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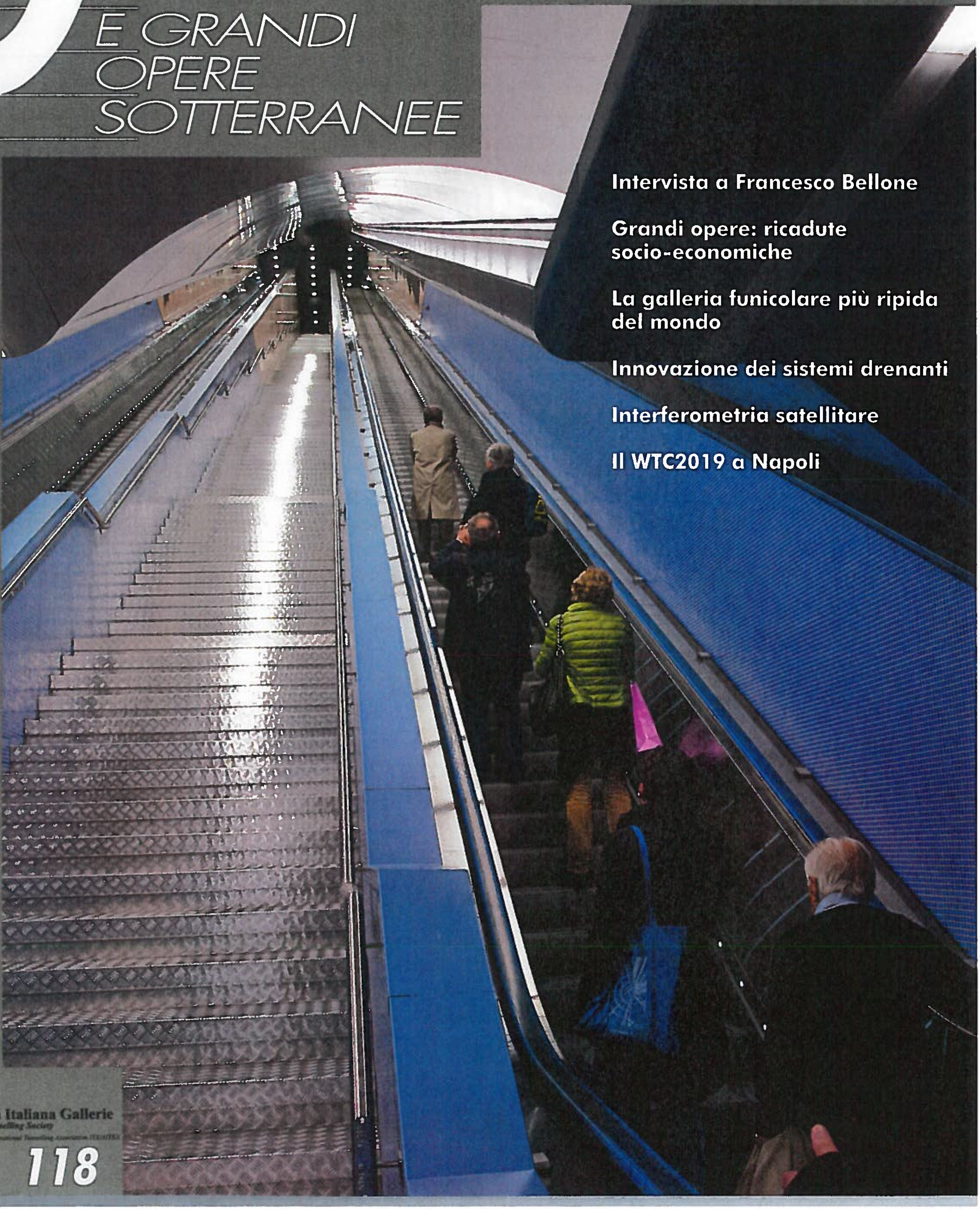

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Lake Mead Intake N. 3 – Chronicle of a World Record

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This paper is focused on the challenges encountered during the TBM excavation of the Lake Mead Intake N. 3 Project (Contract No. 070F-01-C1) located approximately 20 miles (30 km) east of the Las Vegas metropolitan area in Nevada, USA.
This includes the works to construct and lower 330 ft (100 m) the Intake Structure into the Lake Mead, the problems encountered during the excavation of the Starter Tunnel, the TBM mining at operational pressure at the face of as much as 15 bar due to the highly permeable and very fractured rock masses encountered and the related difficulties in performing maintenance on the cutterhead, the structural repair of the cutterhead in difficult hydro-geological conditions, the complete replacement of the cascade sealing system of the main bearing, two replacements of the pinion bearings and the approach of the TBM into the Intake Structure with the breakthrough on December 10, 2014.

Project Background

The goal of this project was the construction of a third intake on the biggest reservoir of the United States, formed by the Hoover Dam, which extends across the Colorado River on the border between Nevada and Arizona. The new intake will lay at depth greater than the two in operation, because of the constant drop of the lake level in the last 15 years, due to different reasons such as increasing water demand, longer draught periods and thinner snow layer on the Rocky Mountains. Forecasts say there is a high risk the more superficial Intake No.1 can turn dry by 2020, resulting in the impossibility for the water supply infrastructure to satisfy the overall demand. This can be overcome by the construction and operation of Intake No.3.

In March 2008, the Vegas Tunnel Constructors (VTC) joint venture, formed by the Italian Impregilo SpA (now Salini-Impregilo SpA) and its American subsidiary SA Healy, has been awarded by the Owner (Southern Nevada Water Authority - SNWA) for the construction of the Lake Mead Intake No.3 project core structures. These include fabrication and positioning on the lake bottom of an intake riser, excavation and lining of a 610 ft (185 m) deep shaft and construction of a 3 miles (4.8 km) long tunnel by means of a tunnel boring machine (TBM) (Figure 1).

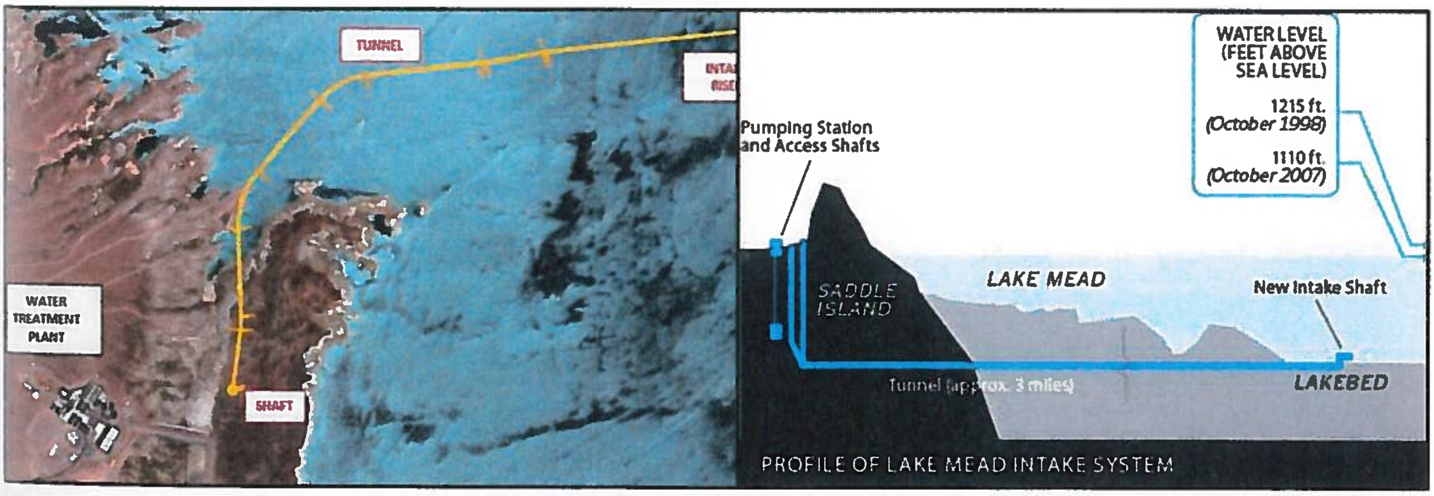


Fig. 1 – Project overview.

Project Challenges

The project has had several difficult challenges to overcome:

- Intake Structure consisted of a 1,300 tons reinforced concrete constructed on a barge and lowered 330 ft (100 m) into Lake Mead anchored with 12,200cy (9,200 m^3) of tremie concrete.
- The drill and blast Starter Tunnel was impacted by three inflow events, resulting in a one year project delay.
- One of the main challenges was selecting the TBM and excavating the tunnel with expected hydraulic head pressure of as much as 17 bar, crossing faulted areas, low rock cover and the risk of tunnel instability due to direct connection with the lake.
- Extensive pre-excavation grouting with a constant head pressure ranging from 12 bar to 15 bar.
- Structural repair of the cutterhead in difficult hydro-geological conditions [water inflow of approx. 4,000 gpm (910 m^3/hr)].
- Complete repair of the cascade sealing system for the main bearing and two replacements of the pinion bearings.
- The TBM approach to the Intake Structure

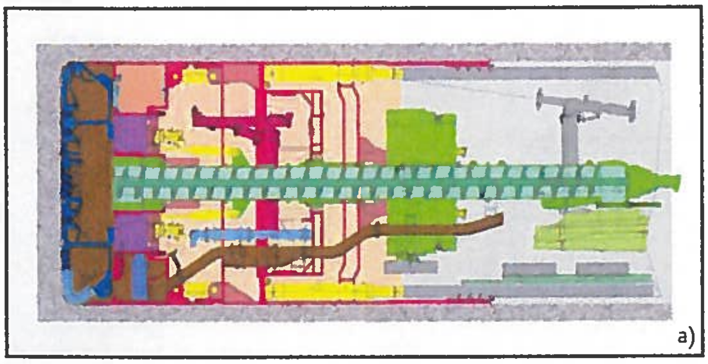
Shaft, cavern and starter tunnel

The Intake N.3 project consists of a concrete lined shaft that is 610 ft (185 m) deep with an internal diameter of 30 ft (10 m). The shaft intersects a cavern which is 200 ft (61 m) long and was design to accommodate the assembly of the TBM. The Starter Tunnel is 360 ft (120 m) long to allow the TBM to start mining in closed mode configuration and to house the belt storage unit when the TBM operates in open mode. The construction of the Shaft started in August 2008 and ended in May 2010. The shaft and cavern were excavated by conventional drill and blast method, 10 ft (3 m) per round and was concrete lined as the shaft was excavated.
Three extensive grouting campaigns were performed to control the high water inflows encountered during the excavation of the shaft.
Mining work on the original Starter Tunnel began in February 2010. The rock condition was supposed to be good, but after 150 ft (47 m) of excavation a large inflow occurred, approximately 6,600 cy (5,000 m^3) of material filled the Starter Tunnel and the cavern. We then mobilized drilling equipment for ground investigation to understand the geological conditions and to evaluate the need of grouting from the surface.
After a month of investigation and grouting the dewatering of the shaft and cavern began. The water was pumped at slow increments to check the condition of the concrete lining and to closely monitor the water inflow coming from the starter tunnel. After the dewatering was completed work began which including removing the buried equipment and reestablishing electricity and ventilation.
On October 26, 2010 we began excavation to reinstate the starter tunnel to its previous face station. On October 27th while excavating the top bench we had a second in-rush of material. A bulkhead was installed to contain the flowing material.
Between October 27th and December 31st, we began drilling additional core holes on surface and underground to look for an alternate alignment. Concurrent work resumed with drilling drainage and grout holes in the original alignment.
On December 31st a third inflow occurred during the drilling of one of the holes. In January 2011 the decision for a new alignment at 23 degrees east the original tunnel axis was taken.
The old Starter Tunnel was abandoned, the new, 360 ft (120 m^3) long, starter tunnel was excavated by drill and blast utilizing a canopy pipe system to ensure the stability of the tunnel. The New Starter Tunnel was successfully completed at the end of July 2011.

TBM tunnel drive

TBM description

The TBM used to excavate the 3 miles (4.8 Km) of the intake tunnel was a Herrenknecht S-502 hybrid machine. It was a prototype with the capability of operating either in open or closed mode, depending on the hydro-geological conditions of the rock masses encountered.
Open mode operation consisted of excavating the ground without any face support, evacuating the excavated material via a 60 ft (18 m) long horizontal screw conveyor. This fed a system of belts which ran along the TBM trailing gear, then on a continuous conveyor along the lined tunnel and terminated at the bottom of the shaft where the muck was discharged into two buckets. Each bucket had a capacity of 20 cy (15 m^3) and ran vertically up the 610 ft (185 m) shaft to the surface (figure 2a and 2b).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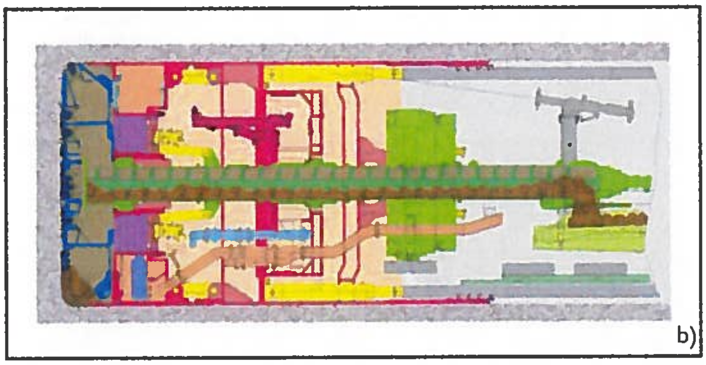

b)

Fig. 2 – a) Open Mode Configuration; b) Closed Mode Configuration.

Once on the surface an overland conveyor was utilized to take the muck to the designated disposal area on the site.
In **closed mode** the TBM operates as slurry machine. Mining was performed by applying a support pressure at the face. This mode was used in order to help stabilize the ground and to reduce the risk of tunnel flooding in the case of encountering highly permeable rock masses or direct connection with Lake Mead.
The machine was designed to withstand a maximum hydraulic head pressure of 17 bar and operate at 15 bar. The cutterhead was equipped with 48 cutters, 17" in diameter excavating a tunnel diameter of 23.7 ft (7.22 m). The cutterhead required 2,800 KW and the total installed power was 5,750 kW. The breakout torque was 10MNm and the thrust ranged from 70,000 kN to 100,000 kN.
All of the equipment necessary to operate the TBM was installed on 15 gantries with a total length of 607 ft (185 m) and a total weight of 1,650 tons.
Among many special features, the TBM was equipped to handle high water pressure and inflows. The machine was also equipped with 3 drill rigs in order to perform either geological investigation (probing and coring) or pre-excavation ground treatment to reduce the permeability and/or increased stability of the rock masses ahead of and around the TBM. Drilling could be carried out through the cutterhead or the shield with a pattern of holes (14 peripheral through the shield; 20 through the cutterhead) characterized by different inclinations (0°, 3.5° and 7°).

Hyperbaric Interventions

Face interventions for maintenance occurred in atmospheric conditions. However, in the event maintenance was required during closed mode operation, the TBM was equipped and the personnel was trained for hyperbaric interventions. The equipment to perform saturation dives at high pressure included:

- 1,200 gas cylinders (heliox), stored on site
- Four tube trailers (135,000cf each), stored off site
- Saturation control van
- Special decompression chamber/medical lock
- Transport shuttle

Geology reach 1: lower and upper plate formation

Geology STA 4+79 to STA 31+81

The Lower plate was characterized by a mix of amphibolite gneiss with presence of quarts-feldspar bedding. In the detachment fault we encountered soft, highly fractured and brecciated clay gauge material.
The Upper plate was characterized by a heterogeneous assemblage of crystalline metamorphic rock predominantly, quartz-feldspar, granite, pegmatite and mica schist.

Drive

The TBM was lunched on December 27, 2011. Based on the expected geological conditions of the Saddle Island Lower Plate, the plan was to mine the first 600 ft (200 m) of the TBM tunnel in closed mode with face support pressure less than 7 bar.
After 460 ft (140 m) of excavation, at push 77, the air bubble pressure was lowered and maintenance was carried out at atmospheric conditions. There, a sub-vertical fault entering the tunnel alignment from left to right was detected and mining resumed with pressure at the face adjusted to 12 bar to compensate for the hydraulic head. The TBM progressed very well into the Detachment Fault and the slurry pressure in the excavation chamber was raised to 13 bar to address the increased groundwater head and the nearly cohesionless material being excavated.
On July 2, 2012, at approximately 920 ft (280 m) of excavation, the TBM penetration values became lower. A decision was made to lower the face pressure and inspect the cutterhead.
In order to assess the feasibility of men entering into the working chamber under atmospheric pressure it was important to estimate the quantity of water inflow. For this purpose the TBM could be used to perform a large-scale piezometric test. The concept was to utilize the slurry line to measure the increase of seepage water by observing the change of water outflow in the slurry line while reducing the bubble pressure in 0.5 bar increments.
In July 2012, 3 piezometric tests were performed but aborted at 10 bar with over 880 gpm (200 m^3/h) of water inflow.
At this point, an inspection of the cutterhead was only possible by using a camera installed on a steel pipe pushed into the excavation chamber through a drill port equipped with a blow-out preventer. The inspection showed that the cutter conditions were not bad, and on August 1, 2012, the TBM resumed mining with a face pressure raised to 14 bar.
During the next 77 pushes, 10 tests were performed and the resulting water inflows reached a maximum of 4,825 gpm (1,100 m^3/h) at 8 bar. With that inflow it was impossible to access the excavation chamber for maintenance under atmospheric pressure.
On September 29, 2012, at push 235, the TBM penetration reduced. The camera inspections detected wear on the cutters. The possible scenarios were to either perform a series of pre-excavation grouting campaigns to allow for maintenance or prepare all necessary equipment for hyperbaric intervention in saturation.
Hyperbaric work at 14 bar pressure had more adherent risk, so we began pre-excavation grouting the ground ahead and also around the TBM. However, the hyperbaric intervention was still an option and the procurement of the gas equipment, and the logistics was planned concurrently with the grouting program.

Pre-excavation grouting campaigns and Cutterhead repair

The ground treatment ahead of the machine was planned and based on the GIN-method, refusal injection pressure and maximum injection volume values were defined in accordance with the fractured ground conditions. A significant difficulty was the fixed pattern of available drilling holes (see green and blue dots in Fig. 3).
The first grouting campaign was carried out at ring 235. The area to be grouted was planned to extend 36 ft (11 m) covering the upper part of the layout shown on Fig. 3. After some drilling and grout injection difficulties the campaign was completed and the machine moved 4 m forward.
The second campaign was performed at ring 237. The umbrella was increased to 50 ft (15 m) with an overlap of 13 ft (4 m) with the first campaign. After completion of the

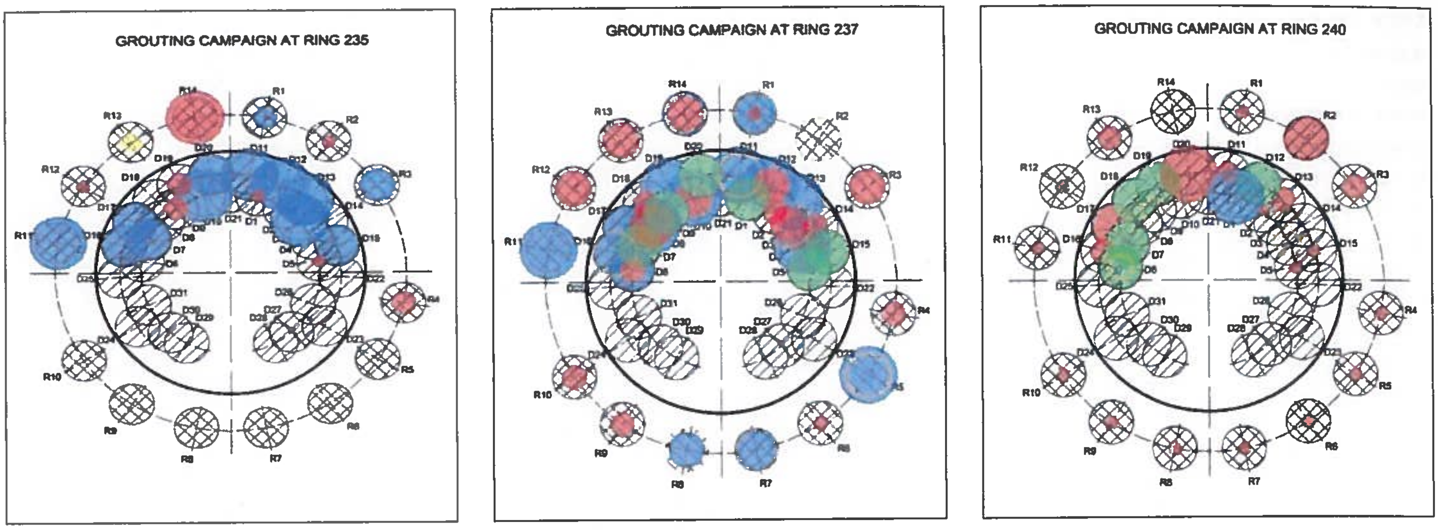


Fig. 3 – Grouting campaigns – grout patterns.

grouting activities, the machine was moved 20 ft (6 m) forward.
The third campaign was executed at ring 240. The umbrella was further increased to 57 ft (17 m), with 18 ft (5.5 m) overlap with the second campaign. This time, both drilling and grouting were performed in 2 different stages: up to 29.5 ft (9 m) for the first, and up to 56 ft (17 m) for the second.
After completion of the third campaign, on February 19, 2013 a large-scale piezometric test was performed. At atmospheric pressure, the water inflow was 965 gpm (220 m^3/h) and a face inspection was accomplished. We began cutterhead maintenance but stopped due to a local instability of the upper right part of the tunnel face. At that point, because of the low water inflow rate, maintenance of the slurry lines was performed. This included replacement of worn pipelines, valves, pumps and installation of a new hydraulic valve on the slurry return line.

When the slurry circuit maintenance was completed the TBM advanced forward so that the unstable area was behind the TBM shield. After 29.5 ft (9 m) and then 53 ft (16 m) of advance piezometric tests were carried out. Water inflow was 3,860 gpm (880 m^3/h) at 2.9 bar and 4,825 gpm (1,100 m^3/h) at 1.9 bar, respectively. The decision to advance forward and find a less permeable location was made, knowing that the machine was leaving the grouted area.
During advance #251 to #253 some steel fragments were found on the magnet at the slurry separation plant. It was decided to stop the TBM from advancing to investigate the problem. On March 25, 2013 a piezometric test was performed. The pressure was successfully lowered to atmospheric and the face inspection showed that the central part of the cutterhead had severe damaged to the cutters and the cutter housing. The water inflow was measured to be approximately 4,000 gpm (912 m^3/h) and the rock condition was stable. With the stable conditions at the face maintenance work was started. A niche was excavated (13 ft x 10 ft x 3 ft) in front of the cutterhead (Fig. 4) using small hand tools. Once the excavation was completed, the structural repair was performed. The water had to be panned away from the work area and ventilation had to be established for the cutterhead repair. Technicians from the TBM manufacturer were brought to site to oversee the repair. The central section of the TBM had to be repaired completely including the disc cutter housings, structure, wear plates and the cutters.

Geology reach 2: muddy creek and red sandstone formation

Geology STA 31+81 to STA 149+00

The muddy creek section was characterized by different sedimentary formation. In the first part was predominantly siltstone, sandstone and gypsiferous mudstone.
From STA 102+00 to STA 108+50 we encountered an intrusion of metamorphic rock, predominantly quartz-feldspar gneiss and mica schist typical of the Upper plate. However, most of reach 2 was characterized by conglomerated breccia with different levels of cohesion.

Drive

The Tunnel boring machine was operated in open and closed mode through this section depending on the ground conditions encountered. The first 5,300 ft (1,615 m) of excavation were completed in 6 months averaging approximately 45.5 ft/day. Along this stretch we had experienced muck handling issues with the conveyor belt and clogging of the cutterhead. In particular we observed that the clogging phenomena was restricted only in the areas where the clay content was higher and the TBM was advancing in closed mode applying high pressure at the face (avg. of 12 bar).
Due to clogging of the cutterhead, closed mode operations resulted generally in lower penetration rates. The reduction of the cutterhead openings partially obstructed the material flowing through the cutterhead. Consequentially, the muck collected in front of the cutterhead and created a stiff layer that hindered the correct operation of the cutting tools (we had several cases of blocked disc cutters or disc cutters with blown gaskets). So, for the same boring force the achieved penetration was smaller.

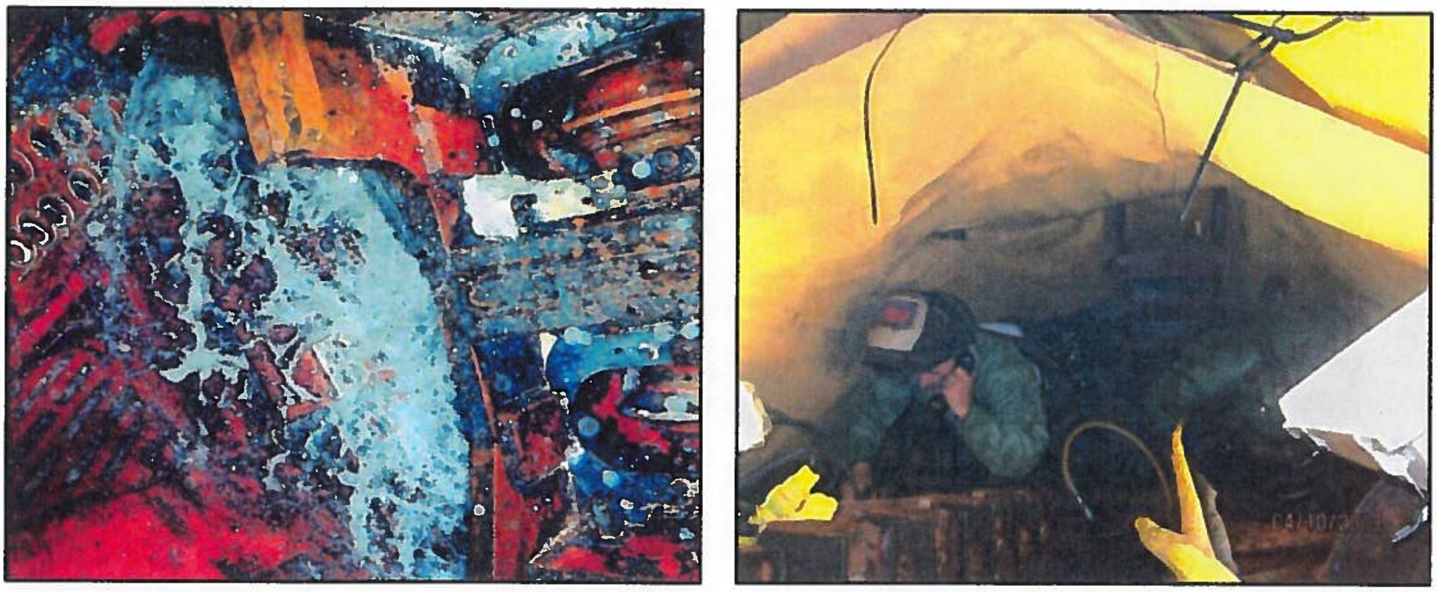


Fig. 4 – Water Inflow 4,000 gpm (910 m^3/h) and the Cutterhead repair.

Moreover, trying to increase the penetration by increasing the boring force would squeeze the material into the gap around the shield, thus developing additional frictional forces on the shield and consequentially reducing the effective force available for boring. (Anagnostou 2013)

Cascade System replacement

On the 2nd of January 2014, after push #1309 we found some lubrication grease (EP2) in the leakage chamber P3 (see figure 5). At that time the TBM was mining in closed mode at approximately 12.5 bar. Production was stopped and full maintenance of the main drive lubrication system was performed.
The TBM resumed mining until we excavated ring #1337. At STA 84+85 the machine was stopped due to low impulses of the gear box oil. The gear box and the pinion oil filter were found plugged with EP2 grease. Herrenknecht technicians were informed and under their supervision we performed a series of tests and we found that it was probably one of the four cascade seals that failed allowing the lubrication grease to travel back into the main bearing and the pinions.
On the 30th of January it was decided to replace the Cascade sealing system. In order to do that we had to excavate a space between the cutterhead and the main bearing to allow the replacement of the seals.
Due to the length of the TBM (approx. 45 ft – 15 m) and the precast lining already in place, moving the TBM backward was not possible. So we excavated a chamber of 25 ft x 25 ft x 5 ft (7.6 mm x 7.6 m x 1.5 m) in front of the machine in order to remove the cutterhead and push it forward (see figure 6).
The chamber was completed in one week and the cutterhead was removed and pushed forward. The total seal replacement took only one month. What we found during this process was that the second gas-

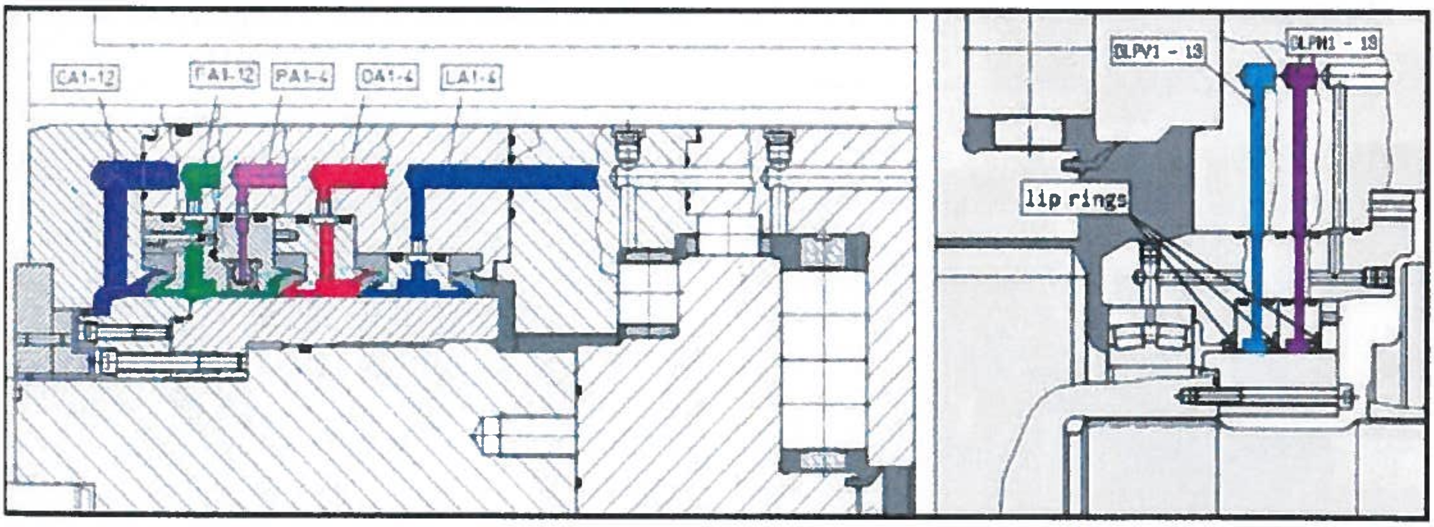


Fig. 5 – Cascade sealing system.

Fig. 6 – Chamber in front of the cutterhead.

ket between the EP2 chamber and the Oil chamber P2 was broken allowing the grease to contaminate the main drive.
Production resumed on March the 17th and mined through different geology without substantial problem, alternating between open and closed modes (avg. pressure 12.5 bar).

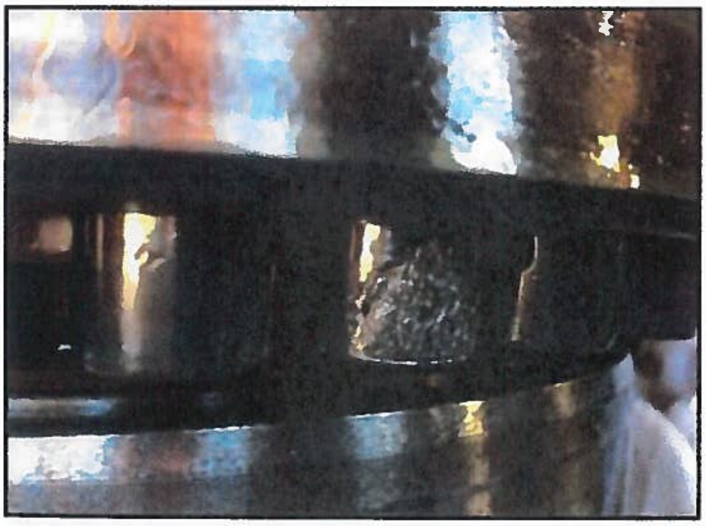
Pinion Bearings Repair

During push #1680 at STA 100+66 the TBM advance was stopped when we found metal shaving in the gearbox filters. The lubrication system of the main drive was inspected and this time it was found that there was metal shavings in the gear box filters.
Over the next few days further tests were conducted under the supervision of a Herrenknecht technician to isolate the problem, which potentially could have caused damage to the main bearing.
One by one all of the pinion gears were removed and inspected. We found that 5 pinion bearings were damaged and were the cause of the metal shavings in the main bearing oil. After inspection of the bull gear and the main bearing showed no signs of wear, we proceeded with the replacement of all of the 12 pinion bearings (see figure 7).
After approximately 100 rings from the replacement of the first set of pinion gears, we had a second failure at push #1884, STA 117+69.
A large amount of metal shavings was found in the gearbox filters, immediately we began the same replacement procedure that was performed during the first pinion gears repair. It was determined the failure of the pinion bearings was directly related to the high cascade pressure on the main bearing seals, which caused and unbalanced ratio axial/radial load acting on the pinion bearings. The solution was to reduce the number of drive motors from 12 to 8 in order to increase the torque and to introduce a new pressurized chamber P7 (3 bar) behind the pinion bearing in order to reduce the axial load (see figure 8).

Geology reach 3: intake approach – intake connection

Geology STA 149+00 to STA 150+42

The rock formation was characterized by different flows of vesicular and non-vesicular Tertiary basalt highly fractured and predetermined to be mined in closed mode.



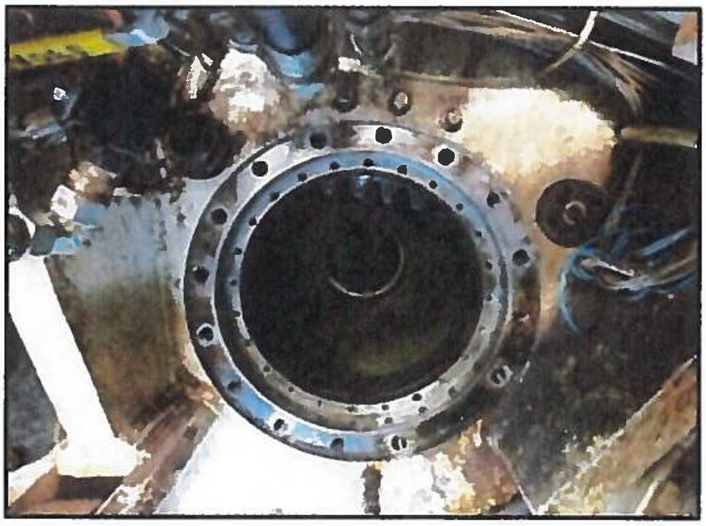


Fig. 7 – Damaged pinion bearing + Gearbox cavity.

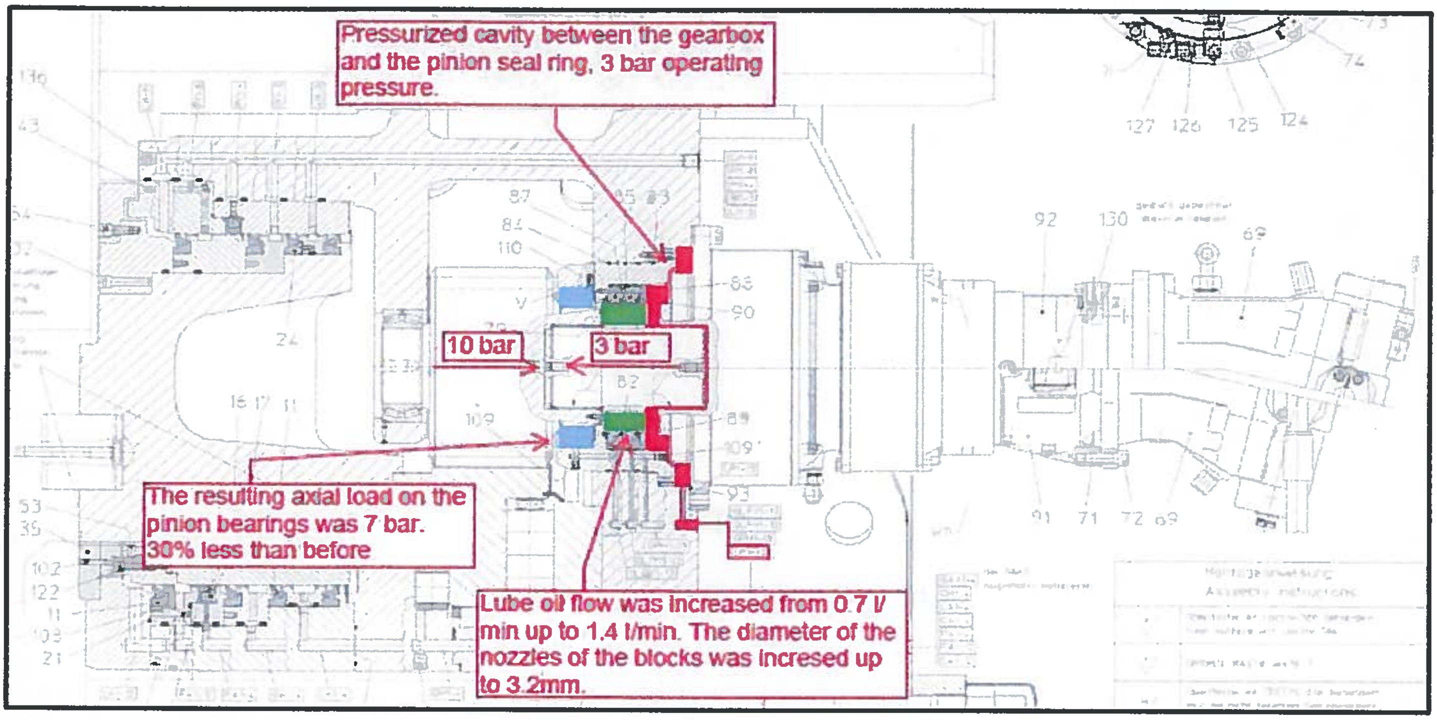


Fig. 8 – Gearbox scheme TBM S-502.

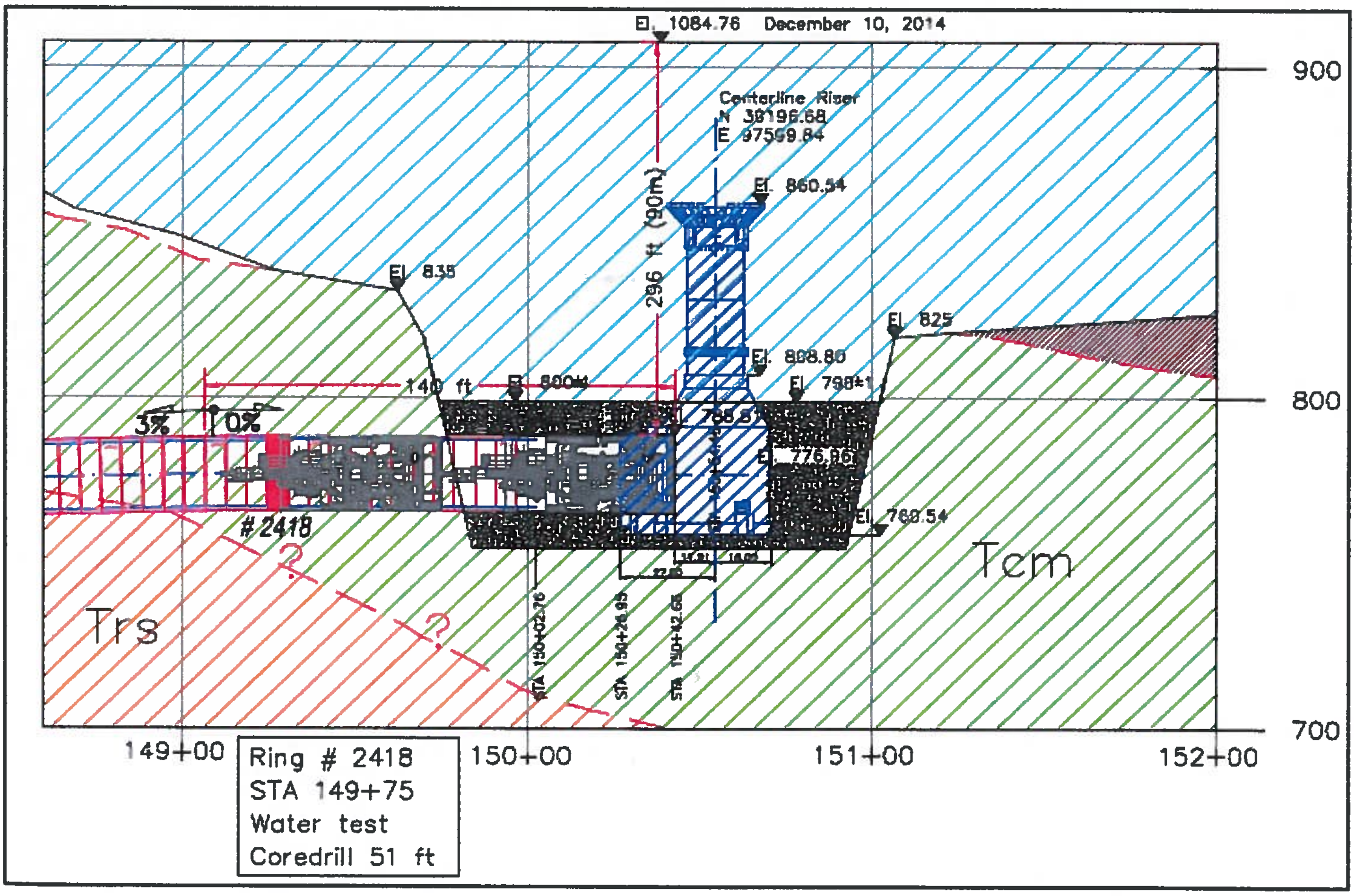


Fig. 9 – Intake approach.

Fig. 10 – Dec 10, 2014 TBM S-502 breakthrough.

Drive

We considered the Intake approach as the last stretch of the drive where the alignment changed from a 3% grade to 0% grade for the final 140 ft (42 m). In the final drive, the geology changed from Red Sandstone to fractured vesicular basalt (see figure 9).The TBM was operated in closed mode due to the thin cover and the large water inflow encountered.

At station 149+75 a core drill was performed to investigate the transition between the basalt and the tremie concrete including the quality of the tremie concrete and the interface of the intake "soft eye" location.

As expected the basalt was highly fractured due to the previous blasts of the Intake Structure. The quality of the tremie concrete was better than expected and the result of the core drill showed a clear joint between the tremie concrete and the Intake Structure.

Prior to the TBM connection, the subcontractor was mobilized to the site to set up the barges in order to perform the marine work which included:

- Removal of the lid from the Intake Structure
- Remote Operating Vehicle (ROV) inspection of the condition of the corbel/bulkhead and sealing flange in the interior of the intake riser
- Inspection with the ROV the final position of the TBM in relationship with the Intake Structure
- Setting the bulkhead once the TBM had reached its final position and dewatering the Intake Structure

The TBM parameters were adjusted to reduce the rate of advance through the tremie concrete and the fiberglass reinforcement of the soft eye. This procedure reduced potential damage to the Intake Structure.

The excavating pressure was set at 9.3 bar during the final drive of the TBM into the Intake Structure which was the theoretical lake pressure.

The material from the soft eye during the last stage of the excavation was inspected at the separation plant. The concrete previously painted on the intake structure/soft eye/intake was seen at the separation plant indicating the TBM was in the correct location. The TBM then continued to push forward until the shield stopped in line with an annulus steel ring cast in the intake structure.

After the installation of the bulkhead we started dewatering of the intake chamber. Once we were able to access the Intake Structure the shunt flow around the TBM shield was measured to be 15 gpm and there was no water leakage from the intake structure/bulkhead.

The Intake connection was a complete success (see figure 10), the TBM alignment was within a tolerance of +/- 3 mm.

Conclusion and Outlook

The project, for the first time worldwide has advanced a TBM at 15 bar which required several innovations developed on site. It has been a very technically challenging and demanding project and it would not have been completed without the dedication and commitment of the Salini-Impregilo/Healy and the Client Sothern Nevada Water Authority (SNWA) working together in a true partnership.

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Lake Mead Intake N. 3 – cronaca di un record mondiale

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Nel Marzo del 2008, la Vegas Tunnel Constructors (VTC), formata dall'italiana Impregilo Spa (ora Salini-Impregilo Spa) e dalla sua sussidiaria americana SA Healy, si aggiudicò la realizzazione, per conto della Southern Nevada Water Authority (SNWA), della terza opera di presa idraulica nella più grande riserva degli Stati Uniti, il lago Mead, formato dalla diga di Hoover, che sbarra il fiume Colorado al confine tra Nevada e Arizona, a circa 30 km sud-est dalla città di Las Vegas . Il progetto prevedeva la costruzione e il posizionamento sul fondo del lago dell'opera di presa, scavo e rivestimento di un pozzo 185 m profondo con diametro interno di 9.15 m e costruzione di un tunnel di collegamento tra pozzo e opera di presa, lungo 4.8 km con rivestimento in conci prefabbricati. La nuova presa è stata posizionata ad una profondità maggiore (100 m sul fondo del lago) rispetto alle due esistenti a causa della costante diminuzione del livello del lago negli ultimi 15 anni. Le previsioni prevedono un abbassamento del livello del lago al di sotto della quota minima di regolazione per la presa No.1, lasciando la sola opera di presa No.2 incapace di soddisfare una richiesta più grande delle sue capacità. Con la realizzazione della terza opera di presa si potrà ovviare a tale rischio.

La costruzione del pozzo iniziò nel 2008 per essere completata nel 2010 insieme con la caverna. Entrambe le strutture sono state realizzate in tradizionale con esplosivi in step di 3 m. Durante lo scavo del pozzo, rivestito in cemento armato, si effettuarono tre campagne di consolidamento per far fronte ad alte venute d'acqua.

Nel 2010 iniziò lo scavo dello Starter Tunnel per essere completato nel luglio del 2011 in seguito a tre eventi di crollo del fronte con venute d'acqua e materiale che portarono alla decisione di ruotare l'allineamento di 23° ad est rispetto al vecchio.

Lo scavo del tunnel (4.8 km) partì il 27 dicembre 2011 utilizzando una macchina ibrida della Herrenknecht (S-502), un prototipo capace di operare sia in modalità aperta che chiusa a fanghi bentonitici, a seconda delle condizioni idrogeologiche incontrate. Per la modalità chiusa essa era stata progettata per far fronte ad una pressione idrostatica di 17 bar ma operò fino a 15 bar (record mondiale). La testa (7,22 m di diametro, 2800 kW) era stata equipaggiata con 48 dischi di taglio da 17". La potenza totale installata era di 5,750 kW, il torque di 10 MNm e la spinta variava tra i 70,000 kN e i 100,000 kN. Il back-up era costituito da 15 carri per una lunghezza totale di 185 m e peso totale di 1,650 tons. Tre perforatrici erano state installate sulla macchina per poter effettuare, anche in presenza di elevate pressioni al fronte, sia perforazioni di sondaggio in avanzamento che consolidamenti attraverso 14 fori posti sul perimetro dello scudo e 20 attraverso la testa. Il pattern di fori permetteva perforazioni con diverse inclinazioni (0°, 3.5°, 7°). La macchina era anche equipaggiata di tutto il necessario per poter effettuare interventi di manutenzione al fronte in condizioni iperbariche (anche se tutti gli interventi erano stati poi effettuati in condizioni atmosferiche).

A rendere unico il progetto sono state le diverse difficoltà, previste e inaspettate, che hanno messo alla prova il team della JV nel corso degli anni. Difficoltà superate con successo:

- Scavo da chiatta con l'utilizzo di esplosivi del letto roccioso a 100 m sotto il livello del lago, per il posizionamento dell'opera di presa
- Opera di presa (Intake Structure) costituita da una struttura composita di 1,300 tons di cemento armato ed acciaio inox, costruita su una piattaforma, calata a 100 m sul fondo del lago e ancorata con 9200 m³ di tremie concrete
- Utilizzo di una macchina di scavo (TBM) capace di operare con pressioni del fronte fino a 17 bar
- Montaggio della TBM in sotterraneo attraverso un pozzo profondo 185 m visto come unica sezione di passaggio per il rifornimento dei materiali e conci di rivestimento della galleria e per l'evacuazione dello smarino
- Attraversamento di estese zone di faglia
- Tratti con basse coperture di roccia al di sotto del letto del lago
- Tre campagne di consolidamento in avanzamento con pressioni idrostatiche costantemente tra i 12 e i 15 bar atte a ridurre la permeabilità del materiale del fronte di scavo
- Manutenzione straordinaria della testa di scavo in difficoltose condizioni geologiche (venute d'acqua di circa 910 m³/hr)
- Riparazione del sistema di tenuta a cascata del cuscinetto della testa con scavo di caverna al fronte
- Due sostituzioni di tutti i cuscinetti dei pignoni dei motori della testa
- Approccio della TBM all'opera di presa e breakthrough (10 dicembre 2014) con una tolleranza di pochi millimetri