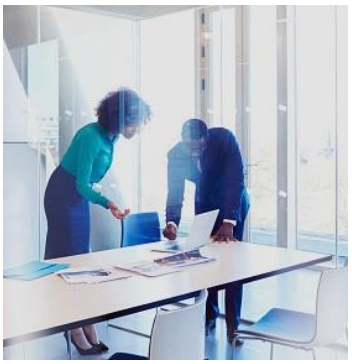
GHD Advisory



# QNI - Independent Verification and Assessment

TransGrid

17 January 2020

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# 1. Executive summary

TransGrid and Powerlink have progressively explored options for expanding transfer capacity between New South Wales (NSW) and Queensland.

As part of the Regulatory Investment Test for Transmission (RIT-T) process, TransGrid and Powerlink have defined the investment need and options as evidenced by the following documents:

- The Project Specification Consultation Report (PSCR) produced in November 2018
- The Project Assessment Draft Report (PADR) on the 30th of September 2019
- Project Assessment Conclusion Report (PACR) submitted to the Australian Energy Regulator (AER) on the 20th of December 2019.

TransGrid and Powerlink have now developed a Contingent Project Application (CPA) that sets out in more detail the preferred option to uprate the Liddell to Tamworth lines, install new dynamic reactive support at Tamworth and Dumaresq and shunt capacitor banks.

GHD has been engaged by TransGrid to perform this independent verification and assessment of its Queensland – NSW Interconnector (QNI) CPA. The scope of GHD's independent verification and assessment is detailed in section 2, and in summary, includes an assessment of scope alignment with the investment need and the preferred option, the reasonableness of capital (capex) forecasts and the effectiveness of the tender process.

Our scope does not include an assessment of risk as no risk allowance has been specifically included in the capex forecast.

TransGrid considered a number of options in the PACR to identify the preferred option. As detailed in the CPA, the preferred option is expected to:

- Deliver approximately $170 million in net benefits over the assessment period, which includes significant wholesale market cost savings that will put downward pressure on electricity prices with flow-on benefits to customers
- Reduce the need for new generation and large-scale storage in NSW to meet demand following Liddell Power Station's forecast retirement over 2022 and 2023
- Lower the aggregate generator fuel costs required to meet demand in the National Electricity Market (NEM) going forward
- Avoid capital costs associated with enabling greater integration of renewables in the NEM
- Generate sufficient benefits to recover the project capital costs seven years after the option is commissioned.

The analysis of investment scope options has been detailed in section 3.2 with the preferred option reported by TransGrid to cost $222.8 million ($M Real 2017-18).

The preferred option will uprate the Liddell to Tamworth 83, 84 and 88 lines based on conventional remediation options and associated tower strengthening due to the line uprating works. It also includes installing new dynamic reactive support at Tamworth and Dumaresq and shunt capacitor banks, substation switchbay uprating at Liddell, Muswellbrook and Tamworth Substations required to accommodate the increased transmission line ratings, with associated communications work at Liddell, Muswellbrook, Tamworth, Armidale and Dumaresq due to removal of line traps associated with this work.

Throughout the process capital forecasts have been progressively developed. Initial forecasts where developed internally using historical costs from TransGrid's Success cost estimating database. These estimates where used for the capex forecast in the PADR.

Subsequent to the PACR, the CPA procurement process has increased the capex estimates from the PADR estimated costs of $175 million to $222.8 million, which represents an increase of 27%. Whilst this reflects market results, the increase includes the following material changes since the PACR:

- Additional $31 million in costs associated with substation augmentation and switchyard extension works
- Additional $14 million in Project Overhead costs
- Additional $6 million in the uprating and deviation works for the transmission lines
- Saving of $4 million in the costs for the SVCs at Dumaresq and Tamworth substations

**Project scope review**

GHD identified the applicable investment scope commensurate with the PADR and subsequently the PACR (submitted 20 December 2019) by reviewing TransGrid documents relating to each stage of the project development. While refinements have been made to the detail within the project investment scope the CPA remains consistent with the investment scope as defined in the PADR and PACR.

Through a review of the tender documents and the QNI Capex forecast inputs, GHD was able to validate that the scope and quantities priced by tenderers is reasonably consistent with the scope requirements aligning with the final CPA capex forecast.

The specifications for the major plant, the balance of plant, and the substation and transmission lines work is considered reasonably accurate, along with the procurement process which included early engagement with the shortlisted contractors involving site visits and workshops to collectively refine the specification for the plant and work scope requirements.

**Capex forecast review**

To support a review of the CPA capex forecast, GHD developed a comparative estimate which is detailed in section 5.5. The comparative estimates developed by GHD indicate a reasonable estimate of costs would be approximately $194 million and this indicates the CPA capex forecast is within GHD's margin for detailed assessment (+/- 20%) at the highest level. GHD's comparative estimate is based on recent project costs and publically available data.

GHD has conducted our review using the following steps and reasons for the approach:

1. Our initial review considered the scope of works as defined with the TransGrid Success version 5 estimate, and our comparative estimates were based on the appropriate building blocks for supply and construction of the specified transmission line and substation assets (refer Appendix A).
2. From tender prices received from the market, market based costs were determined by TransGrid for each of the activities within each work package, and at the aggregate work package level to determine the final CPA estimated capex. This is the price deemed to represent the market value for the works.

   The following assessments were conducted:

a. GHD confirmed the tender specification scope for any adjustments necessary to quantities and the scope defined in the comparative estimating model.

b. GHD then assessed the market based costs for each work package at the aggregate or bottom-line level, and where appropriate, highlighted any factors that are contributing to any variance outside of our nominal ±20% range.

3. The majority of the plant and contract services components were market tested and firm prices obtained. There are some components of the CPA capex build up that were not market tested and GHD has separately assessed these estimates:

    a. Areas of services to be contracted where market prices have not been obtained at this stage (e.g. the Tamworth substation capacitor banks).

    b. Project Overheads (section 5.6.2).

We have concluded from our comparative estimates that the market tested costs inputs within the CPA estimated costs for "Subtotal - Contracted Services & Plant" were:

- 15.9% higher than the GHD's comparative estimate. This is within GHD's estimate range of ±20% at this overall level within the estimates.
- Substation and capacitor banks were in total 35.1% higher than GHD's comparative estimates and hence we have assessed these costs further in section 5.5.5.

The subtotal for "Project Overheads" indicates an increase in internal owner costs and was 37.3% higher than the GHD's comparative estimate and outside the ±20% of the GHD estimate range requiring further detailed assessment.

As detailed in section 5.7, TransGrid's forecast project overheads appear at the higher end of our expectations at 12.9%, when compared to comparative studies. If the market tested direct costs are accepted, and an average owner costs (excluding design costs) of 11% is applied, the CPA capex forecast would be around $215.4 million. However, the proposed forecast of $222.8 million remains within GHD's range of acceptable variation.

**Project schedule phasing**

The project schedule key milestone dates are aligned to the procurement strategy dates as well as the key dates listed in the Request for Tender (RFT)s for the main project packages. The total capital spend profile spreadsheet aligns to the total capital project costs that TransGrid has supplied to GHD.

**Procurement process review**

TransGrid has adopted industry appropriate procurement strategies for the main project components; SVCs, capacitor banks, substations works, transmission line works and High Voltage (HV) switchgear. GHD is able to verify that the tender documents for these work packages are consistent with the scope of work and investment need.

The substation and transmission line work packages had compressed timeframes for tendering and a compressed project delivery schedule to meet a September 2021 in service date, hence the tenderers would have likely included a higher price margin for risks as a result.

## Summary

Table 1 shows a summary of the key findings from the GHD review.

***Table 1 Summary of GHD review***

| Verification | |
|---|---|
| Scope | The CPA QNI scope has remained consistent, except for refinement in detail, since the PADR. GHD is able to verify that the refinements in the scope detail have resulted in a scope of work commensurate with the CPA and that the scope is reasonable and realistic to meet the investment need. |
| Major Plant | GHD can verify that TransGrid has undertaken an early engagement procurement process with vendors to achieve a market tested price and optimum technology solutions. |
| Substation Work Packages | GHD identified an increase in costs in the CPA Forecast for substation augmentation and switchyard extension works compared with the GHD comparative estimate. GHD has verified that these increased costs relate to additional civil works associated with the switchyard extensions, excavation in hard rock and excavation and disposal of contaminated soils.<br>GHD can verify that TransGrid has undertaken a procurement process working with substation panel members to identify detailed scope requirements for the works and to achieve a market tested competitive price outcome. |
| Transmission Line Work Packages | GHD can verify that TransGrid has undertaken a procurement process working with transmission panel members to identify detailed scope requirements for the works and to achieve a market tested competitive price outcome. |
| Project Overheads | GHD is of the view that the project overheads in the CPA estimate representing 12.9% of the total project costs are within an acceptable range of project margins. The level of overheads in the GHD comparative estimate is 11%.<br>We note that the increased allocation is due to the specific nature and risk profile for the project. GHD has verified that only TransGrid staff have the authority (under the Power System Safety Rules) to undertake works within energised HV substations so as to make safe areas of work for contractors. Also, only TransGrid staff are permitted to apply earths to transmission lines to allow for safe working for contractors. |

| Verification | |
|---|---|
| CPA Capex forecast | The variance between the CPA estimate and the GHD comparative estimate is overall 17.3% at the bottom line, which is within our nominal ±20% range. GHD can, therefore, validate that this is a reasonable forecast of costs. GHD considers that the difference is due to our reliance on adjusted historical project costs rather than market-tested tender costs that support the CPA. |
| Project Schedule | The project schedule key milestone dates are aligned to the procurement strategy dates as well as the key dates listed in the RFTs for the main project packages. |
| Procurement process | TransGrid has adopted industry appropriate procurement strategies for the main project components; SVCs, capacitor banks, substations works, transmission line works and HV switchgear.<br>Tenderers may have likely included a higher price margin for risks as a result of tight timeframes for tendering and work delivery schedules necessary to meet the need for a September 2021 in service date. |

**Conclusion**

GHD considers the scope refinements and cost impacts identified by TransGrid are reasonable for this type of brownfield project given the time constraints for tendering, to achieve a more refined scope, and considering the overall compressed delivery timeframe for this project. GHD considers these factors would have resulted in associated risks being priced into tender responses.

From our assessment, we note that generally the TransGrid CPA forecasts are higher than the GHD comparative estimates on a work package basis, and the total CPA forecast is 17.3% higher at the bottom line (which is within the GHD range of ±20% variance for reasonableness). The main contributory factors to this result are that:

- TransGrid estimates are likely more accurate, as GHD's comparative estimate is a Class 4 estimate with an accuracy of ±30% and based on conceptual study information whilst the TransGrid CPA forecast is based on tender outcomes, representing firm offers from tenderers.
- TransGrid has accepted lump-sum arrangements for separate work packages, and we consider that the tenders have been based costs on the most accurate information available which may also include allowances for contingency risks.
- By contrast, the GHD comparative estimates have relied upon costs for similar historic projects that may not have included provision for accelerated construction timelines or any cost pressures due to market conditions or delivery constraints.

# 2. GHD scope

TransGrid has engaged GHD to perform and independent verification and assessment of specific elements to support their QNI CPA submission.

GHD's scope included the following elements.

**1. QNI scope**

An assessment of project scope, having regard to key project elements such as upgrades of transmission lines, new static-var-compensators (SVCs) and shunt connected capacitor banks and installation of additional switchbays and associated equipment at substations to consider reasonableness and appropriateness given the project objectives.

**2. Capex forecast**

An assessment of the reasonableness of the capex forecast, taking into account good commercial and engineering practice and includes an assessment of the capex forecast costs including contracted services, plant and project overheads. The scope excludes any assessment of risk identification, quantification and risk management strategy on the basis that no allowance for risk is included in the capex forecast.

**3. Project schedule phasing**

An assessment of the capex forecast expenditure profile over the financial periods of the project.

**4. Procurement**

An assessment of the reasonableness of the procurement process to achieve the required outcomes for QNI.

**Limitations**

This report has been prepared by GHD for TransGrid and may only be used and relied on by TransGrid for the purpose agreed between GHD and the TransGrid as set out above.

GHD otherwise disclaims responsibility to any person other than TransGrid arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described thought out this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by TransGrid and others who provided information to GHD, which GHD has not independently verified or checked beyond the agreed scope of

work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

GHD has prepared comparative estimates using information reasonably available to the GHD employee(s) who prepared this Report, and based on assumptions and judgments made by GHD.

The comparative estimates has been prepared for the purpose of supporting TransGrid in their CPA submission and must not be used for any other purpose.

The comparative estimates are a preliminary estimate only in 2019 real Australian dollars. Actual prices, costs and other variables may be different to those used to prepare the comparative estimates and may change. Unless as otherwise specified in this Report, no detailed quotation has been obtained for matters identified in this Report. GHD does not represent, warrant or guarantee that the works can or will be undertaken at a cost which is the same or less than the comparative estimates.

Where estimates of potential costs are provided with an indicated level of confidence, notwithstanding the conservatism of the level of confidence selected as the planning level, there remains a chance that the cost will be greater than the planning estimate, and any funding would not be adequate. The confidence level considered to be most appropriate for expenditure modelling purposes will vary depending on the conservatism of the user and the nature of the project. The user should therefore select appropriate confidence levels to suit their particular risk profile.

# 3. Background

## 3.1 Project investment need

### 3.1.1 Project investment need development

TransGrid and Powerlink have progressively defined and assessed the project investment need and scope as evidenced through the following documents:

- PSCR produced in November 2018
- PADR on the 30th of September 2019
- PACR submitted to the AER on the 20th of December 2019.

### 3.1.2 Market benefits

TransGrid's and Powerlink's preliminary market modelling studies indicated that there are market benefits associated with relieving constraints on the QNI interconnector following the effect of recent changes in generation in the NEM. TransGrid and Powerlink have applied the RIT-T to this investment need based on net market benefits with the final document the PACR having been submitted to the AER on the 20th of December 2019.

From the analysis that has been carried out to date, TransGrid and Powerlink have identified a range of classes of market benefits most likely to change materially as a result of increasing the capacity of QNI. These benefits include:

- Changes in generator fuel consumption arising through different patterns of generation dispatch.

  Increased power flow capacity between Queensland and NSW is expected to improve the sharing of generation between Queensland and the rest of the NEM.

  Sharing of generation is expected to facilitate substitution of high fuel cost plant with low-fuel cost plant, which would reduce the overall cost of dispatch by reducing fuel costs and variable operation and maintenance costs.
- Reduces the overall need for new generation investment in the NEM.

  Increased power flow capacity between NSW and Queensland is expected to affect the pattern of future generation development in the NEM.

  Increased interconnector capability is expected to defer the need for investment in new generating plants in Queensland to meet the peak Queensland demand and also to defer the need for new generating plant in NSW to meet peak demand.

  Given the non-coincidence of peak demand in Queensland and NSW, an expansion of the interconnector capacity is therefore expected to improve the utilisation of existing plant across the NEM to meet peak demand requirements. A reduced need for new investment in generating plant, or a deferral of generation investment, would represent a market benefit. The reduced fixed operational and maintenance costs as a result of less generation installed will increase the market benefit.
- Reduces voluntary / involuntary load curtailment.

  Increased power flow capacity would facilitate the substitution of high-fuel cost plant with low-fuel cost plant, which would lead to a reduction in the spot price of electricity and consequently a reduction in

voluntary load curtailment. Greater interconnection would enable electricity to be transported from a location where it is plentiful to a location where it is scarce, which would lead to a reduction in involuntary load curtailment as well.

- Transition to lower carbon emission.

  Greater interconnection would enable renewable energy resources in Queensland, NSW and/or Victoria to be unlocked, contributing further to the overall market transition. Opening up additional geographical areas of the NEM for renewable investment.

### 3.1.3 Project specification consultation report

The PSCR produced in November 2018 progressed the ISP to expand the NSW-Queensland transfer capacity. It summarises the investment need as follows.

"The inaugural Integrated System Plan, released by the Australian Energy Market Operator (AEMO) in July 2018, recommended two key transmission investments in relation to expanding transfer capacity between New South Wales and Queensland necessary to support the long-term interests of consumers for safe, secure, reliable electricity, at the least cost, across a range of plausible futures."

AEMO differentiated these two investments as being needed over the immediate-term (by around 2020) and over the medium-term (by the mid-2020s), respectively.

***Figure 1 The AEMO ISP recommended two expansions to NSW-QLD transfer capacity***


Source: AEMO 2018 Integrated System Plan

The ISP concluded that by 2020, or as soon as they can be built, market benefits associated with the Group 1 upgrade can be realised due to a reduced need for new gas fired generation in NSW to meet demand once Liddell retires in 2022, as well as benefits from allowing more efficient generation sharing between NSW and Queensland.

The ISP forecasts the Group 2 upgrade will provide market benefits from fuel cost savings and capital deferral over the longer-term by allowing greater utilisation of renewable energy and coal-fired generation in Queensland, as further generation is developed to achieve the Queensland Renewable Energy Target (QRET). However, the ISP notes the preferred option for this Group 2 upgrade is sensitive to a range of inputs, including NSW demand forecasts.

TransGrid and Powerlink initiated the RIT-T to progress the ISP's recommendations to increase the transfer capacity between NSW and Queensland with two milestone reports being the PADR and then the final PACR.

The identified need was to increase overall net market benefits in the NEM through relieving existing and forecast congestion on the transmission network between NSW and Queensland.

The key sources of market benefit were expected to be:

- A reduced need for new gas fired generation in NSW once the Liddell Power Station retires
- Allowing more efficient generation sharing between NSW and Queensland, including greater use of existing, relatively modern, coal-fired generation in Queensland and renewable energy development to meet the QRET
- Assisting the nation to meet carbon emission and renewable energy targets at lowest long-run cost.

### 3.1.4 Project assessment draft report

TransGrid produced a PADR on the 30th of September 2019. The PADR focusses on options for increasing transfer capacity between NSW and Queensland in the near-term, consistent with the assessment of the 'Group 1' QNI expansion in the 2018 ISP, as well as guidance from the AER provided since the PSCR. This revised focus was to ensure that the consideration of medium-term options (i.e., 'Group 2' QNI expansion in the 2018 ISP) does not delay the consideration of near-term options required to ensure the greatest net benefits to NEM participants, particularly in light of the forecast closure of Liddell Power Station over 2022 and 2023.

The investment need for a preferred option stated in the PADR was to deliver net market benefits and support energy market transition through:

- Allowing for more efficient sharing of generation across the NEM, thereby avoiding the use of higher cost generators and deferring, or avoiding, the construction of new, more expensive generation and/or storage capacity
- Continuing to provide reliable supply at the lowest cost by deferring the need to build new generation and storage capacity in NSW ahead of the forecast retirement of Liddell Power Station
- Facilitating the transition to a lower carbon emissions future and the adoption of new technologies through improving access to high quality renewable resources across regions, which further avoids the use of high-cost generators and defers, or avoids, the need to build new generation.

GHD has used the above definition as the starting point investment need for QNI. During the assessment of the scope and capital cost forecasts, this definition has been considered to assess whether it has materially changed or whether it has been enhanced in such a way that the scope and cost forecasts have changed as a consequence.

### 3.1.5 Project assessment conclusions report

TransGrid produced a PACR on the 20th of December 2019. The PACR is the final document to be published and submitted to the AER as part of the RIT-T process.

The PACR continues to find that the preferred option is expected to deliver significant net benefits associated with expanding transfer capacity between NSW and Queensland in the near-term. This aligns with both the 2018 ISP recommendations and the draft 2020 ISP recommendations.

The PACR identified the same investment need as outlined in the PADR. The PACR assessed that uprating the Liddell to Tamworth lines and installing new dynamic reactive support at Tamworth and Dumaresq and

shunt capacitor banks deliver the greatest expected net benefits of all options considered and are the 'preferred option' as part of the RIT-T (Option 1A).

## 3.2 The PACR Investment scope

The PACR assessed four credible options to increase transfer capacity. These included four options identified in the PSCR and assessed in the PADR. 'Virtual transmission line' solutions identified as part of the consultation process have not been assessed as part of this PACR due to their untested nature at this scale in Australia.

Table 2 below updates and summarises the four credible options assessed. All credible options are expected to be delivered and inter-network testing completed by June 2022.

***Table 2 Summary of the credible options considered in the PACR[1]***

| Option description | Indicative total transfer capacity (MW) | | Estimated capex ($ million) |
|---|---|---|---|
| | Northwards | Southwards | |
| Incremental upgrades to the existing network to increase transfer capacity | | | |
| Option 1A – Uprate Liddell to Tamworth lines and install new dynamic reactive support at Tamworth and Dumaresq and shunt capacitor banks | 690 | 1,120 | 230 |
| Option 1B – Uprate Liddell to Tamworth lines only | 570 | 1,070 | 43 |
| Option 1C – Install new dynamic reactive support at Tamworth and Dumaresq and shunt capacitor banks | 480 | 1,120 | 187 |
| Option 1D – Sapphire substation cut into line 8C and a mid-point switching station between Dumaresq and Bulli Creek | 480 | 1,110 | 59 |

The preferred option identified in the PACR is Option 1A, with an expected capital cost of $230 million is expected to deliver the greatest net benefits of all options, across all four scenarios considered. These costs reflect project delivery costs in December 2019 dollars. Estimated net benefits for this option is approximately $170 which is similar to the net benefit of Option 1B on a weighted basis however it is expected to deliver greater benefits under the most likely 'neutral' scenario assessed. GHD's report does not consider the benefits associated with Option 1A (or any of the other options) and also does not evaluate the decision making process to select the preferred option except to the extent of verifying and efficient scope and capital forecasts have been developed for the preferred option.

[1] Expanding NSW-Qld Transmission transfer capacity Project Assessment Conclusion Report – Table E.1 page 5

**Description of the investment scope**

Option 1A involves incremental investments to the existing network to increase transfer capacity in the near term. This option is the same as that recommended in the 2018 ISP for Group 1 and remains fundamentally the same as specified in the PSCR. The two key components of Option 1A are:

- Uprating the Liddell to Tamworth lines
- Installing new dynamic reactive support at Tamworth and Dumaresq and shunt capacitor banks.

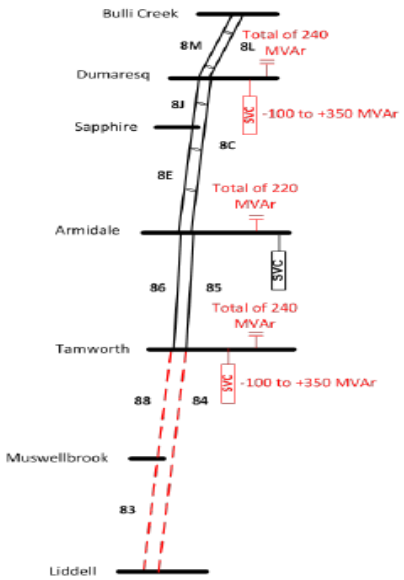
The first component targets northerly QNI thermal limitations by uprating Lines 83, 84 and 88, which are the Liddell to Tamworth via Muswellbrook 330 kV circuits shown earlier in Figure 25. These lines would be uprated from the existing design operating temperature of 85°C to 120°C.

The second component targets both northerly and southerly QNI stability limits by installing dynamic reactive support at both the Tamworth and Dumaresq 330 kV substations, and installing additional 330 kV shunt connected capacitor banks at Tamworth, Armidale and Dumaresq 330 kV substations.

In the PSCR, three options were highlighted for the provision of a dynamic source of reactive support under Option 1A, i.e., Static VAr Compensator (SVC), Static Synchronous Compensator (STATCOM) and a synchronous condenser. The use of a synchronous condenser has been eliminated due to the materially higher cost associated with it (and absence of commensurate benefits).

The estimated capital cost of Option 1A is $230 million (reflecting further option scoping and refinement since the PSCR and the PADR). The estimated costs for this option in the earlier PADR was $175 million.

***Figure 2 QNI 330 kV Upgrade***




**Description of the works**

The Options Feasibility Study (OFS) described the preferred option in upgrading QNI (Queensland to NSW Interconnector) as follows:

**Option 1 – Conventional remediation options**

Uprating 83, 84 and 88 Lines to 120°C design temperature based on conventional remediation options and associated tower strengthening due to the line uprating works.

**Substation switchbay uprating**

Substation switchbay uprating at Liddell, Muswellbrook and Tamworth Substations required to accommodate the increased transmission line ratings, with associated communications work at Liddell, Muswellbrook, Tamworth, Armidale and Dumaresq due to removal of line traps associated with this work. At each site the scope of work requires:

- Liddell Substation:
  - Removal of Line 83 wave trap.
  - Replacement of Line 83 line droppers and Disconnectors (1).
  - Removal of Line 84 wave trap.
  - Replacement of Line 84 line droppers and Bay conductor (Bay bK).
  - Installation of two RAD2104 mux in the existing rack

- Installation of a new 24p NMS switch

- Muswellbrook Substation:
  - Removal of Line 83 wave trap.
  - Replacement of Line 83 line droppers.
  - Removal of Line 84 wave trap.
  - Replacement of Line 84 line droppers.
  - Installation of a new DM1200 (VF) terminal in the existing rack at B5R8.
  - Installation of two RAD2104 mux in the existing rack.
  - Re-terminate the 19c cable to the new DM1200 (VF).
  - Power the new VF from the spare CB in the MER
  - Installation of new 24p NMS switch
- Tamworth Substation:
  - Removal of Line 84 wave traps
  - Replacement of Line 84 line droppers, disconnectors (2), bay conductor (Bay 1E) and overhead strung bus and droppers.
  - Installation of a new DM1200 (VF) terminal in the existing rack at B3R9
  - Re-terminate the 19c cable to the new DM1200 (VF)
  - Installation of two RAD2104 mux in the existing rack
  - Power the new VF from the spare CB in the MER
  - Installation of a new 24p NMS switch
- Armidale Substation:
  - Installation of two RAD2104 mux in the existing rack
  - Installation of a new 24p NMS switch
- Dumaresq Substation:
  - Installation of two RAD2104 mux in the existing rack
  - Installation of a new 24p NMS switch

**Major substation works – Tamworth:**

Installation of 330kV capacitor banks and SVC at Tamworth Substation (Option 2 layout), including:

- 2 x 60MVAr 330kV capacitor banks and associated switchbays
- 1 x 120MVAr 330kV capacitor banks and associated switchbay
- 1 x -100 MVAr to 350 MVAr SVC and associated switchbay
- 1 x 330kV bus section circuit breaker
- 88 Line relocation, 968 Line and 97C Line deviations to accommodate the expanded site layout

**Major substation works – Armidale:**

Installation of 330kV capacitor banks at Armidale Substation (Option 2 layout), including:

- 2 x 50MVAr 330kV capacitor banks and associated switchbays
- 1 x 120MVAr 330kV capacitor banks and associated switchbay
- 1 x 120MVAr 330kV No.5 Capacitor Bank and associated switchbay

**Major substation works – Dumaresq:**

Installation of 330kV capacitor banks and SVC at Dumaresq Substation (Option 2 layout), including:

- 2 x 120MVAr 330kV capacitor banks and associated switchbays

- 1 x -100 MVAr to 350 MVAr SVC and associated switchbay
- 1 x 330kV bay aD
- 1 x 330kV bay aA
- 1 x 330kV bay bA
- 1 x 330kV 'B' Bus PVT bay aZZ

## 3.3 The CPA capex forecast

TransGrid's CPA relates to the request to the AER to amend the revenue requirements and maximum allowed revenue in TransGrid's 2018-19 to 2022-23 Revenue Determination for the QNI Project.

The capex and opex forecasts in the CPA is required to reflect the prudent and efficient costs of delivering the QNI Project. Table 3 summarises the submitted CPA capex forecast for the QNI project ($M, Real 2017-18).

***Table 3 TransGrid's high level cost breakdown of the CPA capex forecast***

| Capex category | Procurement type | Total forecast capex ($M, Real 2017-18) |
|---|---|---|
| SVCs | Directly procure (existing panel arrangement) | 55.5 |
| Capacitor banks | Directly procure and free issue to successful Substation tenderer(s) | 14.6 |
| Substation works | Design and construct | 80.6 |
| Transmission lines and uprating works | Design and construct | 36.4 |
| HV switchgear, transmission line insulators and secondary systems | Directly procure (existing panel arrangement) | 6.2 |
| Transmission line insulators | Directly procure | 0.2 |
| Internal labour costs (project overheads) | Bottom-up-build | 28.7 |
| Connection costs | Distribution network service provider (DNSP) charges | 0.1 |
| Real input costs | Internally bottom-up build using AER's forecast real labour cost escalators. | 0.6 |
| Rounding | - | (0.1) |
| **Total** | | **222.8** |

# 4. QNI scope

## 4.1 Scope assessment methodology

GHD has used the following methodology and steps to review the project scope:

**1. The project investment scope**

Verify that TransGrid has identified the investment need and corresponding project investment scope for the QNI project to which the verification is considered as to whether TransGrid's CPA capex forecast is reasonable and realistic.

**2. Asset performance requirements**

The specified performance parameters of the upgraded QNI asset have been assessed to verify that the parameters have been defined to align with the investment scope and that the specified performance represents an efficient approach to meeting the objectives of the project.

**3. Project scope definition**

The final scope definition is assessed to verify that it adequately defines the scope in line with the optimally planned solution and that it defines the elements and direction to build the work breakdown elements (WBEs).

**4. Assessment of scope refinement and impacts**

This assessment is to verify that TransGrid has considered reasonable refinements and scope impacts and that changes have been systematically assessed to determine the most efficient solution.

**5. Work breakdown elements**

The Work Breakdown Elements (WBE) have been reviewed to verify whether:

- The WBE's (to a reasonable extent) are aligned with the scope and included accurately in tender documents
- The WBEs (to a reasonable extent) align with the final CPA estimate.

This will include whether the WBEs are complete (or with gaps) and without duplicates.

**6. Scope definition for procurement of work packages**

The specified work packages for procurement have been assessed to verify that the specifications are efficient to provide the asset performance requirements. This will include whether the WBE building blocks in the estimates align with the quantities specified in the tender quantity schedules and whether they are complete (or with gaps) and without duplicates.

**7. Project scope definition for procurement of work packages**

The specified work packages for procurement have been assessed to verify alignment to the designed scope and estimated building blocks.

**8. Summary of the scope review**

The summary of the scope assessment provides a combined table of the findings with respect to the above step by step process and the verification outcomes with respect to whether:

- The project scope reflects the approach a prudent Transmission Network Service Provider (TNSP) would adopt
- Procurement work packages have been developed to align with the work scope requirements and clearly specified in the RFT
- The schedule quantities developed for the scope align in the RFT
- Scope requirements and specifications provided to tenderers are appropriate and cover the requirements to enable competitive pricing.

## 4.2 The project investment scope

TransGrid has not prepared a separate overall detailed scope and specification document for the QNI project. GHD used the definition of the QNI project investment scope in the OFS as a starting point prior to confirming the scope and specifications in tender documents which are commensurate with the CPA scope of works.

For the review of whether the project investment scope meets the investment need GHD started with a review of the stated investment need in various documents.

The OFS outlined TransGrid's initial project scope from which a forecast expenditure was developed for inclusion in the RIT–T economic analysis. It states that for this forecast contained several simplifying assumptions:

- TransGrid applied a top down approach to developing the initial project scope. It entailed starting from the high-level requirements, defining key design parameters, and developing a forecast of equipment, materials and labour resources required
- The uprating of transmission lines 81,83 and 84 from 85 to 120 degrees thermal rating
- The specification of the 330 kV substation upgrade works (at Dumaresq, Armidale and Tamworth) is based on standard bay configurations
- The specification of capacitor banks and SVCs (at Dumaresq, Armidale and Tamworth) was the manufacturer's early engagement procurement advice.

In the PADR and PACR for the QNI upgrade interconnector investment need is stated as follows.

"To deliver net market benefits and support energy market transition through:

- Allowing for more efficient sharing of generation across the NEM, thereby avoiding the use of higher cost generators and deferring, or avoiding, the construction of new, more expensive generation and/or storage capacity
- Continuing to provide reliable supply at the lowest cost by deferring the need to build new
- Generation and storage capacity in NSW ahead of the forecast retirement of Liddell Power Station
- Facilitating the transition to a lower carbon emissions future and the adoption of new technologies through improving access to high quality renewable resources across regions, which further avoids the use of high-cost generators and defers, or avoids, the need to build new generation."

The investment scope identified in the PADR and PACR was compared with the investment scope in the OFS. The PADR and PACR describe the investment scope as follows:

The selected Option 1A involves incremental investments to the existing network to increase transfer capacity in the near term. The two key components of Option 1A are:

- Uprating the Liddell to Tamworth lines
- Installing new dynamic reactive support at Tamworth and Dumaresq and shunt capacitor banks.

The first component targets northerly QNI thermal limitations by uprating Lines 83, 84 and 88, which are the Liddell to Tamworth via Muswellbrook 330 kV circuits. These lines would be uprated from the existing design operating temperature of 85°C to 120°C.

The second component targets both northerly and southerly QNI stability limits by installing dynamic reactive support at both the Tamworth and Dumaresq 330 kV substations, and installing additional 330 kV shunt connected capacitor banks at Tamworth, Armidale and Dumaresq 330 kV substations.

The option description in the OFS is titled, "1529-2E Revision 3.0 Reinforcement of Northern Network: New SVCs at Tamworth and Dumaresq, new shunt capacitor banks and uprating of Line 83, 84 and 88. The scope of this option is summarised as follows:

- Installation of a -100 MVAr to 350 MVAr SVC at Tamworth 330 kV Substation
- Installation of a -100 MVAr to 350 MVAr SVC at Dumaresq 330 kV Switching Station
- Installation of 2 x 60 MVAr and 1 x 120 MVAr shunt connected Capacitor banks at Tamworth
- Installation of 2 x 50 MVAr and 1 x 120 MVAr shunt connected Capacitor banks at Armidale
- Installation of 2 x 120 MVAr shunt connected Capacitor banks at Dumaresq
- Uprating of Lines 83, 84 and 88 to a design temperature of 120°C.

This scope is consistent with the PADR and PACR scope which includes a diagram with the same capacity of shunt connected capacitor banks and SVC for each of the substations listed.

GHD has taken the selected option from the OFS to define the starting point for the scope definition which are described in the following sections. The aim of this scope definition is to assist GHD to verify the scope is efficient to meet the high level specified investment scope and that the capital estimates for the QNI capex forecasts are reasonable.

TransGrid's Basis of Estimate (BOE) document[2] has provided the basis for our scope review. This document also provides a summary of the key components of the project and assumptions that had been made with consideration to the costing accuracy required for the RIT-T economic analysis and the refinement of the scope to address those assumptions.

GHD has used the scope defined in the OFS as the starting point to consider the QNI investment scope for the CPA. The investment scope commensurate with the PACR and the CPA is then confirmed by reviewing tender specifications and scope documentation (refer to section 4.7 and section 4.8).

[2] BOE OFS-1529 Development of QNI Interconnector Basis of Estimate Rev A

## 4.3 Scope Definition - Substation Works

### 4.3.1 Muswellbrook 330 kV substation

At Muswellbrook substation the following bay equipment will need to be replaced to achieve the required rating.

***Table 4 Muswellbrook 330 kV substation bay equipment replacement schedule***

| Line | Plant | Quantity |
|---|---|---|
| 83 (Bay 1C) | Remove line traps | 1 |
| | Replace line droppers | 1 |
| 88 (Bay 1D) | Remove line traps | 1 |
| | Replace line droppers | 1 |

### 4.3.2 Tamworth 330 kV substation

At Tamworth substation the following bay equipment will need to be replaced to achieve the required rating.

***Table 5 Tamworth 330 kV substation bay replacement equipment schedule***

| Line | Plant | Quantity |
|---|---|---|
| 84 (Bay 1E) | Remove line traps | 1 |
| | Replace line droppers | 1 |
| | Remove disconnectors (1EA, 1EL) | 2 |
| | Replace bay conductor | 1 |
| | Replace overhead strung bus and droppers | 1 |

### 4.3.3 Liddell 330 kV substation

At Liddell substation the following bay equipment will need to be replaced to achieve the required rating.

***Table 6 Liddell 330 kV substation bay replacement schedule***

| Line | Plant | Quantity |
|---|---|---|
| 83 (Bay J/4) | Remove line traps | 1 |
| | Replace line droppers | 1 |
| | Replace disconnectors (aJL) | 1 |
| | Remove line traps | 1 |

| Line | Plant | Quantity |
|---|---|---|
| 84 (Bay K) | Replace line droppers | 1 |
| | Replace bay conductor | 1 |

It should be noted that the scope of work for the uprating of Lines 83, 84 and 88 includes the replacement of disconnectors at Liddell due to a requirement for 63kA rated equipment.

### 4.3.4 Armidale 330 kV substation

The scope of work at Armidale is for the installation of the following shunt connected capacitor banks:

- 2 x 50 MVAr Capacitor Banks
- 1 x 120 MVAr Capacitor Bank.

It is anticipated that the capacitor banks will be installed on the 330kV busbar.

Designs have previously been completed for the installation of two 50MVAr 330 kV capacitor banks at the southern end of the switchyard. It is anticipated that the third capacitor 120MVAr capacitor bank will be installed on a different section of the 330 kV busbar, on the northern end of the switchyard.

An additional new 120MVAr capacitor bank is shown on the Armidale Substation concept general arrangement. This additional new 120MVAr capacitor bank is for the Network Capability Incentive Parameter Action Plan (NCIPAP) project. The NCIPAP capacitor bank is separately funded and it is not included in the QNI project budget.

The works will involve:

- Bench extension with an estimated cut volume of 9,000m$^3$ and the fill volume of approximately 800m$^3$
- 240m of switchyard roadway
- Expand security fence for the new substation extension
- Extension of the 330 kV busbar
- Construction of three 330 kV switchbays for the capacitor banks
- Construction of three 330 kV capacitor banks and associated compounds
- Installation of control and protection schemes associated with the Capacitor banks and switchbays
- Re-align Line 8C conductors to avoid overhead crossing from the new 120MVAr capacitor bank.

### 4.3.5 Dumaresq switching station

The scope of work at Dumaresq switching station is for the installation of the following equipment:

- 1 x -100 MVAr to 350 MVAr Static VAr Compensator (SVC)
- 2 x 120 MVAr Capacitor Banks.

Designs have previously been completed for the installation of a new -100 to 350 MVAr 330kV SVC and two 120MVAr 330 kV capacitor banks. It is anticipated that the switching station busbar configuration will need to be modified to a double breaker arrangement (i.e. modification of bay aD connection for a double breaker

bus arrangement on line 8L), in order to utilise existing switchbay space for the installation of the new capacitor banks.

Dumaresq will require a bench extension for a new SVC, two capacitor bank, associated switchbays and a new substation runway road for delivery of the major SVC equipment. There will be three new 330kV switchbays required on the existing bench and a connection to the existing spill oil system.

It is anticipated that, based on the area used by the Armidale SVC, the SVC at Dumaresq will require 6000 sqm of bench space, of which 4000 sqm will be from a bench extension. Based on the original geotechnical report for the switchyard construction it is anticipated that the proposed bench extension will require significant excavation of low strength rock.

### 4.3.6 Tamworth 330 kV substation

At Tamworth 330 kV substation there is a requirement for the installation of:

- 1 x -100 MVAr to 350 MVAr SVC
- 1 x 120 MVAr Capacitor Bank
- 2 x 50 MVAr Capacitor Banks.

With operational requirements for the reactive plant to be installed on different sections of 330kV busbar, it is proposed that the SVC can be installed on the section of 330kV busbar currently occupied by Line 88. As such Line 88 will need to be relocated to a new section of busbar, which will be achieved via a bench and busbar extension to the south-east of the existing Tamworth substation.

## 4.4 Scope definition - transmission line works

### 4.4.1 Uprating of lines 83, 84 and 88

A package of works is required to increase the operating temperature from 85°C to 120°C on Line 83, line 84 and Line 88 by using a combination of options. These options being:

- Landscaping under the transmission line where clearances are minimal
- Increasing conductor heights by using an inverted ‘V’ insulator arrangement
- Increasing conductor heights by changing suspension insulators to ‘floating strains’
- New structure replacement
- New mid-span structure replacement.

As a result of the aforementioned up-rating works, strengthening works will be required for a selection of the existing steel lattice structures.

A summary of quantities for the transmission line uprating works are as per Table 7 below:

**Table 7 Transmission line uprating works**

| Total number of towers | Towers to be strengthened | Landscaping | Inverted vee (per insulator) | Floating strain (per insulator) | New structure QSF/S1 | New structure OTK/S2 |
|---|---|---|---|---|---|---|
| Transmission line TL 88 | | | | | | |
| 276 | 29 | 1 | 51 | 120 | 52 | 0 |

| Total number of towers | Towers to be strengthened | Landscaping | Inverted vee (per insulator) | Floating strain (per insulator) | New structure QSF/S1 | New structure OTK/S2 |
|---|---|---|---|---|---|---|
| Transmission line TL 84 | | | | | | |
| 313 | 5 | 1 | 31 | 54 | 6 | 1 |
| Transmission line TL 83 | | | | | | |
| 42 | 0 | 0 | 0 | 1 | 1 | 0 |

### 4.4.2 Inverted V-string insulator arrangement

It is proposed that where clearance violations do not exceed 0.5m that inverted V-string insulator arrangements can be installed to raise the conductor height.

### 4.4.3 D-string insulator arrangement

Standard designs indicate that insulators at suspension towers will be a minimum of 3m long. By removing most of the porcelain disk insulators and installing a D-string arrangement, the suspension insulator arrangement can be shortened by up to 1.9m at the suspension structure. Generally, D-strings are used for clearance violations between 0.5 m and 1.0 m.

### 4.4.4 Transmission tower modifications

Where a clearance violation is greater than 1.0m, more onerous remediation measures must be investigated. It is anticipated that the required conductor height will be achieved by replacing the existing suspension structure with a two pole concrete or steel H-frame structure.

Poles will be jointed structures to allow pole bases to be installed prior to the erection of the main structure and cutover of conductors. Pole structures will be erected as close as possible to the centreline of the existing transmission line route to minimise the impact to the transmission line design and construction.

### 4.4.5 Line rearrangements at Tamworth substation

In order to facilitate the installation of the SVC at Tamworth 330 kV substation, the existing TL 88 structure adjacent to the substation will need to be removed, a new structure to divert TL88 will need to be erected to in a suitable location to bring the TL88 into the new HV switchbay. Additional work is also required to re-align transmission lines 968 and 97C to accommodate for the additional bench for the new 60MVAr capacitor banks.

## 4.5 Asset performance requirements

This section considers whether TransGrid has defined the high level performance requirements for the project to inform further optimisation and detailed design of the scope and specification.

The key documents reviewed for this purpose were:

- OFS1529-2E Rev 3 Reinforcement of Northern Network
- Specification and Contract No.1606 Transmission Line 83, 84 and 88 - WNI Uprating Works
- QNI Upgrade - Transmission Lines: Project Specific Design Requirements Revision No. 2.0

- Quotation Specification No. Q51/18 - RFQ #2 Detuned Shunt Capacitor Installations and Harmonic Filter Systems
- Technical Specification for Static Var Compensators for the QNI Upgrade at Dumaresq 330kV Substation and Tamworth 330kV Substation
- Technical Specification for Armidale 330kV Capacitor Banks and Asset Replacements
- Technical Specification for Dumaresq 330kV Capacitor Banks and SVC Works
- Technical Specification for Tamworth 330kV Capacitor Banks and SVC Works

The OFS defines the performance requirement for QNI through the capacity rating of the transmission lines as follows:

- Increase the thermal rating of the Liddell to Tamworth 330 kV Transmission lines (83, 84 and 88) from 85 to 120 degrees. This increases the northern transfer thermal design limit from 310 MW to 690 MW (for daytime medium demand) for the selected option 1A as outlined in the PACR.
- The increased thermal transmission rating is to be achieved by increasing the minimum clearances to ground in accordance with AS700 through; increasing conductor heights by changing insulator arrangements, replacement of some structures and strengthening of other structures (to meet wind loads) and landscaping changes.
- The QNI Upgrade - Transmission Lines: Project Specific Design Requirements Revision No. 2.0 which was provided to the transmission lines tenders aligns with the above performance requirements outlined in the OFS.

The second component specified in the OFS targets both northerly and southerly QNI stability limits by installing dynamic reactive support at both the Tamworth and Dumaresq 330 kV Substations and installing additional 330 kV shunt connected capacitor banks at Tamworth, Armidale and Dumaresq 330 kV substations. The specific performance requirements are listed as:

- At Tamworth Substation:
  - -100 MVAr to 350 MVAr SVC at Tamworth 330 kV bus
  - 2 x 60 MVAr and 1 x 120 MVAr 130 Hz shunt connected capacitors at Tamworth 330 kV bus
- At Dumaresq Substation:
  - -100 MVAr to 350 MVAr SVC at Dumaresq 330 kV bus
  - 2 x 120 MVAr shunt connected Capacitor banks at Dumaresq 330 kV bus
- At Armidale Substation:
  - 2 x 50 MVAr and 1 x 120 MVAr shunt connected Capacitor banks at Armidale 330 kV bus

The Technical Specification for Static Var Compensators aligns with the reactive range power summarised in the OFS. The technical schedule and a technical specification for the capacitor banks align with the reactive power range in the OFS. These values are also consistent with the values stated in the PADR and PACR.

## 4.6 Assessment of scope refinement and impacts

In this section, GHD considers whether TransGrid has taken the high level performance requirements for the project to inform further optimisation and detailed design of the scope and specification.

The key documents reviewed for this purpose were:

- OFS OFS1529-2E Rev 3 Reinforcement of Northern Network
- QNI Upgrade - Transmission Lines: Project Specific Design Requirements Revision No. 2.0
- Quotation Specification No. Q51/18 - RFQ #2 Detuned Shunt Capacitor Installations and Harmonic Filter Systems
- Technical Specification for Static Var Compensators for the QNI Upgrade at Dumaresq 330kV Substation and Tamworth 330kV Substation
- Technical Specification for Armidale 330kV Capacitor Banks and Asset Replacements
- Technical Specification for Dumaresq 330kV Capacitor Banks and SVC Works
- Technical Specification for Tamworth 330kV Capacitor Banks and SVC Works
- Substation concept drawings - single line diagrams and general arrangements
- PSCR, PADR and PACR documents
- QNI Cost Increase (explained in the Capex Forecasting Methodology)

GHD has sighted the RFT documents for each of the major project packages. GHD have not sighted the tender responses that may detail scope refinements or proposed scope changes. However, to support this assessment TransGrid has provided information, as follows, explaining scope impacts which have had an impact on increasing costs.

- Substations
  - Due to a refined concept design layout, the amount of bulk civil works increased
  - No allowance for excavation in hard rock was allowed for in PADR base cost estimate
  - No allowance for excavation and disposal of contaminated soil was allowed for in PADR base cost estimate
  - The costs received from a competitive tendering process were higher than expected due to:
    - PADR base cost was based on ‘standard’ tendering timeframes and scope development.
    - Time constraints for tendering and more refined scope development.
    - The overall delivery timeframe for this project was compressed to achieve the September 2021 in service date.
    - There are significant resource capacity/capability constraints in the infrastructure delivery market.
- Transmission Lines
  - Due to further geotechnical investigations, the amount of structure foundation civil works increased
  - Due to further site road infrastructure investigations, the final design was for steel poles rather than concrete poles which resulted in an increase in foundation costs. However, if concrete poles were adopted, the site road infrastructure work would have been cost prohibitive.
  - No allowance for excavation in hard rock was allowed for in PADR base cost estimate
  - The costs received from a competitive tendering process were higher than expected due to:

- PADR base cost is based on ‘standard’ tendering timeframes and scope development.
- Time constraints for tendering and more refined scope development.
- The overall delivery timeframe for this project was compressed to achieve the September 2021 in service date.
- There are significant resource capacity/capability constraints in the infrastructure delivery market.

As a result of the absence of the above documentation/information, GHD is only able to assess optimisation of the selected option up to the publishing of the PACR and statements made in the Capex Forecasting Methodology[3] related to working with the shortlisted service providers to further optimise options for each of the different work categories.

The PACR states that TransGrid has progressed the detailed project works specification and procurement steps to deliver Option 1A’s scope and outcomes. GHD was able to note the following scope refinements and optimisation since the PADR:

- TransGrid adopted an early contractor engagement which offered the SVC suppliers the opportunity to support the development of detailed specifications, and, importantly, provided sufficient time for the SVC suppliers to recommend the most efficient and effective solution. Two examples of how this approach has refined the project are:
  - The decision to engage the substation contractor under the SVC foundations and civil works
  - The adoption of a hybrid SVC product (Statcom plus SVC) by the successful SVC tender as the most efficient solution.
- The engagement of a single substation contractor at Tamworth and Dumaresq substation to simplify the interface with the SVC supplier.
- Value engineering workshops were held with the preferred substation and transmission contractors to reduce costs by further refining the design.
- As part of the transmission scoping study, a reconductoring option had been assessed. This option was eliminated as an option as it was determined to be too costly compared to the presented remediation method.

GHD notes and considers that the scope refinements and cost impacts identified by TransGrid are reasonable for this type of brownfield project given the time constraints for tendering, to achieve a more refined scope and the overall compressed delivery timeframe for this project.

GHD considers that these above factors may have resulted in associated risks being priced into tender responses.

## 4.7 Scope definition for estimating building blocks

The WBEs were considered for the purpose of validating to a reasonable level that:

- The required scope and quantities have been included in the estimates
- The required scope and quantities have been included in the current tender packages

[3] Capex Forecasting Methodology for QNI Minor Upgrade Project

- That there are no material gaps, and that the WBEs are aligned with the scope statement.

The review considered the following documents:

- OFS OFS1529-2E Rev 3 Reinforcement of Northern Network
- QNI Upgrade - Transmission Lines: Project Specific Design Requirements Revision No. 2.0
- Quotation Specification No. Q51/18 - RFQ #2 Detuned Shunt Capacitor Installations and Harmonic Filter Systems
- Technical Specification for Static Var Compensators for the QNI Upgrade at Dumaresq 330kV Substation and Tamworth 330kV Substation
- Technical Specification for Armidale 330kV Capacitor Banks and Asset Replacements
- Technical Specification for Dumaresq 330kV Capacitor Banks and SVC Works
- Technical Specification for Tamworth 330kV Capacitor Banks and SVC Works
- Substation concept drawings - single line diagrams and general arrangements

GHD was supplied with one detailed estimate with building blocks for the QNI project - the estimate conducted as part of the PADR. A summary of the updated capital estimate for the PACR was supplied however this estimate only broke up the total into the major capital component. GHD reviewed the quantities listed in the OFS, where they were provided, and compared them to the quantities listed in the detailed estimate. This work breakdown for this basis of estimate for capital expenditure was structured with a breakdown to three levels below each of the following Level 1 elements:

- 330kV Transmission Line 83 works
- 330kV Transmission Line 84 works
- 330 kV Transmission Line 88 works
- 330 kV Transmission Line 88 Deviation works
- 132kV Transmission Line 96B Deviation works132kV Transmission Line 97C Deviation works
- Armidale 330kV Substation Uprating works
- Dumaresq 330kV Substation Uprating works
- Liddell 330kV Substation Uprating works
- Muswellbrook 330kV Substation Uprating works
- Tamworth 330kV Substation Uprating works
- Armidale 330kV Substation Cap Bank works
- Dumaresq 330kV Substation Cap Bank works
- Dumaresq 330kV Substation SVC works
- Tamworth 330kV Substation Cap Bank works
- Tamworth 330kV Substation SVC works

The following comments are noted with respect to the WBEs contained in the initial detailed estimate with the tender specified quantities, schematics and QNI support documentation:

- **330kV transmission line 83, 84 and 88 works**
  - The transmission line works involved modifications to the towers and / or spans to enable the thermal rating to be increased to 120 degrees; landscaping, increasing conductor heights, tower strengthening, structure replacement and mid span structure replacement. The summary of each of these modifications listed in the OFS is aligned with the quantities listed in the estimate.
  - The transmission line tender document which GHD sighted, QNI Upgrade - Transmission Lines: Project Specific Design Requirements Revision No. 2.0 and Specification & Contract No.1606, does not contain any quantities. GHD was therefore unable to comment on any transmission line quantity or scope discrepancies. This document does however reference required Australian standards for design and construction and shows alignment to industry standards for transmission line design and construction.

- **330kV transmission line deviations**
  - Line deviations for lines entering Tamworth substation are required as a result of the new SVC and capacitor banks. The general arrangement diagram for the proposed modifications to Tamworth substation aligns with the extent of work and scope that is contained in the estimate (number of spans, new structures/ poles etc.).
  - The tender information on the line deviations is contained within the technical specification for the Tamworth Substation as well as the general arrangement diagram for the Tamworth substation. The scope of works contained in the OFS aligned with the description in the technical specification and the general arrangement diagram.

- **330kV substation uprating works - Armidale, Dumaresq, Tamworth, Liddell, Muswellbrook**
  - Substation uprating works involved replacing disconnectors, bay conductors, line conductor drops and removal of line traps (electrical plant). The summary of quantities for each of these modifications listed in the OFS is aligned with the quantities listed in the estimate.
  - The single line diagrams and general arrangement diagrams for Armidale, Tamworth and Dumaresq show that these assets are to be replaced or removed. The technical specifications for each of these substations do not specifically refer to these works however the specifications are based on these drawings.
  - GHD has not sighted any tender information for the Muswellbrook or Liddell substations and therefore GHD is unable to comment on the scope changes from the original estimate sighted.

- **330 kV SVC and Cap Bank substation works at Armidale, Dumaresq, Tamworth**
  - The works at these substations involve the supply and installation of SVCs and capacitor banks as well as; associated high switchgear and plant (circuit breakers, disconnectors, CTs, VTs), other primary equipment such as conductor fittings as well as steel support structures and insulators, civil works and foundations and secondary and communications equipment. The summary of quantities for each of these substations listed in the OFS is aligned with the quantities listed in the estimate.
  - The general arrangement diagrams and single line diagrams for Dumaresq and Tamworth Substations align with the quantity and size of the SVCs to be installed, and with the technical specifications for each of these substations.

- The general arrangement diagrams and single line diagrams for Dumaresq and Tamworth Substations align with the quantity and size of the capacitor banks to be installed. The Armidale Substation general arrangement diagram and the single line diagram for Armidale shows a second additional 120 MVAr cap bank that is not listed in the estimate. However, the OFS indicates that this capacitor bank is separately funded to the QNI Project but will be constructed concurrently with the QNI project scope.
- The technical schedule and specifications for the substations, capacitor bank and for the SVCs are also sufficient to confirm that the number and extent of substation modifications and changes to accommodate this reactive plant in terms of bays, circuit breakers, disconnectors and other associated equipment and consistent with the initial estimate quantities.

## 4.8 Scope definition for procurement of work packages

In this section, GHD considers whether TransGrid has provided the prospective tenderers with sufficient detail on the concept designs and that the specifications are sufficiently efficient with respect to the costs and performance required from the assets whilst providing opportunities for the tenderers to be able to refine designs and specifications in this regard. This review is commensurate with the scope of work corresponding to the scope pertaining to the CPA final estimate.

The key documents reviewed generally for this purpose were:

- OFS OFS1529-2E Rev 3 Reinforcement of Northern Network
- Substation concept designs (Single line diagrams and general arrangements)
  - ART1-PYD-SK-100_03 (SLD)
  - ART1-PYD-SK-112_01 (GA)
  - DMQ-PYD-SK-102_02 (SLD)
  - DMQ-PYD-SK-112_01 (GA)
  - TA1-PYD-SK-100_04 (SLD)
  - TA1-PYD-SK-112_01 (GA)
  - Standard Design Manual - Primary Design
  - Standard Construction Manual (Substations)
- Transmission Lines
  - QNI Upgrade - Transmission Lines: Project Specific Design Requirements Revision No. 2.0
- Reactive Plant
  - Quotation Specification No. Q51/18 - RFQ #2 Detuned Shunt Capacitor Installations and Harmonic Filter Systems
  - Q51_18 RFQ 2 Technical Schedule
  - Q51_18 RFQ2 Technical Specification

A review of the tender substation documents and drawings sighted by GHD shows alignment to industry standards for substations layout, configuration, and plant requirements for major 330kV transmission network substations.

A review of the tender transmission line project specific design requirements document sighted by GHD shows alignment to industry standards for transmission line design and construction.

A review of the capacitor bank and SVC tender documents sighted by GHD shows alignment to industry standards for specification of HV plant and equipment. The documents include a specification of the capacitor bank performance requirements and standards to be met and returnable schedules that the tenders are required to complete as part of their submissions.

## 4.9 CPA QNI scope

The intention of this section was to consider the final CPA QNI scope which is contained in the PACR and aligning with the CPA capex forecast. The assessment is with regard to whether the final scope definition adequately defines a scope in line with the optimally planned solution and that the scope accurately aligns with the final estimate of costs submitted for the CPA. This should then lead to verifying whether the scope is efficient in meeting the investment need.

In regard to the scope of work, and based on the assessments conducted, GHD can verify that the scope is efficient in meeting the investment need.

## 4.10 Summary of the scope review

Table 8 provides a summary of GHD findings related to the review of the QNI project scope.

**Table 8 QNI scope – findings, qualifications and verification**

| Findings | |
|---|---|
| 1 | A review of the tender substation documents and drawings sighted by GHD shows alignment to industry standards for substations layout, configuration, and plant requirements for major 330kV transmission network substations. |
| 2 | A review of the tender transmission line project specific design requirements document sighted by GHD shows alignment to industry standards for transmission line design and construction. |
| 3 | A review of the capacitor bank and SVC tender documents sighted by GHD shows alignment to industry standards for specification of HV plant and equipment. |
| 2 | Overall the RFT scope of works aligns with the CPA capex forecast and the initial PADR. |

| Qualifications | |
|---|---|
| 1 | GHD has sighted the RFT documents for each of the major project packages. GHD have not sighted the tender responses that may detail scope refinements or proposed scope changes. However, to support this assessment TransGrid has provided information, detailed above, explaining scope impacts which have had an impact on increasing costs |
| 2 | GHD considers the time constraints for tendering to achieve a more refined scope and the overall compressed delivery timeframe for this project would have resulted in associated risks being priced into tender responses. |

| Verification | |
|---|---|
| Project Investment Scope | GHD has identified the applicable investment scope commensurate with the PADR and subsequently the PACR (submitted 19 December 2019) by reviewing TransGrid documents relating to each stage of the project development. While refinements have been made to the detail within the project investment scope since the PADR the investment scope with respect to the CPA remains consistent with the investment scope also defined in the PADR and PACR. |
| Asset Performance requirements | The OFS and the limited tender documentation sighted by GHD showed evidence that TransGrid has adequately defined the asset performance requirements. |
| Scope refinement and impacts | The PACR and the Capex Forecasting Methodology states that TransGrid has progressed the detailed project works specification and procurement steps to deliver refinements to the Option 1A's scope and outcomes.<br>GHD considers the scope refinements and cost impacts identified by TransGrid are reasonable for this type of brownfield project given the time constraints for tendering, to achieve a more refined scope, and considering the overall compressed delivery timeframe for this project. |
| Scope definition for estimating building blocks | The scope and work breakdown elements defined in the OFS estimate is consistent with the OFS scope. |
| Scope definition for procurement of work packages | For the tender documents sighted by GHD the key scope plant and specifications are reasonably defined in the current tender process to obtain efficient market tested pricing based on the concept designs and scope TransGrid has developed through the planning and options assessments. |
| CPA Scope Definition | The CPA QNI scope has remained consistent, except for refinement in detail, since the PADR. GHD is able to verify that the refinements in the scope detail have resulted in a scope of work commensurate with the CPA and that the scope is reasonable and realistic to meet the investment need. |

# 5. Capex forecast review

## 5.1 TransGrid's capex forecasting process

Considering the path to CPA development, TransGrid developed Class 4 estimates corresponding to the PADR and based on historical costs from TransGrid's Success cost estimating database.

After this stage, the procurement process outlined section 7 took place allowing tender outcomes to be reflected in the CPA capex forecast.

## 5.2 Assessment approach

### 5.2.1 Variance range

Full details of the methodology and assumptions used in the preparation of comparative estimates are provided in Appendix B. In short, our reference comparative estimates for similar projects is used as a test for reasonableness. The comparative estimates are based on inputs from completed projects throughout Australia for similar types of 330 kV substation and transmission projects, older project costs escalated and weighted against new project data being entered.

Variances between the comparative estimates with TransGrid's initial estimate corresponding to the PADR was conducted to build the comparative building block model prior to receipt of final market tested pricing. The selected or adjusted market price selected by TransGrid for each work package is compared using the same model. Where the variation to the comparative estimate is less than ±20%, GHD considers the TransGrid/tender estimate to be reasonable and no further detailed assessment is undertaken.

For those TransGrid/tender estimates where the variation is outside the nominal range, GHD has reviewed any known project specific issues to identify the potential reasons.

### 5.2.2 Estimate comparisons

GHD has conducted our review using the following steps and reasons for the approach:

4. Our initial review considered the scope of works as defined with the TransGrid Success version 5 estimate, and our comparative estimates were based on the appropriate building blocks for supply and construction of the specified transmission line and substation assets (refer Appendix A).
5. From tender prices received from the market, market based costs were determined by TransGrid for each of the activities within each work package, and at the aggregate work package level to determine the final CPA estimated capex. This is the price deemed to represent the market value for the works. GHD conducted the following assessments:
    a. GHD confirmed the tender specification scope for any adjustments necessary to quantities and the scope defined in the comparative estimating model (refer section 4).
    b. GHD then assessed the market based costs for each work package at the aggregate or bottom-line level, and where appropriate, highlighted any factors that are contributing to any variance outside of our nominal ±20% range.

6. The majority of the plant and contract services components were market tested and firm prices obtained. There are some components of the CPA capex build up that were not market tested and GHD has separately assessed these estimates:
    a. Areas of services to be contracted where market prices have not been obtained at this stage (e.g. the Tamworth substation capacitor banks).
    b. Project overheads (section 5.6.2).

### 5.2.3 Tender outcomes

Recognising that the tender results provide third party evidence of cost elements, these have been assessed in section 5.5. The majority of the plant and contract services components were market tested and firm prices obtained. There are some of the components of the CPA capex build up that were not market tested and GHD separately assessed these estimates.

### 5.2.4 Corporate and network overheads

Corporate and network overheads have been detailed in section 5.6. These have been detailed to aid transparency, where appropriate the supporting spreadsheet to the calculation have been checked to validate and in some cases, estimates have been validated to third party evidence.

The final review summarises the CPA estimate compared to GHD's comparative estimate highlighting variances including the market tested scope and the assessment the overhead costs provided in section 5.6.

### 5.2.5 Comparative estimates

To support CPA capex forecast and to provide an alternative confirmatory assessment to tender results, GHD developed a comparative estimate model. These results are summarised in section 5.5.

## 5.3 Assessment outcomes

### 5.3.1 Tender outcomes

Table 9 shows a summary by capex category of the CPA Forecast based on tendered prices for the QNI upgrade works.

***Table 9 Tender outcomes - Capex Category***

| Capex category | Procurement type | Total forecast capex[4] ($M, Real 2017/18) | Tender outcomes ($M, Real Dec 2019) |
|---|---|---|---|
| SVCs | Directly procure (existing panel arrangement) | 55.5 | • SVCs – Armidale and Dumaresq $57 million agreed to tender submission. |

[4] 12_QNI Capex forecast inputs.xlsb

| Capex category | Procurement type | Total forecast capex[4] ($M, Real 2017/18) | Tender outcomes ($M, Real Dec 2019) |
|---|---|---|---|
| Capacitor banks | Directly procure and free issue to successful Substation tenderer(s) | 14.6 | • Capacitor Bank – Armidale $4.9 million agreed to confirmation letter from TransGrid to tenderer.<br>• Capacitor Banks – Dumaresq $3.9 million agreed to confirmation letter from TransGrid to tenderer.<br>• Capacitor Banks – Tamworth $6.1 million, consisting of $4.9 million equipment supply, $0.9 million installation estimate, test $0.3 million estimates. Equipment supply substation agreed to confirmation letter from TransGrid to tenderer. |
| Substation works | Design and construct | 80.6 | $81.9 million, comprising:<br>• $16.3 million for the Armidale substation agreed to confirmation letter from TransGrid to tenderer.<br>• $30.4 million for the Dumaresq substation confirmed against a letter of agreement signed by TransGrid and the winning tenderer.<br>• $35.2 million for the Tamworth substation confirmed against a letter of agreement signed by TransGrid and the winning tenderer. |
| Transmission lines and uprating works | Design and construct | 36.4 | Agreed to confirmation letter from TransGrid to tenderer for $37.4 million. |
| HV switchgear, transmission line insulators and secondary systems | Directly procure (existing panel arrangement) | 6.4 | Prices provided from “rate card” from existing HV equipment supply panel |
| Corporate & network overheads | Bottom-up-build | 28.7 | Based on an internal estimate of TransGrid’s forecasts costs. Refer section 5.6 regarding a GHD comparative estimate for project overheads. |
| Connection costs | Distribution network service provider (DNSP) charges | 0.1 | |
| Real input costs | Internally bottom-up build using AER’s forecast real labour cost escalators. | 0.6 | |
| **Total** | | **222.8** | |

### 5.3.2 Comparative estimates

Table 10 shows a detailed breakdown of the CPA Forecast, by works item, together with a comparison with the GHD comparative estimates.

*Table 10 Comparison of CPA estimate with GHD comparative estimates*

| CPA Item number | Item description | TransGrid CPA estimate[5] ($M, Real 2017/18) | GHD comparative estimate ($M, Real 2017/18) | % Difference CPA to GHD | Comments |
|---|---|---|---|---|---|
| 1 | SVCs | 55.5 | 60.0 | -7.5% | SVC cost reduced compared to PADR estimates - Market Prices |
| 2 | **SVCs** | 55.5 | 60.0 | **-7.5%** | |
| 3 | Capacitor Bank - Armidale | 4.8 | 4.6 | 4.3% | Contract price for 1 x 120 MVar + 2 x 50 Mvar |
| 4 | Capacitor Banks - Dumaresq | 3.8 | 3.6 | 6.6% | Contract price for 2 x 120 MVar |
| 5 | Capacitor Banks - Tamworth | 5.9 | 4.6 | 29.6% | Estimated price for 1 x 120 MVar + 2 x 60 MVar. GHD unable to verify the increased cost for Tamworth as Tamworth has a similar work scope to Armidale. |
| 6 | Substation - Armidale | 15.9 | 12.3 | 29.1% | |
| 7 | Substation - Dumaresq | 29.6 | 21.7 | 36.2% | |
| 8 | Substation - Tamworth | 34.2 | 22.6 | 51.7% | |
| | Substation – Liddell[1] | | 0.3 | | CPA includes costs within Item 17 |
| | Substation – Muswellbrook[1] | | 0.1 | | CPA includes costs within Item 17 |
| 9 | **Substation and Capacitor Banks** | 95.2 | 69.8 | **36.4%** | |
| | Line 83: 330 kV Liddell - Muswellbrook uprate | - | 1.2 | - | |
| | Line 84: 330 kV Liddell - Tamworth uprate | - | 6.8 | - | |
| | Line 88: 330 kV Tamworth - Muswellbrook uprate | - | 20.4 | - | |
| | Line 88: 330 kV Tamworth - Muswellbrook deviation | - | 1.7 | - | |

[5] 12_QNI Capex forecast inputs.xlsb

| CPA Item number | Item description | TransGrid CPA estimate[5] ($M, Real 2017/18) | GHD comparative estimate ($M, Real 2017/18) | % Difference CPA to GHD | Comments |
|---|---|---|---|---|---|
| | Line 968: 132 kV Tamworth 330 - Narrabri deviation | - | 0.5 | - | |
| | Line 97C: 132 kV Tamworth 330, Tamworth 132 deviation | - | 0.9 | - | |
| 10 | Transmission Line, 83, 84 and 88 Uprating works | 36.4 | - | - | |
| 11 | **Transmission Lines** | 36.4 | 31.5 | **15.5%** | Increases in costs within +/-20% of comparative estimating range and market tested pricing |
| 12 | Substation HV Switchgear | 6.2 | 6.2 | -0.3% | |
| 13 | Transmission Line Insulators | 0.2 | 0.1 | 200.1% | % variance is large but $ variance is considered immaterial to overall forecast |
| 14 | Secondary Systems Equipment | 0.9 | 1.4 | -37.0% | |
| 15 | **Free Issue Items** | 7.2 | 7.7 | **-4.9%** | |
| 19 | Dumaresq - Essential Energy and APD Cost | 0.1 | - | - | GHD assumes this is additional work to the PADR scope. |
| 20 | Armidale - Essential Energy and APD Cost | 0.0 | - | - | GHD assumes this is additional work to the PADR scope. |
| 21 | **Connection Cost** | 0.1 | - | **-** | |
| | **Subtotal - Contracted & Plant** | 193.5 | 166.9 | **16.0%** | The larger increases in contracted services balanced by some reduction in plant costs. Overall variance within +/-20% of GHD comparative estimate. |
| 16 | Internal Labour - Project Development | 6.0 | - | - | |
| 17 | Internal Labour - Works Delivery[1] | 17.9 | - | - | |
| 18 | **Internal Labour** | 23.9 | - | - | |
| 22 | Historic indirect capex | 3.3 | - | - | |
| | Other indirect capex | 1.5 | | | |
| 23 | **Indirect capex** | 4.8 | - | - | |

| CPA Item number | Item description | TransGrid CPA estimate[5] ($M, Real 2017/18) | GHD comparative estimate ($M, Real 2017/18) | % Difference CPA to GHD | Comments |
|---|---|---|---|---|---|
| | **Subtotal - Project Overheads** | 28.7 | 20.9 | **37.3%** | Significant increases in project management costs – refer section 5.6 |
| | Real input costs | 0.6 | - | | |
| | **TOTALS** | **222.8** | **189.9** | **17.3%** | This overall margin is inside GHD's +/- 20% comparative estimate range |

Note 1: A value for Muswellbrook and Liddell upgrade work has been removed from works delivery to enable a review of project overheads in section 5.7.2.

We have concluded from our comparative estimates that the market tested costs inputs within the CPA estimated costs for "Subtotal - Contracted Services & Plant" were:

- 16.0% higher than the GHD's comparative estimate. This is within GHD's estimate range of ±20% at this overall level within the estimates.
- Substation and capacitor banks were in total 36.4% higher than GHD's comparative estimates and hence we have assessed these costs further in section 5.5.5.

The subtotal for "Project Overheads" indicates an increase in internal owner costs and was 37.3% higher than the GHD comparative estimate and outside the ±20% of the GHD estimate range requiring further detailed assessment.

## 5.4 TransGrid's QNI capex forecast process

The purpose of this section is to provide a short summary of the process which TransGrid has used to develop their CPA capex forecast. Section 4.3 of the Capex Forecasting Methodology[6] states that a well-defined capex forecasting process has been followed as shown below in Figure 3.

***Figure 3 QNI CPA Capex forecasting process***


Source: Capex Forecasting Methodology - Figure 4.2

Section 4.3 of the Capex Forecasting Methodology has not identified the pre-tender process for developing Class 4 estimates which TransGrid had prepared for the PADR process and prior to the tender process outcomes. This estimate was prepared using historical costs from TransGrid's cost estimating database. GHD developed the initial comparative model based on this estimate and scope definition which effectively allowed us to review the work packages and pricing relevant to the PADR.

[6] Capex Forecasting Methodology for QNI Minor Upgrade Project – p13

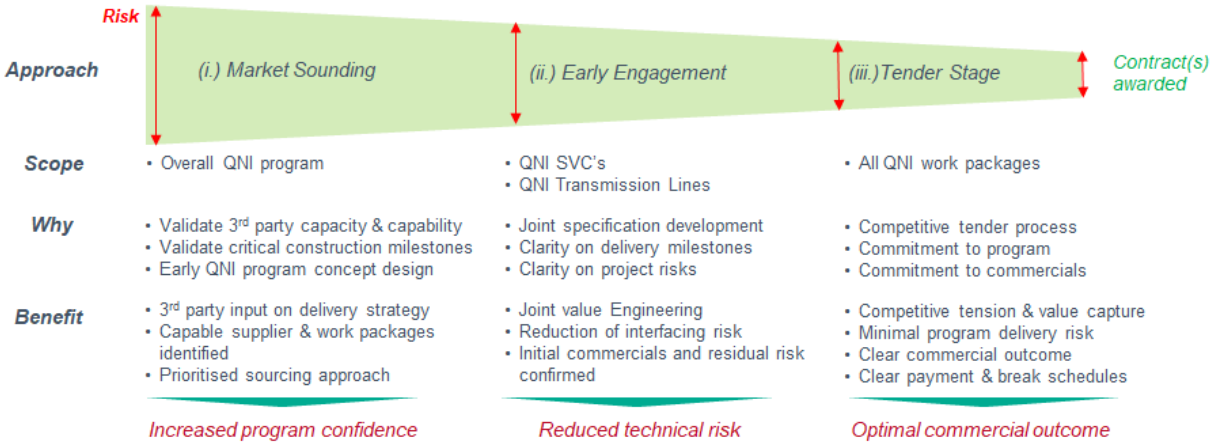
The QNI capex forecasting process used to develop the final CPA capex forecast followed a similar process used for business-as-usual capital projects, with certain changes to account for the size and complexity of the Project. The components and output from Step 1 of the process were relevant to GHD's reviews:

- Tendered prices were obtained through tender processes and were used instead of historical costs from TransGrid's cost estimating database
- A bottom-up-build of indirect costs (project development, works delivery and indirect costs) has been developed instead of applying historically derived percentage values from TransGrid's cost estimating database.

The procurement process (as illustrated in Figure 4) was important in establishing both accurate and efficient costs for the contracted services which represent around 85 per cent of the total project costs. A more detailed assessment of the procurement process is provided in section 7.

Section 5.5 provides a summary of the process undertaken for work packages and conclusions with regard to achieving efficient scope and costs.

***Figure 4 Three key stages to the QNI procurement process***




Source: Capex Forecasting Methodology - Figure 5.2

## 5.5 Review of CPA work packages

### 5.5.1 The review approach

The approach adopted for this review was:

- Recap any changes in the scope in the CPA estimate (from the tender documents) compared to Success 5 Estimate
- Report on the result of the comparative estimates compared to the CPA estimate
- Identify variances and comments with regard to areas of concerns
- Identify changes in scope, unit costs, or overheads from the PACR (initial estimate) compared to the CPA
- Identify variances and comment with regard to areas of concern.

The variance between the TransGrid version 5 estimates and the GHD comparative estimates for each of the transmission line and substation work packages are outlined in following sections.

In each instance, we focussed on the comparison of the standard building block rates for the specified scope of work in each package and adopted the project-specific costs as nominated by TransGrid in the tender specifications.

### 5.5.2 SVC work packages

#### a) Procurement approach

TransGrid minimised technical and commercial risks of the SVC procurement by following an early engagement approach.

In late 2018, TransGrid commenced an initial market engagement and sounding exercise for the procurement of the SVCs and then shortlisted to three business-as-usual network equipment suppliers.

Early engagement allowed TransGrid to offer the three SVC suppliers the opportunity to support the development of detailed specifications, and, importantly, provided sufficient time for the SVC suppliers to recommend the most efficient and effective solution. TransGrid wanted to leave it to the market to identify the most efficient solution.

In December 2018, TransGrid received indicative supplier budgetary and program offers and in early to mid-2019, TransGrid undertook a collaborative engagement exercise with each supplier individually.

However, TransGrid extended the RFT period to mid-October 2019 to enable tenderers to refine their responses technically and commercially, including to address the transfer of key risks[7] from TransGrid to the tenderers.

TransGrid received compliant tender submissions from the three SVC suppliers on a not-to-exceed pricing offer basis. Two suppliers offered "classic" SVC products and the third supplier offered a hybrid SVC product.

The SVC suppliers offered significant improvements between the original tender stage submissions and a subsequent best and final offer process. A key contributor to this was, as stated in the Capex Forecasting Methodology, was that TransGrid provided targeted feedback to each supplier about their individual tender submissions.

#### b) Work scope changes

The SVC suppliers offered significant improvements to the scope which resulted in cost savings, compared to initial estimates in the PADR which would have reflected the initial pricing estimates from suppliers.

#### c) Comparative estimate

Table 11 shows a summary of the tender prices and the GHD comparative allowances for SVCs.

[7] 'Interface risks' are the key risks for SVCs and relate to the SVC supplier providing detailed civil designs by a certain date to the substation supplier.

*Table 11 Comparative estimate for SVCs*

| CPA Item number | Item description | TransGrid CPA est ($M, Real 2017/18) | GHD comparative estimate ($M, Real 2017/18) | % Difference CPA to GHD | Comments |
|---|---|---|---|---|---|
| 1 | SVCs | 55.5 | 60.0 | -7.5% | SVC cost reduced compared to PACR estimate and GHD's comparative estimate. |
| 2 | **SVCs Total** | **55.5** | **60.0** | **-7.5%** | Market tested pricing |

**d) SVC summary**

The early engagement approach is standard practice where a wide range of technology solutions may achieve superior performance and cost outcomes, and where the knowledge of the supplier is critical in developing solutions. The competitive pressure and collaborative approach, and outcome indicate efficient price and solutions have been achieved for the SVC packages. This component represents approximately 26% of the total QNI project costs.

The variance in cost was -7.5% which is well within ±20% of GHD's comparative estimates. GHD had accepted TransGrid's estimate for SVCs from the PACR, hence this also represents a reduction achieved through the procurement process.

### 5.5.3 Capacitor bank work packages

**a) Procurement approach**

TransGrid used a competitive tender process to procure the capacitor banks utilising its existing panel. TransGrid established that there are two potential suppliers of capacitor banks for this Project on the panel that could achieve the in-service completion date of September 2021.

Two separate tenders, one each for Armidale and Dumaresq, were issued to the two capacitor bank suppliers on 11 October 2019. The two suppliers provided their best and final offers for both sites on 15 November 2019.

The tender evaluation process found that the one supplier's final offers for Armidale and Dumaresq ranked first technically and commercially. The Capex Forecasting Methodology does not state whether there were reductions in costs during/after the best and final offers were received.

TransGrid issued its tender for the Tamworth capacitor banks on 6 December 2019 and best and final offers from the two suppliers for the Tamworth capacitor banks were only received in the week commencing 23 December 2019.

TransGrid has based its expenditure forecasts for Tamworth, for the purposes of the CPA capex forecast, on the tendered prices that have been received for Armidale and Dumaresq.

**b) Works scope changes**

The capacitor banks offered are consistent with the scope of work defined in the PADR as this equipment is to a standard design by TransGrid. The scope of work is as follows:

**Dumaresq**

The Success version 5 estimate specified the following scope of works:

- Civil works for 14,690 $m^2$ extension to Dumaresq 330 kV switchyard, including site preparation, earthworks, drainage, earth grid, fencing, access roads, cable duct, control building and auxiliaries
- 1 off 330 kV -100/+350 MVAr SVC
- 2 off 330 kV 120 MVAr capacitor banks
- 1 off 330 kV transformer bay
- 2 off 330 kV capacitor bank feeder bays
- 3 off 330 kV feeder bays
- 3 off 330 kV busbar bays

GHD has assumed the site for the new switchyard is flat and readily accessed, allowing for site preparation, earthworks, earth grid, drainage, roadworks, fencing, cable duct, control building, ancillary services and site mobilisation as per our reference building block and include our assessment of reasonable owner's costs, risks and contingencies.

**Armidale**

QNI scope - the Success version 5 estimate specified the following scope of works:

- Civil works for 6,829 $m^2$ extension to Armidale 330 kV switchyard, including site preparation, earthworks, drainage, earth grid, fencing, access roads, cable duct, control building and auxiliaries
- 1 off 330 kV 120 MVAr capacitor banks
- 2 off 330 kV 50 MVAr capacitor banks
- 3 off 330 kV capacitor bank feeder bays
- 1 off 330 kV busbar bays

GHD has assumed the site for the new switchyard is flat and readily accessed, allowing for site preparation, earthworks, earth grid, drainage, roadworks, fencing, cable duct, control building, ancillary services and site mobilisation as per our reference building block; and include the aggregate TransGrid lump sum allowances of $5.15 million (or 26% of total TransGrid costs) for assessed scope.

GHD has relied upon market costs available to us for the capacitor banks, which are comparable to the allocations included by TransGrid in the version 5 estimate.

NCIPAP capacitor bank - the Success version 5 estimate specified the following scope of works:

- 1 off 330 kV 120 MVAr capacitor banks
- 1 off 330 kV capacitor bank feeder bays
- 3 off 330 kV busbar bays

GHD has relied upon market costs available to us for the capacitor banks, which are comparable to the allocations included by TransGrid in the version 5 estimate.

**Tamworth**

The Success version 5 estimate specified the following scope of works:

- Civil works for 23,430 $m^2$ extension to Tamworth 330 kV switchyard, including site preparation, earthworks, drainage, earth grid, fencing, access roads, cable duct, control building and auxiliaries
- 1 off 330 kV -100/+350 MVAr SVC

- 1 off 330 kV 120 MVAr capacitor banks
- 2 off 330 kV 50 MVAr capacitor bank
- 1 off 330 kV transformer bay
- 3 off 330 kV capacitor bank feeder bays
- 1 off 330 kV feeder bay
- 6 off 330 kV busbar bays

GHD has assumed the site for the new switchyard is flat and readily accessed, allowing for site preparation, earthworks, earth grid, drainage, roadworks, fencing, cable duct, control building, ancillary services and site mobilisation as per our reference building block; and include the aggregate TransGrid lump sum allowances of $6.98 million (or 11% of total TransGrid costs) for assessed scope.

### c) Comparative estimate

Table 12 summarises the estimated costs for the capacitor banks at Armidale, Dumaresq and Tamworth substations.

The CPA values are market tested, compared to the costs based on historical projects used in the GHD comparative estimate.

***Table 12 Comparative estimate for capacitor banks***

| CPA Item number | Item description | TransGrid CPA estimate ($M, Real 2017/18) | GHD comparative estimate ($M, Real 2017/18) | % Difference CPA to GHD | Comments |
|---|---|---|---|---|---|
| 3 | Capacitor Bank - Armidale | 4.8 | 4.6 | 4.3% | • 1 off 330 kV 120 MVAr capacitor banks<br>• 2 off 330 kV 50 MVAr capacitor banks |
| 4 | Capacitor Banks - Dumaresq | 3.8 | 3.6 | 6.6% | • 2 x 330 kV 120 MVAr capacitor banks |
| 5 | Capacitor Banks - Tamworth | 6.0 | 4.6 | 29.6% | • 1 off 330 kV 120 MVAr capacitor banks<br>• 2 off 330 kV 60 MVAr capacitor bank |
| | **TOTAL** | **14.6** | **13.2** | **10.6%** | |

The estimate for capacitor bank works at Armidale excludes consideration of the NCIPAP work.

### d) Capacitor bank summary

TransGrid's procurement process and timeframe for delivery enabled only two suppliers to provide final tenders for capacitor banks. The tender evaluation process found that the one supplier's final offers for Armidale and Dumaresq ranked first technically and commercially.

The Capex Forecasting Methodology does not state whether there were reductions in costs during/after the best and final offers were received.

TransGrid has based its expenditure forecasts for Tamworth, for the purposes of the CPA capex forecast, on the tendered prices that have been received for Armidale and Dumaresq.

The overall variance in cost was 11% which is within ±20% of GHD's comparative estimates. GHD had previously accepted TransGrid's estimate for capacitors from the PACR, hence this also represents a reduction achieved through the procurement process.

However, we have been unable to verify the $6.0 million allowance for the Tamworth capacitor banks, given it has the same overall specification as the works at Armidale, where the estimated cost is $4.6 million.

### 5.5.4 Transmission line work packages

#### a) Procurement approach

TransGrid initially approached the four members of their existing transmission line panel. TransGrid short-listed two panel suppliers during August and September 2019 based on assessments of service performance, capability and availability of resources to meet the September 2021 deadline.

TransGrid issued RFTs for the transmission lines' work to the two transmission line suppliers on 18th October 2019, then held separate workshops with the suppliers to provide detailed information on the works and held compulsory site visits.

The preferred supplier was selected on technical and commercial considerations following submissions received on 28 November 2019.

One of the two tenderers did not provide a binding offer which could suggest that the scope of work has significant risks which this tenderer was not prepared to set a fixed price. This also suggests the preferred tenderer priced in the required margin for the higher scope risks involved in brownfield transmission line works.

TransGrid undertook a value engineering workshop with the preferred supplier with a view to reducing cost by further refining the design. This collaborative approach was aimed at optimising the cost and design of the transmission line works so that the final expenditure is prudent and efficient.

This differed from the substation process where, in that process, the final two tenders were both engaged in workshops prior to providing best and final offers. The Capex Forecasting Methodology document does not state whether there were reductions in costs resulting from the workshop with the preferred supplier.

The approach taken is reasonable, and possibly due to time constraints. There may be some loss of efficient pricing due to the reduction in competitive pressures in the final value engineering workshop phase for the transmission line works.

The variance of costs to GHD's comparative estimate is 14.5% which is within the ±20% range.

#### b) Works scope changes

The scope of works for the CPA Forecast are similar to those defined within the OFS, and relate to the following work packages:

- Line 83: 330 kV Liddell - Muswellbrook uprate
- Line 84: 330 kV Liddell - Tamworth uprate
- Line 88: 330 kV Tamworth - Muswellbrook uprate
- Line 88: 330 kV Tamworth - Muswellbrook deviation
- Line 968: 132 kV Tamworth 330 - Narrabri deviation

- Line 97C: 132 kV Tamworth 330 - Tamworth 132 deviation

### c) Comparative estimate

The comparative estimates for the transmission line uprates and deviations are shown in Table 13 with the CPA estimate providing only a bottom-line estimate of costs at the aggregate level.

***Table 13 Comparative estimate for transmission lines***

| CPA Item number | Item description | TransGrid CPA estimate ($M, Real 2017/18) | GHD comparative estimate ($M, Real 2017/18) | % Difference CPA to GHD | Comments |
|---|---|---|---|---|---|
| | Line 83: 330 kV Liddell - Muswellbrook uprate | - | 1.2 | - | Information not provided to compare CPA estimate at each work package level. |
| | Line 84: 330 kV Liddell - Tamworth uprate | - | 6.8 | - | " |
| | Line 88: 330 kV Tamworth - Muswellbrook uprate | - | 20.4 | - | " |
| | Line 88: 330 kV Tamworth - Muswellbrook deviation | - | 1.7 | - | " |
| | Line 968: 132 kV Tamworth 330 - Narrabri deviation | - | 0.5 | - | " |
| | Line 97C: 132 kV Tamworth 330 - Tamworth 132 deviation | - | 0.9 | - | " |
| 10 | Transmission Line, 83, 84 and 88 Uprating works | 36.4 | - | - | " |
| **11** | **Transmission Lines** | **36.4** | **31.5** | **14.5%** | Increases in costs but within +/- 20% comparative estimating range - Market tested prices. |

The overall variance in the aggregate transmission line cost estimates between the CPA estimate ($36.4 million) and GHD comparative estimates ($31.5 million) is 15.4%.

The variance in the estimated total costs for the five transmission lines is within our nominal range of ±20%. GHD has been able to independently identify that the primary drivers for the variance are:

- Increased allowance for structure foundation civil works following geotechnical investigations
- Design adopting steel poles in lieu of concrete poles to mitigate site road infrastructure costs
- Additional allowance for excavation in hard rock.

## 5.5.5 Substation work packages

### a) Procurement Approach

TransGrid approached all four members of the existing panel, who are each well-established suppliers of substation works and concluded:

- No supplier had the capacity to undertake the required works at all three sites concurrently. This was due to the requirement to achieve a September 2021 in service date
- A supplier could only undertake work at two sites concurrently in the available timeframe

- Having a single substation supplier dealing with a single SVC supplier at Dumaresq and Tamworth would provide significant logistical benefits.

TransGrid undertook separate value engineering workshops with the preferred suppliers with a view to reducing cost by further refining the design. This collaborative approach was aimed at optimising the cost and design of the substation works so that the final expenditure is prudent and efficient.

The best and final offer prices received from the preferred suppliers were lower than the prices in their original Tender responses. The approach taken is standard practice for brownfield projects to identify and minimise associated project costs and risks.

The variance to cost increase was 41% which is outside our nominal range of ±20% of GHD's comparative estimates as a first pass check for reasonableness.

### b) Works scope changes

The scope of works for each of the following substations is described in Appendix A, consistent with the previous OFS:

- Dumaresq
- Armidale - excluding the NCIPAP capacitor bank works
- Tamworth
- Liddell
- Muswellbrook

### c) Substation summary

Table 14 shows a summary of the comparative estimates for the major works at Armidale, Dumaresq and Tamworth, together with communication upgrades at Liddell and Muswellbrook. It highlights the variances with the comparative GHD estimates, with the primary driver being increases in labour costs at each site from the previous TransGrid Success version 5 estimate.

***Table 14 Comparative estimate for substations***

| CPA Item number | Item description | TransGrid CPA estimate ($M, Real 2017/18) | GHD comparative estimate ($M, Real 2017/18) | % Difference CPA to GHD | Comments |
|---|---|---|---|---|---|
| 6 | Substation - Armidale | 15.9 | 12.3 | 38.8% | |
| 7 | Substation - Dumaresq | 29.6 | 21.7 | 35.2% | |
| 8 | Substation - Tamworth | 34.2 | 22.6 | 49.9% | |
| | Substation - Liddell | - | 0.3 | | Scope is included in the CPA within Item 17 |
| | Substation - Muswellbrook | - | 0.1 | | Scope is included in the CPA within Item 17 |
| | **Substations** | **79.7** | **56.6** | **40.8%** | Excluding Liddell and Muswellbrook |

TransGrid approached all four members of the substation panel and concluded that a multiple contractor approach was required to achieve a September 2021 in service date. A single substation supplier was the aim for selection as the SVC substation supplier at both Dumaresq and Tamworth for logistical reasons.

TransGrid undertook separate value engineering workshops aimed at optimising the cost and design of the substation works so that the final expenditure is prudent and efficient.

The best and final offer prices received from the preferred suppliers were lower than the prices in their original Tender responses.

The approach taken is standard practice for brownfield projects to identify and minimise associated project costs and risks, and GHD accepts that these prices are the current market rates.

The variance to cost increase was with 40.8% which was well outside ±20% of GHD's comparative estimate. GHD has been able to independently verify that the variance is due to the following drivers:

- Increase in the bulk civil works required for the switchyard extension works
- Additional allowance for excavation in hard rock
- The requirement for excavation and disposal of contaminated soil.

As a result, GHD is satisfied that the CPA forecast values are reasonable and realistic.

### 5.5.6 Project allowance and overheads

GHD has assessed the project development and works delivery costs developed from bottom up resourcing requirements applied by TransGrid in the development of their final CPA capex forecast. This section includes a discussion of the bottom-up method to determine project overheads in the final CPA estimate.

The following table summarises the comparison of the project overheads included in the CPA Forecast and the GHD comparative estimates.

***Table 15 TransGrid estimates vs GHD comparative estimates of owner's costs***

| CPA Item number | Item description | TransGrid CPA estimate ($M, Real 2017/18) | GHD comparative estimate ($ M, Real 2017/18) | % Variance CPA to GHD |
|---|---|---|---|---|
| 16-23 | Project Overheads incl. internal Project Development and Works Delivery costs | 28.7 | 20.9 | 37.3 |

The total TransGrid project owner's costs of $28.7 million contribute 12.9% of the total estimated costs, based on the CPA estimate the total value of $222.8 million.

GHD considers that TransGrid has based past estimates on Business as Usual (BAU) work of this type. The nature of the scope of work is brownfield, such as working in live substations and working near live overhead conductors with restricted outage windows. The work also involves several contractors (and their subcontractors) working across several work sites.

## 5.6 Corporate and network overheads

### 5.6.1 Forecast indirect capex

The Forecast Indirect Capex dated 20 December 2019 (part of the CPA submission) identifies three key categories of forecast indirect capex. As indicated, these costs, as shown in Table 16, are incremental to TransGrid's regulated (business-as-usual) capex overheads.

***Table 16 Corporate and network overheads cost summary***

| Capex category | 2019-20 ($ million) | 2020-21 ($ million) | 2021-22 ($ million) | 2022-23 ($ million) | Total capex ($ million) |
|---|---|---|---|---|---|
| Works delivery | 4.74 | 11.42 | 1.79 | - | 17.91 |
| Project development | 3.01 | 2.55 | 0.76 | - | 5.97 |
| Other indirect capex | 0.83 | 0.61 | 0.15 | - | 1.55 |
| **Total** | **8.58** | **14.58** | **2.69** | **-** | **25.43** |

Historical indirect capex of $3.39 million has been incurred by TransGrid between 1 July 2018 to 30 November 2019 in progressing the QNI project. The capex is detailed in the table below.

***Table 17 Historical indirect capex***

| Capex category | 2018-19 ($ million) | 2019-20 ($ million) | Total capex ($ million) |
|---|---|---|---|
| Direct Labour | 0.58 | 0.96 | 1.49 |
| External services | 0.84 | 0.99 | 1.78 |
| **Total** | **1.45** | **1.95** | **3.27** |

GHD has noted that the historical expenditure in the total CPA capex forecast is $4.4 million is unable to identify the reason for this difference. We have assumed that the "Other indirect capex" costs may have been partly allocated to "Spend to date" in the CPA capex forecast.

#### a) Works delivery

The Forecast Indirect Capex document details that an additional 43 Full Time Equivalents (FTEs) will be required to deliver QNI.

The Works Delivery FTE's are required to:

- Undertake project and contract management and project controls functions in accordance with TransGrid's project management delivery model
- Undertake the role of Principal Contractor for all brownfield substation construction activities
- Undertake construction management services for all brownfield substation and transmission line construction activities

- Undertake civil, electrical, environmental and safety inspections to ensure that work, completed by the contractors, satisfies contractual requirements
- Coordinate HV equipment outages, for all brownfield substation and transmission line construction activities, to provide safe areas for contractor construction activities
- Provide power system safety rules qualified staff that provide safe access areas (i.e. electrical and mechanical isolations) for contractors on brownfield locations
- Provide qualified oversight of contractors for pre-commissioning checks and in-service commissioning activities of new equipment
- Provide qualified staff to manage interfaces between exiting equipment and systems with the new equipment and systems.

***Table 18 Works delivery costs***

| Works delivery | Estimate ($ million) | Basis |
|---|---|---|
| Labour | 16.02 | The Queensland and New South Wales Interconnector (QNI) Substations & TL Uprating Works Delivery Advice, 2019 – Sections 2.1. and 2.2 identified an additional 43 FTEs across the following resources types:<br>Project Management – 10 roles<br>Substation Works Delivery – 21 roles<br>Transmission lines 88,83 and 84 Works Delivery – 12 roles<br>These FTEs will be required across Armidale, Tamworth, Dumaresq, Liddell and Muswellbrook substation site locations as well as the locations for Transmission lines 88,83 and 84 identified in the detailed scope of works and design.<br>FTE duration and costs allocated to the project have been detailed in Appendix A of the Forecast Indirect Capex.<br>Standard labour rates, effective 30 June 2018, have been applied to calculate the works delivery capex forecast for QNI. These rates were used to calculate the capex forecast for the 2018-23 regulatory period. These rates were reviewed by GHD and reflect reasonable market conditions and constraints within NSW.<br>GHD's comparative estimate for project overheads in section 6.2 indicates that the number of FTEs is at the upper end of expected levels. GHD's comparative estimate indicates a total of 35 FTE roles as an average for this size of the project. |
| Sustenance | 0.87 | This relates to work related travel expenses such as food and accommodation. The forecast sustenance allowance is in line with the Australian Tax Office (ATO) Reasonable Allowance amounts based on a salary of $108,810 which is considered reasonable. |
| Travel | 0.26 | The assumptions underpinning each role, including frequency of travel and location, can be found within the P0016469 – Queensland and New South Wales Interconnector (QNI) |

| Works delivery | Estimate ($ million) | Basis |
|---|---|---|
| | | Substations and Transmission Uprating Works Delivery Advice, 2019.[8] |
| Training | 0.04 | $1.5K per FTE is considered reasonable. |
| Recruitment | 0.63 | Approximately $14K per FTE which is considered reasonable. |
| IT Hardware | 0.06 | Based on IT requirements per FTE. |
| Rounding | 0.01 | - |
| **Total works delivery** | **17.91** | |

### b) Project development

The Forecast Indirect Capex details labour and non-labour costs related to the setup and ongoing project management of QNI.

The additional FTEs are forecasted to include:

- 5 roles for our Major Project Division within the QNI Project Team
- 7 roles resourced to specifically support the QNI program
- 5 roles allocated from the core team of the Major Projects Division
- 19 other support and corporate roles allocated from the Major Projects Division.

***Table 19 Project development costs***

| Works delivery | Estimate ($ million) | Basis |
|---|---|---|
| **Labour** | **4.58** | The number of additional FTEs has been phased over the duration of the project as detailed in the supporting QNI Indirect Costs Working Papers 201220 spreadsheet.<br>FTE duration and costs allocated to the project have been detailed below.<br>Standard labour rates, effective 30 June 2018, have been applied to calculate our works delivery capex forecast for QNI. These rates were used to calculate our capex forecast for the 2018-23 regulatory period. These rates were reviewed by GHD and reflect reasonable market conditions and constraints within NSW.<br>GHD's comparative estimate for project overheads in section 6.2 indicates that the total project development costs (including expenditure to date) are at the upper end of expected levels. GHD's comparative estimate indicates a total of $4 million for additional expenditure over the remainder of the project for development costs. |

[8] P00016469 – Queensland and New South Wales Interconnector (QNI) Substations & TL Uprating Works Delivery Advice, TransGrid 2019 – Prepared by TransGrid Works Delivery team, detailing role assumptions for each FTE including overtime, flights and sustenance allowances.

| Works delivery | Estimate ($ million) | Basis |
|---|---|---|
| QNI Core - Project Management Team | 2.88 | 5 FTEs at 100% to directly manage QNI for TransGrid |
| QNI - Other incremental roles | 1.04 | 14 FTEs at 100% to directly resourced on QNI |
| Major Projects Team | 0.23 | 5 FTEs at 5% to support across Major Projects. The allocation of 5% is based upon and allocated between each of the major projects based on the indicative total capex forecast for each project as detailed in Section 7 of the Forecast Indirect Capex which appears reasonable. |
| Other QNI incremental resources | 0.43 | 19 FTEs at 5% supporting QNI including engineering, regulatory, spatial, finance, HR, ongoing procurement. The 5% allocation is detailed above and appears reasonable. |
| Labour related costs | 0.34 | |
| Travel – QNI Project Management Team | 0.06 | GHD considers costs to be reasonable. |
| Training | 0.02 | $1.5K per FTE is considered reasonable. |
| Recruitment | 0.17 | GHD considers to be reasonable. |
| Office & IT costs | 0.09 | Based upon IT requirements per FTE. |
| **Non-Labour costs** | **1.05** | |
| Consultant and professional fees | 0.34 | External support:<br>• Forecast methodology documentation and advice $1.7K<br>• Forecast indirect capex documentation and advice $0.8K<br>• Expenditure forecasts validation $0.6K<br>• Regulatory compliance review $0.3K<br>These costs are considered reasonable. |
| TL design, HV design, Civil design and equipment engineering | 0.72 | GHD considers these costs to be reasonable. |
| Rounding | (0.01) | - |
| **Total project development** | **5.97** | |

### c) Other indirect costs

***Table 20 Other indirect costs***

| Category | Estimate ($ million) | Basis |
|---|---|---|
| Land and environment | 0.29 | Environment Officer role and associated costs considered appropriate. |
| Stakeholder and community engagement | 0.17 | Community based programs in areas where QNI works will be undertaken<br>Design and communication costs |
| Insurance | 0.89 | Falls within the cost estimation range detailed in the AON QNI Insurance Report dated 29th November 2019. |
| Bidder payments | 0.20 | Forecast for compensatory payments to suppliers where they are asked to prepare detailed designs during the bidding phase of tenders. |
| **Total other indirect** | **1.55** | All of the above costs are considered reasonable for the QNI project within and nearby existing easements. |

### 5.6.2 GHD assessment of overhead costs

The first part of the assessment reviewed the build of the costs based on headcount and hours required over the project duration, including costs already incurred in the early project development phase. This is a bottom up approach to estimating the project development and works delivery labour costs.

A second question relates to whether the overall costs for these owner costs are prudent and efficient.

GHD has used guiding metrics to arrive at an independent estimate of reasonable owner costs and used comparably major civil and electrical industry projects as a guide. This comparison needs to take into consideration the brownfield project environment, and in the case of the QNI project, the overheads involved in managing access and outages on the transmission lines for the uprating works.

Generally speaking, the larger the project, the smaller the project development and management owner costs will be as a percentage of the total however this is more a factor of the interface point with contacted development and construction services.

Project management costs for all phases of a project with project controls managed by the owner, generally the total is somewhere between 9-15 per cent range.

Ernst & Young Transport in 2011 prepared a report for the NSW Department of Transport titled “Infrastructure – Project Cost Benchmarking Study”. The study collected data from eight road and rail authorities across Australia for projects above $50 million in total cost.

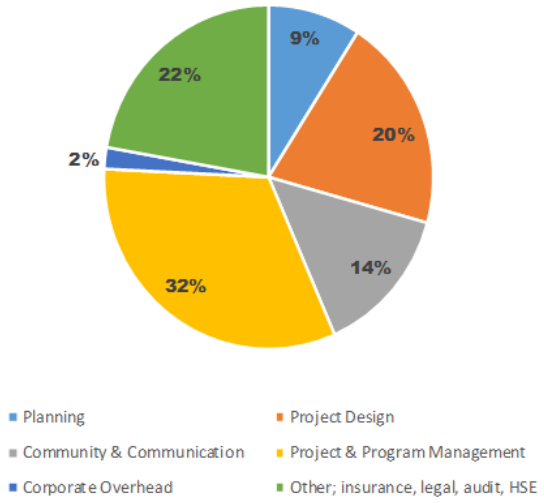
Overall this report found the average owner costs (excluding design costs) for road projects as a percentage of total construction costs was 11%. Including detailed design work, the average percentage increased to 14%.

There were 14 road projects selected for analysis with owner costs (without design) varying from 7% to 16%. Removing the two outliers the range was from 8% to 14%. The average owner costs (excluding design costs) for rail projects was 16%. Including detailed design, the average percentage increased to 21%. There were 14 rail projects selected for analysis with owner costs (without design) varying from 8% to 30%.

Removing the two outliers the range was from 9% to 20%. This illustrates a relatively flat distribution between these ranges for both road and rail projects.

From GHD's experience and data relating to major transmission line projects also indicates project overhead costs aligning with the range found with the road projects.

***Figure 5 Project overhead cost breakdown***




GHD considers that the range of road project is a better match to the brownfield nature of the QNI transmission line project. This also considers that TransGrid applied a margin of 8.5% in their Success 5 estimate for the QNI project, representing business-as-usual type projects. Hence we consider 14% (average owner costs including design costs) would be reasonable if the full range of cost categories was applicable, including the total design.

Figure 5 shows the breakdown of costs over the category of expenditure from the projects analysed. Using this category breakdown and considering which categories partly or fully apply to the QNI project an estimate of reasonable project overheads can be made.

These comparative estimate categories can be allocated into TransGrid categories using assumptions shown in Table 21. This split is indicative only.

***Table 21 TransGrid project overheads comparative estimate***

| Component | Project overheads | Applicable to the QNI project | Apply to QNI | Comparative estimate ($M, Real 2017/18) | Comments |
|---|---|---|---|---|---|
| Planning | 9% | 100% | 9.0% | 2.50 | |
| Community & Communication | 14% | 5% | 0.7% | 0.19 | Existing assets which is much less than a roadwork project |
| Corporate Overhead | 2% | 100% | 2.0% | 0.56 | |
| Project Design | 20% | 15% | 3.0% | 0.83 | 85% of project design is contracted to service providers |
| Project & Program Management | 35% | 110% | 35.0% | 10.70 | Brownfield related project but increased for managing outage windows and Principal Contractor responsibilities |
| Other Costs | 22% | 100% | 22.0% | 6.11 | Considered split 40% work delivery, 40% development and 20% other indirect |
| **Total project overheads** | **100%** | **-** | **72%** | **20.90** | 11% of total project costs |

***Table 22 Comparison with TransGrid project overheads (including expenditure to date)***

| Category | TransGrid project overheads ($M, Real 2017/18) | Comparative overheads estimate ($M, Real 2017/18) |
|---|---|---|
| Works delivery | 17.91 | 12.5 |
| Project Development | 5.97 | 3.4 |
| Other Indirect | 1.55 | 1.2 |
| Spend to Date | 3.27 | 3.8 |
| **Total project overheads** | **28.70** | **20.9** |

Note 1: The total project overheads corresponds to value determined in Table 10 for TransGrid's project overheads and GHD's comparative estimate for overheads (11%).

If market tested direct costs are accepted, but project overheads are limited to 11%, Table 23 shows an alternative total project cost estimate.

***Table 23* Comparison of direct, overheads and total project costs using market tested direct costs**

| Category | TransGrid project overheads ($M, Real 2017/18) | Alternate estimate ($M, Real 2017/18) | Comments |
|---|---|---|---|
| Direct Project Cost | 193.5 | 193.5 | Market tested contact services and plant costs accepted |
| Real input costs | 0.6 | 0.6 | Based on AER escalation |
| Project Overhead Costs | 28.70 (12.9%) | 21.3 (11%) | TransGrid estimate versus comparative overheads estimate |
| **Total Project Cost** | **222.8** | **215.4** | |

The supporting data from the typical road industry projects indicates that the per cent margin for project overhead could be in the range from 8% to 14%. TransGrid has increased its project overheads from a margin of 8.5% at the PADR stage (estimates based on BAU allowances) to 12.9% in their CPA submission.

GHD is of the view that 12.9% is within the acceptable range of project margins.

## 5.7 Summary of the CPA capex forecast

With reference to Table 24 provides a summary of the key GHD findings related to the review of the CPA capex forecast.

***Table 24 CPA capex forecasts – findings, qualifications and verification***

| Findings | |
|---|---|
| 1 | The variance between the CPA estimate and the GHD comparative estimate is 17.3% at the bottom line, which is within our nominal ±20% range for assessing the reasonableness of forecast |

| Findings | |
|---|---|
| | costs. GHD considers that the difference is due to our reliance on historical project costs rather than market-tested tender costs that support the CPA. |
| 2 | The variance is different across the work packages, with the Transmission Line uprates and deviations showing a variance of 15.4% and Substation works (incl. capacitor banks) varying by 35.1%. The overall Contract & Plant cost estimates have a variance of 15.9% which is within the ±20% range. |
| 3 | The main driver for the variance in the transmission line works relates to additional allowances for foundation works and excavation in hard rock that were identified in recent geotechnical investigations. |
| 4 | The main drivers for the variance in the substation works are:<br>• Significant increases in the forecast costs for the substation augmentation works and switchyard extensions at Dumaresq, Armidale and Tamworth due to additional allowances for switchyard extension civil works, additional allowance for hard rock excavation and excavation and disposal of contaminated soil<br>• Whilst there is highly comparable forecast costs for capacitor bank works at Armidale and Dumaresq, there is a 30% variance in estimated costs for the Tamworth capacitor bank works. GHD has been unable to verify the driver for this variance. |
| 5 | Data available to GHD on major electricity industry projects indicate owner costs typically range from 8% to 14% (project overheads). This is similar to road industry projects. |
| 6 | Supporting data from typical road industry projects shows an average per cent margin for project overhead of 11%. TransGrid has increased its project overheads from a margin of 8.5% at the PADR stage (estimates based on BAU allowances) to 14.8% in their CPA submission. |
| 7 | The GHD review of estimated costs has been based on the scope of works as presented by TransGrid and as discussed in section 4. GHD does not have sufficient information available to review any potential areas for cost saving in the implementation of the project. |

| Qualifications | |
|---|---|
| 1 | GHD considers the time constraints for tendering to achieve a more refined scope and the overall compressed delivery timeframe for this project would have resulted in associated risks being priced into tender responses. |

| Verification | |
|---|---|
| Major Plant | GHD can verify that TransGrid has undertaken an early engagement procurement process with vendors to achieve a market tested price and optimum technology solutions. |

| Verification | |
|---|---|
| Substation Work Packages | GHD identified a substantial increase in costs in the CPA Forecast for substation augmentation and switchyard extension works compared with the GHD comparative estimate. GHD has verified that these increased costs relate to additional civil works associated with the switchyard extensions, excavation in hard rock and excavation and disposal of contaminated soils.<br><br>GHD can verify that TransGrid has undertaken a procurement process working with substation panel members to identify detailed scope requirements for the works and to achieve a market tested competitive price outcome. |
| Transmission Line Work Packages | GHD can verify that TransGrid has undertaken a procurement process working with transmission panel members to identify detailed scope requirements for the works and to achieve a market tested competitive price outcome. |
| Project Overheads | GHD is of the view that the project overheads in the CPA estimate representing 12.9% of the total project costs are within an acceptable range of project margins. The level of overheads in the GHD comparative estimate is 11%.<br>We note that the increased allocation is due to the specific nature and risk profile for the project. GHD has verified that only TransGrid staff have the authority (under the Power System Safety Rules) to undertake works within energised HV substations so as to make safe areas of work for contractors. Also, only TransGrid staff are permitted to apply earths to transmission lines to allow for safe working for contractors. |
| CPA Capex forecast | The variance between the CPA estimate and the GHD comparative estimate is overall 17.3% at the bottom line, which is within our nominal ±20% range. GHD can, therefore, validate that this is a reasonable forecast of costs. |

# 6. Project schedule phasing

## 6.1 Project phasing and capex recognition

In this section, GHD has considered the proposed schedule included in the OFS which is the only detailed schedule which GHD has sighted. Any schedule changes based on the individual RFTs are which impact the expenditure profile submitted with the CPA is considered in the following sections.

The review considered the following documents:

- BOE 5.0 final estimate (BOE 5.0)
- QNI Capex Forecasting Methodology
- Specification & Contract No.1606 Transmission Line 83, 84 & 88 - QNI Uprating Works Part 1 General Works
- OFS-1529-2E Rev (OFS)
- Part 1 Technical Specification for Static Var Compensators for the Queensland Interconnection Upgrade
- Technical Specification - Q51 18 - RFQ#2 Detuned Shunt Capacitor Installations and harmonic Filter Systems
- Part 1 Technical Specification for Armidale 330kV Capacitor Bank and Asset Replacements
- Part 1 Technical Specification for Dumaresq 330kV Capacitor Banks and SVC Works
- Part 1 Technical Specification for Tamworth 330kV Capacitor Banks and SVC Works

The QNI Capex Methodology dated 20 December 2020 provides a summary of the key procurement and delivery milestones. The project has a practical completion date of September 2021 for the upgrade in the capacity of QNI. The key dates within this schedule as shown in the following table:

***Table 25 QNI Project - Key dates and milestones***

| Key Dates | Milestone |
|---|---|
| August – December 2019 | RFTs and supplier awards for major packages (SVC, Substation, cap banks, HV switchgear, transmission lines) |
| December 2019 | Submit the CPA - CAPR to AER, based on market pricing |
| March 2020 | AER's determination on the CPA |
| March 2020 | Substation construction works starts |
| March 2020 | Transmission Line construction works starts (Line 88) |
| July 2020 | Delivery of HV switchgear |
| November 2020 | TL88 works completed |
| March 2021 | TL 84 & 83 Line construction works start |
| March 2021 | Cap Bank commissioning completed |

| Key Dates | Milestone |
|---|---|
| April 2021 | Substation construction work completed |
| September 2021 | TL 84 & 83 Line construction works complete |
| September 2021 | SVCs commissioning completed |
| September 2021 | Project Practical Completion |

The above schedule is based on a construction start date of March 2020 and completion by September 2021. This generally aligns with the forecast capex supplied to GHD based on the RFT tender responses with 2020 spending of $74 million in 2020, $116 million in 2021 and $36 million in 2022. The capital spending in 2022 is after the scheduled practical completion, it is expected that this cost would include final payments to contractors after practical completion once defects are closed out as well as payment for spares.

The following table is a summary of the capex forecast per year based on TransGrid's forecast model.

***Table 26 - Capex forecast phasing***

| Asset Class | 2019 ($ million) | 2020 ($ million) | 2021 ($ million) | 2022 ($ million) | Total ($ million) |
|---|---|---|---|---|---|
| **Costs** | | | | | |
| Transmission Lines | 0.3 | 22.7 | 14.2 | 4.9 | 42.2 |
| Underground Cables | - | - | - | - | - |
| Substations | 1.1 | 51.8 | 96.9 | 29.8 | 179.6 |
| Secondary Systems | - | - | 1.0 | - | 1.0 |
| Communications (short life) | - | - | - | - | - |
| Business IT | - | - | - | - | - |
| Minor Plant, MV, Mobile Plant | - | - | - | - | - |
| Transmission Line Life **Extension** | - | - | - | - | - |
| Land and Easements | - | - | - | - | - |
| NSCAS Assets | - | - | - | - | - |
| **Total nominal** | **1.4** | **74.5** | **112.1** | **34.7** | **222.8** |
| **Total inflation adjusted** | **1.5** | **76.6** | **115.3** | **35.7** | **229.1** |

The OFS, dated 11 October 2019, provided the best information on the proposed program it also states a target completion date of September 2021 based on a CPA approval by February 2020.

It lists the following program critical path elements:

- Project CPA approvals
- Manufacture, delivery and commissioning of the SVCs
- Completion of transmission line 84 and 83

The key schedule risks stated in the OFS as of October 2019 were:

- Regulatory Approval timeframe assumes that there will be no contentious issues with the decision to proceed with this project option. However, should the CPA approval provide substantially lesser funding than 10% of the proposed project value, then this may cause delays to project delivery as further negotiations are required with the NSW Government for instructions to proceed.
- The project program is based on the assumption that the overall program will be determined by the time required to design, manufacture, install and commission two SVCs at two locations and that all other works can be delivered concurrently with the SVC design and manufacture. Staging requirements for the work may mean this is not possible. This option requires the procurement of a number of long lead time items of HV equipment, which will require a number of suppliers which may impact on delivery.

GHD reviewed a copy of this project risk register that was provided in the OFS and found the following types and number of schedule risk items:

- General risks associated with the delivery of capital projects
- The program may be delayed if regulatory approval provides significant shortfall in project funding
- The program may be delayed if outages cannot be obtained.
- The project may be delayed as a result of issues detailed in section 7 of the OFS (project delivery method and procurement / tendering approach)

From the analysis, GHD considers the greatest risk to schedule and hence the capital expenditure profile are in four key areas. These key risks will need to be managed as part of this project and in the event that these risks occur there could be significant impacts to the project completion. GHD considers these key areas of schedule delay risks would be more difficult for TransGrid to manage, control or mitigate:

- Multiple contractors / suppliers - TransGrid's procurement strategy creates the potential for schedule delays due to the number of contractors involved and interface issues occurring if a high level of clear and consistent communication and project management is not applied to this project. Furthermore, the project involves works at five substations and on three transmission lines and minor relocation works on several others.
- Brownfield nature of the works - The project involves works on brownfield substations and on existing transmission lines. This can create delays due to outage constraints or due to slower installation or commissioning processes.
- The criticality of the design, manufacturing, delivery, installation and commissioning of the SVCs. This is a highly specialised item of plant that TransGrid will be dependent on the supplier to be able to meet. In addition, the interface between the supplier and substation contractor will be important so that the SVC installation is not delayed by civil works issues.
- TransGrid Resourcing will be critical given the range of contractors, the number of sites and the need to provide operators for outages, commissioning personnel to oversee commissioning as well site personnel to manage OHS and design review personnel to approve designs.

The following sections look at the reasonableness of each of the schedules for each of the main packages.

## 6.2 SVC Schedule

The Technical Specification for Static Var Compensators Part 1 General and Ancillary Services states that the SCV schedule for the supplier is to be divided into 9 separable proportions:

- Separable Portion 1 provision of SVC design for Dumaresq

- Separable Portion 2 procurement, manufacturing, testing, delivery, installation and commissioning for Dumaresq
- Separable Portion 3 SVC building construction and supply for Dumaresq
- Separable Portion 4 - Optional portion - civil design and works for the SVCs for Dumaresq (GHD understands that this work is to be done by substation contractor
- Separable Portion 5 provision of SVC design for Tamworth
- Separable Portion 6 procurement, manufacturing, testing, delivery, installation and commissioning for Tamworth
- Separable Portion 7 SVC building construction and supply for Tamworth
- Separable Portion 8 - Optional portion - civil design and works for the SVCs for Tamworth (GHD understands that this work is to be done by substation contractor
- Separable Portion 9 - Optional portion - Supply of recommended spares for Dumaresq and Tamworth SVCs

TransGrid has nominated a number of key dates and milestones based on the separable proportions which include:

- Transport permit 3 months after the letter of acceptance
- Practical completion for sp1 and sp5 within six months of the letter or acceptance.
- Site documentation 8-10 weeks before the delivery of the SVCs
- Practical completion for sp2, sp3 30 June 2021.
- Practical completion for sp6 and sp7 on 30 July 2021.

The nominated practical completion allows for 2 months for any final approvals by TransGrid and AEMO for the SVCs to be energised which is considered sufficient.

GHD's opinion is that the schedule for the SVCs is achievable but tight given the work already undertaken by the SVC suppliers however this component of the project will require ongoing monitoring to ensure that it doesn't impact on the final practical completion date.

GHD has not seen the successful SVC's program so is unable to comment on any issues that the supplier may see with the required key milestones.

## 6.3 Substation Works Schedule

**Armidale Substation**

The Technical Specification for Armidale Substation Part 1 Capacitor Banks and Asset Replacements for the substation contractor is to be divided into 5 separable proportions:

- Separable portion 1 - 330kV cap banks (no.3, 4 and 6)
  - Cap banks delivered December 2020
  - Practical completion 30th of March 2021
- Separable portion 2 - 330kV cap banks (no.5)
  - Cap banks delivered January 2021

  - Practical completion 30th of March 2021
- Separable portion 3 - 400 V AC Distribution Replacement Works - practical completion 30th of June 2021
- Separable portion 4 - Asset Replacement Works - practical completion 15th of December 2021
- Separable portion 5 - 330kV Reactor Replacement Works
  - Reactor delivered to site - July 2020
  - Practical completion - 30th of October 2020

The substation schedule is dependent on the arrival of the switchgear, capacitor banks, reactors and other free issue material as well as the ability to organise outages or permits when required and the on time completion of the design.

Separable proportion 4 has a practical completion date, 15th of December 2021, after the overall QNI completion date of September 2021. It is therefore assumed that the section of this work to be completed after September 2021 is not required to achieve the additional QNI capacity. TransGrid will need to demonstrate this.

GHD has not seen the successful substation contractor's program so is unable to comment on any issues that the supplier may see with the required key milestones.

### 6.3.1 Dumaresq Substation

The Technical Specification for Dumaresq Substation Part 1 Capacitor Banks and SVC Works contractor is to be divided into the following eight key dates:

- Letter of Acceptance - December 2019
- Contractor granted possession of site - 16 weeks after the letter of Acceptance
- Capacitor Bank No.1 delivered to site - December 2020
- Capacitor Bank No.2 delivered to site - December 2020
- SVC Area Bench Works completed - September 2020
- 400V AC Distribution Replacement Works Completed - October 2020
- Dumaresq Substation Practical completion - August 2020

The substation schedule is dependent on the arrival of the SVCs, capacitor banks and other free issue material as well as the ability to organise outages or permits when required and the on time completion of the design.

GHD has not seen the successful substation contractor's program so is unable to comment on any issues that the supplier may see with the required key milestones.

### 6.3.2 Tamworth Substation

The Technical Specification for the Tamworth Substation Part 1 Capacitor Banks and SVC Works contractor is divided into three separable proportions with the following key dates:

- Separable Portion 1 - QNI Upgrade Works
  - Letter of Acceptance - December 2019
  - Contractor granted possession of site - 16 weeks after the letter of acceptance

  - Capacitor Bank No.1 delivered to site - December 2020
  - Capacitor Bank No.2 delivered to site - December 2020
  - Capacitor Bank No.3 delivered to site - December 2020
  - SVC Area Bench Works completed - October 2020
  - Practical completion - September 2021
- Separable Portion 2 - 400V AC Distribution Replacement Works Practical Completion - July 2020
- Separable Portion 3 - Asset Replacement Works - practical completion - December 2021

The substation schedule is dependent on the arrival of the SVCs, capacitor banks and other free issue material as well as the ability to organise outages or permits when required and the on time completion of the design.

Separable proportion 3 has a practical completion date of December 2021, after the overall QNI completion date of September 2021. It is therefore assumed that the section of this work to be completed after September 2021 is not required to achieve the additional QNI capacity. TransGrid will need to demonstrate this.

GHD has not seen the successful substation contractor's program so is unable to comment on any issues that the supplier may see with the required key milestones.

## 6.4 Capacitor Bank Schedule

GHD has not sighted any key milestone dates in the technical or commercial schedules for the capacitor banks. The only cap bank dates milestones that GHD sighted are the above mentioned substation milestones.

GHD has not seen the successful cap bank contractor's program so is unable to comment on any issues that the supplier may see with the required key milestones.

## 6.5 HV Switchgear Schedule

GHD has not sighted any key milestone dates in the technical or commercial schedules for the HV switchgear.

GHD has not seen the successful HV switchgear supplier's program so is unable to comment on any issues that the supplier may see with the required key milestones for the substation works.

## 6.6 Transmission Line Works Schedule

The Specification & Contract No.1606 Transmission Line 83, 84 & 88 divides the transmission lines works into three separable portions for the with the following key dates:

- Separable Portion 1 - Line 88 works SP1 is for procurement and transportation of 23 QSF/S1 poles structures on Line 88 and associated hardware that TransGrid is not supplying. Also included is the construction, installation and all necessary works of the first 23 QSF/S1 pole structures on Line 88 that need to be installed to increase the operating temperature to $120^0$C.
  - Possession of site - March 2020
  - Practical completion - May 2020

- Separable Portion 2 - is for the balance of uprating designs on Line 88 along with the procurement and transportation of poles and associated hardware that the TransGrid is not supplying. Also included in the construction, installation and all works necessary to complete the balance of uprating works on Line 88 that need to be installed to increase the operating temperature to 1200C.
  - Possession of Site - March 2020
  - Practical completion - November 2020
- Separable Portion 3 - is for the uprating design of Line 83 and Line 84 to increase the operating temperature to $120^0$C, along with the procurement and transportation of poles and associated hardware that TransGrid is not supplying. Also included are construction and installation and all works necessary of the structures on Line 83 and Line 84 that need to be installed.
  - Asset Replacement Works - Practical completion - December 2021

The transmission lines schedule is not dependent on the other major packages of works however it is dependent on some free issue line equipment from TransGrid. The transmission lines works are dependent on gaining the necessary outages which TransGrid have indicated they will only be able to gain during non-summer months hence the works are scheduled to occur during the winter periods of 2020 and 2021.

Separable portion 3 has a practical completion date of December 2021, after the overall QNI completion date of September 2021. It is therefore assumed that the section of this work to be completed after September 2021 is not required to achieve the additional QNI capacity. TransGrid will need to demonstrate this.

GHD has not seen the successful transmission line contractor's program so is unable to comment on any issues that the supplier may see with the required key milestones.

## 6.7 Transmission Line Relocations

The procurement and RFT documentation that outlines the line relocations for lines leaving Tamworth substation is included in the Technical Specification for Tamworth Substation. The Technical Specification outlines that this work is to occur in separable portion 1 before the installation of no foundations and erection of switchgear (due to the lines current location). This sequencing appears to be reasonable and the amount of work that the substation contractor is required to make for this to occur should not be too onerous.

## 6.8 Summary of project schedule phasing

Table 27 provides a summary of GHD findings related to the review of the project schedule phasing and capex recognition.

***Table 27 Project scheduling phasing - Findings, Qualifications and Verification***

| Findings | |
|---|---|
| 1 | GHD found that at a summary level the capital spending by year aligns with the project schedule noting that some spending occurs in 2022 after the practical completion date. It is assumed that this expedite relates to commissioning before the in service date and due to final contract payments after defect periods. |

| Findings | |
|---|---|
| 2 | Achieving the practical completion dates for the SVCs is critical to achieving the overall practical completion date of September 2021. This will require not only the SVC design, manufacture, install and commissioning of the SVCs to be completed on time but also the SVC foundations and civil works to be completed on time by the substation contractor. |
| 3 | Tamworth Substation - Separable proportion 3 Asset Replacement Works has a practical completion date of December 2021, after the overall QNI completion date of September 2021. It is therefore assumed that the section of this work to be completed after September 2021 is not required to achieve the additional QNI capacity. TransGrid will need to confirm this. |
| 4 | Transmission Line Separable proportion 3 - Lines 83 and 84 has a practical completion date of December 2021, after the overall QNI completion date of September 2021. It is therefore assumed that the section of this work to be completed after September 2021 is not required to achieve the additional QNI capacity. TransGrid will need to confirm this. |

| Qualifications | |
|---|---|
| 1 | GHD has not sighted a detailed project schedule since the OFS and therefore is unable to comment on whether the schedule has been updated to reflect responses from tenders. |
| 2 | GHD has not sighted any project schedules from the successful tenders for each package and is therefore unable to comment on whether the tender's schedules align with the required schedules from TransGrid. |
| 3 | GHD has not sighted any RFT information concerning the transmission lines relocations near Armidale substation and therefore, is unable to comment on whether the schedule from these works aligns with the overall schedule. |

| Verification | |
|---|---|
| 1 | The OFS Project Schedule key milestone dates are aligned to the Procurement Strategy dates as well as the key dates listed in the RFTs for the main project packages |
| 2 | The total capital spend profile spreadsheet aligns to the total capital project costs that TransGrid has supplied to GHD |

# 7. Procurement

## 7.1 Introduction

GHD is aiming to verify that the procurement process is reasonable to achieve the required outcomes for TransGrid for QNI and that it achieves efficient costs. For this to be achieved GHD has reviewed:

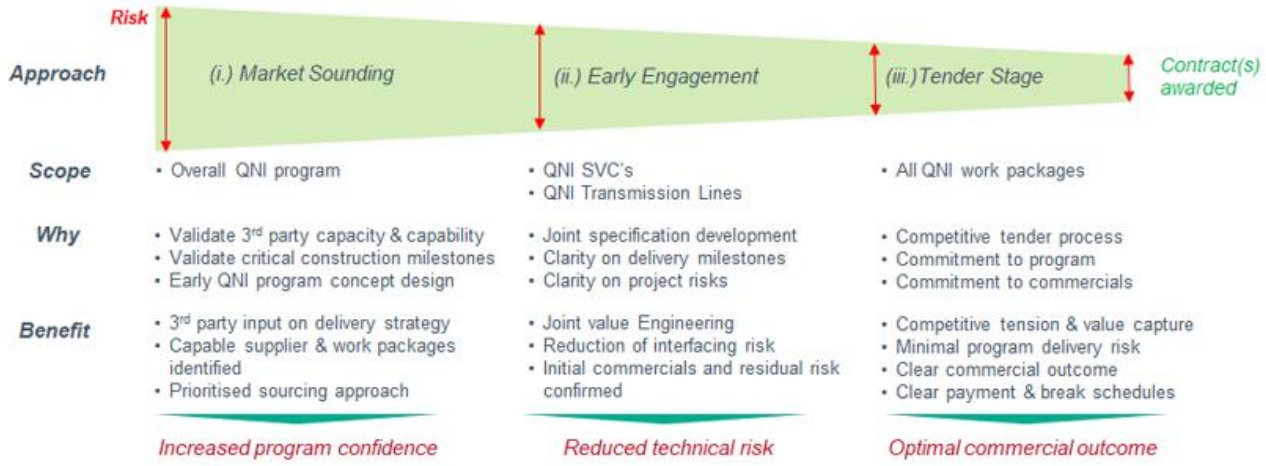
- The governance structure and the procurement process
- What early work was done on market testing
- What work was done with respect to the development of the procurement strategy and how this aligns to other projects of a similar size and nature
- How the tender process is aligned to the procurement strategy
- Tender timelines.

GHD has considered the following documents in our assessment of the procurement process:

- QNI Procurement Process Summary (in the Capex Forecasting Methodology)
- Early Contractor Involvement Agreement
- C1606 - Part 1 Section 1 - Technical  General Requirements Rev 1jl Transmission Line 83, 84 & 88 – QNI Uprating Works
- QNI Upgrade - Transmission Lines: Project Specific Design Requirements Revision No. 2.0
- Quotation Specification No. Q51/18 - RFQ #2 Detuned Shunt Capacitor Installations and Harmonic Filter Systems
- Technical Specification for Static Var Compensators for the QNI Upgrade at Dumaresq 330kV Substation and Tamworth 330kV Substation
- Technical Specification for Armidale 330kV Capacitor Banks and Asset Replacements
- Technical Specification for Dumaresq 330kV Capacitor Banks and SVC Works
- Technical Specification for Tamworth 330kV Capacitor Banks and SVC Works
- Substation concept drawings - single line diagrams and general arrangements

The QNI Procurement Process Summary (in the Capex Forecasting Methodology) outlines a three stage approach to procurement as indicated by Figure 6 below.

***Figure 6 Three stage procurement process***




It further details that TransGrid's procurement strategy is focusing upon the six key components of the project:

- SVCs
- Substations
- Transmission lines
- Capacitor banks
- HV switchgear
- Transmission line accessories.

Two models are being applied to procurement for these assets, namely:

- Design and Construct (D&C) contracts – transmission lines and substations work will be delivered via D&C contracts
- Directly procured assets – SVCs, capacitor banks, HV switchgear and transmission line accessories will be directly procured by TransGrid and have been subject to competitive tenders.

## 7.2 SVC market sounding and RFT

The QNI Procurement Process Summary (in the Capex Forecasting Methodology) indicates that a market sounding exercise was conducted in late 2018. The objective was to identify capable suppliers and to develop preliminary specifications, a work program and cost estimates. SVCs are a high value, specialised and low frequency purchase for transmission authorities such as TransGrid. As such the market sounding and early engagement approach for such an item is considered a prudent approach to managing risks associated with this component of the project.

After the market sounding phase, TransGrid adopted an early engagement approach. This is standard practice where a wide range of technology solutions may achieve superior performance and cost outcomes, and where the knowledge of the supplier is critical in developing solutions. The competitive pressure and collaborative approach, and outcome indicate efficient price and solutions have been achieved for the SVC packages. This component represents approximately 26% of the total QNI project costs.

TransGrid received indicative supplier budgetary and program offers in December 2018 followed by additional engagement early to mid-2019.

TransGrid issued the final specification for both SVCs to all three suppliers in August 2019, as part of a formal design and supply RFT process with tenders closing mid October 2019.

TransGrid received compliant tender submissions from the three SVC suppliers on a not-to-exceed pricing offer basis. Two suppliers offered “classic” SVC products and the third supplier offered a hybrid SVC product.

The SVC suppliers offered significant improvements between the original tender stage submissions and a subsequent best and final offer process. A key contributor to this was, as stated in the Capex Forecasting Methodology, was that TransGrid provided targeted feedback to each supplier about their individual tender submissions.

TransGrid has determined that the foundations and civil works associated with the SVCs are to be completed by the substation contractor. This is a practical approach however it will require additional coordination between the two contractors. TransGrid has developed an interface document to manage this arrangement.

## 7.3 Substation procurement

TransGrid used a competitive tender process to procure the substation works utilising its existing panel. This panel had previously been established using a competitive process in accordance with TransGrid’s business-as-usual procurement policies. TransGrid approached all four members of its substation panel. Following initial approaches to the substation suppliers, TransGrid assessed that:

- No supplier had the capacity to undertake the required works at all three sites concurrently. This was due to the requirement to achieve a September 2021 in service date
- A supplier could only undertake work at two sites concurrently in the available timeframe
- Having a single substation supplier dealing with a single SVC supplier at Dumaresq and Tamworth would provide significant logistical benefits.

TransGrid did not undertake an early engagement process for the substation works on account of:

- There is significantly less uncertainty associated with the works and supplier capabilities than was the case for the SVCs
- The panel had already undergone an evaluation process when it was established.

Between early May and mid-September 2019 TransGrid undertook a detailed specification exercise for each substation and prepared contracts to be released as part of the RFT process.

RFT responses were due on 8 November 2019 and TransGrid received three tender submissions for the Armidale and Dumaresq substations and four tender submissions for the Tamworth substation.

Design and construction contracts using existing substation panel suppliers are considered appropriate industry practice for transmission authorities.

TransGrid undertook separate value engineering workshops with the preferred suppliers with a view to reducing cost by further refining the design. This collaborative approach was aimed at optimising the cost and design of the substation works so that the final expenditure is prudent and efficient. GHD notes that this a common approach used for substation design and construct tendering processes. GHD has not sighted the

value engineering workshop outcomes or minutes and is therefore unable to comment on any efficiencies or cost reductions gained as a result of this process.

The best and final offer prices received from the preferred suppliers were lower than the prices in their original tender responses, although GHD has not sighted either the original or the revised prices. The approach taken is standard practice for brownfield projects to identify and minimise associated project costs and risks.

Included within the Tamworth RFT was the minor line relocation components for one 330kV and two 132 kV lines adjacent to Tamworth substation which is required as a result of the additional space requirements for the SVCs and cap banks.

As noted in GHD's review of scope and the capex forecast, TransGrid has indicated that detailed scope refinements have had an impact on increased costs. For substations, these impacts have occurred due to several factors. Separate to scope detail, it has been recognised that pricing received from the competitive tendering process were higher than expected due to the shorter than optimum tendering timeframes (for detailed scope definition), and the overall compressed delivery timeframe to achieve the September 2021 in service date.

## 7.4 Transmission line procurement

TransGrid deployed a design and construct approach for the transmission lines' component of the project.

TransGrid used a competitive tender process to procure the transmission line works utilising its existing panel. This panel had previously been established using a competitive process, in accordance with TransGrid's business-as-usual procurement policies.

TransGrid initially approached the members of the panel, who are each established suppliers of transmission line works. TransGrid short-listed two panel suppliers during August and September 2019 based on assessments of:

- Past and present service performance in delivering transmission line projects for TransGrid
- General capability and capacity in delivering transmission lines, including having regard for the suppliers' availability given their existing TransGrid and other client projects, and the risks of not meeting the September 2021 deadline.

One of the two tenderers did not provide a binding offer which could suggest that the scope of work has significant risks which this tenderer was not prepared to set a fixed price. This also suggests the preferred tenderer priced in the required margin for the high risks involved in brownfield transmission line works.

TransGrid undertook a value engineering workshop with the preferred supplier with a view to reducing cost by further refining the design. This collaborative approach was aimed at optimising the cost and design of the transmission line works so that the final expenditure is prudent and efficient. GHD has not sighted the workshop outcomes or the minutes so GHD is unable to comment on whether the workshop improved the efficiency or reduced the costs of the transmission lines works.

The preferred supplier was selected on technical and commercial considerations following submissions received on 28 November 2019.

This differed from the substation process where, in that process, the final two tenders were both engaged in workshops prior to providing best and final offers. The Capex Forecasting Methodology document does not state whether there were reductions in costs resulting from the workshop with the preferred supplier.

The approach taken is reasonable, and possibly due to time constraints. There may be some loss of efficient pricing due to the reduction in competitive pressures in the final value engineering workshop phase for the transmission line works.

Design and construction contracts using existing transmission line panel suppliers are considered appropriate industry practice for transmission authorities.

TransGrid has also indicated that pricing for the transmission line work packages received from the competitive tendering process were higher than expected due to the shorter tendering timeframe and compressed delivery timeframe for these works.

## 7.5 HV switchgear and transmission line accessories – period agreements

This project requires new HV switchgear at the Armidale, Dumaresq, Tamworth, Liddell and Muswellbrook substations. TransGrid will provide the HV switchgear as a free issue item to the suppliers who are undertaking the associated works at the relevant substations. The same approach has been adopted with transmission line accessories.

This is a common approach by Transmission authorities as switchgear and the associated plant is frequently procured by the authority and issued to the substation contractor.

## 7.6 Capacitor Bank Procurement

TransGrid deployed a directly procured asset approach for the capacitor banks.

TransGrid used a competitive tender process to procure the capacitor banks utilising its existing panel. This panel had previously been established using a competitive process in accordance with TransGrid's business-as-usual procurement policies. TransGrid established that there are two potential suppliers of capacitor banks for this Project on the panel that could achieve the in-service completion date of September 2021.

The RFTs that TransGrid issued to the two suppliers required their bids to be subject to the standard terms and conditions of the panel. Given this, the evaluation criteria for the tender related to the suppliers technical capacity and capability to deliver the capacitor banks to achieve the in-service date and price.

Two separate tenders, one each for Armidale and Dumaresq, were issued to the two existing capacitor bank suppliers on 11 October 2019. The two suppliers provided their best and final offers for both sites on 15 November 2019. TransGrid completed its tender evaluation process to determine the preferred supplier.

TransGrid has issued the tender for the Tamworth capacitor banks which is not as time critical as Armidale or Dumaresq.

## 7.7 Summary of TransGrid's procurement process

Table 28 provides a summary of GHD findings related to the review of the procurement project schedule phasing and capex recognition.

**Table 28 Project procurement - Findings, Qualifications and Verification**

| Findings | |
|---|---|
| 1 | TransGrid has adopted industry appropriate procurement strategies for the main project components, SVCs, capacitor banks, substations, lines, HV switchgear. |
| 2 | As noted in GHD's review of scope and the capex forecast, TransGrid has indicated that pricing received from the competitive tendering process for substations and transmission lines were higher than expected due to shorter than optimum tendering timeframes for detailed scope definition and due to the overall compressed delivery timeframe for this project. |

| Qualifications | |
|---|---|
| 1 | GHD have not sighted any information concerning the lines or substation value engineering workshops and so is unable to comment on any efficiencies or cost reductions which occurred as a result of the workshops. |
| 2 | GHD has not sighted any RFT responses or early engagement correspondence from suppliers and so is unable to comment on whether such correspondence or feedback has influenced the RFT process or the final contracts. |

| Verification | |
|---|---|
| 1 | GHD is able to verify that the RFTs for the capacitor banks, SVCs, substation and lines components are consistent with industry appropriate procurement strategies. Due to the compressed timeframes for tendering and project delivery necessary to meet a September 2021 in service date, the tenderers would have likely included a higher price margin for risks as a result. |

GHD Advisory

# Appendices

# Appendix A - Review of initial QNI estimate

## A.1 Purpose

The initial QNI project version 5 estimate was made available to GHD on 11 November 2019 and this estimate pre-dated TransGrid's finalisation of market tested pricing and more detailed review of project indirect costs. The version 5 estimated costs for the project was $176.48 million. These costs closely align to the original estimated costs of $175 million (which is a ±25% estimate) in the PADR (refer to Table E.1).

***Table 29 Summary Option 1A – assessed as part of the PADR***

| Option description | Indicative total transfer capacity (MW) | | Estimated capex ($M, Real 2019) |
|---|---|---|---|
| | Northward | Southward | |
| Option 1 A – Uprate Liddell to Tamworth lines and install new dynamic reactive support at Tamworth and Dumaresq and shunt capacitor banks | 690 | 1,120 | 175 |

Source: Expanding NSW-QLD transmission transfer capacity - Project Assessment Draft Report - 30 September 2019 – Table E1

We have prepared an independent comparative estimate based on the scope as defined with the version 5 estimate. This enabled a comparative estimate to be established against the specific scope of work for each package, in readiness for comparison to the final QNI CPA estimate.

The variance between the TransGrid version 5 estimates and the GHD comparative estimates for each of the transmission line and substation work packages are outlined in following sections.

In each instance, we focussed on the comparison of the standard building block rates for the specified scope of work in each package and adopted the project-specific costs as nominated by TransGrid in the version 5 estimate.

## A.2 Project specific cost factors

GHD has reviewed project allowances and factors applied in the initial version 5 estimate and then separately assessed the project development and works delivery costs developed from bottom up resourcing requirements applied by TransGrid in the development of their final CPA capex forecast. This section includes a discussion of the version 5 estimate to assist in understanding allowances that would have been applied for the original PADR estimates and the bottom-up method to determine project overheads in the final CPA estimate.

TransGrid applied a number of project-specific allowances in the version 5 estimate:

- Assessed Scope Allowance – this is interpreted as scope contingency (5-7% of work package cost).
- Ancillary Works Factor – this is interpreted as on site project costs and would be part of the Contractor's work package pricing in the CPA estimate.
- Remote Area Allowance - These costs are based on a percentage reported in the Rawlinson's Construction Handbook for site project management. The forecast costs are calculated as a

percentage multiplied by the construction cost of the works. This would reflect in the Contractor's work package pricing in the CPA estimate.

- Site Establishment - These allowances relate to the mobilisation of the construction crews, and the establishment and operation of the construction offices and laydown areas (and camps if necessary) for the duration of the construction work. This would reflect in the Contractor's work package pricing in the CPA estimate.

For the purposes of this review, GHD has assessed contractor prices for our building block comparative and treated the comparison as follows:

- The Ancillary Works Factor and Remote Area Allowances are included in building block costs for comparison with GHD's comparative rates
- The Assessed Scope Allowance is treated in comparison with GHD's consideration of project contingency and risks commensurate with the project estimate at the stage the estimate was prepared.

TransGrid applied the following Design and Network cost factors in the version 5 estimate:

- DCFE - Design Cost Factor Equipment
- DCFL - Design Cost Factor Labour
- NCFE - Network Cost Factor Equipment
- NCFL - Network Cost Factor Labour

These factors are calculated as a percentage of the total contract and plant estimate for each work package except for the lump sum for large specialised equipment, land and site costs.

GHD expects that the percentage values for each factor have been based on the historic substation and lines projects. For the purposes of this review, GHD has assumed these would reflect as owner's (TransGrid) costs in the CPA estimate.

To make the purpose of these allowances more self-evident, GHD is of the opinion that TransGrid should be more specific as the purpose of each allowance in the success estimates, particularly with regard to any allowances for design, project development and works delivery.

Table 30 summarises the owner's costs (equivalent to project development, works delivery and spend-to-date costs in the CPA estimate) based on the project specific allowances included in the current version 5 estimate. GHD's comparative estimate for the owner's costs is addressed in section 5.6.2 and determined a reasonable value of 11% of total project costs.

*Table 30 TransGrid version 5 owner's costs percentage of project costs*

| Activity | TransGrid estimate | | | GHD estimate | | |
|---|---|---|---|---|---|---|
| | Project ($M, Real 2019) | Owner's costs ($M, Real 2019) | % | Project ($M, Real 2019) | Owner's costs ($M, Real 2019) | % |
| Transmission Lines - Design & Network Cost Factors | 36.3 | 6.0 | 16.6 | 36.9 | 4.1 | 11.0 |
| Substations - Design & Network Cost Factors | 140.2 | 8.9 | 6.4 | 157.4 | 17.3 | 11.0 |
| **Total** | **176.5** | **14.9** | **8.5** | **194.4** | **21.4** | **11.0** |

The total TransGrid project owner's costs of $14.9 million contribute 8.5% of the total estimated costs, based on the version 5 estimate total value of $176.5 million (which is a ±25% estimate).

GHD considers that TransGrid has based past estimates (version 5 estimate) on BAU work of this type. These factors are used at the early stage of a project lifecycle. The factors used are aggregated against typically for projects over a whole portfolio of many projects. Therefore, the application of these factors may inherently downward bias the cost estimate of a single project.

The nature of the scope of work is brownfield, such as working in live substations and working near live overhead conductors with restricted outage windows. The work also involves several contractors (and their subcontractors) working across several work sites.

The owner is the principal contractor on the project, hence the safety and schedule management responsibilities in our opinion justifies a higher margin than was allowed in the version 5 estimate.

## A.3 Transmission line uprating works

GHD prepared an initial review of the scope of work from the OFS[9] which was later reviewed against the tender documents for scope refinement and a revise comparative estimate against the CPA final estimate.

**9. Scope of transmission line works**

From the OFS, the upgrading of Lines 83, 84 and 88 as part of the QNI Project includes the following design and construction works:

- Uprating Lines 83, 84 and 88 to 120ºC design temperature based on conventional remediation and associated tower strengthening
    - Mid-span structure and suspension/tension structure replacement using concrete poles
    - Structure strengthening
    - Landscaping (including achieving ground clearance)
    - Access and clearing

[9] OFS-1529-2E Rev 3 – Reinforcement of Northern Network – New SVC at Tamworth and Du.pdf

- Remediate existing structures that may be over-utilised on Lines 83, 84 and 88
    - Existing structure strengthening through the installation of new steel members
    - Footing strengthening
    - Access and clearing
- Line structure remediation works on Lines 83, 84 and 88
    - Insulator replacement on suspension/tension structures
    - Tower component/member replacement e.g. ladder, tower painting, earthing

We relied upon the scope of works as defined by the Option Feasibility Study - Basis of Estimate[10] and as detailed in the TransGrid Success version 5 estimate for this initial review.

**10. Line 83: 330 kV Liddell - Muswellbrook uprate**

The success version 5 estimate and OFS specified the following design and construction scope of works:

- Replacement of 1 off suspension structure with 48 m 80 kN four-piece concrete pole
- Delivery and off-loading of concrete pole
- Clearing and access of 0.72 km

**11. Line 84: 330 kV Liddell - Tamworth uprate**

The success version 5 estimate and OFS specified the following design and construction scope of works:

- Replacement of 6 off suspension structure and 1 off tension structure with (average) 46 m four-piece concrete poles
- Delivery and off-loading of concrete poles
- 5 off tower strengthening
- Clearing and access of 22.80 km
- Landscaping

**12. Line 88: 330 kV Tamworth - Muswellbrook uprate**

The success version 5 estimate and OFS specified the following scope of works:

- Replacement of 52 off suspension structure with (average) 46 m 80 kN four-piece concrete pole
- Delivery and off-loading of concrete poles
- 29 off tower strengthening
- Clearing and access of 64.00 km
- Landscaping

**13. Line 88: 330 kV Tamworth - Muswellbrook deviation**

The success version 5 estimate and OFS specified the following design and construction scope of works:

- 2 off additional Single Circuit tension steel lattice structures
- 330 metres of Mango ACSR/GZ 54/7/3.00 3-core 431 $mm^2$ conductor

[10] TransGrid*, BOE OFS-1529: Development of QNI Interconnector*, revision A, Appendix A, section A.1, p. 7 and Appendix B, p. 28

- 165 metres of OHEW - SC/GZ 7/3.75 77 $mm^2$
- 165 metres of OPGW - AA/ACS 48-core
- Clearing and access of 165 metres

**14. Line 968: 132 kV Tamworth 330 - Narrabri deviation**

The success version 5 estimate and OFS specified the following design and construction scope of works:

- 3 off additional structures (single pole structures) using 30m 60kN concrete poles
- 330 metres of Neon AAAC 19/3.75 3-core 210 $mm^2$ conductor
- 330 metres of OHEW - SC/GZ 7/3.75 77 $mm^2$
- 330 metres of OPGW - AA/ACS 48-core
- Clearing and access of 300 metres

**15. Line 97C: 132 kV Tamworth 330 - Tamworth 132 deviation**

The success version 5 estimate and OFS specified the following design and construction scope of works:

- 2 off additional structures (3 pole structures) using 30m 60kN concrete poles
- 330 metres of Oxygen AAAC 19/4.75 3-core 337 $mm^2$ conductor
- 330 metres of OHEW - SC/GZ 7/3.75 77 $mm^2$
- 330 metres of OPGW - AA/ACS 48-core
- Clearing and access of 275 metres

**16. Transmission line summary**

Table 31 shows a summary of the contract & plant estimated costs including basic design, site establishment, and design and network costs for the planned 330 kV and 132 kV transmission lines.

***Table 31 Transmission line comparative summary ($M, Real 2019)***

| Line | Element | TransGrid 5.0 Final ($M, Real 2019) | GHD ($M, Real 2019) | Variance GHD to TG (%) | TG contribution (%) |
|---|---|---|---|---|---|
| Line 83 uprate | Assessed scope Allowance | 0.03 | 0.03 | 0.0 | 3.1% |
| | Ancillary Works Factor | 0.09 | 0.11 | -18.2 | 9.2% |
| | Remote Area Allowance | 0.03 | 0.03 | 0.0 | 3.1% |
| | Site Establishment | 0.37 | 0.37 | 0.0 | 37.8% |
| | Support structures & line construction | 0.26 | 0.66 | -60.6 | 26.5% |
| | Contingency | 0.00 | 0.07 | -100.0 | 0.0% |
| | Project Overheads | 0.20 | 0.17 | 17.6 | 20.4% |
| | **Total** | **0.98** | **1.44** | **-31.9** | **100.0%** |
| Line 84 uprate | Assessed scope Allowance | 0.33 | 0.37 | -10.8 | 4.8% |
| | Ancillary Works Factor | 0.66 | 0.76 | -13.2 | 9.6% |
| | Remote Area Allowance | 0.10 | 0.12 | -16.7 | 1.5% |

| Line | Element | TransGrid 5.0 Final ($M, Real 2019) | GHD ($M, Real 2019) | Variance GHD to TG (%) | TG contribution (%) |
|---|---|---|---|---|---|
| | Site Establishment | 1.49 | 1.49 | 0.0 | 21.6% |
| | Support structures & line construction | 2.93 | 3.95 | -25.8 | 42.5% |
| | Contingency | 0.00 | 0.39 | -100.0 | 0.0% |
| | Project Overheads | 1.37 | 0.91 | 50.5 | 19.9% |
| | **Total** | **6.89** | **7.99** | **-13.8** | **100.0%** |
| Line 88 uprate & deviation | Assessed scope Allowance | 0.66 | 0.66 | 0.0 | 2.4% |
| | Ancillary Works Factor | 2.05 | 2.05 | 0.0 | 7.6% |
| | Remote Area Allowance | 0.40 | 0.40 | 0.0 | 1.5% |
| | Site Establishment | 4.48 | 4.48 | 0.0 | 16.6% |
| | Support structures & line construction | 15.35 | 13.93 | 10.2 | 56.8% |
| | Contingency | 0.00 | 1.39 | -100.0 | 0.0% |
| | Project Overheads | 4.08 | 2.92 | 39.7 | 15.1% |
| | **Total** | **27.01** | **25.83** | **4.6** | **100.0%** |
| Line 968 deviation | Assessed scope Allowance | 0.00 | 0.00 | - | - |
| | Ancillary Works Factor | 0.05 | 0.05 | 0.0 | 9.1% |
| | Remote Area Allowance | 0.00 | 0.00 | - | - |
| | Site Establishment | 0.07 | 0.07 | 0.0 | 12.7% |
| | Support structures & line construction | 0.27 | 0.40 | -32.5 | 49.1% |
| | Contingency | 0.00 | 0.04 | -100.0 | 0.0% |
| | Project Overheads | 0.16 | 0.08 | 100.0 | 29.1% |
| | **Total** | **0.55** | **0.64** | **-14.1** | **100.0%** |
| Line 97C deviation | Assessed scope Allowance | 0.16 | 0.16 | 0.0 | 18.2% |
| | Ancillary Works Factor | 0.07 | 0.07 | 0.0 | 8.0% |
| | Remote Area Allowance | 0.00 | 0.00 | - | - |
| | Site Establishment | 0.07 | 0.07 | 0.0 | 8.0% |
| | Support structures & line construction | 0.38 | 0.54 | -29.6 | 43.2% |
| | Contingency | 0.00 | 0.05 | -100.0 | 0.0% |
| | Project Overheads | 0.21 | 0.11 | 90.9 | 23.9% |
| | **Total** | **0.88** | **1.00** | **-12.0** | **100.0%** |
| **All lines** | **Overall Total** | **36.32** | **36.90** | **-1.6** | |

From this analysis, our findings are:

- The aggregate allocations for support structures & line construction for all five lines have a variance of -1.5% between the TransGrid version 5 estimate ($19.19 million) and the GHD comparative

estimate ($19.48 million). Overall, the variance is on the lower limit the nominal ±20% range for assessing reasonableness, with this being due to additional line works for structure component replacement and landscaping that GHD has not been able to independent value.

- The overall variance in the aggregate transmission line cost estimates between the Success version 5 estimate ($36.32 million) and GHD comparative estimates ($36.90 million) is -1.6%.

The variance in the estimated total costs for the five transmission lines is well within our nominal range of ±20%, and given there are additional costs for other minor other works that GHD cannot independently verify (such as individual tower steel member replacement and landscaping), we consider the TransGrid estimated costs for the transmission line work scopes to be reasonable and realistic.

## A.4 Substation works

### 17. Dumaresq substation

From the OFS, the proposed work at Dumaresq Substation as part of the QNI Project includes:

- Extension to existing Dumaresq Substation switchyard
- Installation of one 330 kV SVC, two 330 kV capacitor banks and associated switchbays
- Substation switchbay upratings

We relied upon the scope of works as defined by the Option Feasibility Study - Basis of Estimate[11], and detailed in the TransGrid Success version 5 estimate.

#### a) Major substation works

The Success version 5 estimate specified the following scope of works:

- Civil works for 14,690 $m^2$ extension to Dumaresq 330 kV switchyard, including site preparation, earthworks, drainage, earth grid, fencing, access roads, cable duct, control building and auxiliaries
- 1 off 330 kV -100/+350 MVAr SVC
- 2 off 330 kV 120 MVAr capacitor banks
- 1 off 330 kV transformer bay
- 2 off 330 kV capacitor bank feeder bays
- 3 off 330 kV feeder bays
- 3 off 330 kV busbar bays

GHD has assumed the site for the new switchyard is flat and readily accessed, allowing for site preparation, earthworks, earth grid, drainage, roadworks, fencing, cable duct, control building, ancillary services and site mobilisation as per our reference building block and include our assessment of reasonable owner's costs, risks and contingencies.

Given the specialised nature of the SVC, we have adopted the current lump sum allowance used by TransGrid for this asset, with the final value to be determined by the tender prices. From the version 5 estimate, we had concluded that this SVC would be acquired by TransGrid, and issued to the successful

[11] TransGrid, *BOE OFS-1529: Development of QNI Interconnector*, revision A, Appendix A, section A.1, pp. 7-8

contractor for installation. The lump sum allowance of $30 million represents approximately 59% of the estimated contract & plant cost for this work package.

GHD has relied upon market costs available to us for the capacitor banks, which are comparable to the allocations included by TransGrid in the version 5 estimate.

### b) Switchbay uprating

The success version 5 estimate specified the following scope of communications works due to the removal of line traps associated with the uprating of lines 83, 84 and 88:

- 2 off RAD2104 multiplexers in an existing rack
- 1 off 24p NMS switch

### c) Dumaresq Substation summary

Table 32 shows a summary of the contract & plant estimated costs including basic design, site management and operating costs for the planned works at Dumaresq Substation. This includes the extension of the switchyard, construction of the large specialised equipment and the switchbays necessary to provide the additional service capability required.

***Table 32 Dumaresq Substation comparative estimate summary***

| Element | TransGrid 5.0 Final ($M, Real 2019) | GHD ($M, Real 2019) | Variance GHD to TG (%) | TG contribution (%) |
|---|---|---|---|---|
| Assessed Scope Allowance | 2.76 | 3.18 | -13.2 | 4.7% |
| Remote Area Allowance | 2.08 | 2.39 | -13.0 | 3.5% |
| Site Establishment | 0.86 | 0.99 | -13.1 | 1.5% |
| Switchbays incl structures & foundations | 20.59 | 17.40 | 18.3 | 35.0% |
| Large Specialised Equipment | 30.00 | 30.00 | 0.0 | 51.0% |
| Contingency | 0.00 | 4.79 | -100.0 | 0.0% |
| Project Overheads | 2.58 | 7.24 | -64.4 | 4.4% |
| **Total** | **58.88** | **65.99** | **-10.8** | **100.0%** |

From this analysis, our findings are:

- The contribution of the lump sum allowances currently included in the TransGrid estimate for the large specialised equipment (SVC) is 51%; consequently, the final estimated cost for this substation augmentation work is highly contingent on the costs received from tenderers for this equipment.
- The GHD comparative estimate for the switchbays including the associated civil works required to extend the switchyard is highly comparable to the aggregate switchbay allowance in the version 5 estimate.

Therefore, with the high-level variance of -10.8% being well within the nominal ±20% range for assessing the TransGrid estimate of costs, we are satisfied that the overall estimated costs for the Dumaresq Substation are reasonable and realistic. The final cost estimate is highly dependent upon the final estimate of costs for the large specialised equipment.

## 18. Armidale substation

From the OFS, the proposed work at Armidale Substation as part of the QNI Project includes:

- Extension to existing Armidale Substation switchyard
- Installation of three 330 kV capacitor banks and associated switchbays
- Substation switchbay uprating

We have relied upon the scope of works as defined by the OFS - BOE[12], and detailed in the TransGrid success version 5 estimate.

In addition, to deliver the NCIPAP capacitor bank in conjunction with the QNI works, the separate scope for this augmentation includes:

- 1 off 330 kV capacitor bank and associated switchbay

### a) Major substation works

The Success version 5 estimate specified the following scope of works:

- Civil works for 6,829 $m^2$ extension to Armidale 330 kV switchyard, including site preparation, earthworks, drainage, earth grid, fencing, access roads, cable duct, control building and auxiliaries
- 1 off 330 kV 120 MVAr capacitor banks
- 2 off 330 kV 50 MVAr capacitor banks
- 3 off 330 kV capacitor bank feeder bays
- 1 off 330 kV busbar bays

GHD has assumed the site for the new switchyard is flat and readily accessed, allowing for site preparation, earthworks, earth grid, drainage, roadworks, fencing, cable duct, control building, ancillary services and site mobilisation as per our reference building block; and include the aggregate TransGrid lump sum allowances of $5.15 million (or 26% of total TransGrid costs) for assessed scope.

GHD has relied upon market costs available to us for the capacitor banks, which are comparable to the allocations included by TransGrid in the version 5 estimate.

### b) NCIPAP capacitor bank

The success version 5 estimate specified the following scope of works:

- 1 off 330 kV 120 MVAr capacitor banks
- 1 off 330 kV capacitor bank feeder bays
- 3 off 330 kV busbar bays

GHD has relied upon market costs available to us for the capacitor banks, which are comparable to the allocations included by TransGrid in the version 5 estimate.

[12] TransGrid*, BOE OFS-1529: Development of QNI Interconnector*, revision A, Appendix A, section A.1, pp. 7-8

### c) Switchbay uprating

The success version 5 estimate specified the following scope of communications works due to the removal of line traps associated with the uprating of lines 83, 84 and 88:

- 2 off RAD2104 multiplexers in an existing rack
- 1 off 24p NMS switch

### d) Armidale Substation summary

Table 33 shows a summary of the contract & plant estimated costs including basic design, site management and operating costs for the planned works at Armidale Substation. This includes the extension of the switchyard, construction of the large specialised equipment and the switchbays necessary to provide the additional service capability required.

***Table 33 Armidale Substation comparative estimate summary***

| Element | TransGrid 5.0 Final ($M, Real 2019) | GHD ($M, Real 2019) | Variance GHD to TG (%) | TG contribution (%) |
|---|---|---|---|---|
| Assessed Scope Allowance | 1.21 | 1.39 | -12.9 | 6.1% |
| Remote Area Allowance | 0.33 | 0.38 | -13.2 | 1.7% |
| Site Establishment | 0.54 | 0.62 | -12.9 | 2.7% |
| Switchbays incl structures & foundations | 14.79 | 16.29 | -9.2 | 74.2% |
| Large Specialised Equipment | 0.00 | 0.00 | - | - |
| Contingency | 0.00 | 1.68 | -100.0 | 0.0% |
| Project Overheads | 3.07 | 2.54 | 20.9 | 15.4% |
| **Total** | **19.93** | **22.90** | **-13.0** | **100.0%** |

From this analysis, our findings are:

- The aggregate contribution of the design, site establishment and on-site management and cost factors is $5.15 million (or 26%) of the total estimated cost for Armidale Substation.
- There is generally good agreement across the estimated costs for broad primary plant and switchyard works.

Therefore, with the high-level variance of -13% being within the nominal ±20% range for assessing the TransGrid estimate of costs, we are satisfied that the overall estimated costs for the Armidale Substation are reasonable and realistic. The final cost estimate is highly dependent upon the final estimate of costs for the large specialised equipment.

## 19. Tamworth substation

From the OFS, the proposed work at Tamworth Substation as part of the QNI Project includes:

- Extension to existing Tamworth Substation switchyard
- Installation of one 330 kV SVC, three 330 kV capacitor banks and associated switchbays
- Substation switchbay uprating

We have relied upon the scope of works as defined by the OFS - BOE[13], and detailed in the TransGrid success version 5 estimate.

**a) Major substation works**

The success version 5 estimate specified the following scope of works:

- Civil works for 23,430 $m^2$ extension to Tamworth 330 kV switchyard, including site preparation, earthworks, drainage, earth grid, fencing, access roads, cable duct, control building and auxiliaries
- 1 off 330 kV -100/+350 MVAr SVC
- 1 off 330 kV 120 MVAr capacitor banks
- 2 off 330 kV 60 MVAr capacitor bank
- 1 off 330 kV transformer bay
- 3 off 330 kV capacitor bank feeder bays
- 1 off 330 kV feeder bay
- 6 off 330 kV busbar bays

GHD has assumed the site for the new switchyard is flat and readily accessed, allowing for site preparation, earthworks, earth grid, drainage, roadworks, fencing, cable duct, control building, ancillary services and site mobilisation as per our reference building block; and include the aggregate TransGrid lump sum allowances of $6.98 million (or 11% of total TransGrid costs) for assessed scope.

Given the specialised nature of the SVC, we have adopted the current lump sum allowance used by TransGrid for this asset, with the final value to be determined by benchmarking the tender prices. From the version 5 estimate, we have concluded that this SVC may be acquired by TransGrid, and issued to the successful contractor for installation. The lump sum allowance of $30 million represents approximately 49% of the estimated contract & plant cost for this work package.

GHD has relied upon market costs available to us for the capacitor banks, which are comparable to the allocations included by TransGrid in the version 5 estimate.

**b) Switchbay uprating**

The success version 5 estimate specified the following scope of communications works due to increased transmission line ratings and the removal of line traps associated with the uprating of lines 83, 84 and 88:

- Replacement of 2 of 330 kV isolators
- Replacement of 540 metres of HV conductor
- Replacement of 60 metres of OHEW
- 2 off RAD2104 multiplexers in an existing rack
- 1 off 24p NMS switch
- 1 off DM1200 teleprotection terminal[14]

[13] TransGrid, *BOE OFS-1529: Development of QNI Interconnector*, revision A, Appendix A, section A.1, pp. 7-8

[14] A secure and uninterrupted supply of electricity is only possible with the help of comprehensive protection and control functions, which ensure the reliable operation of the power system. As the complexity and ratings of electrical power systems increase, so do

GHD has assumed the HV conductor is Mango ACSR/GZ 54/7/3.00 3-core 431 mm$^2$ and OHEW is SC/GZ 7/3.75 77 mm$^2$**.**

### c) Tamworth Substation summary

Table 34 shows a summary of the contract & plant estimated costs including basic design, site management and operating costs for the planned works at Tamworth Substation. This includes the extension of the switchyard, construction of the large specialised equipment and the switchbays necessary to provide the additional service capability required.

***Table 34 Tamworth Substation comparative estimate summary***

| Element | TransGrid 5.0 Final ($M, Real 2019) | GHD ($M, Real 2019) | Variance GHD to TG (%) | TG contribution (%) |
|---|---|---|---|---|
| Assessed Scope Allowance | 2.97 | 3.42 | -13.2 | 4.9% |
| Remote Area Allowance | 0.00 | 0.00 | - | - |
| Site Establishment | 0.92 | 1.05 | -12.4 | 1.5% |
| Switchbays incl. structures & foundations | 23.75 | 21.06 | 12.8 | 39.1% |
| Large Specialised Equipment | 30.00 | 30.00 | 0.0 | 49.4% |
| Contingency | 0.00 | 5.16 | -100.0 | 0.0% |
| Project Overheads | 3.09 | 7.47 | -58.6 | 5.1% |
| **Total** | **60.73** | **68.16** | **-10.9** | **100.0%** |

From this analysis, our findings are:

- There is generally good agreement across the estimated costs for broad primary plant and switchyard works.

Therefore, with the high-level variance of -10.9% being well within the nominal ±20% range for assessing the TransGrid estimate of costs, we are satisfied that the overall estimated costs for the Armidale Substation are reasonable and realistic. The final cost estimate is highly dependent upon the final estimate of costs for the large specialised equipment.

## 20. Liddell substation

The Success version 5 estimate specified the following scope of communications works due to increased transmission line ratings and the removal of line traps associated with the uprating of lines 83, 84 and 88:

- Replacement of 1x 330 kV isolator
- Replacement of 2x 330 kV earth switches
- 2 off RAD2104 multiplexers in an existing rack
- 1 off 24p NMS switch

also the demands on the protective devices and systems which have to protect them from damage and preserve power system stability. Protection relays in conjunction with communication links provide the best possible means of selectively isolating faults on HV lines, transformers, reactors and other important items of electrical plants. To prevent the system from failure and damage, the teleprotection system has to selectively disconnect the faulty part by transferring command signals within the shortest possible time.

### 21. Muswellbrook substation

The Success version 5 estimate specified the following scope of communications works due to increased transmission line ratings and the removal of line traps associated with the uprating of lines 83, 84 and 88:

- 2 off RAD2104 multiplexers in an existing rack
- 1 off 24p NMS switch
- 1 off DM1200 teleprotection terminal

## A.6 Summary of GHD initial comparative estimates

***Table 35 Summary of GHD comparative estimates***

| Activity | Name | Element | TransGrid ver 5 ($M, Real 2019) | GHD ($M, Real 2019) | Difference GHD to TG (%) |
|---|---|---|---|---|---|
| **Transmission lines** | Line 83 Uprate | Assessed Scope Allowance[15] | 0.03 | 0.03 | 0.0 |
| | | Ancillary Works Factor | 0.09 | 0.11 | -18.2 |
| | | Remote Area Allowance | 0.03 | 0.03 | 0.0 |
| | | Site Establishment | 0.37 | 0.37 | 0.0 |
| | | Support structures & line construction | 0.26 | 0.66 | -60.6 |
| | | Contingency | 0.00 | 0.07 | -100.0 |
| | | Project Overheads[16] | 0.20 | 0.17 | 17.6 |
| | | **Total** | **0.98** | **1.44** | **-31.9** |
| | Line 84 Uprate | Assessed Scope Allowance | 0.33 | 0.37 | -10.8 |
| | | Ancillary Works Factor | 0.66 | 0.76 | -13.2 |
| | | Remote Area Allowance | 0.10 | 0.12 | -16.7 |
| | | Site Establishment | 1.49 | 1.49 | 0.0 |
| | | Support structures & line construction | 2.93 | 3.95 | -25.8 |
| | | Contingency | 0.00 | 0.39 | -100.0 |
| | | Project Overheads | 1.37 | 0.91 | 50.5 |
| | | **Total** | **6.89** | **7.99** | **-13.8** |
| | Line 88 Uprate & Deviation | Assessed Scope Allowance | 0.66 | 0.66 | 0.0 |
| | | Ancillary Works Factor | 2.05 | 2.05 | 0.0 |
| | | Remote Area Allowance | 0.40 | 0.40 | 0.0 |
| | | Site Establishment | 4.48 | 4.48 | 0.0 |
| | | Support structures & line construction | 15.35 | 13.93 | 10.2 |
| | | Contingency | 0.00 | 1.39 | -100.0 |
| | | Project Overheads | 4.08 | 2.92 | 39.7 |

[15] GHD assumed scope risk and contingency

[16] GHD assumed owner's costs equivalent to Project Development and Works Delivery

| Activity | Name | Element | TransGrid ver 5 ($M, Real 2019) | GHD ($M, Real 2019) | Difference GHD to TG (%) |
|---|---|---|---|---|---|
| | | **Total** | **27.01** | **25.83** | **4.6** |
| | Line 968 Deviation | Assessed Scope Allowance | - | 0.00 | - |
| | | Ancillary Works Factor | 0.05 | 0.05 | 0.0 |
| | | Remote Area Allowance | - | 0.00 | - |
| | | Site Establishment | 0.07 | 0.07 | 0.0 |
| | | Support structures & line construction | 0.27 | 0.40 | -32.5 |
| | | Contingency | 0.00 | 0.04 | -100.0 |
| | | Project Overheads | 0.16 | 0.08 | 100.0 |
| | | **Total** | **0.55** | **0.64** | **-14.1** |
| | Line 97C Deviation | Assessed Scope Allowance | 0.16 | 0.16 | 0.0 |
| | | Ancillary Works Factor | 0.07 | 0.07 | 0.0 |
| | | Remote Area Allowance | - | 0.00 | - |
| | | Site Establishment | 0.07 | 0.07 | 0.0 |
| | | Support structures & line construction | 0.38 | 0.54 | -29.6 |
| | | Contingency | 0.00 | 0.05 | -100.0 |
| | | Project Overheads | 0.21 | 0.11 | 90.9 |
| | | **Total** | **0.88** | **1.00** | **-12.0** |
| **Substation**s | Dumaresq | Assessed Scope Allowance | 2.76 | 3.18 | -13.2 |
| | | Remote Area Allowance | 2.08 | 2.39 | -13.0 |
| | | Site Establishment | 0.86 | 0.99 | -13.1 |
| | | Switchbays incl. structures & foundations | 20.59 | 17.40 | 18.3 |
| | | Large Specialised Equipment | 30.00 | 30.00 | 0.0 |
| | | Contingency | 0.00 | 4.79 | -100.0 |
| | | Project Overheads | 2.58 | 7.24 | -64.4 |
| | | **Total** | **58.88** | **65.99** | **-10.8** |
| | Armidale | Assessed Scope Allowance | 1.21 | 1.39 | -12.9 |
| | | Remote Area Allowance | 0.33 | 0.38 | -13.2 |
| | | Site Establishment | 0.54 | 0.62 | -12.9 |
| | | Switchbays incl. structures & foundations | 14.79 | 16.29 | -9.2 |
| | | Large Specialised Equipment | - | 0.00 | - |
| | | Contingency | 0.00 | 1.68 | -100.0 |
| | | Project Overheads | 3.07 | 2.54 | 20.9 |
| | | **Total** | **19.93** | **22.90** | **-13.0** |
| | Tamworth | Assessed Scope Allowance | 2.97 | 3.42 | -13.2 |
| | | Remote Area Allowance | - | 0.00 | - |

| Activity | Name | Element | TransGrid ver 5 ($M, Real 2019) | GHD ($M, Real 2019) | Difference GHD to TG (%) |
|---|---|---|---|---|---|
| | | Site Establishment | 0.92 | 1.05 | -12.4 |
| | | Switchbays incl. structures & foundations | 23.75 | 21.06 | 12.8 |
| | | Large Specialised Equipment | 30.00 | 30.00 | 0.0 |
| | | Contingency | 0.00 | 5.16 | -100.0 |
| | | Project Overheads | 3.09 | 7.47 | -58.6 |
| | | **Total** | **60.73** | **68.16** | **-10.9** |
| | Liddell | Assessed Scope Allowance | 0.02 | 0.03 | -33.3 |
| | | Remote Area Allowance | 0.01 | 0.01 | 0.0 |
| | | Site Establishment | 0.05 | 0.06 | -16.7 |
| | | Switchbays incl. structures & foundations | 0.23 | 0.23 | 0.0 |
| | | Large Specialised Equipment | - | - | - |
| | | Contingency | 0.00 | 0.03 | -100.0 |
| | | Project Overheads | 0.14 | - | - |
| | | **Total** | **0.45** | **0.35** | **28.6** |
| | Muswellbrook | Assessed Scope Allowance | 0.01 | 0.01 | 0.0 |
| | | Remote Area Allowance | 0.00 | 0.00 | 0.0 |
| | | Site Establishment | 0.03 | 0.03 | 0.0 |
| | | Switchbays incl. structures & foundations | 0.08 | 0.07 | 14.3 |
| | | Large Specialised Equipment | - | - | - |
| | | Contingency | 0.00 | 0.01 | -100.0 |
| | | Project Overheads | 0.05 | - | - |
| | | **Total** | **0.18** | **0.12** | **50.0** |
| **PROJECT TOTAL** | | | **176.48** | **194.4** | **-9.2** |

From our review, we are of the opinion that:

- With the exception of the small work packages in monetary terms (line 83 uprate and the communications upgrades at Liddell and Muswellbrook substations), the variance between the TransGrid version 5 estimates and the GHD comparative estimates for the remaining work packages are all within the nominal ±20% range for assessing the reasonableness of the TransGrid estimate.
- The variance for the aggregate transmission line works is -1.6% and -11% for the aggregated substation works.
- The overall variance between the TransGrid version 5 estimated costs for the QNI upgrade is -9.2% to the GHD comparative estimates. we are satisfied that the TransGrid estimate for the scope of works as defined in the Options Feasibility Study is reasonable, and a starting point based on BAU costs for further consideration of any site-specific project costs and/or overheads that may be

identified during the tendering phase. We consider that the version 5 estimate has likely not fully considered brownfield costs that may be applicable.

## A.7 TransGrid's initial QNI cost estimate (PADR)

The purpose of this initial review was necessary to build a comparative estimate for the scope defined at the time of the PADR submission. The initial comparative estimate therefore closely aligns with the PADR capex, hence any significant changes to scope or unit costs could be tracked and investigated.

The version of the estimated costs available to GHD was the Success version 5 which estimated the total cost of $176.5 million. However, this included the Armidale Substation NCIPAP capacitor bank which is in the TransGrid's project for delivery, but not part of the QNI scope of work.

***Table 36 Summary Option 1A - assessed as part of PADR***

| Option description and estimate comparison | Estimated capex ($M, Real 2019) |
|---|---|
| Option 1 A – Uprate Liddell to Tamworth lines and install new dynamic reactive support at Tamworth and Dumaresq and shunt capacitor banks | 175 |
| Option 1A – TransGrid Success Version 5 estimate | 176.5 |

Source: Expanding NSW-QLD transmission transfer capacity - Project Assessment Draft Report - 30 September 2019 – Table E1

Table 37 shows a summary of the TransGrid estimates from the version 5 estimate against the work elements and capex defined in the CPA capex, and against the GHD comparative estimates which are based on our standard building block unit rates and our benchmark estimate for project development and works delivery costs.

***Table 37*** **TransGrid estimates vs GHD comparative estimates**

| CPA item number | Item description | TransGrid CPA est ($M, Real 2019) | GHD comparative estimate ($M, Real 2019) | TransGrid V5 est ($M, Real 2019) | % Variance CPA to GHD | % Variance CPA to TG V5 |
|---|---|---|---|---|---|---|
| 1 | SVCs | 57.0 | 60.0 | 60.0 | -5.0% | -5.0% |
| 2 | **SVCs** | 57.0 | **60.0** | **60.0** | **-5.0%** | **-5.0%** |
| 3 | Capacitor Bank - Armidale | 4.9 | 4.8 | 6.4 | 3.6% | -22.5% |
| 4 | Capacitor Banks - Dumaresq | 3.9 | 3.7 | 3.7 | 5.8% | 5.8% |
| 5 | Capacitor Banks - Tamworth | 6.1 | 4.8 | 4.8 | 28.6% | 28.7% |
| 6 | Substation - Armidale | 16.3 | 12.7 | 8.8 | 28.0% | 86.4% |
| 7 | Substation - Dumaresq | 30.4 | 22.5 | 20.0 | 35.2% | 55.6% |
| 8 | Substation - Tamworth | 35.2 | 23.4 | 20.0 | 50.5% | 77.5% |

| CPA item number | Item description | TransGrid CPA est ($M, Real 2019) | GHD comparative estimate ($M, Real 2019) | TransGrid V5 est ($M, Real 2019) | % Variance CPA to GHD | % Variance CPA to TG V5 |
|---|---|---|---|---|---|---|
| | Substation – Liddell[1] | 0.3 | 0.3 | 0.2 | - | 65.8% |
| | Substation – Muswellbrook[1] | 0.1 | 0.1 | 0.9 | - | 21.9% |
| 9 | **Substation and Capacitor Banks** | 97.4 | **72.3** | **63.3** | **34.6%** | **53.9%** |
| | Line 83: 330 kV Liddell - Muswellbrook uprate | - | 1.3 | 0.8 | - | |
| | Line 84: 330 kV Liddell - Tamworth uprate | - | 7.1 | 5.5 | - | |
| | Line 88: 330 kV Tamworth - Muswellbrook uprate | - | 21.1 | 21.3 | - | |
| | Line 88: 330 kV Tamworth - Muswellbrook deviation | - | 1.7 | 1.5 | - | |
| | Line 968: 132 kV Tamworth 330 - Narrabri deviation | - | 0.6 | 0.4 | - | |
| | Line 97C: 132 kV Tamworth 330 - Tamworth 132 deviation | - | 0.9 | 0.7 | - | |
| 10 | Transmission Line, 83, 84 and 88 Uprating works | 37.4 | | | - | |
| 11 | **Transmission Lines** | 37.4 | **32.7** | **30.2** | **14.5%** | **23.7%** |
| 12 | Substation HV Switchgear | 6.4 | 6.4 | 6.4 | -0.4% | -0.4% |
| 13 | Transmission Line Insulators | 0.2 | 0.2 | 0.2 | 189.5% | 189.5% |
| 14 | Secondary Systems Equipment | 0.9 | 1.4 | 1.4 | -37.3% | -37.3% |
| 15 | **Free Issue Items** | 7.5 | **8.0** | **8.0** | **-5.7%** | **-5.7%** |
| 19 | Dumaresq - Essential Energy and APD Cost | 0.1 | | | - | |
| 20 | Armidale - Essential Energy and APD Cost | 0.0 | | | - | |
| 21 | **Connection Cost[2]** | 0.1 | | | **-** | |

| CPA item number | Item description | TransGrid CPA est ($M, Real 2019) | GHD comparative estimate ($M, Real 2019) | TransGrid V5 est ($M, Real 2019) | % Variance CPA to GHD | % Variance CPA to TG V5 |
|---|---|---|---|---|---|---|
| | **Subtotal - Contracted services & Plant** | 199.4 | **173.0** | **161.4** | **15.3%** | **23.5%** |
| 16 | Internal Labour - Project Development | 9.5 | | | - | |
| 17 | Internal Labour - Works Delivery[1] | 17.0 | | | - | |
| 18 | **Internal Labour** | 26.5 | | | - | |
| 22 | Spend to Date | 4.4 | | | - | |
| 23 | **Spend to date** | 4.4 | | | - | |
| | **Subtotal - Project Overheads** | 30.9 | **21.4** | **14.9** | **44.5%** | **107.0%** |
| | **TOTALS** | **230.3** | **194.4** | **176.5** | **18.5%** | **30.6%** |

Note 1: Liddell and Muswellbrook substation costs are included in the CPA within TransGrid's internal labour works delivery costs

Note 2: Connection costs are shown as part of the "Subtotal – contacted services and plant" so that the "owner's costs" are separated for analysis and direct comparative purposes.

We have concluded from our comparative estimates that the market tested costs inputs within the CPA capex forecast for "Subtotal - Contracted Services & Plant" against the TransGrid version 5 estimate was:

- 23.5% higher than the TransGrid Success 5 estimate and similar (but not exactly) the project costs estimated in the PADR. This is much higher than the accuracy level of ±25% defined within the PADR submission.
- 15.3% above the GHD comparative estimate. This is within the ±20% of the GHD estimate range however we have further analysed the subcomponents in section 5.5.
- 53.9% variance for substation and capacitor banks above the TransGrid Success 5 estimate. This is in section 5.5.5.

The subtotal for "Project Overheads" indicates a significant increase in internal owner costs and was:

- 107% higher than the TransGrid Success 5 estimate and similar (but not exactly) the project costs estimated in the PADR. This is outside the accuracy of ±25% defined within the PADR submission.
- 44.5% above the GHD comparative estimates.

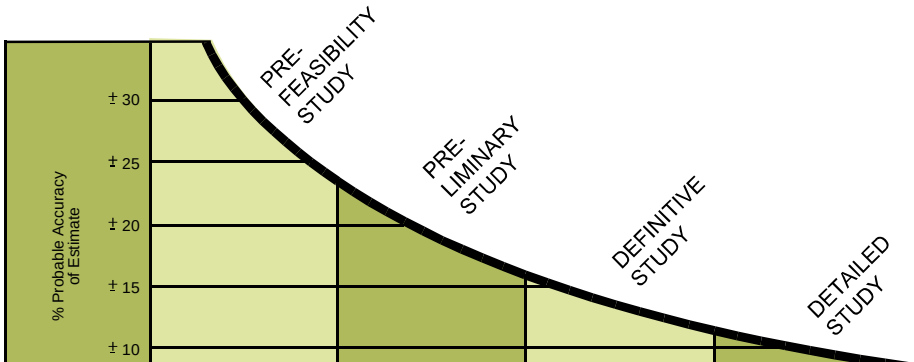
# Appendix B - Unit cost benchmarking methodology and assumptions

## B.1 Estimate accuracy for assessment

In assessing the QNI estimate, consideration must be given to the level of accuracy that can be achieved in generating indicative cost estimates for the network augmentation work packages identified.

The graph shown in Figure 7 indicates the levels of accuracy that can be expected for estimates prepared for capital works at various stages of project development. Due to the different levels of engineering input, and completeness in the design, there are various levels of accuracy that can be reasonably expected in forecasts.

***Figure 7 Standard estimate accuracy levels***




| Type of Estimate | Order of Magnitude | Preliminary | Definitive | Detailed |
|---|---|---|---|---|
| Provided Documentation | • Product capacity and Location<br>• Cost Data on Similar Projects<br>• Major Equipment List | • Preliminary Equipment List<br>• Engineering Line Diagram<br>• Plant Outline General Arrangement<br>• Maps and Surveys<br>• Bench Test Results<br>• Nature of Facilities | • Equipment Specifications and Vendor Quotations<br>• Construction Schedule<br>• Electrical One Lines<br>• Piping and Instrumentation Flow Diagrams<br>• Soil Data and Architect Features<br>• Site Survey and Labour Complete | • Bulk Material Specifications and Vendor Quotes<br>• Construction Specification and Sub Contractor Quotations<br>• Engineering Advanced Approximately 10% |
| Definition of Scope of Work | Conceptual | Approximate | Clearly Described Essentially Complete | Complete. Well Detailed |
| Estimating Procedure | Factoring | Combination of Factoring and Quantity Take-Off | Most Quantity Take-Off. Very little Factoring | Complete Quantity Take-Off |
| Use of Study | Comparison/ Rejection | Final Feasibility | Budget | Funding |

Table 38 shows the classification of estimates as defined in the AACE International *Recommended Practice No. 17R-97 Cost Estimating Classification System*.

***Table 38 AACE IRP No. 17R-97 generic cost estimate classification matrix[17]***

| Estimate class | Primary characteristic | Secondary characteristic | | | |
|---|---|---|---|---|---|
| | **Level of project definition**<br>Expressed as % of complete definition | **End usage**<br>Typical purpose of estimate | **Methodology**<br>Typical estimating method | **Expected accuracy range**<br>Typical +/- range relative to best index of 1 (a) | **Preparation effort**<br>Typical degree of effort relative to least cost index of 1 (b) |
| Class 5 | 0% to 2% | Screening or Feasibility | Stochastic or judgement | 4 to 20 | 1 |
| Class 4 | 1% to 15% | Concept Study or Feasibility | Primarily stochastic | 3 to 12 | 2 to 4 |
| Class 3 | 10% to 40% | Budget, Authorisation or Control | Mixed, but primarily stochastic | 2 to 6 | 3 to 10 |
| Class 2 | 30% to 70% | Control or Bid/Tender | Primarily deterministic | 1 to 3 | 5 to 20 |
| Class 1 | 50% to 100% | Check Estimate or Bid/Tender | Deterministic | 1 | 10 to 100 |

a. If the range index value of 1 represents +10/-5%, then an index value of 10 represents +100/-50%

(a) If the cost index of 1 represents 0.005% of project costs, then an index value of 100 represents 0.5%

The level of information available to us for assessing the augmentation work packages was typical of concept study level. Therefore, we consider our comparative estimates are based on 1% to 15% project definition and should be classified as Class 4 estimates with an accuracy of ±30%.

## B.2 Unit cost and capex forecasting assessment methodology

GHD has adopted a nominal criterion of ±20% as the first pass for comparing the TransGrid estimates with our reference comparative estimates for similar projects as a test for reasonableness.

Where there are is a variance between the TransGrid allowance for a network capacity augmentation project and our comparative estimate of less than ±20%, GHD will consider the TransGrid estimate to be reasonable and realistic, and no further detailed assessment will be undertaken.

For those TransGrid estimates where the variation is outside our nominal range, GHD reviewed any known project specific issues to identify the potential reasons, and where appropriate adjusted our switchbay configuration or switchyard construction factor.

[17] AACE International, *Recommended Practice No. 17R-97: Cost Estimating Classification System (TCM Framework: 7.3 – Cost Estimating and Budgeting)*, 12 August 1997, p. 2

## B.3 Data sources

The data sources used for the development of unit rates include:

- Costs for large specialised equipment from recent projects that TransGrid has undertaken
- Contract and procurement costs available for recent projects completed by electricity utilities
- Material cost data that may be obtained from suppliers
- Market cost data available through recent operational and capital expenditure reviews for electricity transmission utilities
- Recent asset valuations by GHD
- Cost data available in the public domain, including standard labour costs.

As such, these costs may not necessarily reflect the actual costs for individual asset material cost or installation costs held in the TransGrid Success estimating system.

GHD has also considered recent project or vendor cost information provided by TransGrid, where these have been market tested through a tender process, or can be demonstrated to be material costs provided directly by suppliers.

Our market data costs have been used in project cost comparative estimates for both substation and transmission works, and potential augmentation works to support the development of Renewable Energy Zones in Queensland and NSW. These building block costs have also been used as benchmarks for unit rate comparisons for capital and operational expenditure reviews for Australian electricity utilities.

## B.4 Unit rates

Our standard estimating unit rates have been based on the following:

- Our standard 330 kV and 220 kV switchbay configurations, and HV substation switchyard establishment components
- Our standard transmission line configurations for overhead lines on steel support structures (towers and poles)
- All steel support structures considered to have normal or typical foundations.

The following adjustment factor has been applied to the unit rates in our estimates:

- Remote area working allowance of 5% for labour costs.

## B.5 Inclusions and exclusions

GHD considers our comparative estimates to be class 4 (±30%), based on the level of project definition and network data available in the public domain.

Our estimates include consideration of the following:

- No contingency allowance in line with the TransGrid Success PEC Contract and Plant estimates
- No allowance for any overtime associated with an accelerated construction program based on a 6-day working week
- Project specific costs as nominated by TransGrid for design and development, site mobilisation and demobilisation, and site management and operation

- Land acquisition costs for new substations, as specified by TransGrid in the Success Contract and Plant estimates[18]

The following have been excluded from the estimates:

- No Goods and Services Tax (GST) allowance
- All new transmission lines are assumed to be on flat or undulating terrain, and therefore no terrain factors have been included
- No consideration of construction difficulties with transmission line support structure foundations
- No separate consideration of any transmission line crossings
- All substation sites to be extended have sufficient spare space available for the extension, the land is flat and suitable for construction, and has ready access
- No relocation works are required within existing substations for the proposed augmentations
- No switching costs associated with work on existing 330 kV and/or 220 kV lines
- No allowance for costs associated with line easements, other than any specific lump sum allowances included in the TransGrid Contract and Plant estimates.

## B.6 Comparative estimate approach

GHD has used market data available to develop standard building block costs for switchbays, substation establishment, transmission line structures and conductor stringing. These we have applied to each of the identified work packages, relying upon the defined scope of work as provided by TransGrid and modified to suit the SLDs and GAs provided in the QNI Interconnector Basis of Estimate.[19]

This generated an estimate for the primary and secondary plant based on a building block approach, and provided us with a benchmark of our understanding of typical market costs against the TransGrid estimated costs.

In generating the final project estimate for each work package, we have used the lump sum allocations nominated by TransGrid for project-specific costs such as:

- Project design and development
- Site mobilisation, management and operating costs
- Land acquisitions

Where TransGrid has included these project-specific costs in the Success estimates, GHD has adopted these values in our comparative estimates so that these particular allocations do not distort any comparison of the substation and transmission line primary and secondary building block estimates.

[18] Success version 5 estimates for transmission line and substation uprate, and substation augmentations

[19] TransGrid, *BOE OFS-1529: Development of QNI Interconnector*, revision A

# Appendix C - Glossary

| Term | Definition |
|---|---|
| AEMO | Australian Energy Market Operator |
| AER | Australian Energy Regulator |
| BAU | Business as Usual |
| CPA | Contingent Project Application |
| D&C | Design and Construct |
| DG1 | Project Commencement |
| DG2 | Project Approval |
| DNSP | Distribution Network Service Provider |
| FTE | Full Time Equivalents |
| ISP | Integrated System Plan |
| NEM | National Electricity Market |
| NCIPAP | Network Capability Incentive Parameter Action Plan |
| NOS | Need and/or Opportunity Statement |
| NOSA | Needs and/or Opportunity Screening Assessment |
| NSW | New South Wales |
| OER | Options Evaluation Report |
| OFS | Option Feasibility Study |
| OSA | Options Screening Assessment |
| PACR | Project Assessment Conclusion Report |
| PAD | Project Approval Document |
| PADR | Project Assessment Draft Report |
| PIP | Project Implementation Plan |
| PSCR | Project Specification Consultation Report |
| PSS | Project Scoping Study |
| QNI | Queensland – NSW Interconnector |
| QRET | Queensland Renewable Energy Target |
| RFT | Request for Tender |
| SSD | Scope and Specification Description |
| STATCOM | Static Synchronous Compensator |
| SVC | Static VAr Compensator |
| RIT-T | Regulatory Investment Test for Transmission |
| TNSP | Transmission Network Service Provider |
| WBE | Work Breakdown Elements |

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https://projectsportal.ghd.com/sites/pp07_01/transgridqni/ProjectDocs/Report/GHD Report for Transgrid - QNI - Scope Independent Verification and Assessment 8 Jan 830am.docx

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GHD Advisory

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