordable way.

Collaboration and working in partnership between EnergyAustralia and Arup in the development of the project, between asset owner and engineering designer, was a key objective to realise the benefits the two organisations could gain from this project. Development of the Front-End Engineering Design benefitted from the shared interest in the project.

Arup has committed to the 17 United Nations (UN) Sustainability Development Goals (SDGs) and to contributing to sustainable solutions for all our clients in the world. Co-development of the Cultana SPHES was a tangible opportunity to be able influence and deliver on our aims in relation to Sustainable Development.

EnergyAustralia saw an opportunity to partner with Arup for the Cultana SPHES development. The alignment between Arup’s deep engineering knowledge, design ability and environment and planning expertise matched to EnergyAustralia’s appreciation of the South Australian energy market dynamics and capability to integrate a PHES facility into its generation portfolio. Partnering with Arup on the Cultana SPHES project contributed towards the delivering of one of EnergyAustralia’s strategic objectives to ‘*Lead and accelerate the clean energy transformation for all*’.

3.7 Key Learnings

Despite a seawater PHES being technically feasible, the corrosion associated risks with seawater would attract a higher contingency premium in the design, equipment supply and construction. Equally there remains a level of uncertainty with respect to the reliability and durability of mechanical equipment and structures in contact with the seawater. Most suppliers suggested the repairs and maintenance requirements, including downtime for routine maintenance would be twice that as compared with a freshwater PHES.

Capital cost projections for the 225MW, eight hours storage, freshwater PHES as developed under the reference design ranged from Australian Dollars (AUD) $700 million to $750 million (including contingency, excluding owner's costs). With further investigation, select contractor involvement and value engineering we believe AUD $50 million to $100 million in savings can be identified. The final capital cost is estimated to be approximately $650 million ($2.9m/MW). This is higher than global PHES benchmarks of $1.5m/MW to $2.0m/MW for eight hours of storage.

Pumped hydro energy storage projects are bespoke by nature with no two PHES being the same. Some of the key design inputs impacting on the capital cost include head (the difference in elevation between the upper and lower reservoir), penstock length (the distance between upper and lower reservoir), transmission length and storage time (storage volume). Other variables that will impact on cost include land tenure, local topography, geological conditions, available site construction material, available water source (and quality), environmental and approval issues and flood risk.

None of these variables were particularly onerous with respect to seeking a desirable design outcome. So why was the proposed Cultana SPHES so expensive?

The primary factors that contributed to the high capex cost specific to Cultana include the long penstock relative to overall head (height), large reservoir structures (required due to low head) formed from non-ideal site sourced materials with need for impervious long life reservoir linings, and complexity of a deep powerhouse constructed to levels below the natural water table. Also there may have been a premium applied by EPC tenderers due to complexities of security and access to the live firing DoD site.

One of the key challenges is PHES financing, primarily due to the high capital investment versus low operating costs and long service lifetime of the plant (typically 60 to 90 years). Assets of this nature may be better financed and owned by the State or Federal Government who may be more comfortable with much longer payback periods on investment, whereas many private entities would seek an economic design life of 30 year for their financial business case and thus require higher revenue assumptions and / or lower upfront capital expenditure.

Finally, it is vital to have a detailed understanding of the land upon which the project is being developed, considering technical and commercial risks. Although there were a number of project technical and market risks, it was the inability to secure a land lease that ultimately led to the end of the project. Having land security before significant development expenditure is incurred is very important.

4 Technical Design

This section of the knowledge sharing report sets out the results of the studies and technical design of the proposed Cultana SPHES project. There were a variety of stages undertaken to inform the design of the project. These were:

1. Initial Feasibility study (described in the previously issued September 2017 Cultana SPHES Knowledge Sharing Report)
2. Geotechnical, topographic survey, flooding and site investigations to inform the Front-End Engineering Design (FEED) of the project
3. Options Assessment (as described in Section 3)
4. Owners Requirements, including key performance guarantees
5. FEED study to develop a reference design for the project
6. Market sounding with a variety of technology suppliers and contractors to determine suitability and feasibility of design
7. Independent verification of the reference design
8. Value engineering based on market sounding.

The findings and results of each of these stages are described in this Chapter. Where relevant, decisions made have been described to assist in the development of future PHES projects.

4.1 Freshwater PHES versus Seawater PHES

The use of seawater is a unique option within the potential global PHES market; however, the lack of proven examples of seawater used for energy storage brings about several challenges. If these challenges were overcome, great long-term industry benefit could result.

However, during initial enquiries to hydro pump-turbine Original Equipment Manufacturers (OEM's), the seawater option did not sit favourably with many of the vendors. Equally the durability engineers flagged inherent challenges associated with meeting the design life requirements with some of the seawater exposed civil structures, penstocks and steel casings.

Specific to the Cultana location obvious challenges also existed with the siting of the water intake/outfalls accessing the sea at the end of a closed estuary. Drawing and discharging 3 GL of seawater daily could result in the same body of seawater being repeatedly cycled which would tend to compound impacts on smaller biota which could not be separated from the incoming water stream.

This issue could be mitigated through the use of a two-reservoir sea water scheme where the daily seawater throughput could be reduced substantially but compounds the operating salinity problem through concentration from evaporation over time. With these issues in mind the development team decided to also assess the merits of a desalinated water (freshwater) versus natural seawater system.

To sufficiently compare both options, a high-level design of each water supply system was completed with the input of technical specialists and international benchmarking. From each design the key factors where considered, forming a comparative analysis between the two water supply options.

Option 1: Seawater- Seawater intake with minimal filtration (no reduction in Total Dissolved Solids (TDS) or chlorides), and continuous purge and replacement of the working fluid over time in a two-reservoir system to minimise the build-up of TDS and chlorides to approximately 1.1 times the concentration of seawater.

Option 2: Reverse Osmosis- Desalinated seawater intake with pre-treatment media filtration and a single pass RO (99% TDS and chloride rejection rate). This is designated 'fresh water' for the purposes of the option comparison and would have a chloride concentration of around 200 mg/L. This would increase overtime due to evaporation and must be kept below a predetermined level to protect against corrosion. For this reason, a continuous bleed line is to be used during operation to feed water back to the RO plant to be re-treated. As with all desalination systems a brine waste stream is produced which is typically disposed by velocity mixing and dispersion on discharge back to the sea water environment.

The outcome of the comparative design analysis was the selection of an RO water supply based system. As summarised in the Table below, the capital cost of both options were in a similar range to one another, but the risks associated with the seawater option were higher than the system based on RO technology.

The use of seawater would have been a unique water supply option within the global PHES market; however, the rarity of examples of seawater use was ultimately the options undoing due to the number of design reliability difficulties identified. RO is a well understood, low risk and established technology forming the reasoning behind its selection for the Cultana SPHES.

Table 3 – Comparison between Seawater and RO water supply options

Item	Seawater Option	RO Option
Capital Cost	Neutral	Neutral
Operational Cost	High	Medium
Availability & Effective Life	Lower availability and lower effective life	Freshwater thus in line with other PHES schemes globally
Risks	Considerably higher and will attract contingency for risk	Relatively well know

Reputational Risk	Higher chance of having a negative reputational impact than the RO option	Low chance of a negative reputational impact
Global Impact of the Project	Potential to have a high global impact when future project is built of the learning from Cultana SPHES	Less likely to have a global impact

Overall, it was found that although a direct seawater PHES could be technically viable, the risks associated, particularly with regards to saltwater corrosion mean that, currently, freshwater or desalinated water PHES systems are favoured.

4.2 Lower Reservoir versus Spencer Gulf

4.2.1 Lower Reservoir Siting

The Stage 1 study centred on the use of the Spencer Gulf as the lower reservoir.

During the Stage 2 development, the project team continued technical investigation and environmental evaluation of the proposed reservoir location. Subsequently the lower reservoir option was assessed as an alternative to the large sea water intake structure located in the Spencer Gulf.

The social, technical, environmental and financial assessment of the change to including a lower reservoir provided several possible benefits for the PHES, as summarised below:

4.2.2 Financial Benefits

The financial benefits are as follows:

- reduced operational and maintenance costs associated with marine structures and a seafront submerged powerhouse
- increased round trip efficiency from reduced frictional losses in the penstocks
- reduced capital costs required by:
  - shortening the penstocks
  - removing the need for a large scale, low velocity marine intake / outlet structure
  - removal of the submerged powerhouse at the shoreline.
- these reductions in cost were offset to some extent by:
  - the additional cost of construction of the lower reservoir
  - the available head was reduced by 15 per cent which led to increased flow rates, increased equipment size being required for the same

generation capacity, and increased reservoir size for the same amount of storage.

4.2.3 Technical and Risk Benefits

The technical and risk benefits are as follows:

- reduced marine works and associated construction risks
- a largely dry powerhouse excavation increases the range of construction methods available and reduces seepage into the powerhouse
- removed spoil from the powerhouse excavation could likely be used to build the lower reservoir walls
- instead of exchanging water with the marine environment on a large scale, the lower reservoir means the water would be contained within the system. This enables the water quality, chemical composition and salinity to be controlled or modified at reduced costs, and with minimal impact on the marine environment.

4.2.4 Social and Environmental Benefits

The social and environmental benefits are as follows:

- eliminated the requirement to dredge a channel in the Spencer Gulf
- reduced the environmental impact on the Spencer Gulf in construction and operation phases
- reduced noise and vibration impacts for residents during construction and operation
- reduced extent of the approvals required
- a single land holder for most of the plant and equipment which was expected to simplify the planning and environmental approvals required.

4.2.5 Summary

With the new siting of the lower reservoir moved away from the Spencer Gulf, the nominal elevation head between the upper reservoir and turbines reduced from 260m to 220m. This available head reduction resulted in the need to increase the equipment size and flow rate to maintain the original generation capacity.

Consequently, the upper and lower reservoir volumes were increased from 2.9GL to approximately 3.5GL when compared to the stage 1 feasibility study. This larger volume is required to achieve the nominated power generation period of eight hours.

The location and size of the upper reservoir, the penstock and powerhouse have been adjusted to complement the lower reservoir location. The revised locations are shown in Figure 3 below.

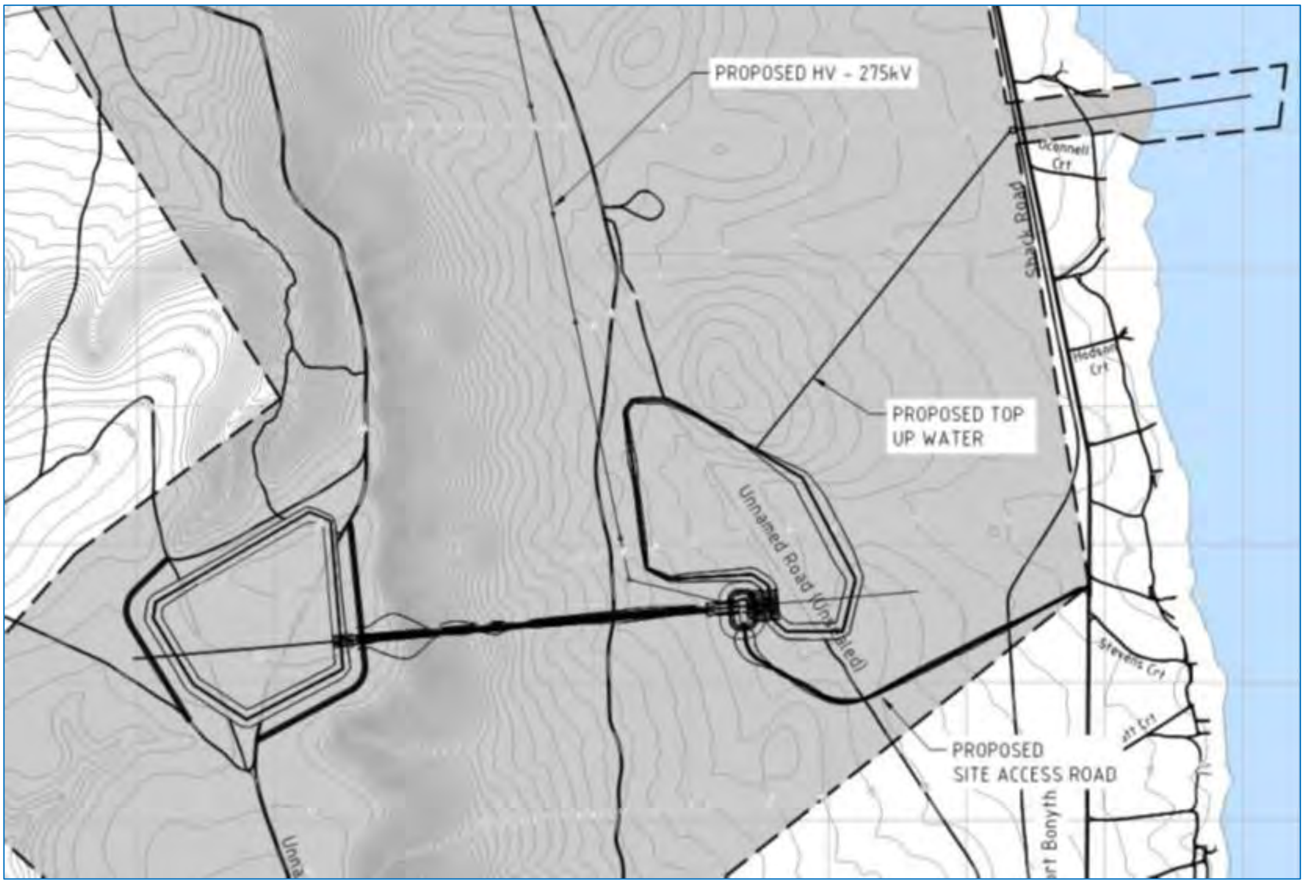

Figure 3 – Upper and lower reservoirs and powerhouse locations

4.3 Final Site Layout

Figure 4 shows the proposed final site layout of the proposed Cultana SPHES system including the key components:

1. upper reservoir and intake
2. penstock
3. powerhouse
4. lower reservoir and intake
5. grid connection substation
6. RO plant
7. marine intake.

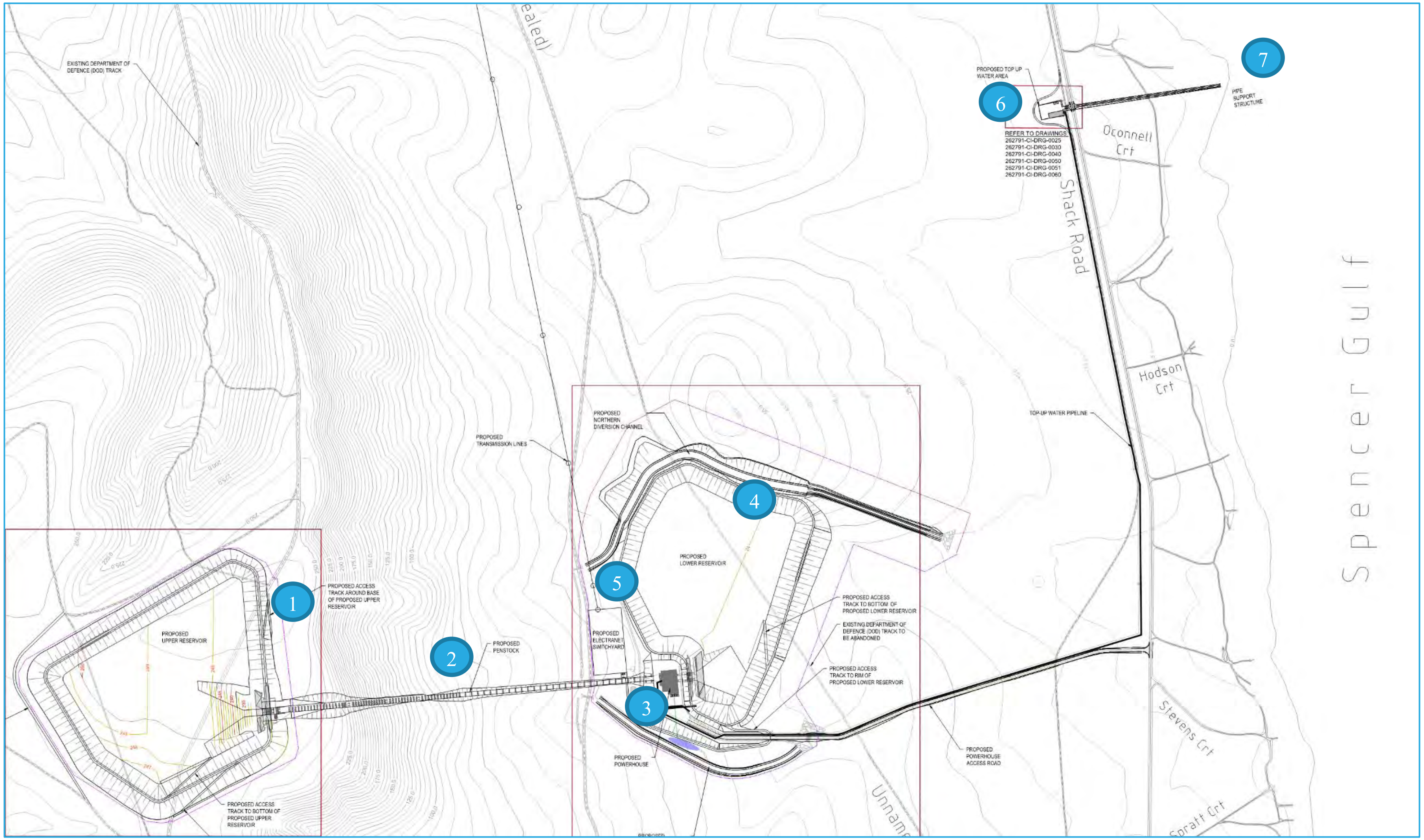

Figure 4 – Site Layout

4.4 Reservoir Siting and Geotechnical Investigation

4.4.1 Geotechnical Investigation

A comprehensive ground investigation was conducted to provide geotechnical design input for the major structural elements of the proposed project which involved excavation of many test pits and drilling of boreholes. Figure 5 shows the site works carried out in connection with the ground investigation.

Figure 5 – Drill rig and cores during site investigation

The geotechnical investigations were undertaken across the project area and demonstrated the suitability of the site for the proposed project. The Ground Investigation Plan shown in Figure 6 sets out the extent of the investigations across the project area.

The subsurface conditions encountered at the available test locations near the upper reservoir consist of hard residual clay up to 2m thick overlying meta-sandstone bedrock of the Simmens Quartzite member. The clay foundation was expected to be a suitable foundation for the embankment. There is a silty topsoil horizon that is up to approximately 0.4m overlying the hard clay that would be removed to expose a suitable clay foundation.

The subsurface conditions encountered at the available test locations near the lower reservoir consists of Alluvium (clay) up to 2m thick over shale of the Tregolana Shale member.

Figure 6 – Ground Investigation Plan

4.4.2 Flood Modelling

An analysis of the proposed Cultana SPHES storages was carried out to determine the Consequence Category from dam failure impacts, which inform design requirements for operating levels and structural capacity for the design flood as well as seismic loadings.

It should be noted that a number of design iterations occurred which were each assessed to various levels of scrutiny, supporting the final refinement of the design to a revised location for the lower reservoir and exclusion of any catchment for the lower reservoir, which had originally included a 3.7 km² catchment. The final assessment iteration was undertaken to confirm the Acceptable Flood Capacity (AFC) event for the finalised design.

Based on this analysis, the lower reservoir was to be designed to minimise and mitigate the risk of flooding failure in accordance with ANCOLD guidelines, being assessed to be a High C consequence category reservoir for 'Sunny Day' failure and High A for 'Flooding Failure'.

Figure 7 – 'Flooding Failure' assessment Lower Reservoir

4.4.3 Final Project Location

During the 2018 ground investigation at the lower reservoir, a previously unmapped fault was encountered. In Borehole 110 at a depth of approximately 18.5m, under the planned lower reservoir, a fault was encountered displacing a cemented clayey sand inferred to be part of the Pleistocene-aged Hindmarsh Clay.

The location of the fault had an impact on the proposed design, being located under the nominated area for the lower reservoir. Upon review, the development team decided to relocate the lower reservoir off the fault to reduce the risk to constructability, cost and long-term risk of the project.

A brief options assessment of the possible alternatives indicated that the best option was to move the lower reservoir approximately 200m closer to the upper reservoir which ensured that no part of the PHES structures was crossing the fault. This provided the advantage of shortening the penstocks but reduced the overall head available for the system to 215m compared with 220m.

4.5 Front End Engineering Design

FEED is the term given to project design works at an early stage of a project to develop the design into a tender specification. The tender specification is then intended for use for contracting of the building works to a specialist contractor or set of contractors.

The FEED study consisted of developing a reference design for the Cultana SPHES system. The reference design included design and integration of the reservoirs, intakes, Pump Turbine Units (PTU's), penstocks, powerhouse, associated mechanical and electrical equipment, water supply plant and civil works.

The reference design was developed *'for information only'* and it was the requirement of the EPC contractor to develop the project through additional design development for pricing. The contractor was responsible for developing an independent tender design that satisfies the performance requirements of the contract documents, and for all further design phases.

At a high level the reference design includes two lined rock filled dams as reservoirs, two high strength steel penstocks, two PTUs, an open cut powerhouse structure, associated High Voltage (HV) electrical equipment, sea-water intake structure and RO processing plant, all associated balance of plant and all required civil works.

Table 4 below provides an overview of the system.

Table 4 – Overview of System

System Parameter	Value
Plant Generating Nameplate Capacity	234MW Gross, 225MW net
Energy Storage	1,800MWh
Turbine Type	Fixed Speed Reversible Vertical Francis/Synchronous
Number of Units	2
Round-trip Efficiency	75%
Unit Voltage	11kV
Connection Voltage	275kV
Storage Type	Upper Reservoir: 'Turkey-nest' Lower Reservoir: Horseshoe shaped embankment
Storage Volume	3.5GL
Penstock	2 Pipes x 4.2m internal diameter
Maximum Flow rate	$120m^3/s$
Design Head	223m
Working Fluid	Treated Water (Single pass RO seawater)
System Inertia	680MWs

4.5.1 Operational Requirements

This section of the report describes the different modes of operation of the proposed Cultana SPHES system. Each of these modes would enable the facility to deliver the required commercial outcomes for the project.

The Cultana SPHES system as proposed provides a large volume of daily energy storage that could be dispatched quickly and flexibly on demand improving electricity grid security and reliability. Cultana as envisaged could have allowed increased penetration of renewable energy into the SA electricity market. This could have been achieved as the plant would provide load during periods of high renewables output plus a range of grid stabilising ancillary services to the NEM.

The Cultana SPHES was designed to operate in the following electricity markets:

- wholesale 'spot' market on the NEM
- FCAS) markets:
  - regulation: Raise and Lower
  - contingency: Slow and Delayed (60 seconds and five minutes), Raise and Lower
- NSCAS

- SRAS (also known as 'Black start').

To operate in each of the markets listed above and provide improved electricity grid security and reliability, each PTU was required to have several operational modes. The facility must be responsive to market signals by increasing (ramping up) or decreasing (ramping down) system output. The facility would additionally respond to market signals by changing the PTU operational mode. There were six intended operating modes, they are as follows:

1. **standstill -** the plant is not operational
2. **pump -** the facility is in pumping mode thus is importing electricity from the grid to charge the upper reservoir creating storage
3. **generate -** the facility is in generating mode when water is released from the upper reservoir to drive the PTU's in generating mode, thus generating electricity for export to the electricity grid
4. **synchronous condenser -** the facility uses the rotational inertia of the PTU's without either pumping or generating to provide ancillary services to the electricity grid
5. **speed no load -** to allow fast response for the transition to generating mode
6. **shut down -** to allow safe shut down of the plant to standstill mode.

Figure 8 provides a diagrammatical representation of each of the operating modes. The arrows and numbers correspond to each possible combination of change in operating mode, for example, arrow 1 shows that the plant could move directly from standstill mode to pump mode.

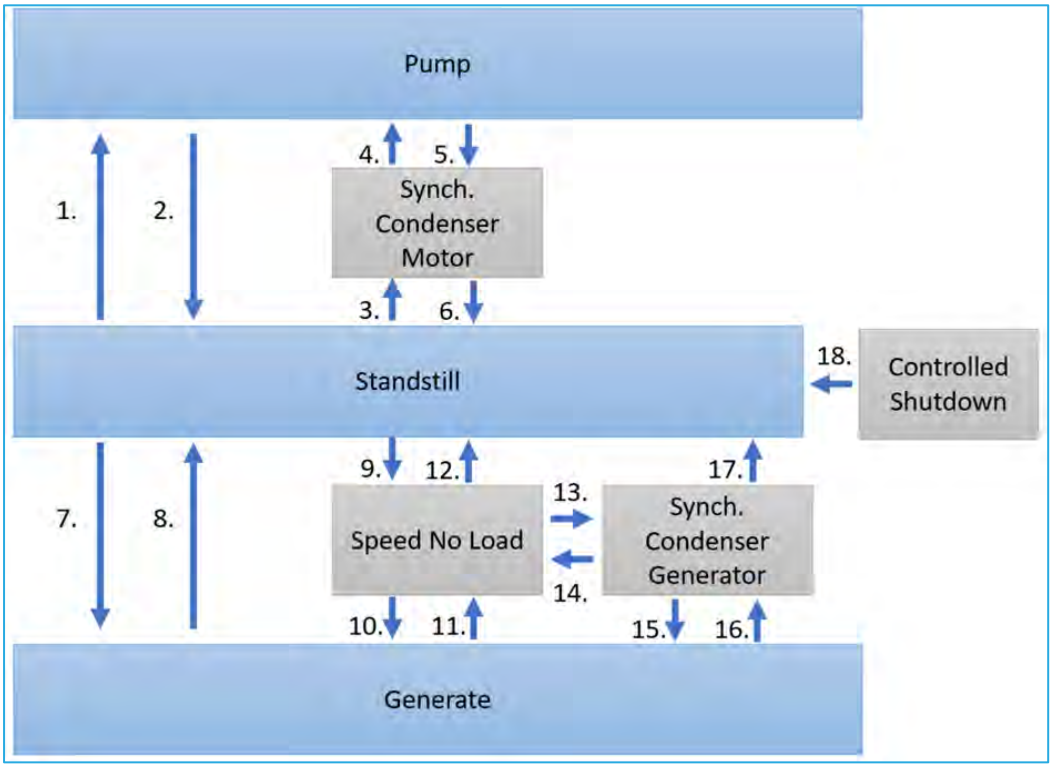

Figure 8 – Cultana SPHES Operational Modes and Mode Change Diagram

4.5.2 Key Performance Requirements

The key performance requirements were developed to form part of the tender package which the contractor would be contractually required to meet. These requirements included:

- water to be sourced from the Spencer Gulf and desalinated prior to entering the Lower Reservoir
- between 2 and 4 PTUs were to be installed (reference design is for 2 PTU's)
- capability of producing 1800MWh of electrical energy over 8 hours of operation
- pumping time to be not more than 10 hours
- system could complete the equivalent of 1.25 complete cycles per day
- full load generation capacity between 225-250MW (reference design is for 225MW net)
- the individual PTUs could operate in synchronous condenser mode
- round trip efficiency no less than 75 per cent
- PTUs could run independent of the other PTU(s)
- operate and provide services in the following markets:
  - wholesale 'spot' market on the NEM
  - FCAS markets:

    - regulation: Raise and Lower
    - contingency: Slow and Delayed (60 seconds and five minutes), Raise and Lower
  - NSCAS
  - SRAS (Also known as 'Black start').

Design Life

The design life of the Cultana SPHES varied on a component by component basis. This is typical for power generation assets where wear parts are replaced according to a maintenance schedule.

The majority of components would have a design life of 50 years, however the facility itself with sufficient maintenance activities would continue to operate for 100 plus years.

Redundancy

The facility was designed to ensure that no single equipment failure would inhibit the operation of more than one Pump Turbine Unit stream whilst meeting availability and safety requirements for the Facility.

Availability

The Facility's proposed availability over the design life of the plant was:

- 92 per cent at 100 per cent capacity
- 6 per cent at 50 per cent capacity for planned maintenance
- 2 per cent at 0 per cent capacity for unplanned maintenance.

4.5.3 Storage Reservoirs

The proposed Cultana SPHES system requires two reservoirs, an upper reservoir and a lower reservoir. These reservoirs hold water for storage. The action of pumping from the lower reservoir to the upper reservoir charges the PHES system. The action of releasing water from the upper reservoir and allowing it to flow through the PTU's to the lower reservoir releases the stored energy and generates electricity. The reservoirs need to retain water in either the upper or lower reservoir therefore each reservoir were sized to contain all water in the system. Figure 9 shows a render of the upper reservoir and intake looking toward the lower reservoir.

Figure 9 – View of proposed upper reservoir towards lower reservoir

Like the previous knowledge sharing report, a Lined Rock-filled Dam (LRD) was selected for both the upper and lower reservoirs. A LRD was selected based on favourable cost comparison, resilience to reservoir cycling, resilience to seismic deformation and the expected availability of quartzite and shale rockfill from the penstock and Lower Reservoir excavations.

The upper reservoir was to be constructed as a ‘turkey-nest’ style embankment with excavated material re-used from the dam basin utilised in the embankment construction. The embankment would be closed and would not allow inflow from the local catchment.

The lower reservoir would be constructed as a horseshoe shaped embankment with excavated material re-used from the penstock excavation and material excavated from within the reservoir area. The lower reservoir would be open on the western side with diversion channels to divert stormwater runoff around the reservoir to prevent inflow from the external catchment. Figure 10 provides a plan view of the proposed lower reservoir.

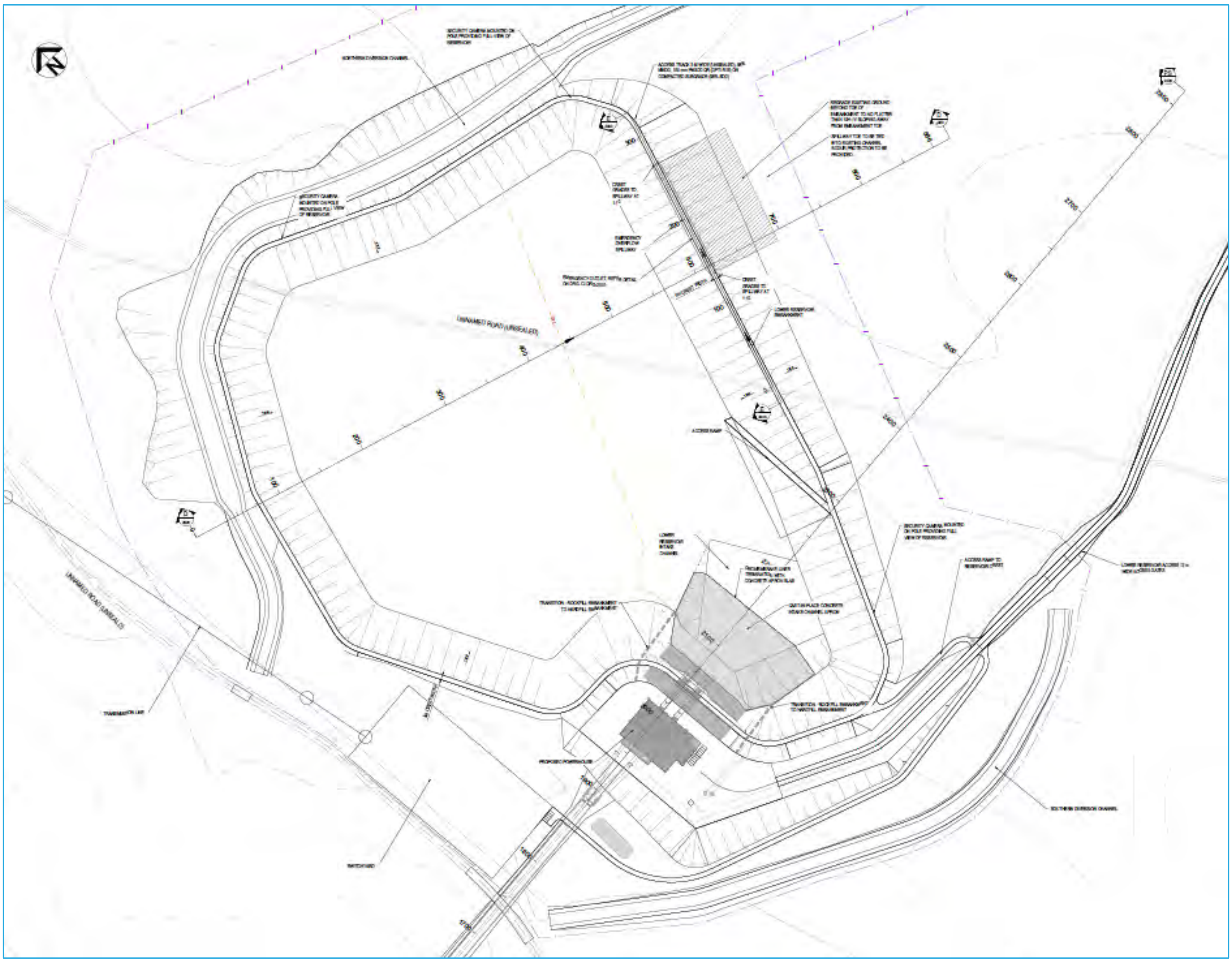

Figure 10 – Plan of Lower Reservoir with diversion channels

Both the upper and lower reservoirs would be lined with a geomembrane liner to restrict water along the embankment and minimise water loss from seepage. Reducing the amount of seepage decreases water released into the environment and reduces water lost. Any water lost due to seepage would require to be compensated for by production of additional RO water which is an operational disadvantage.

Both reservoirs would include an under-drain system comprising of a flow-net fabric and sand/gravel layer constructed beneath the liner system. The underdrain system helps to reduce uplift pressures and facilitate seepage capture and measurement. It was proposed that the underdrain system be divided into several subsystems so that the source of seepage could be identified. A network of flow monitoring devices at the outlets of the seepage collection system was proposed to measure seepage rates to be utilised for monitoring impact to the environment and for condition monitoring of the reservoirs.

The reservoirs would also include the intake structures that connect the penstock to the reservoirs (Figure 11 below). The intake structures were to be constructed using concrete and backfilled to form part of the reservoir. The intake structures were designed to isolate the reservoirs from the system for maintenance or during a failure. Within the intake structures Intake Operating Gates (INOG) were intended that automatically close during an earthquake event or penstock rupture. Located on the reservoir side of the intake structure were spatial provisions for stop logs that are manually placed for additional isolation and maintenance.

Figure 11 – Proposed Powerhouse with intake structure

4.5.4 Powerhouse

The powerhouse is the structure that houses the PTU's and associated generators. The powerhouse is the heart of the proposed Cultana SPHES.

In general, there are two arrangement types for a proposed powerhouse. Shaft type and underground powerhouses. Within a shaft type powerhouse, sub-categories exist such as buried, partially buried and silo type. Typically shaft type powerhouses are open cut excavated, constructed and then back filled. Underground powerhouses typically consist of a cavern type powerhouse that is constructed into the rock mass using tunnelling and mining techniques. Typically, underground powerhouses are used in conjunction with tunnelled penstock and has efficiencies over shaft type powerhouses.

There are advantages for utilising an underground powerhouse such as increased submergence depth that reduces PTU sizing, however given the lack of geotechnical information prior to commencing the FEED study, and the design decision to utilise above ground penstocks, it was considered not feasible to pursue an underground powerhouse.

An open cut, partially buried powerhouse was proposed for the reference design as it represented the lowest risk option when balancing submergence depth and buoyancy.

The powerhouse contains the PTUs, Main Isolator Valve (MIV), spiral case, powertrain and associated equipment. It was proposed to consist of underground levels that contain balance of plant and electrical equipment including a sump drainage pit for water management. The main service bay was to contain the bridge crane and required area for plant laydown. Adjacent to this were the generator disconnect modules and circuit breakers. Figure 12 provides a section through the powerhouse structure highlighting the tailrace, PTU, associated underground levels, main service bay, bridge crane and step-up transformers/PTU switchgear area.

Figure 12 – Powerhouse section

4.5.5 Pump-Turbine Unit Selection

There were two types of PTUs that were considered:

1. ternary sets, consisting of a turbine (either Pelton or Francis) that is accompanied with a standalone pump. The two units utilise the same motor/generator with a clutch device that engages either unit
2. reversible francis unit, i.e. a single machine unit that can operate as both a pump and a turbine.

When considering a Ternary set, there are operational benefits associated with the pumping and generating units spinning the same direction such as decreased change over time, increased efficiency, less stresses on the machine and the ability to operate in pump and generate at the same time. This mode is called hydraulic short-circuit mode. Ternary sets typically require larger powerhouse structures due to the larger machines, which can increase the civil costs associated with the project.

Comparatively, Reversible Francis Units are much more compact and can operate in either direction, however, require the unit to change direction when swapping between pump and generator modes. While operationally Reversible Francis Units are simpler, they offer reduction in capital costs associated with the machine's costs and additional civil costs. Two or more Reversible Francis Units can operate in hydraulic short circuit with at least one unit operating in either generate or pump mode. As such, a Reversible Francis type and vertical arrangement was selected for the reference design due to combination of system head, layout of the plant, operational requirements and capital costs.

The main pump-turbine and motor-generator parameters chosen for the Cultana SPHES system are presented in the Table below.

Table 5 – Key PTU parameters

Parameter	Value
Number of Units	2
Facility Nameplate Capacity (net)	225MW
Pumping Power	240MW
Power Factor (generation / pump mode)	0.9 / 1
Synchronous Speed	300rpm
Rated Voltage	11kV

4.5.6 Penstock

The penstock is the pipework, or tunnel, that connects the upper reservoir with the powerhouse and the lower reservoir.

During the FEED study, two options were considered for the penstock:

- option 1 – Piped penstocks, above ground on pedestals, with a co-located inlet structure supplying water to a single penstock for each of the turbines
- option 2 – Tunnelled penstock, with a co-located inlet structure supplying water to stub penstocks that manifold into a single tunnelled penstock. When the tunnelled penstock daylights, manifold to a single penstock for each turbine.

A piped penstock utilises high strength rolled steel plates welded together. The penstock requires anchoring and support to be able to withstand hydraulic loads. Some risks associated with piped penstock include:

- slope stability and geohazards associated with anchoring
- excavation costs
- foundations for pedestals.

A tunnelled penstock involves a horizontal tunnel from the powerhouse via drill and blast techniques with a raised bore to create a vertical shaft that intersects the horizontal tunnel and the upper reservoir. The risks associated with a tunnelled option include

- geotechnical risk associated with tunnelling. This is a major risk and requires significant geotechnical investigations to mitigate. Without investigations, it is not possible to determine or mitigate this risk
- tunnelling costs are largely unknown and highly dependent on the geotechnical investigations
- reduced operational flexibility due to a single tunnel.

While there are some benefits to a tunnelled solution such as potentially faster construction time and improved round trip efficiency, at the time of reference design there was insufficient geotechnical information to assess the technical feasibility and cost of a tunnelled penstock. As such, a piped penstock was chosen for the development of the study. Figure 13 shows a render of the penstock structure, looking from the upper reservoir towards the lower reservoir.

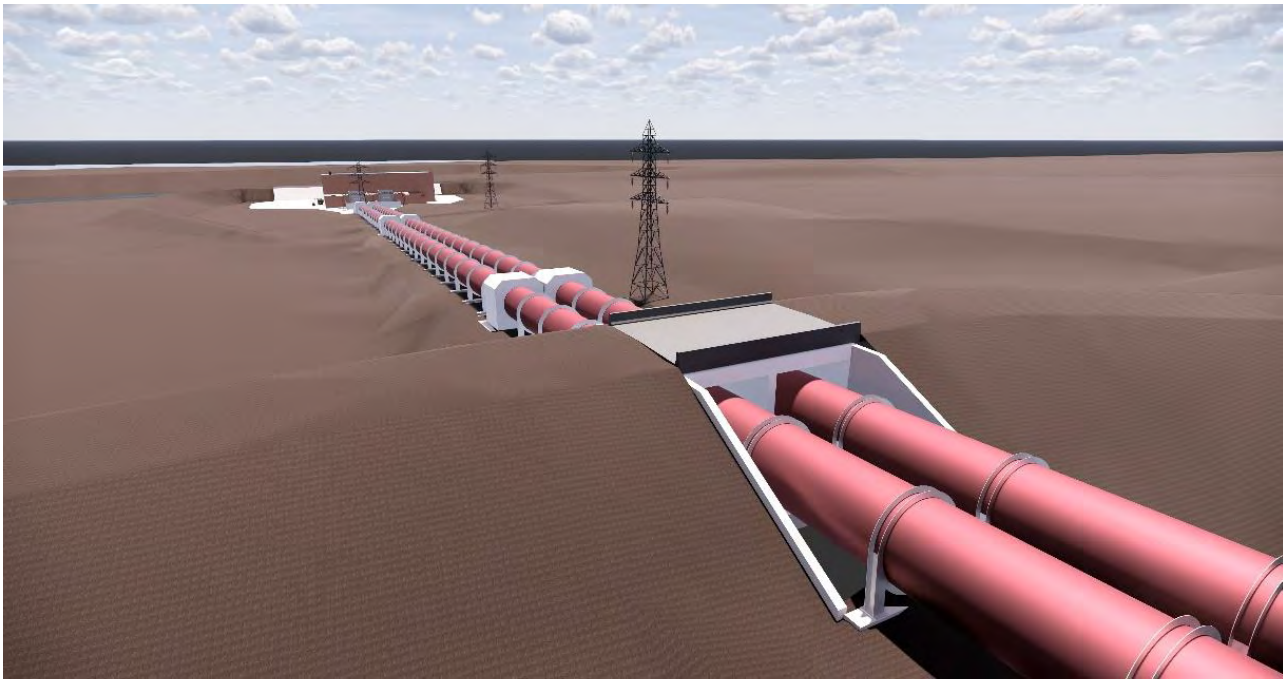

Figure 13 – Penstock alignment

There are a variety of different alignments of the penstock that could have been used. The alignment of the penstock would have to be considered on a case by case basis depending on the following parameters:

- shortest route between reservoirs
- mitigate slope instability
- excavation costs,
- intake structure position.

The penstock alignment chosen for the Cultana SPHES system was selected to reduce the slope of the upper escarpment by repurposing soil from this area and placing on the lower portion of the slope. The intake structure could be positioned so that the penstock travelled in a straight line from upper reservoir to powerhouse with no required bends. The penstock was intended to be above ground, not buried, to assist with maintenance and visual inspections which is important for the project given the potential corrosion issues associated with utilising first pass RO water as the working fluid. There was potential that over time, the salinity in the water would increase and cause potential localised corrosion. An internal and external corrosion protection layer was intended to be applied to reduce the potential for corrosion.

Thrust blocks were intended to be located periodically along the pipeline to transfer the load into the rock mass.

4.5.7 Powertrain

The section of this report describes the powertrain which consists of the onsite electrical infrastructure of the facility. The powertrain includes:

- generator motor
- static frequency converters
- Low Voltage (LV) and HV electricity infrastructure
- switchboards
- transformers (generator and auxiliary)
- switchyard.

Figure 14 provides a graphical representation of the Cultana SPHES generator switchyard.

Figure 14 – Generator Switchyard (without transformers)

Generator Motor

The generator motor is a key component of the PTU and powertrain of the proposed Cultana SPHES system. The generator motor is attached to the PTU via a spinning shaft thus allowing the transfer of kinetic energy to electrical energy and vice versa. The design includes two fixed speed generator motors that are rated to 117MWe in both generate and pump modes. The generator motors operate at 3 phase and 50Hz. The characteristics of the generator motor are vendor specific and it is likely that the generator motor will operate at a voltage of between 11kV and 25kV.

The combined gross output of the generators proposed is 234MW. The facility parasitic load was anticipated to be approximately 9MW. Therefore, the net electrical output to grid was 225MW. These losses are associated with the balance of plant, powertrain and RO plant.

Station Auxiliary Supply Switchboard, Static Frequency Converters and Auxiliary Transformers

The proposed Station Auxiliary Supply Switchboard is an 11kV Medium Voltage switchboard powered by the grid. It has isolating transformers upstream of the switchboard to reduce the fault levels. It provides dual supplies to the Powerhouse and Balance of Plant LV system, RO Plant, upper reservoir kiosk and single supplies to the SFCs.

There were also a series of auxiliary transformers for small power purposes, stepping down voltage as required to meet the requirements of the balance of plant.

Unit Auxiliary Transformers and Excitation Systems

Each proposed PTU has a unit auxiliary transformer supplied by the grid that provides power to the unit's excitation system and individual control system to allow for the PTU to be unitised. The reference design uses a static excitation system to provide excitation to the generator motor. This system also performs critical power quality and regulation capability including automatic voltage regulation, excitation limiters, voltage frequency limiters and power system stabilisers.

Generator Circuit Breaker and Phase Reversal Disconnecting Switches

Generator circuit breaker and phase reversal disconnecting switches were proposed between each PTU and the generator transformers. The generator circuit breakers are used to synchronise the PTUs to the grid and for protection of the PTU to faults and excessive stresses. The purpose of phase reversal disconnecting switches is to reverse two phases to change the mode of operation from Generation to Pump load and vice a versa.

Isolated Phase Busducts

Isolated Phase Busducts (IPBs) were proposed to connect the generator output to the Generator Step Up Transformer as well as all connections between the two along the main power train. Isolated Phase Busducts are used as the main conductor due to the high currents involved and properties during a short circuit or fault event.

Generator Transformers and Generator Switchyard

Two Generator Transformers were proposed rated at 145MVA each that step the voltage from 11kV to the transmission voltage 275kV. They were to be outdoor type, oil immersed, conservator type with a cooling classification ODAF. The 275kV generator step up transformer termination was designed to be aerial to allow for the overhead conductors to continue through the generator switchyard comprising of 275kV protection, metering and surge arresters. From the generator switchyard the Cultana SPHES system was proposed to connect via overhead conductors and a gantry system to ElectraNet's proposed Hannah Dam Substation.

4.5.8 Grid connection (Technical)

The Cultana SPHES system was to be grid connected to the ElectraNet network at 275kV. The onsite connection point proposed was the generator switchyard. From the onsite generator switchyard, the plant was to be connected to the proposed Hannah Dam Substation owned and operated by ElectraNet and built adjacent to the Cultana SPHES facility.

Hannah Dam Substation

The Cultana SPHES system was proposed to be connected to the Eastern circuit of the 275kV Davenport to Cultana transmission line via a new Hannah Dam Substation. The proposed transmission line is approximately 2.4km from the Generator Switchyard and ElectraNet's design extends a double circuit line to the new Hannah Dam Substation adjacent the Generator Switchyard.

The Cultana SPHES system was proposed to connect to the Hannah Dam Substation via overhead conductors and a gantry system. The gantry system within the Hannah Dam Substation was to be the delineation of assets between ElectraNet and the Cultana SPHES.

4.5.9 Water Supply

A vital component of any hydropower system is the working fluid, water. Water naturally evaporates meaning that the reservoirs will slowly empty over time. Rainwater acts as a natural water replacement however, the Cultana site is arid and the volume of rainwater that would be captured in the reservoirs would not be sufficient to offset the volume of water evaporated from the reservoirs. For this reason, a method of water replacement had to be devised.

There were a variety of options considered throughout the FEED process. These were:

- use of potable mains water from a nearby (2km to the North) mains water supply

- use of borehole water, where water is extracted from boreholes in the ground from the natural water table
- use of seawater, either directly as a saline solution or indirectly via a water desalination plant.

Each of the methods of water supply were investigated in turn. Use of borehole water was discounted primarily because the quality of the water from boreholes in the area was found to be poor, high in suspended solids and high in salinity. To treat the bore water, a water treatment plant similar to a seawater treatment plant would have to be used. A brine discharge would also be created that would have to be disposed of. Overall, it was not considered economically viable to utilise borehole water in this area.

Use of potable mains water was found to be a viable option from both a technical and economic perspective, however, it was not viewed as the most sustainable source of water in the area. The project team was concerned that use of potable water that could otherwise be used for human consumption in an arid, drought prone area was not a sustainable option. There was also a risk that the water supply to the PHES system would be cut off should significant drought conditions occur, which would lead to a loss of storage capacity and present a risk to the viability of the project from a power generation perspective.

For this combination of reasons, a seawater PHES system was chosen. Section 4.1 of this report sets out the typical differences between using seawater directly as the working fluid and providing a desalination plant to use desalinated water as the working fluid. The following report section sets out the chosen design solution that was determined as part of the FEED.

Reference Design Solution

The reference design for the Cultana project was to source seawater from the Spencer Gulf which was then to be treated by RO to produce water of a quality suitable for operation of the pumped-hydro system (i.e. desalinated and treated water).

Seawater extracted from Spencer Gulf was to be treated by multimedia filtration followed by first pass RO. The reservoirs required a continuous supply of treated water to fill and maintain the storage volume to account for working fluid losses due to evaporation and seepage through the reservoir linings. Desalinated water was also intended to be used as the primary supply for the Primary Cooling Water System, Seal Water System, and Fire Water Systems.

A second pass RO plant was proposed to produce water with a quality suitable for the Secondary Cooling Water System, Chilled Water System, Plant Service Water and Potable Water System. Chemical dosing was to be used to stabilise the second pass RO permeate for use in the Potable Water System. Drinking water was to be supplied via water coolers.

The following parameters need to be considered for any PHES system when designing the water supply system:

- top up water required due to evaporation
- top up water required due to seepage of water from the reservoir through the liner
- natural addition of water through rainfall
- chloride and TDS levels within the reservoir itself which will increase over time
- treatment required for the source water to ensure compatibility with the chosen material and equipment (including turbine requirements)
- discharge of treatment residues
- allowance for treated water tanks to store treated water to allow for changing water demand
- volume of water required for process use including fire water tanks, cooling, seal water and other service water requirements
- potable water requirements
- worst case operating parameters, prolonged periods without rainfall and stormwater and flood allowances in design.

The final solution proposed for Cultana included:

- small submerged intake structure on the Spencer Gulf to pump water from the Spencer Gulf to the Cultana SPHES Facility
- a series of pumps and pipes to facilitate water flow
- Reverse Osmosis water treatment plant for desalination and treatment of seawater
- discharge pipe for brine (salty water) back to the Spencer Gulf
- a variety of tanks for treated water storage and fire water storage
- pipework systems to distribute process water around the Cultana site
- a typical selection of water treatment chemicals for use in the RO plant to achieve the desired water quality.

This design allowed for supply of water compatible with the materials and process plant specified for the Cultana SPHES. The exact water quality and level of treatment required vary on a project by project basis depending on the type and quality of the raw water as well as the turbine, penstock and reservoir materials chosen.

4.5.10 Marine Seawater Intake and Structure

A proposed seawater intake system was required to transfer seawater from the Spencer Gulf to the RO Plant for treatment including a seawater intake screen, pump station, support structure and pipeline. The intake system was specified to be designed for the required flow to enter the RO Plant to achieve first fill design flow and to utilise materials to meet the design life requirement in consideration of the aggressive nature of seawater.

Seawater Intake Screen

The proposed seawater intake screen was required to prevent jellyfish and other marine life and debris from being drawn into the seawater intake pump station and was to be located at the head of the seawater intake pipeline.

The proposed screen specified was to be a Johnson type screen or similar with an aperture and intake velocity that meets the relevant environmental requirements. It was to include an automatic air purge system to combat screen blinding from trapped matter.

Seawater Intake Pump Station and Support Structure

A proposed seawater intake pump station was required to draw seawater from the gulf through the seawater intake screen and pump it to the RO Plant for treatment. It was proposed to be located on a dolphin type support structure not connected to the shore in any way. The seawater intake pump station and support structure were to be located a distance away from the brine outfall pipeline to avoid the discharged brine from re-entering the system (short-circuiting).

The pump station was specified to include a shock chlorination system or an equivalent pump suction cleaning strategy to prevent biological growth within the suction pipework.

The proposed support structure consisted of a concrete pile cap supported by steel tubular piles, although other options including a steel superstructure may have been considered if the specified durability and maintenance requirements could be met.

Seawater Intake Pipeline

The proposed seawater intake pipeline was required to connect the seawater intake pump station to the RO plant for seawater treatment.

The section of pipeline from the intake screen to the shoreline was proposed to be laid underwater along the sea floor where it then transitioned to a belowground pipeline between the shore and the RO Plant.

The seawater intake pipeline was sized to accommodate the first fill design flow.

5 Financial Viability

This section describes the perceived financial viability of the project based on the development activities carried out.

5.1 EPC verses ECI

At the May 2018 commencement of the phase 2 development for the proposed Cultana SPHES Project it was contemplated that Early Contractor Involvement (ECI) for two discipline paths Civil and Mechanical/Electrical would be incorporated in the FEED program.

The ECI approach is known to often result in excellent technical solutions as:

- it encourages collaboration between the developer and the civil, and M&E contractors from the start
- it provides early opportunity for innovation and design optimisation.

The ECI approach also relies on selected sourcing of contractors and successful collaboration between all parties to result in executable construction contracts.

However, there was a concern that an ECI based process would not maintain competitive tension to achieve a competitively bid EPC Contract. Choosing a preferred ECI party ahead of market price testing was not consistent with EnergyAustralia's corporate procurement and commercial governance processes, which drive towards requiring a competitively bid EPC style contracting approach. The EPC approach was viewed to offer a lower risk path to achieving FID as:

- contractors and OEM's establish their own working relationships up front
- contracting terms and conditions are known by all parties' up front
- the EPC approach timeframes are easily defined and controlled
- the EPC approach matches well with governance requirements
- technical optimisation can be included in shortlist phase
- best and final offers round sustains competitive tension to final selection.

The EPC approach however requires development of the project technical concept to a high level, requiring a Reference Design to provide a platform of minimum technical requirements and performance-based specifications.

5.1.1 Why was the EPC approach preferred?

The EPC approach was considered to offer a greater certainty of a successful commercial outcome.

Upsides:

- opens the process to a wider field of EPC capable contractors
- maintains competitive process until the final selection
- enables civil contractors to court an OEM team-mate
- OEM’s don’t select Civil contractors they don’t rate
- less risk of Civil and OEM mismatch blocking achievement of a viable EPC
- enables a smooth commercial governance pathway
- places the commercial terms for an EPC bid front and centre
- best EPC package delivers strongest project commercial performance
- provides true market pricing.

Downsides:

- EnergyAustralia and Arup didn’t get to hand pick Civil and OEM pairings
- technical concept is less refined, higher reliance on the EPC to produce design
- longer pathway to final technical solution
- the best OEM may not be paired with the best Civil Contractor.

Implementing the EPC Contracting strategy

Consideration of EPC vs ECI relative merits resulted in the selection of the EPC sourcing pathway. It was determined there was greater certainty of a successful outcome under the EPC sourcing approach. The change in contracting strategy from ECI to EPC also required a re-alignment of FEED Program deliverables to provide the Reference Design and specifications.

The EPC Contracting strategy sought to implement a four-step procurement process focussed on tier 1 Australian and international civil construction contractors teaming with a hydro-turbine OEM for supply of turbine and generator equipment.

The fours step process entailed:

1. pre-qualification
2. EPC tender
3. optimisation
4. final offer.

Pre-qualification of Civil Contractors

Civil Design and Construct Contractors with capability to perform as the leading partner in a consortium with an OEM were identified through an initial

Prequalification process. The Prequalification was 'open to market' and evaluated on financial standing, expertise and track record including experience teaming with an OEM hydro turbine supplier. Civil companies were required to nominate their intended OEM partner(s). Successful prequalification enabled selection of intended Consortia to participate in the second phase of EPC Tender by invitation.

EPC Tender by invited Consortia

Prequalified Consortia were invited to respond to an EPC Tender on a binding price, contract terms and conditions basis. The EPC tender documents issued included the Reference Design detailed concept drawings, performance specifications, design basis memo's, and detailed survey, geotechnical and other detailed information produced by the FEED Program. After tender submission, clarifications and evaluation, a short list of two Consortia was intended to be selected to continue to the final stages of the selection process.

Optimisation

Short listed Consortia from the EPC tender phase would be requested to technically Optimise their proposals. The inputs would be informed by the final detailed FEED information on grid connection and the Consortia's own further refinements of their proposals including innovations with respect to configuration and performance.

Final Offers

On conclusion of Optimisation, and to finalise the EPC selection process shortlisted Consortia would be requested to provide their Final Offer. Evaluation of the Final Offer would result in selection of the successful EPC Contracting Consortium.

EPC Tenders Received

On the 21 May 2019 EnergyAustralia issued the Invitation to Tender to three invited consortia including a full form EPC Contract, Owners Requirements specification and Reference Design informed by detailed site survey and geotechnical investigation works. The Tender period was 20 weeks with binding offers received from three international consortia by EnergyAustralia in early October 2019.

5.2 EPC Tender

To prepare the EPC tender packages, the project team developed a series of documents that had varying levels of contractual obligation for the EPC tenders to adhere to. The documents are summarised as following:

1. Key Performance Criteria: Specific performance metrics that the facility would be able to meet through operation

2. Owners Requirements: A detailed set of requirements that the EPC tenderers were contractually obliged to adhere to
3. Specifications: A series of performance specifications for each system and sub-system that the contractor was obliged to adhere to
4. Reference Design: A non-binding specific design of the system including drawing packages and design reports.

Through the tender period, the contractors were required to develop their own tender design utilising the reference design for information and interpretation of the owners' requirements. Tenderers were also invited to provide where applicable design optimisations based on their experience and value engineering opportunities.

Tenders were received and reviewed for compliance. All tenderers meet the minimum specification requirements with a range of proposed technical optimisations.

The tender responses received are bidders IP, confidential and remain the property of the individual tenderers. Construction Costs

Each of the EPC tenderers provided a pricing schedule alongside the tender return. The tenderers provided a contract price breakdown against the owners' requirements, associated specifications and their tender design.

The tendered prices cannot be provided for confidentiality reasons. The project teams all-inclusive estimated final cost for the facility based on the reference design and EPC tenderers pricing, including contingency and owners' expenses was $790.5 million, equivalent to $3.5 million per MW net installed generating capacity.

This is high in comparison to the benchmark range for PHES projects published globally which indicate typically cost in the region of $2 million per MW. The Cultana project was therefore indicated to be significantly more expensive than was expected during the pre-feasibility stage.

The Table below shows the high-level breakdown of project costs.

Table 6 – Project construction cost summary

Item	Cost
EPC Lumpsum Turnkey Contract Price (indicative)	$700.0m
EPC Contingency (5%)	$35.0m
Owners Costs (including 10% contingency)	$55.5m
Total Cost	**$790.5m**
Cost Confidence	**+/- 10%**

The high cost of the project was a significant factor in Energy Australia reaching a negative FID.

5.3 Operations and Maintenance Costs

EnergyAustralia as an owner and operator of power generation facilities was intending to perform the Operations and Maintenance (O&M) of the facility in-house.

For the Cultana SPHES facility, operating and maintenance expenditures (opex) arise from four primary sources. In order of decreasing materiality these are;

1. labour costs related to:
    a. the full time equivalent (FTE) staffing levels required to run the plant
    b. outsourced services which are required to ensure the safe, secure and smooth running of the plant
2. grid connection and market participant related charges
3. annual planned and unplanned maintenance
4. consumables needed to treat the seawater, maintain the equipment and to support the functions of the plant.

In addition, while the pump/generator units are specified to have a 30-year operation life, there is an expectation that a half-life major maintenance refit will be required to maintain unit integrity and round-trip efficiency.

5.4 EnergyAustralia Financial Model

EnergyAustralia primarily uses its internal market modelling capability to support new investment decisions, with these internal forecasts typically supplemented with external forecasts for FID.

EnergyAustralia uses Plexos simulation software to model the NEM energy prices. Plexos is a high-performance linear programming simulation platform that replicates AEMO’s NEM Dispatch Engine (NEMDE). Plexos is broadly used by energy market participants, system planners, investors, regulators, consultants and analysts worldwide, and is used by AEMO’s planning team for work such as the Integrated System Plan and Statement of Opportunities.

Given the inherent uncertainty regarding the longer term NEM market outlook, EnergyAustralia adopts a scenario-based approach to its market forecasts. EnergyAustralia utilises AEMO published ISP and ESOO assumptions as inputs into its market scenarios.

Key assumptions that vary across market assumptions include:

- demand outlook and behind the meter assumptions for rooftop photovoltaic (PV), batteries and electric vehicles (EVs)
- renewable and emission policies at state and federal level
- retirement of existing generators and new entrant generators
- interconnector augmentations
- technology capex and operational assumptions.

EnergyAustralia uses Plexos to forecast energy arbitrage value for storage assets. In the case of the Cultana SPHES, the pumping and generation regimes are a result of the cost minimisation objective of the linear program in Plexos. The energy storage module in Plexos shifts energy from trough (pump) to peak (generate), taking account of round-trip efficiency losses and storage volumes.

Cultana SPHES has been modelled assuming the physical characteristics presented in the reference design, the output of which is an indicative operational profile for the asset. This operational regime is likely to change over the life of the asset, as the makeup of the generation fleet in SA, and the NEM, evolve over time. SA is a relatively small market compared to the other NEM states and as such, is likely to be more sensitive to new entrants of the scale of the Cultana SPHES.

The output of the market modelling delivers various pumping/generation profiles under various scenarios supported with further views on the development of long-term capacity markets, and ancillary services. These outcomes are then run through a comprehensive Financial Model that enables the assessment of the overall financial viability of the project under several operational, funding, market and Capex profiles to determine the overall financial viability of the project.

The NPV for the project was calculated based on a 30 year financial model. Forecasting FCAS services is quite problematic and exacerbated due to the regulatory uncertainty regarding market re-design and was not included as part of the overall revenue assumptions.

5.5 EnergyAustralia Final Investment Decision

On 25 November 2019 the EnergyAustralia Cultana SPHES Project Steering Committee made a negative FID decision with respect to the Cultana project. The arrival at the negative FID decision was the culmination of eighteen months of work by the project team to determine the ability for an FID to be delivered by the project target date of December 2019.

The negative decision was taken as the Steering Committee, executive committee and other key stakeholders were not convinced that trends in evidence with respect to capex, approvals, funding, market need and investment hurdle rates could be resolved without significant additional time and development funding, against the back drop of uncertainty in the rapid market transition, competing PHES projects, emerging technologies and planned interconnections between the SA and other States.

5.5.1 What were the Trends?

At the November 2019 Steering Committee meeting the members were advised on the following outcomes.

Project Capex - EPC Tender issued and returned with 3 x binding lump sum bids revealed capex likely to be 50 per cent higher than indicated in the initial feasibility study ($477m) and well above modelled limits for a financially viable project based on EA's market and arbitrage assumptions.

Commonwealth EPBC Act Referral – Submission to Department of Environment and Energy (DoEE) for consideration of accreditation under state approvals process in March 2019 only received determination that approval would need to be sought on submission of Preliminary Information advised in September 2019 with a further minimum of six months likely needed before any decision.

Market modelling – analysis of portfolio performance and expected revenue of the PHES under a selection of renewables growth, transmission interconnection, competing PHES projects and fossil generator retirement scenarios indicating near term need for PHES in SA energy was marginal for a project with significantly higher than expected Capex. Longer term prospects were better after further renewable build out where a competing PHES was not present.

Financial Modelling – Determining the merits of the business case for the project revealing corporate internal hurdle rates for investment were unlikely to be achieved in the current context of market and capex.

Emerging Technology – Battery technology advancements and falling prices cast doubt on the case for large scale investment in PHES, particularly given the long-term nature of the investment in a market that is rapidly changing and subject to uncertain government intervention

Competition Uncertainty – With a number of competing projects in South Australia the risk of price cannibalisation from a second PHES was considered a major risk factor in evaluation of the Cultana SPHES. Modelling suggested that at this stage the SA market could not support two financially viable PHES. In addition the planned EnergyConnect transmission project and rapid development of BESS is expected to significantly impact market opportunities for large scale storage, at least in the initial years. Market uncertainty and a high level of competition presented a tough environment for justification of investment in a high capex and long pay back PHES project.

5.5.2 Negative Financial Investment Decision

Facing regulatory and market uncertainty, the advancement of new storage technology, acute uncertainty of achieving investment hurdle rates and the need for significant reductions in project capex necessitating likely large-scale redesign to achieve a financially viable project, the Steering Committee determined a negative FID with a resolution of no further expenditure on development of the Cultana SPHES project by EnergyAustralia.

5.6 Development Transfer

EnergyAustralia reached a negative FID for the Cultana SPHES project in late November 2019. Under the co-development agreement between Energy Australia and Arup, Arup had two options:

1. pause the project and cease development activities;
2. exercise the right to development transfer which passes the project development to Arup solely.

After internal review, Arup felt that the importance of the project to the South Australian energy market was high and, from its perspective, provided an excellent opportunity for further development of this technology and investment.

Arup therefore initiated the development transfer and proceeded with taking the project forward through the final stages of development independent of EnergyAustralia. Arup felt that the project, for reasons described throughout this report, was still a viable investment for SA and would prove to be a vital infrastructure asset providing support to the South Australian electricity grid.

Part of Arup's reasoning to continue the project was the opportunity for value engineering of the current design, explained in the following section.

In addition, Arup was considering alternative strategies with respect to the time horizon over which the business case is modelled. EnergyAustralia modelled a 30 year time horizon: however PHES assets, with sufficient maintenance expenditure, can operate for much longer timescales.

5.7 Value Engineering Opportunities

Value engineering is the process of rationalising and optimising a project to benefit commercial performance. Typically, value engineering processes occur following the completion of major design milestones such as business case, reference design, tender design or final design submissions. Given the stage of the Cultana SPHES project, there was potential to engage with further studies and engineering to help reduce capital and operational requirements, increase potential revenue, increase sustainability metrics and de-risk the project. There were multiple value engineering opportunities for the Cultana SPHES, these opportunities are explored in the sections below.

Following the reference design, the value engineering opportunities can be split into three discrete sections:

1. procurement strategy
2. technical and operational value engineering
3. additional site investigations.

5.7.1 Procurement Strategy

An opportunity to work collaboratively with a preferred delivery contractor post EPC tender but prior to final contact award was likely to see a balance between performance and capital cost providing a better net project outcome.

5.7.2 Technical and Operational Value Engineering

Through the reference design, there were opportunities raised that could provide additional value engineering. Given the time constraints through reference design, they were not included in the final package for EPC tenderers. In addition, through consultation with the EPC tenderers and internal review process following the official tender period, some potential savings were identified.

Following internal review, there was estimated to be between \$50m to \$150m AUD in potential savings that could be explored through further engineering and development.

5.7.3 Additional Site Investigations

The reference design was developed simultaneously together with geotechnical site investigations and other specialist environmental studies. Some of these studies impose a financial risk on the project and given the limited information, assumptions were carried through to the EPC contractors. Allowing time to incorporate additional site studies, completing additional specialist studies and optimising the design to suit the local materials on site could have found additional cost savings.

5.8 Project Completion

Unfortunately, the Department of Defence confirmed in August 2020 that a land lease for the Cultana SPHES could not be given. The change in stance for the DoD came about due to the direction in the 2020 Defence Strategic Update and the 2020 Defence Force Structure Plan issued on 1st July 2020. This outcome has ultimately led to project completion. It is not feasible to proceed with the project without the land from the DoD. If the land had been secured, Arup would have proceeded with the project.

View from Upper Reservoir location to Lower Reservoir site and Spencer Gulf

6 Regulatory, Market and System Development Issues

6.1 State Based Renewable Energy Targets

In 2019, the Climate Council awarded SA first place in a ranking between Australia's states and territories based on their performance across numerous renewable energy metrics[2]. The Climate Council reported that SA was a global leader in the renewable transition, with over half of the state's electricity generation from wind and solar, teamed with the state's impressive goal to have net 100 per cent renewable electricity by 2030. To meet this target renewable energy penetration will subsequently increase across the state.

The Victorian Government has legislated renewable energy targets of 40 per cent by 2025 and 50 per cent by 2030[3]. In 2019 Victoria was reported to have the greatest capacity of wind and solar projects in their pipeline[2]. Victoria and SA are currently connected by the transmission network, enabling them to share electricity generation. The Victorian renewable energy targets are of keen interest to SA PHES projects as an increased penetration of renewables in SA's neighbouring state will increase storage demand to firm intermittent renewable generation.

NSW is yet to set a state based renewable electricity target but they have set a net zero emissions target by 2050. NSW and SA are not currently connected with transmission infrastructure but an electricity interconnector (known as EnergyConnect) between the two states is currently under a Regulatory Investment Test for Transmission by ElectraNet[4]. If the proposed SA-NSW interconnector came to fruition, NSW's renewable generation and storage demands would be favourable to SA PHES projects like Cultana.

6.2 Future SA Market Scenarios

Energy market transition is accelerating with record levels of rooftop PV installations and development of utility scale renewables. Whilst the evidence is clear regarding these trends, the market impact is yet to be become fully visible with many committed utility renewable projects yet to come online.

[2] https://www.climatecouncil.org.au/resources/states-renewables-2019/
[3] https://www.energy.vic.gov.au/__data/assets/pdf_file/0030/439950/Victorian-Renewable-Energy-Target-2018-19-Progress-Report.pdf
[4] https://www.aer.gov.au/news-release/aer-approves-south-australia-%E2%80%93-nsw-interconnector-regulatory-investment-test

6.2.1 Duck Curve

As a starting point, the duck-curve impact from rooftop PV installations is becoming more apparent year on year, as demonstrated in the chart from the University of Melbourne Climate and Energy College, Figure 15.

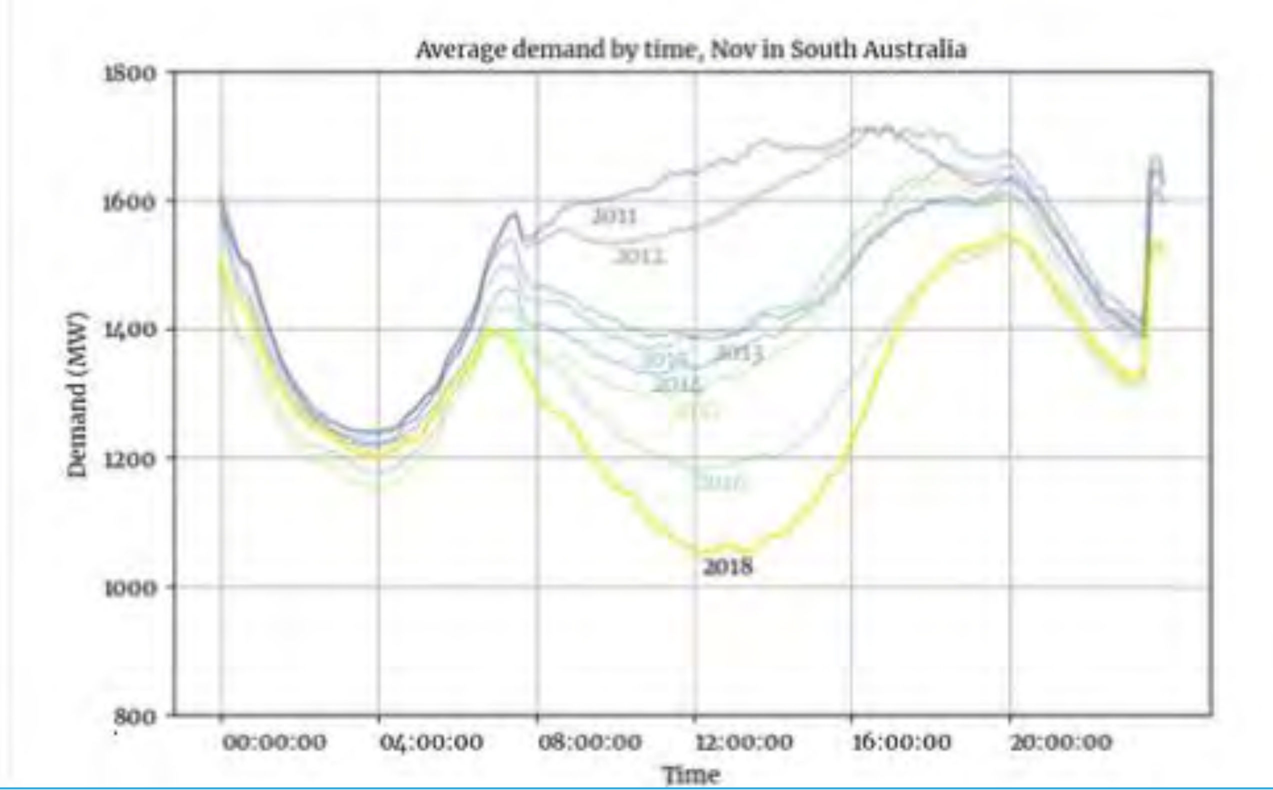

Figure 15 – Duck Curves, South Australia 2011 to 2018

The duck curve phenomena will strengthen as rooftop PV penetration rates increase; indeed, AEMO is forecasting regular negative minimum demands in SA by 2025.

The rise of utility solar will compound the duck curve impact during daylight hours when highly correlated rooftop and utility solar are producing at full output. This will lead to surplus energy production, creating the market opportunity for storage to minimise energy spill. In regions such as SA with high rates of wind generation, high wind periods will also create the opportunity for storage to help to manage excess energy production. It should be noted that dispatchable storage will also be a valuable lever to assist AEMO with maintaining system security during periods of excess energy production.

6.2.2 Higher Renewables Penetration

Future high renewable scenarios create stronger drivers for energy storage. For a hypothetical 50% renewable scenarios (where the renewable target is based on energy production), the required installed renewable generation capacity will by default exceed average NEM demand (if the average capacity for variable renewables across available technologies was 30%[5], the installed capacity to deliver 50% renewables would be 167% of average NEM demand [average NEM demand x 50% renewables / 30% capacity factor])

The uptake of rooftop and solar PV creates an opportunity for medium duration daily storage (6-10 hours per day). Pumped hydro is a strong candidate technology for this role, and pumped hydro has cost, capacity degradation and technical life advantages compared to lithium ion batteries for this scale of storage over medium durations.

High renewable uptake will also increase the need for flexible, dispatchable capacity to 'firm' renewables and to provide increased market ramping requirements as correlated renewables increase and decrease their outputs in unison. High renewables may also bring forward economic pressures on incumbent coal generators, potentially bringing forward closures and creating the need for replacement dispatchable capacity.

It is assumed gas peaking generation and medium duration storage are the two leading candidates for providing flexible dispatchable capacity. Whilst gas generation is less energy constrained than storage, it cannot take advantage of the potential excess energy created by correlated variable renewables. Accordingly, a long-term NEM supply will likely feature a mix of renewables, storages of different durations and gas fired generation, with the supply mix including both centralised and distributed resources.

SA has one of the peakiest demand profiles found globally with average schedule demand approximately 1300 MW and forecast maximum demand around 3200 MW. SA also has one of the greatest uptakes of renewable energy globally, with the installed capacity of renewables far exceeding average demand. Figure 16 represents this graphically.

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[5] Illustrative assumption based on mix of 18% rooftop PV, 30% utility PV and 40% wind

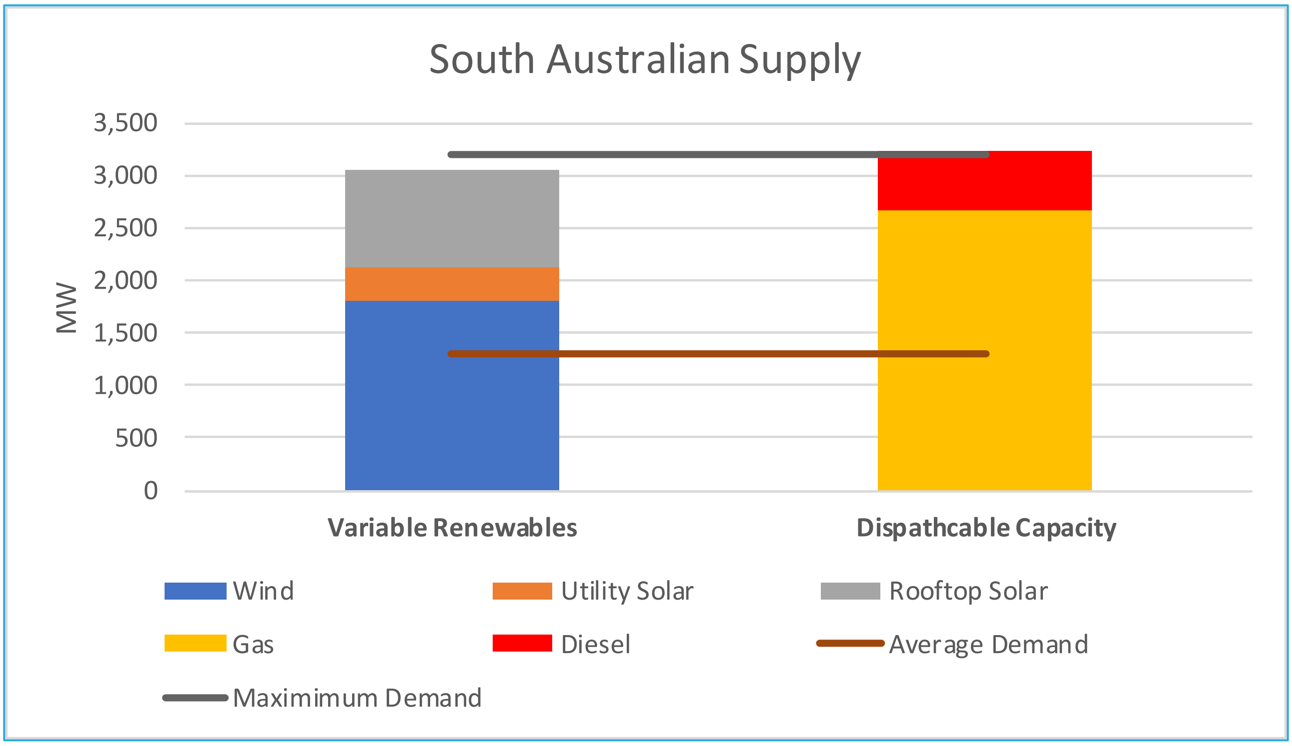

Figure 16 – South Australian Generation Supply

During high renewable periods (sunny and/or high wind periods), low cost variable renewable supply exceeds average demand can more than cover South Australian demand, creating opportunities for low-cost storage charging. Conversely during periods of low renewable generation (dark and still), there is a significant opportunity for storage to discharge at prices lower than gas short-run margin cost, which is likely to be approx. $150 / MWh. Collectively these supply side dynamics create a strong opportunity for storage to generate arbitrage value.

6.2.3 Interstate Interconnectors

Interconnectors are the other swing-player in SA and currently provide an outlet to excess renewable generation and a source of lower-cost energy via imports from Victoria when renewable generation is low. Interconnectors are direct competitors to storage projects, which reduce potential arbitrage and capacity value. Whilst the impact of the existing Victorian interconnectors is clear, approval of the EnergyConnect development for the 800MW NSW – SA interconnector presented an additional economic challenge for the Cultana SPHES.

Greater connectivity between SA and the eastern states will dampen South Australian market price volatility and depress the opportunity for arbitrage through providing increased interstate outlets for excess renewables, and a pipeline for fossil-based generation to support demand in still and dark conditions.

In the medium to longer term the further expansion of Renewable Energy Zones and eventual coal generation retirements will return the diurnal swing to the South Australian market increasing opportunity for large scale storage projects.

6.2.4 5-minute settlements

On 28 November 2017 the Australian Energy Market Commission (AEMC) made a final rule to change the settlement period for the electricity spot price from 30 minutes to five minutes, planned to commence in 2021. The AEMC states that this move to five-minute settlement will provide a better price signal for investment in fast response technologies.

PHES is a fast response generation technology that can ramp from zero to full output in 170 seconds. This compares to 10 – 20min for Open Cycle Gas Turbines, and multiple hours for coal power stations.

The benefit of fast ramping generation technologies is their ability to respond quickly to high price events, meaning a greater proportion of energy is generated in the trading interval that needs it.

In theory, the move to a 5 min settlement period will mean that short term price spikes won't be averaged out over the 30 mins, and therefore, those technologies that respond quickly will be able to 'capture' more of the high price events, which helps project economics.

This should be a competitive advantage for energy storage projects over other generation technologies as it should be more successful in 'capturing' high price events.

7 Land Access

7.1 Land Access

There are a variety of stakeholders who have a primary interest in granting access to the land required for the Cultana SPHES facility, which includes:

- the DoD and Commonwealth of Australia for approvals related to CTA land
- local Aboriginal people, the Barngarla people
- the State Government for State Crown land approvals
- private landowners
- the Local Council for council land access and local planning approvals.

Figure 4Figure 4 shows the final site layout for the seawater PHES facility on the CTA, across Shack Road and the coastal foreshore area to the sea.

7.1.1 Land Ownership Boundaries

The majority of the proposed Cultana infrastructure were planned to be located on DoD land including the access road, upper reservoir, lower reservoir, penstock, powerhouse and grid connection/substation as well as the desalination plant. A small structure for the marine inlet was to be housed on state government and crown land. There was to be no construction elements that interfere with private property or private landholders.

The Table below shows the various stakeholders consulted throughout the process.

Table 7 – Stakeholders in land use

Stakeholder	Comment
Department of Defence / Commonwealth of Australia for CTA access and environmental & heritage approvals	Land west of Shack Rd. This is the proposed site for all of the infrastructure excluding the small marine inlet structure and water pipe.
Local Aboriginal People – The Barngarla People	Consultation with the Barngarla people was undertaken up to the point of FID.
State Government for State Crown Land access and environmental, marine, planning and heritage approvals	East of Shack Rd. This is where the intake/outlet structure and associated coastal interface infrastructure in the Spencer Gulf.
Local Council for Council Land access and local planning approvals	The intake/outlet structure and associated infrastructure in the Spencer Gulf.
Private Land Holders	East of Shack Rd. No project infrastructure would be on private land, but private land holdings (both permanent & holiday homes) are located along the Shack Rd shoreline to the south of the proposed intake/outlet structure.

7.2 Native Title

Native Title has been determined for a large extent of the Eyre Peninsula, including in the project area, and the Barngarla people are now legally recognised as the Traditional Owners. Native Title exists on the State Crown land and intertidal zone but has been extinguished on the DoD land.

7.3 Stakeholder Engagement

The project team engaged with each of the stakeholders identified in Table 7 to assist in reaching FID.

7.3.1 Department of Defence

Siting a privately-owned generation facility in Commonwealth owned Defence training area land presents specific challenges unique to the Cultana SPHES project.

The land access agreements needed for most of the Cultana SPHES facility works including the ElectraNet substation could only be granted by the DoD, necessitating very close co-operation during development to determine mitigations to impacts on Defence training activities. Significant interaction with the DoD was undertaken. Unfortunately, a land lease agreement was not secured for the project.

7.3.2 State and Local Government

EnergyAustralia engaged with State and local government through a hierarchy that paralleled with the development application process. At the highest level the project held monthly meetings and submitted monthly progress reports to Department for Energy and Mining (DEM) through the Low Carbon Industry Development Unit and received assistance with submissions to various government departments and agencies.

The project sought and received its technical certificate from the Office of the Technical Regulator's (OTR) as a prerequisite to seeking Crown Sponsorship from DEM. Regular updates were held with Department of Planning, Transport and Infrastructure (DPTI) as the project sought advice on how best to resolve the potential impasse between development pathways for Commonwealth land within SA and inputs to requirements for submission of Development Applications under first the Development Act and later the PDI Act. As part of preparations for the environmental studies consultations were held with EPA, Conservation Council SA, and the SA Research Development Institute – Marine Division.

At the local level the project engaged and consulted with Port Augusta City Council including periodic briefings with the Chief Executive, Mayor and Planning Officer.

Additional Regional groups engaged included:

- Arid lands NRM
- Upper Spencer Marine Authority
- Port Augusta Marine advisory Committee
- Conservation Council SA
- Regional Development Australia Far North
- Primary Industries and Regions SA
- Repower SA
- Business Port Augusta.

7.3.3 Native Title

The Cultana project team received the honour of meeting with Elders of the Barngarla Traditional Owners on several occasions for presenting project updates and to seek advice on matters relating to the project and its siting on Country. An Initial Cultural Heritage Agreement was formed to provide for the gathering of information and participation of Barngarla people in cultural heritage surveys together with anthropologists on the proposed site in late October 2018. The results of the survey work provided inputs for Barngarla's consideration of potential impacts or loss of cultural heritage that might arise during the construction of the Cultana SPHES facility, and similarly to understand infrastructure planned for installation on Native Title lands at the foreshore to the Spencer Gulf.

7.3.4 Private Landholders

The coastal strip along Shacks Road in Port Augusta is the location of approximately 285 beach front homes used mostly as weekenders but increasingly occupied as fulltime residences. The owners of these houses are organised within a group called the Port Augusta Coastal Homes Association which has been successful advocating over several decades for freehold title, roads and services to the coastal homes.

The project team met with Coastal Homes association members many times and presented on the Cultana SPHES project to their annual general meetings (AGM) in January 2018 and again in 2019.

The Coastal Homes association members were proactive expressing interest and concern about aspects of the project with particular interest in potential noise, traffic, road degradation, dust, seawater quality and fishing impacts.

For the period while the project was mooted to be seawater based with the gulf as lower reservoir the Coastal Homes association actively sought clarification on many environmental impact related questions with respect to biofouling controls, impacts to juvenile marine organisms and recreational fishing. Following the decision to utilise a two-reservoir system with RO plant to produce fresh water for top up purposes many of the environmental concerns raised were reduced such that dust control, road traffic and road degradation seemed to be the residual concerns.

It should be noted that the planned configuration for the Cultana SPHES facility did not cross or require access to any private lands for its implementation.

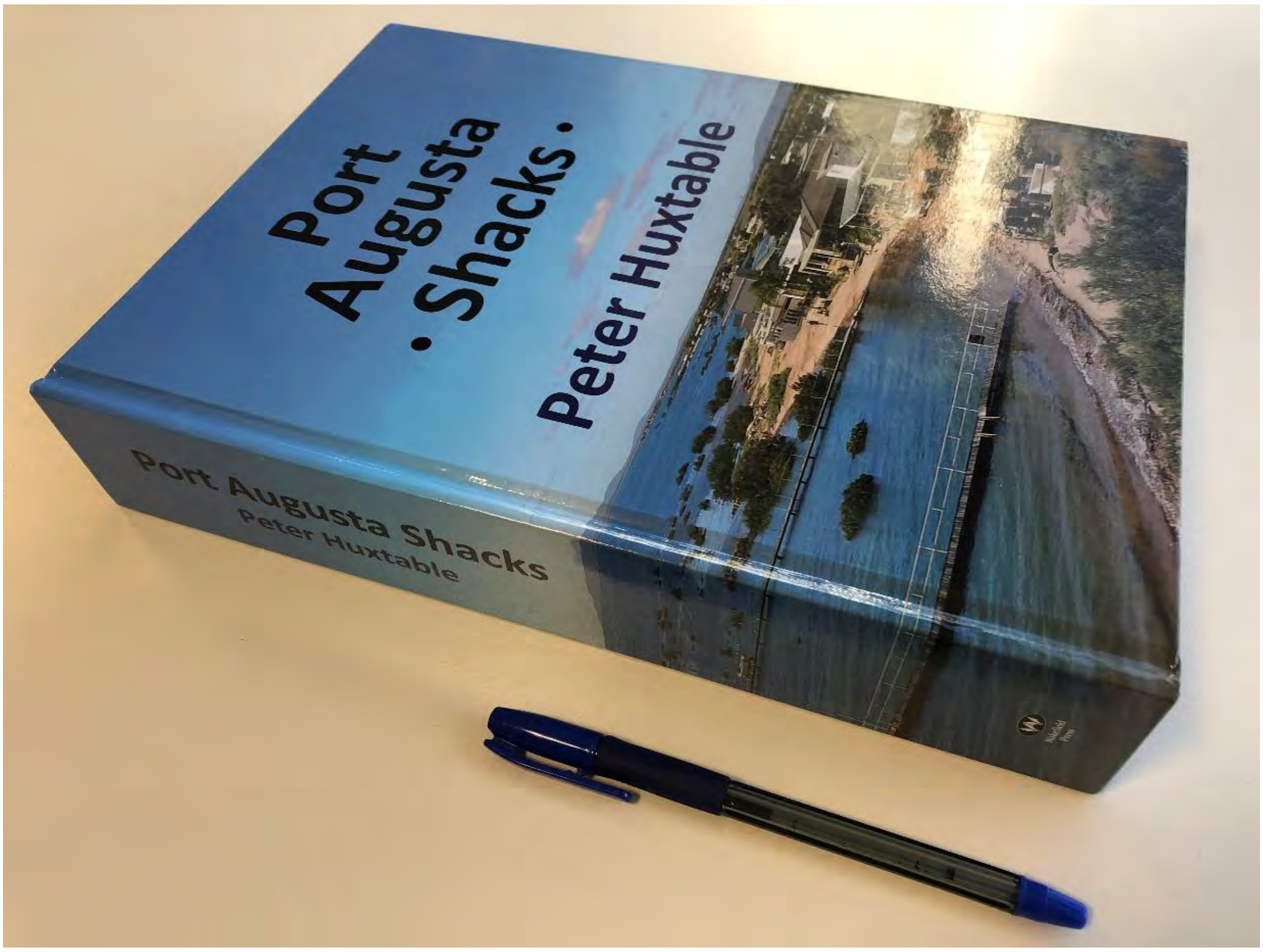

Figure 17 – Coastal Homes Association book: Port Augusta Shacks by Peter Huxtable

8 Land Use Planning and Environment

8.1 Planning and Approvals

As the project was planned to be predominantly located on land owned by the DoD, but would also require infrastructure to cross State Crown land and into State marine waters (the Spencer Gulf), early consultation (commenced July 2018) was carried out with the South Australian Department DPTI and the Commonwealth DoEE regarding the statutory approvals required for the project.

Advice was also sought around whether South Australian legislation applied to DoD land. Initial advice from DPTI was that South Australian legislation does apply to Defence land.

As such, the approvals pathway for the project was determined as:

- submission of a Development Application sponsored by the DEM for assessment and approval under Section 49 of the South Australian Development Act 1993 (Development Act)
- referral of the project under the Commonwealth Environment Protection and Biodiversity Conservation) Act 1999 (EPBC Act) for potential impacts to the environment on Defence land (Commonwealth land under EPBC Act) and matters of national environmental significance (MNES) on State Crown land.

As a first step the project applied for and received a technical certificate from OTR which opened capability for submission of a request for Crown Sponsorship by DEM which was received with respect to planned lodgement of the Development Application under Section 49 of the Development Act 1993. This step was completed with Crown Sponsorship was received on the 9 April 2019.

Following referral of the project to DoEE on 19 March 2019 and the provision of additional information on 10 July 2019, it was decided by a delegate of the Commonwealth Minister for the Environment on 21 August 2019 that the project is a ’controlled action’ and subject to further assessment under the EPBC Act (separate and additional to the State assessment process). To allow for a ‘whole-of-environment’ assessment, the further assessment was to include activities on DoD land, State Crown land and State marine waters.

The South Australian PDI Act 2016 was passed in 2016 and is being rolled out in stages to eventually revoke the Development Act 1993. On 1 July 2019, the PDI Act became operational for outback areas and ‘Land Not Within a Council Area’. As the project is partly located in an area classified as ‘Land Not Within a Council Area’ (the State marine waters), it was confirmed with DPTI in July 2019 that the project (as a whole) had become subject to assessment under the PDI Act 2016 (and no longer under the Development Act 1993).

The approvals pathway for the project was then subsequently confirmed as:

- submission of a Development Application sponsored by DEM for assessment and approval under Section 131 of the South Australian PDI Act
- submission of Preliminary Documentation for assessment and approval under the Commonwealth EPBC Act.

Additional approvals, licences, permits and agreements required included:

- an Indigenous Land Use Agreement (ILUA) for areas subject to Native Title
- authorisation under the Aboriginal Heritage Act 1988 for the disturbance of Aboriginal sites, objects or remains and an Aboriginal Heritage Management Plan (AHMP) to be developed in consultation with the Barngarla People and to the satisfaction of Aboriginal Affairs and Reconciliation
- approval under the Crowns Land Management Act 2009 for any occupation of Crown land
- permission under the Marine Parks Act 2007 for carrying out works in a designated South Australian Marine Park, in a General Managed Use zone
- approval under the Native Vegetation Regulations 2017 for the clearance of native vegetation. It was expected that the final proposed vegetation clearance activity would be subject to a further risk assessment under the Native Vegetation Act 1991 and require the delivery of a Significant Environmental Benefit (SEB) offset
- Additional approvals and licenses under the Environment Protection Act 1993 for operation of the Reverse Osmosis plant and for various elements of construction
- Building Rules Consent pursuant to Section 131(21) of the PDI Act.

8.2 Environmental Assessment

This section of the report sets out the variety of environmental assessments that had to be carried out for the project throughout the planning and approvals process.

Building on the work carried out during the pre-feasibility study, baseline conditions for the project were established through:

- review of available online data sources including environmental databases, mapping platforms and published material (previous reports, etc.)
- undertaking site specific investigations and targeted surveys for aspects such as marine and terrestrial ecology, cultural heritage, landscape and visual, geotechnical, contamination, and groundwater, etc

- consultation with local, State and Commonwealth government agencies and other key stakeholders.

A preliminary environmental risk assessment, informed by the baseline conditions and early design, was carried out to:

- identify potential environmental impacts and risks for key project activities (positive and negative)
- evaluate the likelihood and consequence of the potential environmental impacts identified
- identify areas requiring further technical assessment
- help inform the approvals pathway and an appropriate level of assessment.

Key issues identified from the preliminary environmental risk assessment and through stakeholder consultation shaped the technical studies subsequently completed for the project, which included:

- coastal processes and marine water quality
- marine ecology
- terrestrial ecology
- land contamination
- groundwater
- surface water and flooding
- air quality
- noise and vibration
- traffic and transport
- landscape and visual
- land use and planning
- aboriginal heritage
- social and economic considerations.

An environmental assessment framework was developed to ensure a consistent approach was applied to the assessment of each aspect. The overall approach taken regarding environmental management has been to firstly prevent or avoid significant impacts through early stages of design development, then to reduce impacts through the implementation of mitigation, and finally, for any significant residual impacts, to provide compensation for the impact where applicable (i.e. through provision of offsets).

A pro-active consultation program throughout project development allowed for a robust environmental assessment that addressed key risks and stakeholder concerns and incorporates local knowledge. It also allowed for potential impacts to be prevented through design where possible. This consultation included:

- two community information sessions in Port Augusta seeking feedback from key stakeholders and the local community in August 2017 and October 2017
- attendance at the Port Augusta Coastal Homes Association Inc. annual general meetings in January 2018 and January 2019 to discuss key concerns regarding the project
- early engagement and development of a preliminary Aboriginal heritage agreement with the BDAC
- a cultural heritage field survey in October 2018 with representatives from the BDAC and development of recommendations by the BDAC on how the project could avoid impact and emphasise the heritage values identified within the project area
- engagement with the DoD
- engagement with DPTI, Port Augusta City Council and DoEE
- engagement with State government agencies and key stakeholders.

Figure 18 – Cultana flora

9 Grid Connection

In August 2017 as part of the initial feasibility work ElectraNet provided a Connection Options Report (COR) and Indicative Pricing Offer (IPO) for the options and cost of connection of the proposed Cultana SPHES facility to the SA electricity grid. The IPO included the capital cost of the connection from its high voltage (275kV) Davenport-Cultana transmission line through to the proposed Hannah Dam Substation and the costs of operation and maintenance of these assets over the operating life.

On the 29 March 2019 EnergyAustralia executed a Preliminary Works Agreement and Work Order No 1 with ElectraNet for design and detailed feasibility studies for the proposed connection assets required for grid connection. The assets comprise the 275kV Hannah Dam Substation and new connector transmission line to turn in an existing circuit running between Davenport and Cultana substations, as illustrated in Figure 19. Subsequently, ElectraNet proceeded with the detailed design and tendering for supply and construction of the proposed Hannah Dam Substation and transmission line adjacent to the Cultana SPHES facility.

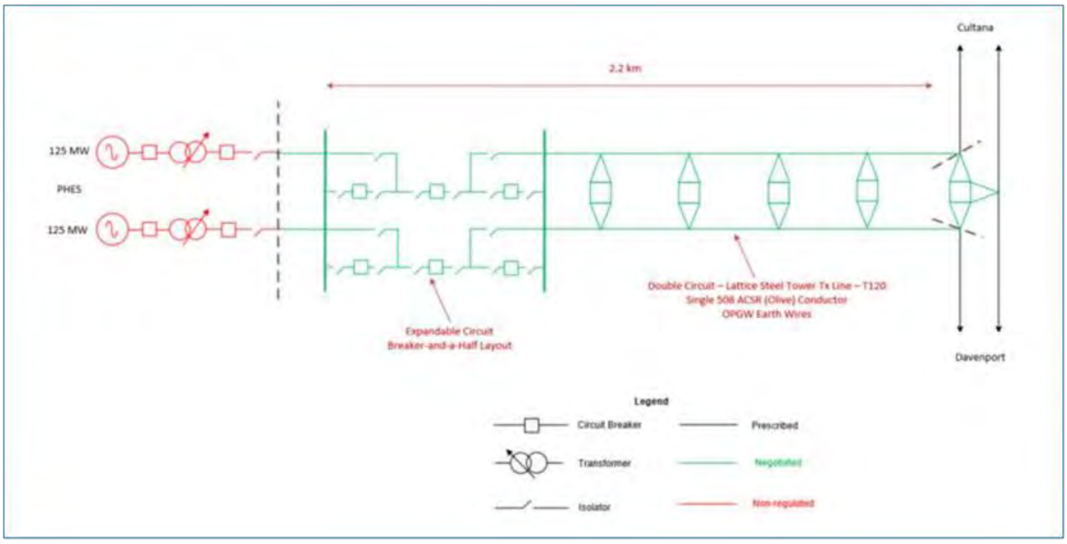

Figure 19 – Simplified Single Line Diagram of Grid Connection

As at October 2019 the design of the grid connection infrastructure was ostensibly complete.

Figure 20 – ElectraNet and EA staff at Cultana SPHES Grid Connection location June 2019

The next step in the grid connection process was to undertake the GPS study. This study is required for all projects in the NEM to receive a formalised grid connection offer. Network Service provider sign off on the modelling results is a prerequisite to receiving a grid connection offer and final connection approval from AEMO.

The GPS is an expensive and deep electrical engineering study that requires precise electrical equipment parameters requiring the exact make and model of the generator to be selected. This also means that the final main turbine and generator equipment supplier must be chosen.

This aspect of the grid connection process is extremely onerous and is a significant barrier to the development of new generation assets in Australia. To get to the point where the GPS is complete, significant development expenditure (in the millions of dollars) is often incurred. It has also been the practice of project developers to bundle the procuring of GPS studies and AEMO Connection Approval together into the services to be delivered under the EPC contract. This expenditure is incurred at high risk as there is no guarantee of a grid connection offer at the end of the process.

EnergyAustralia reached FID before the GPS study could be progressed.

10 Conclusion

EnergyAustralia and Arup completed the Phase 2 development of the Cultana Seawater Pumped Hydro Energy Storage project over an 18 month period from June 2018 to December 2019 enabling the determination of an FID by EnergyAustralia. The development work delivered a reference design with market competitive EPC pricing specific to the Cultana location which revealed a total project implementation specific cost of $3.4m/MW. The high capex cost, rapidly changing energy market, planned interstate transmission interconnectors and rapid development of BESS resulted in evaluation of the project with an insufficient business case to support a positive FID by EnergyAustralia.

Subsequently Dept of Defence confirmed a strategic change in August 2020 which precludes any future development of a PHES project within DoD land at the proposed Cultana site.

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