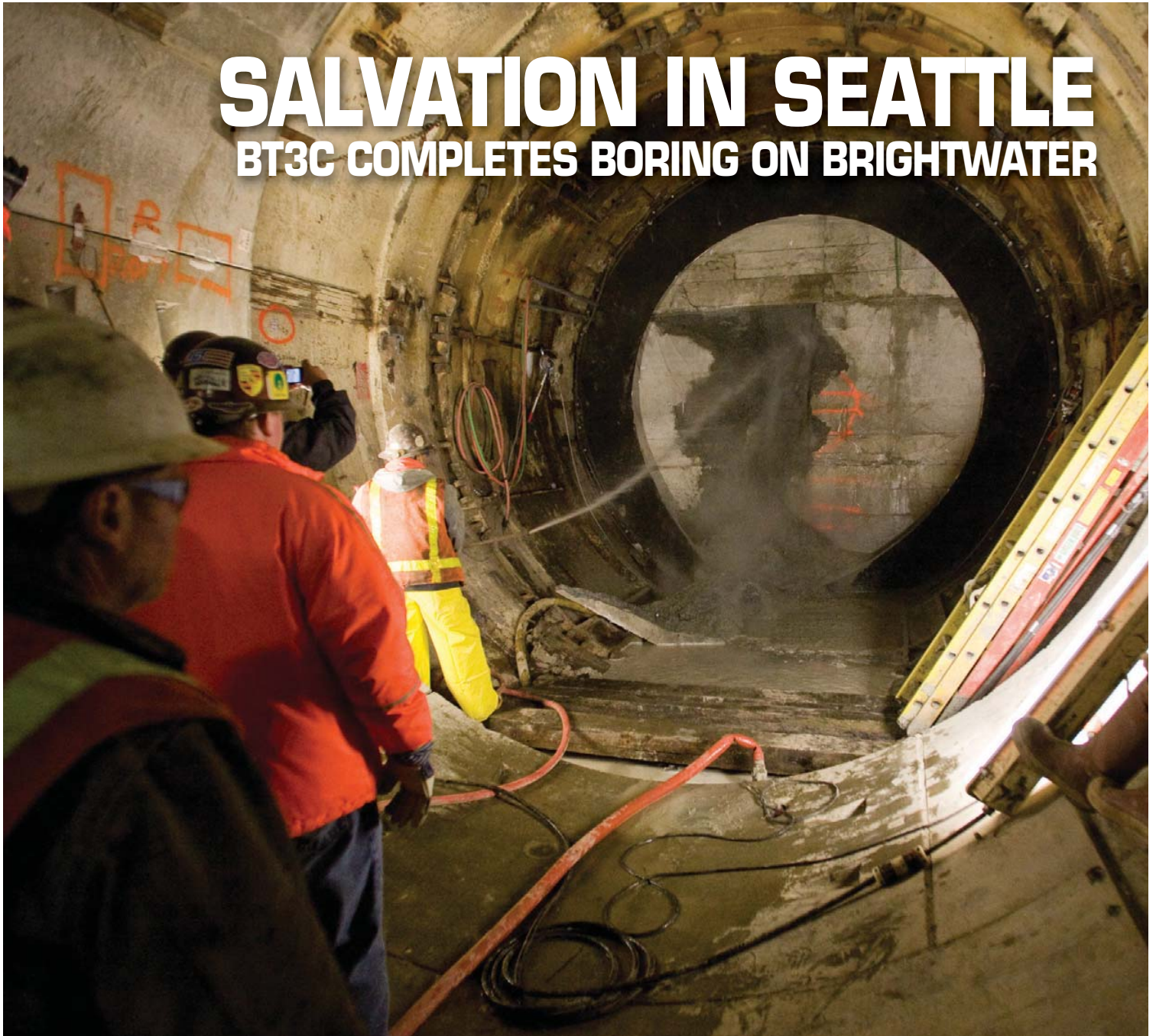


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SALVATION IN SEATTLE BT3C COMPLETES BORING ON BRIGHTWATER



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**SUPPORTING
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NATJ LOOKS AT
GROUND SUPPORT
TECHNIQUES IN USE
IN THE BIG CITY



**TO BROOKLYN
AND BACK**
GROUND BREAKING
ON THE BROOKLYN-
BATTERY 60 YEARS
AGO THIS MONTH



THE 13-MILE (21km) long Brightwater tunnel is the main component of a \$1.8 billion project to increase sewage treatment capacity in the greater Seattle region of King County, Washington. The 13-17ft (4-5m) i.d. tunnel – which was split into four excavation contracts (Figure 1) – has been bored at depths of up to 475ft (144m) using two Lovat EPBMs and two Herrenknecht Mixshields and has involved some of the longest and most challenging soft ground drives in the US to date.

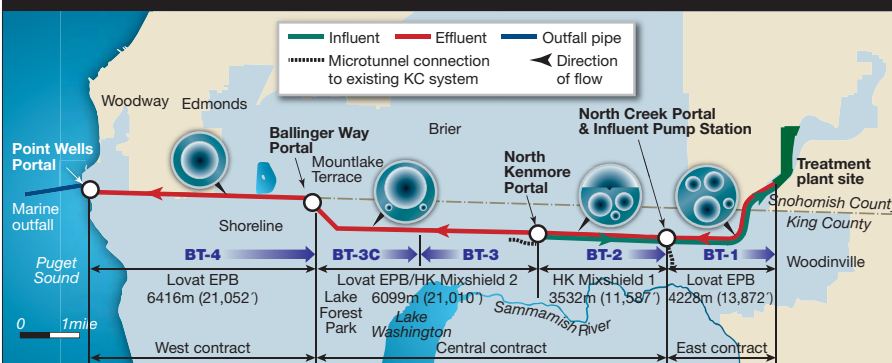
The tunnel will ultimately collect flows from two existing trunk sewers and divert them to the new Brightwater treatment facility. Once treated, effluent will also be conveyed back through the tunnel to a new 1-mile (1.6km) long marine outfall in the Puget Sound.

Due to the highly-variable complex mix of glacial soils found along the tunnel alignment – combined with long drive lengths and widely varying groundwater conditions – pressurized TBMs and sealed shaft techniques were specified for all four contracts. On the East and West tunnels the choice of EPB or slurry was left to the contractors, with both opting for EPBMs. However, due to predicted groundwater pressures of up to 7.5 bar on the Central tunnels two slurry TBMs were specified. The risk of soil abrasion, damage from boulders and clogging in sticky clays were a concern from the outset. However, in May 2009, TBM inspections revealed severe wear damage to the cutterhead rims on both

This August, following numerous trials and tribulations, tunneling was finally completed on the Brightwater Project, in greater Seattle. Amanda Foley recently caught up with Greg Hauser, Project Manager for the JCT JV, to find out how the West Contract's Lovat EPBM was used to complete the final stretch of the Central Contract's BT3 drive

Steering a path to **SALVATION IN SEATTLE**

Figure 1: Map showing Brightwater's tunnel contracts, TBM drives and final liners



the Central contract's 16.7ft (5.1m) diameter Herrenknecht slurry machines. Efforts to complete these drives added a year onto the overall project schedule and ultimately led to the abandonment of one of the machines.

Project background

Having been awarded to the Kenny/Shea/Traylor JV (KST) in December 2005, the East tunnel's EPB drive (named BT-1) was the first contract to get underway on Brightwater. The 19.5ft (5.9m) Lovat machine was launched in October 2007 and, following a tricky start, achieved good advance rates, up to 550ft

(168m) per week. The 14,050ft (4.28km) East drive was completed in November 2008.

Meanwhile, in July 2006, project owner King County awarded the Central contract – comprising the 11,600ft (3.5km) eastbound BT-2 slurry drive and the 20,100ft (6.1km) westbound BT-3 slurry heading – to Vinci/Parsons RCI/Frontier Kemper (VFPK) JV, at a bid value of \$209.8 million. In order to excavate the complex soils anticipated on these drives VFPK purchased two 17.4ft (5.3m) Herrenknecht Mixshield TBMs. The BT2 machine was launched east first, in October 2007, before stopping to allow the BT-3 machine to launch west shortly afterwards.

Jay Dee/Coluccio/Taisei Joint Venture (JCT) was awarded construction of the West contract in January 2007 at a bid value of \$102.5 million. To excavate the 21,000ft (6.4km) long BT-4 drive JCT selected a 15.4ft (4.7m) Lovat EPBM, which launched east from the Point Wells shaft towards Ballinger Way.

Ballinger Way approach

In January of 2010, JCT had almost completed the BT-4 drive and was preparing to tunnel into the shaft at Ballinger Way, which had been constructed by the Central contractor VFPK for the reception of its west-bound Mixshield. The Mixshield had been stranded mid-drive for eight months at this stage. “The original shaft excavation by VFPK was accomplished by freezing the soil to depth and excavating in frozen ground,” says Greg Hauser, Project Manager for JCT. “That freeze had been turned off and the ground was now less than structurally frozen.”

The contract documents called for ground conditioning “by others” prior to JCT tunneling into the shaft. “The apparent choice of ground conditioning appeared to be cement grouting the soil, and this was not acceptable to JCT. Also, nobody was able or willing to advise what the soil conditions would be now that the ground had thawed,” says Hauser. JCT felt the only solution was to refreeze the soil and were engaged in that activity, from the shaft bottom and for a distance of 50ft (15m). This would provide stable ground conditions for the full length of the JCT EPBM prior to entering the shaft.

JCT selected a local freezing subcontractor, Soil Freeze, to perform the engineering and furnish the freezing equipment. The freeze system was drilled out from the shaft bottom and the freeze pipes were being installed when King County indicated they might be interested in having JCT continue past the Ballinger Way shaft to complete the BT-3 Tunnel’s western leg of the Central project.

The Mixshield TBM for the BT-3 Tunnel had suffered wear damage that required extensive repairs in unstable ground and under pressures of around 6 bar. This would result in a large additional expense and a delay in the Brightwater Project’s overall completion. Faced with this alternative from the Central

contractor, King County requested JCT to evaluate the possibility of tunneling through the shaft and continuing some 10,000ft (3km) downhill under pressures up to 7.2 bar and tying into the stranded TBM 300ft (90m) under the City of Lake Forrest Park.

“Based on this request and the possibility that JCT would continue past Ballinger Way, JCT advised King County that they should issue a Stop Work Order prior to JCT entering the western freeze zone, to avoid deteriorating this freeze and to be able to install a similar freeze to the east for re-launch from the Ballinger Way shaft,” says Hauser. JCT recommended that their TBM stop 50ft (15m) short of the 50ft freeze zone or 100ft (30m) from the Ballinger Way shaft. This was accomplished by the end of day shift on February 3, 2010. At that point the JV stopped until a new contract was negotiated between King County and Jay Dee Coluccio



JV. JCT was also given direction for the installation of another freeze system east of the shaft in the anticipation that a successful agreement would be reached to complete the BT-3 Tunnel. “This avoided a further delay by having this work completed as the new contract was negotiated,” says Hauser.

Completing Central

Negotiations with King County resulted in a new agreement in place between Jay Dee Contractors and Frank Coluccio Construction. Taisei decided not to participate due to uncertainty in the international market and prior commitments. The new BT3-C contract was issued to Jay Dee Coluccio JV (JDC) by King County with a Notice To Proceed (NTP) date of April 12, 2010. The \$77.3 million contract called for JDC to complete mining on the tunnel by September 2011, with \$2 million in incentives for completing the mining on time.

During the negotiations and as a necessity of being able to agree that this feat could be accomplished, Caterpillar Tunneling (formerly Lovat), performed a detailed analysis of the TBM and what would be required for the more extreme conditions of the BT-3c drive. The TBM tunneled the final distance into the

Ballinger Way shaft and holed through on June 18, 2010. “After traveling 21,000ft (6.4km) with no surface survey checks, the TBM hit the shaft eye, 200ft (60m) deep, dead nuts in the center,” says Hauser. Once securely in the shaft the cutterhead was removed to the surface for rebuilding and the additional enhancements to the TBM were started. The TBM was upgraded and refurbished to mine the next 9,900ft (3km) East to the stranded BT3 Mixshield.

JDC’s EPBM was outfitted with new seals and a new ground conditioning system to allow for the increased pressures, up to 7.3 bar. The cutterhead was rebuilt and additional gage cutters added, the flood doors were also reinforced. JDC added an extension to the tail can to allow for the installation of an additional row of tail seal brushes, a total of four rows and additional tail seal grease lines. Also, another 20ft (6m) of screw conveyor and a third guillotine gate were added.

Once the cutterhead was reassembled and the TBM moved forward, to complete the tail can extension and additional tail seal brushes, a minor leak was noticed in the cutterhead that was thought to be nothing more than a loose fitting. This turned out to be a major problem as the center swivel had completely deteriorated and required removal and shipment to Caterpillar (Lovat), in Canada.

“Working around the clock, the Caterpillar technicians completely rebuilt the swivel and got it returned to the project in time to meet the milestone date for resumption of mining, September 30, 2010,” says Hauser.

After the TBM and all the trailing gear had advanced past the Ballinger Way shaft, about 400ft (120m) of tunnel, the TBM stopped for a cutter check and the ventilation was moved up to blow in from the Ballinger Way shaft, still ventilating at the Point Wells portal. All tunnel muck was hauled back to Point Wells in muck boxes by rail, then taken from the shaft to the muck bin using conveyors. Conveyors also were used to move the muck from the muck bin to the existing Paramount Petroleum pier and then moved off site by barges to the disposal site near Port Ludlow on the Kitsap Peninsula.

Following the re-launch from Ballinger Way mining went well, working two 10 hour shifts, five days a week. Maintenance was done on Saturdays and all cutter changes were done in free air, with no compressed air work needed for the entire BT3-C drive.

In early May 2011, JDC was working below the Lake Forrest Park aquifer, which required manning the heading 24/7. Production for the first week in May was nearly 100ft (30m) per day, 495ft (150m) for the five days of production. “On Monday May 9, 2010 there was a plug in the screw conveyor that took until Tuesday to clear and get tunneling again,” says Hauser. “Wednesday 11th was the best day of mining, 23 rings for 115ft (35m) of segmentally lined tunnel, with a

Cutterhead woes on Central

In March 2010, King County Executive Dow Constantine issued a declaration of emergency in order to expedite a change of contractor on the troubled westbound BT3 section of Brightwater's Central Tunnel contract. The Executive's declaration enabled King County to waive procurement requirements and hire the JDC JV to complete the remainder of the BT-3 Tunnel from the east. The Central contract's Vinci/Parsons/Frontier-Kemper JV (VPFK) remained under contract to finish the resumed eastbound BT-2 Herrenknecht slurry machine drive.

Construction on the two Central tunnels was temporarily suspended in May 2009 after inspections revealed severe wear damage to the rear cutterhead rims on both of VPFK's 16.7ft (5.1m) diameter Herrenknecht slurry machines (area of wear marked as red on diagram below).

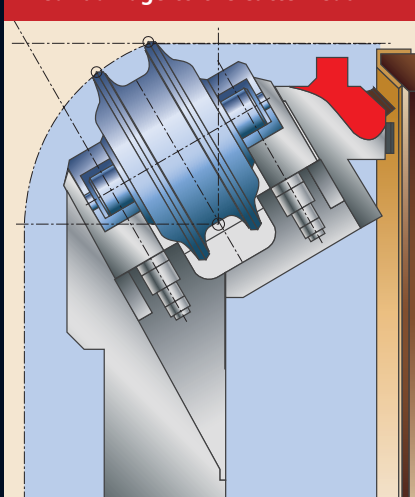
With both machines approximately 330ft (100m) deep and under about 5 bar of pressure, manned interventions into the cutterhead at 5 to 5.5 bar using Trimix gases were required during the initial attempts to repair the damage.

Working times at these pressures were one hour per intervention followed by five to six hours of decompression, resulting in a net productive repair time of just three hours a day. Ultimately, permissions were gained to locally dewater the ground around the BT-2 machine and VPFK successfully completed repairs to the BT-2 cutterhead and resumed excavation in March 2010. VPFK also remains under contract to complete the final tunnel liner in the BT-3 tunnel and to restore the Kenmore property that served as a staging area and access portal during tunnel construction.

VPFK had estimated that an additional \$98 million would be required to repair the BT-3 machine, which was more heavily damaged than the BT-2 machine, and complete the remainder of the slurry drive. King County staff estimated that on this basis the project would not be complete until December 2013, resulting in a cost increase and significant schedule delays that the Executive deemed unacceptable.

The BT-3 machine, nicknamed "Rainier," began tunneling west from the Brightwater North Kenmore portal in the fall 2007. The machine was stalled about 1.9-miles (3km) into the 4-mile (6.5km) long BT-3 Tunnel segment. King County and VPFK are disputing who is responsible for \$206 million in costs overruns above the contractor's \$213 million contract.

Wear damage to the cutterhead rim



heading that was over 29,000ft (8.8km) from the portal." Then on Thursday, May 12, in the mid afternoon, everything came to an abrupt halt. "The screw conveyor was jammed tight and the cutterhead would not turn. When the chamber was opened up it was discovered that a boulder had hit the TBM almost dead center, pushed the center cutter and swivel back into the cutterhead and torn off all the boxes covering the cutterhead hydraulics and ground conditioning hoses, which were also torn away," says Hauser. Again the center swivel had to be sent to Toronto for Caterpillar to rebuild and all the cutterhead cover boxes had to be made from scratch in the JDC shop on site. "The center cutter was completely destroyed and the mounts and housing had to be completely rebuilt also."

It required 28 days of frantic work to repair and rebuild all the damage. JDC continued working 24/7 for the first three weeks but ground conditions were so stable that this requirement was dropped by King County. Work continued until June 9, when mining began again and remained fairly normal through the remainder of the drive. On July 12, this year, JDC arrived at the "parking station" 100ft (30m) in front of the stalled TBM, a full 50 days ahead of schedule.

The 100ft from the stricken VPFK TBM was 50ft (15m) outside a freeze that had been put in place from the surface, some 300ft (90m) above. The freeze allowed VPFK's crews to gut the stricken TBM and remove the cutterhead. JDC then filled the shell with concrete, placed a receiving seal on the concrete face and prepared to mine into the abandoned TBM.

On Friday, August 12, JDC resumed mining and got within 10ft of the frozen ground. JDC mined through the frozen ground and freeze pipes to the face of the concrete plug in the abandoned TBM on Monday, August 15.

"That night crews removed the gauge cutters and the surveyors checked their calculations for the hundredth time," says Hauser.

"Tuesday, August 16, the TBM 'Elizabeth' tunneled smoothly through the concrete plug to emerge right on the money inside the gutted Mishield shell. With much appreciated assistance from VPFK's crews the area around the cutterhead was cleared and the two TBMs were joined by a welded in place steel bulkhead and securely grouted together."

The work then began to remove all the backup gear and support equipment, gut the EPBM and pour a closure between the two sections of segment lined tunnels.

The concreting work back to Ballinger Way is expected to take until March 2012, then JDC will continue to the Point Wells site and install the 2500ft (760m) of 10ft (3m) liner and complete the connection to the Outfall that was completed in 2008.

Flows are anticipated in the Brightwater Conveyance System by September 2012, with final completion of the West project by June of 2013.

