2015 Small Bridges Conference, Melbourne

Moreton Bay Rail Project

Bridges

one team ON TRACK

MORETON BAY RAIL

Moreton Bay Rail Project - Bridges

Authors: Debbie McMillan, Aurecon

Phil O'Connor, AECOM

Ardie Purwodihardjo, Golder Associates

Andi Lesmana, Golder Associates

Executive Summary / Abstract

The Moreton Bay Rail Project is a $1.15 billion project that primarily consists of a 12.6 kilometre rail line that connects the greater Brisbane rail network to the rapidly growing Moreton Bay region. The rail component of the project consists of 12.6km of track, structures and six new stations between Petrie and Kippa-Ring, and an upgrade of the rail between Lawnton and Petrie Stations. The project also includes a number of local road upgrades and a shared path that runs parallel to the rail line between Petrie and Kippa-Ring.

The project is scheduled to be operational in 2016. The project is funded jointly by the Australian Government, Queensland Government and Moreton Bay Regional Council. The project is being delivered by Thiess Contractors (Leighton Contractors) with design by the Aurecon-AECOM JV (lead consultant), Hassell (architecture and landscaping) and Golder Associates (geotechnical).

The bridges form a substantial component of the project and include:

- 4 rail bridges as part of the Lawnton to Petrie
- 7 rail bridges as part of the new rail line between Petrie and Kippa-Ring
- 6 road bridges as part of the upgrades to the local road networks
- 4 shared path bridges

Table of Contents

Table of Figures

1. Introduction

1.1 Background and History

Moreton Bay is located approximately14km from central Brisbane and is one of Queensland's most important coastal resources. It is a popular destination for recreation anglers and commercial seafood operators alike and it contains environmentally significant habitats and large areas of sandbanks.

Currently, the Moreton Bay region has a population in excess of 350,000, making it the third-largest local government area in Australia. It is also one of the fastest-growing areas in the country, with the population set to exceed 500,000 by 2031. The vast majority of the region's population use vehicular transport to travel to and from work each day, which leads to severe congestion on major roads and has a detrimental impact on the local economy and environment.

Proposals for a rail link between Redcliffe and Brisbane were first suggested at the end of the nineteenth century but it was not until the later part of the twentieth century that more serious studies were undertaken and land was purchased by the state government in anticipation of the new line.

From 1999 to 2003 the Queensland Government undertook the Petrie to Kippa-Ring Public Transport Corridor Study. In consultation with the community, this study assessed the feasibility and impact of the corridor including the mode of transport, the route and location of stations, future public transport usage, and the timing for construction

The study recommended a preferred alignment for the corridor, with the preferred transport mode being heavy rail. Heavy rail was found to be the most effective option as it could be an extension of the existing network, to Brisbane, it's capacity would better manage the expected increasing number of future public transport users, and the cost would be similar to that of light rail or busway, but with higher carrying capacity and faster journey times.

Based on this study, the Department of Transport and Main Roads (formerly Queensland Transport) commissioned the development of a Final Impact Assessment Study for the corridor. It concluded that the preferred corridor between Petrie and Kippa-Ring area was the original preserved corridor because the land was already owned by the State of Queensland with the alternative options disrupting existing land uses and habitat making management of environmental impacts difficult. It was also able to effectively accommodate six new railway stations.

In July 2010 an agreement was signed between the Australian Government, Queensland Government and the Moreton Bay Regional Council (MBRC) to build the project, with all three levels committing funds to the project. Figure 1 shows the project location and planned route of the new line.

Thiess Pty Ltd, a subsidiary of Leighton Holdings, was awarded the contract in August 2013 for the design and construction of the 12.6 kilometre rail link line with designers Aurecon-AECOM JV as the lead consultant and Golder Associates as the geotechnical consultant. Detailed design was substantially complete within a year of award of the contract and rail corridor construction works commenced in early 2014. Currently the rail corridor structural and civil works are approaching substantial completion with the new line expected to be operational in mid to late 2016. The various associated road works are planned to be completed in a staged manner with practical completion expected in late 2016.

Figure 1: Locality Plan

1.2 Project Aims and Benefits

Some of the benefits provided by the new Moreton Bay rail link are:

- A reduction in congestion of the road network, including the Bruce Highway, by providing a faster, economical and more reliable alternative to car travel to the Brisbane CBD with travel time savings of up to 15 minutes in peak periods.
- A reduction in carbon emissions by providing sustainable and active transport options – every full train on the new line will take about 600 cars off the road.
- The provision of improved access to major employment centres both within and outside the Moreton Bay region and help attract investment to the area and create business opportunities, which will in turn create a significant number of new jobs.
- The inclusion within the project of major improvements to the local road network providing access to the new stations and maintaining connectivity.
- The provision of a shared path for cyclists and pedestrians between Petrie and Kippa-Ring, providing connectivity along the corridor and providing access to all stations.

The project benefits listed above will be provided by inclusion of the following permanent works:

- Six new rail stations at Kallangur, Murrumba Downs, Mango Hill, Mango Hill East, Rothwell and Kippa-Ring.
- Train stabling facilities at Kippa-Ring.
- Connection to the existing North Coast Line railway infrastructure and the upgrade of 1.5km of rail between Lawnton and Petrie to provide additional track capacity for the future efficient operation of passenger services from the new Moreton Bay Rail line.
- Rail overpass bridges at Dohles Rocks Road, Goodfellows Road, Brays Road and the Bruce Highway.

- New rail overpass bridges at Capestone Boulevard and Mango Hill Boulevard, near Mango Hill East Station to enable for future connectivity across the rail line.
- A new road connecting the Duffield/Goodfellows Road intersection with the Russell Street/Dohles Rocks Road intersection providing access to Kallangur Station which will include a rail overpass for the new station access road.
- New rail overpasses over North Pine River, Yebri Creek, Freshwater Creek and Saltwater Creek.
- A new bridge structure at current road level will replace a section of Freshwater Creek Road between Halpine Drive roundabout and Brushwood Court allowing the rail line to pass underneath the road.
- A four-lane upgrade of Dohles Rocks Road between Bluegum Street and Ogg Road.
- Two new roads from Anzac Avenue providing access to Rothwell Station – one at Gynther Road and one west of Finnegan Street.
- A new access road connecting Cecily Street to Brays Road providing access to Murrumba Downs Station.

1.3 Project Areas

The Moreton Bay Rail project contains two quite separate project areas:

- Petrie to Kippa-Ring (P2K) - a “greenfield” portion which comprises the new 12.6km rail spur from existing Petrie Station to Kippa Ring; and
- Lawnton to Petrie (L2P) - a complex “brownfield” upgrade of the existing Queensland Rail corridor between Lawnton and Petrie Stations to facilitate the passage of northbound trains from the western side of the corridor across to the eastern side to access the new rail line, without reducing the capacity of existing freight and passenger services along the existing north coast line corridor.

1.4 Technical Criteria

The design requirements for the new works were detailed in the project Scope of Works and Technical Criteria (SWTC). This document covered all aspects of design required for the project, with bridges specifically dealt with in Appendix 24. The project required that a mixture of standard specifications be used for bridge design and construction as both road and rail bridges from significant elements of the project.

The SWTC required that road bridges be designed and constructed to the Department of Transport and Main Roads (TMR) design guidelines and standard specifications while the rail bridges were to be designed and constructed in accordance with Queensland Rail (QR) specifications and standard bridge drawings. This required some overlapping and substitution of standards between the two areas which had to be carefully managed both during design and construction.

Additional durability requirements over and above typical standards were also nominated in Appendix 24, with different requirements for concrete mixes being required for bridges which ultimately became the maintenance responsibility of MBRC compared with those owned and maintained by TMR and QR.

1.4.1 Functional requirements

1.4.1.1 Rail bridges:

- Two ballasted tracks typically
- Lawnton to Petrie: 300A rail loading + 12kPa for trackwork

- Petrie to Kippa-Ring: 200A rail loading + 12kPa for trackwork
- Maintenance walkway each side – 5kPa loading
- Rail Maintenance Access Road (RMAR) not required to cross bridges
- Rail over road clearances – generally 5.5m, but 6.5m at Bruce Highway and 6m at Dohles Rocks Road
- Anti-throw screens required on Bruce Highway and Duffield Road Rail Bridges
- Allowance for future widening of Dohles Rocks Road, Brays Road and the Bruce Highway without major works to the rail bridges.

1.4.1.2 Road bridges

- Reinstatement of Freshwater Creek Road with 3.5m wide footpaths on both sides
- Provision of a Cecily Street connection to Brays Road
- Provision of a new access road to Rothwell Station from Anzac Avenue
- Provision of new road bridges over the rail at Capestone and Mango Hill Boulevard to provide for connectivity to future residential developments
- SM1600 / HLP400 loading
- Upgrade of existing Gympie Road Bridge piers to current rail collision loading
- Road over rail clearance – 6.4m

1.4.1.3 Shared Path Bridges

- 4m clear shared path width
- 5kPa pedestrian loading
- Maintenance vehicle loading

2. Bridges Overview and General Design Approach

2.1 Overview

The bridges and retaining walls form a substantial component of the project and include:

- 4 rail bridges as part of the Lawnton to Petrie
- 7 rail bridges as part of the new rail line between Petrie and Kippa-Ring
- 6 road bridges as part of the upgrades to the local road networks
- 4 shared path bridges

2.1.1 Rail Bridges

2.1.1.1 Lawnton to Petrie

- North Pine River Rail Bridge
  - 315m long, 14 span, QR PSC slab and super T girder bridge
- Grade Separation Rail Bridge
  - 18.5m long, single span, post-tensioned through girder bridge
- Yebri Creek Up Main Rail Bridge
  - 45m long, 3 span, QR PSC slab bridge
- Yebri Creek Down Main Rail Bridge

- 45m long, 3 span, QR PSC slab bridge

2.1.1.2 Petrie to Kippa-Ring

- Dohles Rocks Road Rail Bridge
  - 110m long, 4 span, super T girder bridge
- Duffield Road Rail Bridge
  - 60m long, 2 span, super T girder bridge
- Goodfellows Road Rail Bridge
  - 32m long, single span, super T girder bridge
- Brays Road Rail Bridge
  - 100m long, 4 span, TMR deck unit bridge
- Bruce Highway Rail Bridge
  - 100m long, 4 span, super T girder bridge
- Freshwater Creek Rail Bridge
  - 150m long, 6 span, QR PSC girder bridge
- Saltwater Creek Rail Bridge
  - 325m long, 21 span, QR PSC slab bridge

2.1.2 Road Bridges

- Northbound Gympie Road Bridge
  - Pier Strengthening
- Freshwater Creek Road Bridge
  - 25m long, single span, TMR deck unit bridge
- Cecily Street Bridge
  - 57m long, 3 span, TMR deck unit bridge
- Capestone Boulevard Bridge
  - 78m long, 3 span, TMR deck unit bridge
- Mango Hill Boulevard Bridge
  - 84m long, 3 span, super T girder bridge
- Rothwell Access Road Bridge
  - Originally 16m long, single span, TMR deck unit bridge
  - Replaced with culverts during detail design

2.1.3 Shared Path Bridges

- Yebri Creek Shared Path Bridge
  - 45m long, 3 span, TMR deck unit bridge
- Bruce Highway Shared Path Bridge
  - 100m long, 4 span, super T girder bridge
  - Collocated on the rail bridge substructure
- Freshwater Creek Shared Path Bridge
  - 150m long, 6 span, TMR deck unit bridge
  - Collocated on the rail bridge substructure

- Saltwater Creek Shared Path Bridge
  - 326m long, 21 span, TMR deck unit bridge

2.2 Design Approach

Our design approach to the bridges aimed to:

- Include design improvements to ensure structures met SWTC requirements and are cost effective.
- Test design specifications and standards to innovate new solutions that further reduce cost while achieving functional requirements.
- Facilitate simple and repeatable construction methodologies
- Economical bridge structures generally adopt industry standard forms except in special circumstances.

2.2.1 Standard structural forms utilised

2.2.1.1 Superstructure

- Queensland Rail PSC slabs

These are precast pre-stressed concrete (PSC) members in the form of a two-cell box approximately 2m wide, as shown below. The depth varies from 400mm to 915mm, covering a span range of 3.5m to 15m. These PSC slabs, as they are designated, are very quick to erect as they are simply placed side by side on the headstocks, which have an upstand to restrain the slabs laterally. Two slabs are required for each track. There is no cast-in-place deck slab.

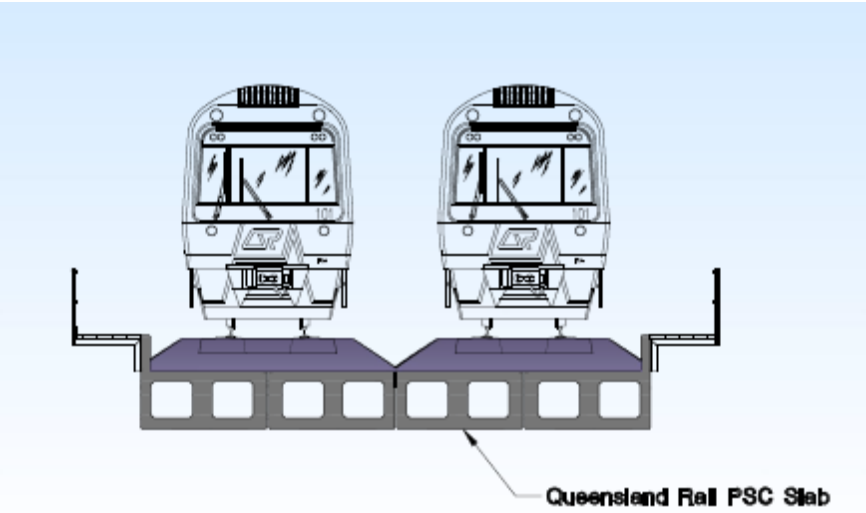


Figure 2: QR PSC Slabs

- Queensland Rail PSC girders

These are precast pre-stressed concrete girders with a 1290mm wide top flange, as shown below. The depth varies from 1100mm to 1600mm covering a span range of 15m to 25m. The girders are grouted to connect the top flanges and diaphragms, which are then transversely post-tensioned. Three girders are required for each track. There is no ‘cast-in-place’ deck slab. Queensland Rail girders cannot be skewed and are limited to set span lengths.

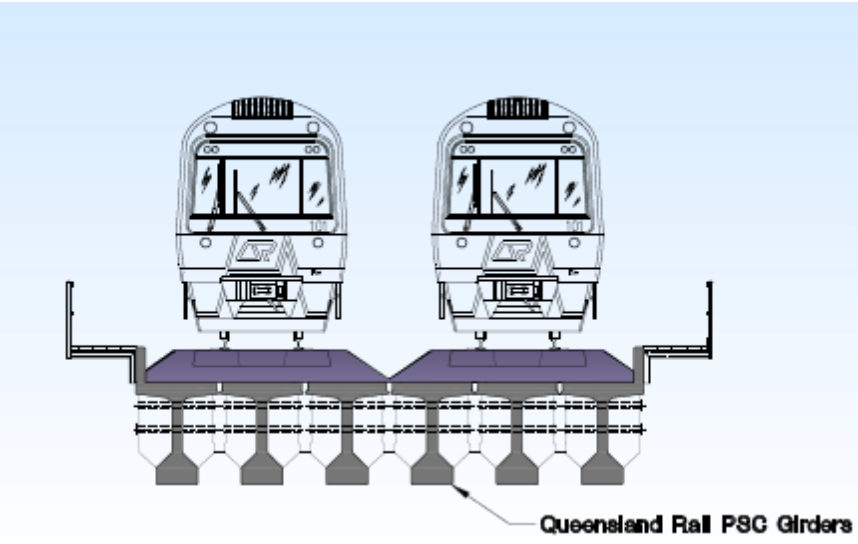


Figure 3: QR PSC Girders

- TMR deck units

These are precast pre-stressed rectangular sections, 600mm wide, with internal voids, as shown below. The depth varies from 400mm to 1050mm, covering a span range of about 10m to 25m for SM1600 highway loading, which is similar to 200A railway loading for these span lengths. The deck units must be connected by either grouting and transversely post-tensioning or casting a deck slab. Thirteen deck units are required for dual track rail bridges.

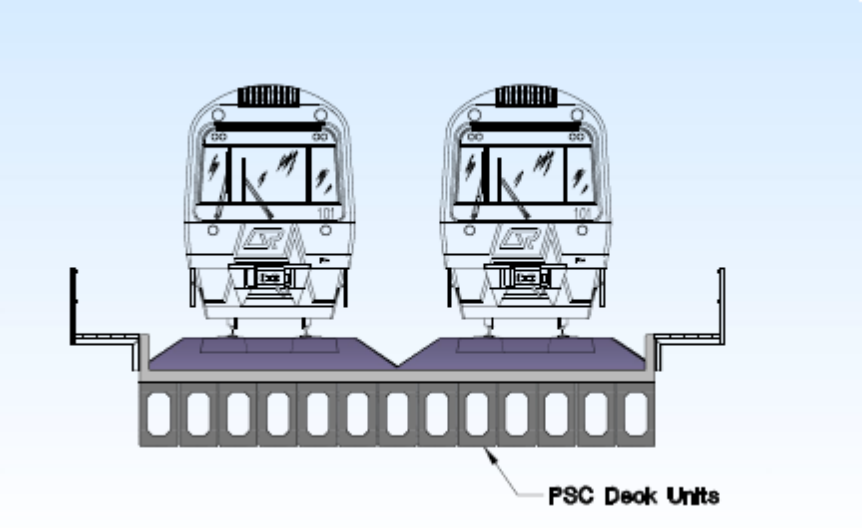


Figure 4: TMR deck units

- Super T girders

These are precast prestressed concrete beams in a u-shaped section with top flange wings of variable width, as shown below. The beams are available in either 1500mm or 1800mm depths plus a 'cast-in-place' slab covering a span range of about 25m to 35m for SM1600 highway or 200A rail loading.

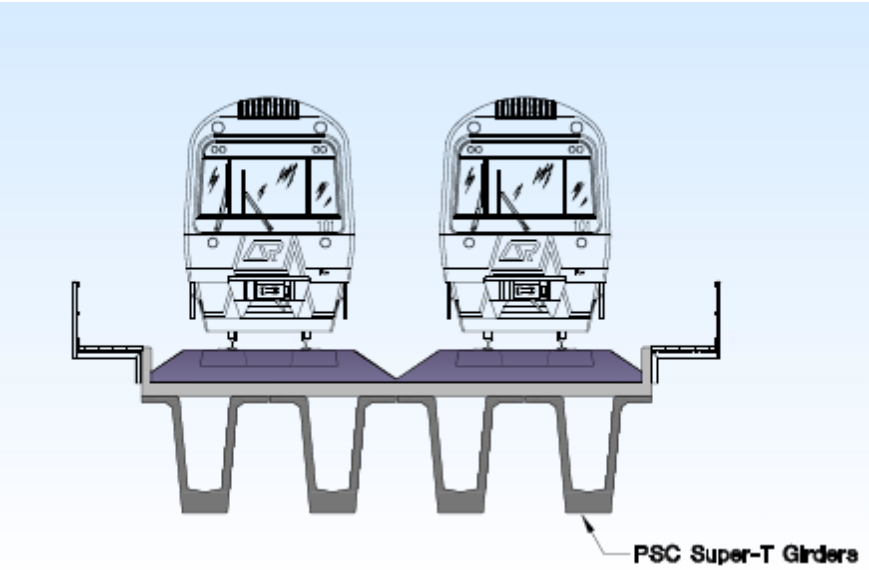


Figure 5: Super T girders

2.2.1.2 Abutments

- Spill-through abutment

These abutments, as shown below, have headstocks (supported by columns, or piles or footings) which in turn support the superstructure. Below the headstock the embankment 'spills-through' with a slope in front of the abutment. These abutments are economical but require a longer bridge length.

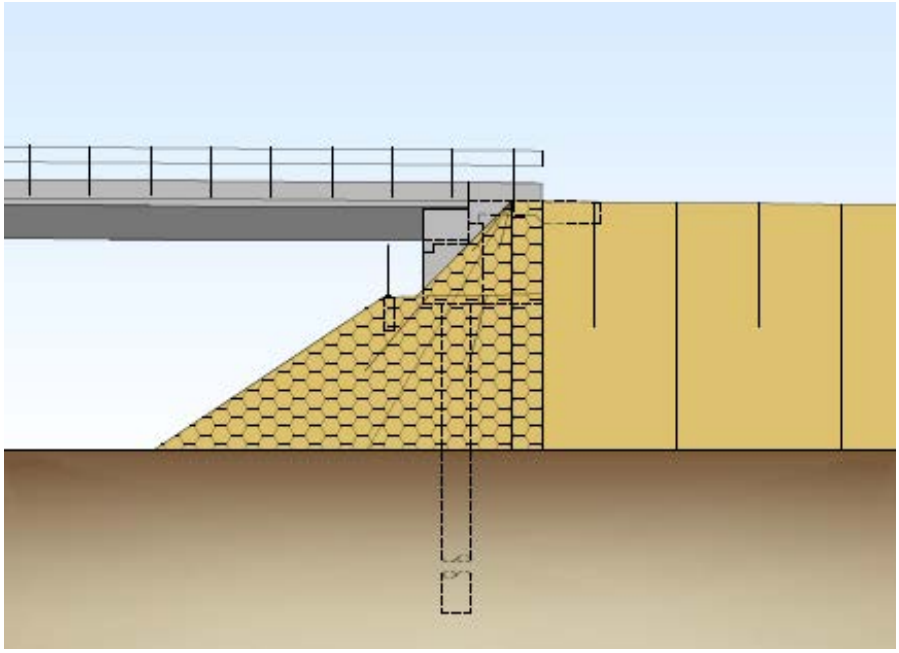


Figure 6: Spill-through abutment

- Retaining abutment

These abutments, as shown below, retain the soil behind the abutment by means of a vertical wall. An economic and widely used type of wall is a reinforced soil structure (RSS) in which facing panels are

held back by galvanized steel straps anchored in the compacted soil. These abutments are more expensive than spill-through abutments but savings accrue from the reduction in bridge length.

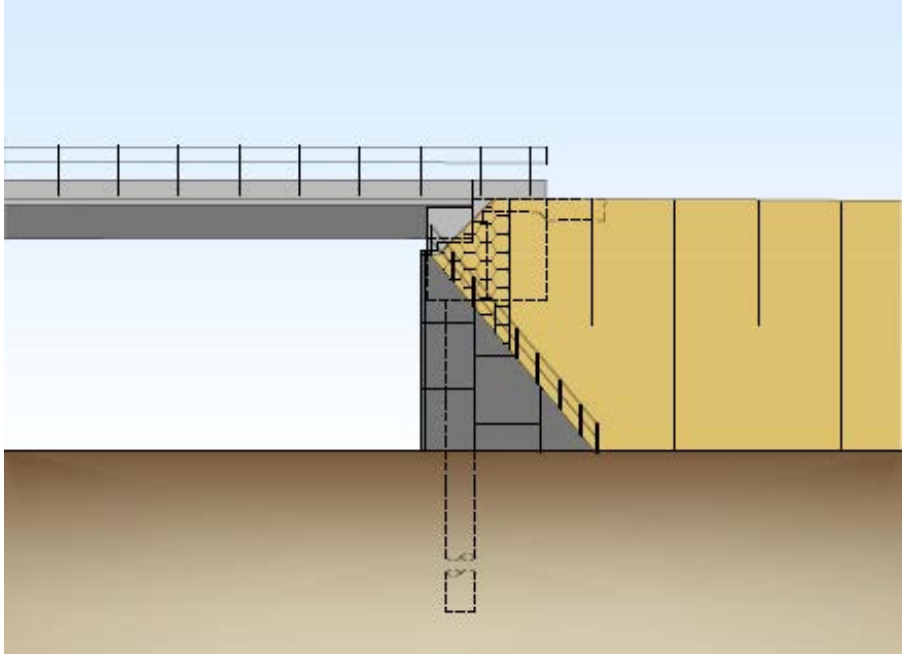


Figure 7: Retained abutment

2.2.1.3 Foundations

- Driven pre-stressed octagonal piles

These piles, with widths of 450mm up to 550mm and lengths up to about 22m, are driven into the ground by a large pile driving rig. Their capacity can be reliably measured on site using instruments to measure stress waves in the pile during driving. They are widely used by TMR and others.

- Cast-in-place piles

These piles have a range of diameters from about 500mm up to 2100mm and can be very deep if necessary. The piling rig drills a hole in the ground into which reinforcement and concrete are placed. The hole requires support in the form of steel liners which are left in place permanently for works done using TMR's specifications which was required for this project.

- Pad footings

This type of footing is typically provided where the material close to the surface has a strong bearing capacity and piling is therefore less economical.

2.2.2 General approach to selection of bridge type

The general approach to design of the rail bridges was based on the following broad principles:

- For rail bridges standard Queensland Rail precast slabs and beams were generally the preferred option unless the site conditions precluded the span lengths or superstructure depth
- For road bridges TMR deck units were preferred unless longer spans are required due to site constraints.
- Where vertical clearance was critical, lesser structure depth for rail bridges was obtained by using TMR deck units

- Where the rail is over the road, TMR deck units or Super T girders were typically used to provide a waterproof deck and prevent water from flowing onto the roadway.
- Bridge length was determined by:
  - Hydraulic requirements
  - Width of roads (including future widening and services corridors)
  - Urban design requirements adjacent to station entrances
  - Environmental conservation requirements
- Preference for shorter bridges.
- Selected driven or bored piles according to the surface and geotechnical conditions. Where appropriate, extended piles direct to the headstock without a pile cap
- Considered the group of bridges as a whole and looked for efficiencies in the widespread application of common dimensions and details
- Minimised the whole-of-life cost by selecting the option which had the least initial capital cost without significant increase in the net present value of future maintenance or replacement costs; with cognisance of the varying exposure conditions along the alignment
- Incorporated principles of safety in design throughout.

The significance of any of these factors varied from bridge to bridge.

2.2.3 Safety in design

Some of the key safety in design principles adopted for the bridges on the Moreton Bay Rail project were:

- Use of standard structural forms and construction methods
- Provided inspection walkways and safety harness anchors at spill-through bridge abutments (longer span required)
- Provided jacking shelves to facilitate future bearing replacement (wider headstocks required)
- Protected piers and RSS wall abutments for rail bridges over roads by concrete barriers
- Provided maintenance walkways on both sides of rail bridges, also suitable for emergency evacuation of train
- Provided additional walkway width for maintenance of signals or cabinets on the bridge, if any
- Provided guide rails to keep a derailing train on the bridge deck.
- Anti-throw screens provided on North Pine River, Duffield Road and Bruce Highway Rail Bridges to protect road users, and designed for future provision of throw screens on all other rail over road bridges.

3. North Pine River Rail Bridge

3.1 Background

Currently northbound passenger trains heading up the North Coast Line (Caboolture Line) travel on the western side of the corridor and therefore need to transition across to the eastern side of the corridor to enable their connection onto the line to Kippa-Ring. This transition occurs between Lawnton Station and Petrie Station – over a distance of approximately 1.5km.

The Caboolture Line is a critical component of Queensland Rail's suburban network. It carries passenger services, long-distance rail services using the North Coast Line and considerable freight traffic into and out of Brisbane. Prior to this project, only two tracks ran north of Lawnton Station and these ran across a single bridge over the North Pine River between these two stations. Part of this project involved upgrading of the corridor to provide a third and fourth track with this new trackwork being re-configured to accommodate the passage of trains to the Kippa-Ring Line, whilst not inhibiting the capacity of the existing north-south network of other services.

The existing track configuration contains numerous sub-standard curves, non-compliant turnouts and grading changes and operates at reduced speed at a number of locations as a result of this.

Figure 8: North Pine River Rail Bridge - Aerial View

The reference and tender designs for the North Pine River crossing utilised the existing 100 year old 2 track bridge and provided a new 2 track rail bridge immediately adjacent to the existing bridge to provide the additional NCL capacity. During the detail design process the rail alignment and design concept through the Lawnton to Petrie section of the project was revised and as part of this a new four track structure was introduced with the main advantages being:

- Disruption to current operational train services during new bridge works significantly reduced.
- Simple and more regular structural layout possible as constraint to match existing bridge pier locations is reduced.
- Reduced number of piers required following the removal of the existing bridge piers. This results in improved flood immunity.
- No reliance made on unknown durability of existing 1993 reinforced concrete substructure and driven piles, which was constructed to lower design standards.
- No reliance made on potentially overstressed piles in existing 1993 driven reinforced concrete piles.
- No potential for unforeseen problems due to construction works associated with modifications to an existing structure.

Figure 9: North Pine River Rail Bridge - Plan View

3.2 Structural Form

The North Pine River Rail Bridge (BR0150) has 14 spans is approximately 315 m long and carries the NCL over Leis Parade, Leis Park and the North Pine River. The general arrangement of the bridge and the span lengths are influenced by the geometry of the existing local road and the North Pine River. Following completion of the new bridge, train movements will be redirected onto the new structure so that demolition works may be undertaken on the existing bridge structure.

The rail bridge superstructure is typically a 16 m wide four track ballasted rail bridge. Spans 1 to 5 and 14 consist of standard 15m long Queensland Rail PSC slabs. Span 2 passes over Leis Parade and maintains the existing clearance to the road below. Spans 6 to 13 are longer and consist of 1800 mm deep, super T girders with a 200 mm in situ reinforced concrete deck. Standard Queensland Rail steel walkways are provided on both sides of the bridge with trunking to accommodate rail systems conduits. Cable access pits are provided at each abutment as well as mid-point on the bridge to facilitate pulling of cables. Provision of conduits for the Automatic Warning Systems (AWS) are incorporated at Spans 4 and 13. OHLE portals are supported from the piers where required.

The bridge piers consist of a headstock supported on 4 x cast in place piles / column. Wider headstocks were required at Piers 4, 7, 9, 11 and 13 to accommodate the OHLE portal frames. Piers 2 and 3 adjacent to Leis Parade are protected by concrete barriers.

The abutments also consist of a headstock supported on 4 cast in place piles. Pier 1 (Abutment A) has a spill-through embankment with hand packed grouted rock pitching with additional rip rap toe for scour protection. Pier 15 has a deepened headstock and wingwall to provide a retaining structure for the

adjacent shared path. Slope protection to the shared path batter slope is handpacked grouted rock pitching with an additional rip rap apron provided for scour protection.

Road works were required at Leis Parade and at the Leis Park Access Road to accommodate the new bridge works. Modification works to the internal access road within Leis Park were also required to accommodate the new bridge works. These works include alignment changes to a bitumen sealed track and new signage. The shared path on the northern bank of the North Pine River was also vertically realigned to match the shared path levels under the existing bridge in order to provide a minimum 2.5m clearance to the new structure.

3.3 Geotechnical Design/Challenges

Geotechnical data available during the design phase indicated complex geological conditions at the site, particularly at the southern end of the bridge (between Pier 1 to Pier 6) where a thrust fault zone with associated “disturbed” rock conditions was inferred. The thrust fault zone posed challenges during the design process and consequently the pile type was selected to address the challenges.

3.3.1 Geological conditions

According to the Geological Survey of Queensland Geological Map Commentary for the 1:100 000 Caboolture sheet, the alignment crossing of the North Pine River is situated at the confluence of three major geological formations, including (in order of decreasing geological age):

- **The Rocksberg Greenstone** *(Carboniferous to Permian age)* - consists of regionally metamorphosed (to greenschist facies) basic igneous rocks including basaltic tuffs and agglomerate, with minor intercalations of pelitic schist and phyllite.
- **The Kurwongbah Beds** *(Carboniferous to Permian age)* – comprise phyllite, slate, basic metavolcanics, minor chert, muscovite schist and rare siltstone. The Kurwongbah Beds structurally overly the Rocksberg Greenstone. Together, these two units make up the Kurwongbah Block.
- **The Landsborough Sandstone** *(Late Triassic to Early Jurassic age)* - comprises continental fluviatile sedimentary rocks including quartzose sandstone, feldspathic labile to sub-labile sandstone, siltstone, shale and minor conglomerate.

In addition to these three rock units, a localised area of the Brisbane Tuff is also indicated on the geological map, located just to the south-west of the North Pine River crossing. Quaternary alluvial (soil) deposits overly the bedrock formations in the vicinity of the river.

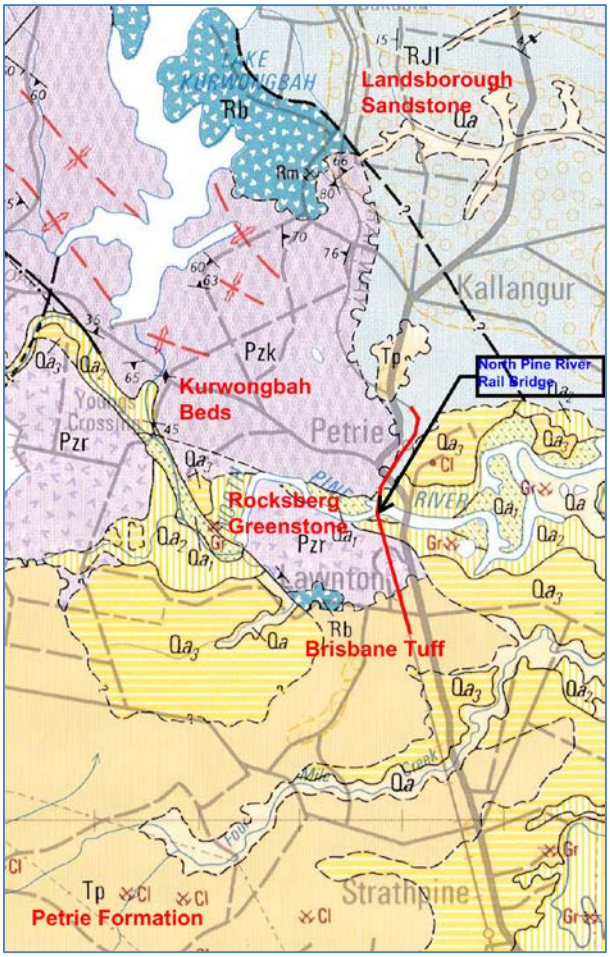


Figure 10: Regional Geology within the vicinity of North Pine River Bridge (extracted from Caboolture sheet 9443, 1:100 000 Geological Series Map first edition 1979)

3.3.2 Ground Conditions

On the southern side of the river in the vicinity of Leis Parade, an abrupt transition in the lithology and structure of the underlying bedrock is indicated by the boreholes. The transition (from south to north) is characterised by a change from:

- Moderately fractured metavolcaniclastic greenstone, which appears relatively unaffected by faulting or shearing (encountered in borehole behind Pier 1), interpreted to be part of the Rocksberg Greenstone formation; to
- A zone of variably (and in places intensely) sheared and fractured, intercalated greenstone, sandstone, siltstone and minor tuff, displaying often abrupt strength changes ranging from Extremely Low to High rock strength (as observed in boreholes at Piers 1 to 5). It is noted that in two of the boreholes within this zone (borehole at Piers 2 and 5), the greenstone is observed to overly the sandstone, with the transition between the two rock types being marked by a zone of intense shearing; to
- Apparently unsheared, moderately to widely fractured, typically Low to Medium rock strength sandstone (observed in boreholes at Piers 6 to 15), interpreted to belong to the Landsborough Sandstone formation.

Based on the prominence of intense shearing and deep weathering within the transition zone, and the repeated superposition of the Rocksberg Greenstone rocks over the Landsborough Sandstone, this zone is interpreted to have been formed by late stage (i.e. post early Jurassic) thrust faulting resulting in the 'stacking' of multiple thrust block (Figure 2).

From the distribution of the different rock types and shear zones within the boreholes, and the dip of the shearing fabric observed in the core, the thrust fault zone was interpreted to dip moderately to steeply towards the south-west. It was expected that the presence of the thrust zone will adversely affect subsurface conditions along the alignment over a distance of approximately 80 m to 100 m (US Ch 27510 to Ch 27590), resulting in rapid and difficult-to-predict changes in depth of weathering, rock strength and rock structure.

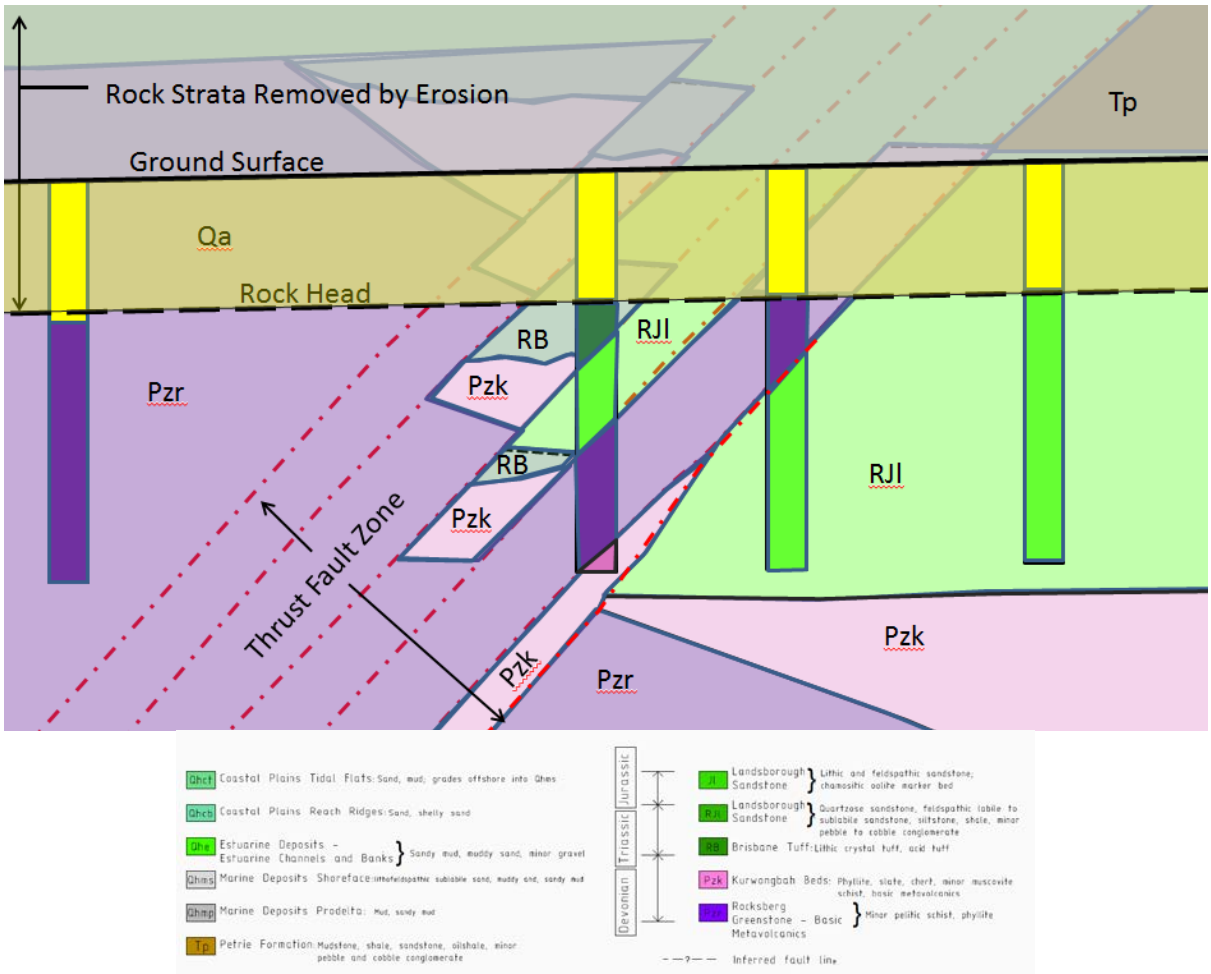


Figure 11: Sketch of Thrust Fault Zone at North Pine River Rail Bridge

3.3.3 Geotechnical Design

During the tender design process of BR0150, rock socketed bored piles were adopted as the preferred foundation type, considering the anticipated geotechnical conditions suggested by the limited available borehole investigation data. Further ground investigation (boreholes and geophysical surveys) were carried out during the detailed design. The results of additional investigation indicated complex geological conditions (thrust fault zone with weak and disturbed rock) are present beneath part of the proposed bridge alignment at an area around Pier 1 to Pier 6.

Following this finding, a driven pile option was considered within Piers 1 to 6. However, due to cost considerations this option was dismissed by the contractor, and the bored pile solution was again adopted for the affected Piers. At these Pier locations, sacrificial steel liners were provided to support the excavation to the top of rock and polymer slurry was used to support the excavation within the sheared and fractured rock. For the remaining piers located outside the thrust fault zone, rock socketed bored piles with sacrificial steel liners socketed into weathered rock were adopted.

Based on our assessment of the rock core from within the thrust fault zone, at some locations the rock quality to the depth of investigation (18.9 m penetration into rock) is quite poor with some cored material recovered as gravel and extremely low strength material. Due to the associated uncertainty in this area, the rock socket length was estimated by assuming a low end bearing resistance and greater reliance on socket shaft friction

4. Gympie Road Northbound Bridge Strengthening

4.1 Background

The existing Gympie Road crosses over the rail corridor on two separate structures, the southbound bridge, which was constructed in 2003 and the northbound bridge, which was constructed in the 1970s. The northbound bridge is lower and has an existing minimum clearance to the existing tracks of approximately 5.1m while the southbound bridge has an existing clearance of 6.4m.

For the MBR connection to the North Coast line, the project required the addition of two additional tracks under the Gympie Road bridges. Originally the northbound bridge was to be removed and replaced with a new bridge, however, due to road closure restrictions as well as land and road geometry constraints, an alternative design leaving both the northbound and southbound Gympie Road bridges in place was developed.

The alternative solution was to leave the existing northbound and southbound Gympie Road bridges in place and run the additional tracks through existing spans previously not utilised. The Queensland Rail structural gauge requirements could be met but the northbound bridge piers would require strengthening. It is envisaged that this arrangement may remain in place until the life expiry of the structure or the “future pathing” configuration is required for the quadruplication to Strathpine.

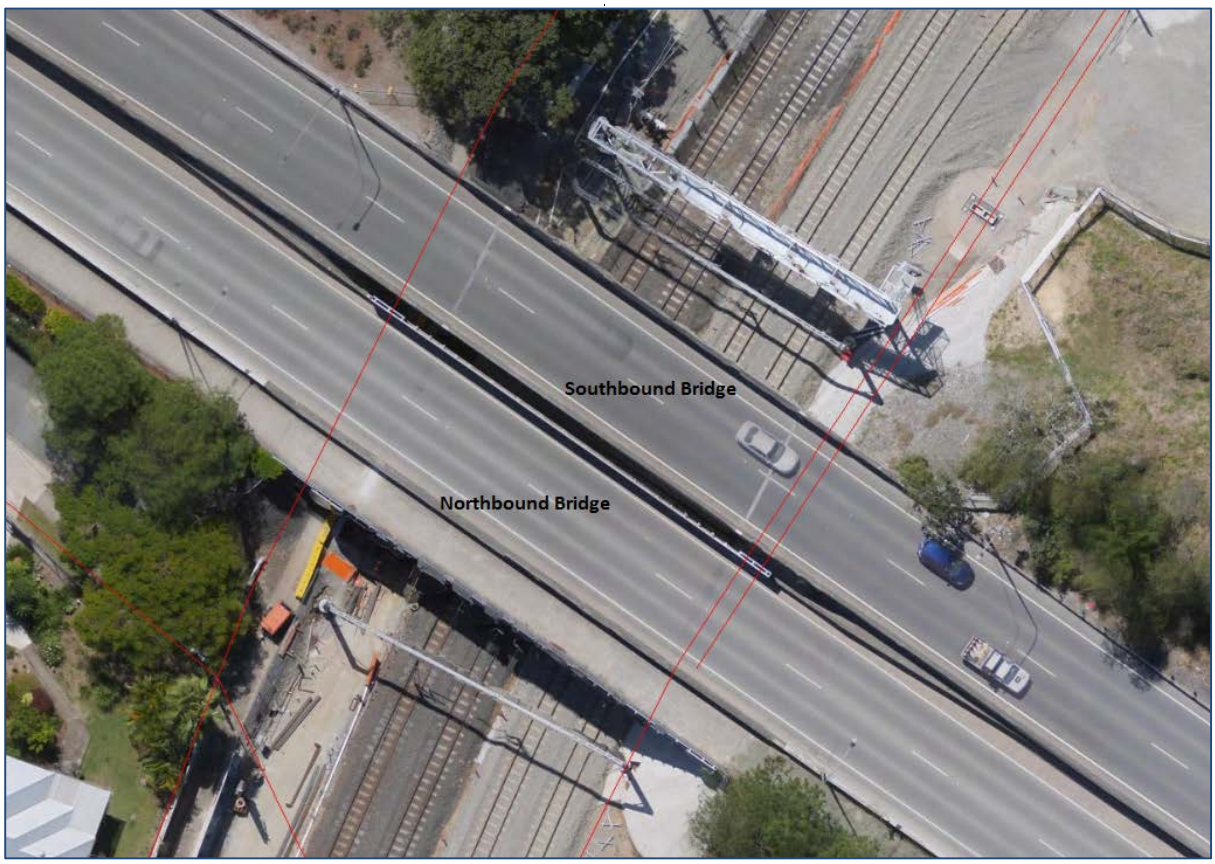


Figure 12: Gympie Road Northbound Bridge - Plan View

4.2 Design Standards

The northbound bridge was constructed in the 1970s when rail impact loads on overpass piers were much less than current day requirements. The piers on this bridge consist of three slender columns which will have very little capacity in the event of a train strike.

The adjacent southbound bridge was constructed in 2003 and was designed to the Austroads 1992 Bridge Code, which specifies rail collision loads which are more robust than 1970s' design standards but still less than the current bridge design standard AS5100-2004.

In addition to the Australian Standards, Queensland Rail introduced a technical standard CIVIL-SR-012 in 2007 which has even greater collision loads in some cases, such as when certain lateral clearances are not achieved.

The pier strengthening concept was developed for the northbound bridge to meet the following requirements:

- Capacity that meets AS5100 rail collision load requirements but not required to meet CIVIL-SR-012 requirements
- Minimal impact on existing NCL operational tracks Middle Road (MR) and Down Main (DM)
- Permanent works to be outside the structural gauge for all existing and future tracks under the bridge for the MBR and NCL.

As discussed above, it was proposed to leave the existing southbound bridge in place without pier strengthening on the basis that the drawings for the structure indicated that the piers were designed to 1992 Austroads Bridge Design Code.

4.3 Existing Northbound Bridge and Strengthening Works

The existing Northbound Bridge is comprised of four spans of transversely stressed deck units set on mortar beds or elastomeric strips. The deck units are connected to headstocks with dowels. The dowels are grouted except at Piers 1 and 4 where longitudinal movement is allowed. The abutments are spill-through and do not have relieving slabs. And the piers have three rectangular columns (914 mm x 381 mm) on a pile cap with a single line of piles. All piles are reinforced concrete 406 mm square precast piles.

The new strengthening works consisted of the following:

- Cutting the abutment batters to a steeper slope, with reinforced concrete slope protection, to enable access to the top of the pile cap.
- Provision of new 750 mm and 1200 mm diameter cast-in-place piles in Spans 2 and 4. Piles directly under the existing northbound bridge are limited in depth to 4.5 m maximum by piling rig headroom limitations.
- Provision of a 600 mm thick raft slab above the piles, connected to the adjacent pile caps by scabbling, drilling, and epoxying reinforcing bars. A further 700 mm deep ground beam is at each end of the raft slab and supports a relieving slab.
- The addition of blade piers at Piers 1, 2, 3, and 4, utilising steel plate permanent formwork, which surround the existing columns on two or three faces but do not extend beyond the face of the existing column on the rail side. The blades are connected to the columns, pile cap and headstock by scabbling, drilling, and epoxying reinforcing bars.
- The transmission of part of the collision load along the superstructure, by grouting up the previously ungrouted dowels in the deck units at Piers 1 and 4.

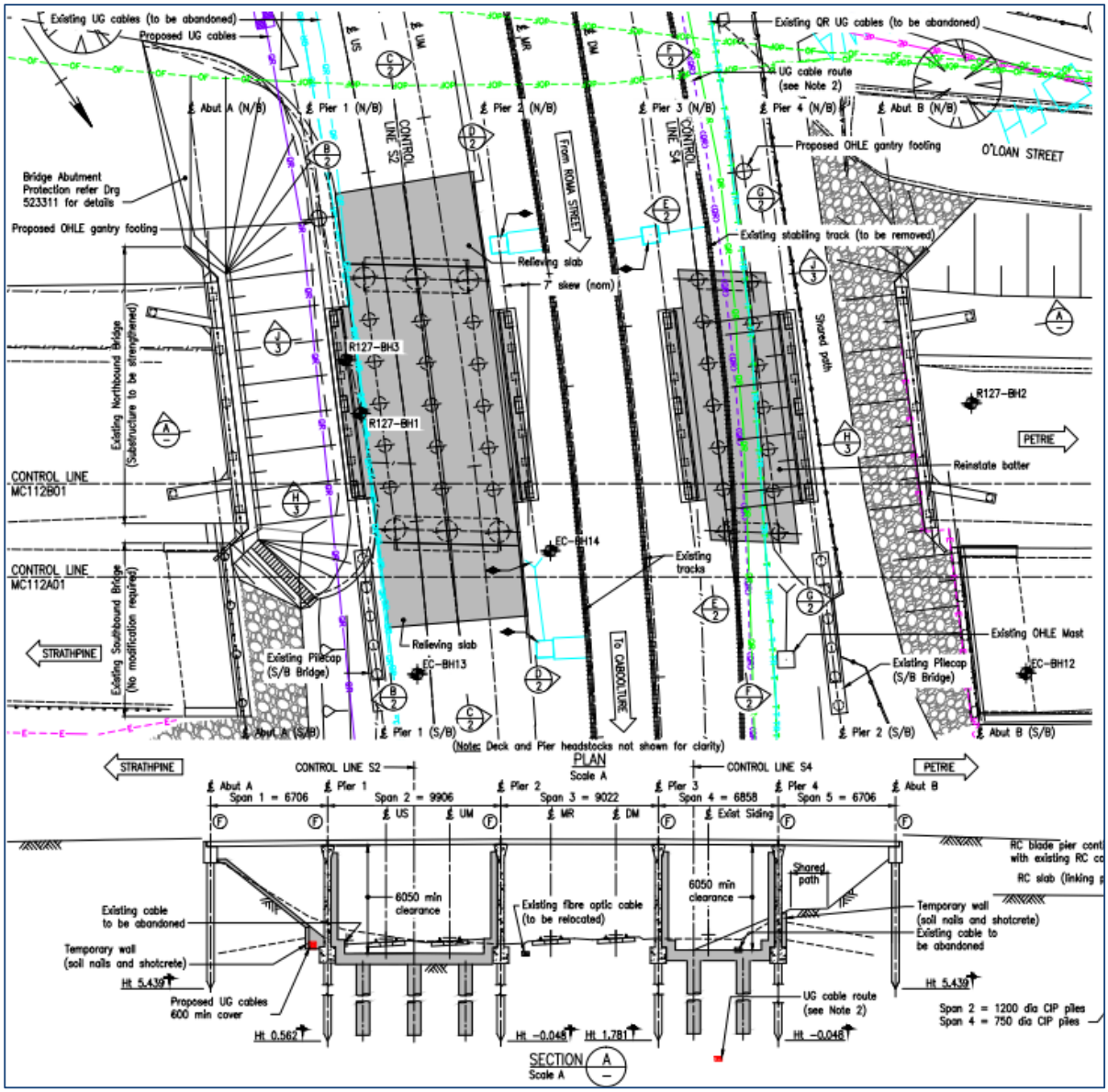


Figure 13: Gympie Road Northbound Bridge Strengthening – Plan and Sections

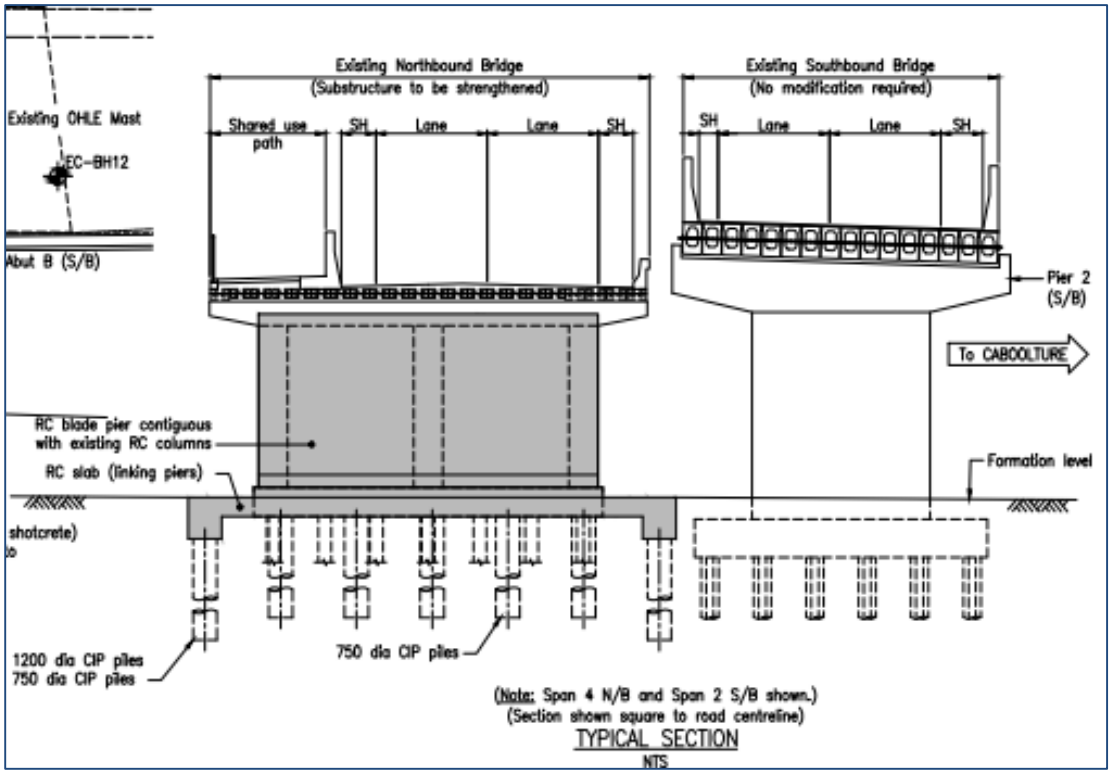


Figure 14: Gympie Road Northbound Bridge Strengthening – Typical Section

4.4 Design Method

A train collision imparting the design load is an ultimate limit state event. The bridge will not collapse, but it will be damaged. The parts of the bridge most likely to suffer serious damage are the existing piles, as discussed below.

The bridge was analysed using a three-dimensional model taking account of the existing and new structures. Dead loads of the existing structure were analysed by a model of the existing structure alone. The existing piers have an unfavourable arrangement in that the outermost pile is directly under the outer column and carries a much higher load than the adjacent pile. One significant finding of the analysis was that the maximum axial load in the existing piles from vertical loads is not increased. The extra dead load from the blade pier is offset by the superior distribution of live load amongst the existing pile group.

The existing piles are heavily loaded in bending from the collision load, even though this load is shared through the raft slab to the new piles, as well as to the superstructure. Soil springs providing horizontal restraint were provided by the geotechnical Engineers, Golder. For the collision load case, the stiffness of the existing piles was reduced to account for cracking. Analysis shows that the existing piles at Abutment A are overloaded geotechnically from current vertical loading, which is unaffected by the strengthening works. These piles have performed satisfactorily in service and are expected to continue to do so.

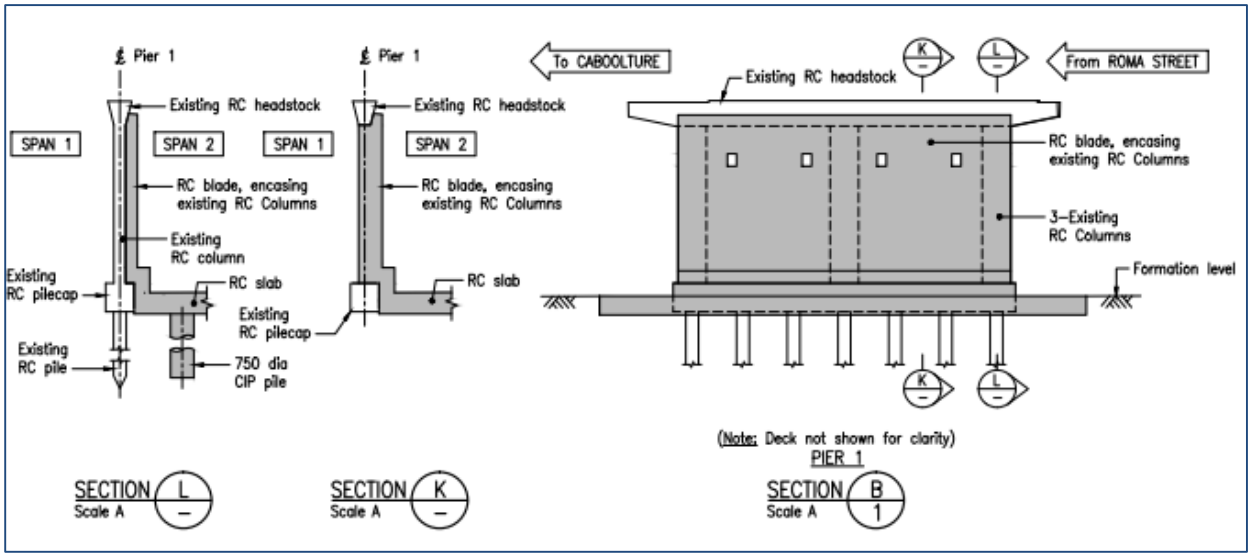


Figure 15: Gympie Road Northbound Bridge Strengthening – Pier 1 Blade Pier

4.5 Geotechnical Design/Challenges

As discussed above, one of the challenges for the pier strengthening of the existing north bound bridge was the limitation of the headroom of about 6.4m. This constraint poses a geotechnical challenge in designing the foundation system for the pier strengthening.

Based on discussions between the structural engineer, geotechnical engineer and construction team, and considering the favorable ground conditions which comprise mainly residual stiff to hard silty clay materials overlaying extremely weathered sandstone, a combination/hybrid footing solution was envisaged. In principal, the footing system adopted comprised existing 400 mm square reinforced concrete (RC) driven pile, additional 750 mm and 1200 mm cast-in place (CIP) bored piles, and 600 mm thick RC slab. Based on the construction team's inputs, the design solutions was chosen to limit the pile founding depth to 5 m below the reinforced concrete slab soffit level due to the limitation of piling machine.

Based on the structural model of the hybrid footing system, design axial loads (E_d) of the existing RC piles were calculated. These design loads were then checked against the assessed ultimate geotechnical ($R_{d,ug}$) to assess the corresponding geotechnical reduction factor (ϕ_g). The assessment indicated that the calculated ϕ_g was ranges from 0.49 to 0.81. In Abutments A, B and Piers 3, the ϕ_g values are marginally greater than 0.6 value as per the project SWTC requirements.

Design loads for the pier strengthening and collision load case were compared to the conditions prior to the pier strengthening. The structural engineer indicated that there are no additional axial loads to the existing piles due to pier strengthening and collision load case and the loads on existing piles for the hybrid footing are similar or less when compared to the existing bridge configuration.

We also noted that the existing northbound bridge has been in use for the last 40 years without any known structural foundation issue. This suggests that the analysis upon which the assessment ϕ_g was made is probably conservative. For this basis, our design recommended the acceptance of the apparent non-conforming strength reduction factors but at the same time recommended the performance of the bridge and the existing piles to be monitored regularly

4.6 Constructability and Staging

During design development very careful consideration was given to the coordination of the strengthening works design with other disciplines. There were significant constraints due to working in a live rail corridor and adjacent to the associated existing and proposed rail services. There were also the difficulties of connecting a new structure to the existing, the practicalities of construction access, and the construction safety risks. The design and the sequence of the construction staging activities were greatly influenced by these factors and the design team worked on close coordination with the Construction team and with Queensland Rail Engineers throughout the development of the detailed design.

Figure 16: Gympie Road Northbound Bridge Strengthening - Pier 1 Blade Pier Completed

Figure 17: Gympie Road Northbound Bridge Strengthening - Piers 2 & 3 Blade Pier Completed

5. Grade Separation Bridge

5.1 Background

The Moreton Bay Rail project tie in to the existing North Coast line was a significant challenge for the project. The site was very constrained spatially and in terms of existing train operations. However the team developed a significant alternative arrangement that proved highly beneficial to the outcome of the project.

The reference design provided a grade separation solution at the tie-in whereby the new Kippa-Ring Line passed over the existing North Coast Line. The MBR design swapped this arrangement around and grade separated the NCL, achieving a number of benefits including a 30% reduction in the length of grade separation structure that was able to be built in a “greenfield” rather than a “brownfield” environment and a more effective grading arrangement that better suited the new operational arrangements.

Other benefits of the new arrangement were as follows:

- Reduced complexity enabling safer and simpler construction
- Enabled retention of the existing Petrie Station footbridge and a significantly more functional platform arrangement
- Reduced impact on existing infrastructure
- refined track geometry with whole of life (WOL) benefits
- Provided an upgradable solution
- Cost effective and value for money ($30M saving)

Figure 18: Petrie Grade Separation

5.2 Structural Form

The Grade Separation Bridge is an 18.5m single span post-tensioned, through-girder bridge that carries the realigned North Coast Line (NCL) over the Down Kippa-Ring Line (DKR). The bridge width is 7m, which accommodates a single track and maintenance walkway.

Track slab was required for the both the NCL on the bridge and the DKR in order to achieve the required 6.1 m minimum vertical clearance. Transition slabs are provided at both abutments to accommodate the change from track slab on the bridge to the ballasted track either side of the bridge.

The NCL is on a 40 degree skew to the DKR below which provided some key design challenges with the arrangement of the post-tensioning in the deck, the setout of the track slab and the design of the transition slabs.

Figure 19: Grade Separation - Bridge Elevation

The vertical abutments are designed for rail impact and the adjacent RSS walls are provided to retain the NCL embankment. Three rows of driven octagonal PSC piles and a reinforced concrete pile cap support the abutment walls and resist the earth pressure and impact loading. Cement stabilised sand is provided immediately behind the RSS panels to 3.0m above top of rail to resist rail impact force and to prevent backfill material from flowing out in the instance of rail impact damaging the RSS wall panels.

The low point of the DKR rail level in the vicinity of the Grade Separation Rail Bridge is below the 100 year ARI flood level. This location is protected by a bund which is incorporated into the RMAR to provide 100 year ARI immunity to this location. The track slab in this area provides a robust track formation which assists in the reinstatement of the track after extreme events in excess of the 100 year ARI event.

This location forms the low point of a small catchment collecting runoff along the KRL rail line which is drained by a long culvert. The culvert outlet is far enough downstream to provide the rail with 100 year ARI flood immunity due to flooding via backwater from Yebri Creek (backflow prevention devices were not utilised due to the high maintenance requirements and the risk of failure of such devices).

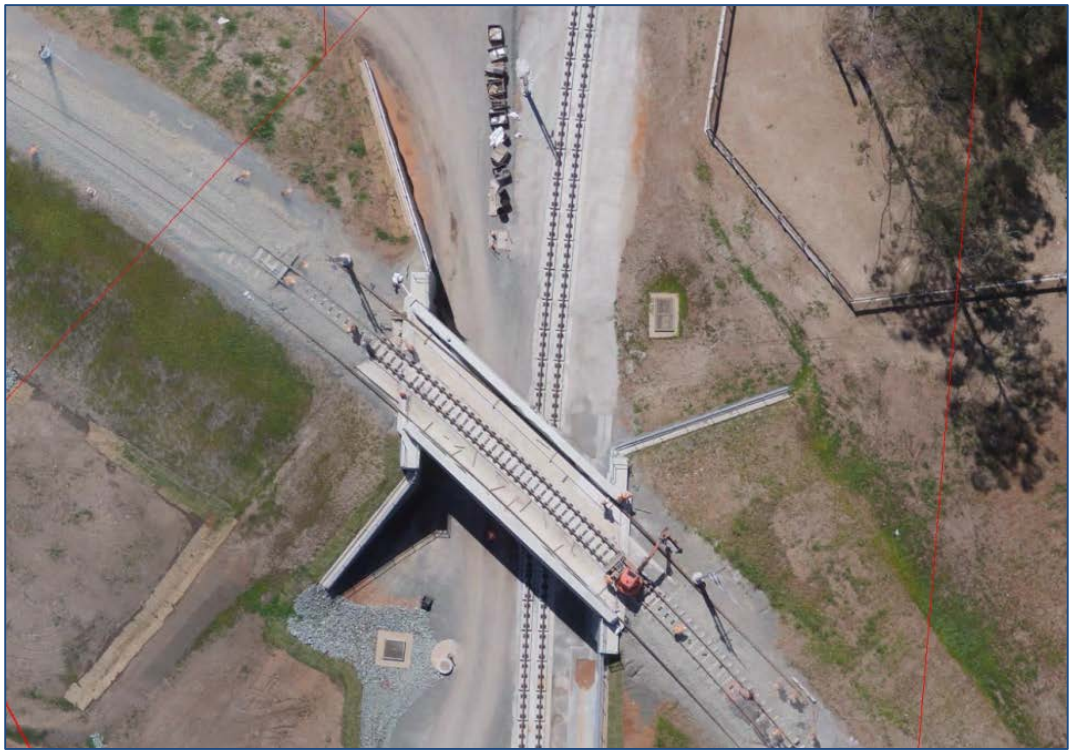


Figure 20: Grade Separation Bridge - Plan View

6. Saltwater Creek Bridges

6.1 Bridge Description

Saltwater Creek Rail Bridge has 21 spans, is 325 m long and carries the MBR alignment across Saltwater Creek at Hays Inlet. The rail alignment is constrained by land availability and flood levels in the creek and the bridge configuration is defined by the environmental regulatory requirement to keep embankment construction above Highest Astronomical Tide (HAT) of 1.36m, with the bridge soffit being above Q1000 and Q2000 flood levels. This eastern section of the rail alignment through the Saltwater Creek / Hays Inlet area includes soft ground favouring an embankment height that is kept as low as possible to minimise settlement, but with the top of formation above 100 year ARI flood level. This leads to a bridge form with shallow depth and therefore fairly short spans.

Figure 21: Saltwater Creek Rail Bridge and Shared Path Bridge - Plan View

The adjacent Saltwater Creek Shared Path Bridge runs parallel to the rail bridge with an approximately 3m clear separation between the structures and adopts the same span configuration. It has a separate superstructure and foundations but shares the approach embankment and abutment spill-through.

Figure 22: Saltwater Creek Rail Bridge and Shared Path Bridge - Aerial View

6.2 Structural Form

The rail bridge superstructure is typically an 8m wide two track ballasted rail bridge formed from standard 15m Queensland Rail PSC slabs. A single span of standard 25m Queensland Rail PSC girders is provided across the low flow channel of Saltwater Creek to minimise disturbance to the creek habitat. Standard Queensland Rail steel walkways are provided on both sides of the bridge with trunking to

accommodate rail systems conduits. OHLE masts are supported from the piers where required. The bridge piers are formed from eight 550mm driven prestressed octagonal piles, arranged in two rows of four in order to resist the braking loads, which extend directly to a 3m wide reinforced concrete headstock. The abutments are formed from four 550 driven prestressed octagonal piles with a reinforced concrete headstock. Abutment slope protection is hand packed grouted rock pitching with additional rip rap toe for scour protection.

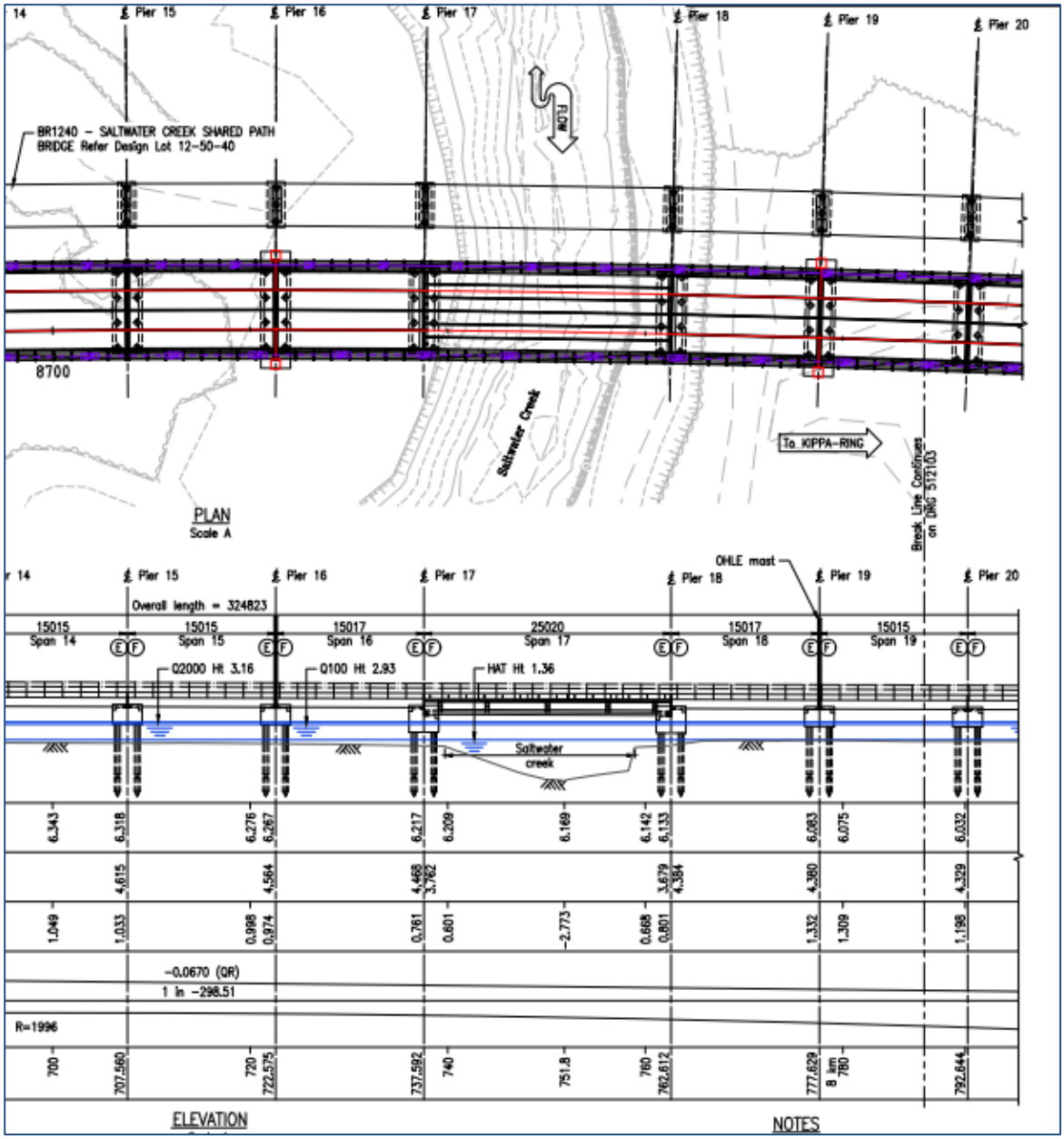


Figure 23: Saltwater Creek Rail Bridge and Shared Path Bridge - Typical Span Layout

The shared path has a 4m clear width deck cross section between steel balustrade parapets. The superstructure typically consists of four spaced 15m long 500mm deep precast prestressed deck units with a 200mm thick composite slab with hinge slabs to minimise the requirement for movement joints. A single span of 25m long 800mm deep precast prestressed deck units with a 200mm thick composite

slab is provided across the low flow channel to minimise disturbance to the creek habitat. The steel balustrade is 1400mm high to suit cyclists is provided on both side of the shared path and the bridge deck is free draining as there are no kerbs. The bridge piers and abutments are formed from three 550 driven prestressed octagonal piles extending directly to a reinforced concrete headstock.

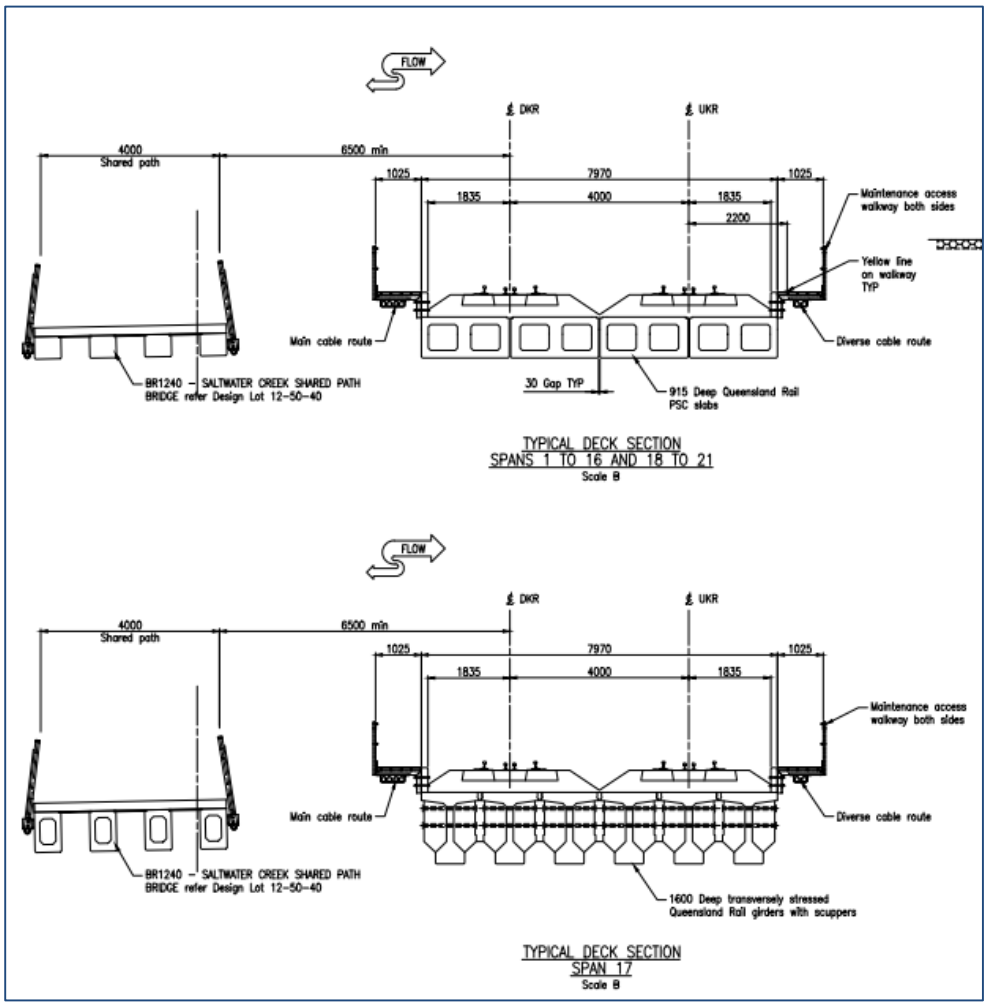


Figure 24: Saltwater Creek Rail Bridge and Shared Path Bridge – Cross Sections

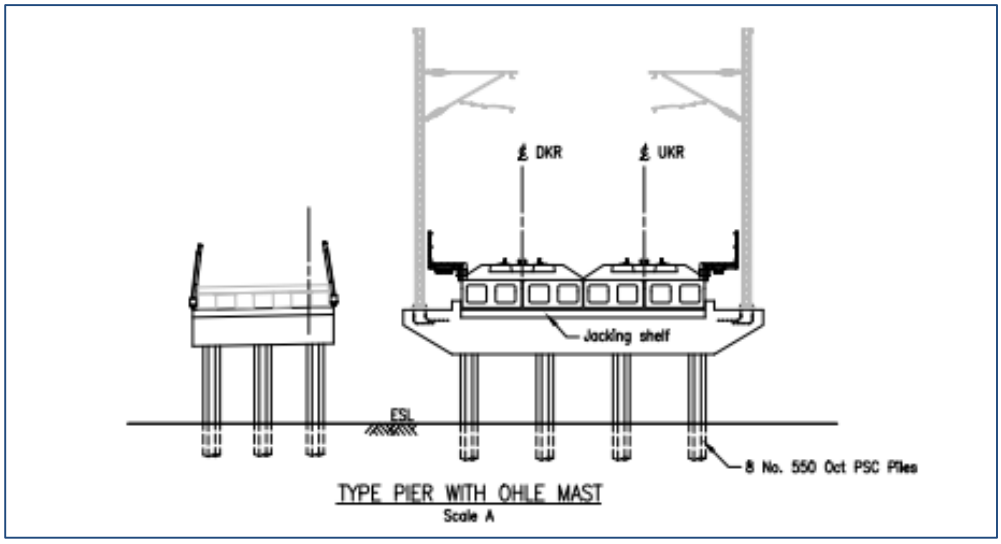


Figure 25: Saltwater Creek Rail Bridge and Shared Path Bridge - Typical Pier Layout

6.3 Geotechnical Design / Challenges

The main geotechnical challenge for the Saltwater Creek Bridges was the environmental constraints for the site investigation to obtain geotechnical data for the pile design. As shown in Figure 25, the Saltwater Creek Bridges were located within the marine park area. Within this area, the approval process of environmental permit for the full construction work required about 3 to 4 months. During the detailed design, the available environmental permit only allowed minimum disturbance of the area, i.e. maximum of one metre width disturbance of the marine park vegetation (mainly saltwater couch) along the proposed bridge alignment.

Figure 26: Minimal ground disturbance to marine environment during the geophysical surveys at Saltwater Creek Bridges

In order to progress the design and considering the environmental permit restriction, an innovative site investigation method, i.e. geophysical survey investigations using seismic refraction and multichannel analysis of surface waves (MASW) methods were adopted. The objective of MASW survey was to understand the soil consistency for material above rock level (mainly for soft to firm soils), while the objective of seismic refraction survey was to understand the top of rock level. The geophysical survey methods were proposed to TMR. Due to the environmental permit limitation and urgency to progress with the design, TMR provided an approval of the proposal. Figure 26 illustrates the geophysical survey undertaken with minimal disturbance to the sensitive marine park environment.

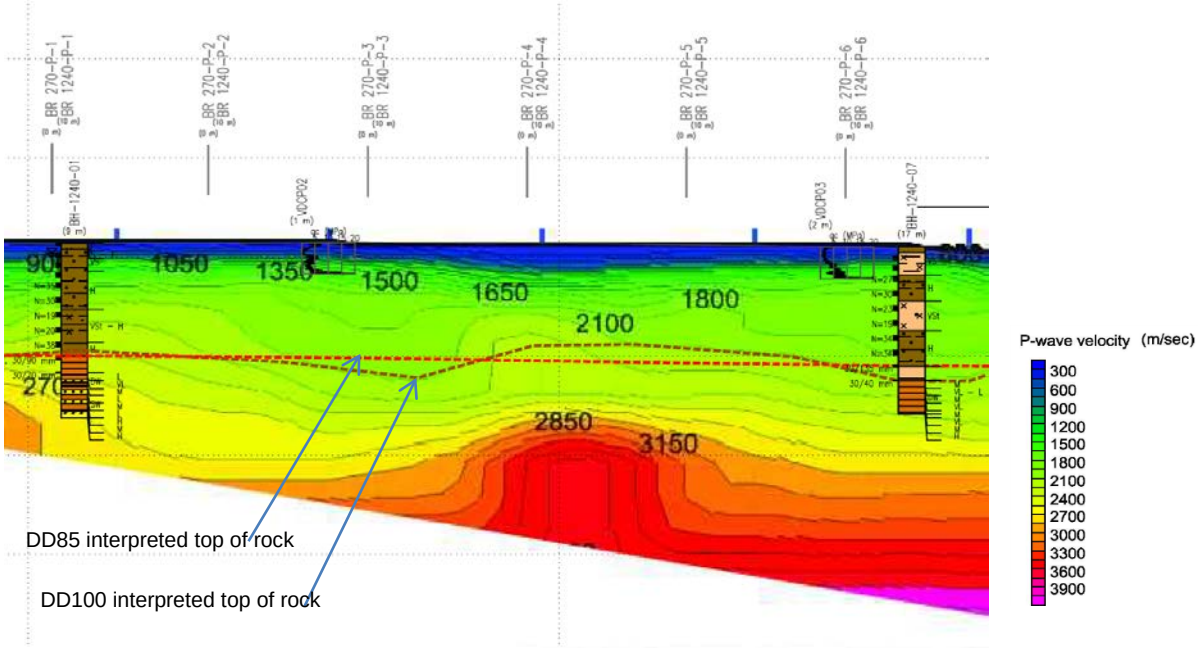


Figure 27: Seismic refraction survey interpretation for Pier 1 to Pier 6 of Saltwater Creek Bridge

For the development of geotechnical design to detailed design stage of 85% (DD85), the geotechnical condition along the proposed bridge alignments is interpreted based on the published geological map and information from two available historical boreholes, one piezocone penetration test and four additional boreholes due to limited access. Additional geophysical surveys along the proposed bridge alignments were then scheduled before the PTU stage (Permit to Use or DD100). The main objective of the additional geophysical survey is to fill the gaps between the available geotechnical information and also to refine the initial ground model.

The interpretations of soil strata and top of rock levels from DD85 were compared against the information from the geophysical surveys. The comparison suggested only minor adjustments of the DD85 interpretation were required. This finding provided a better confidence of the interpretation of geophysical survey results. Figure 27 presents a samples of seismic refraction and MASW surveys interpretation respectively for the Saltwater Creek Bridge.

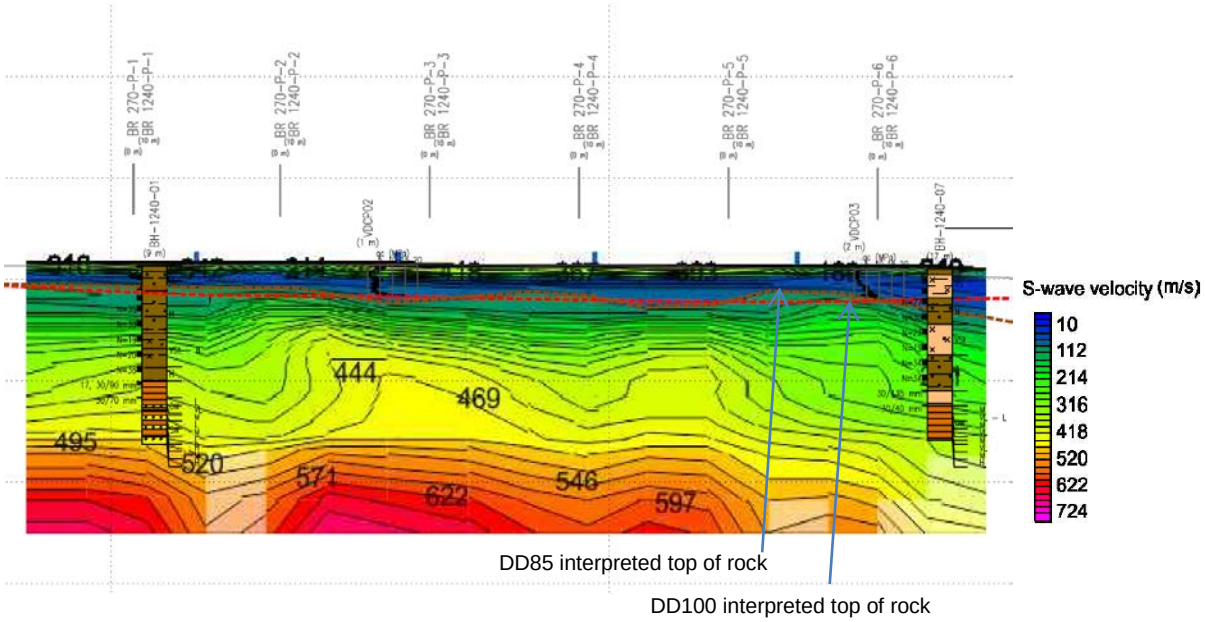


Figure 28: MASW refraction survey interpretation for Pier 1 to Pier 6 of Saltwater Creek Bridge

550 mm octagonal prestressed concrete driven piles were adopted as the pile solution for the bridge. The driven pile was design to be driven to refusal, with minimum penetration into weathered sedimentary rock of 1 m. Based on the interpretation of geophysical surveys (particularly the top of rock level), the driven pile capacity and the corresponding pile toe levels were estimated during the design.

The actual pile capacities were confirmed using PDA tests and CAPWAP analyses at all pier locations. End of Drive PDA was carried out during pile driving on a minimum of one pile at every third pier of each bridge. Restrike PDA testing (at least 48 hours after driving) was carried out on a minimum of 1 pile per pier, for all piers that were not selected for End of Drive testing. An estimation of pile capacity using Hiley formula was also applied based on calibration to the Restrike PDA testing and CAPWAP analysis. The calibrated Hiley formula was used to estimate the pile capacity for the remaining piles that were not PDA tested.

The as-built pile records indicated that the actual pile toe levels are generally within ± 2 m of the design pile toe levels. Only at some pier locations, the actual pile toe levels deviate up to – 4 m.

Considering the actual pile records, it is considered that the interpretation of geophysical surveys was quite successful and could provide meaningful geotechnical information for the design purposes.

The adopted site investigation technique using geophysical surveys and minimum borehole for the 450 m long Saltwater Creek bridges is the first site investigation approach undertaken in Queensland and probably in Australia.

Figure 29: Saltwater Creek Rail Bridge and Shared Path Bridge - Piling

Figure 30: Saltwater Creek Rail Bridge and Shared Path Bridge - Piling

7. Freshwater Creek Road Bridge

Figure 31: Freshwater Creek Road Bridge - Plan View

7.1 Bridge Description

Freshwater Creek Road Bridge is a single 25.3m span structure which carries the existing Freshwater Creek Road across the new MBR infrastructure. The 15m wide MBR corridor provides for the dual tracks, rail services and drainage channels. The bridge cross section replicates the existing road cross section in terms of the number of traffic lanes and shared paths thus maintaining the functionality of the original Freshwater Creek Road. The geometry of the bridge is on an approximate skew of 32 degrees due to constraints in the rail alignment.

The grade separation was constructed in three stages. During the first stage site establishment, services relocations and temporary asphalt tie-ins were completed. During the second stage, a side track diversion on the southern side of the Freshwater Creek Road was constructed to maintain connectivity for local residents across the rail corridor. During the third stage, the full width of the bridge was constructed in using a top down methodology. Finally, permanent tie-ins with the existing road were completed and footpaths and services reinstated on the new bridge.

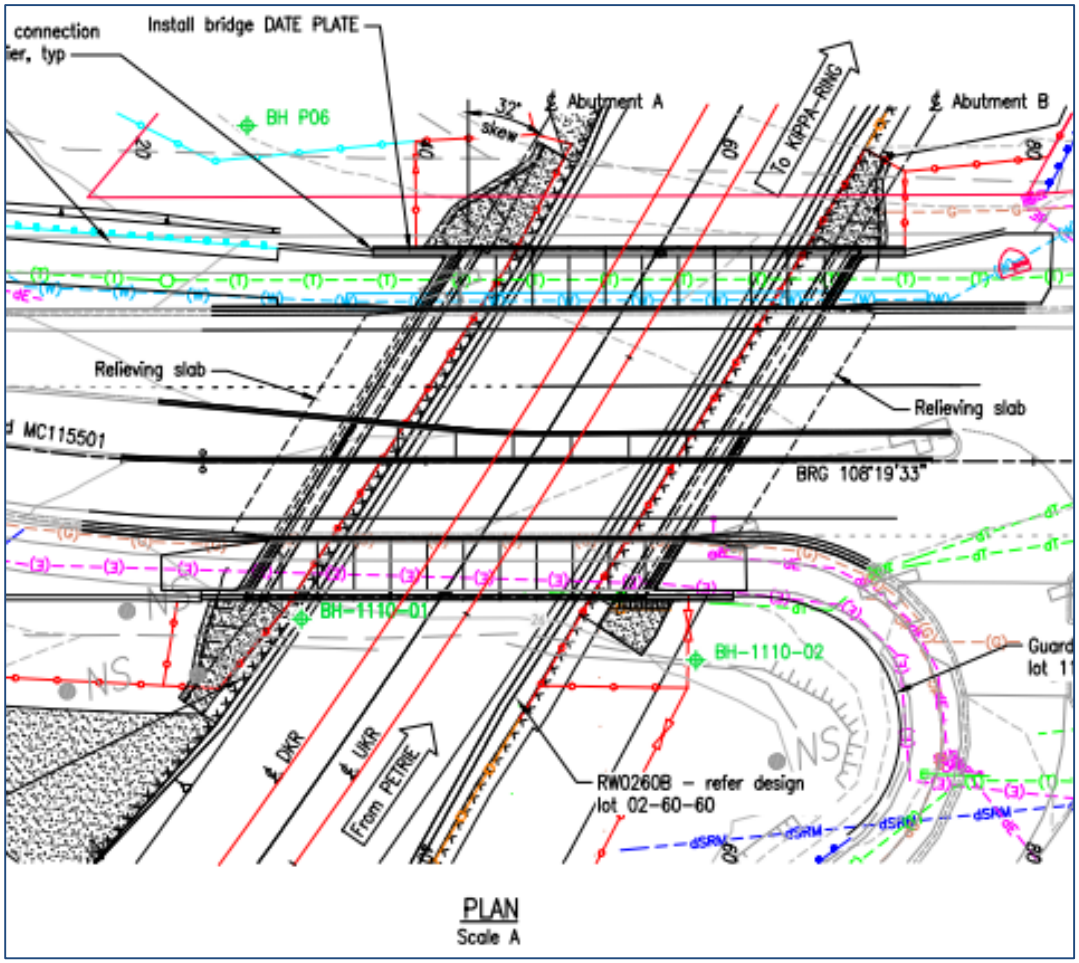


Figure 32: Freshwater Creek Road Bridge - Plan View

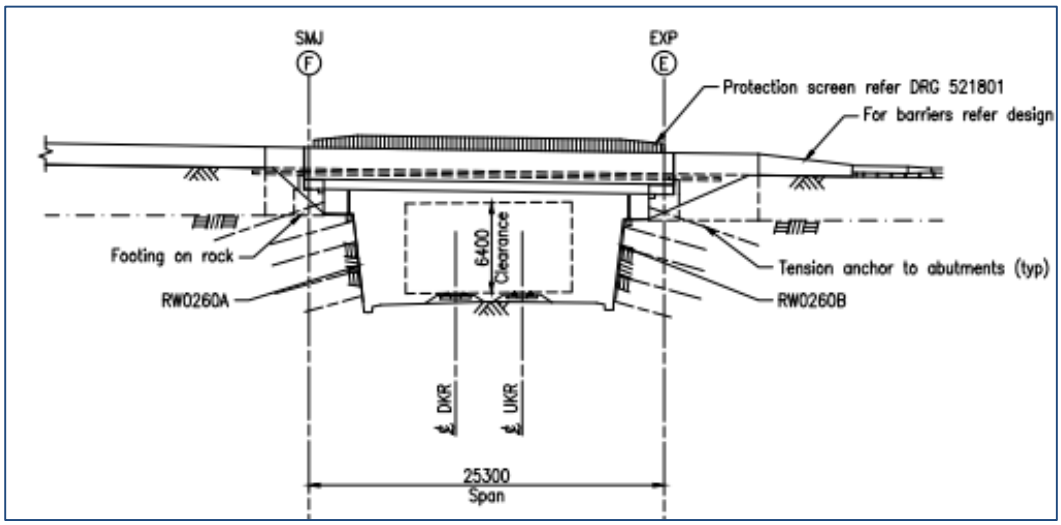


Figure 33: Freshwater Creek Road Bridge – Typical Long Section

7.2 Structural Form

The bridge superstructure is formed from 1050mm deep pre-stressed concrete deck units composite with a 200mm minimum deep deck slab. 1.5m high medium performance parapet barriers with an anti-throw screen extending to 2.4m above pavement level are also provided. Upon agreement between Thiess and the utility companies, a 450mm diameter PE water main and a 110mm diameter gas main in a 400mm diameter PE sleeve are encapsulated in reinforced concrete between the deck units. Additional Telstra and Energex conduits are accommodated in the footpaths above the deck slab.

The subsurface geology in this bridge location consists of extremely weathered (EW) extremely low strength sandstone at a depth of 2m to 3.2m which generally increases in strength with depth. The abutment headstocks are cast on a rock ledge with the leading edge of the footing setback by 1.3m from the edge of the cut face for footing stability. Each abutment headstocks is additionally restrained by a single row of nine, 7.7m long, active ground anchors through the footing to meet bearing capacity, sliding and overturning stability requirements.

Below the abutment headstocks, the rock face is cut at a 1:10 slope and is strengthened with passive rock dowels (soil nails) and finished with a minimum of 175mm thick shotcrete facing reinforced with SL81 galvanized mesh and incorporating vertical strip drains. This nailed shotcrete structure extends beyond the footprint of the bridge to form extensive retaining walls on both sides of the cutting.

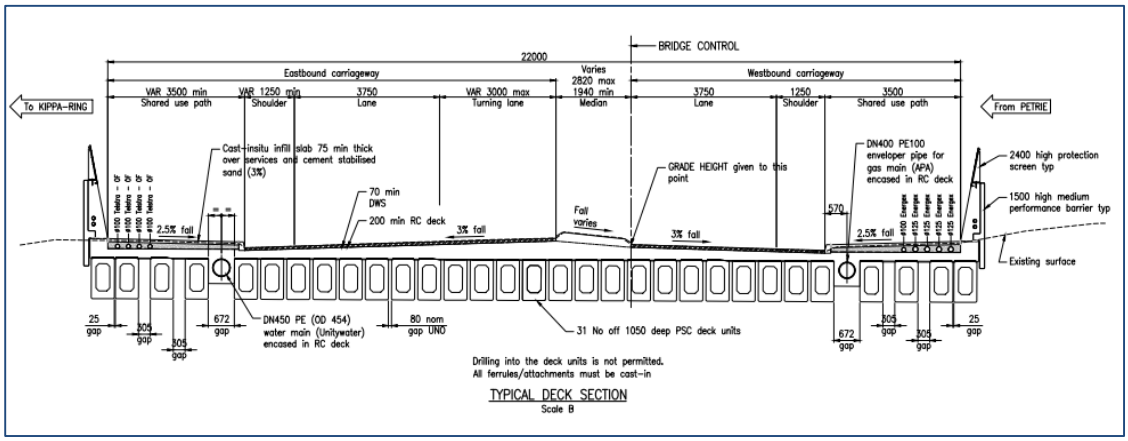


Figure 34: Freshwater Creek Road Bridge – Typical Deck Section

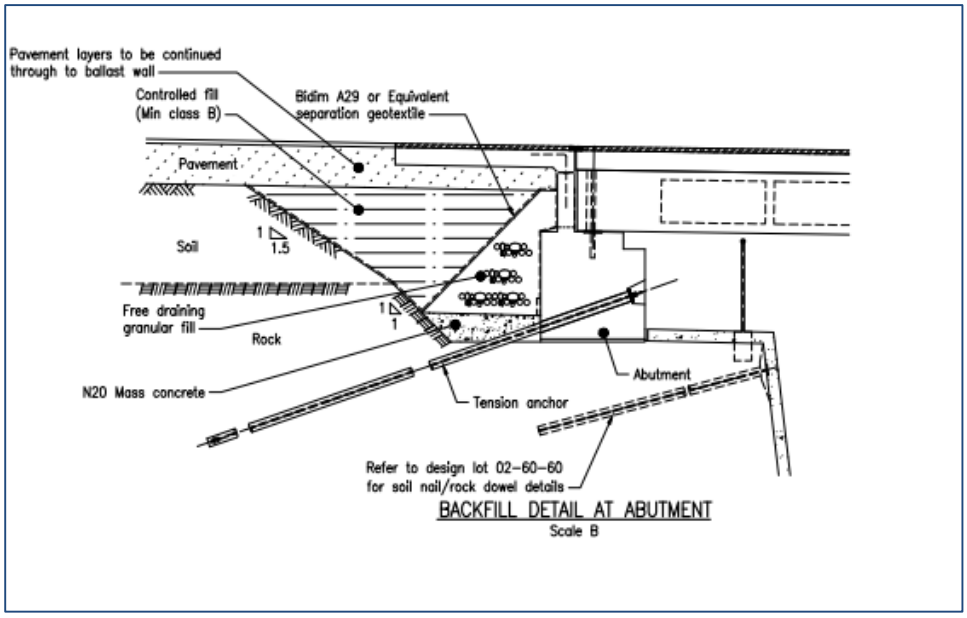


Figure 35 Freshwater Creek Road Bridge – Typical Abutment Detail

7.3 Geotechnical Design/ Challenges

During the development of design in tender stage, several foundation options were investigated to obtain the least disturbance to the existing road traffic and provide the most economical design solution.

The first design option was to construct the bridge and the associated cutting using a cut and cover tunnel design option using soldier pile wall supported with ground/rock anchors. This option was discarded after cost estimation exercise revealed that the cut and cover tunnel option was not cost effective to construct.

The second design option explored was to support the bridge abutment using rock socketed bored piles and to support the excavation walls between piles using the shotcrete wall and ground/rock anchors.

After a close examination of the available borehole investigations, it was recognised that rock surface within the bridge location was encountered at shallow depth (i.e. around 2 m to 3.2 m depth). For this reason, a third design option was explored and was eventually adopted as the design solution. As depicted in Figures 3 and 5 above, in this option, the bridge abutments are supported by shallow strip footings, which in turns are supported by reinforced cut using passive soil/nail rock dowel. The abutment shallow footing is supported by active rock anchor. The purpose of the active rock anchor at the abutment footing was to overcome the sliding issues and to improve the bearing pressure distribution (i.e. to improve the eccentricity of load at the base of the shallow footing). Cost estimation exercise indicated that the third option was the most economical option.

A rigorous geotechnical analysis including global slope stability using a limit equilibrium computer program (SLOPE/W), finite element analyses using a computer program Plaxis 2D and local planar sliding failure analyses were undertaken in order to ensure the design solution using shallow foundation on reinforced cut is robust.

The design solution adopting a shallow footing on reinforced cut as bridge abutment foundation for the freshwater creek road bridge was accepted by TMR and this solution was considered the first of its kind for the road bridge design and constructed in Queensland

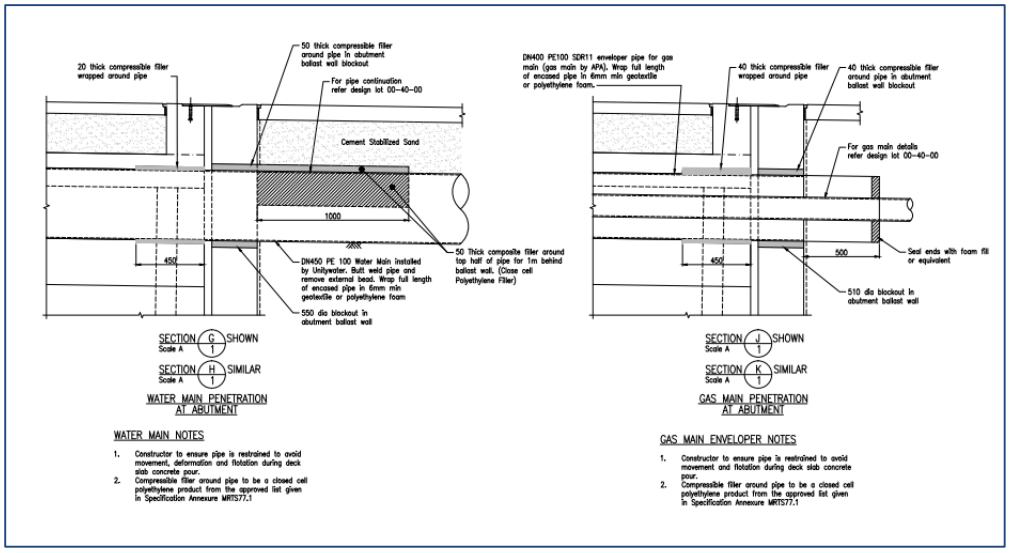


Figure 36: Freshwater Creek Road Bridge – Utility Pipe Abutment Details

Figure 37: Freshwater Creek Road Bridge – Completed Elevation

8. Conclusion

The Moreton Bay Rail project is on track for completion in 2016, providing the residents of the Redcliffe Peninsular area with their long-awaited rail link. The detail design of the bridges was carried out over 14 months from August 2013 to October 2014 and the construction of the bridges was completed mid-2015. The bridges formed a substantial part of the project and the collaborative design process between all parties facilitated economical bridge designs that overcame the various technical challenges encountered throughout the project resulting in the successful delivery of the design and construction of 18 bridges in approximately 24 months.

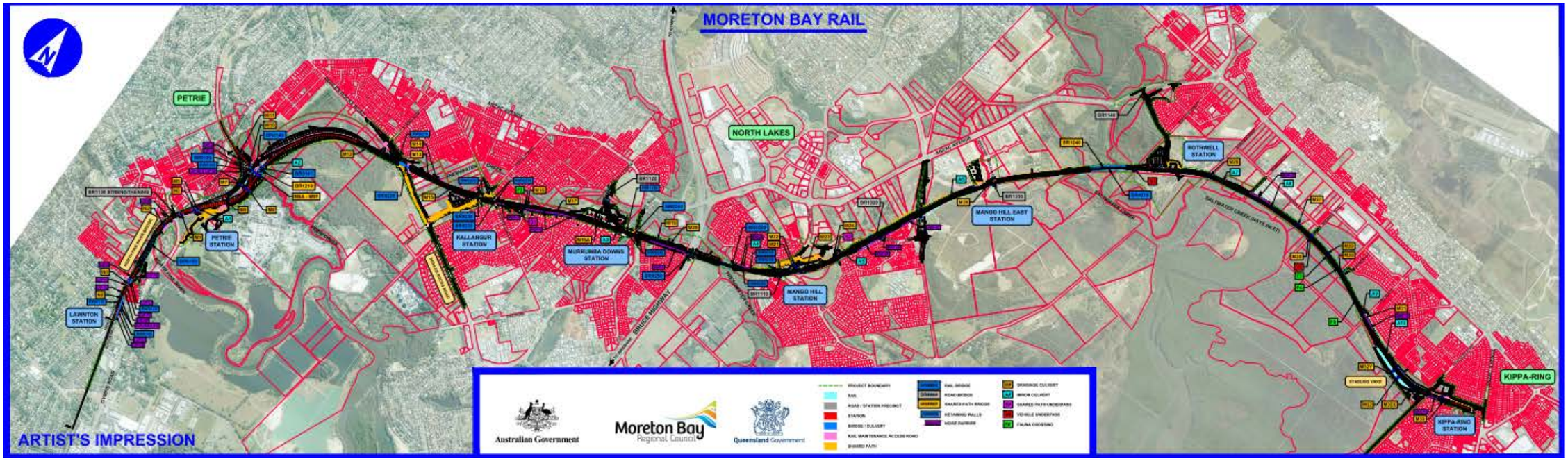
9. Acknowledgements

The authors would like to acknowledge the following participants:

- Client and project sponsors, the Department of Transport and Main Roads, Queensland Rail and Moreton Bay Regional Council
- The project contractor, Thiess (Leighton) and in particular the engineering management team
- Hassell architects, designers of the project stations and landscape design
- Other members of the AECOM-Aurecon JV and Golder Associates design teams that contributed to the successful design of the bridges and foundations.

Appendix A

Project Plan



Golder Associates

AECOM
aurecon