north american
Tunneling journal
www.tunnellingjournal.com
Dec 2016/Jan 2017

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ANACOSTIA
KEEPING IT CLEAN

The Anacostia River Tunnel, part of DC Water's $2.6bn Clean Rivers Project, holed through in November. We caught up with owner and the design-builder to ask what the challenges have been so far. By Kristina Smith.

ON 5 NOVEMBER 2016, just over a year after its launch, Herrenknecht EPB machine Nannie completed its 12,300 ft (3750m) drive for the Anacostia River Tunnel in the District of Columbia. The tunnel is one of five – or possibly six – tunnels and other works that make up the Clean Rivers Project, a programme which will relieve the whole area of some nasty flooding problems and, as its title suggests, clean up the District's rivers.

"The Anacostia River Tunnel is one of our main tunnel projects which will help us to meet one of our milestones we have in the Federal Consent Decree," says Carlton Ray, director of the DC Clean Rivers Project for the District of Columbia Water and Sewer Authority (DC Water). "Once we complete our tunnel system, all the sewage that's going into the Anacostia 75 to 85 times a year will reduce, with overflow volume reducing by 98%."

As well as the TBM drive, joint venture design-builder IHP, made up of Salini Impregilo, S.A. Healy and Parsons, has also built six shafts, a challenging 100-foot long section of SEM tunnel, two of three adits, and now has the task of constructing hydraulic internal structures and M&E works inside each shaft which will direct the flow of existing combined sewer outfalls into the new tunnel.

"The tunnel was completed in one year, while the whole project duration is more than four years," says IHP project manager Shane Yanagisawa of Salini Impregilo. "Civil works such as the concrete internal structures and bypass are one of the biggest challenges in the project."

For IHP's design team, led by Parsons, the highest hurdle came early in the project: gaining permits from regulatory and permitting stakeholders. Although the tunnel's route largely follows that of the river itself, it crosses under several critical pieces of existing infrastructure including; prestressed concrete water and sewer mains, Sousa Bridge, 11th Street Bridge highway interchange, CSX railroad tracks and the Green Line subway tunnels. These critical crossings were significant considerations in the planning and design process.

"The biggest design challenge was not so much technical, it was process-related," says Jonathan Taylor of Parsons, design manager for IHP. "The challenge was fitting the design deliverables within the overall construction schedule."

Mitigating risk

DC Water awarded the $254m Anacostia River Tunnel project to IHP in May 2013. Like


The Anacostia Tunnel site

SALINI IMPREGILO


Critical shaft design and construction was a major factor in the project

SALINI IMPREGILO

several of the projects in the Clean Rivers programme, Anacostia was procured using a Design-Build form of contract.

"Tunneling is a risky business so we need to understand the risk associated with the project and ways to mitigate that risk," says Ray. "One of those ways has been the procurement method, Design-Build, where we want to bring good ideas into the process sooner."

As part of the procurement process, DC Water included an eight-month collaboration, or early contractor involvement (ECI), period where each of three short-listed Design-Build teams sat down with DC Water to talk through various elements of the project. "From a designer's point of view, it was helpful and useful in a number of ways in that we could work through design alternatives and discuss them with the owner," says Taylor.

The pre-award collaboration period has evolved from project-to-project, says Ray. For example on the Anacostia River Tunnel, DC Water required formal reports on each of a number of topics; on subsequent bids, it has asked for power point presentations instead which requires less time from both bidder in creating the reports and client in reviewing them.

"DC Water's approach is to continue to receive feedback from the Design-Build teams to assist in improving this valuable process," says Ray.

Parson's initial plan involved 11 design deliverables. This plan required modification post-contract award in order to meet both the contract requirements and external regulatory agency permit approvals.

"We had to re-evaluate the design schedule," says Taylor. "We broke it up into more than 50 mini packages that would allow small portions of work to proceed while the remaining packages were developed so that we could facilitate the construction schedule."

The approval process required the design team to deliver Construction Impact Assessment Reports or CIARs to evaluate the impact of the tunneling and construction operations on existing structures and set out any necessary monitoring and instrumentation, together with pro-active measures such as compensation grouting.

"This was a critical component of DC Water's overall goal," says Ray, "to deliver the project while protecting a variety of existing infrastructure."

Gaining third-party approvals and permits is always an onerous task on a project of this magnitude and can introduce risk in terms of delivering the programme on schedule. In a bid to mitigate this risk, DC Water performed extensive coordination with District agencies, executing a Permit with the National Park Service, which owns the majority of the property where the tunnel is constructed; signing various Memoranda of Understanding with regulatory agencies to expedite reviews; negotiating haul routes and traffic plans with the transportation department; paying for independent parties to review permit packages; and coordinating the electrical service needed to power the TBM operations.

From the design-builder's point of view, although the design-build form aims to encourage new ideas, the need to meet the schedule can stifle innovation, says Taylor: "Proponents say it allows for more innovation, more collaboration... to an extent that's true but the overarching focus is about meeting schedule and proactively addressing schedule constraints."

IHP took some opportunities to make changes and gain efficiencies. For instance, for three of the six shafts – the larger diameter ones – the design team made the slurry outer walls composite with the final liner which reduced the overall cost.

"The challenge within the Clean Rivers programme was the design of all the permanent structures has to be in accordance with ACI 350 (Environmental Engineering Concrete Structures)," explains Taylor. "The goal behind the design criteria of ACI 350 is to limit crack width, required here because the project has a 100-year design life and wastewater contains hydrogen sulphide which is very corrosive to reinforcement."

Ground water presented a further challenge to the design and construction of the shafts which were built by the slurry wall method; specialist contractor Bencor installed the slurry walls after which IHP excavated and constructed the inner concrete lining.

The ground along the alignment contains a sandy layer known as the Patuxent Formation which carries artesian groundwater, situated generally below the invert of the tunnel but not below the bottom of the shafts, some of which reach down 140 feet (43m). IHP designed a dewatering system to lower piezometric levels below the base of the shaft, rather than choosing to construct in the wet.

"This allowed for high-quality connections between the base slab and the slurry wall, and the cast in place liner. It meant we could expose all the connections, and make the connections in the dry rather than using divers," says Taylor.

The groundwater pressure, and the requirements of ACI 350, meant that the bases of the large shafts had to be 12-feet (3.7m) deep and heavily reinforced. Rather than install cooling pipes, which would be the standard way to cool mass concrete and prevent cracking, Taylor employed a specialist design consultancy to re-think the concrete mix, substituting slag and fly ash for cement to lower the heat of hydration.

"Because installing cooling pipes is both costly and time-consuming, using a specialist mix design worked very well," says Taylor.

When IHP began on site in June 2013 one of its first major tasks was to construct two of the three largest shafts, situated close to-

CLEAN RIVERS PROJECT: THREE MORE TUNNELS TO COME

The Clean Rivers Project dates back to 2005, when the District of Columbia Water and Sewer Authority (DC Water) entered into a Consent Decree with the US Government. The agreement set down a timetable, or long-term control plan (LTCP) for it to sort out the problem of combined sewage being discharged into the District's rivers.

Around one-third of the District's land area – 12,478 acres (5,050 hectares) - is served by combined sewers which means that when there is a rain event, untreated sewage passes through one of 47 active combined sewer outfalls (CSOs) into the Anacostia River, Potomac River and Rock Creek. The Anacostia River receives the biggest volumes: 2 billion gallons delivered over 82 occasions in an average year. Once this program is complete in 2025, that volume will be reduced by 98%.

The 20-year plan has a number of milestones, some have been accelerated as a result of serious flooding in the North West of the District. The First Street Tunnel has been built early, acting as a storage vessel with a pumping station to transfer stored wastewater into the existing system once it can cope. And the completion of the Northeast Boundary Tunnel, which will connect the First Street and Anacostia Tunnels, was also brought forward.

When the Anacostia River Tunnel's TBM broke through in November, it was the third in the Clean Rivers Project to do so. The Blue Plains TBM had broken through a year earlier, and the shorter First Street tunnel finished its 2,700 ft (823m) drive in December 2015.

There's more tunnelling to come, though. DC Water and its shortlisted bidders are finishing up the pre-tender collaboration period for the 27,000 ft (8,230m)-long Northeast Boundary Tunnel; with cost and technical proposals are due in early 2017 and Notice to Proceed expected in Fall 2017. Keen to improve with each tender, DC Water has decided to strip out some of the early parts of the Northeast Boundary tunnel project, with a contract to relocate utilities already underway.

"One of the things we have learned is that while the tunnels' Design-Build teams are great at designing shafts and virgin structures, a lot of times they may come from out of the city or even out of the country so they don't know the local utilities as well as DC Water does," says Carlton Ray, director of the Clean Rivers Project for DC Water. "We will still include some utilities in the design-build package but the goal is to try to get as much relocation done prior to the contractor getting out there on site so that he's not being held up by the local utilities."

Looking further ahead, DC Water is also planning the Potomac River Tunnel and the Rock Creek Tunnel. Ray expected the Potomac River Tunnel to be 4.5 miles long and 15 to 18 feet in diameter, with construction starting around 2025. It's not clear yet whether the 9,500 ft (2,896m) Rock Creek Tunnel will be needed. The Clean Rivers Project includes the creation of green infrastructure and DC Water will wait to see how well that performs before it decides.

Nannie the Herrenknecht EPBM

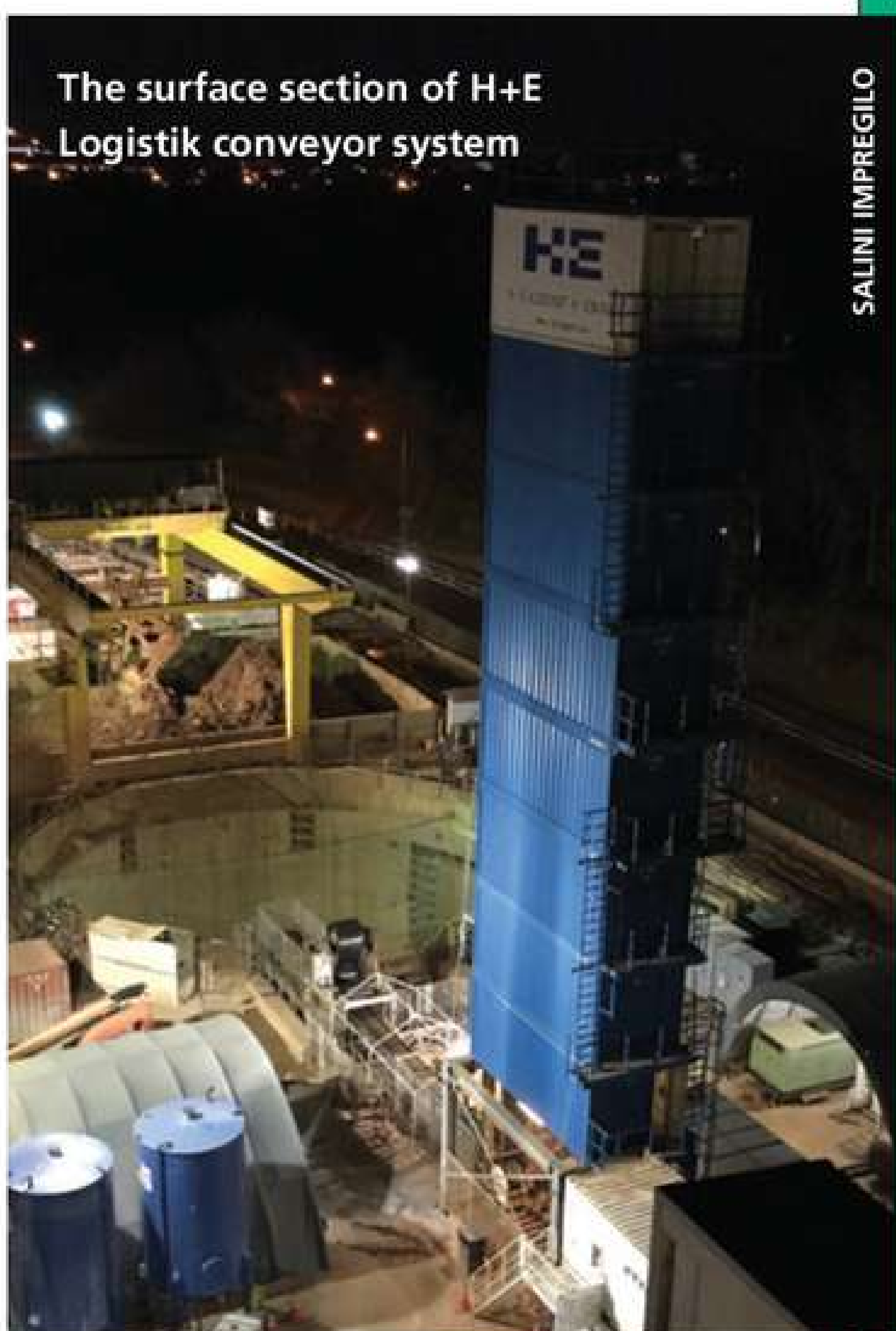
gether at the North end of the tunnel's alignment. Together with a 110 ft (33.5m) sequentially excavated method (SEM) connecting tunnel, known as the Inter-Shaft Connecting Tunnel, the two shafts had to be complete so that the TBM could be launched.

The design of this section of SEM tunnel, 26ft (7.9m) in diameter and built with a top heading and bench in 3-ft (0.9m) advances, was challenging, says Taylor. It also proved to be challenging once tunneling was underway.

"We had a little bit of a problem with it but we worked through it," says Ray. "We had a run from the surface into the tunnel. Everybody got out safely. We ended up jet grouting the area around the run area and then finished the construction between the two shafts."

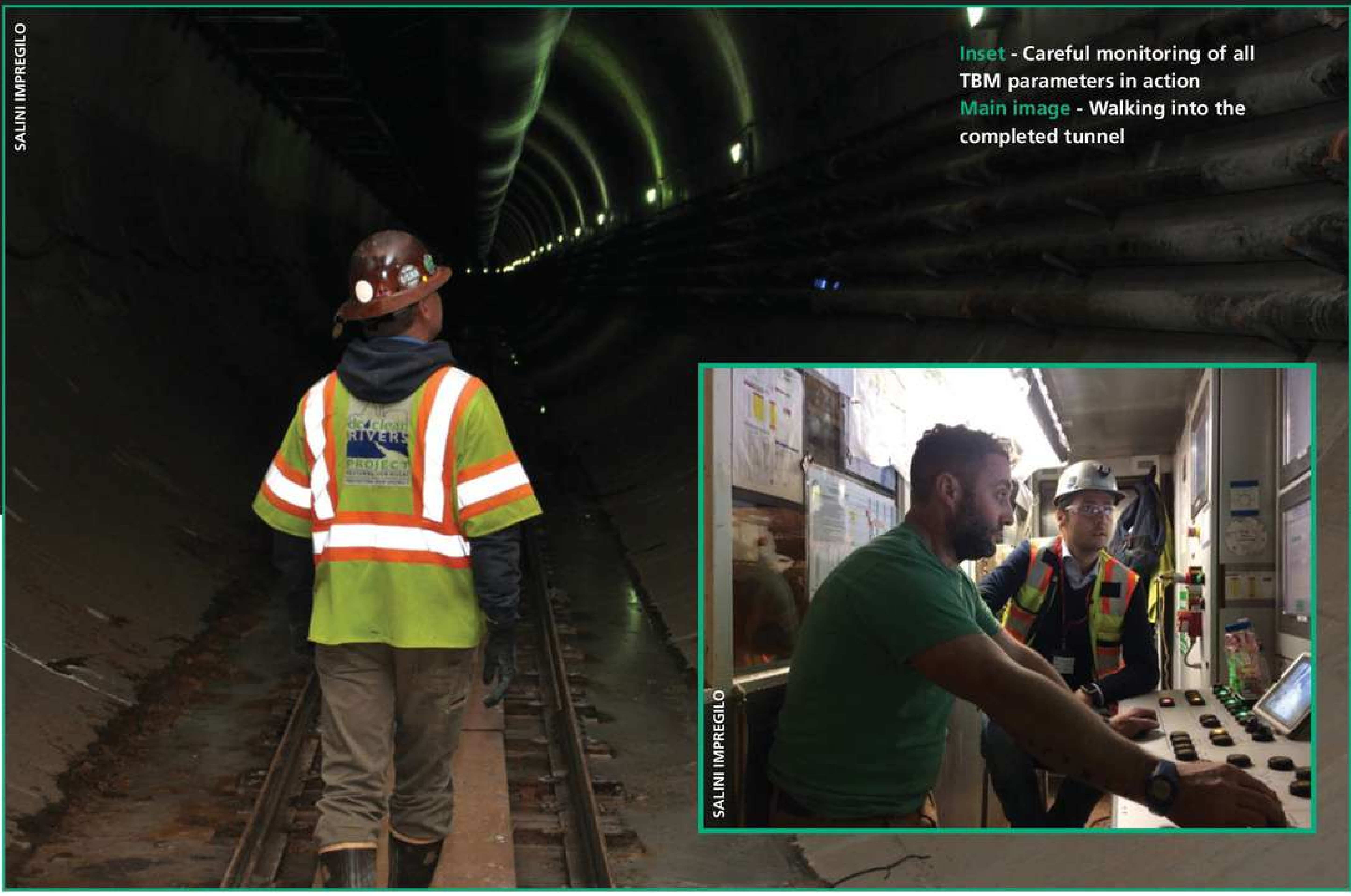
Steady progress

The 26ft-diameter Herrenknecht EPBM, named Nannie after local civil-rights activist, educator and religious leader Nannie Helen Burroughs, began tunneling on 4 November 2015. Its route starts near the Robert F. Kennedy Stadium, heading south along the west bank of the Anacostia River before crossing under the river to run along the other bank before meeting the Blue Plains Tunnel at a junction shaft at Poplar Point.



The surface section of H+E Logistik conveyor system

Nannie was launched in a shortened form, with six of her nine gantries, while she moved



SALINI IMPREGILO

SALINI IMPREGILO

Inset - Careful monitoring of all TBM parameters in action
Main image - Walking into the completed tunnel

through the Inter-Shaft Connecting Tunnel, with a further three added once tunnelling proper began. The tunnel's lining is made up of steel fibre-reinforced concrete segments, 12 inches (0.3m) thick to give an ID of 23 feet (7m).

The tunnel's alignment ran mostly through stiff Arundel Clay of the Potomac Group. Though the machine was equipped for compressed air interventions, none were necessary with all interventions taking place under free air in the heavy clay. The mucking operation was served by an H+E Logistik conveyor system.

"The TBM excavated in ground conditions varying from heavy and sticky clay to saturated sands, as indicated in the GBR," says Yanagisawa. "In order to achieve good production rates and a proper control of the process, conditioning was definitely a key factor. Proper annular grouting was also fundamental to control settlements, especially during tunneling under sensitive structures or under the Anacostia River."

Where the tunnel crossed under the 9ft-(2.7m) diameter pre-stressed concrete sewer force main, and a 48 inch- (1.2m) diameter prestressed concrete water main, IHP installed instrumentation and compensation grout pipes. The existing pipes were monitored as the TBM bored beneath, with grout injected as required to maintain the level of the pipes.

Real time monitoring was also in place for the excavation under the CSX railroad tracks, the WMATA Green Line and several highway structures, which was displayed in real time at the TBM, site offices, and at the owner's facilities. Instrumentation included extensometers, ground monitoring arrays, utility monitoring points, piezometers, tilt meters and seismometers.

Generally, settlements were less than expected. "In our CIAR reports and analysis we calculated, in general, that at ground level on the tunnel centre line, there would be settlements of just over one-third of an inch, and at around 8 to 10 feet above the crown, three-quarters of an inch," says Taylor. "For around 85% of the alignment, ground settlement was less than predicted. Movements at depth were significantly less and at ground level they were negligible.

There was one area were settlements were more than twice calculations suggested, although they were not sufficient to cause any detrimental impacts. Around 20% through the drive, as the TBM was about to bore beneath the Sousa Bridge, there were problems with the annular grout.

"We wanted to minimize any settlement on the project so we were figuring out whether to use bentonite at the front of the machine to minimize ground loss," says Ray. "We tried it initially but once we had got a better handle on Nannie and what her capabilities were, we decided not to use it."

There were also reports of bubbles appearing in the Anacostia River thanks to Nannie.

"At the end of the [river] crossing, in correspondence with a layer of more permeable sand, we had communication of air from the tunnel heading up to the river," explains Shane Yanagisawa. "The conditioning parameters were adjusted immediately and the excavation continued without interruption across the river."

A second TBM

There is still one section of connecting tunnel to be completed with a 12-foot (3.7m) diameter slurry machine, and that is a 300-ft (91m) long adit tunnel between the CSO 018 shaft and main tunnel. The adit runs below transportation department structures and CSX railroad tracks. The other two shorter connecting adits, at CSO 005 and CSO 007, were built before the TBM passed through using the jack-and-bore method.

"We looked at other methods, but the adit runs under transportation department structures and the CSX rail road and in the early planning of the work, DC Water had committed to pressurized face means in order to minimize the potential impact," says Taylor.

IHP has until 13 December 2017 to construct this final tunnel and the structures and M&E inside the shafts. Three months later, the Anacostia River Tunnel should be in operation, carrying waste water down to the junction with the Blue Plains Tunnel and on to the Blue Plains Advanced Wastewater Treatment Plant.