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Cleaning up in Buenos Aires

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Buenos Aires is undertaking a complete overhaul of its clean water provision, namely the Agua Sur System, that includes 13.5km of 4.6m diameter tunnel currently being excavated by CMC di Ravenna using two Terratec TBMs, reports Nicole Robinson

Argentina has been improving access to clean water over the last three decades. However, in 2017 government estimates found some 7 million people still lacked drinking water and developed a national water plan to mitigate the problem. The goal is to provide clean water to 100% of the population—a task that will require at least US$44bn in investments.

AySA, the water and sanitation authority in Argentina, has embarked on a 10-year project called the Agua Sur System that includes a raw water intake, two pump stations and 46km of pipeline connections among other major infrastructure upgrades. This new system will provide drinking water to areas in the south of Greater Buenos Aires, meeting the needs of 2.5 million people who currently do not have access to potable water. This is the country's largest water infrastructure project in 40 years.

All of these infrastructure works and upgrades connect via a new 23km-long tunnel called Río Subterráneo a Lomas. This is really the backbone of the Agua Sur project, and the global pandemic arrived at an all too unfortunate time for the work underway. However, despite these unprecedented challenges, tunnelling has maintained steady progress since the first TBM launched a year ago in September.

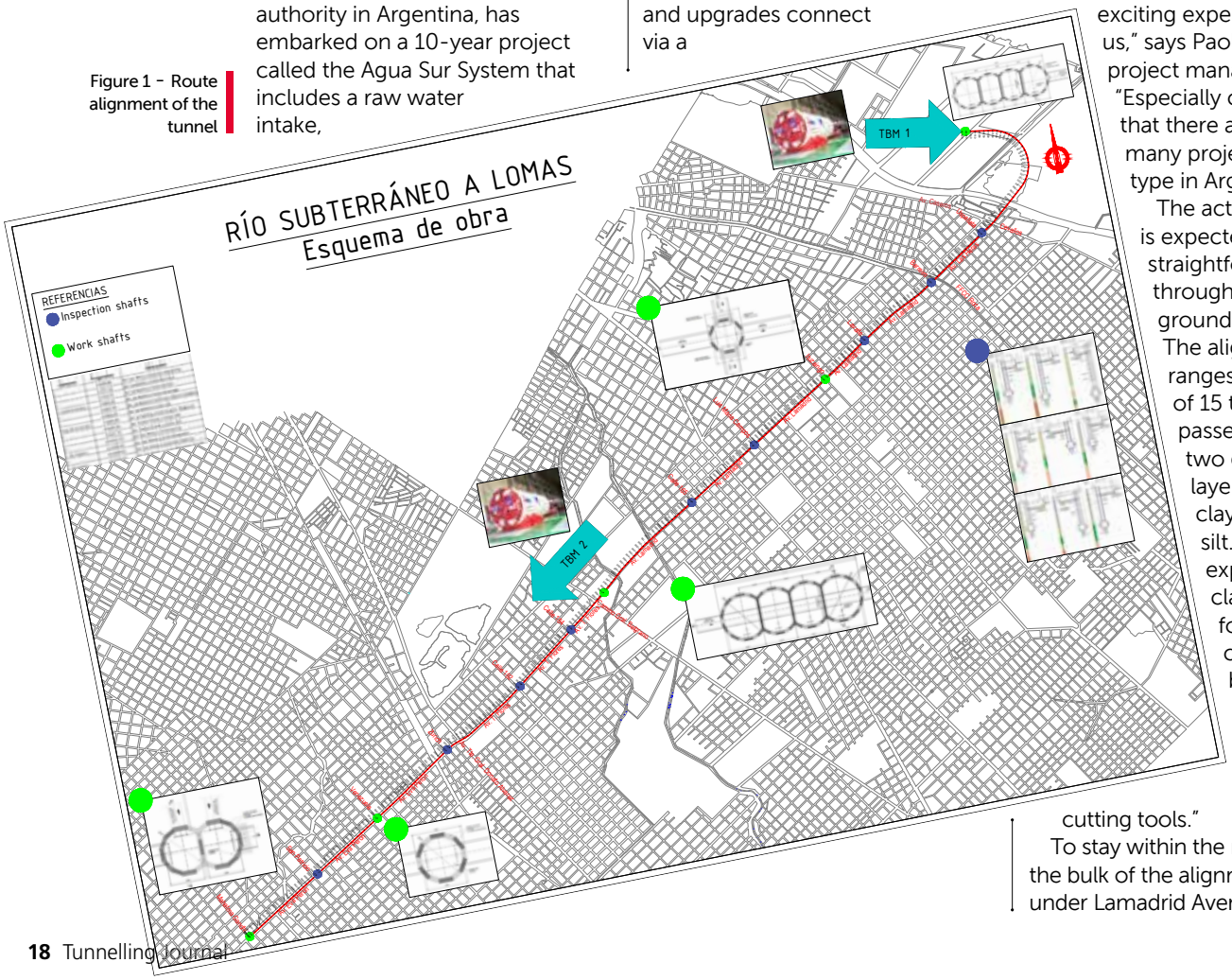


Figure 1 - Route alignment of the tunnel

Río Subterráneo a Lomas

AySA awarded Italian construction company CMC di Ravenna the tunnel contract in September 2017. The work is being undertaken by the company's new Argentina branch. This includes TBM-excavation for a 13.5km-long tunnel, 4.6m in diameter, along with excavating associated chambers and shafts. CMC is also manufacturing the tunnel lining and has installed a segment factory on site. At a later date, AySA will award a second contract that extends the tunnel another 9.7km for the total of 23km. Tunnelconsult Engineering is the project's designer.

"Starting from the very beginning in a new country was an exciting experience for us," says Paolo Padovese, project manager for CMC. "Especially considering that there are not so many projects of this type in Argentina."

The actual tunnelling is expected to be fairly straightforward and through competent ground conditions. The alignment ranges from depths of 15 to 25m and passes through two geological layers, mainly clay and Tosca silt. Padovese explains, "this clay is suitable for tunnel construction because it is easily excavated and there is low wear on the cutting tools."

To stay within the right of way, the bulk of the alignment runs under Lamadrid Avenue, a main

road through the Quilmes district. However, CMC's main work site and the first TBM launch shaft is alongside the General Belgrano water treatment plant, which is on the opposite side of an artificial lake from Lamadrid Avenue (Figure 1).

This meant CMC faced the most challenging aspect of the entire tunnel at the very start of the first drive—completing a 400m radius curve to circumnavigate the lake. Further complicating the situation, the contractor needed to launch the TBM from a shaft, requiring TBM assembly in three phases.

In a separate contract, as part of the Agua Sur programme, construction is underway to expand the General Belgrano water treatment plant. While these adjacent work sites are located at the edge of the city, in what is was more recently a countryside area with horses in pastures, there is still limited space for all the coinciding construction operations.

Constructing a shaft in four stages

Construction started in 2018 for the launch shaft at the main work site and the CMC crews found the clay soil offered good stability for excavation. This first launch shaft is actually four overlapping, circular shafts of 25m depth that are connected along the bottom 5m.

"We chose this type of shape where we avoid placing horizontal strutting because that left more free space to carry out all the tunnelling operations we need to do in the shaft," Padovese explains.

Working with local subcontractor, Concret Nor SA, they excavated 1m-thick diaphragm walls using a clamshell bucket. The trench is held open with bentonite slurry during excavation, and then by installing the reinforcement and concrete. Each of the four overlapping cells is 14m in diameter.

"After we did the walls, we excavated each cell from the ground level to the bottom slab with a backhoe loader," explains Andrea Berti, CMC's technical office manager. "We took special care not to overload the central diaphragms by staggering the excavation in each cell."

The total depth of the excavation was 26m, and they concreted the four bottom slabs with 1.5m-thick reinforced concrete.

"For constructing the shafts, the clay ground conditions were favourable," Berti says. "We didn't need to do jet grouting for the bottom plug because we were a considerable distance to the permeable layer. The probability of bottom uplift was low."

And considering the location's proximity to the artificial lake the contractor fortunately had only minor issues. "While we were excavating the shafts and concreting the bottom slab we did have some water ingress, which we have controlled with a drainage bed under the slab, and we have installed pump wells, too," he explains.

After finishing the bottom slabs for the four shafts they needed to cut open the central diaphragm walls that divide the four cells in order to connect the bottoms of the shafts. These "windows" are approximately 5m high by 6.75m wide and cut with diamond wire. The total length of the shaft at the open bottom is around 45m long.

Construction of the four stage launch shaft

The launch shaft in the main works area including segments store

Factory acceptance of the first of two Terretec TBMs

Launching under Covid constraints

The pandemic has been one the project's biggest challenges for the contractor. Terratec is supplying both of the 4.66m diameter EPBMs, holding factory acceptances in-person in 2019. However, with travel restrictions Terratec staff weren't able to travel to Argentina for assembly as planned and arrived later in August 2020. Everyone on the project attributes excellent coordination between the two companies—as well as working closely with consular services—as the solution of overcoming these problems.

"Our original schedule had to be modified due to the advance of the pandemic in Argentina in the winter season," Padovese explains. "Before we could start up the first machine we needed to set up all new sanitary protocols that directly impacted all of our work tasks."

Keen to keep the project moving while also protecting the health of all the workers and their families AySA developed a Covid-2019 Protocol document. "This outlined the requirements to be met as established by the Ministry of Health to prevent the spread of the virus," explains Javier Koller, a project manager with AySA.

Despite the set-backs posed by the pandemic, CMC and AySA were able to celebrate a project milestone in June 2020 with the president of Argentina, Alberto Fernández, joining them at the worksite to lower the cuttterhead into the shaft.

"The fact that the TBMs are launching from a shaft has required us to make full use of a modular design and umbilical launching system to work in the confined space," explains Emilio Saraniero, Terratec project manager. "This is why a hydraulic drive solution was chosen for the TBMs."

Terratec and CMC developed a three-phrase assembly process to make the best use of the launch chamber's available space. Starting that June, CMC lowered the cutterhead, shield components and three back-up gantries into the shaft.

"As the space was reduced during this step, we put a discharge hopper at the end of car number three, and we used two small muck cars, which allowed us to do mining in stages," explains Santiago Dib, TBM engineer for CMC. "After we installed the 38th ring we were able to dismantle the discharge hopper and add the rest of the gantries."

During the initial drive, only one train line was working, so each time an excavation cycle was carried out CMC had to disassemble the train in the shaft in order to unload the muck cars, and then load the supplies for the TBM and the ring segments.

In December 2020, CMC installed a triple track interchange in the shaft and a Californian switch inside the tunnel. "We can leave part of the train inside the tunnel while handling the loading and unloading logistics with an auxiliary locomotive inside the shaft," explains Antonio Barbedo, TBM manager.

Flattening the curve

CMC made all of these start-up and logistical adjustments while mining the most complex part of the project—the 400m radius curve that extends for a length of more than 850m. And as part of that initial drive along the curve the TBM also needed to pass under a second, smaller artificial lake as well as a main highway.

"We designed the curve and the radius to be easy going for

the TBM by introducing as little offset as possible between rings," explains project designer Nicola Della Valle of Tunnelconsult.

Terratec also devised measures to accommodate this potentially-problematic stretch of the project, including desiging the TBM for a horizontal curve radius of 250m. It is also equipped with an extendable copy cutter to help negotiate the curve. This cutter can be opened, that is extended, to enlarge the section of excavation during mining. This gives the operator more clearance between the shield and the ground.

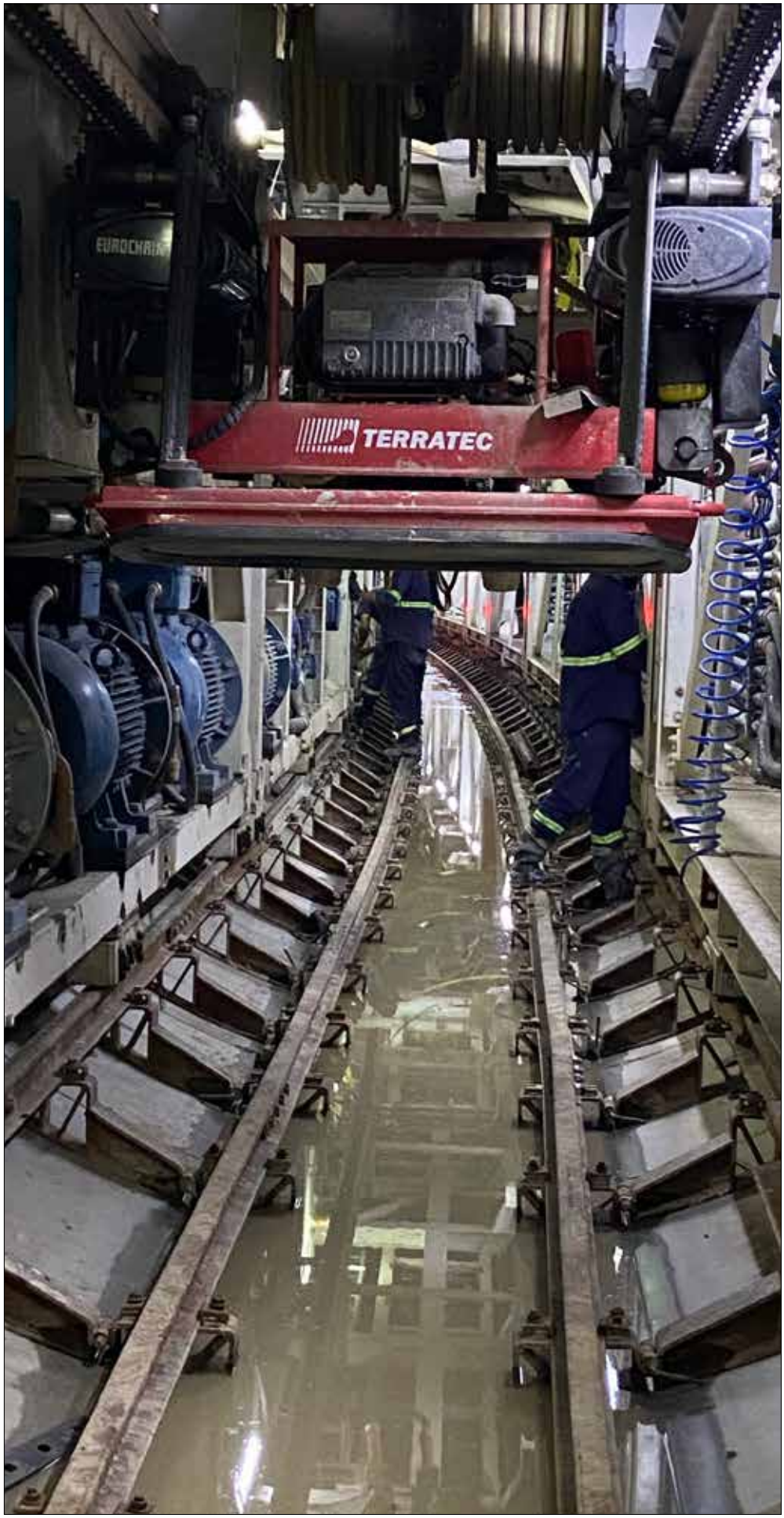
"There were several challenges to overcome along the curve," says Paolo Gobbi, CMC construction manager. "Things like operating the conveyor belt because of its shape, and the guidance system, due to the small window available to view the targets. But actually, being in soft ground we didn't need to over-excavate to guide the machine through the curve."

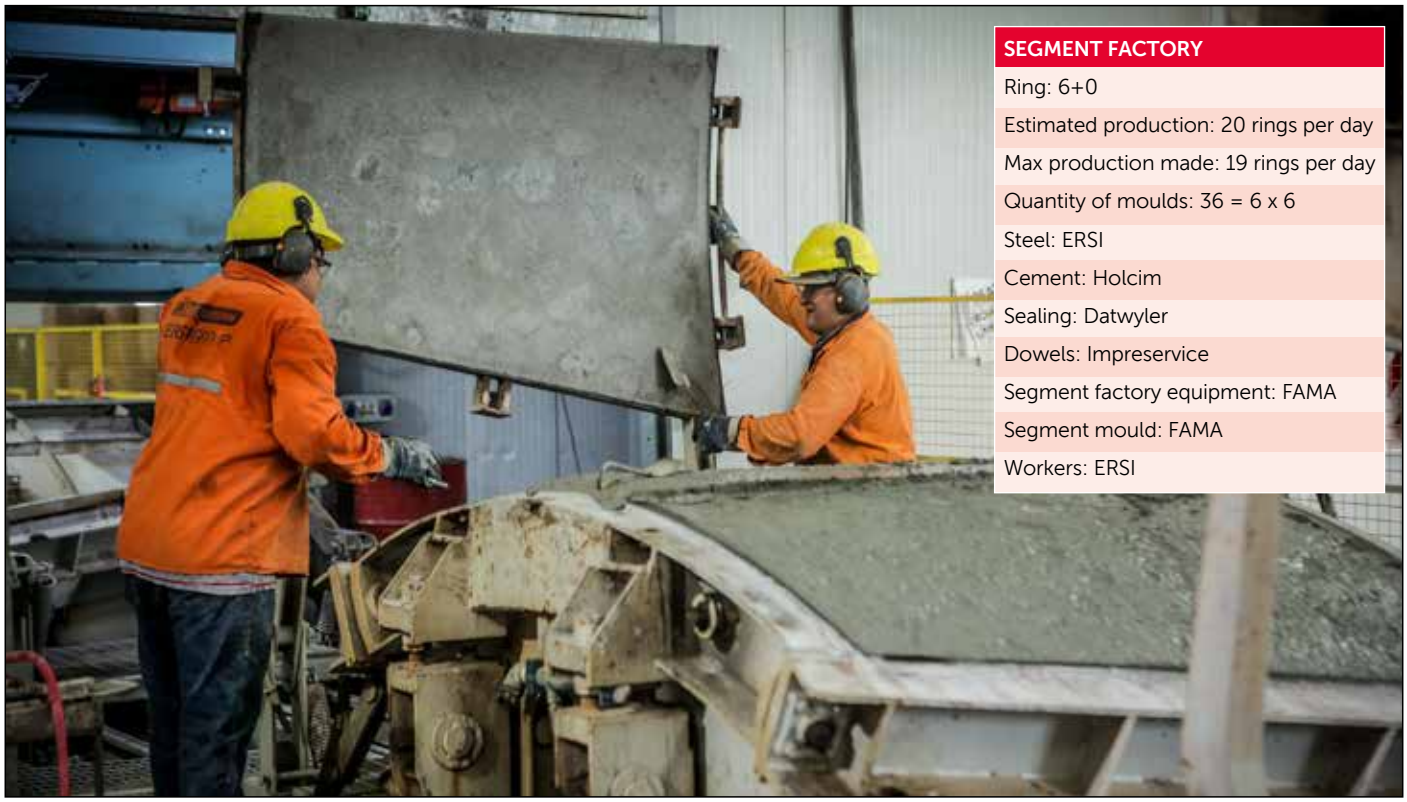
The design team had made recommendations for maximum excavation pressures while the machine passed under the second lake. However, the ground conditions did not present any difficulties during excavation, Gobbi says. "We were careful and we kept the mechanical parameters of the TBM always well below the limits."

This was the biggest design challenge, Della Valle says of passing under the second lake with close to one diameter of cover.

"We paid special attention to the segmental lining rings to be sure we could withstand any traction induced by the inner pressure, which might affect the tightness of the tunnel," he explains. "One of our concerns was to guarantee the closure of the gasket, which we accomplished with shear connectors between rings."

The precast segmental lining is also the tunnel's final lining. CMC started its on-site segment factory in November 2019, and has since made 25,000 segments, managing a monthly average of 2,300. These are 250mm thick by 1,400mm wide and a ring comprises four parallelograms and two keys (see side bar). "There are very few potable water tunnels in the world with single pass linings and this project accommodates that," Della





SEGMENT FACTORY
Ring: 6+0
Estimated production: 20 rings per day
Max production made: 19 rings per day
Quantity of moulds: 36 = 6 x 6
Steel: ERSI
Cement: Holcim
Sealing: Datwyler
Dowels: Impreservice
Segment factory equipment: FAMA
Segment mould: FAMA
Workers: ERSI

Valle adds. Even with the limited space in the shaft, paying special attention to how they coordinate gantry crane and construction crane lifts has enabled the TBM to do 10 to 11 rings per shift.

The long drive home

With the curve successfully completed earlier this year, the TBM is now making its straight drive below Lamadrid Avenue. CMC does expect some water in the clay soil, and is prepared to do ground conditioning if necessary. Both machines have been designed with spoke-style, high-torque cutterheads and a 49% opening ratio. The cutting tools consist of fixed and back-loading knife bits.

"These should help with TBM advancement and hopefully minimise interventions on these long drives," explains Saraniero. "We have detection bits to show the condition of the cutterhead and from the values of the parameters during the boring operations we can identify if we need to do some interventions."

With the pandemic's impact on the schedule the contractor is still working out when and where the second TBM will launch. Regardless, the tunnel ends in the Lomas de Zamora district where CMC will excavate an

A view down the completed tunnel

8m-diameter shaft, comprising two overlapping circular chambers, to retrieve the machine and connect the tunnel with the pump station. There is another smaller curve later in the drive, but nothing as dramatic as the first.

"The logistics have been the hardest part on this project, especially with the pandemic," says Saraniero said. "But actually the tunnelling is all going well because the job site is organised, and because of the way the contractor has prepared and how they've optimised all the lifts in and out of the shaft."

Along the 13.5km-long alignment CMC will also excavate nine shafts for inspection chambers for the client to do long-term maintenance of the tunnel. These are approximately 2m in diameter and spaced 1km apart. Two more 8m-diameter circular shafts will be excavated along the alignment, and are designed to stay preserved underground, enabling future tunnel connections to expand the system and serve other parts of Buenos Aires.

"This is an incredibly important project because there hasn't been many tunnel projects like this in Argentina over the last 20 years. It will bring potable water to so many people," Della Valle says. When completed, the Agua Sur system alone will supply more than one-third of the 7 million Argentines who currently lack access to drinking water.

Speaking at the TBM cutterhead ceremony in June 2020, president Fernández said, "the pandemic has given us the opportunity to put things in their place. We already know what is essential that we need as a society, we already know the injustice that we have in our society. And what we have is the opportunity to change this, so that justice prevails between us...having access to education, health and water, that is justice."