

HELLS GATES DAM FEASIBILITY STUDY

FEASIBILITY REPORT

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The Hells Gates Dam feasibility study was instigated by the Australian Government in 2016 in response to initiatives driven by the Developing Northern Australia and Agricultural Competitiveness white papers. The study was added to the National Water Infrastructure Development Fund (NWIDF) program by the Commonwealth Department of Infrastructure, Regional Development and Cities for administration by the Queensland Department of Natural Resources, Mines & Energy (DNRME). The study was not part of the competitive round of funding run by the Australian Government to gain access to the NWIDF feasibility study funds. It is also noted that this project is a feasibility study of a specified proposal rather than a business case to assess options to meet an identified demand for water. This differentiates this study from many of the other NWIDF feasibility studies.

Townsville Enterprise Limited (TEL) has managed the delivery of this feasibility study into the proposed Hells Gates Dam, with a consortium led by SMEC delivering the works. Townsville Enterprise Limited and SMEC have instituted significant stakeholder consultation throughout the investigation and final delivery processes across all three levels of government as well as the community, landholders, traditional owners, environmental interest groups and numerous other stakeholders. From this consultation, a range of important stakeholder views and technical/economic items have been considered in this study.

It is acknowledged that the scale of the report could make it difficult for readers to identify some of the critical caveats, assumptions and clarifications. This statement is intended to bring many of those key items into a consolidated location that allows an objective view in the context of the study's terms of reference.

Townsville Enterprise Limited acknowledges the positive approach from DNRME and the study's Project Leadership Group (comprising Charters Towers Regional Council, Townsville City Council and members of the TEL Board) in guiding the Project Directors through a complex project that has taken over a year and comprises almost all engineering disciplines as well as economic, environmental and cultural heritage elements. DNRME has contributed multiple rounds of review, commentary and feedback that have led to several contextual considerations being identified during the technical and economic phases of work.

This section provides an outline to the limitations of the scope and the approach taken to address some of these, providing context to the assumptions that were made for the purpose of the assessment and relevant commentary resultant of the final review of the final Hells Gates Dam feasibility study. This section should be read in conjunction with the whole report.

Townsville Enterprise Limited and SMEC note it is critical to keep the following items in mind when considering the technical and economic outcomes of this study:

- While this feasibility study was delivered through the Australian Government's NWIDF program, it is not a business case as would be expected under the Building Queensland (BQ) Project Assessment Framework (PAF). While many of the PAF guiding principals have been utilised by the project team, as a feasibility study it is not as definitive in many of the economic requirements of PAF.
 - For example, the assessment identifies the potential opportunities associated with suitable soils and irrigation potential in the vicinity of Hells Gates Dam rather than including specific needs analysis to assess the demand for water from the proposal informed for example by market testing and analysis.
 - In addition, there is no assessment and shortlisting of other potential water supply options that could meet the identified needs and/or opportunities, i.e. consideration of water supply infrastructure other than Hells Gates Dam.
- There is no current project proponent, either from a government or private sector source that could participate in project development from this point. It seems logical that further de-risking work is needed before a project proponent could invest confidently in the project, especially given the scale of development, long term infrastructure investment outlook needed and the multi-billion-dollar construction cost.
- A risk of the project outcomes is that the Burdekin Water Plan, administered by the Queensland DNRME and due for review in 2019, currently does not allow for Hells Gates Dam and hence construction of the dam does not comply with the Plan. To enable a major dam to be built at the Hells Gates site, the Water Plan would need to be altered to make additional water resource allocations available. Such an alteration will require public consultation as part of the Burdekin Water Plan review in the future, and considered along with other competing interests and development options for water resources in the area as well as any impacts to existing users and the environment. The project

team has identified this in the report, however, the Water Plan is critical to future development and this report could and should form part of the input to the Water Plan review.

- The Project Directors also acknowledge that:
 - it is likely that commencement of construction of the Hells Gates Dam and major irrigation network may not occur for the best part of a decade given the investigative works needed to determine its viability.
 - significant additional technical (field investigations and design development), social (cultural heritage), environmental (EIS) and commercial (economic modelling) de-risking is required to advance this project. These would be undertaken during a subsequent Business Case that would align with the BQ PAF.
 - the level of technical investigations undertaken to date has allowed the development of a concept design for the inundation area, dam and irrigation scheme components as well as the supporting infrastructure. Further investigations may see changes to the scale of the inundation area, type of dam used, and the components of the irrigations scheme once technical inputs are included – for example assessments of geology, geotechnical drilling, environmental and cultural heritage investigations amongst others. These changes and refinements could have material effects on the cost of development and scale of the irrigation network, will allow the removal of risk and contingency elements in the project cost estimate and thus could positively or negatively affect the economic outcomes and viability.
 - a deliberately non-prescriptive approach has been used when identifying the crops within the cropping assessments and economic assessment. This non-prescriptive approach was taken to ensure that real market forces drive cropping at the time of the irrigated agricultural development, responding to demands for agricultural produce that cannot be accurately defined at this point in time.
 - an assumption of the economic modelling is therefore, that this product driven demand will ensure that single crops that could over supply the markets in which they will be sold will not be developed, thereby driving down prices
 - the cropping yields and crop values that are used have been sourced from public data and can be interpreted in several ways, especially given the extensive development timeline for this project. The assumptions include some subjective views and, in most cases, were chosen based on a high level of take up of agricultural best practices to maximise the effectiveness and efficiency of the irrigated agriculture. Different subjective views could affect the economic model outcomes.
 - while the scale of Hells Gates Dam and the associated irrigation scheme represents some 30% of the Federal Government’s target of doubling Australia’s agriculture output, it should not be considered as “instead of” a range of other proposals. To meet the Government’s goal, Hells Gates Dam plus numerous other irrigation schemes could be needed.
 - Hells Gates Dam cannot be considered a competing potable water source to either Stage 1 (duplication of the Haughton Pipeline) or Stage 2 (extension of the 1.8 metre diameter pipeline to Clare) of Townsville City Council’s water security plan. Any potential town water supply from Hells Gates Dam to Townsville is likely to be in the extreme long term.
 - there has been no consideration of the pumped hydro project past a desktop assessment. As a result, no revenue or cost elements of a large scale pumped hydro project have been included in the economic assessments. Future investigations need to technically de-risk this element of the project and firm up the economic effects to allow the positive or negative effect to be included in the modelling and Benefit Cost Ratio.

In addition, the main risks to the project are articulated in the report and include issues such as costs of water likely to restrict the viable cropping opportunities, the absence of a water allocation or allowance under the Water Plan and the capacity of markets to absorb significant additional horticultural production. However, the recommended assessments and further work proposed by the report focus on detailed engineering and environmental assessments that don’t appear to substantially mitigate all the major risks identified in the report.

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Benefits of the Scheme



12,000+
Construction JOBS



STAGED
to optimise
funding options



Potential for
**SUPER
BATTERY**
pumped hydro



Harnessing **HIGHEST
FLOW AUSTRALIAN
RIVER RESOURCES**
to build **LONG TERM
PROSPERITY**



Enabling up to
50,000 ha
IRRIGATED
AGRICULTURE



Major pumped hydro
power generation
in NQ with **8 HOURS
STORAGE**

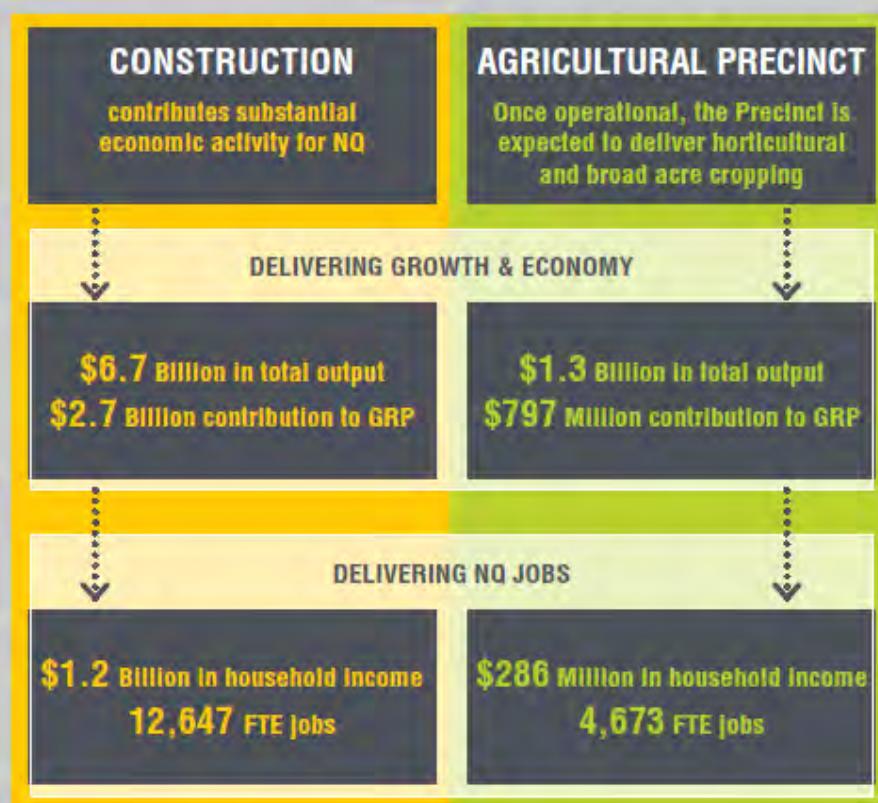


WATER STORAGE
providing sustainable
**LONG TERM WATER
SECURITY** for Townsville
& Charters Towers

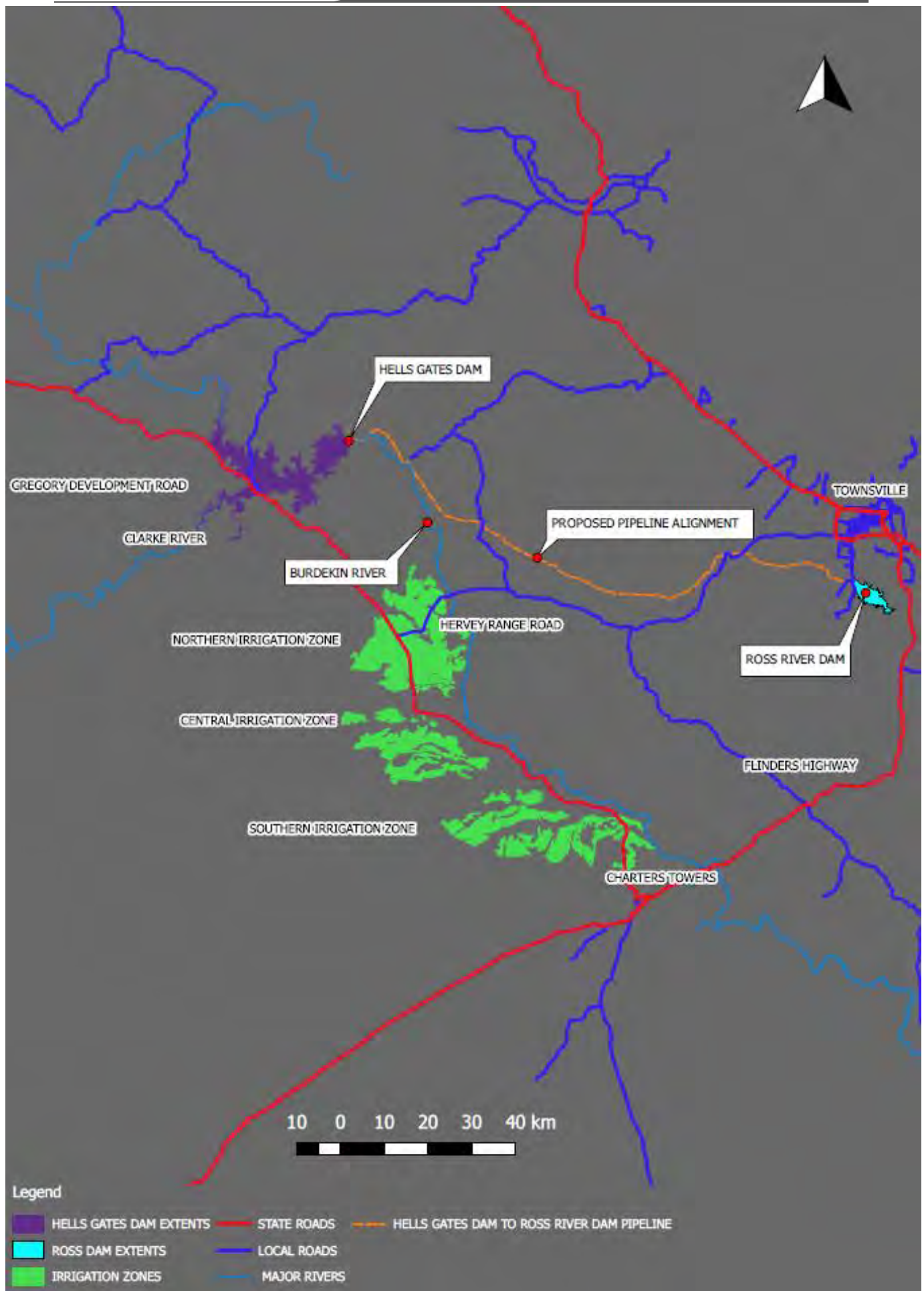
Sustainable Growth for Northern Queensland



Cropping Scenarios Demonstrate:
NPV between \$1.2 and -\$1.0 Billion
BCR between 1.4 and 0.68
IRR between 9.8 % and 3.9%



Hells Gates Scheme will become the powerhouse of sustainable agriculture, water security and renewable energy for North Queensland



1. Executive Summary

This report forms the Hells Gates Dam Feasibility Study Report, summarising the technical, economic and financial assessment of the Hells Gates Dam project feasibility along with identifying the future works needed to progress this project further. These works include environmental and physical site investigations that will further inform the design concept, refine project costs, de-risk the project and assist in clarifying the positivity of the Cost Benefit Ratio of the project. The intention of this report is to support all levels of State and Federal Government to better understand the opportunities around the proposed Hells Gates Dam development and to progress to the future stages of this project recommended as part of this report.

The potential staging of the development of this scheme has been identified. The scheme is, by any judgement, a major nation-building-scale undertaking involving over \$5 billion in enabling infrastructure and over \$1 billion of on-farm investment during construction, resulting in ***the creation over 4,000 long-term regionally appropriate jobs and delivering \$1.3 billion of GRP annually into the North Queensland economy.***

The Hells Gates Dam Project and the associated infrastructures will open and future-proof the North Queensland economy through bulk agricultural produce, renewables energy, water security and socio-economic development for the region.

1.1. Headline Technical Results

The environmental, cultural heritage and engineering work undertaken established the potential of a 2,110 GL dam that could supply water to a 50,000 ha irrigated infrastructure scheme, while also providing long term water security to both Charters Towers and Townsville.

While the design remains at feasibility level, and requires significant additional field studies, drilling and investigation, there is a technical pathway to a project that includes:

- Immediate development of up to 5,000 ha of annual crops with potential for additional perennial cropping by securing water from Big Rocks Weir
- Staged infrastructure development to support 50,000 ha of irrigated horticulture, including fruit, vegetables, pulses / legumes, and broad-scale agriculture of both perennial and annual crops
- Upgrades to the road network to handle freight and tourism traffic
- Economic development opportunities in food processing in Charters Towers, Greenvale and the Townsville State Development Area
- Export opportunities of fresh foods and processed foods through the Port of Townsville and Townsville Airport to south-east Asia and southern Australian cities
- A pumped hydroelectric scheme of up to 1200 MW
- A 20 MW solar farm and 15 MW run-of-river hydro facility at the toe of the dam
- Major upgrades to the power network in the Charters Towers region to allow development of on-farm water pumping and food processing
- Long-term water security for the City of Townsville, post-2035 (from Hells Gates Dam)
- Long-term water security for Charters Towers Regional Council (from Big Rocks Weir)
- Socio-economic development of the communities around the Hells Gates irrigated scheme and long-term employment for over 4,000 people
- Recreational (fishing, water sports) and tourism (caravan parks, gourmet foods) activities on a dam that will hold more capacity than the current largest dam in Queensland (Burdekin Falls) within 2.5 hours of Townsville.

The authors reiterate that further investigation works are substantial – potentially exceeding \$24 million in drilling and study costs, and taking as long as 4 years to complete. This will then lead to refined designs, de-risking of the project, environmental surety and satisfaction of cultural heritage interests, enhanced economic

modelling and a better understanding of the staging process required to ensure a viable scheme can be rolled out without affecting target markets and without flooding the market with development land for horticulture.

1.2. Headline Economic Results

The development of the proposed Hells Gates Dam is a challenging investment proposition given its nation-building scale and the likely ramp-up time for production of high value tree crops. It is the opportunity of a lifetime to develop a large tract of highly viable land, create 4,000+ jobs and inject \$1.3 billion of GRP annually into the North Queensland economy.

Modelled water costs are well above those seen in established irrigation areas that have viable economic scenarios growing broad acre crops (for example the established horticulture areas such as the Murray-Darling Basin). This is not an unexpected outcome – this greenfield site was never intended to compete domestically with Murray-Darling sourced produce, while the 2014 study that concentrated on sugar cane showed that traditional broad acre cropping was highly unlikely to be internationally competitive.

A critical message from this study is that delivery of an attractive investment proposition requires expansion of export quantities to the ASEAN and European markets for high value crops, and/or a substantial increase in grower returns for traditional broadacre cropping.

Hells Gates Irrigation scheme needs to be set up to maximise a mosaic of high value produce such as tree crops (avocado, citrus, table grapes) and premium vegetables (capsicum, pumpkin, pulses) for the export market while not flooding those markets with single crops. There is potential for broad acre farming of crops such as sugar and cotton, but these lower value crops would not form the core investment return for the scheme.

Despite these challenges, the scheme represents a significant opportunity for the development of Northern Australia. The identified scheme has unique scale, at up to 50,000 ha, providing significant synergies in the development of new and existing markets. Furthermore, the high-security water supply allows for the development of a broad range of high-value perennial and annual crops, with long-view investment in food-bowl production for the emerging middle class of Asia.

The timeframes for development allow for positive macroeconomic trends, including rising emerging market demand for agricultural produce. Key steps to support and de-risk the proposed Hells Gates Dam development include:

- Releasing water allocations for development and irrigation of parcels of land adjacent to the Burdekin River, referred to as the Burdekin Zone, prior to Dam construction
- Supporting trial cropping to de-risk production on a significant scale, especially within the initial developments of the Burdekin Zone and to secure water supply available from the near-term construction of Big Rocks Weir
- Gaining environmental approvals and delivering developed engineering works to reduce the identified capital costs. The current early-stage design retains significant risk factors that are highly likely to be reduced with further research and design development
- Financial support for the development, including through Commonwealth and State grants. During construction, support through the National Water Infrastructure Loan Facility and the Northern Australia Infrastructure Facility, potentially complimented by the Clean Energy Finance Corporation
- Further development of related high-return opportunities such as the prospective large-scale pumped hydro-electric scheme (PHES) that could improve the overall scheme CBR, NPV and IRR results significantly if proven to be technically viable.

Excluding the prospective PHES and bulk water supply to Townsville, construction of the proposed Hells Gates Dam development has the potential to support substantial economic activity for North Queensland. During construction, the project is estimated to support:

- \$5.7 billion in total output (including \$3.7 billion directly)
- A \$2.3 billion contribution to gross regional product (GRP) (including \$1.4 billion directly)
- \$1.0 billion in income for local workers (including \$474 million directly)
- 10,855 FTE jobs (including 4,607 direct FTE positions).

On an annual basis, the agricultural precinct (once fully-operational and assuming a mix of horticultural and broadacre cropping and excluding the Townsville pipeline and PHES) is expected to provide:

- \$1.5 billion in total industry output (including \$1.2 billion directly)
- A \$823.4 million contribution to GRP (including \$669.5 million directly)
- \$341.0 million in income for households (including \$273.9 million in direct wages and salaries)
- FTE employment totalling 5,564 jobs (including 4,565 direct FTE positions).

Flow-on impacts to the state and national economies are estimated to be even larger, where the scheme can be developed on a sustainable basis and where horticultural production based at the site does not negatively affect existing producers.

Under any judgement, this is a game changing and Nation Building opportunity for the development of North Queensland and Northern Australia. No other project in the North has the potential to directly employ over 4,000 people in jobs that are innately suited to regional populations, and that will support the overall Northern Australia economy for decades to come to the extent of \$800M in GRP annually.

Cost-Benefit Assessment (CBA)

The CBA examined the construction and operating costs associated with the project over a 30-year timeframe. Specifically, the following costs and benefits were assessed:

- Costs:
 - Water storage capital costs
 - Water storage operational costs
 - On-farm capital costs.
- Benefits:
 - Agricultural net revenues
 - Operational wages
 - Local recreational amenity
 - Asset residual value.

The economic analysis undertaken outlines the present value (PV) of the identified costs and benefits between the financial year ending June 2027 and the financial year ending June 2056, at discount rates of 4%, 7%, and 10%.

The CBA modelling at the discount rate of 7% produced the following results:

- Mixed cropping scenario – net present value (NPV) of -\$1.5 billion, benefit-cost ratio (BCR) of 0.70, and internal rate of return (IRR) of 4.3%
- Perennial cropping scenario – NPV of \$1.5 billion, BCR of 1.33, and IRR of 9.3%

These economic results remain the result of preliminary investigations, and are indicative of a highly attractive project that is deserving of further investigation. These investigations are to be aimed at confirming design characteristics, delivering environmental and cultural heritage clearance, to de-risk the project and reduce risk elements in the cost estimation that would likely see the overall capital investment amount reduce. During the period of project development in the next 4 years, agricultural produce prices are likely to increase significantly with the emergence of the Asian Middle Class, thus improving the potential cost-benefits on both sides of the CBR equation.

1.3. Works Undertaken & Features Identified

1.3.1. Economics

Economic analysis of the scheme assessed the 2,110 GL storage dam and an agricultural district of up to 50,000 ha, as identified in Milestone 4 – Technical Feasibility. The results provide estimates of water pricing, agricultural capacity to pay, and return on investment, given the identified timings and capital requirements for

development. The economic analysis has also fed back into the technical feasibility and driven commercial changes to staging and cropping assumptions.

The Economic Impact Assessment (EIA) of the potential direct and flow-on economic impacts on the project provided a Cost Benefit Assessment (CBA) estimating the net socio-economic benefits of the development. The analysis considers two cropping scenarios to analyse the potential opportunities that can be generated by the scheme, building upon the works undertaken in Milestone 4:

- Mixed cropping scenario – 50,000 ha under irrigation with a mix of annual and perennial horticultural, and broadacre cropping.
- Perennial cropping scenario – 30,000 ha under irrigation, using high-reliability water for permanent cropping. Under the perennial cropping scenario, only two of the three major irrigation areas would be developed, mainly due to the higher water requirements of the perennial crops.

1.3.2. Soils

The development process of the proposed agricultural area included the refinement of the initial 100,000 ha of mapped agricultural area to a reduced 50,000 ha of suitable agricultural land, with a high level of confidence in providing adequate and suitable irrigable land for high-value and high-return crops. There are various factors that support the 50,000 ha scheme, however the impact to downstream water flows, Gregory Development Road, and direct environmental constraints from the inundation reservoir are some of the key drivers. The 50,000 ha area was further investigated through on-site soil sampling and laboratory testing to identify the soil chemistry and composition unique for agricultural purpose. The reporting in subsequent chapters of this report identifies the soil types unique to the area and subsequently provides a refined crop matrix that can support a mosaic of high-value crops in the region.

1.3.3. Water Resources

An assessment of the water reliability for irrigation has been carried out based on the total daily inflows (rainfall, run-off, and stream inflows) and the total daily outflows (evaporation losses, environmental flows, irrigation release, and spills). The water balance model has been refined and re-iterated over numerous stages to optimise the supply and demand reliabilities for the overall 50,000 ha scheme. Assessment of the water reliability therefore confirmed an FSL of 372 m AHD and a storage volume of 2,110,000 ML to primarily supply the 50,000 ha scheme, with approximately 36,000 ha of annual crops and 14,000 ha of perennial crops. A key feature is the ability to scale the quantum of annual and perennial crops up or down to meet the market characteristics and economic efficiencies, provided the water demand does not exceed the upper limit for irrigation. This scenario represents a utilisation of approximately 30% river flows at the upper northern extent of the Burdekin Catchment. It was expected that the average crop water demand would most likely be in the range of 10 – 12 ML/ha/year. This has been used in the water balance model with a target annual reliability of 70%, meaning the full crop water demand would be met 70% of the years as a result of wet / dry years as determined from historical rainfall data.

1.3.4. Zoning and Staging

The 50,000 ha scheme was initially broken up into three logical distinct irrigation zones fed by irrigation channels: the North (17,130 ha), Middle (19,730 ha), and South (13,090 ha) Zones, separated by geographical features unique to these areas. During the economic analysis, it was further identified that there is approximately 5,000 Ha absolutely contiguous to the river's route that is suitable for high value agriculture and which does not necessarily require a dam to be built to allow initial development. This area is now referred to as the Burdekin Zone. The benefits of staging is more fully described in the staging Of the Project Section of this report.

This zoning provides the ability to both scale and stage the development across four regions, based on their proximity to the proposed dam, their proximity to the river, their proximity to existing infrastructure (such as transportation routes and electrical infrastructure) and therefore their cost-to-develop. A key element of staging is to ensure that the early developments in the Burdekin Zone are low in capex costs, extract water direct from the river, and clearly demonstrate the viability of the land within the overall scheme for cropping of high value annual crops. Further early work potential to provide a low capex cost perennial water supply for

the very high value crops is linked to the early/immediate development of the Big Rocks Weir, which would allow perennial crops to be grown in the areas of the Burdekin Zone located in the Southern Zone.

For any of the larger zones to be developed, the Dam will need to be established to provide water security to the scheme.

Irrigation infrastructure is designed to be unique to the three distinct zones. Each zone will require the provision of a weir pool, irrigation intake infrastructure, a pump station, and a network of gravity irrigation channels. The locations of irrigation channels are based on 10 m SRTM contour data and follow an approximate downhill path within the existing terrain to use gravity as the driver for water delivery, thereby minimising pumping costs.

It is an assumption of the feasibility works to date that farmers will develop their own on-farm irrigation systems to draw water from the river or the irrigation channels in accordance with the crop types, irrigation types, distance to farm gates, and farmers' ability to develop and up-scale the size of their farms.

1.3.5. Survey

A major constraint on availability of data identified within this report includes the limitations of the 10 m SRTM contour data, warranting the need for future phases of this project to obtain more accurate survey data and refine the irrigation channel locations.

1.3.6. Townsville Water Security

The water stored in the Hells Gates Dam is largely intended for irrigation. A small portion of that water, however, can be reserved to augment the Townsville and Charters Towers urban water supply, needed during drier periods or droughts in North Queensland. The concept design considers two scenarios for the provision of water to Townsville via a pipeline route from the proposed Hells Gates Dam to the Ross River Dam. These two scenarios include an interim case (190 ML/day supply) through a single pipeline and a potential future case (320 ML/day supply) involving duplication of the initial interim case pipeline to meet the population growth demands of Townsville.

1.3.7. Big Rocks Weir

Similarly, the construction of the Big Rocks Weir, north of Charters Towers, could provide the Charters Towers community with a higher level of water security. Big Rocks Weir will have the ability to serve multiple purposes, including a weir pool where farmers are able to draw reliable water for irrigation within the Southern Zone, a crucial sediment control weir that will likely collect and store sediment from farming and run-off from the agricultural areas north of the weir, and augmentation of Charters Towers' urban water needs. Charters Towers Regional Council has long campaigned for the construction of Big Rocks Weir, and the findings of feasibility study strongly support its construction in the early stages of the Hells Gates irrigation scheme development, before or in parallel with the construction of the proposed Hells Gates Dam.

1.3.8. Transport Infrastructure

A major component of the overall scheme is transportation infrastructure (both new and existing) to support construction works, the overall agricultural scheme, and transporting produce from farms. Major routes that will be directly affected, should the Hells Gates Dam project proceed, are Gregory Development Road, Hervey Range Road, the Flinders Highway and Mount Fox Road, as well as other ancillary infrastructure (such as the Port of Townsville, Townsville Airport, and the Mount Isa-Townsville Rail Line). The impact on these road and rail networks will largely come as a consequence of increased traffic flow expected to arise from shipping high volumes of produce between the agricultural area and Townsville, Charters Towers, and surrounding townships. Transport will form an integral part of the development and operability of the entire scheme, and therefore warrants the development or upgrade of transport infrastructure to support the project.

The impact on Gregory Development Road will be significant, due to its proximity to the proposed Hells Gates Dam inundation reservoir at 372 m AHD. The road will therefore require major upgrades, including bridge construction at the Clarke River crossing, to bring it above the inundation level. The location of Gregory Development Road and the cost of raising this section of the road is therefore a significant constraint on the upper limit of the dam's storage capacity (and subsequently, the scale of the agricultural scheme). It is prudent

to note, however, that a 50,000 ha agricultural area would be one of the largest stand-alone irrigation schemes in Northern Australia and is, in itself, a major undertaking that is nation building.

1.3.9. Environmental Assessment

An Environmental Assessment was carried out, based on desktop assessment and site flora and fauna surveys. The Environmental Assessment did not identify any major barriers to development. The proposed site's proximity to various environmentally-sensitive areas such as wetlands and river systems, however, dictates that a formal Environmental Impact Statement (EIS) be conducted in subsequent development phases.

1.3.10. Cultural Heritage

The cultural heritage component of the investigation did not identify any culturally-sensitive artefacts or constraints during on-site soil sampling on site. However, a thorough consultation process and site monitoring was carried out with the Gudjala and Gugu Badhun Aboriginal groups to ensure the appropriate legislation and processes were followed. Significant further investigations are needed within the inundation zone of the Dam.

1.3.11. Hells Gates Dam Concept Design

A site geological investigation was carried out to identify the geological features of the sites, including Hells Gates Dam and potential weir locations along the Burdekin River that will be utilised as the weir pools for pumping water to the Northern, Middle and Southern agricultural districts. A more detailed assessment of the geological features unique to the proposed Hells Gates Dam site is provided in Geology and Geotechnical section of Chapter 2.

Various options have been investigated for the Hells Gates Dam construction, including a zoned earthfill embankment, a concrete-faced rockfill dam, and a concrete gravity dam. The concrete gravity dam was determined as presenting the best solution at this stage, considering all associated factors, including the observed geological conditions, modern spillway design, the height of the dam, and industry solutions for various projects of similar scale and type. This conclusion requires significant further work to be confirmed, including extensive drilling to confirm geological and geotechnical conditions and further design of the dam formations to ensure no undue undermining or scouring will occur.

1.3.12. Power Systems

Based on the irrigation demands, it is expected that the agricultural area will require a large volume of water and, therefore, significant energy to deliver the water from the Burdekin River to irrigation channels. A large amount of electrical and power infrastructure will need to be developed, in a location with constrained power delivery capacity. To supplement the existing power infrastructure, it is proposed that a 20 MW_{ac} solar farm be located close to the North Zone and adjacent to the existing 132 kV Ross-Kidston Transmission Line. Similarly, hydropower opportunities are available at the toe of the dam to potentially generate 10 MW – 15MW, which would be developed concurrently with the construction of the dam.

Power supplied from the 132 kV Ross-Kidston line, and that generated from the toe-of-dam 10-15MW hydro and 20MW solar farm, can then be distributed via a new substation to the North Zone pumps through a network of new transmission routes.

The Middle and South Zones could be powered by a combination of upgrading existing Ergon infrastructure to Charters Towers and provision of new sub-transmission lines from Charters Towers to the location of the major water pumps located at the Middle and South weir pools where distribution voltage substations would be located.

1.3.13. Pumped Hydro-Electric Scheme Concept

Early desktop analysis has been conducted into other potential hydroelectric options, such as a pumped hydro-electric scheme (PHES), with potential secondary storages north of the main dam, that could generate up to 1,200 MW. The extent of the storage volume requires significantly more study work, as does the suitability of the upper dam site and the geology of the headrace, tailrace tunnels and the generation cavern required for such a large-scale generation site. The early stage of this concepting completed does not allow the economic benefits of the PHES to be included in this feasibility, and significant work is needed to confirm proof-of-

concept. Regardless the PHES is entirely dependent on the establishment of the Hells Gates irrigation scheme in the first place.

Additionally, a small-scale hydro opportunity within the water pipeline from Hells Gates Dam to Ross River Dam, located at a ~270 m drop on Hervey Range, would likely to generate 4MW – 5MW. Again, this is in very early conceiving given the likelihood that this pipeline will not be required before 2035.

1.3.14. Tourism and Recreation

It is likely (but not the subject of this report) that a large water body and significant produce production zone will also generate tourism traffic and subsequent economic opportunities. The transport network will cater for RV-style vehicles and caravans, while water supply, power supply, and the dam will likely see caravan parks and gourmet food / beverage operators develop over time, as has been seen in many irrigation areas, such as the King Valley, Sunraysia, Murray-Goulburn, Burdekin, Atherton Tablelands, and Murrumbidgee regions.

1.3.15. Socio-Economic Analysis

An assessment under the Social Impact Evaluation guideline identified a number of nett positive socio-economic impacts from the delivery of the Hells Gates Irrigation Scheme and associated infrastructures. Some of the key positive impacts arising from the scheme includes opportunities for local businesses, increases revenue to the local economy, development of educational and health care facilities in the area, better quality of living, improved real estate markets, on farm employment opportunities and a number of similar benefits to the communities.

2. Introduction

SMEC, in partnership with a range of specialist sub-consultants, has been commissioned by Townsville Enterprise Limited (TEL) to deliver the Hells Gates Dam Feasibility Study project under the Department of Natural Resources, Mines & Energy (DNRME).

Five prior reports pre-date this report, including:

- Milestone 1 – Project Management Plan
- Milestone 2 – Gap Analysis
- Milestone 3 – Agronomy, Water Resources, Environment and Cultural Heritage
- Milestone 4 – Technical Feasibility
- Milestone 5 – Economic Feasibility.

The purpose of this Project Feasibility Report is to draw together the 12 months of project deliverables into a single report, compiling the outcomes of the various analysis, engagement, environmental, technical and economic works.

Milestone 3 responded to the Agronomy, Water Resources and Environmental aspects of the project that led to the development of Milestone 4 the Technical Feasibility and engineering design for irrigated horticulture, dam, channels, and associated infrastructure through engineering design inputs from various disciplines, which ultimately formed the basis of the development of Milestone 5 Economic and Financial Analysis.

Every feasibility study evolves as the concepts are further investigated, and this study is no exception, with additional review work required on the Milestone 3 works to supplement Milestone 4, and revision of staging decisions in Milestone 4 resulting from the economic analysis.

This report therefore includes the collated results from Milestones 3, 4 and 5 reports, which have been modified to suit the changing conditions and evolving conclusions of the project from their original form of issue. This report also includes additional elements requested of the feasibility study delivery team following delivery of Milestone 4, that includes discussion on the options analysis as well as documentation of the risk register that has been documented with new and mitigated risks throughout the project and beyond.

In compiling such a large volume of work from multiple sources, the various technical and economic chapters of this report include concept designs and analysis of the major infrastructure that will support development of a large-scale agricultural area in the Charters Towers region, along with the output of complex economic modelling.

It is noted that some features of the overall concept design were not fully envisaged prior to the feasibility study being commissioned. There are also a number of elements for further investigation and development works, to address items that are identified as either risks or future elements of work, within this chapter.

3. Methodology

3.1. Risk Approach

Attached in Chapter 3 of this milestone report is the project Risk Register, which documents the risks and suitable mitigations either applied or identified, which have been examined throughout the course of the project.

Many of these risks applied to the feasibility study itself – others apply to the ongoing development of the project and the establishment of the major infrastructure development that is the Hells Gates Irrigation Scheme.

Numerous areas of major unmitigated risks remain in the field engineering elements of the project. As is the nature of a feasibility study, limited field investigations have been completed during this \$2.2 million study. These field investigations have sought to maximise their impact by targeting the revenue streams of the project (land suitability and crop matching) and the major risk factors of environmental and cultural heritage issues, while also attempting to confirm the results of previous study works from the 1970s and 2014.

Major items for attention are described in the following sub-sections:

3.1.1. Environmental Impact Statement

The assessments undertaken focussed predominantly on the two dam sites identified, assisting in identifying Hells Gates as a preferential site over Mount Foxton. There is an essential body of work under Commonwealth and Queensland law for an Environmental Impact Statement to be delivered, covering all of the proposed water bodies as well as the irrigated agriculture lands identified.

Those water bodies include Hells Gates Dam, Big Rocks Weir and three weir pools to be established to store water in the Burdekin River for offtake into the three main irrigation channels.

Undertaking an EIS for a 2100GL dam, 4 weirs and 50,000Ha of irrigated land is a significant undertaking and could take two to three years to complete.

3.1.2. Cultural Heritage

The project team has enjoyed a very open relationship with the two affected Cultural Heritage groups, the Gudjala and the Gugu Badhun, to this point. This was achieved through active and genuine consultation, with both groups providing guides to assist the soil assessment and environmental teams to ensure there was no disruption to important sites during intrusive investigations. Both groups expressed support of the project concept, and both groups see significant ongoing employment and prosperity benefits for their respective people as a result of the development.

A key outcome of these consultative works is the identification of poor record keeping of culturally important sites along each of the river systems and in the farmland areas. The river systems are the most likely to contain areas of historic indigenous activity, as the rivers provided sustenance to both cultural groups.

There is an extensive body of work to be done to inspect the inundation area of the Burdekin and Clarke Rivers to confirm what sites of cultural significance exist. Without knowing what is there, there is no way to assess the relevance or importance of the river to the cultural groups – and therefore no way for either group to assess the merits of the economic development and prosperity of their people against the potential loss of heritage. There is also no way currently to mitigate heritage site loss as the extent of what exists has not been accurately established.

During the EIS a significant effort will be required to inspect the Burdekin and Clarke River surrounds for important cultural sites, while similar assessment of the proposed 50,000 Ha of farmland is also needed. As with the EIS, these works can be expected to take 2 years and should be conducted concurrently with the EIS.

3.1.3. Dam Construction Technique

Indicative information on geological formations and geotechnical conditions have led to a number of assumptions being made about the design of the dam using RCC techniques, along with the design of the spillway and the rest of the main dam features.

There is extensive drilling of the dam site needed to ensure that the proposed RCC dam is the most suitable construction format, and also to inform the development of design works of the spillway and major dam features.

This body of physical investigation is essential in ensuring the most suitable dam construction technique is identified and designed, as this set of design criteria are the single most critical technical elements of the project.

3.1.4. Weir Construction

Similar to the main Hells Gates Dam wall, assumptions have been made with regard to the observed geology and the underground geotechnical conditions that may be found at each of Big Rocks Weir and the three weir pool walls. Drilling of these sites will confirm the geology and geotechnical conditions and de-risk the design elements of these weirs.

As Big Rocks is likely to be one of the first structures constructed, it would seem logical to accelerate design of Big Rocks in the early stages of the next body of work, especially as Big Rocks may form a critical part of crop trials for perennial high value crops that will drive the economic benefits of the overall 50,000 ha project.

3.1.5. Water Extraction Direct from Burdekin River

The proposed staging of the scheme, utilising the immediately contiguous land or the “Burdekin Zone” along the Burdekin River, assumes that there is sufficient year-round flow in the river to support annual cropping. The reality is that the major rainfalls feeding the Burdekin River occur in a few short months of the year, resulting in extreme flows for short periods, with long periods of the year where low flows occur.

There needs to be physical confirmation that under-boring the river diagonally will result in pumping wells being free flowing and relatively silt-free to allow the Burdekin Zone farmers to access year-round water supplies. This would require the sinking of a number of river under-bores along the river to confirm the suspicion of the project engineers that there will be sufficient bore flow underneath the river to sustain such pumping, and therefore sustain annual crops.

The establishment of Big Rocks Weir is likely to be needed to allow the first of the perennial crops to be planted as river under-bore pumps may not present a reliable enough source of water for 30+ year production lifetime crops to be established. It is therefore crucial to implement a long-term solution by construction of the Hells Gates Dam to drought-proof the water supply for the Burdekin Zone and to control the downstream flow regimes.

3.1.6. LiDAR & Distribution Infrastructure

The exiting survey data is limited to 10 m SRTM contour data. This is insufficient to develop channel and pipeline designs sufficiently past concept phase. Additionally, the 10 m SRTM contour data is also substandard for the purpose of defining the inundation area of the weir pools, which will be critical in determining the effect on transport infrastructure and pumping equipment.

The next phase of works must therefore include the collection of LiDAR data across the entire inundation area, the extent of the rivers from the top of the inundation area down to Big Rocks Weir, and also the entire area identified for irrigated agriculture.

3.1.7. Pumped Hydro-electric Scheme

While this is an exciting bolt-on to the construction of Hells Gates dam in terms of electricity network security and the potential to significantly increase the BCR and NPV of the entire scheme, it remains a body of work that is in its infancy.

Before any real conclusions can be drawn on the viability or otherwise of a PHES of up to 1200 MW north of the Hells Gates dam, significant investigations need to be undertaken in the field. These investigations can be

staged to limit expense, with stage-gates implemented and further funding drawn down once critical barriers-to-development have been overcome.

3.1.8. Power System Capacities

The power network within the Hells Gates zone is owned and operated by Ergon Energy, and at this time does not have the capacity to supply the ~90MW of power demand that would be needed by the Hells Gates Irrigation Scheme once fully developed.

The under-feasibility Renewable Hub 275kV powerline proposed between Mt Fox and Kidston could have a significant impact on the potential to connect a large scale PHES into the national grid, while also freeing up the Ross-Kidston 132kV line to supply the Northern Zone of the scheme.

There may be significant upgrade works required on one or more of the 132kV and 66kV lines that feed into the Charters Towers/Milchester supply network that would be utilised for the supply of power to the Southern and Middle Zones. Significant investigation work is needed to confirm the capacity constraints, the upgrade works, and the ability to upgrade to the existing 11kV line route into the Southern and Central zones from Charters Towers to 66kV.

3.1.9. Capital Cost and Resultant CBR

The cost estimate performed cannot be highly accurate given the level of risk attached to the various system components of the overall scheme. As with any cost estimation, there is a cost allocated to risk – the higher the risk, the higher the allocation. It is very clear to the authors of this document that de-risking the project is likely to reduce the capital cost estimate of the scheme.

Reducing the cost estimate will clearly flow through to BCR and NPV/IRR improvements, by the application of value engineering the reduction of contingency and providing certainty to the Quantity Surveyors.

3.2. Stakeholder Engagement

As part of the delivery of the Hells Gates Dam Feasibility Study a number of stakeholders were contacted, in particular the local residents affected by the Land Capability Assessment (LCA) testing. A stakeholder engagement plan was implemented that included directly contacting all local residents via phone to obtain the necessary approvals to access the proposed agricultural districts prior to commencing any testing works. A stakeholder consultation specialist lead and managed the communications to ensure all local residents have provided the necessary approvals prior to conducting any site testing works.

The overall responses from majority of the stakeholders was generally positive and received well with a large number of residents taking on the Hells Gates Dam project as a positive opportunity that will open up the North Queensland economy through large scale agricultural development.

Although land acquisition is excluded from this project at a feasibility study level, it is a critical element that requires collaborative negotiations between State, Federal and Local Governments prior to discussions with the landowners. Due to the large-scale of agriculture proposed it is expected that internal local-roads will be required during the irrigation land development phase and therefore resumptions of land is expected to be required prior to the construction phase. At the initial stages of the project a town-hall meeting was held in Charters Towers to provide an overview on the intent of the Hells Gates Dam Feasibility project whilst providing the local stakeholders the opportunity to discuss the project and ask questions from the projects' leadership team.

3.3. Options Selection Approach

Within the context of the technical assessment of the overall project, a range of macro options were assessed across a number of critical decision points. These preferred macro options were investigated and led to further optionality within each of the discipline investigations – many of these macro options were based around identifying a solution that was potentially viable, from a very limited field, given a range of physical constraints in environment concerns, infrastructure, topology and land availability.

As this project was demand-driven in its approach, many of the macro options self-selected to meet the requirements of market demand, and were not driven by typical assessment of multiple options based around a set of selection criteria.

The terms of reference of the project initiated this demand driven approach, which in turn drove the self-selection of the macro options.

The nature of the approach means that a traditional Options Analysis was not part of the scope of works – it uses a problem-solution driven methodology as opposed to an optionality methodology. In many cases there was a single option available, which was the result of research, innovation and physical site investigations.

As a result, this element of the report describes the problem, and the investigations undertaken to identify the optimal solution. Where a traditional options analysis was used – such as in determining the dam location and dam construction concept – the traditional method is documented here.

Meanwhile, the critical staging options were driven by the economic assessment around which elements could or should be built in which order, to ensure economic sustainability along with avoiding oversupply of produce markets. Again, the demand driver is critical to the process and negates a typical options analysis.

Following are descriptions of the major option considerations around scale of agricultural zone, type of horticulture, dam location and construction type, pipeline routes, channel routes and location of some weir pools to service irrigation zones.

Finally, the economic analysis provided further input to the staging options.

3.4. Scale of Agricultural Zone

Five key inputs determined the scale of the irrigation zone:

- Knowledge that a maximum of 30% of river flows could be harvested at the dam site in the upper Burdekin
- The holding capacity of a dam at Hells Gates (which was confirmed as the preferred site by options analysis) at 372 m AHD of 2100 GL, which determined the amount of annual capacity available to provide water security in every 10-year cycle
- The quantum of quality horticultural land within reasonable proximity of the River for irrigation infrastructure to reach
- Limitation of existing infrastructure damage in the inundation zone, which in turn dictated the AHD 372 m level to restrict flooding of roads and farmland
- The known requirement for high value horticulture, and the subsequent likelihood of 10 – 12 ML/ha/year of water on-crop.

This mix of inputs very clearly indicated that two development options available. These are:

- Mixed cropping scenario – 50,000 ha under irrigation with a mix of annual and perennial horticultural, and broadacre cropping
- Perennial cropping scenario – 30,000 ha under irrigation, using high-reliability water for permanent cropping. Under the perennial cropping scenario, only two of the three potential irrigation areas would be developed, mainly due to the higher water requirements of the perennial crops.

A third scenario of broad acre cropping was identified in the 2014 Hells Gate Agriculture Feasibility study as predominantly unviable, and all economic analysis conducted by this Study Team confirms that the scheme cannot be predominantly based around a broad acre crop. However broad acre crops do feature in the mixed cropping scenario for the lower productivity lands in the Middle irrigation zone.

How these scenarios play out will be determined on the whole by future prevailing market conditions and the behavioral activities of large scale agribusiness developers. Demand will drive the balance between purely perennial and mixed cropping, with that demand driven predominantly by the ASEAN market, not the domestic market.

As a result, the study team considers both options to be perfectly valid and has produced economic scenarios with both options.

Staging of the development, described below, does have an element of traditional options analysis.

3.5. Types of Horticulture/Cropping

As this study is not definitive in addressing what crops are to be grown, or where – that will be driven by market demand and investment behavior. This study simply puts forward the results of the soil survey and matched cropping in the North Queensland climate.

No option has been selection, and as discussed above, two scenarios remain in play in terms of the mix between perennial and annual high value crops:

- Mixed cropping seeing 14,000 Ha of perennials and 36,000 Ha of mixed annual crops with good water security
- Dedicated perennial cropping of 30,000 Ha with high water security.

3.6. Dam Location

A traditional options analysis was undertaken to determine the dam location between the two immediate options, as identified in the SMEC investigations of 1975 and the GHD works in 2014. A clear winner in this analysis was the smaller, deeper and cheaper Hells Gates Dam which has environmental and cultural heritage advantages. The results of the options analysis are detailed in Table 1.

Table 1: Dam Location Options Analysis Results

Benefit Type and Description	Benefit Rating		Comments / Assumptions
	Hells Gates	Mount Foxton	
Efficient deep storage with minimised evaporation	Suitable	Modestly suitable	Hells Gates is a deeper dam with less surface area for a 2100GL dam capacity
Dam width leading to construction costs	Minimised	Bigger dam wall	Halls Gate has a higher, shorter dam that has significant construction cost advantages
Minimised inundation area for costly resumptions	Smaller	Larger	Mt Foxton would inundate a significantly larger area than Hells Gates due to the shallow nature of the formations closer to the dam, covering productive farmland (beef cattle)
Minimisation of environmental issues related to areas of significance	Minimised impact	Several significant areas	Mt Foxton would inundate a significantly longer length of river system and important swampy wetland areas and also dam more tributaries than Hells Gates due to the shallow nature of the formations closer to the dam. Critical to this was native species in Running River unique to the area.
Minimisation of river system inundation WRT cultural heritage risk	Limited impact	More impact	Mt Foxton would inundate a significantly longer length of river system where regular indigenous activity is likely, including in Running River
Availability of dam construction materials nearby	Suitable	Suitable	Both options present with suitable construction materials nearby based on an initial assessment of the geology. Further investigation will need to be carried out to quantify suitability and availability of the construction materials.
Suitability of geological formations to damming	More suited	Less suited	Taller, shorter dam at Hells Gates with suitable geological structures on either side of the river
Storage Capacity meets 2100GL	Suitable	Suitable	Both dams deliver the requisite capacity

Benefit Type and Description	Benefit Rating		Comments / Assumptions
	Hells Gates	Mount Foxton	
Improved opportunities for indigenous business development and employment	Modest	Modest	Neither represents an advantage – both would be in the same cultural group lands
Potential for power generation at the toe of the dam using hydro-electric generation.	10–15 MW	N/A	Mt Foxton dam wall too low to be economically suitable to run-of-river given low head. Hells Gates would support a small toe-of-dam hydro
Impact on existing infrastructure	Significant	Slightly less significant	Each dam inundated (disused) Greenvale rail line, Mt Fox Rd, Gregory Development Rd at Clarke River Crossing and an 11kV power line from Greenvale. Neither provided a significant advantage although inundation of Gregory Development was slightly minimised with Mt Foxton

3.7. Dam Construction Type

A dam construction options analysis was undertaken using three broad options that were developed for evaluation. High level conceptual layouts and costings were developed, generally using the layouts presented in the SMEC 1975 report. Specific design criteria were updated based on analysis completed as part of this feasibility study.

Initial hydraulic spillway design was carried out to allow the spillway to be sized and to determine dam heights for options evaluation.

The three options were:

- An earth and rockfill embankment with a crest at RL 396 m, using a 200 m wide ogee spillway located in a saddle to the north. Spillway flows would be directed back to the river via a reinforced concrete return channel approximately 600 m in length.
- A concrete-faced rockfill dam (CFRD) with a crest at RL 396 m, using a 200 m wide ogee spillway located in a saddle to the north. Spillway flows would be directed back to the river via a reinforced concrete return channel approximately 600 m in length.
- A concrete gravity dam with crest level at RL 395 m with a 100 m wide ogee spillway located on the dam itself.

The concrete gravity dam was selected as the preferred option at this stage of development due to:

- The ability to incorporate the outlet works into the concrete gravity structure
- The ability to pass flows over the crest rather than constructing a separate spillway
- A smaller construction footprint
- A much shorter diversion tunnel is required
- Availability of slightly weathered to fresh rock (SW – FR) to establish foundations with a high bearing strength to prevent failure from:
 - Overturning due to compression of founding materials at the dam toe
 - Shear and translational failure due to the dam sliding along the contact with the founding material or kinematically-feasible defects within the foundation
 - Uplift pressures building beneath the dam due to seepage
 - Differential settlement of the founding material, introducing tension into the dam.

At this stage of the assessment – which is clearly in concept phase given no drilling has been undertaken and only above ground observations from 1974 and 2017 and public domain desktop geological mapping have been taken into account – the indicative result is that an RCC dam for the Hells Gates site will deliver a smaller and cheaper dam footprint, will incorporate the spillway into the gravity section, which will then reduce the earthworks requirements while still meeting all ANCOLD requirements, Queensland Government dam safety regulations and the general good engineering design requirements attached to best-practice and fit-for-purpose. The recent changes to the ANCOLD requirements will be incorporated into the next development phase of the project to ensure the design is compliant to the regulatory design guidelines of the future.

When drilling and further geological investigations have been completed in subsequent phases of development, the construction technique for the dam will be critically reviewed with all of the facts in hand. At that time, a fully informed options analysis will need to be completed

3.8. Townsville Pipeline Route

An options analysis was applied to the selected route for the proposed Townsville Pipeline routes. A clear winner using the Greenvale Rail line route across Hervey Range was identified. The process of the options analysis considered the geometric constraints, existing tunnels, existing water courses and the presence of the decommissioned Greenvale Railway Line, following which the refined option was developed and designed. The results of the options analysis are detailed in Table 2.

Table 2: Pipeline Route Options Analysis Results

Benefit Type and Description	Benefit Rating				Comments / Assumptions
	Greenvale Rail	GDR / Flinders Hwy	Paluma	Hervey Range Road	
Length of Pipeline	Limited	Longest	Modest	Significant	Running to Paluma is the shortest route by ~ 100km
Extent of head to pump up	Modest	High	Significant	Modest	Paluma would require a 600m head climb to Paluma Dam, Flinders Hwy must cross Mingela Range while the other two are generally flat/inundations to the range fall/divide.
Range crossing difficulties	Limited	Significant	Significant	Significant	The existing rail line has already traversed the range, and while still a large fall with challenges, it is a better solution than Harvey Range.
Corridor availability	Available	Available until the range crossing	Not existing	Available until the range crossing	The rail line corridor is available all the way across the range with only a short new corridor needed to Ross dam. Both road routes have minimal corridor available across the Range

Benefit Type and Description	Benefit Rating				Comments / Assumptions
	Greenvale Rail	GDR / Flinders Hwy	Paluma	Hervey Range Road	
Construction difficulties	Minimised	Minimised	Significant	Modest	Paluma crosses rough country while the other three tend to follow existing corridors with construction access and relatively known soil conditions
Crossing WHA or National Parks	Nil	Nil	Cuts wha and national park	Nil	Paluma cannot avoid entering the WHA and would likely trim National Park land as well, ruling it out as an option
Cost to build	Minimised	Modest	Significant due to high uphill grade	Higher than Greenvale	Greenvale would be the shortest, cheapest of the non-Paluma options. While Paluma is shortest, it has significant terrain issues and WHA incursion
Proximity to current Townsville Water dams	Middle	Furthest	Closest	Middle	Proportional to increase in size of irrigation area.
Ability of TW to utilise supplied water to supplement Haughton Pipeline	Ross Dam	Ross Dam	Northern Beaches only	Ross Dam	Paluma dam only supplies the Northern Beaches and cannot currently supply water (capacity or connectivity) to Townsville city
Use of otherwise complimentary infrastructure	Nil	Nil	Significant	Nil	Paluma empties into Paluma Dam with existing treatment and pipeline facilities to the Northern Beaches of Townsville

3.9. Weir Pool Locations, Irrigation Channel Scheme and Routes

These items were effectively self-selecting once it became clear from the soil testing that three distinct sets of high value soils were available, with the knowledge that the three separate zones are effectively separated by natural features.

In each case the survey contours determined the channel routes, while shortest-routes determined the pipelines and the desired locations of pump stations and weir pools for each of the North, Middle and South Zones. The future stages of the project will require more detailed survey to ascertain the topography of the natural terrain more accurately which will ultimately support a more refined and detailed infrastructure design.

3.10. Staging Options

An options analysis was conducted to determine optimum staging based on technical parameters, and refined with the delivery of the economic assessment resulting in adding in the Burdekin Zone and options analysis summary is detailed below. The Burdekin Zone is the irrigable areas in proximity to the Burdekin River that

requires minimal capital infrastructures for the development of potential farmlands. The results of the options analysis are detailed in Table 3.

Table 3: Staging Options Analysis Results

Benefit Type and Description	Benefit Rating				Comments / Assumptions
	Burdekin	North	Middle	South	
Soil suitability to high value perennial or high value annual crops	Annuals	Maximised	Limited	Perennials and annuals	Northern zone and Southern Zone will deliver the highest revenue per Ha
Suitability to 30,000 ha perennial cropping scheme	Moderate	Strong	Limited	Strong	Northern and Southern will provide the highest value perennial crops.
Suitability to 50,000 ha mixed cropping scheme	Significant	Significant	Significant	Significant	All zones needed to deliver 50,000 Ha mixed cropping scheme
Proximity to power assets	Furthest	Closest	Furthest	2 nd closest	Based on existing high capacity power lines
Proximity to transport infrastructure	Significant	Significant	Significant	Significant	All access Gregory Development and Hervey Range Roads
Proximity to dam	Traverses all	Closest	Middle	Furthest	Note Burdekin zone may not require the dam for annual cropping on its own
Proximity to direct river pumping	Closest	Middle	Middle	Furthest	Different zones are geographically located and allows for direct river pumping differently
Development cost relative to value of land to high value cropping	Least	High but mitigated by high value product	Highest given low value crops	Could utilise big rocks for mid-range development	Each of the large zones requires the Dam and thus has high development costs
High cost of water restricts viable cropping opportunities	Significant	Significant	Significant	Significant	The cost of water and the affordability to pay by the farmer will have significant impact on the viability of the scheme when competing with cheaper water prices from the Burdekin Irrigation Scheme
Absence of water allocation under the current Water Plan	Significant	Significant	Significant	Significant	Requires the amendment of the Water Plan accordingly
Interest from current landholders to develop	Significant	Significant	Significant	Significant	High interest across the board
Staging Urgency Ranking	1	2	4	3	Result of OA

4. Staging of the Project

The economic assessment as delivered by this study does not currently support the construction of all stages of the project concurrently. The extensive need to perform field studies and design work, and then finance the initial major infrastructure elements, means that there will be a significant time delay between the delivery of this report and the commencement of dam construction. This delay could be in the realm of 5-10 years.

At 50,000 ha, any one perennial crop grown on that scale would flood the Australian and ASEAN markets. The result is the need for a mosaic of crops catering to the needs of the export market, transported either through airfreight from Townsville International Airport or via refrigerated containers from the container terminal at the Port of Townsville.

The staging of the overall Hells Gates Irrigation Scheme would allow major infrastructures to be brought online via a strategic approach for the following key agricultural districts:

- Burdekin Zone Annual Crops
- Big Rocks Weir Perennial Crops
- Hells Gates Dam and the North Zone
- South and Middle Zones
- Future Development to 130,000 ha

Furthermore, there is a strong case to argue that for any large scale multi-crop irrigated agricultural project to be successful in the way that the Murray-Darling is successful, it will be developed over a longer rather than a shorter time period. This development cycle will respond effectively to market conditions and the growing demand seen from the ASEAN region for high value produce.

There is also a practical need to demonstrate that the soils can support quality produce, and that the transit systems to deliver fresh produce into the ASEAN region are reliable and effective.

Additionally, the current water resource allocations from the Upper Burdekin System, due to be re-examined by the State of Queensland in 2019, do not support the development of large scale irrigated agriculture in the region.

As a result, the Study Team has formulated a possible staging of the project development that could be implemented concurrently with major study works, and lead to as much as 5,000 Ha of high value cropping development prior to the construction of the Hells Gates dam wall. In terms of risk mitigation related to soils, transport, cropping values, farming returns and proofing the value-of-water, this initial staging plan will be invaluable. It provides an opportunity to commercially de-risking the overall project, providing investor confidence across the board in Government, Corporates and the Farming Community, as well as helping to build support networks in worker availability, transport, manageable jobs growth, worker upskilling, cool store development and secondary food processing facilities.

While needing further development and some field studies to support the staging, as well as significant alterations to the water allocations available from the Upper Burdekin combined with early development of Big Rocks Weir, the staging program suggested includes:

4.1. Burdekin Zone Annual Crops

There are up to 5,000 Ha of identified cropping soils that are contiguous to the Burdekin River along the length of the irrigation zone. As a result of the economic analysis, an additional zone “Burdekin” was identified that carves off areas of each of the Northern, Middle and Southern Zones, as these areas can pump directly from the River.

A number of direct benefits of developing these 5,000 ha first can be seen, however there are a number of risks that require further review and field investigation. These are described in more detail in Risk Assessment Section of this document, with mitigations described in the Next Phases of Development Work section, but in short, the issues include:

- The Burdekin River has exceptionally high flows for short periods of the year. For the balance of the year very modest flows are seen above-ground

- If there are no weir pools established to store quantities of water for delivery to the farm gate, potentially there may be large periods of the year where no water is available, and as such irrigated cropping would not be viable
- If there is no Dam established to regulate flow in the river to support irrigated agriculture, there is a large unmitigated risk to farmers that is likely to see little or no development take place, as has been the case to this point
- Without evidence of water availability, the State is unlikely to lift limits on water allocations to make flows available for additional irrigated agriculture.

There are two possible resolutions to this lack of water regularity in the river:

- Farmers build large storage dams to contain up to 10 months of water supply on their properties, harvesting during floodwater flow. This is an inefficient result, as it involves multiple water handling transactions, will lead to grossly inefficient regional water management and does not provide for any multi-year surety for farmers. That this activity has not been commonplace in the Upper Burdekin to this point indicates that, on the whole, regulators and farmers recognise that it is not a viable solution
- Currently some farmers in the Upper Burdekin, who have properties fronting the river, underbore the river to create a diagonal well to supply permanent water to small scale irrigation blocks. Discussion with these farmers indicates that these bores permanently flow, indicating a possible sub-surface river flow and/or significant water storage within the silty layers underneath the riverbed. This activity supports a number of smaller scale operators growing product from table grapes to sweet potatoes, lettuces and other higher value crops that are sold to the domestic market.

Clearly to confirm the theory that diagonal bores can produce a free-flowing water supply – albeit on a limited scale - some bore drilling is needed with test pumping to confirm flows and any observable surface effects.

This is likely to support only small-scale developments, and then only likely to support annual cropping. It is highly unlikely that any large-scale agribusiness investor would use this technique for 25-30 year lifespan crops on anything other than a demonstration basis to test soils.

The real benefit of providing water allocations and river pumping solutions is proving that the soil conditions are suitable for irrigated cropping, especially niche high-value crops, while allowing initial development of produce handling networks into the domestic market. Further, rapid annual crop rotation could be supported to respond to changing market dynamics, with niche crops able to be grown on a scale that would not depress domestic or short route export markets.

The lack of powerline capacity in the areas contiguous to the river to supply pump stations may well restrict any river pumps to operating on diesel, which limits scale and creates some sensitivities around diesel storage in and around the river.

It is highly unlikely that 5,000 ha could be supported without at least a weir pool being developed (such as Big Rocks Weir), more likely the initial developments would be in the realm of 1,000 ha – 3,000 ha if water allocations were made available.

4.2. Big Rocks Weir Perennial Crops

The early development of Big Rocks Weir could provide an additional aspect to the early, low cost development of sections of the Southern Zone, subject to water allocations being made available. Big Rocks Weir is estimated to have a \$30-\$50 million construction cost, so is a relatively inexpensive solution to deliver permanent water storage (albeit limited in scope and security) that would provide reasonable surety for existing farm owners to develop high value perennial crops such as table grapes, avocado and mango.

Additionally, larger operators with a longer-term interest could well use the weir as a permanent supply to provide test cropping to high value perennial crops in the Southern Zone further afield from the river, utilising their own short water pipelines. The scale of horticulture could start to see regular export of high value crops to ASEAN, while 2,000-3,000 Ha of mosaic cropping it is unlikely to provide a scale that depresses local markets.

As with the annual cropping in the early stages, the lack of power supply capacity in the area could be a major limitation. However Big Rocks Weir is relatively close to the major 66kV infrastructure at Charters Towers,

which could see a number of pump stations supported with electricity. The likelihood is that a number of pump stations will remain diesel driven.

4.3. Hells Gates Dam and the North Zone

In order to open up larger scale perennial and high value annual cropping, the construction of Hells Gates Dam is essential. It provides the requisite level of water security and also can be used to regulate flows to downstream weirs such as Big Rocks.

Staging will likely see the North Zone commencing first, due its proximity to the proposed dam and power supply infrastructure. At over 17,000 Ha, the North Zone also possesses a lot of the soils suited to high value perennial cropping, thus could see a large operator take a significant development stake in properties in the area for a single or multiple perennial crop for export, such a citrus, durian, mango, table grapes or avocado. This area is also suited to annual cropping of high value vegetables such as capsicum and pumpkin.

North Zone is also close in proximity to the 132kV Ross-Kidston power line, the likely toe-of-dam hydro and the proposed solar power station. Other than the large expense of the dam and the infrastructure relocations, the assets required for development include the North weir pool, power substations and power lines, a major pump station, balancing storage, pipeline and several channels.

It is highly likely that multiple major agribusiness investment commitments to perennial and high value annual crops of up to 15,000 ha will be needed to drive dam and infrastructure financial commitment, and as such the investor strategies and ASEAN market drivers are likely to influence the timing of the North Zone staging more than the forward projections developed by the study team.

4.4. South and Middle Zones

Depending on cropping uptakes, it is possible that only one of the South and Middle Zones will be developed outside of the “Burdekin” contiguous zone. Under the perennial cropping scenario, only 30,000 Ha would be supported by the assessed water resource, given the higher water needs and tighter water security needs of the perennial crops, which can have a 30-year lifespan.

Under a mixed cropping scenario – the most likely to be the case in what is effectively a multi-user infrastructure facility – the full 50,000 ha would be developed with some annual crops having much lower water consumption needs than the perennial crops. With good annual and perennial soils, and proximity to the Charters Towers power systems, it seems likely that the South Zone would be the next weir pool / pump / pipeline / channel system developed. This would likely see commencement of broad acre cropping for annual cash crops such as mung beans and pulses, where major processing facilities (mills and gins) are not required.

The development of the Middle Zone, with its soils suited to broad scale agriculture in the main, would likely be driven by a single low value annual crop that requires a major processing facility, but which has a relatively low capacity to pay for water. The income into the overall scheme from this element of the mosaic remains critical to the overall viability of the scheme, assuming multi-cropping, but it is clear that the overall scheme will not be based around a broad acre crop as the primary product.

An element that has not been able to be modelled effectively is the value of by-products from a central processing facility. There remain significant advances in milled by-products, such as ethanol and fertilisers, as well as the potential for large scale waste-to-energy generation of baseload power. There is a strong likelihood over the coming decade that developments in high value secondary and tertiary products from advanced milling would significantly alter the capacity-to-pay for such crops. However, the doubt surrounding development of these technologies means that such considerations cannot currently be economically modelled with any degree of certainty, thus they are raised here as a potential future value -add that are not considered in the economics of the feasibility study.

4.5. Future Development to 130,000 ha

While Hells Gates irrigation scheme is proposed by this study as a 50,000 ha project, over 130,000 ha of suitable lands are currently identified within irrigable distance of the River. The balance of 80,000 ha outside of the initial scheme are admittedly further from the river and would have higher pumping costs. That in no way rules out their development if water allocations are made available for more than 50,000 ha of development.

5. Next Phases of Development Work

The authors believe that the next stages of development should be working towards a full business case. A business case for the Hells Gates Dam requires a strong emphasis on detailed site investigations, along with the further development and confirmation of design concepts, followed by confirmation of the economic modelling carried through from the feasibility report. It is acknowledged that this may take several years to complete and may not be able to be funded in any one financial year.

It is therefore likely that a process will be needed to stage site / investigative works, design and business case level economic assessment. That process remains outside of the scope of this project, however.

5.1. De-Risking the Project

The aim of the next stage of works is to de-risk the project commercially, technically, environmentally and from a cultural heritage perspective through the delivery of numerous concurrent activities, or a staged series of activities depending on availability of funding.

It is important to note the concept of a developed design to support a business case is not a fully detailed design – it takes the feasibility level concepts and proofs them for further work through interpretation of extensive site testing, to confirm a concept into a de-risked level of preliminary design that still has extensive detailing yet to be delivered.

The following subsections describe site and design progression works that are required, however it is not the author's intent to designate the order of works to be carried out.

5.2. Further Investigative Work

- Dam and weir design, geology and geotechnical investigation and survey works
 - Acquisition of LiDAR across the entire inundation area.
 - 3 drilling crews onsite
 - 46 drills, vertical and incline
 - 100 test pits
 - Temporary camp
 - Construction of some tracks and drilling pads needed
 - Concrete trial mix to be performed for RCC Dam in this location
 - Core drilling storage onsite in shipping containers
 - 5x River underbores for bore pump testing
- Environmental Impact Statement
 - Baseline environmental studies including:
 - terrestrial flora and fauna
 - aquatic flora and fauna
 - water quality
 - Four part EIS
 - Initial Advice Statement (IAS) and subsequent Terms of Reference (TOR)
 - Draft EIS addressing issues of state and national environmental significance,
 - Addendum EIS report responding to agency and public submissions
 - Comprehensive stakeholder consultation program
- Cultural Heritage
 - Two Cultural Groups to extensively consult with – Gugu Bardon and Gudjala
 - Significant inspection program throughout the Burdekin and Clarke Systems in the inundation area for the dam
 - Inspection program for the four weir inundation areas
 - Inspection program for the irrigation zones
- Distribution Infrastructure

- Acquisition of significant LiDAR covering the River, proposed pipelines and channels to confirm route selection
- Pumped Hydro Concept & Options Assessment
 - Options analysis of the pumped hydro options that includes a Hold Point for decision on whether to proceed into Preliminary Site Investigations
- Pumped Hydro Preferred Option Investigation
 - Preliminary Site Investigations into geology, topology, siting of assets, social and environmental aspects including a Hold Point for decision on whether to proceed into detailed investigations
 - Detailed site investigations
 - Preliminary engineering design of the preferred option
 - Geotech drilling of the upper dam site and the headrace tunnel as well as the proposed generator cavern.

5.3. Developed Design Work

- Detailing of Dams & Weirs
 - Auxiliary details to be further developed such as spillway length, chute type, stilling basin configuration and bypass tunnels
 - Investigation of the footing and foundation conditions of the dam and the locality and type of borrow materials
 - Site investigations for the 4 proposed weirs including developed design of the weirs and pools
- Distribution Infrastructure
 - Development of the design of
 - The holding storages
 - The agricultural pumps stations and lift stations
 - The pipelines and channels for irrigation distribution
 - The toe-of-dam hydro and solar power stations
 - The line routes and concept designs for new and upgraded sub-transmission power lines and substations
 - Extensive negotiations with Ergon and Powerlink, payment of development fees charges by Ergon for access to the power grid for loads as well as the hydro and solar options
- Pumped Hydro Preferred Option Development
 - Preliminary design of the upper dam, inlet and outlet structures, headrace and tailrace tunnels and generator cavern
 - Yield and performance estimates
 - Business Case level reporting
- Cost Estimation
 - Quantity Surveying, working off those works delivered for the Feasibility study to further identify each element's construction cost to a more accurate, de-risked level
- Economic Assessment
 - Further analysis of the economic aspects, working of the models created by the feasibility study, to further de-risk the economic returns of the project.

5.4. Community Engagement

- Further engagement with the Charters Towers community and CTRC, with a focus on local landholders and their needs to trigger development

- Development of discussions with major Agribusiness first both in Australia and SE Asia to identify their trigger points for investment and market the project to likely major developers
- Confirm staging options to suit community needs, local landholders and major Agribusiness firms
- Investigation of financing arrangements, both traditional and non-traditional/creative, for local landholders, consortiums and major agribusiness to access to overcome barriers to investment

5.5. Business Case Development

- Delivery of a business case report to meet either BQ or Commonwealth Government requirements

5.6. Project Management

- Development and management of early works, contracts, engagement of the delivery consortium, Project Management Plan, detailed WBS and project planning
- Fiscal and delivery management of the project over the 2+ years of the project's delivery
- Ongoing stakeholder Management in Townsville, Queensland Government, Commonwealth government, offshore investors and various community stakeholders and public representatives
- Formation and ongoing delivery of a high-level Project Leadership Team taking input from Local, State and Commonwealth Government of other commercially astute high profile North Queensland individuals and entities
- Delivery of final reporting to all required stakeholders, in NQ, Queensland, Australia and offshore including investors and Agribusiness partners.

5.7. Potential Cost of Further Studies

The cost to deliver the proposed scope of works is estimated at \$17.7M. Delivery will take over two years with the longest lead time items being the EIS and Cultural Heritage investigations.

At this time, a 10% contingency has been included. Further development of the required works and definition of scope may help to reduce this to 5%. The indicative cost schedule for such works is itemised as follows:

Table 4: Business Case Draft Cost Estimate

No.	Sub-Tasks	Details	Duration	Cost Estimate (ex. GST)
1	Geotechnical Investigation & Survey			
1.01	Drilling, dam axis	Assume 16 boreholes, inclined and vertical. Diamond Coring.	20 weeks	\$1,000,000
1.02	Drilling pump and hydropower stations, borrow areas and quarry	Assume 30 vertical boreholes.	20 weeks	\$1,000,000
1.03	Weir drilling	Drill each of the 4 weirs & interpret results.	20 weeks	\$500,000
1.04	Test pitting	Assume 100 test pits in borrow areas and along pipe alignments.	8 weeks	\$250,000
1.05	Laboratory testing	Material classification, unconfined compressive strength (rock), triaxial testing (soil, petrographic analysis).	4 weeks; following drilling and test pitting	\$250,000
1.06	Concrete mix design and testing	Batching trials, compressive strength testing, rock adhesion testing and shear testing.	6 months	\$200,000

No.	Sub-Tasks	Details	Duration	Cost Estimate (ex. GST)
1.07	Interpretation and reporting		12 weeks	\$150,000
1.08	Miscellaneous	Approvals, cultural heritage, land access.	Ongoing	\$100,000
1.09	Topographic Survey	Weirs and critical infrastructure		\$210,000
1.10	Accommodation	Construction, operation and removal of temporary site camp		\$200,000
1.11	Drilling Contingency	Market constraints, competition for rigs and mining taking up slack		\$708,182
Geotechnical Investigation Total				\$4,560,000
2	Environmental Studies and EIS			
2.01	Baseline Environmental Studies	Including flora and fauna studies	12 months	\$1,250,000
2.02	EIS - Part 1	Terms of Reference (TOR) and Initial Advice Statement (IAS)	12 months	\$500,000
2.03	EIS - Part 2	Draft Report	6 months	\$1,500,000
2.04	EIS - Part 3	Supplementary Report	3 months	\$500,000
2.05	EIS - Part 4	Consultation	3 months	\$600,000
2.06	Business Case Summary		3 months	\$100,000
2.07	Environmental Implementation Cost		3 months	\$100,000
2.08	Cultural Heritage investigations	Site visits, consultation, reporting and documentation	24 months	\$1,000,000
Environmental Studies and EIS Total				\$5,550,000
3	Detailing of Dam and Weirs			
3.01	Sizing of diversion and outlet works	Including flooding assessment for the dam and 4 weirs	6 months	\$500,000
3.02	Dewatering and temporary works	Design of temporary dams and preparation works for construction	3 months	\$300,000
3.03	Concrete aggregate suitability	Material assessment	4 weeks	\$200,000
3.04	Erosion assessment	Detailed assessment and design of spillway and immediate downstream structures to prevent undermining of dam wall, banks and downstream scouring over time	3 months	\$400,000
3.05	Failure impact assessments	Modelling of various disciplines to ensure failure points are identified, well understood and catered for across the dam and 4 weirs	3 months	\$300,000

No.	Sub-Tasks	Details	Duration	Cost Estimate (ex. GST)
3.06	Flood impact assessments	Including structural input and downstream and upstream effects	8 weeks	\$200,000
3.07	Fishway design	Including environmental input and design of the fishways for 5 sites	4 weeks	\$200,000
3.08	Design and Drafting of feasibility design incl Big Rocks	Estimate 30 drawings for dam, 10 per weir, 20 for Big Rocks	4 months	\$1,000,000
Detailing of Dam and Weirs Sub-Total				\$3,100,000
4	Distribution Infrastructure			
4.01	Transfer Pump Stations x3	Developed structural, mechanical and electrical design	4 months	\$200,000
4.02	Transfer Pipelines x3	Developed civil and mechanical design including route and material selection	4 months	\$200,000
4.03	Hydropower & Solar Stations	Developed structural, mechanical and electrical design	6 months	\$200,000
4.04	Holding storages x3	Developed structural, mechanical and electrical design	4 months	\$300,000
4.05	Distribution Pipelines & Channels	Developed civil design including route and material selection and LiDAR acquisition to 0.1cm	6 months	\$600,000
4.06	Power Distribution Lines & Substations	Civil, structural and electrical route selection, concept design & negotiations with Ergon plus Ergon fees for investigations plus developed design for the 132/66/33/11kV substation and the three 66/11kV substations	18 months	\$500,000
4.07	Drafting of feasibility design	Estimate 100 drawings	4 months	\$300,000
Distribution Infrastructure Total				\$2,300,000
5	Pumped Hydro Investigation			
5.01	Options Analysis incl preferred	Identification and basic analysis of three options * HOLD POINT	3 months	\$150,000
5.02	Memo and Workshop for Options	Memo to outline options and preferred, workshop to present	0.5 months	\$20,000
5.03	Preliminary Site investigations	Basic topographical, geological, social and environmental studies	3 months	\$150,000
5.04	Site investigations (preferred option)	Detailed Topographic Survey and Mapping and initial Geological, Geotech & Geophysical Investigations (SMEC)	3 months	\$300,000

No.	Sub-Tasks	Details	Duration	Cost Estimate (ex. GST)
5.05	Preliminary Engineering Design of Preferred Option	Preliminary Civil (dam, waterway, access routes etc), E&M design and plant sizing, energy and cost estimation, financial evaluation and project execution strategy	4 months	\$300,000
5.06	Site investigations (Geotech Drilling)	Drilling and Borehole Testing, Laboratory Testing and Report (by third party)	5 months	\$500,000
5.07	Reporting	Report of findings	1 month	\$80,000
Pumped Hydro Investigation Total				\$1,500,000
6	Cost Estimation and Economic Assessment			
6.01	Bill of quantities		3 months	\$300,000
6.02	Estimation of Capital Costs	Including civil, structural, mechanical and electrical capital costs	3 months	\$250,000
6.03	Estimation of Operational Costs	Including expenses and revenue	2 months	\$300,000
6.04	Economic Assessment		4 months	\$400,000
Cost Estimation and Economic Assessment Total				\$1,250,000
7	Community Engagement			
7.01	Community Engagement	Including general community and user engagement	4 months	\$100,000
7.02	Firm up Early Irrigator Commitments	Discussions with major corporations and economic impact assistance	6 months	\$300,000
7.03	Assessment of Staging Options	Confirm which sections are buildt in which sequence	2 months	\$200,000
7.04	Further Assessment of Financing Arrangements	Creative financing optioneering - offshore, community groundswell, regional banking	2 months	\$50,000
Community Engagement Total				\$650,000
8	Business Case Report			
8.01	Prepare Draft Report		12 months	\$400,000
8.02	Presentation and Discussion on Draft Report		3 months	\$50,000
8.03	Finalise Report		3 months	\$50,000
Business Case Report Total				\$500,000
9	Project Management			
9.01	Preparation, initiation, contracting, early works, PMP and project planning.		3 months	\$300,000

No.	Sub-Tasks	Details	Duration	Cost Estimate (ex. GST)
9.02	Ongoing Project Oversight delivery & fiscal management		21 months	\$1,000,000
9.03	Stakeholder management, meetings, delegations and inquiries		21 months	\$500,000
9.04	Project Leadership Group		24 months	\$400,000
9.05	Deliver Reporting to Stakeholders		2 months	\$200,000
Project Management Total				\$2,400,000
Sub-Total				\$21,818,182
Contingency (10%)				\$2,181,818
TOTAL COST ESTIMATE				\$24,000,000