# Human-centered Project Safety Review (PSR) for Risk Management in Infrastructure Projects

*Lessons from the Field and the Shift Toward a Safety-First Culture*

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# Introduction & Objectives

Infrastructure projects, especially tunnelling, are inherently high risk.

Accidents, delays, and rework are common when risks are unmanaged.

Objectives:

Define what a Project Safety Review (PSR) is

Present a tunnelling case study.

Demonstrate cultural impact of PSRs.

# What Is a Project Safety Review (PSR)?

# PSR Process

The Project Safety Review (PSR) process comprises of 2 elements:

- PSR (Safe-To-Build) demonstrates the civil hazard management
- PSR (Safe-To-Use) demonstrates the system safety.

The objective of the PSR is to provide a staged and robust check-and-balance process on safety assurance of infrastructure projects and facilitates the overall certification of the projects before they are opened for public.

# Types of Safety Submissions

- Civil Feasibility Safety Submission (CFSS)
- Civil Concept Safety Submission (CCSS)
- Civil Design Safety Submission (CDSS)
- Civil Construction Safety Submission (CNSS)
- Civil Handover Safety Submission (CHSS)

# Civil Design Safety Submissions (CDSS)

- Hazards identified in the CCSS
- Highlight hazards which cannot be eliminated through design and requires mitigation measures during construction
- Highlight maintenance hazards and their proposed operation measures
- Specific compliance required during construction for safety and health.

# Civil Construction Safety Submissions (CNSS)

- Demonstrate that the residual hazards transferred from the CDSS have been mitigated and that contractor has in place the necessary arrangement for managing safety risks.
- Major hazards related to temporary works design - such as temporary support structures, falsework system decking support for road traffic etc.
- Add major hazards identified by the contractor and mitigation measures for these new hazards.
- CNSS does not need to focus on common construction activities such as heavy lifting, hot works and formwork erection etc. These can be addressed through Method Statement.

# Timing of Safety Submissions

**Civil Feasibility Safety Submission (CFSS)**

- The report shall be submitted together with the Feasibility Study Report.

**Civil Concept Safety Submission (CCSS)**

- The submission shall be made 2 months before the tender call for D&B and A&E contracts and 6 months before the civil tender call for in-house design.

**Civil Design Safety Submission (CDSS)**

For D&B and A&E contracts:

- The draft CDSS shall be submitted 1 month after the pre-final design stage and the final CDSS shall be submitted 1 month after the final design stage.

For In-house design:

- Only one Civil DSS is required and to be submitted 2 months before the civil tender call.

# Timing of Safety Submissions

## Civil Construction Safety Submission (CNSS)

For D&B contracts:

- 2 months before application for permit to excavate.

For A&E contracts and in-house design:

- 2 months before application for permit to excavate or structural submission to BCA for underground works

## Civil Handover Safety Submission (CHSS)

- For projects with major system elements: 1 month before the completion of system test running or handling over of project to Operator for trial run, whichever is earlier.
- For road project without major system elements: Submission shall be no later than 4 months before end of DLP.

# PSR vs Safety Audits

## Safety Audit

- Retrospective, compliance-driven
- Conducted after activities
- Findings often too late

## Project Safety Review (PSR)

- Prospective, risk-focussed
- Conducted before or during activities
- Builds accountability and prevention

# The Role of the Risk Facilitator

- Neutral guide for structured discussion
- Encourages no-blame dialogue.
- Uses 'What if…?' scenarios.
- Ensures participation and follow-through.
- Turns reviews into productive conversations.

# Roles and Responsibilities

## Risk Management Facilitator (RMF)

- Facilitate in risk workshops
- Prepare safety submissions
- Liaise with the external RMFs on hazards management etc.

## Independent Reviewer (Client's Internal review process)

- Assist the PSR sub committee in reviewing the safety submission
- Identify missing hazards
- Review sufficiency of proposed control measures
- Reasonableness of Risk Assessment

# What is required for Safety Submissions

- Summary of works highlighting major concerns.
- Complete Hazard register with control measures for each hazard identified.
- Each Hazard must have suitable control measures.
- At Concept stage residual risk after control measures to be at “Tolerable” (Category C) and for subsequent stages residual risk category should be as for as possible reduce to “Negligible” Category.
- Statutory responsibilities of AC and QP(S) should not be treated as proposed mitigation measures

# Presentations to PSR Subcommittee

- Detailed plan & sections for various works
- Latest soil profiles and other investigation findings.
- Adjacent critical structures, utilities and interfaces.
- Highlight existing Rail transit systems if any, on plan and sections.
- Include sketches and details when presenting a complex construction work.
- Don’t read the hazard register when presenting.

# Case Study: C933 DTL3 Tunnel Project (Singapore)

## Urban rail tunnel project

- Stakeholders: Penta-Ocean, Land Transport Authority (LTA)

## Challenges:

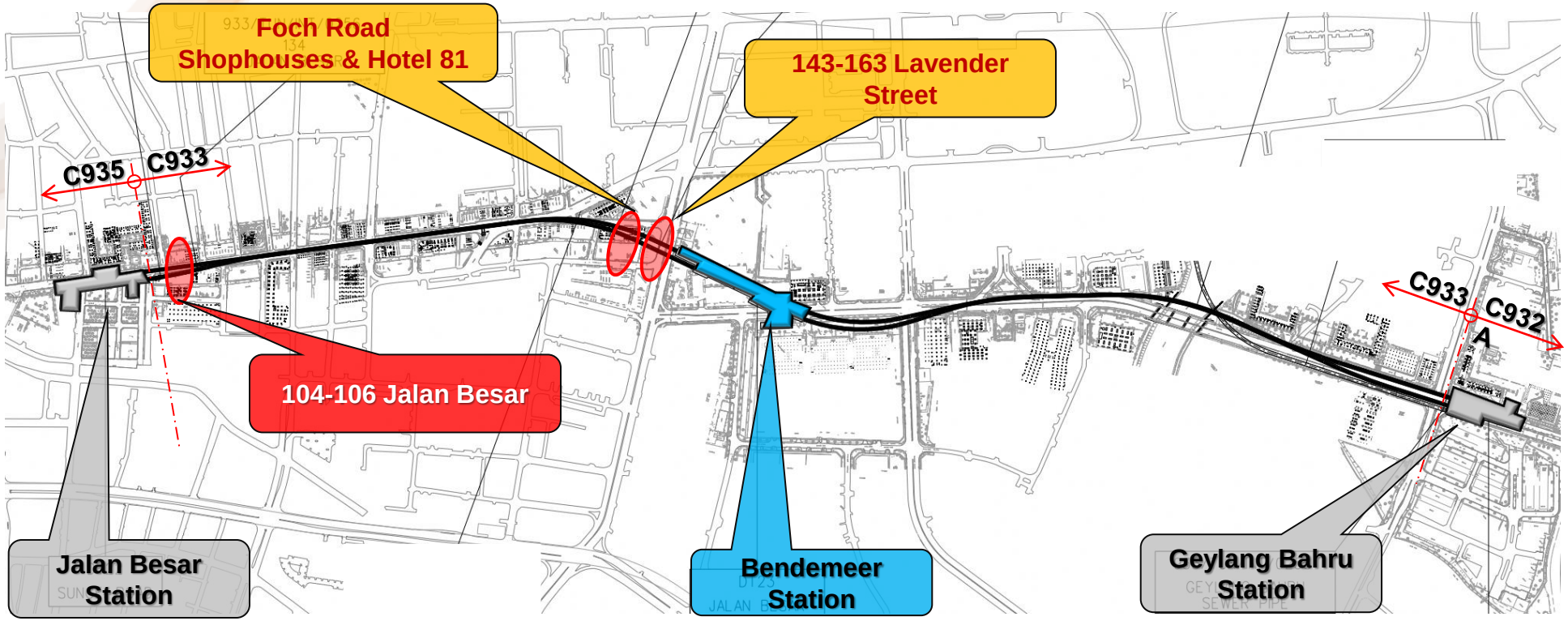
- Adjacent old buildings with shallow foundations
- Geotechnical variability
- Ventilation and confined space hazards

## Initial state:

- Planning based on tender details, reactive safety

# Tunnelling under Shophouses

# Tunnelling under buildings




Foundation were shallow or details not available

| Property | Action |
|---|---|
| **143 -163 Lavender Street** | 1. Additional site investigation conducted to verify possible voids under building and the pile depth<br>2. Magnetic logging was used for investigations<br>3. Buildings were propped before the TBM passing |
| **Foch Road - Shophouses & Hotel 81** | |

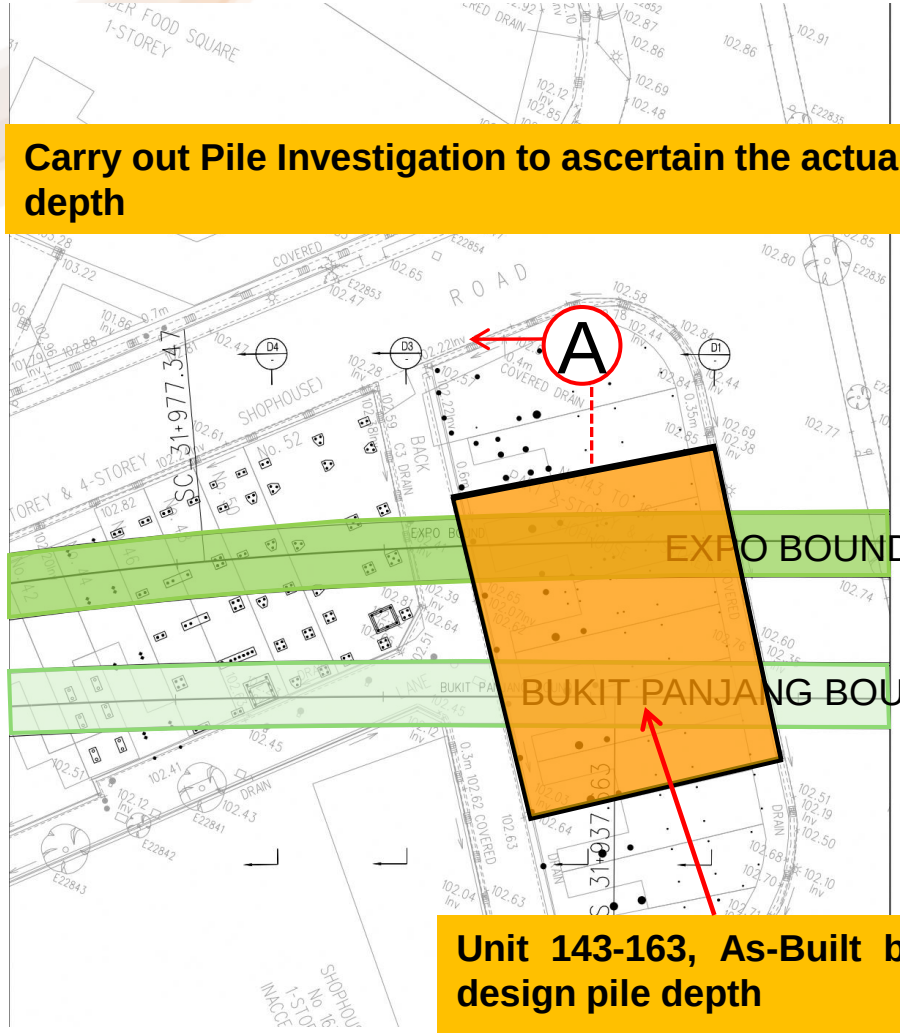
# Sensitive Buildings – Towards Sungei Road

143-163 Lavender Street

Foch Road Shophouses & Hotel 81

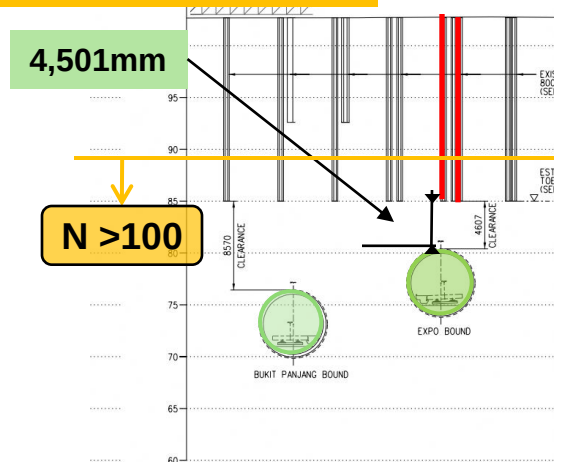
# Tunnel Interface 143-163 Lavender Street

**Carry out Pile Investigation to ascertain the actual pile depth**




**Unit 143-163, As-Built based on design pile depth**

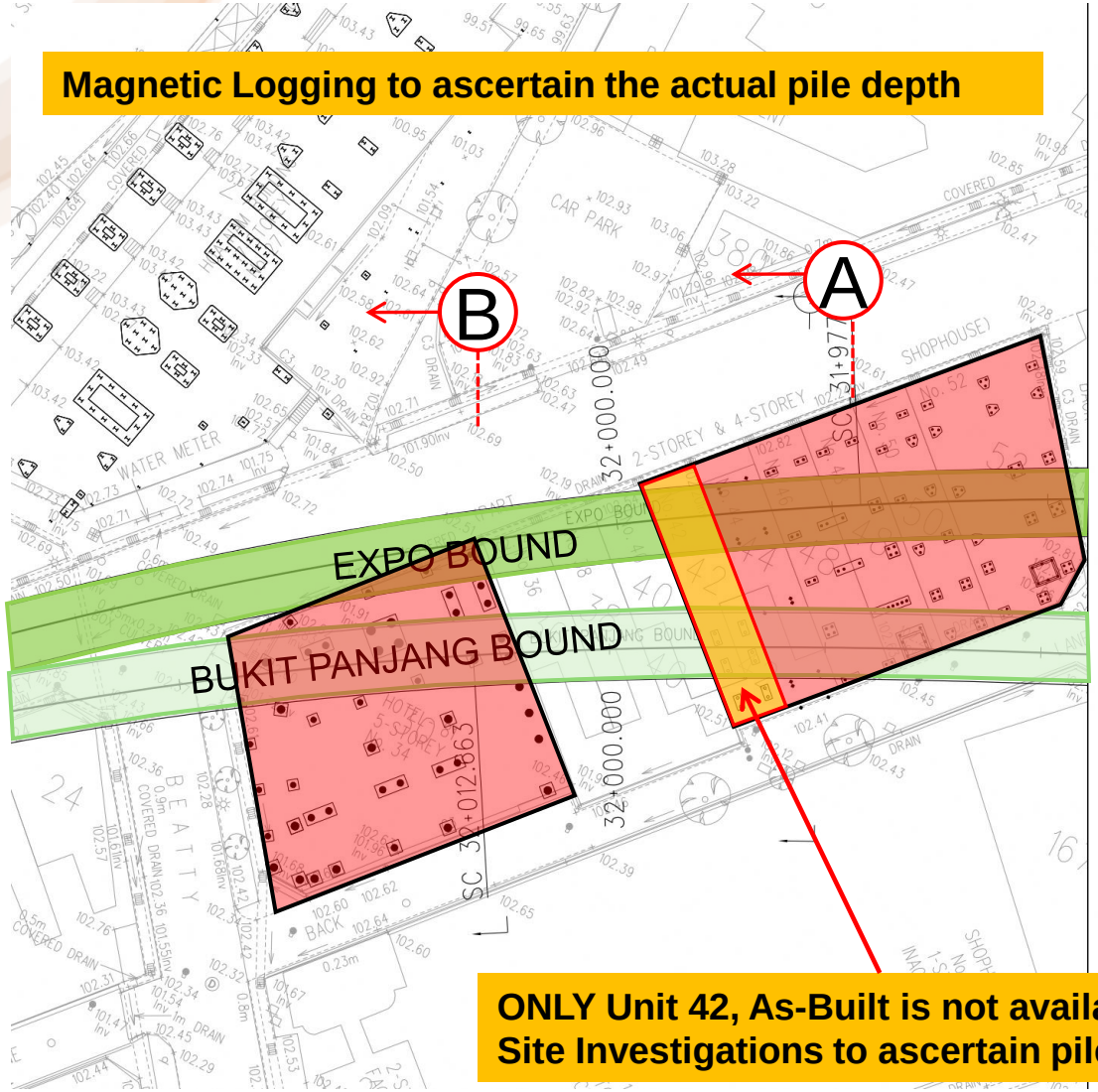
**Estimated pile length**




Section – A

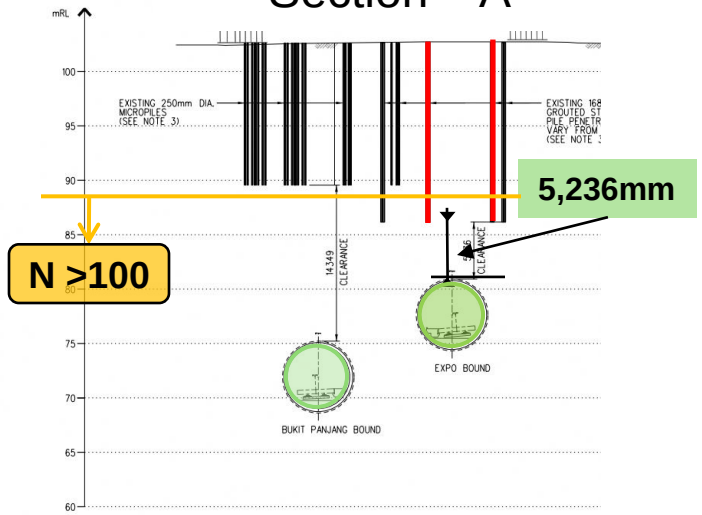
# Foch Road Shophouses & Hotel 81

**Magnetic Logging to ascertain the actual pile depth**

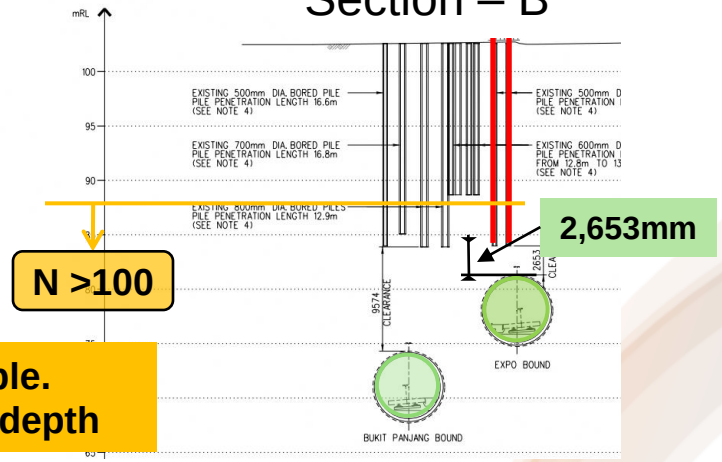



**ONLY Unit 42, As-Built is not available.**
**Site Investigations to ascertain pile depth**

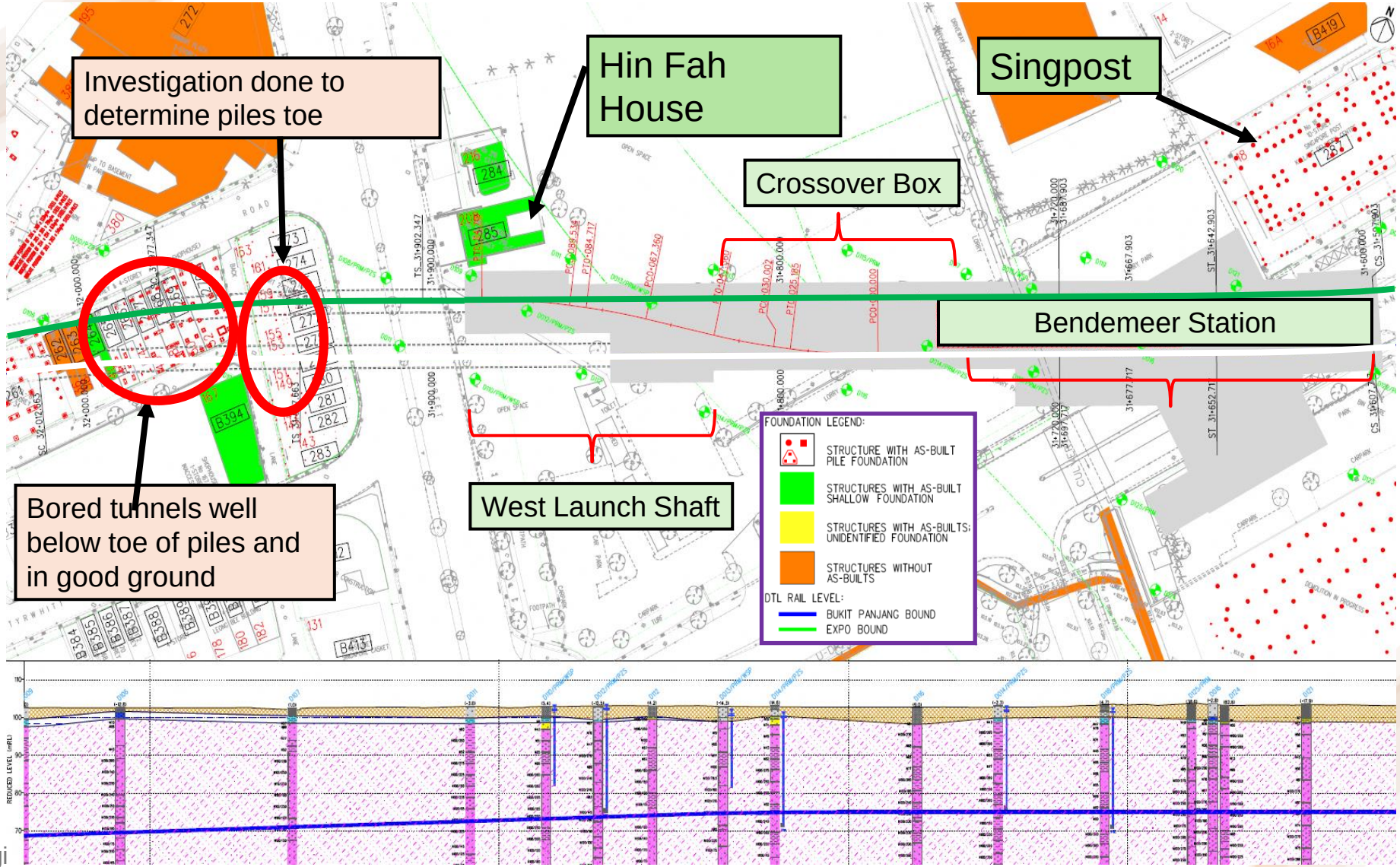
Section – A




Section – B



# Tunnel Interface – Nearby critical structures



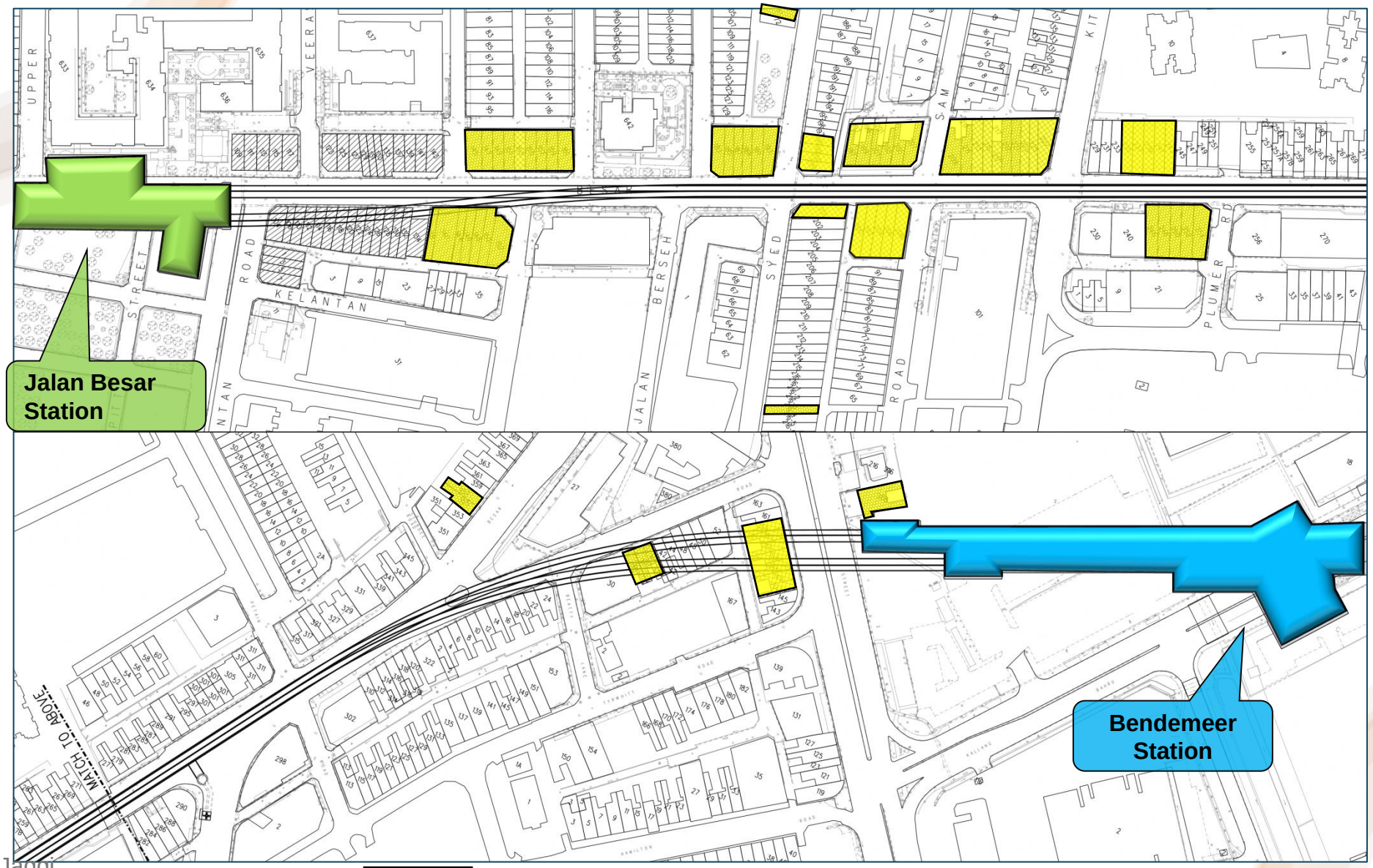
# Preventive Measures

**No TBM Interventions below shophouses**

**Contingency Plans**

1. PR pamphlets / SPRO visits before tunnel approached
2. Buildings were propped 3 months before tunnel arrived
3. Standby additional props and installation team
4. Standby Building Repair Team (active within 24 hours)
5. Cutterhead intervention avoided sensitive buildings
6. Standby grouting equipment on surface

# Buildings Protection Layout

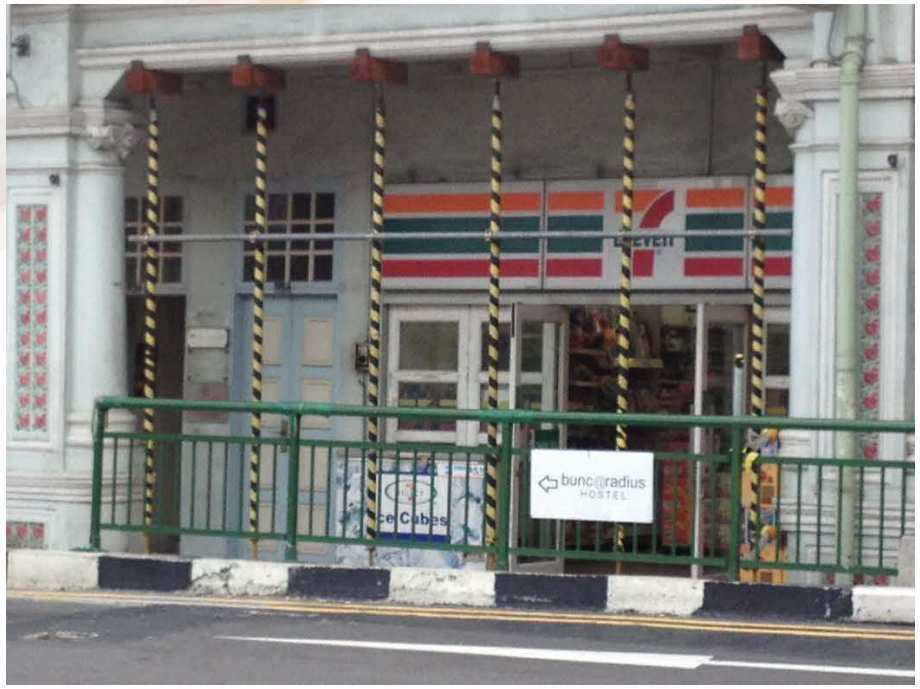


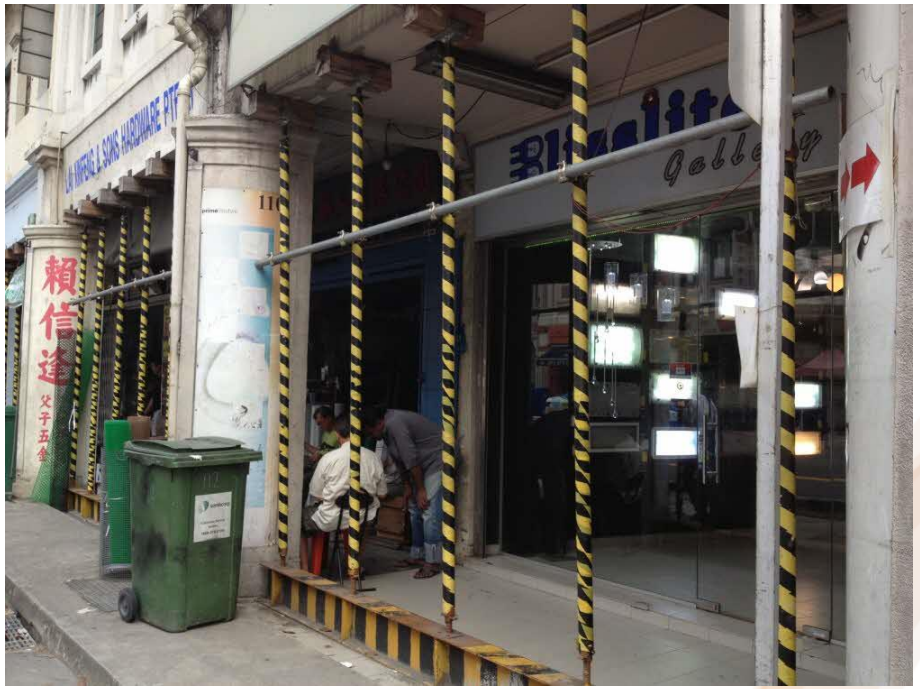

Buildings were propped before TBM passing

# Buildings propped at Lavender Street

143-163 Lavender Street

# Buildings propped at Jalan Besar

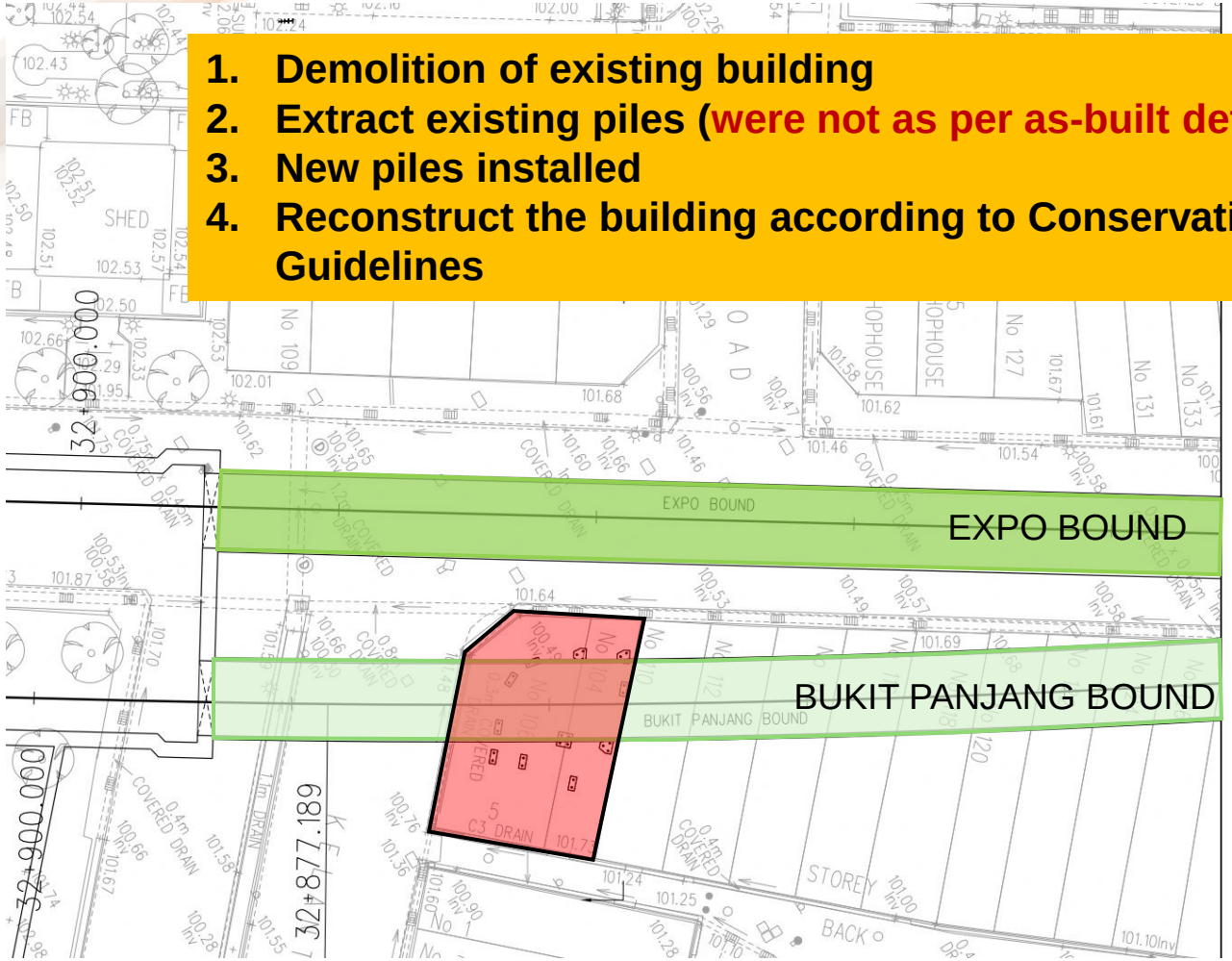


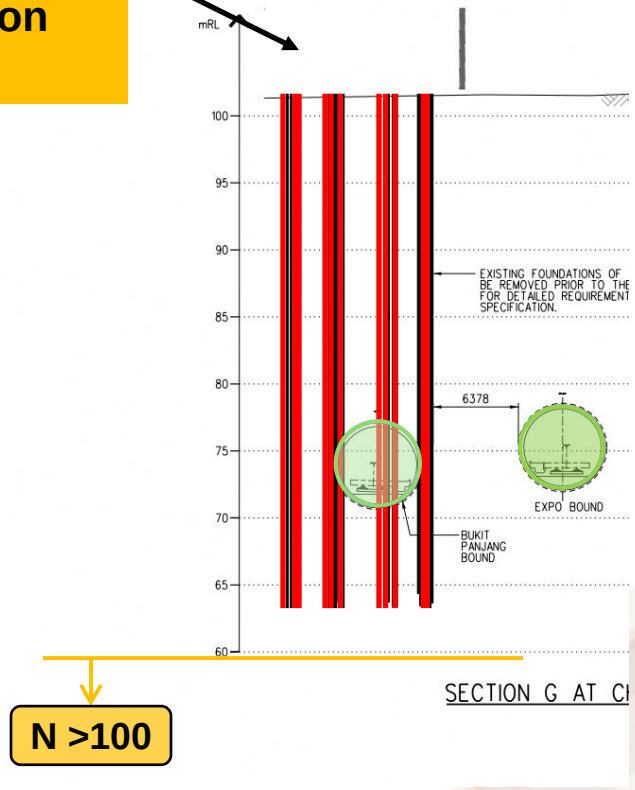



# DEMOLITION & RECONSTRUCTION OF 104-106 JALAN BESAR

# Demolition & Reconstruction of 104-106 Jalan Besar

1. **Demolition of existing building**
2. **Extract existing piles (were not as per as-built details)**
3. **New piles installed**
4. **Reconstruct the building according to Conservation Guidelines**



# 104-106 Jalan Besar – Before Demolition


The building was adjacent to occupied shophouses and traffic, which prevented use of many conventional construction methods

**Had to be redesigned and built according to Conservation Guidelines stipulated by URA design rules**

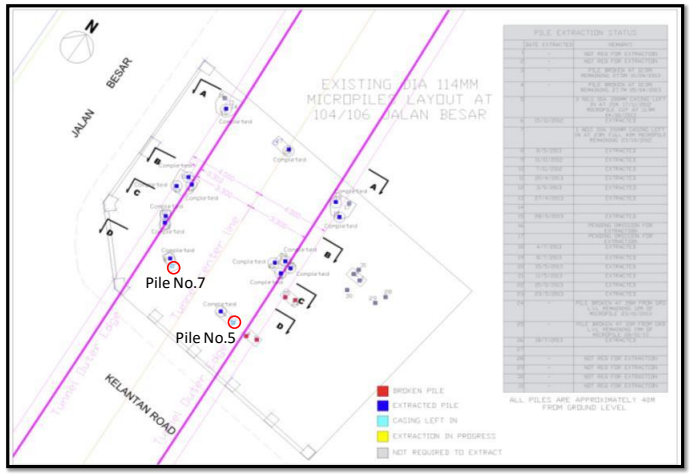
# 104-106 Jalan Besar – During Demolition


Protection of adjacent building by propping (Designed by C933)

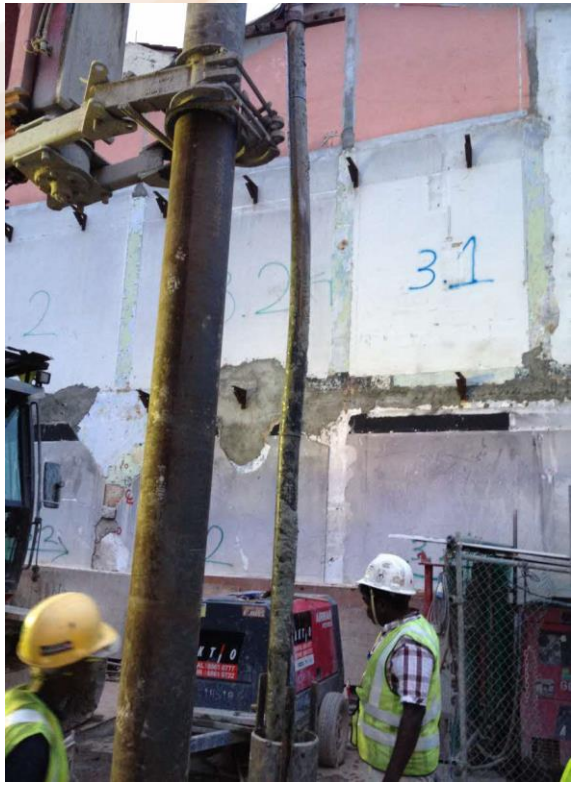
# 104-106 Jalan Besar – Extraction of existing steel piles

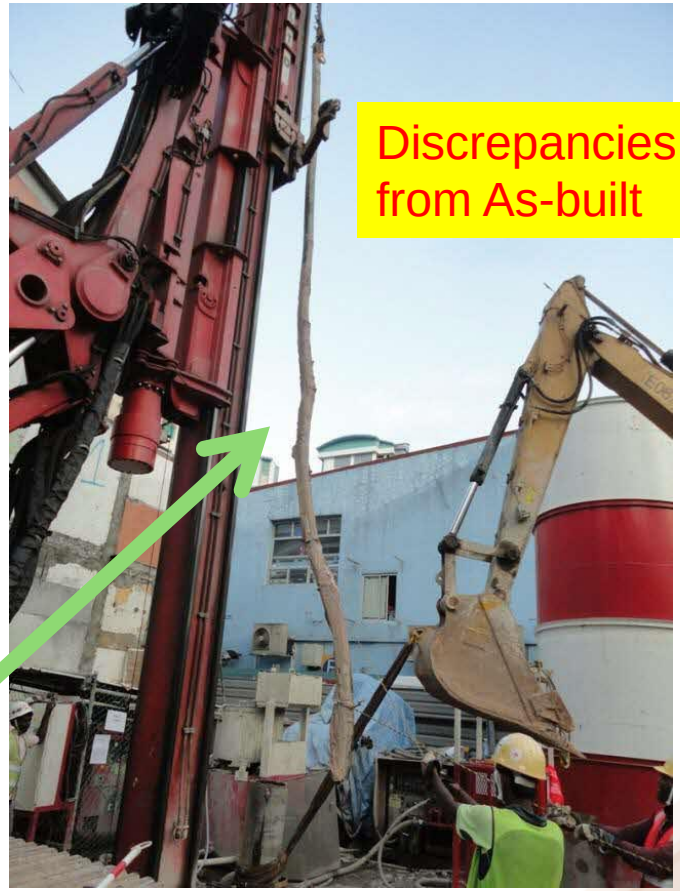
# 104-106 Jalan Besar – Foundation Works

# 104-106 Jalan Besar – Create Grout Block


# 104-106 Jalan Besar – Extraction of existing steel piles




**Actual Piles on site**

**27 piles (168mm steel & 114mm pipe) in 12 groups at average depth of 39m**
**Equipment: Micropile Rig – SM-401;**
**ABI rig –TM-18/22B with 300mm casing**

# 104-106 Jalan Besar – Removal of Steel piles

# 104-106 Jalan Besar - Reconstructed


**Designed and Built according to Conservation Guidelines stipulated by URA design rules**

# The Risk Landscape in Tunnelling Projects

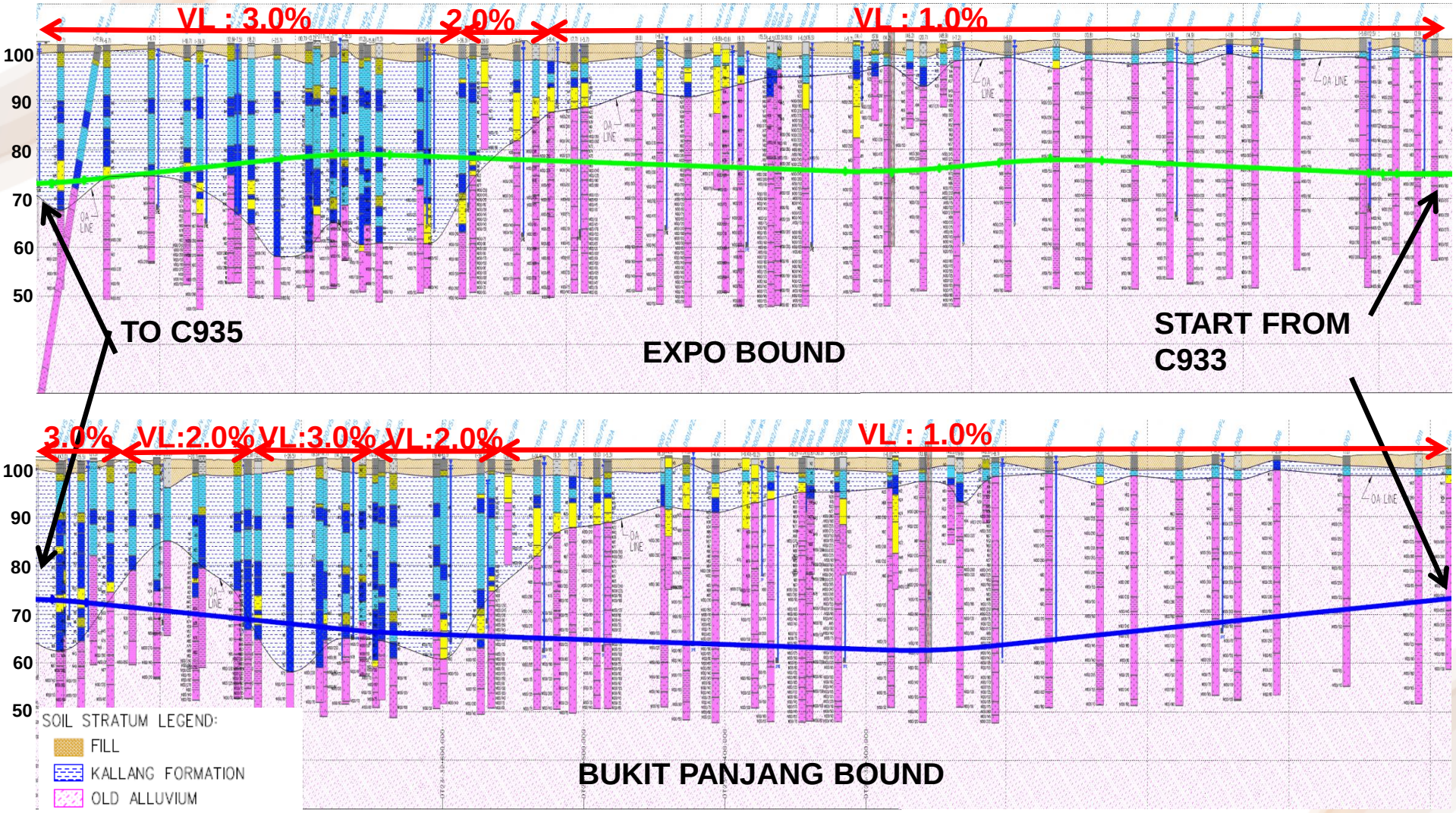
## Typical risks

- Geotechnical variability and soil unpredictability
- Confined spaces and limited escape routes
- Groundwater ingress
- Adjacent structure impacts

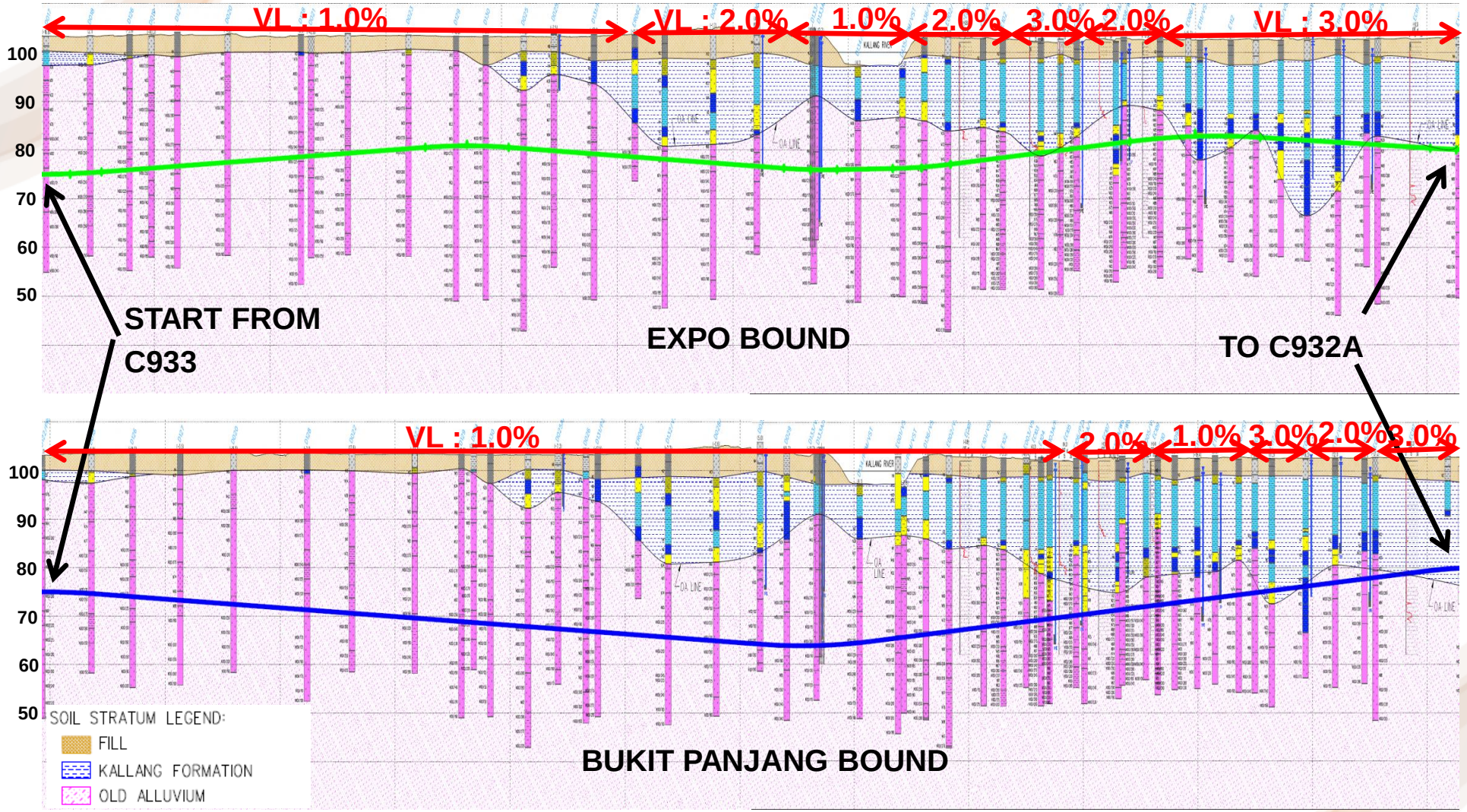
## External pressures

- Tight schedules
- Budget constraints
- Shortage of skilled labour

# GEOLOGICAL PROFILE - C933 to C935



# GEOLOGICAL PROFILE - C933 to C932A



# Tunnel Excavation Management

## Excavation Management

1. Full time supervision by a competent and experienced person watching the soil consistency change during drive under buildings.
2. Soil Volume loss to be monitored through:
   - ❖ Volume in Belt Conveyor (through weighing)
   - ❖ Quantity in skip
   - ❖ Theoretical Volume

## Mitigation

1. During the tunnelling settlement of the ground / building due to tunnel boring was monitored through instrumentation reading and with the assistance of QP(S).
2. A surface watchman will be full time along tunnel alignment
3. A grouting rig shall be on standby.
4. Water trucks shall be available to curb any foam flow.

# How PSRs Were Implemented

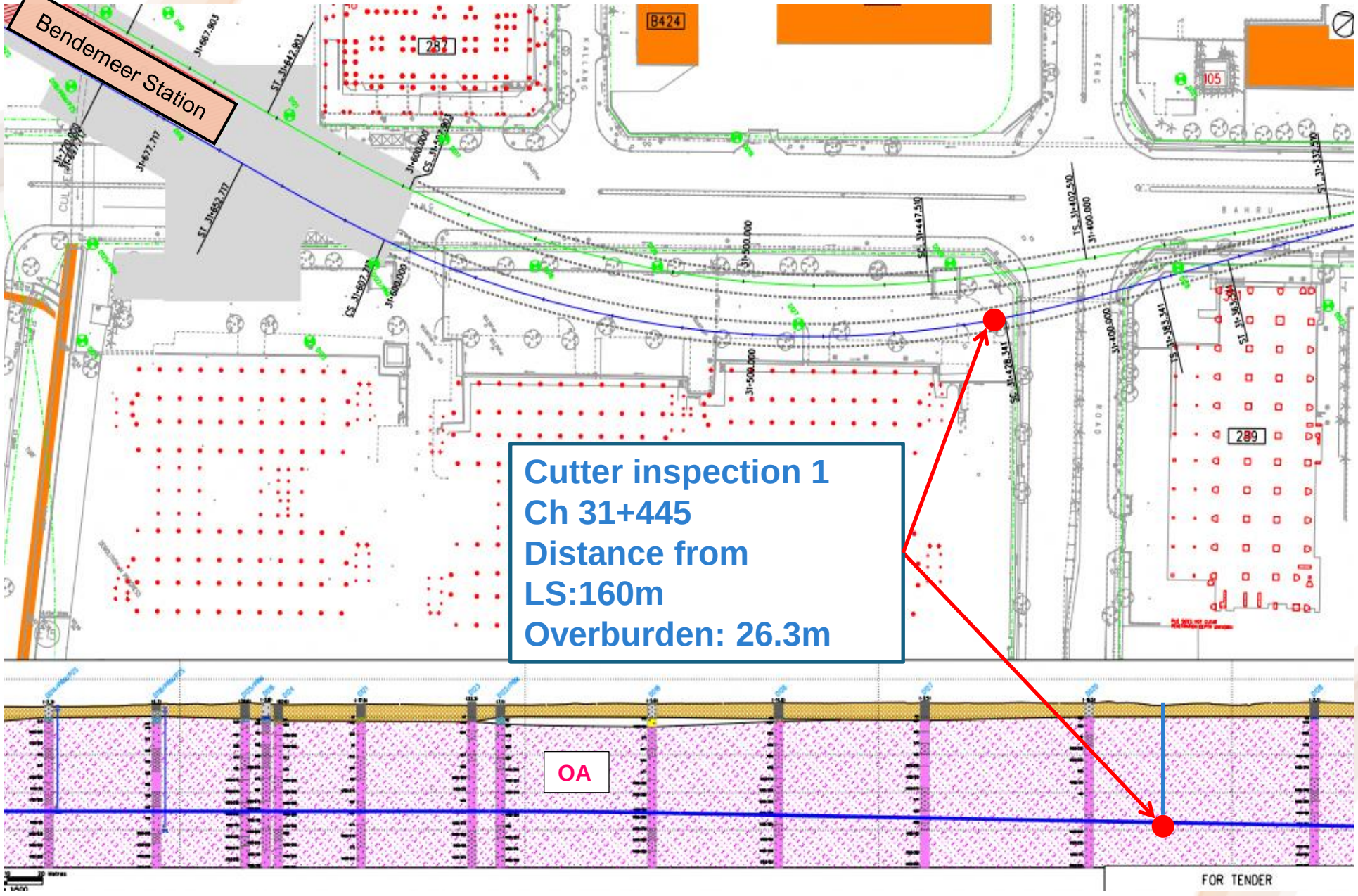
- Weekly meetings - PSRs during high-risk phases.
- Team: PM, Discipline engineers, contractors, safety leads, Risk facilitator.
- Process:
  - ✓ Review upcoming scope
  - ✓ Document risks in log
  - ✓ Assign mitigation actions
  - ✓ Track decisions and follow-up weekly

# Impact of PSRs – Interventions and Metrics

- **Key Interventions:**
  - ✓ CHI places revised → avoided clashes.
  - ✓ Ventilation redesign → improved air safety.
  - ✓ Emergency access routes improved.
- **Metrics:**
  - ✓ 40% drop in near-misses in 3 months
  - ✓ 3-week schedule recovery
  - ✓ 60% increase in risk reports

# C933 – C932A CUTTERHEAD INSPECTIONS/ INTERVENTIONS

# Location of Cutter Inspection and Intervention (Bukit Panjang Bound TBM No.3)



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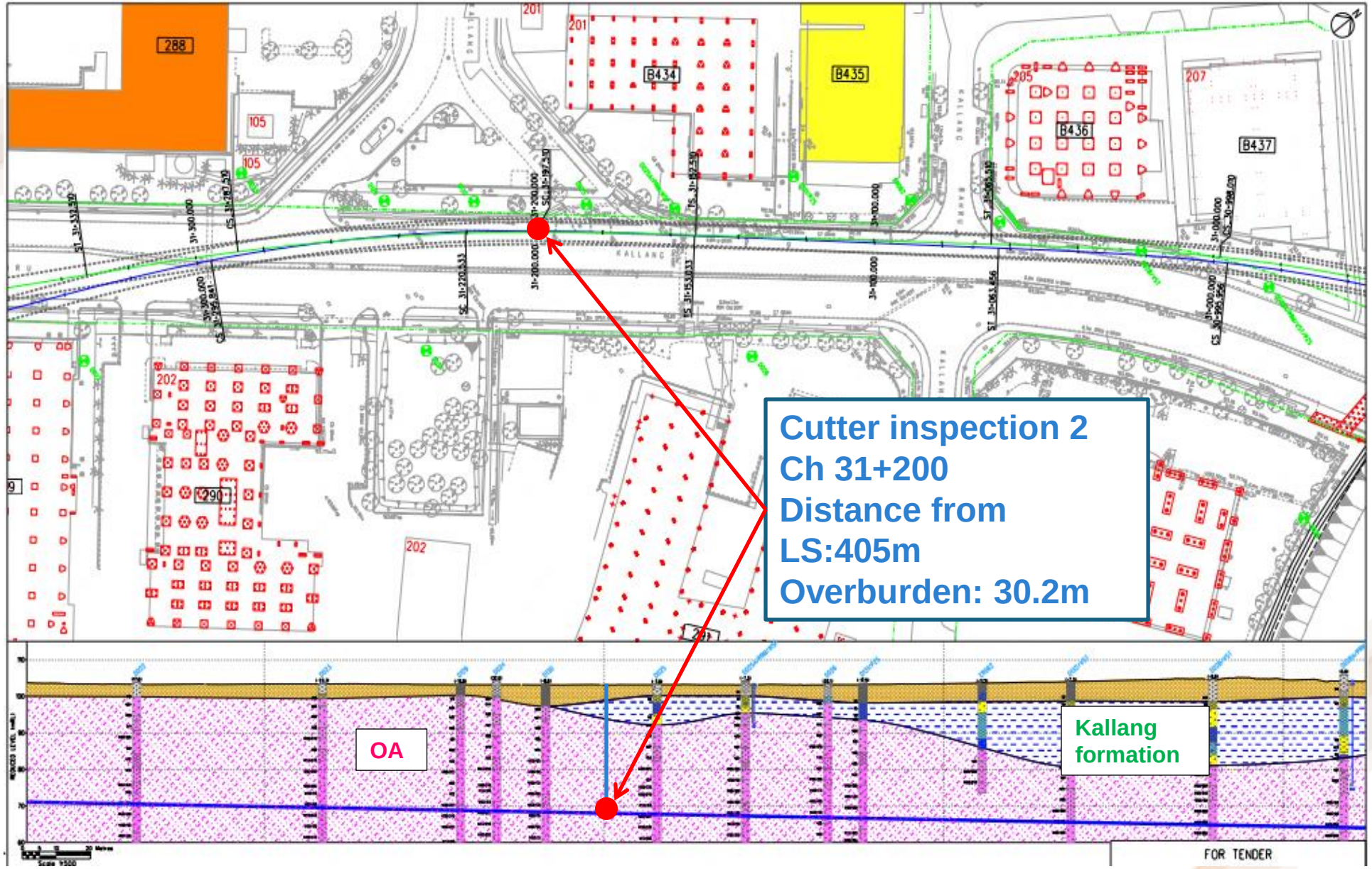

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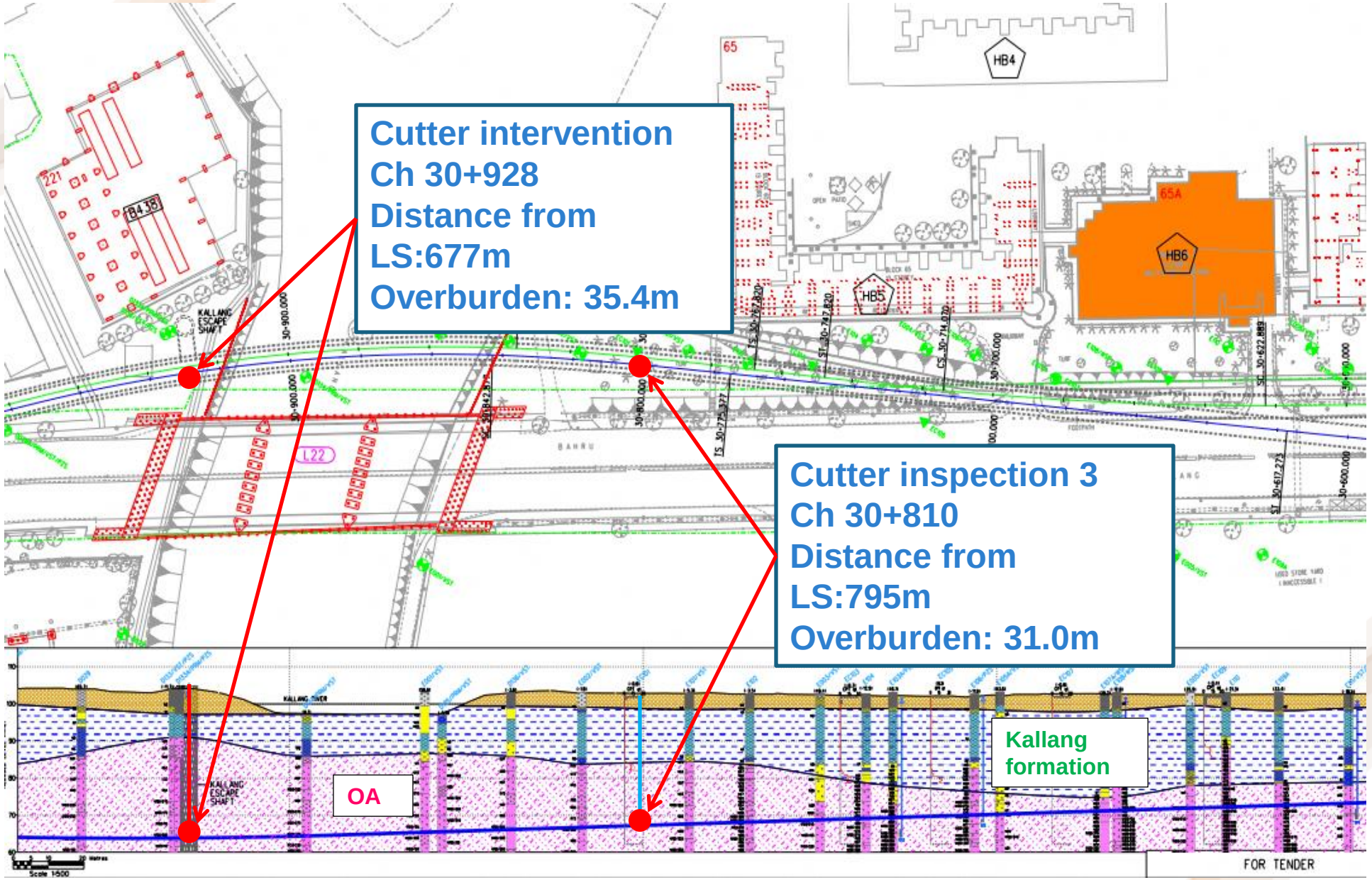
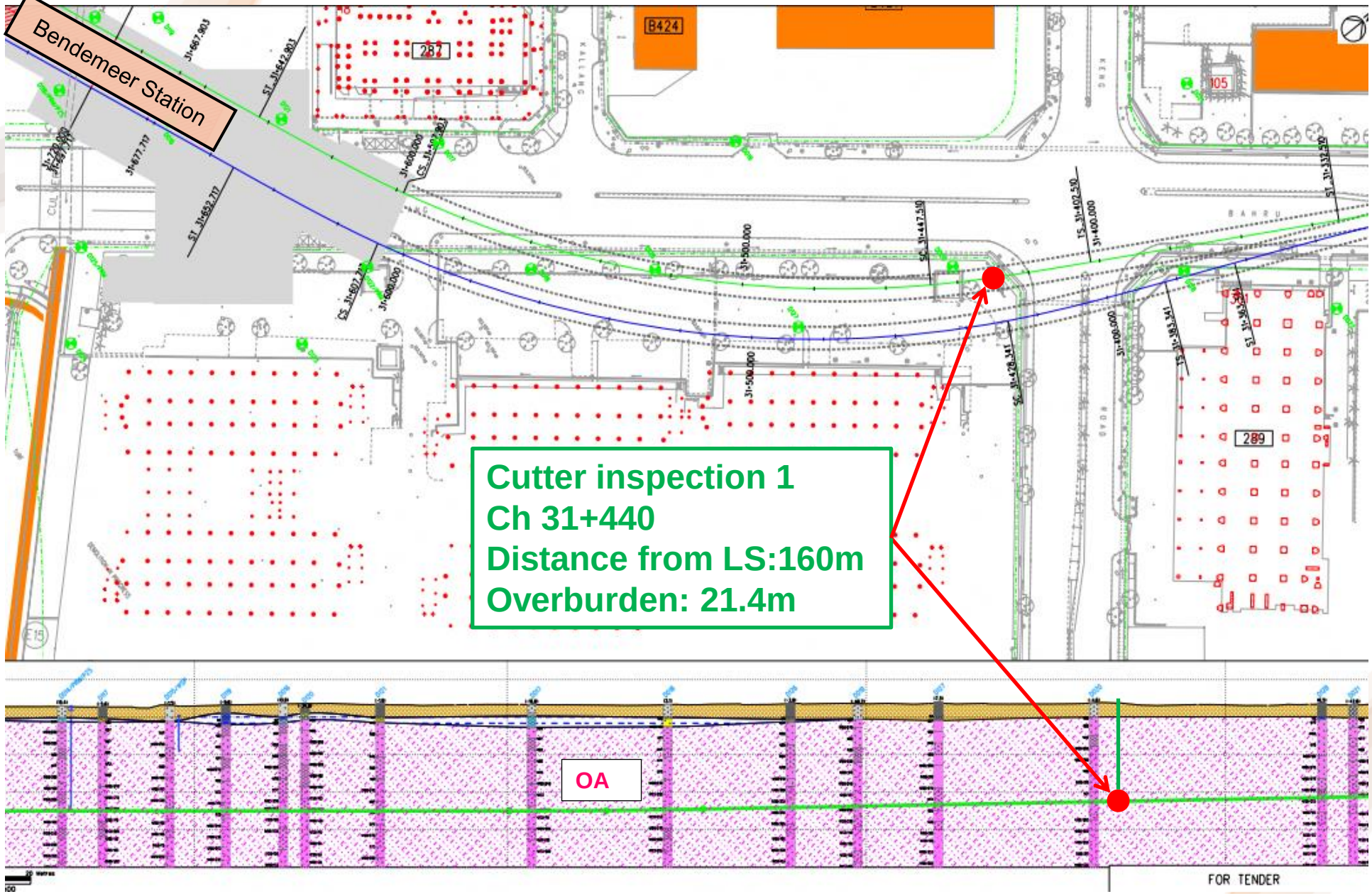
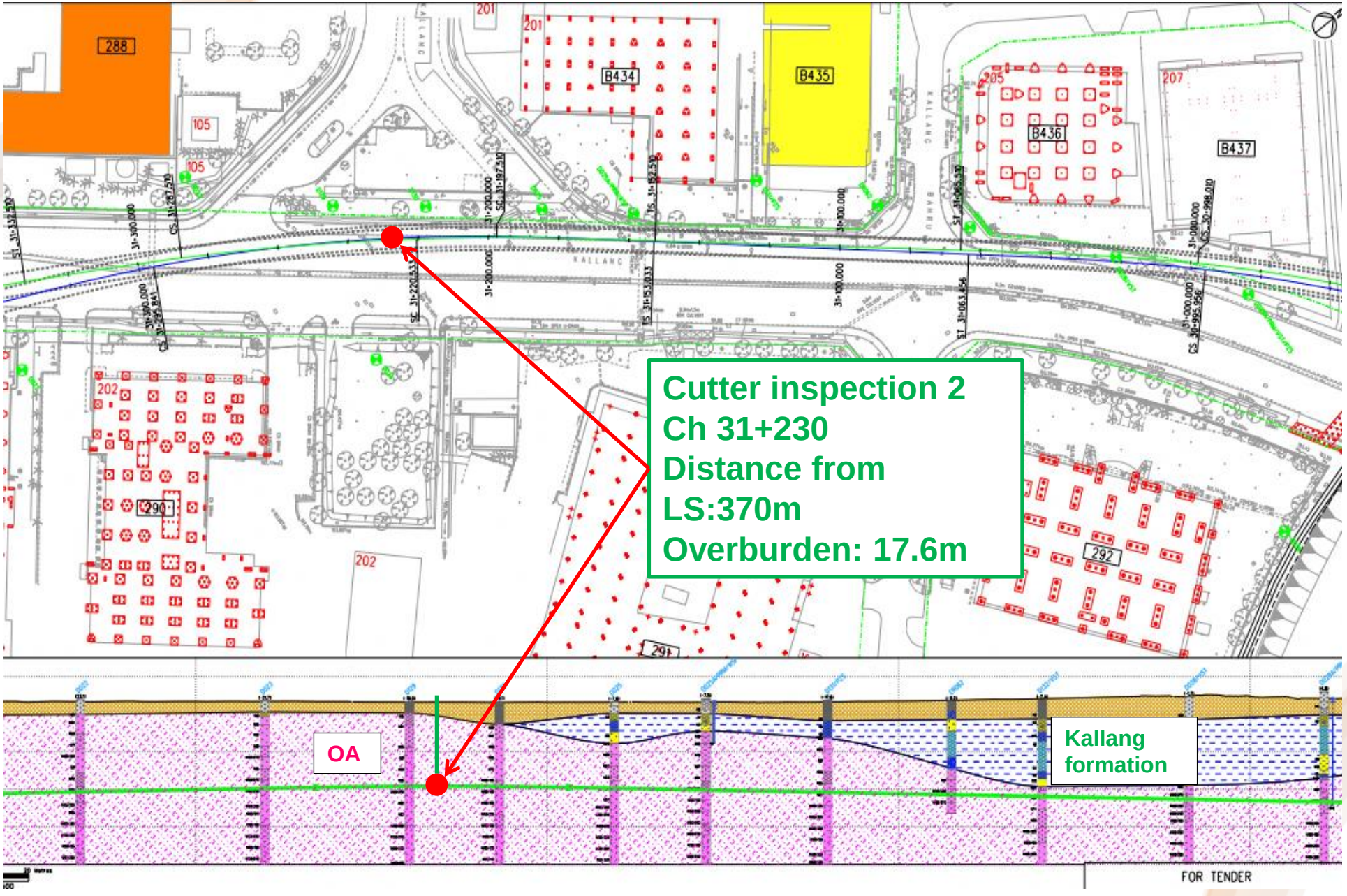


# Location of Cutter Inspection and Intervention (Expo Bound TBM No.4)



# Location of Cutter Inspection and Intervention (Expo Bound TBM No.4)



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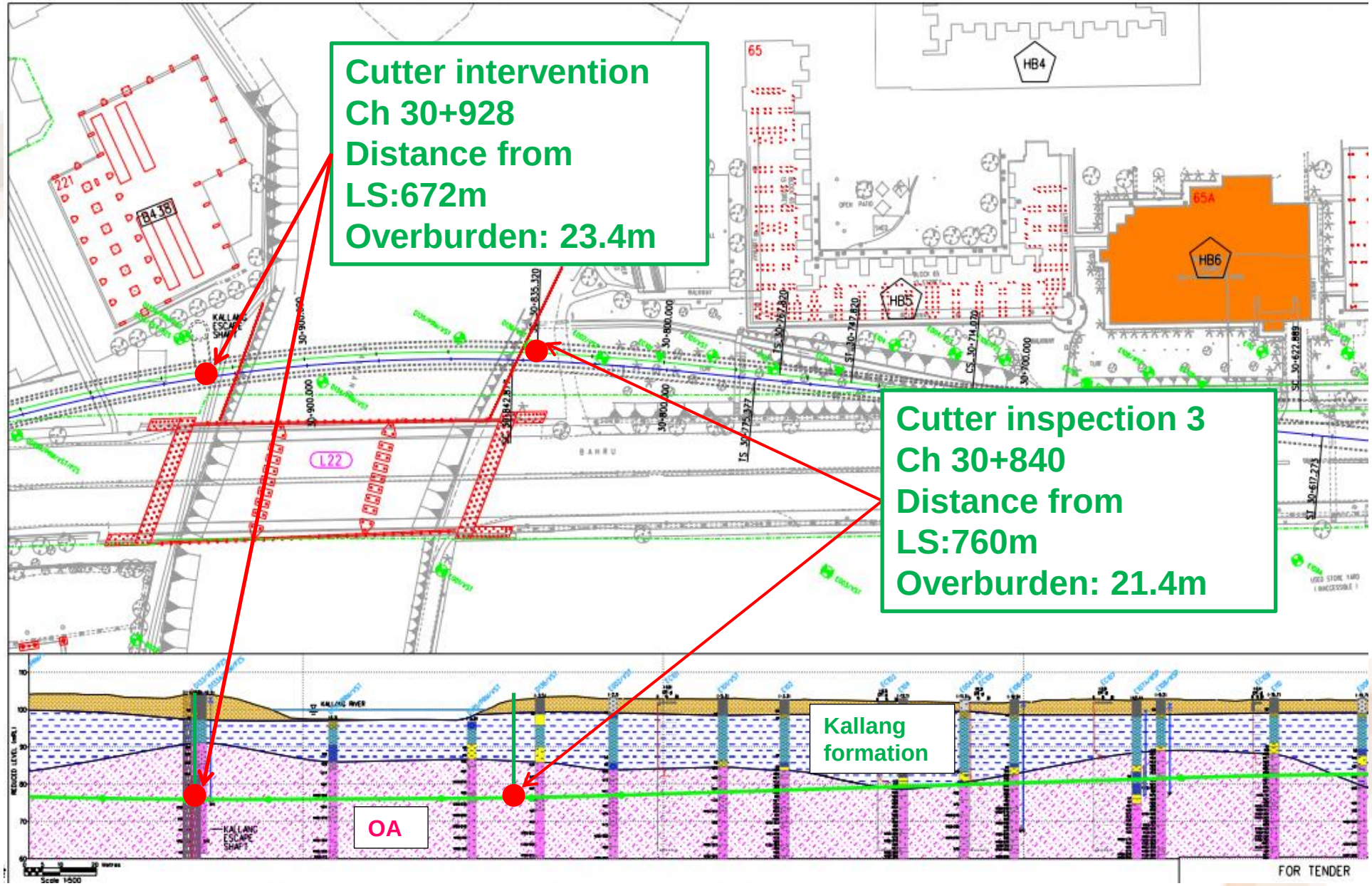


# Cultural Transformation Through PSRs

- Observed changes:
  - ✓ Risk discussions in daily toolbox talks
  - ✓ Supervisors proactively raised risks
  - ✓ Workers reported hazards freely in a language they were familiar
- Shift:
  - ✓ Safety as shared responsibility

# Leadership’s Role in Reinforcing PSRs

- Leadership actions:
  - ✓ Senior managers attended PSRs
  - ✓ Escalated unresolved risks
  - ✓ Linked participation to KPIs
- Cultural message: 'Reporting risk is leadership'

# COMPLETING
# 4 TBMS ON-TIME

# Completing 4 TBMs On-time

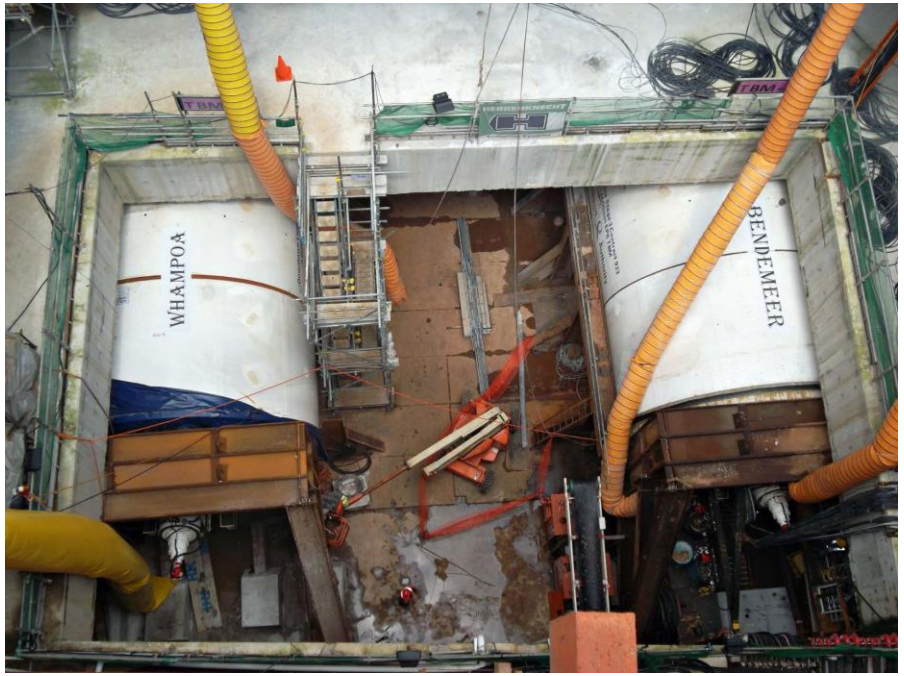
## View in Aug 2014


## View in May 2015

# TBM Assembly at East Launch Shaft (ELS)

**Space limitations to handle 2 TBM in the shaft**

# TBM Assembly at East Launch Shaft (ELS)



# Disposal of Excavated Material

## Concerns

1. Peak quantity of Tunnel excavated material ~ 1,440$m^3$ (x 4 months) required 52 lorries x 4 trips per day (7$m^3$ / load)
2. Excavated material – High moisture content (very wet)
   - ❖ Not acceptable by LTA staging ground
   - ❖ Need to treat dry for LTA staging ground
   - ❖ Long queue at LTA staging ground

## Mitigation

1. Source for Haulage Contractor who has large stockpile land to dry
2. Rented land near site for stockpiling for Chemical Treatment – Limestone/Cement Mixing

# OVERCOMING EXTREMELY HIGH SOIL ABRASIVENESS

# Overcoming High Soil Abrasiveness

During driving 4 TBM's, we encountered **extremely high abrasive soil** and eventually more CHIs (Cutter Head Interventions) were required and productivity dipped and resulted in tunnelling duration prolongation.

# Overcoming High Soil Abrasiveness

**Plan CHIs vs Actual CHIs**

| TBM 2 | CHIs | Pre-Cutters | Bite Cutters |
|---|---|---|---|
| Planned | 4 | 62 | 198 |
| **Actual** | **6** | **97** | **208** |

| TBM 4 | CHIs | Pre-Cutters | Bite Cutters |
|---|---|---|---|
| Plan | 4 | 62 | 198 |
| **Actual** | **7** | **164** | **210** |

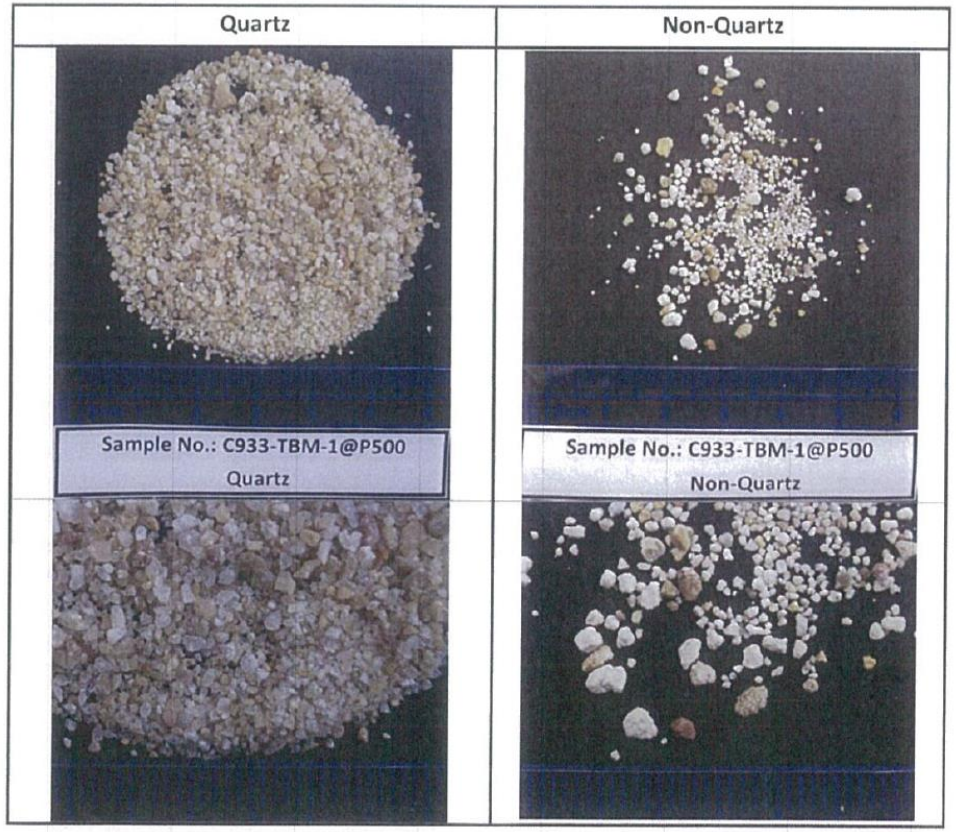

| TBM 1 | CHIs | Pre-Cutters | Bite Cutters |
|---|---|---|---|
| Plan | 4 | 62 | 198 |
| **Actual** | **11** | **280** | **434** |

| TBM 3 | CHIs | Pre-Cutters | Bite Cutters |
|---|---|---|---|
| Plan | 4 | 62 | 198 |
| **Actual** | **8** | **208** (114 after R333) | **375** (180 after R333) |

The unanticipated increase in CHI (2x) was due to the unforeseen ground conditions (extremely high quartz content) in the form of more abrasive Old Alluvium (OA) encountered.

# Overcoming High Soil Abrasiveness

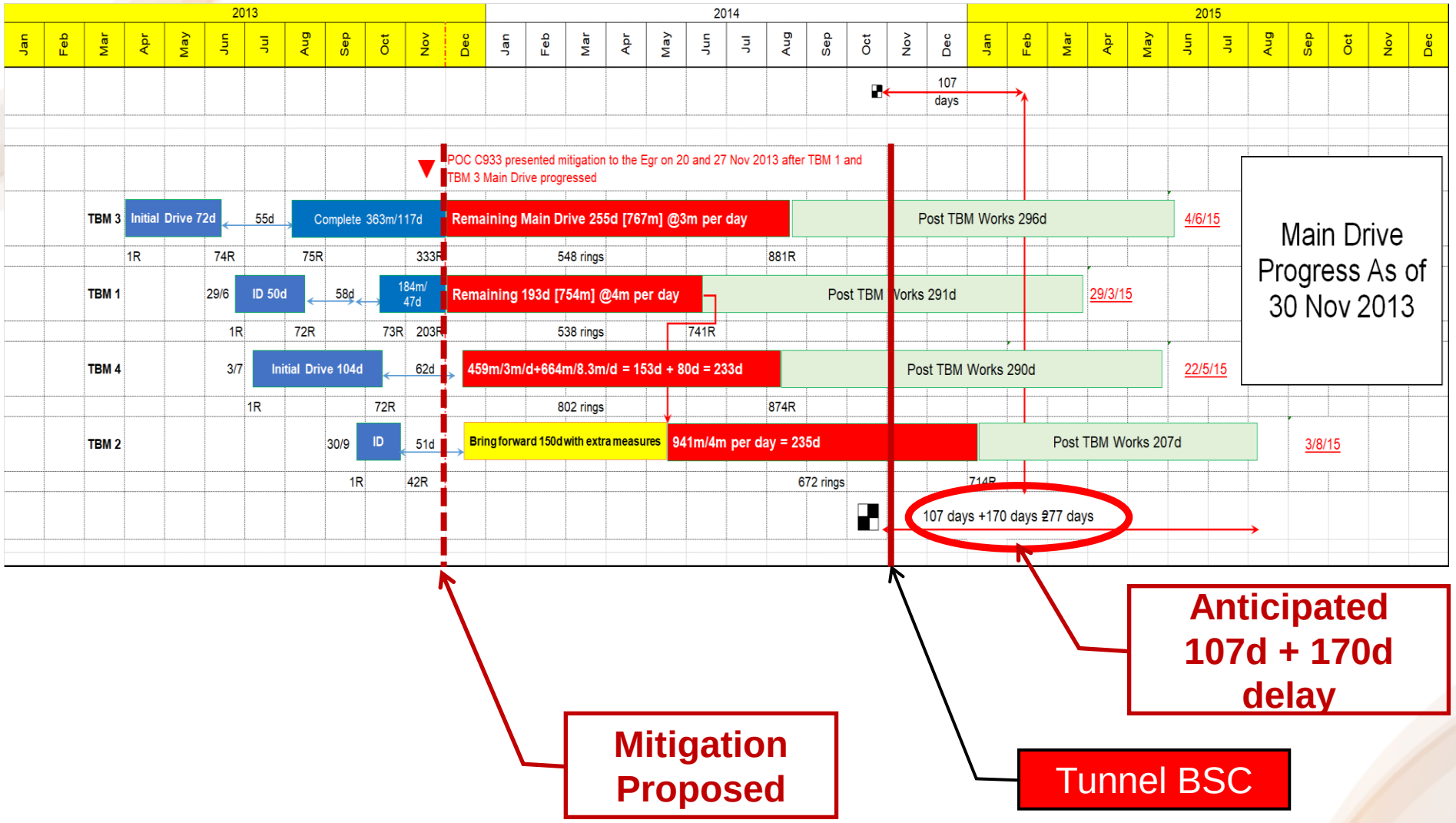
**Quartz Contents Test conducted**




| S/N | TBM | Ring No. | Quartz (%) y |
|---|---|---|---|
| 1 | TBM-1 | 210 | 68.40 |
| 2 | TBM-1 | 304 | 66.90 |
| 3 | TBM-1 | 388 | 72.30 |
| 4 | TBM-1 | 416 | 77.30 |
| 5 | TBM-1 | 436 | 78.50 |
| 6 | TBM-1 | 486 | 89.70 |
| 7 | TBM-1 | 492 | 92.60 |
| 8 | TBM-1 | 500 | 89.50 |
| 9 | TBM-2 | 183 | 83.60 |
| 10 | TBM-2 | 353 | 71.30 |
| 11 | TBM-2 | 443 | 90.50 |
| 12 | TBM-3 | 333 | 79.20 |
| 13 | TBM-3 | 427 | 69.50 |
| 14 | TBM-3 | 484 | 71.00 |
| 15 | TBM-3 | 553 | 78.20 |
| 16 | TBM-3 | 605 | 71.20 |
| 17 | TBM-4 | 114 | 87.10 |
| 18 | TBM-4 | 171 | 80.70 |
| 19 | TBM-4 | 354 | 85.50 |
| 20 | TBM-4 | 475 | 80.20 |

> 60% of original estimate

# Impact on Progress due to highly abrasive soil




**Mitigation measures were presented to LTA on 20 & 27 Nov 2013 while TBM 1 & 3 Main Drive were progressing.**

# Mitigation Measures implemented to Control delays

1. Shift 40t Gantry Crane from ELS to WLS
2. Add Two - 200t Crawler Crane at ELS
3. Locomotive for TBM#4
4. Chiller System for TBM#4
5. Additional Muck Pit and Tipping Frame
6. Additional Rails & Sleepers, Switches etc.
7. Additional Excavators for Soil Disposal for Day & Night Shift
8. Additional Tunnel Workers for TBM#4 ($7^{th}$ & $8^{th}$ Team)
9. Lifting Team for Day & Night Shift
10. Additional E&M Manager

# Mitigation Measures implemented to Control delays


ELS Modification

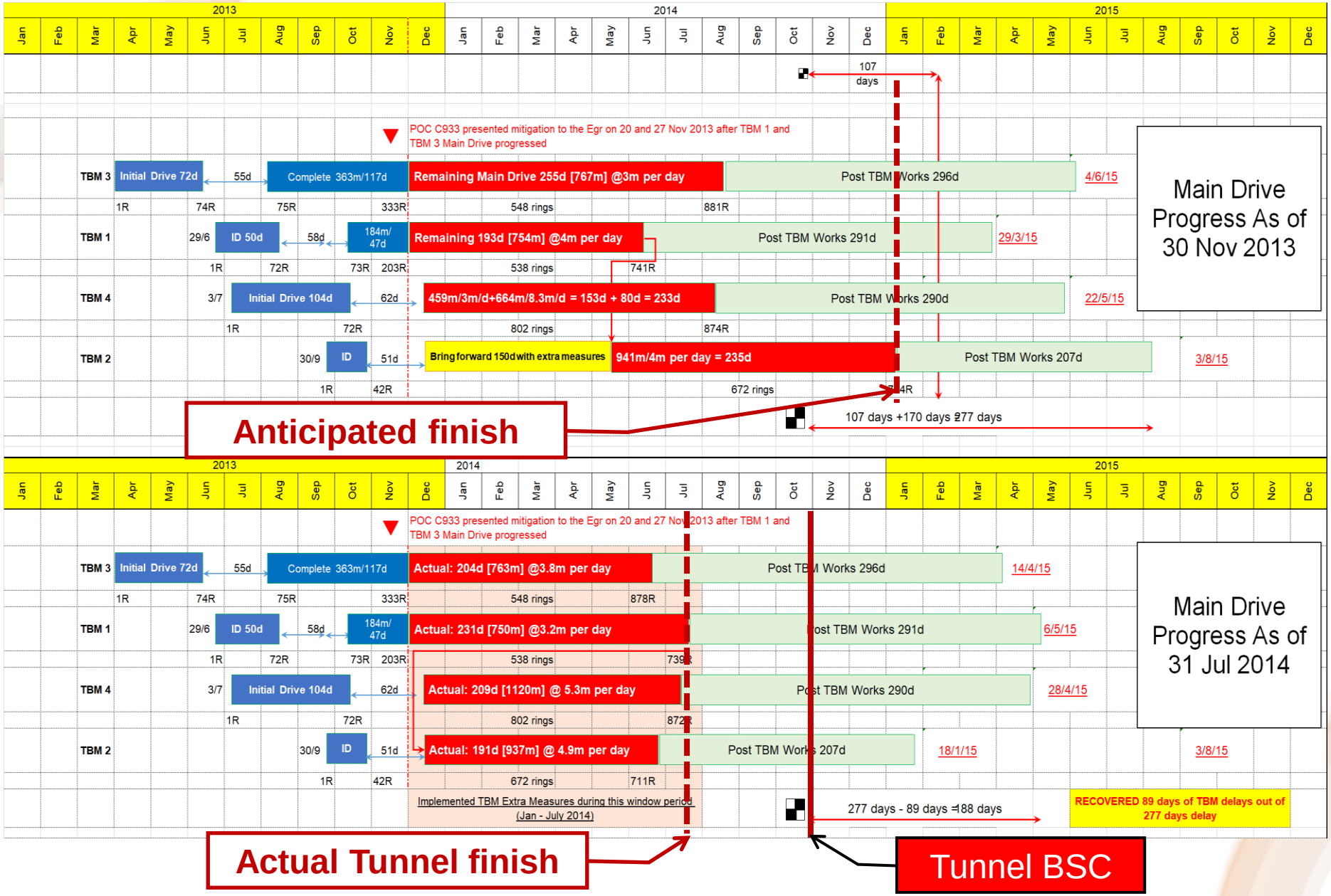
Removed 40t Gantry Crane from ELS & added 2 Crawler Cranes

# Mitigation Measures implemented to Control delays


WLS Modification

Shift 40t Gantry Crane from ELS to WLS

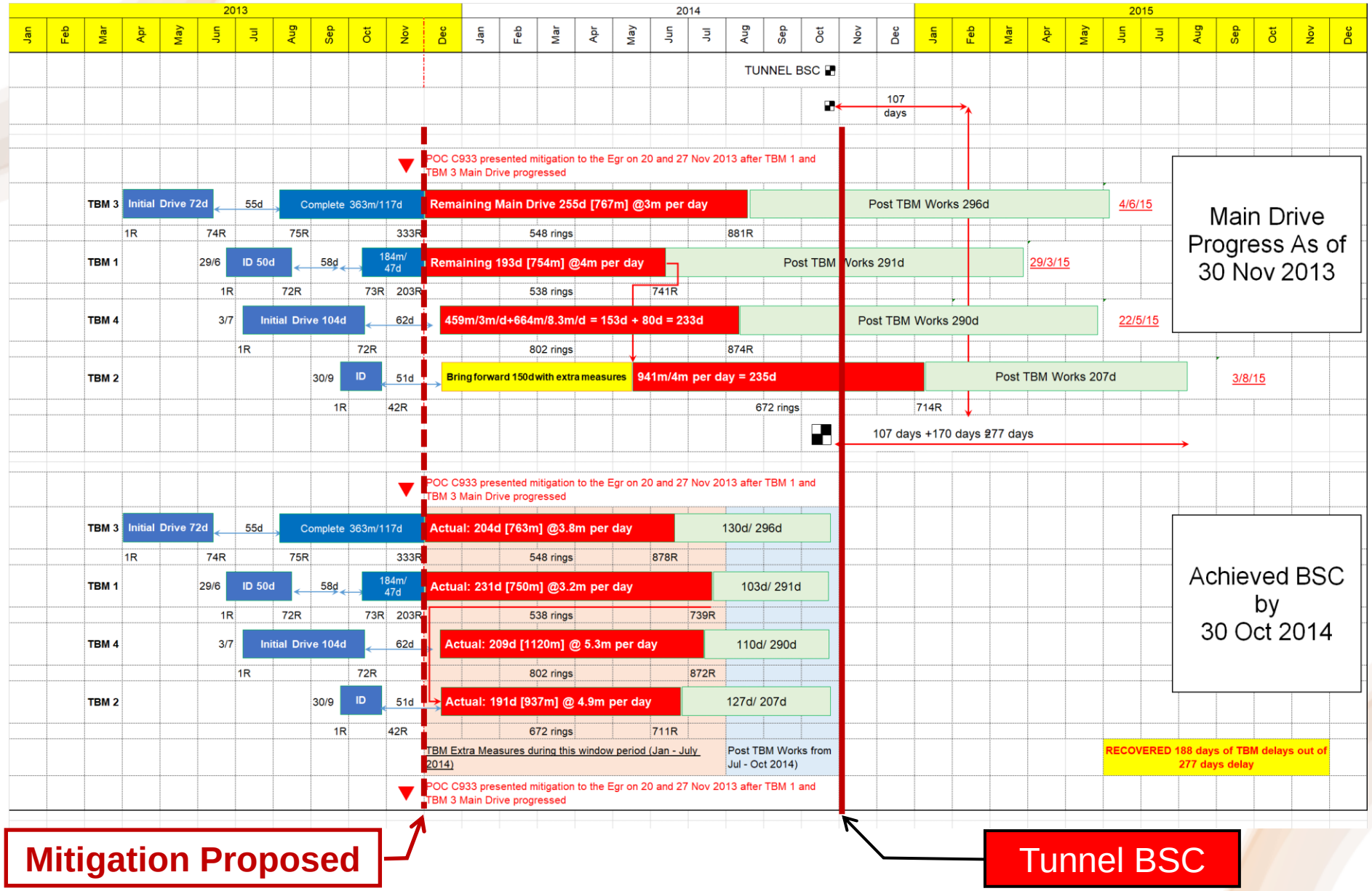
# Comparison after Mitigation Measures implemented



# Mitigation Measures to complete Post TBM works

1. First Stage Concrete & Bracket installation done concurrently with two additional teams
   - First stage concrete done in 45 days
   - 58,000 brackets installed in 2 months
2. At docking points, expedite cast in-situ inside TBM machine (Additional 2 sets of steel lining formwork deployed)
3. Additional Tunnel Engineers and Supervisors
4. Expedite TBM dismantling with additional transporter & bigger crane - All 4 TBMs dismantled and retrieved in 60 days

# All Post TBM works completed by Tunnel BSC



# Overcoming Barriers

## Challenges

- Contractor resistance: 'another meeting'
- Misunderstanding PSRs as audits

## Strategies

- Pilot PSRs on limited scope
- Showcase early wins
- Time-box sessions to 30–45 minutes

# Key Lessons Learned

1. Proactive PSRs prevent incidents and delays.

3. Skilled facilitation builds trust.

2. Cross-functional reviews uncover hidden risks.

4. Culture must be deliberately cultivated.

# Practical Recommendations

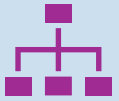
- Start PSRs in design phase
- Use standardized tools (risk logs, dashboards)
- Train facilitators across disciplines
- Align reviews with milestones and high-risk activities

# Closing Reflections

**No construction project is risk free, risk can be managed, minimised, shared, transferred or accepted. It cannot be ignored.**

**Systematic Risk management process from project initiation to completion to mitigate the risks.**

**PSR process implemented as a Risk management approach to manage and mitigate the risks at various levels from project initiation to implementation stage**



**'A safe project is one where risks are seen, shared, and addressed early.'**

# Thank You!

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