

A tale of **two tunnels** that is setting **new best-practice standards**

New Zealand's biggest road project underwent extremely rigorous economic and risk assessment procedures before the final contracts were signed, Jenny Pretorius reports

The NZ\$1.4 billion Waterview Connection project currently being built by the Well-Connected Alliance provided a series of unique uncertainties, risks and challenges for the project's owner, the NZ Transport Agency.

The usual construction and peripheral pressures associated with large-scale construction work such as building a major inner-city road were compounded by a variety of other factors not often seen in local projects.

These included the project's complex underground tunnel construction component, the length of the tunnels that required specialised fire and life-safety features and the fact that construction was taking place in a built-up urban area with major traffic issues and a sensitive cultural, physical, and social environment.

The competitive alliance procurement method offered the best option to minimise the risks, achieve complete certainty with respect to outcomes and optimise value for money, according to one of the key experts involved in the tender selection process.

Managing risk

NZ Transport Agency Chief Advisor Engineering Assurance Peter Spies says the success or failure of a project such as this can often be traced back to decisions made prior to and during the procurement of the contractor when the potential consequences of these decisions are not well understood.

"Effective risk management

decision making is key to ensuring the selection of an appropriate procurement model while also ensuring that all relevant information is sourced and shared to ensure a common understanding of residual risks through the construction phase," he explains.

These risks can then be managed using appropriate processes managed by the right people. "However there always remains the danger that commercial pressures can lead to decisions that elevate construction risk profiles," Mr Spies notes.

"The commercial model and alliance principles inherent in an alliance agreement, while not substitutes for effective risk management practices, are considered to be effective catalysts in ensuring project risks are managed in accordance with the 'as low as reasonably practicable' (ALARP) best-practice principle."

The increasing importance placed on risk management in this context was largely due to the losses suffered by tunnel insurers over the last decade as various projects such as Boston's Big Dig and the Highway 99 tunnel under downtown Seattle encountered huge, unexpected, and expensive failure problems while under construction.

Moreover, the insurance industry noted a general trend towards high-risk type construction methods, often delivered using design-and-build contracts with one-sided contract conditions in an environment of fierce competition.

There was, therefore, an acknowledgement that risk management practices need to be instigated well in advance of commercial phases so that commercial competition didn't lead to a significant elevation of project risk.

Sharing risks and rewards

The cost of transferring risk is prohibitive but the alliance model not only provides for risk sharing but also allows the project solution to be progressively refined and developed to reflect emerging risk, leading the Transport Agency to conclude that this collective approach to assessing and managing risk produces better outcomes.

In addition, the risk-sharing element required the tenderers to combine a target outturn cost (TOC) of the design and construction phase with a TOC for the 10-year operate-and-maintain phase.

"The operating costs of tunnels are high," Mr Spies notes. "This allowed optimal decision-making by the tenderers that would be informed by a whole-of-life approach across the two phases, and that would ensure operational efficiency would not be compromised to achieve a competitive initial price."

But risk sharing is only part of the success recipe: the commercial arrangements in the alliance model strongly incentivise tenderers to achieve value for money. The competitive element of the alliance model then further drives innovation to achieve a lower initial TOC; as has been demonstrated across a number



Artist's impression of appearance of junction on south end

Images courtesy of NZ Transport Agency, Well-Connected Alliance



From left, Aurecon's Tom Ireland with NZTA Chief Advisor Engineering Assurance Peter Spies



View of construction work on the north end



of projects in Australia and New Zealand.

In addition, the alliance model allows the combination of the skills of all parties to be applied to the collective outcome by maximising the full integration of the traditional roles of client, constructor and designer.

As an added bonus, the Transport Agency had already acquired the skills and capacity to influence or participate in the development and delivery of the project through previous road infrastructure projects delivered via the alliance model.

The agency went a step further to ensure an excellent outcome by not only integrating key staff within the Well-Connected Alliance but also introducing an Owner Interface Manager (OIM) accountable for

the delivery of Western Ring Route (WRR) projects and delegated to making project decisions on behalf of the client.

The OIM in turn was supported by the Agency's Owner Verifier (OV), Aurecon's Tom Ireland, who also acted as the technical advisor and provided independent technical advice on behalf of the Transport Agency during procurement.

Another Transport Agency innovation that served to manage risk and provide value for money was its policy of reimbursing tenderers a fixed sum of expected tendering costs, in this instance equivalent to 60 per cent.

The \$18 million pool allocated for the Waterview Connection tender gave the agency ownership of the intellectual property generated by

both original project contenders, including all tender design material and risk mitigation methods.

The tender IP ensured that the project risk and cost could be further reduced by incorporating good ideas from the losing tender, including alternative designs for the ventilation fans and lighting that generated savings greater than the tender cost imbursement to the losing tenderer.

Special case

There was however a kink in the cable – the project had to start as fast as possible to provide a stimulus for the New Zealand economy following the 2008 recession.

There were only 24 months following confirmation of the tunnel option in December 2009 for environmental assessments, planning

approval – the road corridor was not in place and therefore the planning process also needed to include the designation of the motorway corridor – and the contract award.

This was a very short timeframe so the agency took the unusual approach of running the procurement and consenting processes concurrently along with obtaining planning approval through an Environmental Protection Authority Board of Inquiry (BoI) rather than through the resource consents process using the local authority, saving 12 months on the pre-contract phase programme and two years-plus in the project development programme.

The competitive tender design and procurement pricing phase began in November 2010 with tender



Aerial view of Big Alice prior to starting work on the south end

submission scheduled for early June 2011, so when the competitive phase of the tender commenced the planning process had already been running for two months.

The parallel programmes were aligned so that the tender would not close until the final consent conditions were available, as the Transport Agency considered that the competitive pricing would be compromised without finalised consent conditions that formed part of the requirements to be met by the alliance.

Tight connections

The NZ Transport Agency used a three-stage procurement process over a 19-month period to appoint the alliance, placing advertisements in July 2010 seeking Registrations of Interest (ROIs) from appropriately experienced consortia to deliver the Waterview Connection project, including the Waterview Connection Tunnels and Great North Road Interchange project.

Three consortia registered interest and an inception meeting on 4 August 2010 explained the Transport Agency's procurement process and requirements to the applicants and issued Statement of Interest and Ability (SIA) documents.

One specific identified risk was the low, 9m cover to the arterial road at the northern end of the



The tunnel's progress – breakthrough of the first tunnel at the end of September

tunnel, and tenderers had to comply with the consent conditions that included prescriptive requirements for monitoring and management of settlement effects.

Several additional minimum requirements were also included by the Transport Agency within the tender documentation in order to mitigate the risks associated with third-party impacts.

These refinements to the

procurement documentation ensured compliance with the Code of Practice for Risk Management of Tunnel Works (TCoP) prepared by the International Tunnel Insurance Group in 2006, and other international best-practice and home-grown risk mitigation measures were also included to ensure successful procurement.

The principle of shared risk in an alliance incentivises the common

understanding of project risks prior to finalising the alliance agreement, Mr Spies explains. "This ensures superior risk management through construction and beyond," he says. "As best-practice risk management is a primary objective of TCoP this procurement method was beneficial to all concerned."

"In particular the practice of gaining commercial advantage by taking on a potentially unmanageable level of

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The tunnel's southern end at the beginning of the project in May 2013



The southern end showing the tunnel portal of the first of the twin tunnels: the 14-metre diameter art work Te Haerenga Hou, meaning New Journey, that was designed especially for the Waterview Connection project by Auckland artist Graham Tipene guards the northbound tunnel's planned opening.

risk – which has seen other similar projects across the globe fall into serious difficulties – is an outcome that can be avoided by the use of the TCoP,” Mr Spies adds.

The TCoP risk management procedure formally documents the identification, evaluation and allocation of risks, with three significant sections addressing pre-design activities – including definition of the client role and responsibilities, project development requirements and contract procurement stages.

The three consortia that submitted SIAs were further assisted by two interactive meetings with the three-member Tender Evaluation Team (TET) held separately with each applicant before submissions closed on 4 October 2010.

The TET reviewed the submissions and met to complete their assessment, resulting in the Well-Connected Alliance and Tuhono being selected to proceed to the next Request for Proposals (RFP) stage.

The Transport Agency put significant effort into optimising

the RFP documentation and the interactive tendering process, leading to close of tenders in July 2011. “This effort was focused on what the Agency’s project team referred to as the three Ps – product, process, and people – as it was recognised early on that to successfully procure a proponent that would be working with the Transport Agency to deliver the project, we needed to ensure that we were being offered and could build the right product through a robust process delivered by the right people,” Mr Spies comments.

In addition to the technical and procurement expertise within the project team, a check sheet was developed to ensure that TCoP recommendations were either addressed as part of the procurement process or that appropriate steps had been taken to ensure that the successful proponent would be able to address these in the delivery phase.

This resulted in a seven-month interactive tender process that was a critical aspect of the risk reduction

sought by the TCoP, as procurement methodologies used on previous projects internationally have led to the elevation of project risk.

The interactive component comprised a combination of alignment workshops and technical consent meetings held separately with each proponent that focused on technical matters such as the Requirements and Minimum standards (MRs), which the Transport Agency attempted to keep as generic as possible to encourage innovation, as well as any proposed departures from these standards.

In addition, the Transport Agency adopted the “Certificate A” concept from its Design and Construct procurement process, which saw each proponent submit their preliminary conceptual design reports eight weeks before close of tender for review by the project team and appropriate feedback.

The Transport Agency placed high value on design and construction mitigation measures proposed in order to address ground risks, developing an Alliance Geotechnical Baseline Report

(AGBR) process to ensure alignment on the level of geotechnical risks.

The AGBR provided a comprehensive discussion of geotechnical risks and posed a series of detailed questions of the proponents’ design and construction methodologies to discover how they would address all geotechnical risks.

It used commonly agreed wording to provide definitive statements about the nature, form, composition and structure of the ground, both artificial and natural, and groundwater; together with geotechnical properties.

The AGBR also set out the contractual definitions of ground conditions where the Transport Agency would accept a variation to the agreed TOC, with the agency covering only the direct cost of additional work, while allowing the contractor to receive reasonable and fair direct costs but not to profit from a baseline geotechnical risk that was well received by the two bidders at the time of the tender.

The use of a variation benchmarking register and associated workshop exercises ensured that the



Work gets underway Great North Road interchange



The northern end showing ramps as at June 2014

proponents fully understood what could or could not be considered a variation in an alliance contract.

A further refinement to its typical conditions insurance saw professional indemnity and public liability and contract works set as a provisional sum, with the Transport Agency carrying the full cost of obtaining insurance rather than it becoming an item that proponents would attempt to price in the bid phase.

The agency recognised that obtaining insurances for tunnelling projects is a complex matter, and

that marketing was best done at the conclusion of the procurement process when the alliance was established, the conceptual design developed, and a detailed understanding of the construction methodology and associated risks sufficiently demonstrated.

Ready, steady, go

Evaluation was undertaken in accordance with Transport Agency procedures, which use a two-envelope system, with one envelope containing price information and the

other non-price information.

The second category included the detailed conceptual design and associated information such as construction methodology, the risk register, and the requested further 10-year operations and maintenance plan.

The Well-Connected consortium comprising Fletcher Construction, McConnell Dowell Constructors, Parsons Brinckerhoff, Beca Infrastructure, Tonkin and Taylor, and Japanese construction company Obayashi Corporation was announced as the preferred

candidate on 18 August.

Pre-award activities were successfully concluded in late November 2011, and the contract awarded to the Well-Connected consortium for a TOC of \$1,100m-plus to complete the project by March 2017, followed by a 10-year operation and maintenance period.

"The alliance process ensured that the Transport Agency was able to award a project within budget that fully met functionality requirements with a high degree of certainty that the project will be delivered within the agreed TOC," Mr Spies concludes.

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Creative connection closing the commuting circle

The multi-faceted road project that is designed to provide vital additional capacity for a major Auckland ring route is literally breaking new ground

The NZ \$1.4bn Waterview Connection in Auckland that will complete Auckland's Western Ring Route (WRR) is on track to hit its early 2017 completion target.

One of New Zealand's seven Roads of National Significance, the Waterview Connection will deliver a massive increase in the capacity of the Auckland motorway network by providing a 47km motorway alternative to Auckland's central motorway congestion.

Bypassing the city to the west, the connection will link Manukau, Auckland, Waitakere, and North Shore regional centres via State Highways 20 (the South-western Motorway), 16 (the North-western Motorway) and 18.

The enormous project that is the largest of the five that comprise the WWR features a new 1.7km motorway interchange built at the northern end to create free-flow links for all traffic movements between the motorways while also maintaining connectivity for the local interchange.

The heart of the project, however, is the twin 2.4km, three-lane, 13.1m diameter motorway tunnels that will pass up to 45m under a built-up residential area and a major local arterial road carrying



An artist's image of the complete project with the ramps on the north end

over 50,000 vehicles per day in Avondale to link the two ends.

They are being built by an earth pressure balance tunnel boring machine (TBM) affectionately known as Alice, which is now halfway through her underground journey from the southern tunnel portal located just off SH20 in Owairaka to the northern portal in Waterview, and back.

Since breaking ground in November 2013 she has bored the tunnel that will carry southbound traffic while simultaneously installing the two metre-wide concrete rings that line and support the structure.

Now at the Waterview portal, the TBM is being unhitched from her trailing gantries and moved onto a

heavy-duty steel cradle. The TBM is being moved sideways, turned 180 degrees using hydraulic jacks and pushed up against the entry portal of the northern tunnel. The first of the two trailing gantries will then be retrieved from the completed tunnel and moved into position behind the TBM. Together they will be re-launched in December to bore 300 metres of the new tunnel, far enough for the other trailing gantries and the culvert gantry to take their positions behind them.

The full drive south will resume in March and the final breakthrough at Owairaka is expected before October 2015.

Progressing apace

Work is continuing apace at both ends of the tunnel, with the northern end of the project focusing on a five-hectare area parallel to Great North Road, incorporating part of the former Waterview Reserve and Cowley Street.

The northern approach trench has been built using diaphragm wall methodology to support the trench wall, with bentonite from an on-site plant used to condition the sandy soil.

From the northern portal, the motorway will rise up in the form of a 1.7km-long interchange comprising four ramps that will link the North-western SH16 and South-western SH20 motorways and effectively complete the Western Ring Route.



An artist's impression of Hendon footbridge



Inside the tunnel boring machine - Alice's wonderland



Segment delivery to the TBM by means of a special trailer



Segment erection on the TBM: the Waterview tunnels will be completely lined by 24,040 pre-fabricated tunnel lining concrete segments installed by an erector that picks up the segments that enter the TBM via a gantry and installs them one at a time

They require the construction of 53 bridge spans comprising 54 columns founded on bored piles, 44 crossheads, three table tops, and 279 Super-T beams each up to 36 m long, the latter being placed by a purpose-built, 100m-long, self-launching girder known to its operators as Dennis.

Much of the work on the southern end of the project has been completed including:

- the construction of the motorway alignment linking the tunnels and SH20
- the construction of a motorway overpass to take Richardson Road

- over the motorway
- the construction of the spoil handling facility
- the construction of an overpass above Oakley Creek (Auckland's longest freshwater creek)
- realignment and improvement of other sections of Oakley Creek
- relocation of a major Watercare sewer away from the motorway alignment
- and construction of storm water treatment ponds.

The interchange at Sh16/20 will provide direct motorway connection between the Auckland CBD and

Auckland International Airport with the developing areas in the southwest and northwest, cutting travelling time between the CBD and airport.

More than roads

The NZ Transport Agency says the Waterview Connection project is not simply about roads, but about connecting people. "It's not just a tunnel, but a complete urban development project focused on improving outcomes for all, for the communities involved as well as for the whole of New Zealand," a spokesperson says.

Not all the work will be for the unique benefit of motorway users: the Waterview Connection project will integrate road bridges, cycle ways, and pedestrian bridges within a suite of urban design, landscaping, and environmental enhancements.

The inclusion of these elements will be complemented by on-going community involvement, as the Transport Agency commits to delivering its biggest project with maximum benefit and minimum disruption to the local community.

Areas of Oakley Creek Te Auanga have now been designed to replicate

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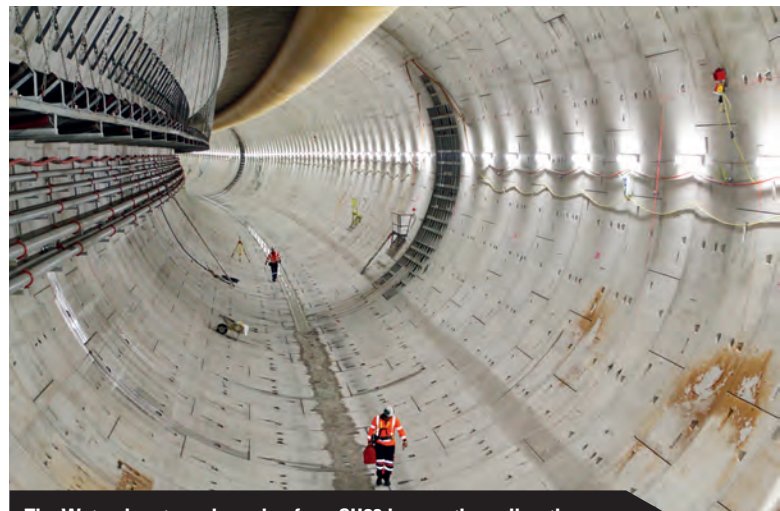


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The culvert is being progressively backfilled with a road bed consisting of a 2.2m high culvert in the centre with sides filled with 40mm road base material to culvert level before a 1.2m high second stage backfill is placed on top



The Waterview tunnel running from SH20 in a northern direction, showing the sheer beauty of the new construction

the flow of a more naturalised stream and better accommodate flood flows while gentle battered slopes leading down to the stream will provide access for bird, fish and

insect life.

The green areas next to the creek have been planted exclusively with native plants and will be open to the public as a new reserve when the

Waterview Connection is completed in early 2017, providing footpaths, shared-use cycle ways, and footbridges crossing the creek and the motorway.

Other community additions include a shared foot and cycle bridge across the motorway in the south and a shared path connecting Waterview and Mt Albert that will effectively link the city's North-western cycleway along SH16 and South-western cycleway with connections to the airport.

The Waterview Connection project will thus provide a major boost to New Zealand's biggest city and the economic gateway through which 61 percent of the country's imports and 32 percent of its exports pass, not only in terms of greater economic efficiency but enhanced quality of life for Auckland citizens.

Competitive alliance the coming concept?

Competitive alliance project procurement is becoming increasingly common worldwide as it offers several key advantages over conventional infrastructure procurement methods.

The concept sees the project owner or client work collaboratively with its suppliers under the core alliance philosophy – all parties win or all lose.

The owner forms an alliance with one or more service providers – for instance the designer, constructor and supplier – for the purpose of delivering outstanding results on a specific project.

Performance obligations and risk sharing are collective – participants commit to work together in good faith to achieve the successful delivery of the work, wearing the hat of the alliance, or virtual new company.

The alliance is paid 100 percent of direct expenditure on the work,



The 3.7m wide and 2.2m high culvert on the floor of the main tunnel will run below the completed motorway and carry the services required to operate the tunnel, including the ventilation, communication, fire detection and lighting systems

including project-specific overheads and a fixed lump sum fee to cover corporate overheads and profit.

There are also provisions for an equitable sharing of gain and pain depending on how actual outcomes compare with pre-agreed targets in cost and non-cost performance areas.

The project is governed by a project alliance board (PAB) with representatives from all parties who carry full authority to take decisions that bind the alliance but must make unanimous decisions.

An alliance management team (AMT) with members assigned on a best-for-project basis without regard to their employer handles day-to-day management of the project.

There is an express commitment to resolve issues within the alliance without recourse to litigation except in the case of wilful default. The alliance participants develop and commit to work within an agreed set of alliance principles.

The key difference between a pure alliance and competitive alliance is found in the procurement stage prior to the signing of the project alliance agreement (PAA).

In a competitive alliance the tenderers, or proponents, compete with each other to deliver best and most predictable outcomes and best value for money.

The competitive element drives them to innovate – with an acute



The 68m-long culvert gantry before installation in the tunnel

regard for risk minimisation – to achieve a lower initial target outturn cost than the participants in a pure alliance.

The winner is then selected through a process that involves an assessment of both price and non-price attributes, with the final PAA representing the “lowest evaluation net total target outturn cost”.

First used in the UK oil and gas infrastructure procurement sector in the early 1990s and widely found in Australia, project alliancing

isn’t used extensively in the rest of the world – though interest in the concept is growing.

Locally, the NZ Transport Agency used the model in 2000 to procure the Grafton Gully project, a major connection between the Auckland Port and State Highway 1, since when eight State Highway projects have been successfully delivered or are being delivered as alliances.

The Waterview Connection project is a NZ Transport Agency project, and is being delivered by the Well-

Connected Alliance comprising the Agency, Fletcher Construction, McConnell Dowell Constructors, Parsons Brinckerhoff, Beca Infrastructure, Tonkin and Taylor, and Japanese construction company Obayashi Corporation.

The Well-Connected Alliance has formed further partnerships with New Zealand precast concrete suppliers Wilson Tunnelling to manage the construction of the tunnel lining and SICE to manage the long-term maintenance and operation.

DELIVERING THE WATERVIEW CONNECTION – A COLLABORATIVE APPROACH

Beca is proud to be part of the Well-Connected Alliance delivering the \$1.4 billion Waterview Connection project for the NZ Transport Agency and for the community of Auckland.

As one of New Zealand’s leading employee-owned professional services consultancies, it is a privilege to be part of the talented team delivering a roading system that will lead the city into the future, unlocking its potential to become a truly world class city.

It has been an incredible journey. We have been there right from the very beginning, assisting the NZ Transport Agency with the initial consenting route protection aspects and all of the necessary statutory approvals.

Our planning and construction teams developed seamless solutions in advance of construction on site. And while our fully integrated design teams focus on aspects like geometrics,

bridges, retention structures, buildings, tunnel systems and hydrogeology, we are also providing whole of life assessment so this vital connection can help to keep Auckland moving well into the future.

We enjoy the challenges that a project of this scale and significance delivers, and have enjoyed celebrating the project’s many milestones and achievements with our Alliance team and the community. A defining moment was when Alice, the famous tunnel boring machine, broke through into daylight at the north end of the tunnel.

We look forward to celebrating many more exciting moments together!

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Waterview tunnelling machine has a healthy appetite

The \$55 million, 3,600 tonne tunnel boring machine affectionately known as Alice consists of a shield and a train of three cars, or gantries, which sit behind the shield.

The shield contains the cutting head that removes the soil to create the tunnel – the tunnelling phase – and the equipment that installs prefabricated concrete panels that form the walls of the tunnel – the ring-building phase.

An earth pressure balance machine such as Alice balances the shield cutting head pressure to that of the surrounding area, stopping the ground from caving in until it can be supported properly by using pre-cast segments and bolting them together.

Hydraulic thrust cylinders that apply pressure of up to 22,800 tonnes to push the thick steel cutting wheel against the tunnel face during the tunnelling phase rotate at speeds up to 1.9 revolutions per minute as Alice grates the earth.

Twenty four electric motors with 8400kW of usable power generating 82,546kNm of torque power the cutting wheel via the main drive, enabling the high-strength cutter to remove soil conditioned using a foaming agent injected with water and compressed air into the cutting area through pipes in the rotary cutting head.

These pipes are connected to injection nozzles at the front of the head, which spray the conditioning mixture on to the cutting face and condition the soil till it becomes pliable to ensure it doesn't clump

and stick to the cutting head and can be easily removed from the cutting chamber.

The spoil enters the excavation chamber through openings in the cutting wheel and mixes with soil mush that has already been removed; the pressure bulkhead transfers the thrust cylinder force to the soil mush to balance the earth pressure.

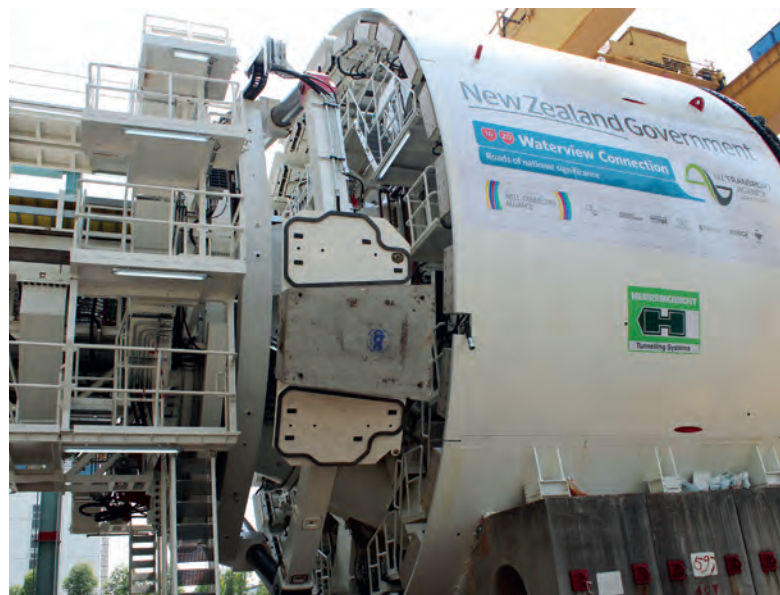
Excavated spoil is removed from behind the shield via a screw conveyor as hydraulic cylinders around the shield circumference relentlessly drive the cutting head forward by pushing against the concrete wall linings Alice leaves in her wake.

Ten concrete lining segments that enter the machine via a gantry make up a tunnel ring, with each of the 2m-long, 450mm-thick segments being picked up by an erector that installs them under atmospheric pressure and then bolts them into place.

Cement grout is continuously forced into the remaining gap between the segment's outer side and the soil through injection openings in the tail skin to ensure there are no gaps between the excavated earth and the tunnel-lining rings and thus maintain the stability of the 24,040 prefabricated tunnel-lining concrete segments that will eventually completely line the Waterview tunnels.

The tunnel segments are produced in a new production facility about 26km from the tunnel site. The factory produces 21,726 segments, 2418 invert culverts and 279 Super-T beams for the Great North Rd interchange. Segments are transported to the site and stored in a yard with capacity for enough segments for 2.5 days of TBM production. Special multi service vehicles transport the segments to the TBM.

Tunnelling spoil is offloaded onto a 1.2m-wide strengthened rubber conveyor system built progressively in Alice's wake that runs at 3.5m per second and can ship up to 3,500



Alice's shield can withstand the pressure 45m underground

tonnes of spoil per hour.

The conveyor structure, inside a soundproof casing that allows round-the-clock operation, elevates from about 4.8m in the tunnel portal to 14m high at the spoil-handling building entrance.

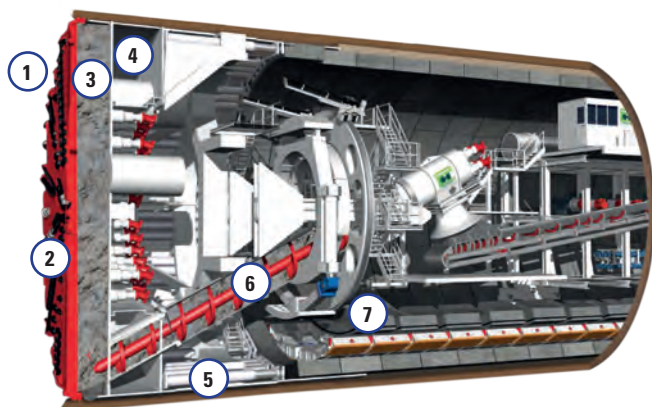
Alice produces 330 cubic m of spoil for every two m she progresses and will eventually remove some 835,000 cubic m of ground – enough to fill 320 Olympic-size pools.

The 170m-long spoil-handling building that contains eight individual bins with a total capacity of 13,000 cubic m is also acoustically lined to allow round-the-clock loading of the spoil, which remains in the bins for 24 hours to dewater and is then trucked to a quarry in Wiri, South Auckland.

Following closely behind Alice, a special 68m-long lifting gantry installs a 3.7m-wide and 2.2m-high culvert that sits on the floor of the main tunnel and will carry the services required to operate the tunnel.

The culvert will run below the completed motorway and carry the cables for the ventilation, communication, fire detection, and lighting systems required to operate the tunnels after they open to traffic in early 2017.

Built by Herrenknecht in Germany and China, transported in pieces and arriving in July 2013, Alice took three months to put together again using a 600 tonne Terex-Demag CC2800-1 crane brought to site to lift the TBM components into the trench.



1. Tunnel face 2. Cutting wheel 3. Excavation chamber
4. Pressure bulkhead 5. Thrust cylinder 6. Screw conveyor
7. Concrete lining segments

FAST FACTS

- Alice's working depth: 15 to 45m below ground
- Weight: 3600t, or about the same weight as 750 elephants
- Cut diameter: 14.46m
- Shield diameter: 14.41m
- Number of electric motors installed: 24 pieces
- Motor power: 350kW
- Total installed power: 8400kW
- Maximum torque: 82,546kNm
- Maximum rotation speed: 1.9rpm
- Cooling system: 2600L/min 25°C
- Propulsion: 9.5rpm
- No of cylinders: 56
- Propulsion stroke: 3000mm
- Max rate of cylinder extension: 85mm/min
- Total thrust force: 228,000kN
- Length of tunnelling machine shield: 12m
- Maximum length of back-up car or gantry: 28m
- Top speed: 85 mm/min
- How long Alice would take to drill to the centre of the earth? 2,655 years