SVCW - Gravity Pipeline Project

Webinaire
« Regards croisés sur la pratique de la géotechnique à l'international - 2ème édition »

CFMS

09-Mai-2023
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1. PROJECT DETAILS

**Owner**: Silicon Valley Clean Water. Joint Powers Authority

**Contractor**: Barnard Bessac Joint Venture
- Barnard: 70%
- Bessac: 30%

**Engineer**: ARUP North America.

Progressive Design and Build.

Initial Contract Amount: $212,302,346
Expected Contract Amount: ~ $225,000,000
1. PROJECT DETAILS

- Drive #2
- Drive #1
- Airport access shaft (AAS)
- Bair Island shaft (BI)
- Receiving Lift station shaft (RLS)
- San Carlos shaft and adit (SC)
1. PROJECT DETAILS
1. PROJECT DETAILS

SCOPE OF WORK:

Gravity sewer/ rainstorm large tunnel replacing an aging 60” ID RC gravity pipe converted into a force main with 64 ruptures.
1. PROJECT DETAILS

SCOPE OF WORK:

- Construction of AAS Shaft
- Construction of BI Shaft
- Boring and lining of Drive 1 to BI (5125 LF / 1562 m)
- Boring and lining of Drive 2 to RLS (12307 LF / 3751 m)
- Construction of SC shaft and adit
- Supply / install / grout FRPM pipes
- Connection between the existing Reinforced concrete pipe at BI and the FRPM pipe with a Vortex type drop structure
- Connection between the SC pump station and the FRPM pipes with a Baffle drop structure
1. PROJECT DETAILS – PROGRESSIVE DESIGN & BUILD

**Type of Contract**: Progressive design and Build in 2 stages

- RFQ and Award based on a 10% Design
- Stage 1: Design up to 60% - Alternative Proposal – Permitting – Open Book cost estimate.
- Stage 2: Design to 100% - Construction services and construction for the completion of the Project.
- At the end of the stage 1, 3 possibilities:
  - Award for a Guaranteed Maximum Price (T&M + Overhead and Profit).
  - Award on a Lump Sum basis.
  - Rejection of the DB proposal.
- Stage 1 was performed under the GMP type of contract.
- Stage 2 was awarded to BBJV on a Lump Sum Basis.
1. PROJECT DETAILS – PROGRESSIVE DESIGN & BUILD

- **Procurement**
  - Team selection
  - Qualifications
  - Project approach
  - Price component

- **Stage 1: Design**
  - Collaborative design
  - Deliverables: BODR, 30%, 60%
  - Cost estimates at major milestones

- **Stage 2: Final Design and Construction**
  - Final design
  - Construct facilities
  - Startup, testing, and joint operation

BESSAC
1. PROJECT DETAILS – PROGRESSIVE DESIGN & BUILD

PROGRESSIVE DESIGN AND BUILD:

 Practically:
  ▪ Promote collaboration between the client, the CM, the contractor and the EOR
  ▪ Develop alternative designs to achieve:
    ✓ 1 year faster on schedule,
    ✓ 20% minimum cost reduction,
    ✓ 100 years design life

<table>
<thead>
<tr>
<th>Evaluation Criteria</th>
<th>Maximum Possible Points (Proposal / Interview)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qualification and Experience</td>
<td>10 / 10</td>
</tr>
<tr>
<td>Understanding of Key Issues / Challenges</td>
<td>15 / 15</td>
</tr>
<tr>
<td>Project Approach</td>
<td>20 / 20</td>
</tr>
<tr>
<td>Innovative / Alternative Ideas</td>
<td>20 / 20</td>
</tr>
<tr>
<td>Schedule</td>
<td>10 / 10</td>
</tr>
<tr>
<td>Pricing Approach</td>
<td>5 / 5</td>
</tr>
<tr>
<td>Approach to Consideration of Lifecyle Cost</td>
<td>5 / 5</td>
</tr>
<tr>
<td>Fee Scoring</td>
<td></td>
</tr>
<tr>
<td>Stage 1 Cost Proposal</td>
<td>5</td>
</tr>
<tr>
<td>Stage 2 Mark Up Percentages</td>
<td>14</td>
</tr>
<tr>
<td>Indicative Cost Estimate</td>
<td>10</td>
</tr>
<tr>
<td>Total Possible Points</td>
<td>200</td>
</tr>
</tbody>
</table>
1. PROJECT DETAILS – PROGRESSIVE DESIGN & BUILD

**BBJV main alternatives:**

1. Multiple layers of defense (ventilation, odor control; turbulence control)
1. PROJECT DETAILS – PROGRESSIVE DESIGN & BUILD

2. Replacing HOBAS pipe with HDPE liner or Combi segment
1. PROJECT DETAILS – PROGRESSIVE DESIGN & BUILD

3. Cancelling temp launching shaft (launch from Bair island, change tunnel alignment)
1. PROJECT DETAILS – PROGRESSIVE DESIGN & BUILD

4. Overlap design and construction

- Order TBM, mould, precast, shaft during Stage 1
- Issue construction and environmental permits during stage 1
- Reschedule Key design elements based on critical path,
2. GEOLOGICAL CONTEXT
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2. GEOLOGICAL CONTEXT
2. GEOLOGICAL CONTEXT
A Geotechnical Data Report (GDR) is a compilation of factual subsurface data collected during a project investigation. Data are collected during borehole drilling, laboratory testing, test pit excavation, geophysical survey, geologic mapping, literature review, and other means that provide quantitative or objective data about the subsurface. The GDR contains factual data only. The GDR provides objective data that a GBR author uses to interpret subsurface conditions. (Robin Dornfest, Nate Soule & Ryan Marsters, Lithos Engineering)
The GBR provides information about the anticipated subsurface, discussion of similar nearby projects if available, and a section on feasible construction methods and the potential problems these methods may encounter during construction. However, the GBR’s “baseline statements” (“baselines”) make the document unique. The baselines are a set of contractual assumptions about ground conditions and behavior. (Robin Dornfest, Nate Soule & Ryan Marsters, Lithos Engineering)
2. GEOLOGICAL CONTEXT

2.1 FOCUS ON GEOTECHNICAL DATA

Soil groups from Boreholes

Boreholes yield physical soil samples for visual inspection and selective testing in a soils laboratory. Soil samples were visually classified in accordance with the Unified Soil Classification System (USCS) as recorded in borehole log records.

<table>
<thead>
<tr>
<th>Soil Group</th>
<th>USCS Soil Classification</th>
<th>General Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fines-Fat</td>
<td>CH, MH</td>
<td>Greater than 50% passing #200 sieve; Liquid Limit &gt; 50.</td>
</tr>
<tr>
<td>Fines-Lean</td>
<td>CL, ML</td>
<td>Greater than 50% passing #200 sieve; Liquid Limit &lt; 50.</td>
</tr>
<tr>
<td>Mixed-Finer</td>
<td>SC, SM, SC-SM</td>
<td>12% &lt; % passing #200 sieve &gt; 50%; % Sand &gt; % Gravel</td>
</tr>
<tr>
<td>Mixed-Coarser</td>
<td>GM, GC, GC-GM</td>
<td>12% &lt; % passing #200 sieve &gt; 50%; % Gravel &gt; % Sand</td>
</tr>
<tr>
<td>Sand</td>
<td>SP, SP-SM, SP-SC, SW, SW-SM, SW-SC</td>
<td>Less than 12% passing #200 sieve; % Sand &gt; % Gravel</td>
</tr>
<tr>
<td>Gravels</td>
<td>GP, GP-GM, GP-GC, GW, GW-GM, GW-GC</td>
<td>Less than 12% passing #200 sieve; % Gravel &gt; % Sand</td>
</tr>
</tbody>
</table>

1 Unified Soil Classification System defined for visual classification (ASTM D2488, 2017b) and laboratory classification (ASTM D2487, 2017a)
CPTs have been utilized to evaluate subsurface conditions along the proposed alignment. CPTs do not provide physical soil samples for inspection and classification; however, the data obtained are nearly continuous through the soil column and provide an indication of soil behavior. Classification of soil from CPT data is referred to as soil behavior type (SBT) and is often processed and presented as normalized soil behavior type, or SBTn.

### Table 5  Definition of CPT-based Soil Behavior Types after Robertson (2010)

<table>
<thead>
<tr>
<th>Soil Group</th>
<th>Soil Behavior Type No. (SBT&lt;sub&gt;n&lt;/sub&gt;)</th>
<th>SBT&lt;sub&gt;n&lt;/sub&gt; Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fine Behavior</td>
<td>1</td>
<td>Sensitive, fine-grained</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Organic soils – clay</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Clay – silty clay to clay</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Silt mixtures – clayey silt to silty clay</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>Sand mixtures – silty sand to sandy silt</td>
</tr>
<tr>
<td>Coarse Behavior</td>
<td>6</td>
<td>Sands – clean sand to silty sand</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>Gravelly sand to dense sand</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>Very stiff sand to clayey sand</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>Very stiff, fine-grained&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>1</sup> Heavily overconsolidated or cemented, behavior may vary.
2. GEOLOGICAL CONTEXT

2.1 FOCUS ON GEOTECHNICAL DATA

Soil Behavior Types from CPTs

CPTs have been utilized to evaluate subsurface conditions along the proposed alignment. CPTs do not provide physical soil samples for inspection and classification; however, the data obtained are nearly continuous through the soil column and provide an indication of soil behavior. Classification of soil from CPT data is referred to as soil behavior type (SBT) and is often processed and presented as normalized soil behavior type, or SBTn (Robertson, 1990).
Soil Behavior Types from CPTs

The tip resistance (Qc) is measured by load cells located just behind the tapered cone.

The tip resistance is theoretically related to undrained shear strength of a saturated cohesive material, while the sleeve friction is theoretically related to the friction of the horizon being penetrated.

J. David Rogers, Ph.D., P.E., R.G, Fundamentals of CONE PENETROMETER TEST (CPT) SOUNDINGS
2. GEOLOGICAL CONTEXT
2.1 FOCUS ON GEOTECHNICAL DATA

Soil Behavior Types from CPTs

The friction ratio is given in percent. It is the ratio of skin friction divided by the tip resistance (both in tsf).

It is used to classify the soil, by its behavior, or reaction to the cone being forced through the soil.

High ratios generally indicate clayey materials (high c, low Ø) while lower ratios are typical of sandy materials (or dry desiccated clays).

J. David Rogers, Ph.D., P.E., R.G, Fundamentals of CONE PENETROMETER TEST (CPT) SOUNDINGS
2. GEOLOGICAL CONTEXT
2.1 FOCUS ON GEOTECHNICAL DATA
2. GEOLOGICAL CONTEXT

2.1 FOCUS ON GEOTECHNICAL DATA

Soil Shear Strength correlation from CPT

Cone tip resistances can be used to estimate numerous soil parameters such as Shear Strength.

- For coarse-grained soils within the tunnel zone, cone tip resistances on the order of 50 tsf and 200+ tsf suggest internal friction angles of 30 to 36°, respectively. (Mayne, 2007). Note that the correlated friction angles were reduced by 5 degrees to account for the high fines content of the sands (Iowa DOT, 2015).

- For fine-grained soils within the tunnel zone, undrained shear strengths were estimated from cone tip resistances for fine-grained ULS per the correlation from Lunne et al. (1997). The Nkt parameter utilized in the correlation was set to 18 project-wide, which calibrated to available field and laboratory testing data, mainly from the shaft locations.

<table>
<thead>
<tr>
<th>Tunnel Reach</th>
<th>Average Shear Strength Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fines – $S_d$ (psf)</td>
</tr>
<tr>
<td>AAS-TRS 1 (TRS to STA 38+00)</td>
<td>1507</td>
</tr>
<tr>
<td>AAS-TRS 2 (STA 38+00 to 75+50)</td>
<td>1787</td>
</tr>
<tr>
<td>AAS-TRS 3 (STA 75+50 to AAS)</td>
<td>1702</td>
</tr>
<tr>
<td>AAS-BIS 1 (AAS to STA 168+50)</td>
<td>1761</td>
</tr>
<tr>
<td>AAS-BIS 2 (STA 168+50 to BIS)</td>
<td>1834</td>
</tr>
</tbody>
</table>

Psf (pounds per square foot)
1000 psf = 48 kPa
2. GEOLOGICAL CONTEXT

2.1 FOCUS ON GEOTECHNICAL DATA

Soil Abrasivity

Table 15  Laboratory Test Results on Soil Abrasion Test Samples

<table>
<thead>
<tr>
<th>Sample Location and Depth</th>
<th>USCS Soil Classification</th>
<th>Moisture Content, %</th>
<th>Specific Gravity</th>
<th>LL/PL/PI , %</th>
<th>% Fines (Passing #200)</th>
<th>SAT, Test#1</th>
<th>Test#2 Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-301P 56 – 59</td>
<td>CL</td>
<td>29</td>
<td>37/18/19</td>
<td>97</td>
<td>12.5 9.8</td>
<td>11.2</td>
<td></td>
</tr>
<tr>
<td>B-301P 65 – 67.5</td>
<td>SC-SM</td>
<td>23</td>
<td>2.82</td>
<td>36</td>
<td>23 23.3</td>
<td>23.1</td>
<td></td>
</tr>
<tr>
<td>B-302P 40 – 42.5</td>
<td>CL</td>
<td>29</td>
<td>2.90</td>
<td>98</td>
<td>3.2 3.4</td>
<td>3.3</td>
<td></td>
</tr>
</tbody>
</table>

The Soil Abrasion Test (SAT) provides measurement of an abrasion index (Nilsen et al., 2006). Lower SAT values are less abrasive than higher SAT values. A soil with a SAT value less than 7 is considered to have low abrasivity while a soil with a SAT value greater than 22 is considered to have high abrasivity. A soil with SAT values between 7 and 22 is considered to have medium abrasivity. The results indicate a wide range of abrasivity from low to high.
2. GEOLOGICAL CONTEXT

2.1 FOCUS ON GEOTECHNICAL DATA

Soil Abrasivity

Lower SAT values are less abrasive than higher SAT values.

A soil with a SAT value less than 7 is considered to have low abrasivity.

A soil with a SAT value greater than 22 is considered to have high abrasivity.

A soil with SAT values between 7 and 22 is considered to have medium abrasivity.

Nilsen et al., 2006
## 2. GEOLOGICAL CONTEXT

### 2.1 FOCUS ON GEOTECHNICAL DATA

<table>
<thead>
<tr>
<th>Soil Property/Parameter</th>
<th>FHII</th>
<th>YBM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Unit Weight (pcf)</strong></td>
<td>122/130/133</td>
<td>70.5/92/97*</td>
</tr>
<tr>
<td>Lowest/Mean/Highest Standard Dev/No. Tests Baseline Range</td>
<td>5/5</td>
<td>5/60</td>
</tr>
<tr>
<td><strong>Water Content (%)</strong></td>
<td>88/120/133</td>
<td>102/128/138</td>
</tr>
<tr>
<td>Lowest/Mean/Highest Standard Dev/No. Tests Baseline Range</td>
<td>9/58</td>
<td>6/73</td>
</tr>
<tr>
<td><strong>Liquid Limit (%)</strong></td>
<td>110 – 130</td>
<td>115 – 135</td>
</tr>
<tr>
<td>Lowest/Mean/Highest Standard Dev/No. Tests Baseline Range</td>
<td>14/18/23</td>
<td>3/18</td>
</tr>
<tr>
<td><strong>Plastic Limit (%)</strong></td>
<td>20/34/112</td>
<td>15/24/61</td>
</tr>
<tr>
<td>Lowest/Mean/Highest Standard Dev/No. Tests Baseline Range</td>
<td>15/44</td>
<td>6/83</td>
</tr>
<tr>
<td><strong>Plasticity Index (%)</strong></td>
<td>60 – 120</td>
<td>7 – 55</td>
</tr>
<tr>
<td>Lowest/Mean/Highest Standard Dev/No. Tests Baseline Range</td>
<td>7/58</td>
<td>7/7</td>
</tr>
<tr>
<td><strong>Fines (%)</strong></td>
<td>2/38/59</td>
<td>1/23/54</td>
</tr>
<tr>
<td>Lowest/Mean/Highest Standard Dev/No. Tests Baseline Range</td>
<td>6/44</td>
<td>5/55</td>
</tr>
<tr>
<td><strong>Saturated Hydraulic Conductivity (m/s)</strong></td>
<td>28 – 75</td>
<td>20 – 30</td>
</tr>
<tr>
<td>Lowest/Mean/Highest Standard Dev/No. Tests Baseline Range</td>
<td>20 – 30</td>
<td>15 – 20</td>
</tr>
<tr>
<td><strong>Soil Strength</strong></td>
<td>1 x 10^-6</td>
<td>1 x 10^-7</td>
</tr>
<tr>
<td>Refer to Section 5.3 for Tunnels and Section 6.2 for Shafts</td>
<td>1 x 10^-7</td>
<td>1 x 10^-7</td>
</tr>
</tbody>
</table>

*Pcf (pounds per cubic foot) 100 pcf = 1602 kg/m³*
2. GEOLOGICAL CONTEXT

2.1 FOCUS ON GEOTECHNICAL DATA

Notes:
1. Chart adapted from Hollmann and Thewes (2013)
2. Consistency Index (CI) = (LL - Wp) / PI
3. Wp = natural (in-situ) water content
4. Hollmann and Thewes indicate that for a given PI, by changing the water content (WC), it is possible to alter the clogging potential of the soil. Each soil moves downwards and to the left with increasing WC, starting with Wp.
5. All Young Bay Mud tests plot as Very Soft or Liquid.
6. Not all Young Bay Mud data points shown for clarity of scale.
2. GEOLOGICAL CONTEXT

2.1 FOCUS ON GEOTECHNICAL DATA

Psf (pounds per square foot)
1000 psf = 48 kPa
2. GEOLOGICAL CONTEXT

2.1 FOCUS ON GEOTECHNICAL DATA
2. GEOLOGICAL CONTEXT
2.1 FOCUS ON GEOTECHNICAL DATA

Settlements

Warning value: 1/4in = 6 mm
Limit value: 1/2in = 12 mm

Classic 2D FEM (Finite Element Method)
2. GEOLOGICAL CONTEXT

2.1 FOCUS ON GEOTEchnical DATA

Settlements
3. SHAFTS – LAUNCHING SHAFT
3. SHAFTS – LAUNCHING SHAFT

Main information:
- Internal diameter = 58’ / 17,67m
- Depth (excavation) = 56,5’ / 17,22m
- Bottom slab thickness = 4’ / 1,22m
- Cut Off depth compare to ground level: 84’ / 25,60 m
- Geology:
  El 105 to 99: Imported fill material.
  El 99 to 85: Young Bay Mud.
  El 85 to 49: Stiff clay (Upper Layer Sediment)
- 2 depressurizations wells have been installed in order to reduce the pressure in the sandy layer. Depth 125 Feet and screened between El -18 and +7.
3. SHAFTS – LAUNCHING SHAFT
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3. SHAFTS – LAUNCHING SHAFT
3. SHAFTS – LAUNCHING SHAFT
3. SHAFTS – LAUNCHING SHAFT (STARTER TUNNELS)

Two starter galleries for both drives, each being 42’ long to be able to assemble, prior mining, the TBM and the gantry 1.

For the launching sequence, steel half rings were installed on the cradle to create the shifting way and we used a muck pump to bring muck from TBM to inclined conveyor.
3. SHAFTS – LAUNCHING SHAFT (STARTER TUNNELS)
3. SHAFTS – LAUNCHING SHAFT (STARTER TUNNELS)
3. SHAFTS – LAUNCHING SHAFT (STARTER TUNNELS)
3. SHAFTS – LAUNCHING SHAFT (STARTER TUNNELS)
An inclined conveyor made by H+E is used to extract the muck produced by the TBM from the launching shaft to the storage area. With a slope of 10°, it rolls through a steel inclined tube 9' / 2.74m in diameter and 250'/75 ml long.
3. SHAFTS – LAUNCHING SHAFT (INCLINED TUNNEL)
3. SHAFTS – LAUNCHING SHAFT (INCLINED TUNNEL)
3. SHAFTS – RECEIVING SHAFT (BAIR ISLAND)
3. SHAFTS – RECEIVING SHAFT (BAIR ISLAND)

Main information: The support of excavation is made of sheet piles, struts and walers.

- Length = 59.73’ / 18.21m
- Width = 32.17’ / 9.81m
- Depth (excavation) = 48’ / 14.63m
- Bottom slab thickness = 3’ / 0.91m
3. SHAFTS – RECEIVING SHAFT (BAIR ISLAND)
3. SHAFTS – RECEIVING SHAFT (BAIR ISLAND)
3. SHAFTS – RECEIVING SHAFT (SFS)
The construction of this shaft is outside our scope of work.

**Main information:** The support of excavation is made of concrete diaphragm walls.

- Wall thickness = 4ft / 1,2 m
- Strength = 13,000 psi / 90MPa
- Shaft Diameter = 37’ / 11 m
- Depth (slab) = 80’ / 24 m
3. SHAFTS – OTHER SHAFT (SAN CARLOS)
Main information: The support of excavation is made of secant piles.

- Piles Diameter = 2,8’ / 880 mm
- Shaft Diameter = 15’ / 4,5 m
- Depth (excavation) = 48’ / 14.63 m
- Bottom slab thickness = 3,5’ / 1 m
3. SHAFTS – OTHER SHAFT (SAN CARLOS)
3. SHAFTS – OTHER SHAFT (SAN CARLOS)
3. SHAFTS – OTHER SHAFT (SAN CARLOS)
3. SHAFTS – OTHER SHAFT (SAN CARLOS)
3. SHAFTS – OTHER SHAFT (SAN CARLOS)
4. TUNNELING WORKS - TBM

TBM is an HK EPB machine 4 910 mm diameter designed:
- To cope with 650 LF radius curve
- For a maximum advance speed of 4 inches/mn
- 100 mm/mn
- For the concrete lining described on the next slide
- For excavated material transport
  - with muck pump for launching.
  - with continuous conveyor belt
- For stacking 2 full rings with quick unloader
- For ring erection with mechanical lifting table
- The backup is made of 17 gantries, i.e. 620 LF / 190 m.
- Annular void injection by Bi-Component grout.
4. TUNNELING WORKS - TBM
4. TUNNELING WORKS - TUNNEL

- Excavation diameter 4.910 mm / 16’ and 1”
- Precast concrete segments 13’ and 6” inner diameter
- Cellular grout
- Fiberglass Reinforced Polymer Mortar Pipe (FRPM pipe) 10’ and 11’ inner diameter

The maximum gradient is 0.15% except at the arrival at BI where the gradient increase to 1.3% on 628 LF (191 m).

The maximum curve is 800 LF (244 m).
4. TUNNELING WORKS - TUNNEL
Rings are Universal type and have been designed with Left and Right type to erect rings bottom up for safety reason.

**Main characteristics:**
- Outside diameter: 182 inches / 4623 mm
- Inside diameter: 162 inches / 4115 mm
- Segment thickness: 10 inches / 254 mm
- Segment length: 5 feet / 1524 mm
- Weight: 2.2 T / 4,800 lbs
- Ring distribution: 5+1
- Steel fiber reinforced concrete (50lb/CY – 29.6kg/m3)
- Compressive strength: design 6000psi/41.3MPa, actual 8644 psi/59.6 Mpa.
4. TUNNELING WORKS – TUNNEL (SEGMENTS)
4. TUNNELING WORKS – TUNNEL (SEGMENTS)
Stage 1: Break-out and excavation from the ASS for a distance of 240 LF / 73 m, 48 installed rings. Install umbilical’s connection for power supply, hydraulic, communication and utilities with the backup gantries 2 to 15 installed and assembled at the surface on rails.

A muck pump was used to extract the excavated muck from the TBM.

Then, first extended TBM stoppage to install gantries 2 through 8.
4. TUNNELING WORKS – LAUNCHING
4. TUNNELING WORKS – LAUNCHING
4. TUNNELING WORKS – LAUNCHING

**Stage 3:** Excavation of an additional 90 LF / 27,5 m, 118 installed rings. Third extended TBM stoppage to install gantries 16 through 17.

**Stage 4:** Excavation of an additional 310 LF / 94,5 m, 180 installed rings. TBM stoppage for installation of continuous conveyor and California switch.
4. TUNNELING WORKS – EXCAVATION

DRIVE 1 AAS-BI:
- In final configuration:
  - Excavation of 1 272 m in 41 days ➔ 31 m per day (10h/shift, 2 shift per day, 5 days a week)
  - Max production ➔ 42 rings in 24 hours, 63 m.
4. TUNNELING WORKS – EXCAVATION

**DRIVE 2 AAS-SFS:**
- Launching method improved, 2 weeks saved.

- In final configuration:
  - Harder clay encountered at first: high torque on CH and clogging issues at the conveyor transitions
  - Excavation of 3367 m in 185 days $\Rightarrow$ 18.2 m per day (10h/shift, 2 shift per day, 5 days a week)
  - Max production $\Rightarrow$ 34 rings in 20 h, 51 m
4. TUNNELING WORKS – BREAKOUT (BAIR ISLAND)
4. TUNNELING WORKS – BREAKOUT (BAIR ISLAND)
4. TUNNELING WORKS – BREAKOUT (BAIR ISLAND)
4. TUNNELING WORKS – BREAKOUT (SFS)

13,000 psi concrete! (90 Mpa)
4. TUNNELING WORKS – BREAKOUT (SFS)
4. TUNNELING WORKS – BREAKOUT (SFS)
4. TUNNELING WORKS – BREAKOUT (SFS)

JET GROUTING

- **Block dimension:** 17ft x 15ft x 34.5ft
- **Columns:** 3ft diameter, 2.33ft on center
- **Target:** 450 psi @ 28days (3MPa), $1 \times 10^{-5}$ cm/s

**Production Columns:**
- Double Fluid jetting full length
- Jetting w/c = 1.4
- 5mm nozzle
- Lift rate = 8’/min Elev. 27.05 to Elev. 61.55
- 8 to 10 RPM

**Pre-Treatment Holes:**
- Drill to 46 feet below ground surface (approx. Elev. 60)
- Single Fluid jetting from Elev. 60 to Elev. 95
- Jetting w/c = 1.4
- 6mm nozzle
- Lift rate = 8’/min
- 8 RPM
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4. FRP PIPES – GROUTING – DROP STRUCTURES

Up to 34 pipes per day (2 x 10h) = 680ft/207m
THANK YOU!
ANY QUESTIONS?