

**M** sydney  
METRO | northwest

# BREAK THROUGH

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Building Australia's longest railway tunnels



Rodd Staples, Mike Baird and Andrew Constance

*This critical public transport project is taking shape before our eyes; I pay tribute to all the men and women who have worked on this massive project.*

**Mike Baird**

Premier of New South Wales and Minister for Western Sydney

*This is just the start of Sydney's great tunnelling boom as we deliver new world-class infrastructure for tomorrow's Sydney. This is not only city building, this is state building and nation building.*

**Andrew Constance**

Minister for Transport and Infrastructure

*Sydney Metro is being built to grow with The Hills region and with Sydney as a whole. My priority has been to work as quickly as possible to deliver Australia's biggest public transport project.*

**Rodd Staples**

Program Director Sydney Metro



THE BIG DIG

Sydney Metro is Australia's biggest public transport project.



A new standalone railway network, it will deliver 31 metro stations and more than 65km of new metro rail between Rouse Hill in Sydney's North West and Bankstown in the South West.

The \$8.3 billion Sydney Metro Northwest, formerly known as the North West Rail Link, is Stage 1 of Sydney Metro. Services start in the first half of 2019 with a train every four minutes in the peak.

One of three major delivery contracts, the \$1.15 billion Tunnels and Stations Civil works contract was awarded on 25 June 2013 to the Thiess John Holland Dragados joint venture, subsequently known as CPB John Holland Dragados.

This is the journey of how Australia's longest railway tunnels were delivered for Sydney Metro Northwest.

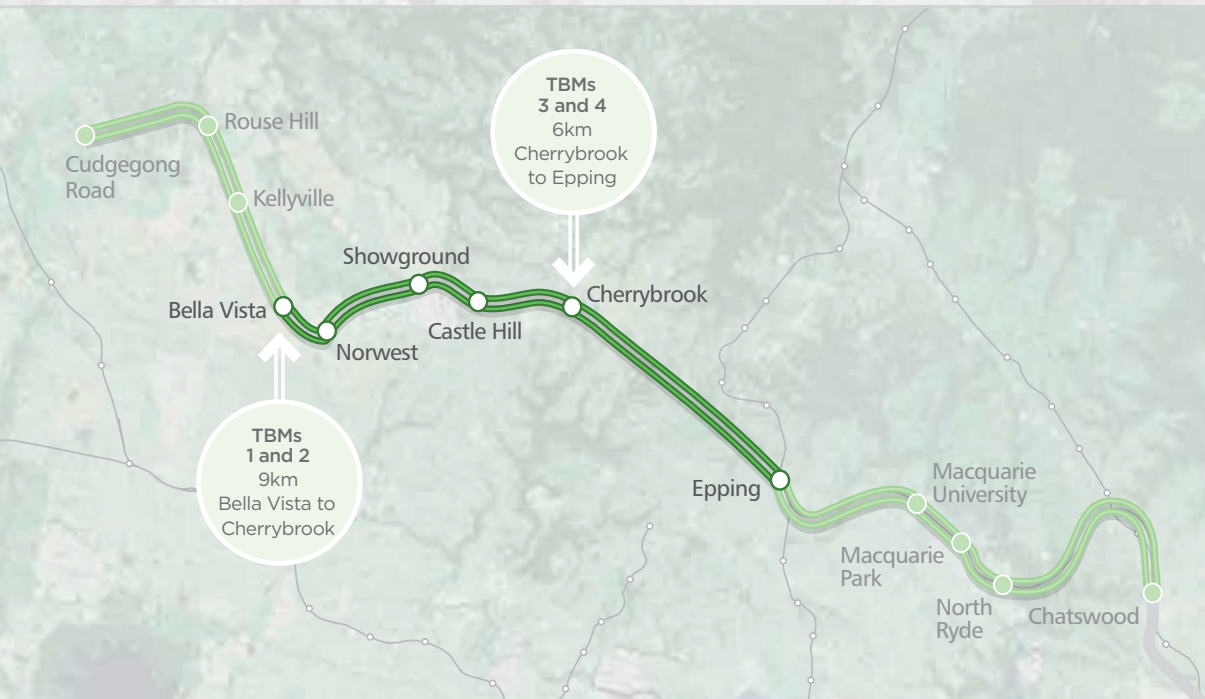
- 15km twin tunnels, Bella Vista to Epping
- Four tunnel boring machines
- 10 break-throughs
- 4.476 million tonnes of rock excavated
- 100 per cent of crushed rock from tunnelling recycled
- 2,006 cutters replaced
- 98,184 concrete tunnel segments made
- 16,290 concrete tunnel rings installed
- More than 4,600 workers

▶ **Click on the Play button to watch videos throughout this book.**

# OUR MEGA MACHINES

Sydney Metro Northwest was the first transport infrastructure project in Australian history to use four tunnel boring machines.

- Double-shield, hard rock, gripper-type tunnel boring machines (TBMs)
- Designed and built specifically for Sydney's geology by France-based NFM Technologies
- Each TBM tunnelled an average 173m a week through Sydney sandstone and shale
- 24/7 underground operation by a rotating crew of 15
- Each cutter-head weighed 105-tonnes and was made up of 40 tungsten steel cutters
- Each cutter weighed 250kg and was replaced about every three weeks
- 30km tunnelling task; twin tunnels from Bella Vista to Epping
- TBMs 1, 2 and 4 were named by the community in public competitions; TBM3 was named by the tunnel builders on behalf of workers



## TBM1 Elizabeth

Launch	8 September 2014
Completed	1 December 2015



Named after local colonial pioneer Elizabeth Rouse (1772-1849).

Elizabeth arrived in New South Wales as a free settler in

1801 with her husband Richard Rouse (1774-1852) and they later lived on a property near Windsor.

The property, Rouse Hill, became the cornerstone of the family's farming.



## TBM2 Florence

Launch	31 October 2014
Completed	14 January 2016



Florence Taylor was Australia's first female architect, structural engineer and civil engineer.

Florence (1879-1969) completed a draftsman's

course at Sydney Technical College at the turn of the 20th century.

A qualified town planner and reportedly the first woman to fly in Australia in 1909, she even proposed the idea of a tunnel under Sydney Harbour.



## TBM3 Isabelle

Launch	3 November 2014
Completed	18 September 2015



Named by tunnel builders CPB John Holland Dragados after four-year-old Isabelle Andersen, whose father Grant and mother Anne both worked on the project.

Isabelle represented the families of the workers. Working safely and getting home to loved ones every day was a big motivation for everyone on the project.



## TBM4 Maria

Launch	13 January 2015
Completed	29 October 2015

Maria Lock (c.1805-1878) was an Aboriginal landowner born near Richmond and the daughter of Yarramundi, Chief of the Richmond Tribes.

In 1824, Maria married convict carpenter Robert Lock, the first officially sanctioned union between a convict and an Aboriginal woman.

Maria was the first female Aboriginal to be given a land grant at Liverpool. The process took almost 20 years.

The twin 15km tunnels highlighted on the 36km-long Sydney Metro Northwest alignment

# THE BOXES



Bella Vista Station, June 2014

Sydney Metro Northwest's \$1.15 billion tunnelling contract included:

- Delivering the twin 15km tunnels from Bella Vista to Epping
- Excavation and civil works for five new metro stations at Cherrybrook, Castle Hill, Showground, Norwest and Bella Vista
- Two services facilities excavated at Cheltenham and Epping.

Tunnelling generated more than 3.2 million tonnes of crushed sandstone and shale from:

- The twin metro tunnels and 55 cross passages linking them
- A giant underground cavern at Castle Hill
- Two 300m tunnels at Epping connecting the end of the new tunnels to the existing railway tunnels between Epping and Chatswood.

A further 1.2 million tonnes were excavated from the other sites.

In a major project achievement, 100 per cent of excavated material was recycled, most of it on commercial, industrial and housing developments across Greater Western Sydney including an environmental re-use project at Prospect Reservoir.

Bella Vista was the site of the first station box excavation, with 144,000 tonnes of rock excavated in just five months so the first TBM could be on site and assembled by September 2014.

At Showground, 244,000 tonnes of rock were excavated in 10 months to get to the station platform construction level, 26m below the surface.



Showground Station, March 2015



Cherrybrook Station, April 2015



Recycling Sydney's monorail beams, February 2014



Monorail being installed at Norwest, April 2014



Norwest Station, July 2014

## Sydney's transport past helped build the city's public transport future.

Sixty steel beams removed from the Sydney Monorail in 2013 were refurbished and used to build a temporary road bridge at the site of the new Norwest Station in 2014.

Original plans proposed a lengthy closure of Brookhollow Avenue at the intersection of Norwest Boulevard so the underground station could be built.

Following feedback from the community and local businesses, a temporary bridge was built at road level and the road then re-opened to traffic. The excavation of the new station continued under the bridge, reducing disruptions above ground.

This innovative solution dramatically cut the length of time Brookhollow Avenue had to be closed - from up to three years to just over three months.

The monorail beams were welded and refurbished to make 29 bridge girders, each weighing between 11 and 17 tonnes and spanning more than 32m in length.



Norwest Station with the temporary bridge at top right of picture, July 2014



# FIRST LOOK



TBM1 Elizabeth factory acceptance testing, June 2014



*Construction is underway,  
jobs are being created.*

**Gladys Berejiklian**  
Minister for Transport  
24 March 2014

*Elizabeth was a strong woman.  
The boring machine needs to  
be strong and ready for battle.*



**Alexandra Marshall, aged 12**  
8 September 2014

On major tunnelling projects around the world, underground workers look to Saint Barbara for protection. Because of this, machines that work underground are traditionally given female names.

A public competition was held to name three of the four TBMs under the theme: "Women who have made a positive contribution to life in Sydney."

As part of the project's *FastTracking the Future* education program, school students in the North West were invited to name TBM1.

The winner was Alexandra Marshall from Rouse Hill Anglican College with Elizabeth, after 1800s colonial farming pioneer Elizabeth Rouse.



Alexandra Marshall, left, who named Elizabeth, and her sister Tara, September 2014

TBM1 Elizabeth factory acceptance testing, June 2014

# SHE'S HERE



Welcome, Elizabeth.

*In dozens of parts, the smallest of which still dwarfing the Port of Newcastle dock workers charged with unloading her on to trucks, Elizabeth is now being trucked by police escort to Bella Vista, where she will be reassembled ready for work.*

*It will take nearly 50 truck trips to make the voyage, which will take place mostly at night.*



**David Catt**  
Editor  
*Hills Shire Times*  
25 July 2014





# TUNNELLING BEGINS

- Following assembly and factory testing in Shenyang, China, the four TBMs were shipped to the Port of Newcastle then trucked to Sydney's North West.
- Each TBM was delivered to site in thousands of small components packed into 18 shipping containers, as well as 22 large pieces.
- Each TBM weighed 900 tonnes and was 120m long - almost the length of two A380 super jumbos back-to-back.
- Re-assembly on-site took six weeks by a team of more than 70 workers.
- Two 500-tonne cranes took about seven hours to secure and lift each 105-tonne circular cutter-head into place.
- Each cutter-head had 40 hardened tungsten steel cutters.
- Each cutter weighed 250kg and was replaced about every three weeks. All up, 2,006 cutters were used in tunnelling.
- The TBMs were connected to tunnelling support services above ground including power, ventilation, compressed air, grout plant, hydraulic cooling towers, water pumps, a water treatment plant and spoil conveyors.
- TBM1 Elizabeth started tunnelling on 8 September 2014, four months ahead of schedule.
- By mid-January 2015, all four TBMs were tunnelling - the first time four TBMs had been used on an Australian transport infrastructure project.
- Cherrybrook was the only construction site to see all four TBMs: TBM1 Elizabeth and TBM2 Florence ended their 9km journeys here while TBM3 Isabelle and TBM4 Maria started from here, each digging 6km to Epping.



TBM1 Elizabeth from above, just before her launch at Bella Vista, September 2014


“ Today, I'm delighted to stand here as the first massive tunnel boring machine begins its historic journey digging Australia's longest railway tunnels. ”

**Mike Baird**  
Premier of New South Wales and Minister for Western Sydney  
8 September 2014

TBM1 Elizabeth launch at Bella Vista, 8 September 2014



About 25m below Sydney's Norwest Business Park, crews of 15 dirty and sweaty men are operating a giant machine 24 hours a day, burrowing through the earth to help build one of the biggest public transport projects in NSW history.

The work is hot, humid and noisy as the giant machine creeps forward more than a metre every hour, cutting a 7m diameter tunnel. 

**Jim O'Rourke**  
Transport Reporter  
*The Daily Telegraph*  
18 November 2014




Spoil was carried by 29km of conveyor belts from the back of the TBMs to storage areas like this one at Bella Vista



Workers installing segments underground on TBM1 Elizabeth, December 2014



When the four machines are tunnelling they will each send about 3300 tonnes of spoil a day out of tunnels on conveyor belts. 

**Jacob Saulwick**  
Transport Reporter  
*Sydney Morning Herald*  
18 November 2014





# 98,184 SEGMENTS

Australia's longest railway tunnels are lined with 16,290 concrete rings, creating a strong and waterproof internal lining.

A purpose-built pre-cast concrete factory at Bella Vista started work in May 2014 on the 98,184 concrete segments required for the project.

Each ring was made of six segments and installed underground as the TBMs moved forward.

More than 3,600 tonnes of cement was needed. Each segment weighed 4 tonnes.

Stacked on top of each other, these segments would stretch 26km.

The factory's best production day was on 27 May 2015, when 437 segments were made.

Over 18 months, it took 635,000 working hours to complete the segments.



The last concrete segment, November 2015



Six segments make one tunnel ring, March 2015

While a precise ratio of water to cement is essential for strong segments, there's another design innovation that keeps them waterproof once assembled - a rubber gasket that's built into the concrete.

**Mark Horstman**  
Host  
*Catalyst*, ABC-TV  
20 November 2014

Some of the 98,184 concrete segments used to line the tunnels, Bella Vista pre-cast yard, June 2015



First completed section of tunnel, 20m under Lexington Drive, Bella Vista, October 2014

TBM1 Elizabeth reached her first milestone at Norwest after a 2.1km dig from Bella Vista. In just four months, the TBM:

- Excavated 206,000 tonnes of crushed rock
- Installed 7,300 concrete segments
- Was an underground worksite for 85 workers, including tunnellers, maintenance crews, geologists, surveyors and engineers, who combined spent more than 25,000 hours underground
- Had 40 hardened steel cutters replaced, worn down from the harsh forces of cutting the Sydney sandstone and shale.



TBM1 Elizabeth breaking through at Norwest



Following the first break-through, TBM1 Elizabeth traverses the Norwest Station site, February 2015



*Over the past 12 months we've gone from a vacant site to what you see here today.*

*We waved Elizabeth farewell at Bella Vista last September and she's been working hard for the past four months.*



**Rodd Staples**  
Program Director  
Sydney Metro  
21 January 2015

# FIRST BREAK-THROUGH



# CAVERN



View from the crossover cavern to the future Castle Hill Station site, October 2015



Crossover cavern interior, September 2015

The most complex section of tunnelling was 25m under Castle Hill and didn't involve TBMs, even though two passed through it.

A 160m-long crossover cavern was excavated next to the station box to allow trains to swap tracks underground, a key part of ensuring reliable train services.

The cavern - 23m wide and up to 17m high - was an engineering feat and is one of the largest spanning excavations in shale in Sydney. More than 26,000 tonnes of concrete was used to line the cavern's walls, roof and floor.

The cavern had to be completed before TBM1 Elizabeth and TBM2 Florence arrived at Castle Hill, so they could be moved through it and continue tunnelling to Cherrybrook.

A road header tunnelling machine was used to excavate the cavern. Two road headers were also used at the Epping Services Facility to build two 300m tunnels connecting the new Sydney Metro rail tunnels to the two existing railway tunnels between Epping and Chatswood.

# TEAMWORK

Sydney Metro Northwest was the start of Sydney's great tunnelling boom.

Australia's first tunnel simulation training centre was set up on Sydney Metro Northwest to develop the next generation of tunnellers, with more than 100km of tunnels to be built in the city over coming years.

The tunnel builder's \$1.2 million initiative included a week-long unique program developed with TAFE NSW to ensure the workforce was familiar with the TBM environment before going underground.

Tunnellers also used 3D virtual reality goggles to "walk through" a TBM, with the technology also used at the project's Community Information Centre to give the community the same experience.



*This is Sydney's great tunnelling boom.*

*Tunnelling is a highly specialised skill and we're nurturing it for the future – I congratulate the tunnel builders on Sydney Metro Northwest for investing in their workforce for the future.*

**Andrew Constance**  
Minister for Transport and Infrastructure  
15 September 2015

*This investment is helping create the next generation of skilled tunnellers.*

*The joint venture companies take their responsibility very seriously to develop a highly skilled and competent tunnelling workforce for not just this job, but future projects.*

**Terry Sleiman**  
Project Director  
CPB John Holland Dragados  
15 September 2015

*They are among the first to travel inside Sydney's newest tunnel, but they're not passengers – they're building it.*

*Construction continues around the clock with some 400 tunnellers and massive machines.*

**Lee Jeloscek**  
Reporter  
Seven News  
15 September 2015



Top: Crossover cavern, Castle Hill  
Left: TBM3 Isabelle's crew at Epping  
Right: Bella Vista pre-cast team



# RARE SIGHT



A rare event in the world of tunnelling occurred when TBM3 Isabelle and then TBM4 Maria literally popped their heads up for air at Cheltenham.

Most TBMs arrive face-first at a site, breaking through a wall of rock.

But at Cheltenham the TBMs only stuck the top 3m of their cutter-heads out then kept on tunnelling through the site - exactly how engineers planned it.

Working hand-in-hand with the community has been a hallmark of Sydney Metro Northwest.

In September 2015, 20 people were given a once-in-a-lifetime chance to watch a TBM in action at the break-through of TBM2 Florence at Castle Hill.

More than 1,500 people entered the competition, which was promoted through the project's Facebook page and website.

In late 2015 and early 2016, more than 2,000 people attended open days at the Castle Hill and Cherrybrook construction sites, where TBMs were on display.

And almost 3,000 children have learned about tunnelling through school holiday programs and the project's education program, *FastTracking the Future*.



Community tours at the Cherrybrook construction site, 31 January 2016

“My priority has been to work as quickly as possible to deliver Sydney Metro Northwest and bring rail back to the Hills after almost 90 years - but this time it's going to be bigger and better, and it's here to stay.”

**Rodd Staples**  
Program Director  
Sydney Metro  
30 November 2015

# COMMUNITY



Community tours at Cherrybrook construction site, 31 January 2016



Community members watch TBM2 break-through at Castle Hill, 2 October 2015



*This project will be a game changer for Sydney and NSW. The reality of a new 65km railway network for Sydney is taking shape before our eyes every day.*

**Andrew Constance**  
Minister for Transport and Infrastructure  
24 June 2015

*My grandfather helped build the Sydney Harbour Bridge, installing the hot rivets on the southern arch.*

*I grew up hearing stories in the lounge room on a Sunday afternoon about how the great Coathanger changed Sydney.*

*I hope my kids are telling the same stories in the future - and how Sydney Metro helped change the way we get around this great city, making it easier and faster.*

**Rodd Staples**  
Program Director  
Sydney Metro  
20 November 2015

Castle Hill Station construction site, February 2016



Community tours at the Castle Hill construction site, 11 October 2015

*The community interest as we build Australia's longest railway tunnels is a reminder of how fortunate we are to be playing a part in delivering this iconic project.*

*Local people have made the joint venture team feel welcome to their area, be it with very high expectations - expectations of well-designed and high-quality construction works, industry-leading safety and environmental standards and an open and honest approach to consultation. I'm pleased to report that we are delivering on all those fronts.*

**Terry Sleiman**  
Project Director  
CPB John Holland Dragados  
May 2015

*The North West Rail Link will change forever the economic development of this region, taking it to an even greater level. Delivering rapid transit rail will bring lasting benefits for generations to come on how people live and work in Sydney's North West. Not least it will inspire the creation of new businesses, greatly boosting our capacity as a major employment centre and improving the day-to-day lives of our local communities.*



**Anthony Moss**  
Chairman of the Board  
Sydney Hills Business Chamber  
May 2015



Two 300m long tunnels linking the new twin tunnels to the existing railway tunnels between Epping and Chatswood were completed in mid-2015



TBM4 Maria cutter-head retrieval at Epping, 23 November 2015



TBM1 Elizabeth cutter-head retrieval at Cherrybrook, 7 January 2016



TBM2 Florence cutter-head retrieval at Cherrybrook, 6 February 2016

Getting the four TBMs back to the surface was a precision operation.

In four carefully-choreographed manoeuvres, the massive 105-tonne cutter-heads were all lifted back to the surface using 600-tonne crawler cranes.

It took about six weeks to pull apart each TBM and about 50 trucks per machine to transport away all components, with many pieces travelling at night due to oversized vehicle road restrictions.

The four TBMs went through a combined 2,006 hardened steel cutters in excavating more than 2.5 million tonnes of rock.

# RETRIEVAL



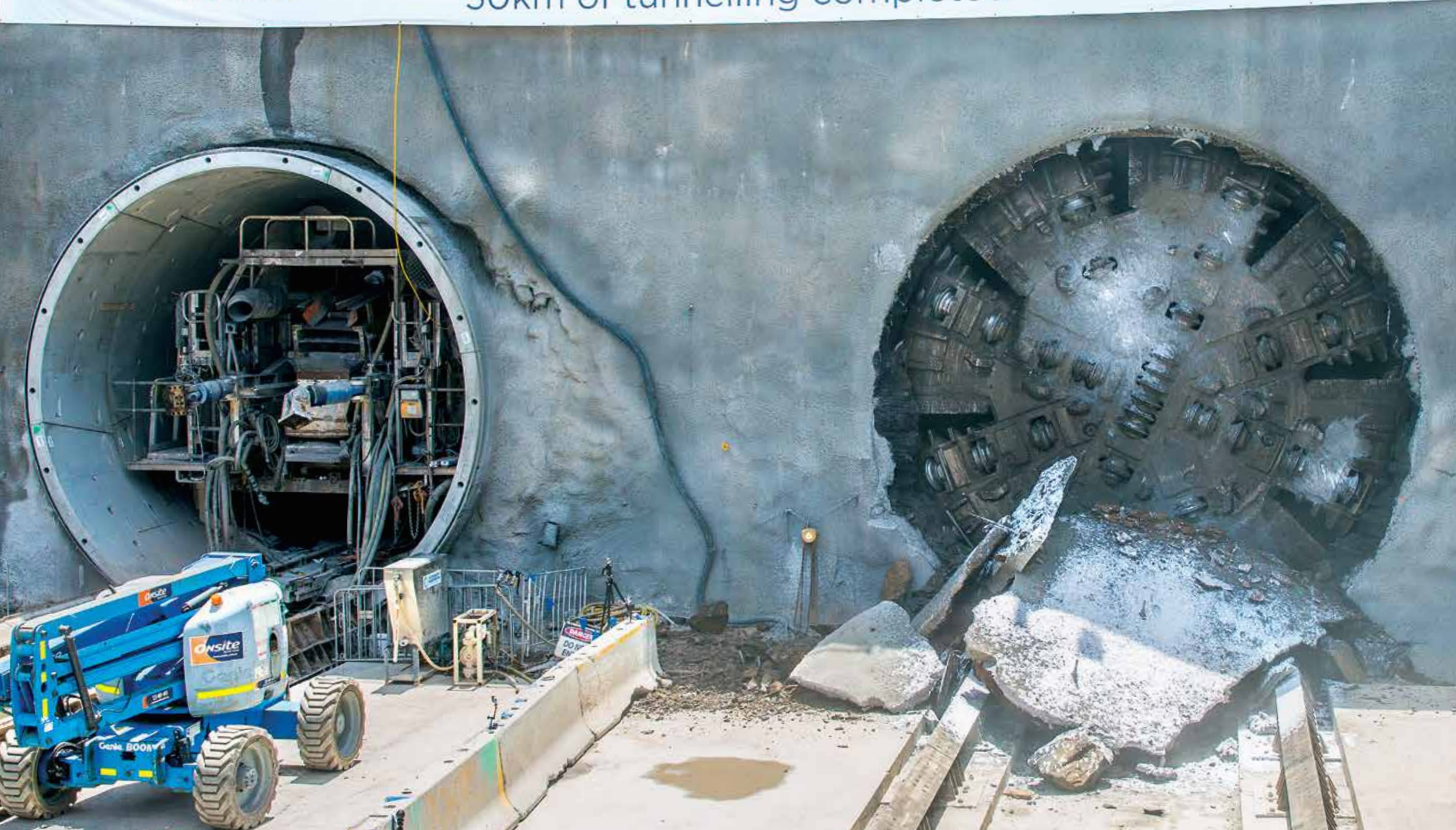


# AUSTRALIA'S LONGEST RAILWAY TUNNELS

## 30km of tunnelling completed



Transport  
for NSW



# END OF TUNNELLING

After 16 months, tunnelling finished at 2.04pm on 14 January 2016.

Australia's longest railway tunnels were safely completed when TBM2 Florence broke through into Cherrybrook Station, marking the end of 30km of tunnelling.

Tunnelling work also included the construction of 55 cross passages linking the twin 15km tunnels every 240m.

Tunnel builders CPB John Holland Dragados operated eight work sites spanning 16km, as well as the global procurement and delivery of the four custom-made TBMs.



TBM2 Florence was the last mega borer to finish work



Premier Baird and Minister Constance at the final break-through

# AUSTRALIA'S LONGEST RAILWAY TUNNELS

- 16 months
- Four TBMs
- 30km tunnelling task



BELLA VISTA

NORWEST

SHOWGROUND

CASTLE HILL

CHERRYBROOK

CHELTENHAM

EPPING

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