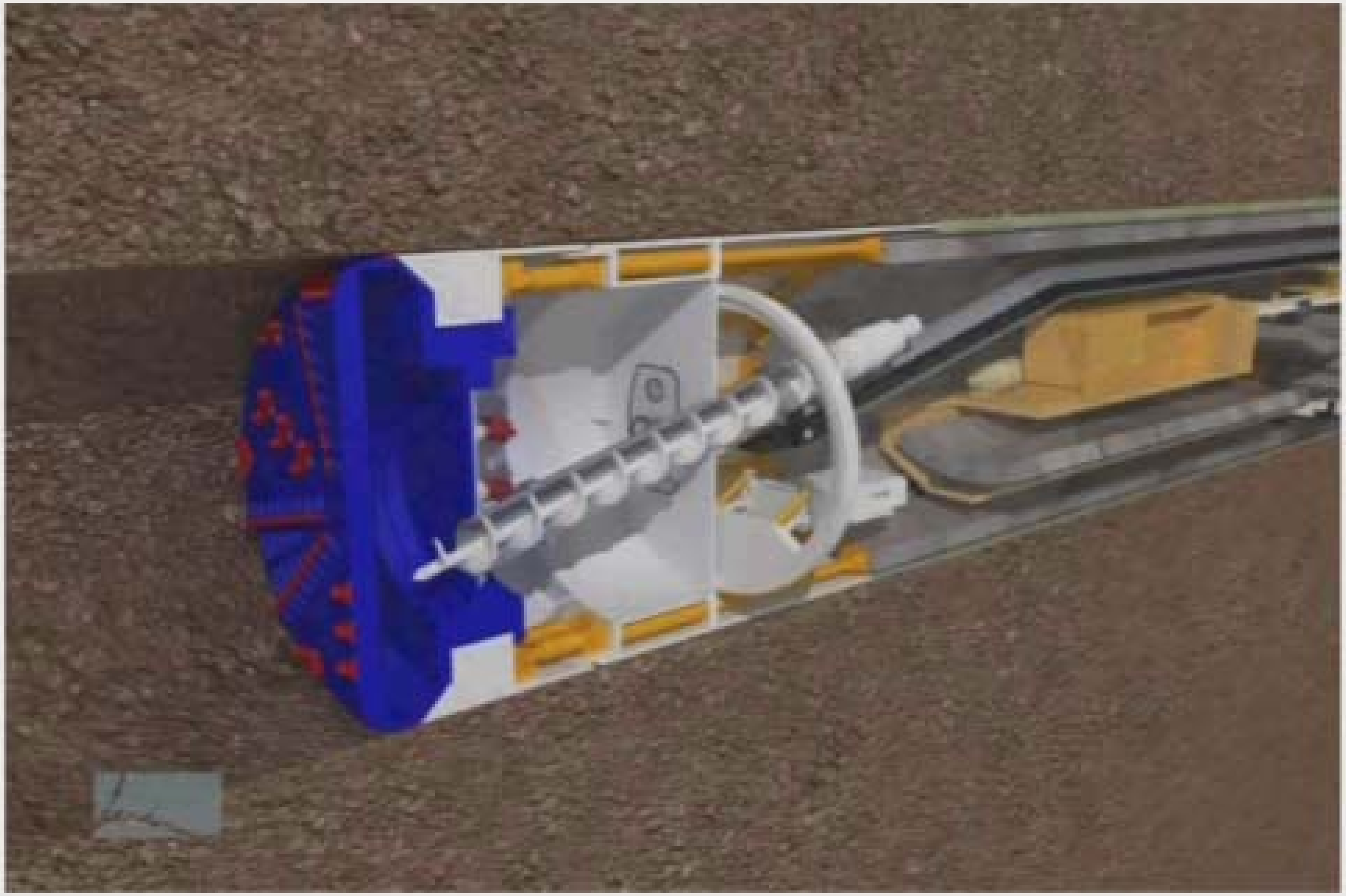
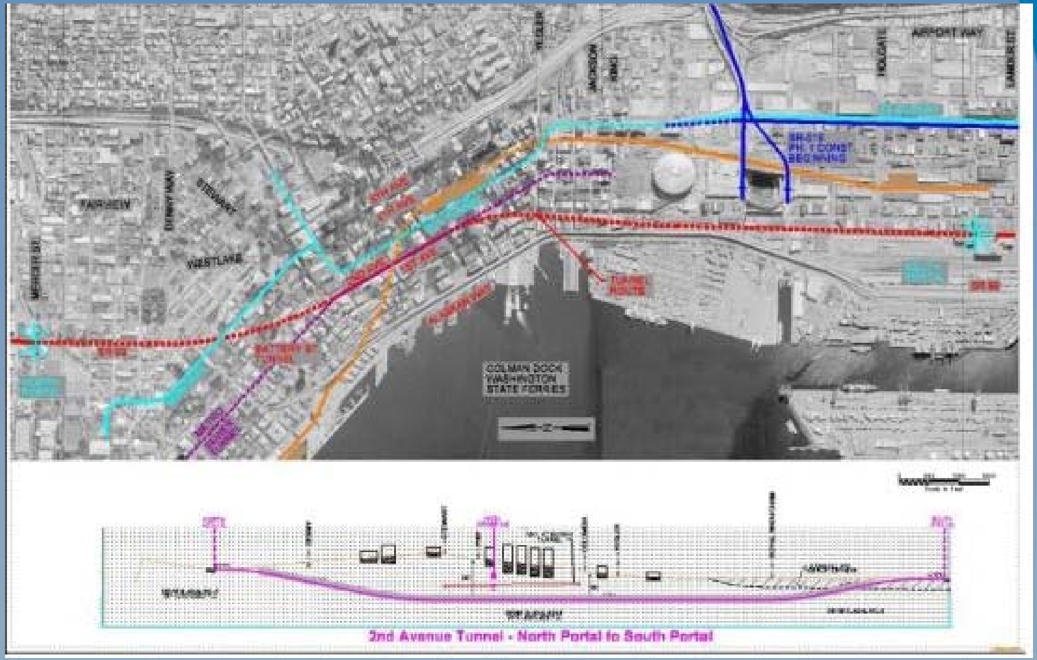
Alaskan Way Viaduct and Seawall Replacement Program
Tunnel Boring Machine Animation
September 2009



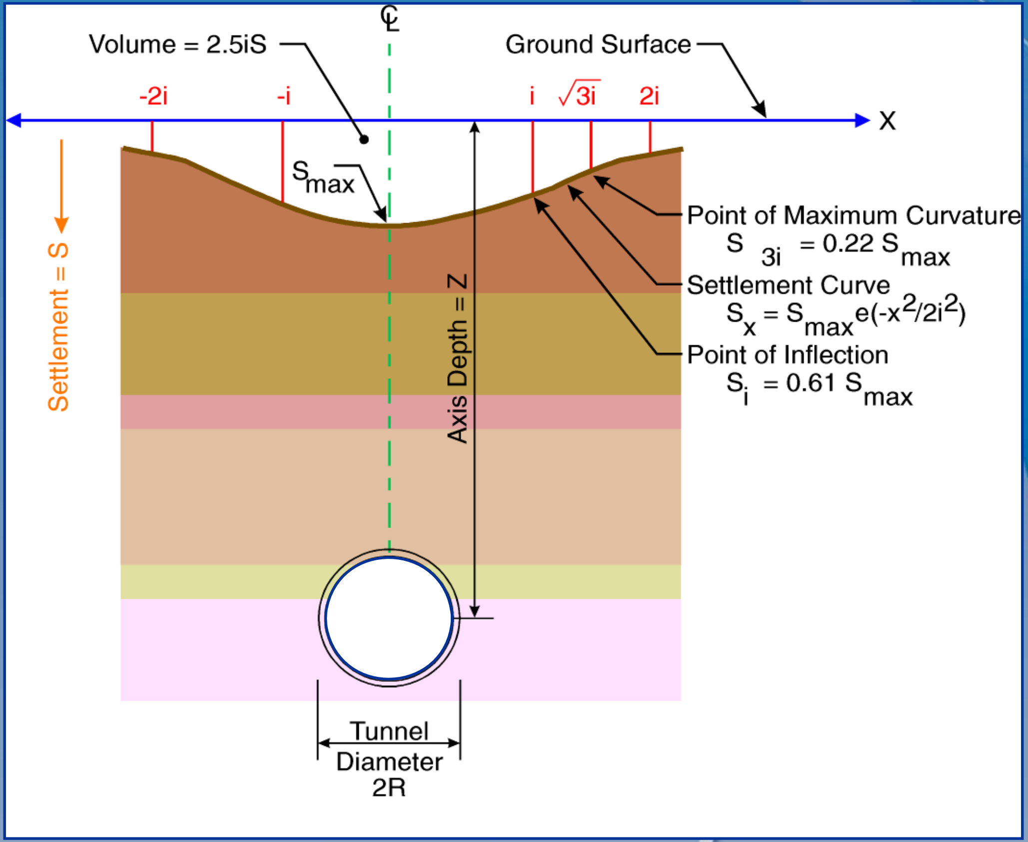
Objectives

- Minimize impacts due to tunneling:
  - Surface settlement
  - Structure cracks and deflection
  - Buried utilities



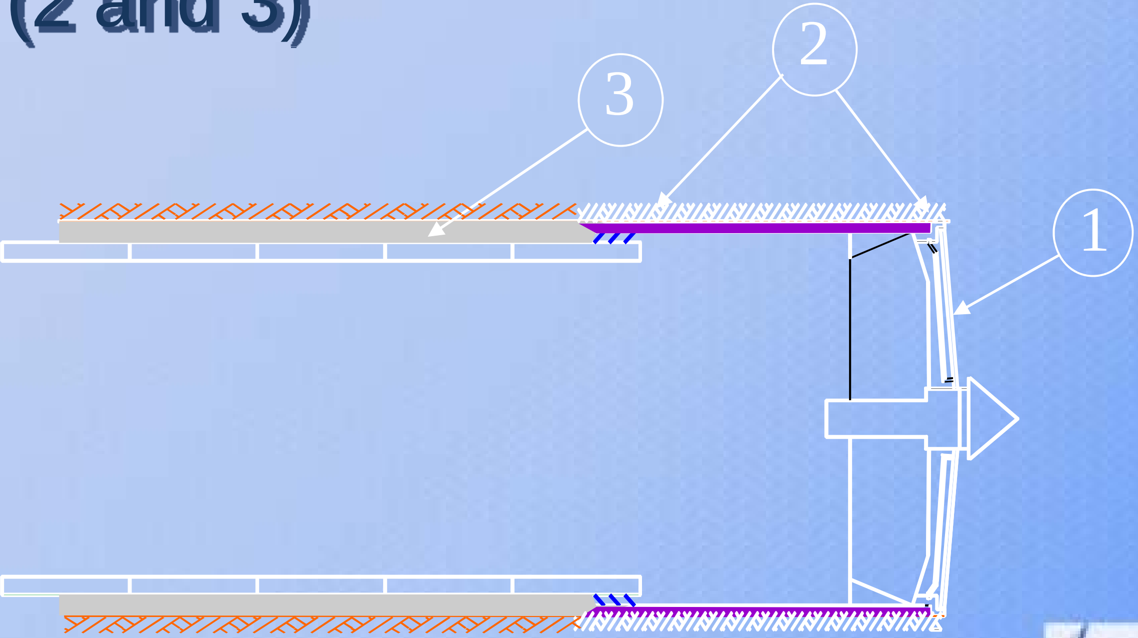
Settlement Trough

- Volume loss
  - Will transfer to the surface
  - Well established equation for settlement trough



Sources of V_L during Tunneling

- Loss Through Face (1)
- Excessive Overcut for Steering (2)
- Filling of the Tail Void (3)
- Plowing (2 and 3)



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Instrumentation

- Measurement Objectives
  - Vertical displacements
    - Surface settlement monitors
    - Deep settlement monitors
    - Structure settlement / distortion
  - Lateral displacements
    - Ground – inclinometers
    - Structures – tilt meters
  - Water level indicators
  - Relative / absolute displacements
    - Tape / Rod Extensometers
  - Temperature effects
    - Gages / thermocouples

On the alert for settlement

One of the most extensive ground monitoring surveys ever attempted is now under way in Amsterdam, years before tunnelling starts for the city's metro. David Hayward reports.

Little moves in Amsterdam these days without the team of engineers planning the city's new $985M underground metro knowing all about it. Every creak or groan from up to 1,600 city centre buildings is being continuously monitored, while ground movements 50m beneath the streets will soon be meticulously recorded every hour.

A mammoth six year settlement survey, being carried out by French monitoring specialist Soldata, has just started. And with 140,000 readings currently being fed to the computers of the city's engineers every week, the $12.5M survey is claimed to be the most extensive for any tunnelling project.

Close scrutiny of Amsterdam's infrastructure is seen as crucial in ensuring that driving the metro's twin tunnels, directly beneath the historic heart of the Dutch capital, causes minimal surface settlement. Yet, curiously, the start of tunnelling is still three years away.

"It is vital to establish, from an independent contractor, how these buildings behave naturally over the course of a full year and long before we begin tunnelling," explains Frank Kaalberg, design manager for Witteveen + Bos, Dutch consultant for metro client the Municipality of Amsterdam. "Our overriding aim during tunnelling is to cause no structural damage to any buildings."

To achieve this goal of negligible settlement, in a city where most old buildings are continually subsiding naturally in the weak ground at an average 1mm every year, demands the cooperation of engineers, surveyors, computer software experts and tunnelling machine manufacturers.

Kaalberg and his team are now 60% through an eight year pioneering research project to design and build an "intelligent" tunnel boring machine to drive the metro's 3.8km underground section. It will be a TBM designed to interact with, and respond to, 3D computer analysis of building and subsurface movements during tunnelling. The aim is both to predict and reduce ground settlement. Working with German TBM manufacturer Herrenknecht, the team is designing a full face EPB tunnelling machine capable of exerting minimal subsoil disturbance – and therefore minimal surface settlement (see box).

Kaalberg is confident that two $9.8M intelligent machines will be off the drawing board and in the ground ready to start the twin 5.8m finished diameter drives by the end of 2004.

It is a technical challenge that must not fail, for the possibility of causing damaging surface settlement is politically just not acceptable. City residents are well aware of the potential for disruption.

The first time metro construction was planned, early in the 1970s, tunnelling technology was much less developed and the likelihood of considerable settlement ruled out bored tunnels altogether. Unfortunately, the chosen alternative for an east-west line – forming the tunnels by sinking pneumatic caissons – demanded such widespread building demolition that it triggered riots in the streets from annoyed inhabitants. Ensuring good public relations this time, for construction of the total 9km north-south line running right beneath the city centre, is seen as a major priority.

Extremities of the line will run at grade or in cut and cover. But the central 3.8km section will be routed through twin tunnels driven at an average depth of 30m directly beneath Amsterdam's main thoroughfares lined with many of the city's most architecturally important buildings.

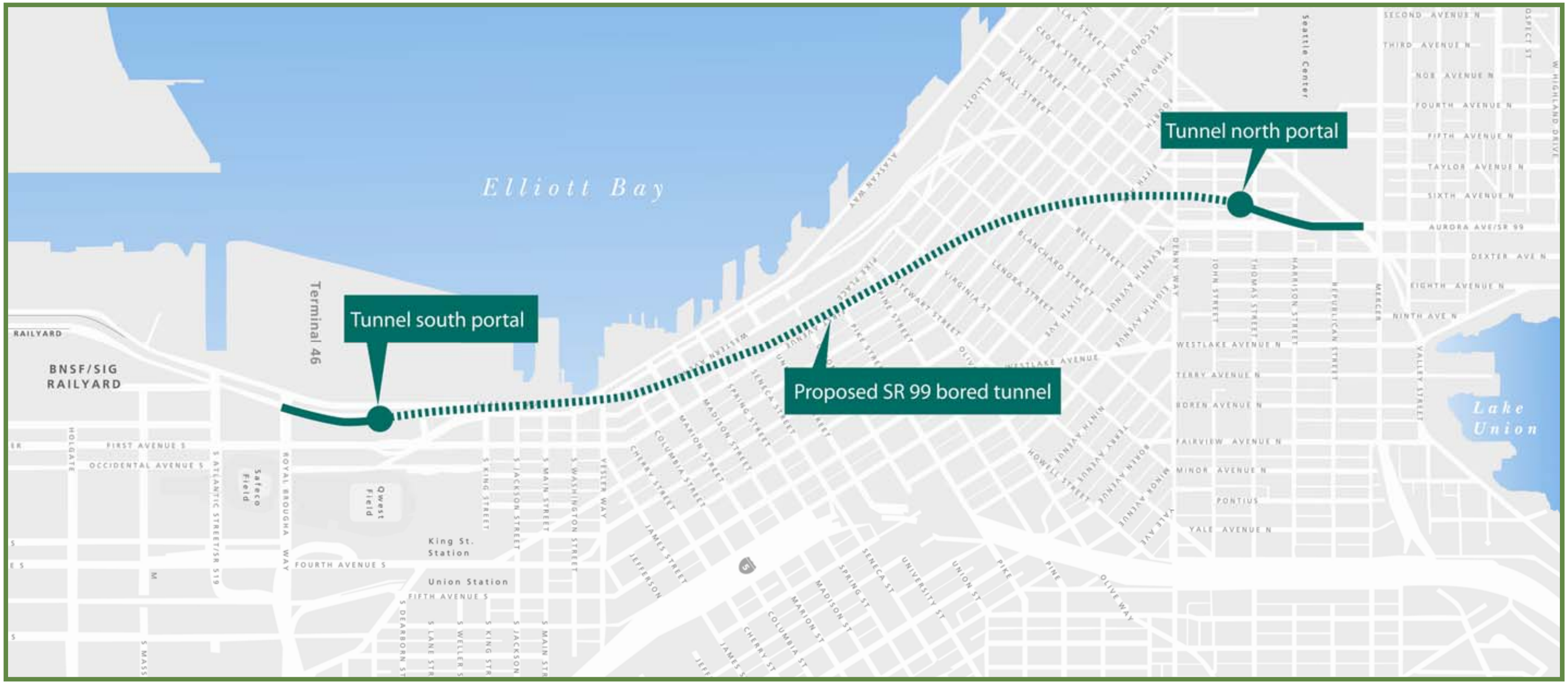
Four of the nine stations will be formed in large cover and cut boxes lined with diaphragm walling

Left: The central 3.8km section of the 9km metro route will run in 5.8m diameter twin tunnels driven beneath Amsterdam's main streets. Four of the nine stations will be built within large 30m deep cut and cover boxes excavated 30m deep and only metres from historic timber piled buildings.

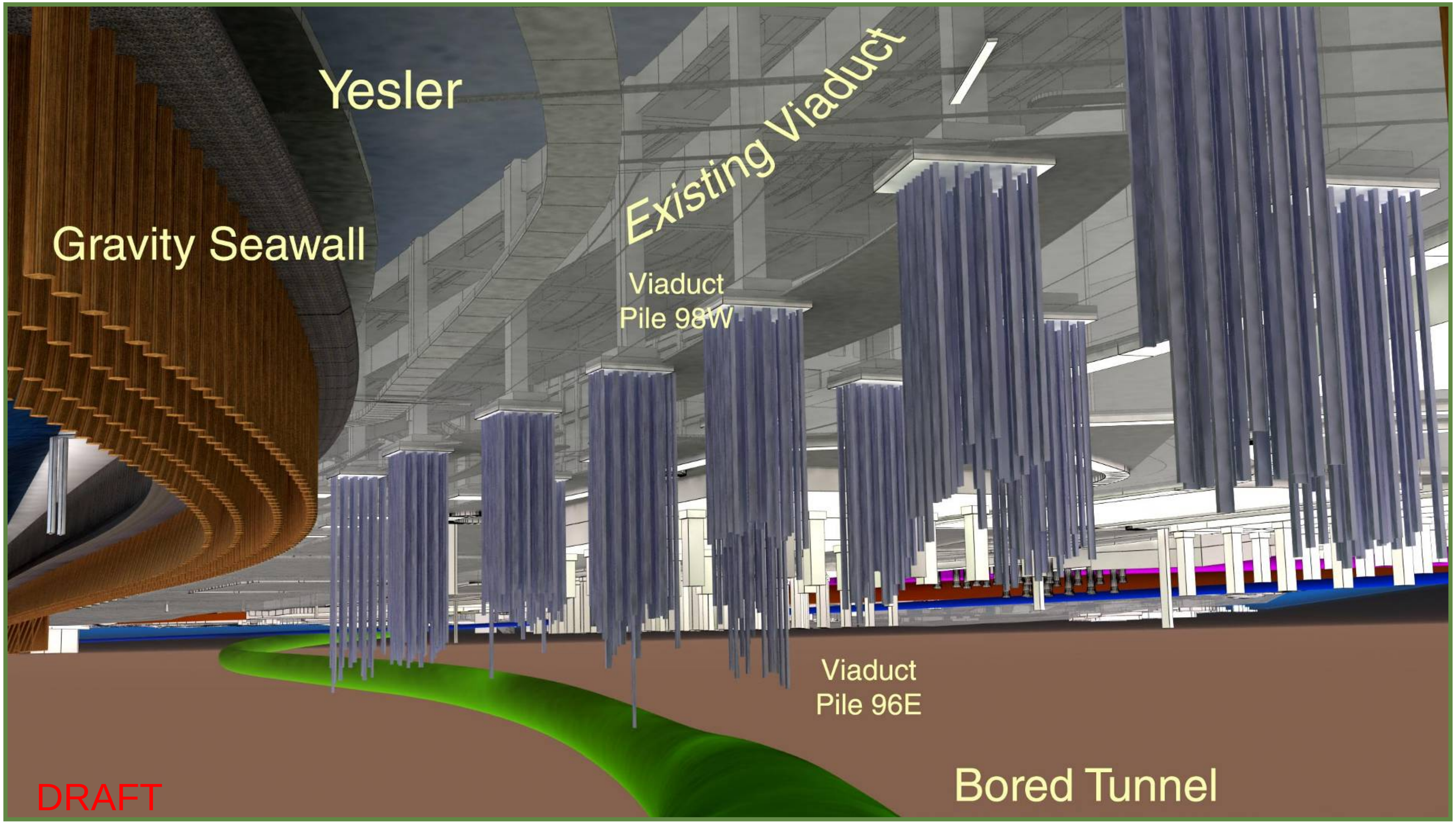
Mitigation Measures

- Grouting Methods
- Freezing Methods
- Face Conditioning Agents

Proposed SR 99 Bored Tunnel Alignment



Underground View



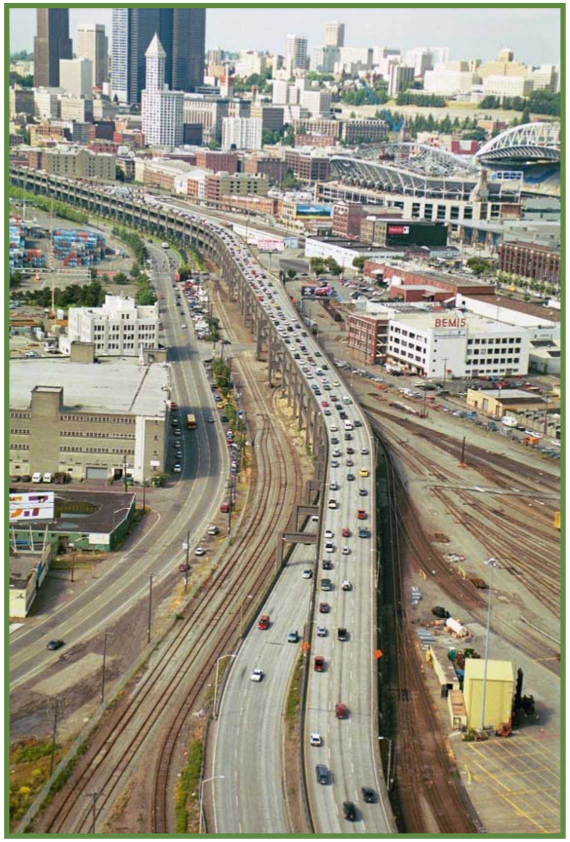
South Portal

South Portal

North Portal


Seattle
Seattle

Alaskan Way Viaduct and Seawall Replacement Program




Follow our progress: www.alaskanwayviaduct.org

Back Pocket

First Avenue Streetcar

- Connects to the First Hill Streetcar.
- Connects to Ballard and West Seattle RapidRide lines.
- Connects to Amtrak, Commuter Rail and Light Rail at King Street Station.
- Provides easy access to Colman Dock.
- Connects major activity centers: Seattle Center, Pike Place Market and the stadium area.

Transit Service Enhancements

Transit enhancements will provide important mobility during and after construction and are critical to the success of the bored tunnel solution.

- Enhanced service to accommodate demand
  - Additional bus service
  - First Ave. Streetcar
- Access to downtown
- Construction mitigation
- Environment

Toll Scenarios

<table>
<tr><th></th><th>Overall Toll Level</th><th>Extent of Tolling</th><th>Toll Variation</th></tr>
<tr><td>Scenario A
Medium Tolls
Tunnel Only</td><td rowspan="2">Medium</td><td>Tunnel Only</td><td rowspan="4">Toll Rates vary by Time of Day — Directionally Different</td></tr>
<tr><td>Scenario B
Medium Tolls
Tunnel & Corridor</td><td>Corridor Tolling
(Adds SR 99 N & S segments inbound AM peak outbound PM peak period)</td></tr>
<tr><td>Scenario C
High Tolls
Tunnel Only</td><td>High</td><td>Tunnel Only</td></tr>
<tr><td>Scenario D
Medium-High Tolls
Tunnel & Corridor</td><td>Medium High</td><td>Corridor Tolling
(Adds SR 99 S segment during AM & PM peak periods)</td></tr>
<tr><td>Scenario E
Low Tolls
Tunnel Only</td><td>Low</td><td>Tunnel Only</td><td>Tunnel tolled in the AM & PM Peaks Only
(Directionally Different)</td></tr>
</table>

*All scenarios assume full AWV Program improvements and a tunnel open date of Jan 1, 2016

Generates $100M

Relocate Electrical Lines

- Relocated electrical lines to locations east of the viaduct between Massachusetts and Railroad Way.
- Installed two man-hole vaults between Atlantic and Royal Brougham.
- Installed conduit between Atlantic and Royal Brougham.

Construction: September 2008 – December 2009

Status: Complete

COMMENTS EXCERPT FROM FEBRUARY 23, 2010, NORTHWEST REGION'S 2010 DESIGN-CONSTRUCTION CONFERENCE, SHORELINE, WA; PRESENTED BY MATT PREEDY AND LINEA LAIRD DIRECTORS OF SOUTH, CENTRAL AND NORTH PROJECTS – ALASKAN WAY VIADUCT AND SEAWALL REPLACEMENT PROGRAM

RE: MASSACHUSETTS TO UNION STREET MOVING FORWARD PROJECT

"As the city has grown up around the viaduct, so has the web of utility lines that weave around and under it. These lines need to be moved to better protect downtown's power supply in the event of an earthquake, and to prepare us for taking down the viaduct south of S. King Street.

The project began in September 2008 and will take a little more than one year to complete.
We do not anticipate any power outages for this work. The electrical systems are redundant. Even if one line must be shut down temporarily, it would not affect the city's power supply.

Currently, ELR construction crews have work happening at all areas of the project site. The site runs between S. Massachusetts Street to the south and Railroad Way, S. to the north and between the viaduct to the west and to about a half a block east of the viaduct.

Crews are currently trenching along Colorado Avenue S. between S. Massachusetts Street and S. Atlantic Street. Crews have built a temporary by-pass road for freight traffic which will be opened starting Monday, March 2. Colorado Avenue S. will be closed to through traffic, but drivers will still be able to access the Bemis Building parking lot. Southbound freight traffic must use the temporary bypass road and northbound freight traffic must use Utah Avenue S. Drivers will notice a series of traffic revisions on Colorado Avenue S. for the next three months and should pay close attention to the signed detour.
In the staging area between S. Atlantic Street and S. Royal Brougham Way, crews are installing conduit and have also already installed two manhole vaults.

Crews have relocated water lines and installed conduit under S. Royal Brougham Way and will repave that section of road this week.

WSDOT suspended work between S. Royal Brougham Way and Railroad Way S., until further design is complete on the southern portal for the bored tunnel section of the central waterfront section of SR 99. However, crews have already shored and excavated for one vault and have removed abandoned railroad lines from the old WOSCA property. [Emphasis added]

Additional work will be needed to relocate some of the remaining lines between Railroad Way S. and Union Street and others between Railroad Way South and electrical vaults on S. Washington Street and Yesler Way. The exact location, method and schedule for relocating these electrical lines will depend on the solution chosen for the viaduct's central waterfront section."

EXHIBIT D

Transit Enhancements and Other Capital Improvements

WSDOT, King County and the City of Seattle have agreed upon a list of projects to keep people and goods moving during SR 99 construction.

These projects include:

- I-5 variable speed limits
- SR 519 freight connections
- Spokane Viaduct improvements
- Increased bus service
- Real-time traveler information

Construction: 2008-2011

Status: In Construction

Separation Plant

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Earth Pressure Balance Machines

- Developed by Japanese in mid 1970's
- Needed to broaden the range of applicable ground conditions
- Much simpler than the Slurry Machine
- Face supported by conditioned excavated material
- Excavated material removed from the face with a screw conveyor and transported by train or conveyor.
- Has to some extent replaced the use of Slurry Machines

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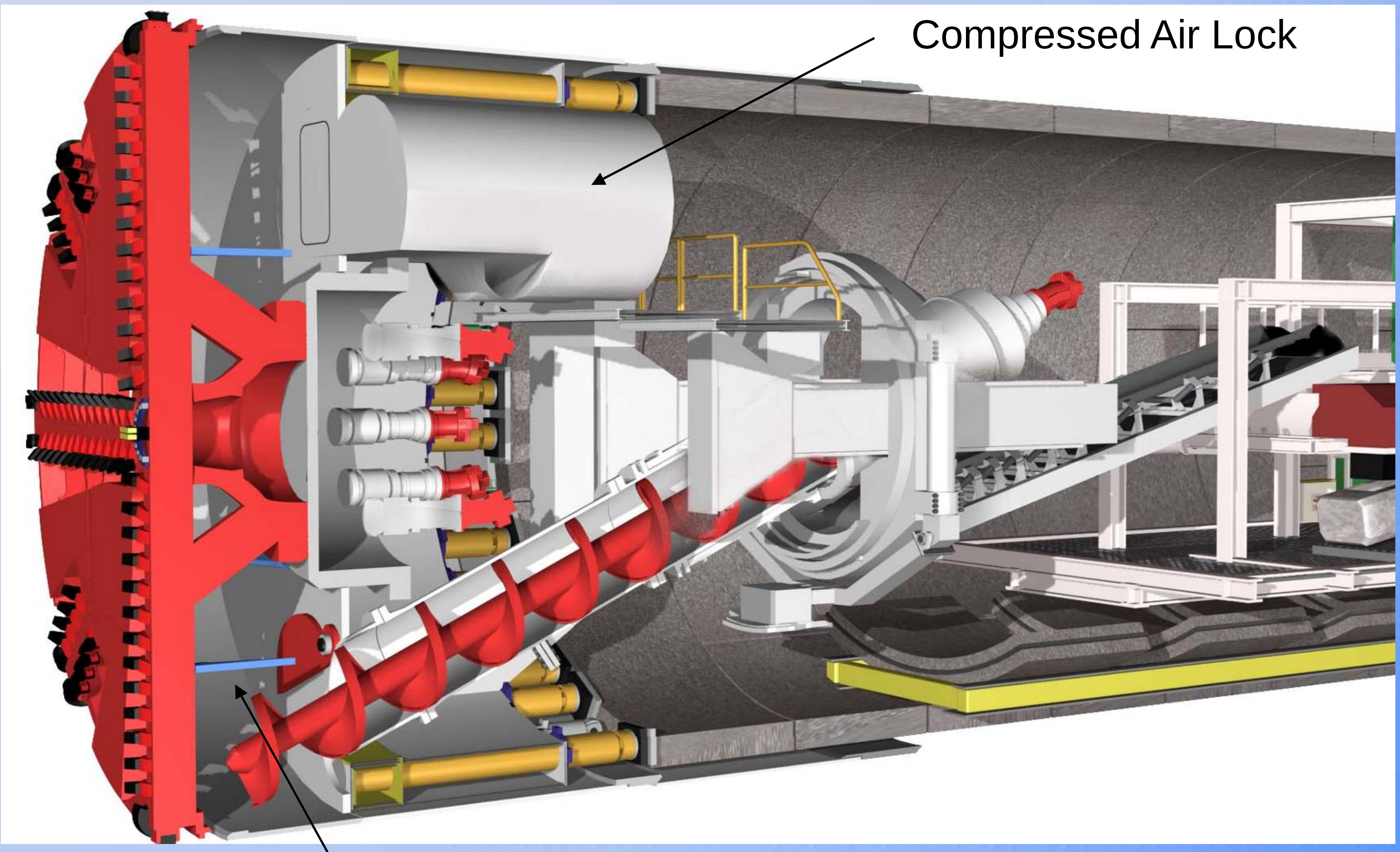
Access to Chamber and Cutter Head



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Installing the Gaskets

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Mechanical Segment Erector

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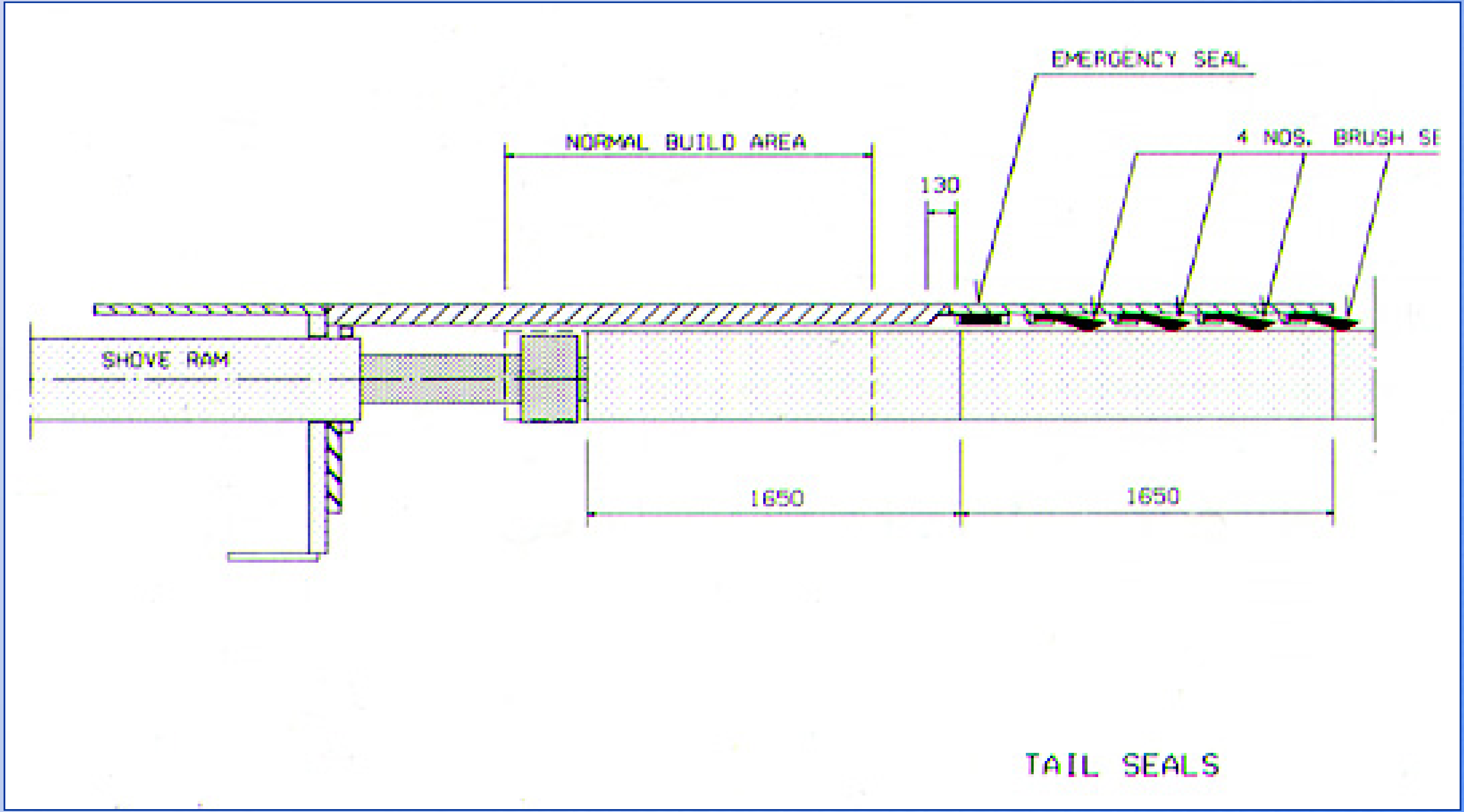
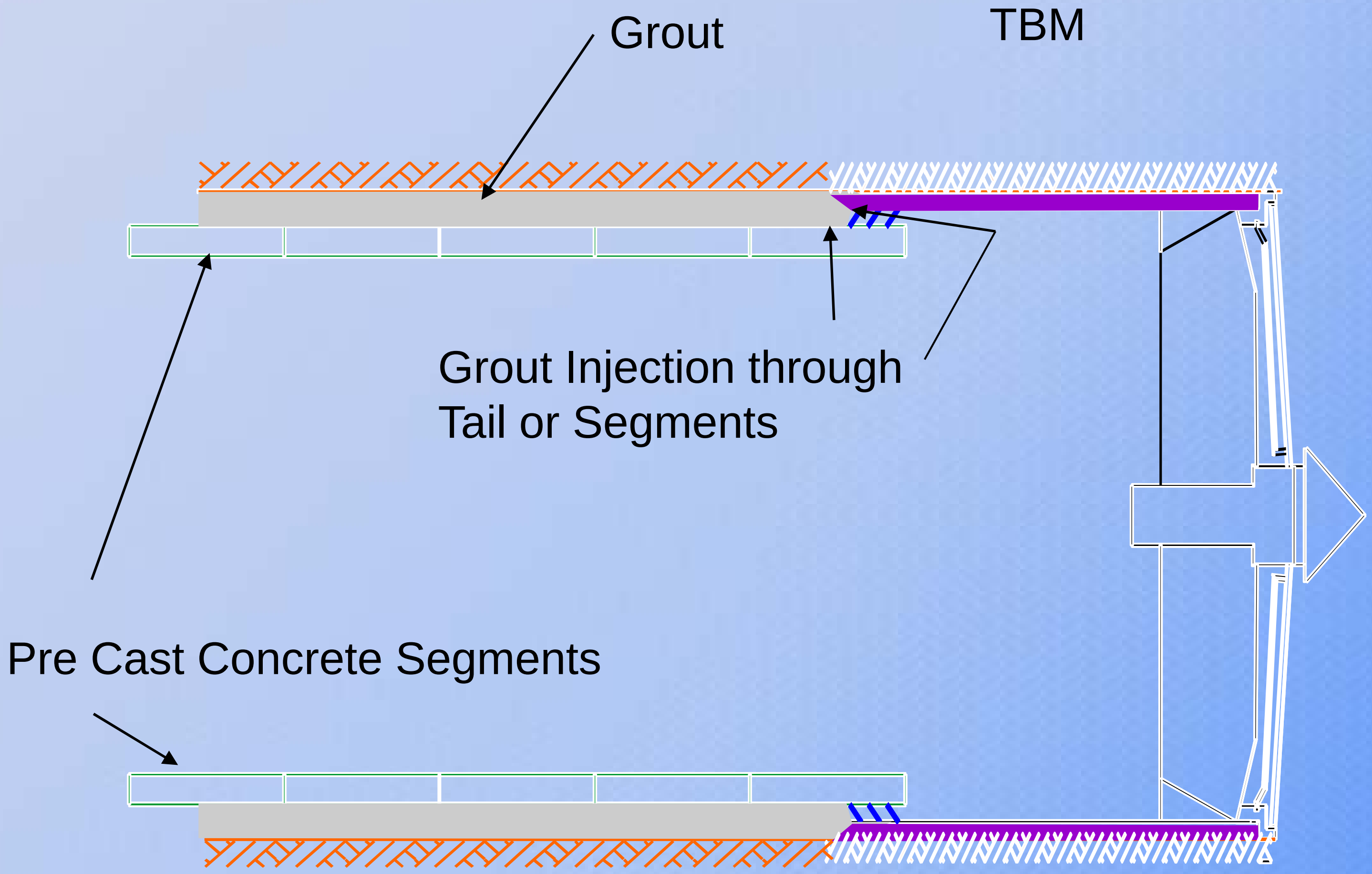
Vacuum Segment Erector

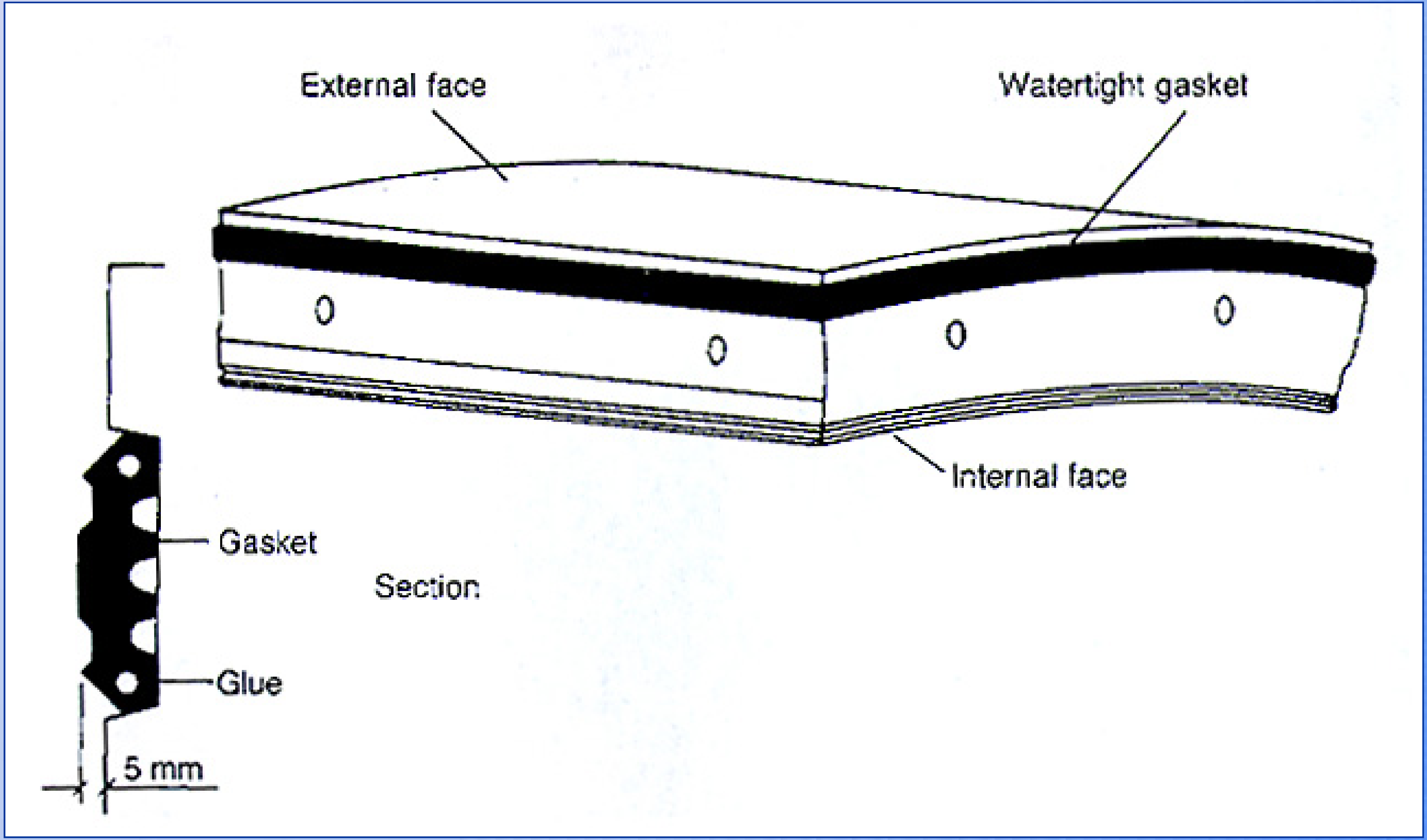
EPBM Tail Seal



Tail Grouting



Precast Concrete Segment



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Volume Loss Magnitudes

- Historical Standards — Volume Loss, V_L
  - Good practice in firm ground — 0.5%
    - better soils and excellent ground control
  - Good practice in slow raveling ground — 1.5%
    - considered good ground
  - Fair practice — 2.5%
    - More face and tail loss
  - Poor practice — 4.0%
    - Yet more face loss
    - Tail void mostly unfilled

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Slurry Machines

- Slurry Machines were initiated by John Bartlett's patent of 1964
- Developed for use in soft ground
- Mainly used in granular materials below the water table
- Face supported by a mixture of excavated material and bentonite slurry
- Excavated material transported in a slurry pipeline
- Separation plant required

TBM - Key Components

- Cutter Head
  - Main Bearing
  - Head Access
- Muck Removal System
  - Screw conveyor to trains or conveyor
  - slurry line
- Push Rams
  - Sufficient to overcome:
    - Face pressure
    - Friction
- Tail Seals
  - Tail Grouting
- Tunnel lining
  - Erector system
  - Pre-cast concrete segments
  - Watertight Gaskets

Engineering Analyses

- Ground Characterization
- Volume Loss, V_L at tunnel depth
- Settlement Trough at surface
- Condition Assessments
- Effects on Structures