CHALLENGES DESIGNING WET SERVICES FOR PUKEAHU NATIONAL WAR MEMORIAL PARK

C. Chryssafis (Memorial Park Alliance, Wet Services Technical Advisor), C. Everett (Memorial Park Alliance, Wet Services Team Lead) and M.A. Knappstein (Memorial Park Alliance, Wet Services Design Engineer)

ABSTRACT

The Pukeahu National War Memorial Park was constructed as the Government's major project to commemorate the centenary of the First World War. In order to build the park, construction of an underpass (the Arras Tunnel) was required to accommodate State Highway 1 (SH1). The Arras Tunnel now carries SH1 traffic west, passing under the Park. This project was completed on budget and ahead of time by the Memorial Park Alliance (the Alliance) driven by effective collaboration between the Alliance (comprising client, contractor and designers) and key stakeholders. This paper outlines some of the challenges, design solutions, and working methods that were important to the success of the wet services design. The key threads that are covered in this paper include:

- Managing a tight urban site with complex and multiple services
- Protection measures for the Tory Street heritage sewer
- Developing a solution for the stormwater overland flows from surrounding streets that enter the tunnel
- Application of sustainable urban drainage approaches for stormwater management in the park
- Resilience of wet services for the Home of Compassion Crèche during a seismic event
- Considering safety in design for construction and operation of assets
- Collaborative team approach.

KEYWORDS

Alliance, Collaboration, Water Supply, Stormwater and Wastewater Services

1 INTRODUCTION

Pukeahu National War Memorial Park (the Park) was constructed as the Government's major project to commemorate the First World War. To enable the park to exist, Buckle Street (State Highway 1) had to be put underground in a "cut and cover" tunnel.

The project was facilitated by the National War Memorial Park (Pukeahu) Empowering Act 2012, which allowed the Alliance to fast track standard consenting requirements. This was necessary to complete the design and construction works within the tight timeframes and by the immovable deadline of 25 April 2015, being the centenary of the ANZAC landings at Gallipoli.

Following the Government awarding the project to the Alliance on 7 August 2012, the Alliance began planning and first broke ground on site on 3 October 2012, the date of assent of the Empowering Act. The Arras Tunnel was officially opened on the night of Sunday 28 September 2014 and practical completion of the Park was agreed on 25 March 2015. The official opening took place on the 18 April 2015 to allow final preparations for Anzac Day, 25 April 2015.

1.1 INVESTOR STAKEHOLDERS

The Memorial Park project investor stakeholders are: the New Zealand Government, represented by the Ministry for Culture and Heritage and the New Zealand Transport Agency, and local authority Wellington City Council.

1.2 ALLIANCE PARTICIPANTS

The project was delivered by the Memorial Park Alliance comprising: New Zealand Transport Agency, Downer, HEB, Tonkin + Taylor and URS (now AECOM).

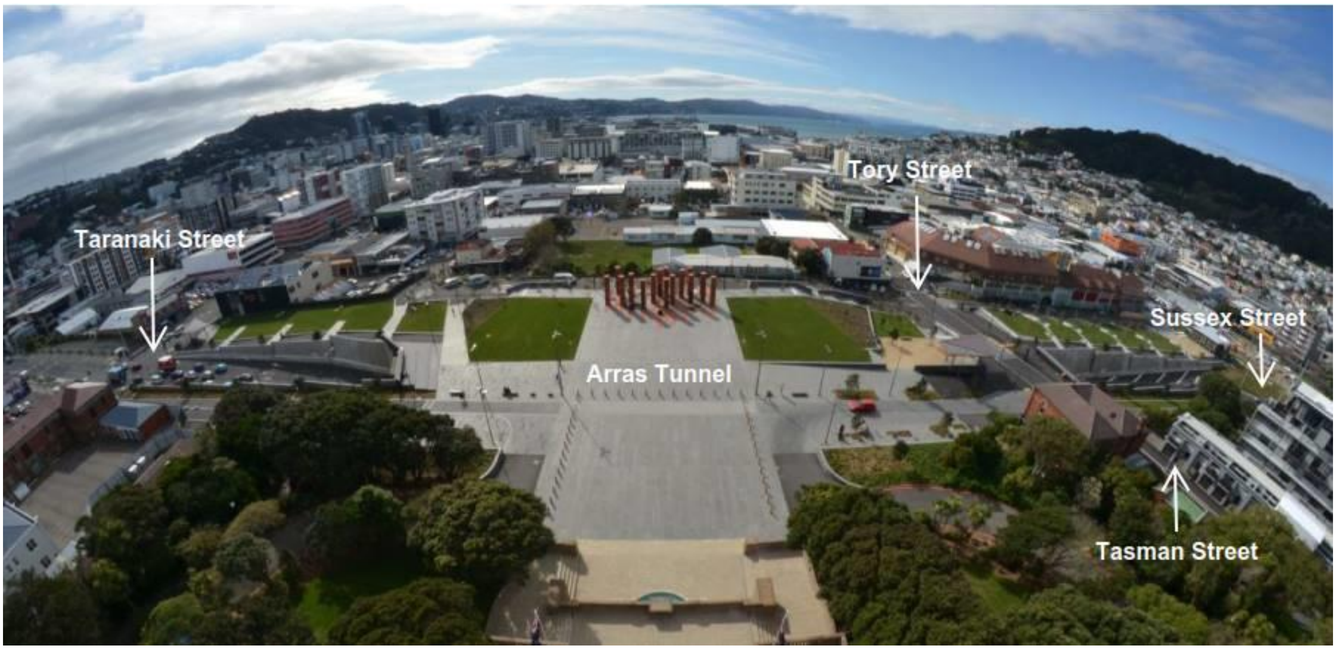
1.3 LOCATION

The project occupied a site approximately the size of three rugby pitches in a bustling part of central Wellington. A school, a university, businesses and residential apartments were the most sensitive of the immediate neighbours to the construction site.

The Arras Tunnel is located between the Taranaki Street intersection and the Sussex Street as shown on Photograph 1. Existing ground levels at Tory Street and the level of the Tory Street heritage sewer strongly governed the Arras Tunnel geometric design.

Many of Wellington's most important underground services traversed the site including two historic brick sewers and major power cables. There was a strong preference, by the Alliance, Wellington City Council, and Wellington Electricity to avoid relocating these services due to heritage values, as well as time and cost limitations. This decision directly impacted the design and the physical works.

Photograph 1: Site location



2 MANAGING A TIGHT URBAN SITE

The site was constrained between the Carillon, the heritage Mt Cook police barracks, Tasman Garden apartments and the NZ Defence Buildings to the south and Te Papa archives and Mt Cook School to the north. Within this constrained space SH1 with a traffic volume of approximately 22,000 vehicles per day had to be kept live throughout the project. Prior to construction of the underpass, diversion of services and traffic from the site was required.

2.1 RELOCATED SERVICES

Two corridors running from west to east on the north and south sides of the tunnel were allocated for relocated services. Approximately 900 metres of stormwater, wastewater and water supply pipes and 5.6km of dry services were located in their existing positions and relocated into these corridors to allow excavation of the tunnel to begin. The tight timeframes of the project meant that decisions were being made very early in the project about which services would be relocated and where relocated services would go prior to the Arras Tunnel and park design being complete. In order to prevent services being relocated more than once, collaboration between design disciplines, the construction team and stakeholders was critical. To add to the complexity, major services such as water supply trunk mains and wastewater pipes were required to be kept live throughout the project, temporary sheet pile walls and anchors had to be avoided and locations of manhole lids and other surface features had to be considered in order not to compromise the finished look and final levels of the park.

One of the most challenging pieces of infrastructure to relocate and replace was the 450mm diameter trunk water main that crossed Buckle Street from Tasman to Tory Street and also connected to the 450mm diameter trunk water main that runs east to west down Buckle Street. This line is a critical piece of Wellington City water supply infrastructure and Wellington Water decided that betterment works were required for this line. The 450mm line was replaced with a 914mm steel pipe from Tasman Street to a new 450mm steel branch across the underpass to Tory Street. The 914mm pipe then reduces to a 667mm steel pipe along the remainder of Buckle Street to Taranaki Street. It was important that the water supply services were not interrupted during the construction works, and this required careful logistic sequencing of the works and close liaison with Wellington Water. The existing trunk main was removed while supply was maintained to service connections from other trunk mains and the new 450mm pipe was constructed above the Arras Tunnel structure. The limited cover at Tory Street due to the presence of the heritage sewer below made this service relocation challenging, and the construction tolerances were very tight. The 914mm steel pipe also had to negotiate crossing 33kV power cables and a plethora of other services to get to its new alignment on Buckle Street. The new 450mm branch was butt welded to increase seismic resistance and was designed to be able to move independently of the concrete underpass structure during a seismic event to reduce the risk of damage to the pipeline.

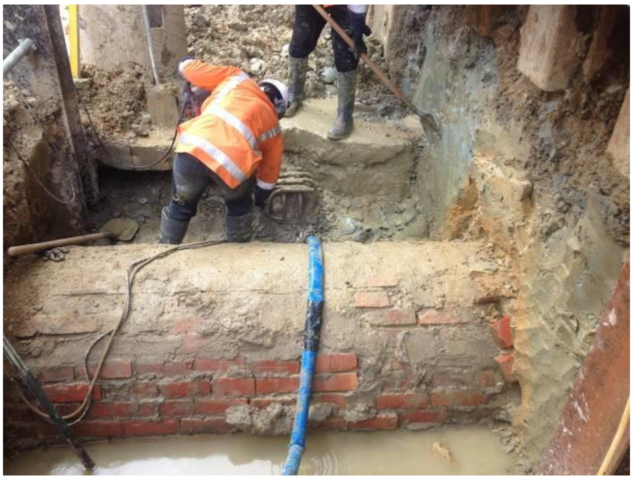
2.2 SPECIAL DESIGN TO AVOID RELOCATION OF SERVICES

2.2.1 HERITAGE BRICK SEWER

A brick ovoid sewer, 600mm wide by 900 mm high and dating from 1895, runs along Tory Street at a depth of up to 10m below ground. Apart from its critical function as a conveyor of Wellington's wastewater, the Tory Street interceptor sewer is part of Wellington's heritage infrastructure and has high archaeological value. It includes bricks fabricated by prisoners in the Tasman Street Police Barracks compound. The initial design involved removal and replacement of a section of this sewer to enable construction of the Arras Tunnel.

Photograph 2: Tory Street Historical Sewer

Photograph 3: Tory Street Historical Sewer Exposed



This important heritage sewer was inspected and concluded to be in remarkable condition for infrastructure of this age. Wellington City Council and the Alliance were eager to retain this sewer for its heritage value. High costs (up to $750,000), long construction works duration (approximately 3 months), and technical difficulties in replacing this sewer also prompted a review of the design.

Through careful structural and geometric design, the Arras Tunnel box structure and the cover levels above the Arras Tunnel were revised. These modifications meant that the overall depth of the Arras Tunnel was reduced by approximately 1.5m. This reduction allowed the Arras Tunnel box structure to cross above the heritage sewer, with approximately 200mm clearance.

The profile of Tory Street and the Arras Tunnel box structure meant that levels in this area were tightly constrained. Services that passed above the Arras Tunnel structure were required to be relocated towards the West where the levels were less constrained and more cover was available.

The construction of the Arras Tunnel required removal of approximately 10m of material from above the heritage sewer. The removal of this ground from above the sewer created a risk that the release of this ground pressure from above the bricks would cause the bricks to relax and the sewer to collapse.

Careful work to install concrete protection around the sewer was undertaken to ensure that the risk of damage to the sewer was minimised. The sewer condition was monitored before, during, and after the construction works to ensure that no damage had occurred.

Implications of the modification also included improvement of the road geometry, with 4% entry and exit slopes being reduced to approximately 2.8%. The modification also had a positive effect on the stormwater drainage system for the Arras Tunnel by facilitating the construction of the directionally drilled pipe which drains the low point in the tunnel.

As a result of careful structural, geotechnical, and geometric design and construction, the heritage sewer was retained and the project saved approximately $1.8M in design and construction costs. The modification and the construction programme savings directly contributed to the Arras Tunnel being opened one month ahead of schedule.

2.2.2 33 KV CABLES

In addition to the Tory Street heritage sewer, two old gas filled 33kV power lines run east to west across the entire. One circuit goes out to Hataitai and includes supplies to the airport and the second goes to Evans Bay. These gas filled cables are no longer produced and any modification of these power cables would have required installation of four expensive adaptor joints, each costing $750,000. In addition these joints had a long lead time (6 months) for procurement, which jeopardised the tight project deadlines. Therefore all new and relocated services were designed to avoid these cables. The geometry was also constrained where Buckle Street crosses the 33kV to ensure there was adequate cover over the 33kV in order to protect them adequately from damage.

Careful construction and conscious design of the wet services was important to minimise the risk of damage of these cables.

3 TARANAKI STREET STORMWATER OVERLAND FLOW

Flooding of the Arras Tunnel via overland flow from Taranaki Street was identified as a high project risk. Stormwater drainage for the tunnel is required to collect and convey the 1 in 100 year return period storm event and prevent damage to the structure, mechanical and electrical equipment during a 1 in 500 year event.

The Taranaki Street catchment above the intersection of Taranaki, Buckle and Arthur Streets is 23.3 ha. It is a relatively steep catchment with a high proportion of impervious surfaces. The storwmater flows that enter the intersection from Taranaki Street in a 500 year ARI storm event were estimated at 5.4 m^3/s of which 1 m^3/s is flow through the primary pipe network and 4.4 m/s^3 as overland flow. The quantity of water that would enter the underpass was uncertain due to the complicated geometry of the intersection. A three dimensional Computational Fluid Dynamics (CFD) model was completed to refine the intersection surface design and assist in striking the best balance between road safety and flood protection. This model was independently verified with a two dimensional MIKE 21 model.

Outputs from the CFD model including flows, depths and velocities were used to size stormwater pipes and position catchpits within the underpass.

4 DIRECTIONALLY DRILLED PIPELINE

The road geometry required a sag (low point) in the Arras Tunnel profile. Stormwater is collected throughout the tunnel and is piped from the low point to the Wellington City Council network at Cambridge Terrace. The following constraints made the design of the Arras Tunnel drainage system challenging:

- The pipe size needed to be sufficient to prevent any ponding in the underpass during a 1 in 100 year storm event and limited ponding during a 1 in 500 year event
- The stormwater system (pipeline and chambers) needed to be watertight to prevent groundwater leakage into the pipeline not to affect the natural water table
- The need of the pipeline to capture and divert tunnel wash-down water to the wastewater system
- Stormwater treatment of first flush flows was required to capture pollutants
- The pipeline route was within the water table where pockets of unstable ground were known to exist
- Limited hydraulic gradient between the pipe invert level at the underpass and the 1800mm diameter receiving culvert at Cambridge Terrace.

The depth of the pipe and challenges in an excavation of this magnitude which crossed SH1 meant that installation of the pipe through directional drilling was the best solution. The 192m long, 710mm diameter HDPE pipe is approximately 10m below ground at its deepest section. The pipe slope is approximately 1.3%, which required strict tolerances on the drilling works. The invert levels of the pipe at the Arras Tunnel and the Cambridge Terrace culvert prevented the adoption of a steeper gradient. The drilled pipe had to pass beneath the Tory Street heritage sewer, and maintain sufficient head drop through the stormwater treatment device at the downstream end of the pipe.

A pipe was drilled successfully through Pleistocene Alluvium material, high groundwater table, and risk of pockets of gravel and unstable ground. Within 10m of the downstream extent, the drill hit a soft spot of material which caused a slight dip in the pipe. The effect of the dip in the pipe was assessed and an air vent installed to prevent the risk of trapped air reducing the flow capacity of the pipe.

5 SUSTAINABLE URBAN DRAINAGE

5.1 RE-USE OF STORMWATER RUNOFF FOR IRRIGATION

During the concept design phase for the wet services of the park a feasibility study was undertaken to assess the potential for installing a sustainable irrigation system. Four scenarios were assessed:

1. Base scheme (standard irrigation system supplied from WCC water main)
2. Base scheme drought (1 in 5 year return period)
3. Sustainable scheme (with underground retention tanks collecting stormwater which is then treated and pumped for irrigation use)
4. Sustainable scheme drought (1 in 5 year return period).

Water balance calculations were undertaken for the sustainable scheme to determine an appropriate sized tank given the catchment, area to be irrigated and irrigation frequency. It was found that a tank of between 300 and 400 m^3 would be required.

The need to remove suspended solids and to provide UV sterilisation were considered for protecting the irrigation system from clogging and for protecting against health risk from casual contact with the irrigation water.

A cost benefit analysis was completed for each of the scenarios. Capital costs and running costs including maintenance were taken into consideration as well as criteria around safety, contribution to the park (aesthetics, media attention), relationships & reputation, environment (sustainability/resource efficiency), whole of life impacts (future proofing, M&O impacts), legacy (cultural, legacy for New Zealand/Wellington), programme and constructability.

It was found that the cost of the sustainable irrigation scheme did not have sufficient payback and so was not adopted. This was due to the low cost of water from the town's supply and the high cost of large storage tanks together with the treatment and pumping costs.

5.2 NATURALLY IRRIGATED GARDEN BEDS/RAIN GARDENS

Sustainability concepts were however incorporated into the park's landscaping by providing naturally irrigated garden beds and tree pits for the park. This has a positive effect on water management within the park and also provides stormwater treatment and retention in storm events up to a 1 in 20 year return period.

The final stormwater design for the park was created through collaboration with the Ministry of Culture and Heritage and the Alliance, particularly the landscape architects Wraight Athfield Landscape + Architecture. The aim was to develop a maintenance friendly, sustainable and appropriate stormwater solution that overcame the constraints of the site and the challenging design requirements.

The stormwater design had to provide an unobtrusive and discreet solution and reinforce the urban design vision. This was achieved through careful contouring of the finished surfaces and use of linear drains and dish channels, as well as providing passive irrigation to garden beds and tree pits.

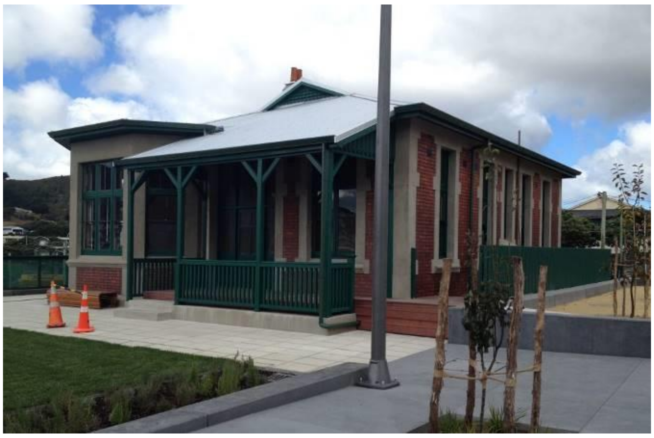
Challenges encountered during design and construction included the sloping nature of the ground, limited depth between the ground surface and the roof of the Arras Tunnel, underground services, retaining walls, and parade ground pavement requirements.

6 CRÈCHE WET SERVICES

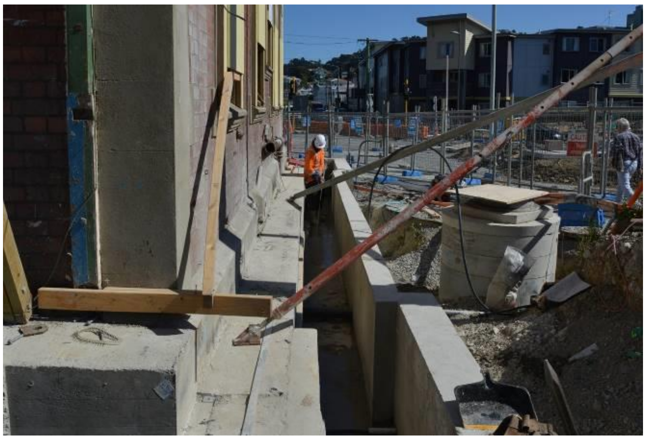
The Home of Compassion Crèche (the crèche) was built in 1914 and is registered as a Category 1 historic place with the New Zealand Historic Places Trust (Photograph 4). The crèche is the oldest remaining purpose-built crèche building in New Zealand and has historical significance as one of the few Sister of Compassion buildings under Mother Suzanne Aubert's management. Mother Suzanne Aubert is considered one of the pioneers of practical social work in New Zealand. The building was designed by John Swan in a domestic Gothic style and is built of reinforced concrete and brick. In 2016 the crèche was re-purposed as the Queen Elizabeth II Pukeahu Education Centre which is New Zealand's gift to the queen to mark her 90^{th} birthday. It now gives school students and visitors a place to learn more about New Zealand's experience of military conflict, peace keeping and commemoration.

To enable completion of the Arras Tunnel and construction of the Park, the crèche was moved to the north and west of its original location. In its new location the crèche is protected from seismic activity by being placed on four base isolators surrounded by a rattle space (Photograph 5) to isolate the crèche during seismic movements. The rattle space extends beneath the crèche. The wet services for the crèche were required to accommodate seismic movements of at least 500 mm in any lateral direction (maximum design movement in a seismic event). Use was made of the rattle space beneath the crèche to design cost effective wet services that can accommodate the seismic movements.

Photograph 4: Home of Compassion Crèche



Photograph 5: Crèche Rattle Space



6.1 STORMWATER

The stormwater drainage for the crèche collects runoff from the roof and rattle space and discharges into a new 300 mm diameter pipe running from the corner of the Te Papa Archives building to the 1800 diameter stormwater culvert at Cambridge Terrace.

The downpipes run down the outside face of the crèche and discharge over gully dishes installed in the concrete slab of the rattle space beneath the crèche. This arrangement allows the downpipes to accommodate seismic movement while retaining the original architectural character of the building and also allows the draining of the rattle space.

Maintenance access is provided to the drainage system via a removable section of downpipe that passes beneath the crèche and by the provision of rodding eyes, manholes and trap doors in the crèche.

6.2 SANITARY SEWER

The sanitary sewer system of the crèche services the crèche toilet and hand basin and can be extended to service any future additional facilities. The system includes an overflow relief gully with a dedicated drip feed water supply to maintain the water seal within the gully. The sewer system discharges into a 180 mm diameter sewer pipe south on the south side of the crèche.

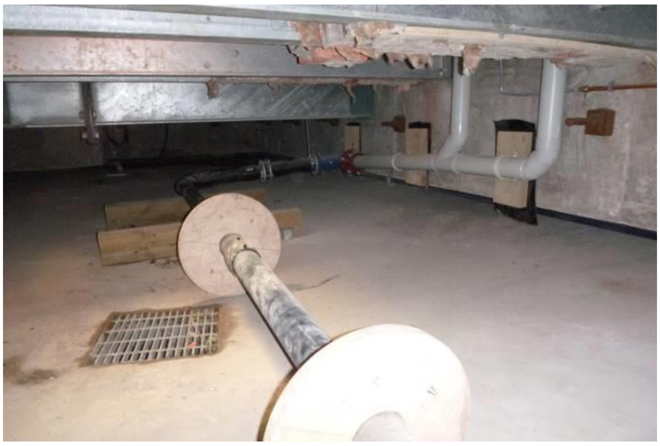
To allow for seismic movements the sanitary sewer drainage pipe has an ‘L’ shaped PE loop in the rattle space beneath the crèche (Photograph 6, below). This shape was chosen as it allows the ground to move 550mm in any direction while the building remains static and without compromising the recommended minimum bend radius of the PE pipe. The pipe is supported on hard wood support rings of diminishing diameter to provide a constant downward gradient on the pipe.

The ‘L’ shaped loop can be unbolted at two flanges on the north and south side of the loop for maintenance purposes, and a rodding eye has been provided along the main collector pipe.

6.3 WATER SUPPLY

Water supply to the crèche is via a 25mm diameter PE service pipe. To allow for seismic movements, the service pipe has a circular loop in the rattle space (Photograph 7). This shape allows the ground to move 550mm in any direction without compromising the recommended minimum bend radius of the pipe. The pipe is supported on rubber rings to prevent abrasion of the pipe during any seismic movements. The loop can be unbolted at two flanges on the north and south side to allow for maintenance.

Photograph 6: Crèche Wastewater Connection



Photograph 7: Crèche Water Supply Connection

7 SAFETY IN DESIGN

Health and safety for the construction, operation and maintenance staff was considered throughout the design process for the whole lifecycle of each asset. This was achieved through close collaboration with contractors and asset owners early in the design process which continued through each stage of the design. Safety in design workshops which were attended by constructors and designers within the Alliance were instrumental in identifying high risk items. These items were looked at further during design to see how the risks involved could be eliminated or mitigated.

Considering health and safety and constructability early in the design process enabled the design process to be streamlined as there was less redesign at later stages due to construction difficulties.

Another aspect which has improved the safety in design for this project is the 'human factor'. This has come about through the attitude and actions of the Alliance to promote health and safety as a core component of Alliance culture. Regular informal gatherings e.g. barbeques and breakfasts were held for everyone that was working on the project. At these occasions, labourers, site engineers, designers, senior management and others socialised and gained an understanding of what each other did. This meant that during the design process designers were aware of who would be constructing the works and what they are capable of. This information was informally used to tailor the design to the people that were constructing and maintaining the works.

7.1 COLLABORATION

Given the tight programme and immovable deadline, collaborative and flexible working was necessary. The team approach engendered by the Alliance was key to ensuring a good understanding of interface issues, allowing for appropriate and flexible design outcomes to account for works in this inner-city site.

Regular meetings were held on site between the design and the construction staff to ensure a good understanding of the interaction between design elements and construction challenges. The design process incorporated formal design review stages where feedback and input was sought from each design discipline as well as the construction team.

Good relationships and early involvement of the construction staff meant that the design was developed to an appropriate level for construction, which reduced unnecessary design detailing. Changes that occurred during construction, due to the presence of unknown services, changes to urban design or structural details were resolved efficiently.

The strong relationships extended to the public and Mt Cook School in particular whose pupils used the project as a great learning experience on their doorstep. Alliance team members regularly visited the school to explain the project and their personal involvement in it and answer questions. Site visits were also arranged to provide students with the opportunity to see the project progressing first hand.

A strong partnership with both Wellington City Council and Wellington Water was developed through regular communication throughout the project. This open and honest working relationship focused on two-way idea exchange, which was very effective in identifying issues that arose during construction and finding appropriate, workable solutions.

8 CONCLUSIONS

The Arras Tunnel and Pukeahu National War Memorial Park project presented a range of challenges that were ideally suited to the application of the Alliance procurement model. The removal of the traditional boundaries between client, designer, contractor and stakeholders created a collaborative environment that allowed for innovative, time and cost effective solutions to be developed. The collaboration with the subsequent owners, designers and builders ensured the solutions were fit for purpose.

The challenge for the wet services team was to efficiently remove, replace and add new components to a complex network of water supply, stormwater, and wastewater services in a busy part of Wellington where these services were critical to the wider city network, while constructing the challenging project by an immovable deadline.

Innovative solutions were required to deal with the area's tight urban setting, constraints imposed by the Arras Tunnel excavation, the Park design, the tunnel geometry, the numerous services crossing the site, protection of the historic sewer, and the requirement to keep the State Highway open at all times.

Complications included the need to move services before the complete scope of the Arras Tunnel and Park design was known and to redesign services as the Arras Tunnel and Park design was developed.

Strong collaboration with other design disciplines and the construction team, as well as good relationships with authorities, were critical to overcoming these challenges.

Integration of the wet services into the urban design fabric was key to achieving the urban design vision for the Park. The success of the high profile Pukeahu National War Memorial Park is evidence of the good collaborative working methods adopted by the Alliance, with the project being completed on budget and ahead of schedule.

The Alliance achieved early delivery on the construction programme, opening the Arras Tunnel five weeks early and the Pukeahu National War Memorial Park four weeks early and most importantly, in time for the ANZAC commemorations.

ACKNOWLEDGEMENTS

This paper seeks to recognise a magnificent team effort right across the Memorial Park Alliance. However, I would like to particularly acknowledge the contribution of the wet services design team who worked tirelessly and diligently throughout the project:

Design Engineers - Karly Shields, Michelle Knappstein, Scott Williamson, and Katherine Heays

Design Review – Costas Chryssafis, Simon Norton, Neville Laverack, Carys Everett, Johnny Priestley and Tim Fisher

Photos courtesy of Colin McLellan and Stephen Patience.

REFERENCES

New Zealand Transport Agency (2015). National War Memorial Park and Underpass [Online].

Available: http://www.nzta.govt.nz/projects/memorial-park/index.html?r=1