

An Independent View of the Pinheiros Station Accident (Sao Paulo Metro) and Lessons Learnt for Future Contractual Arrangements

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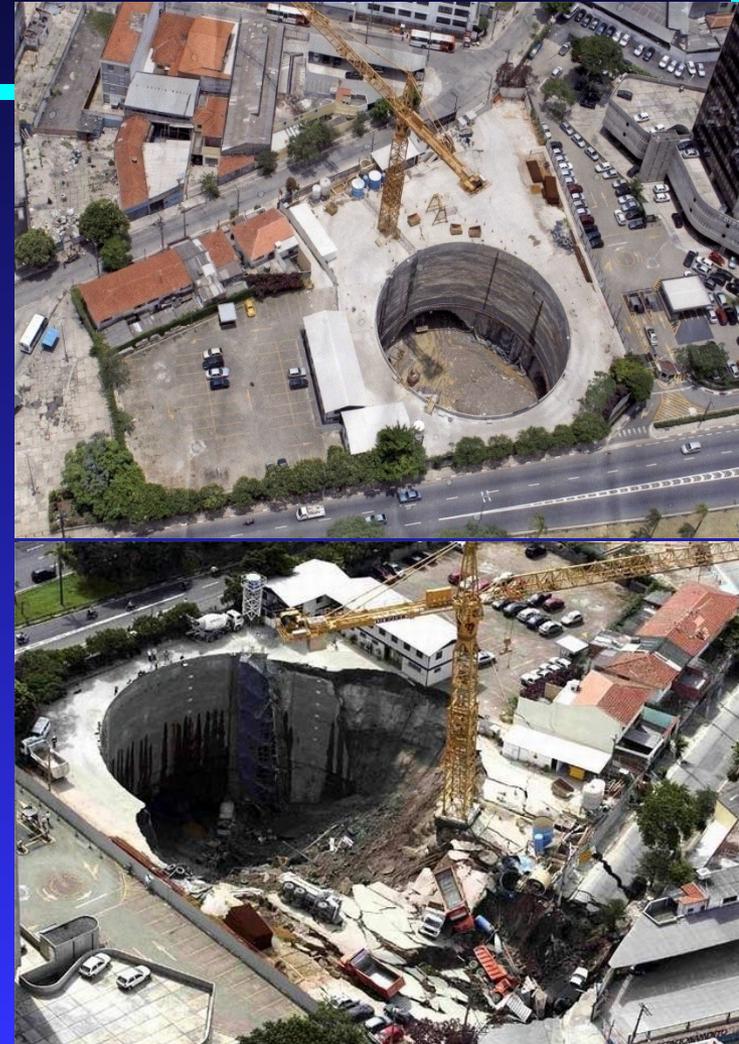
ITA Open Session: Contractual Practices Worldwide

ITA World Tunnel Congress, Agra, India – 19-25/09/2008

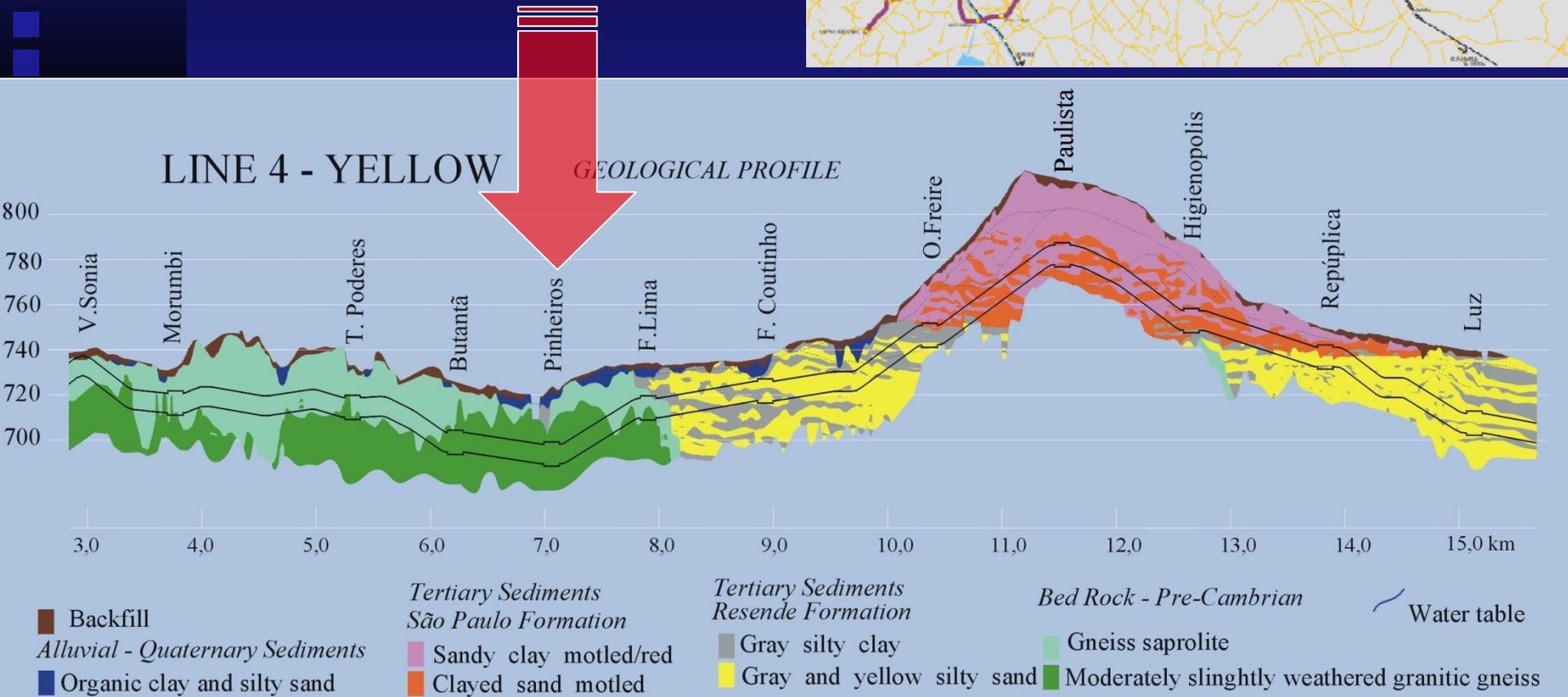
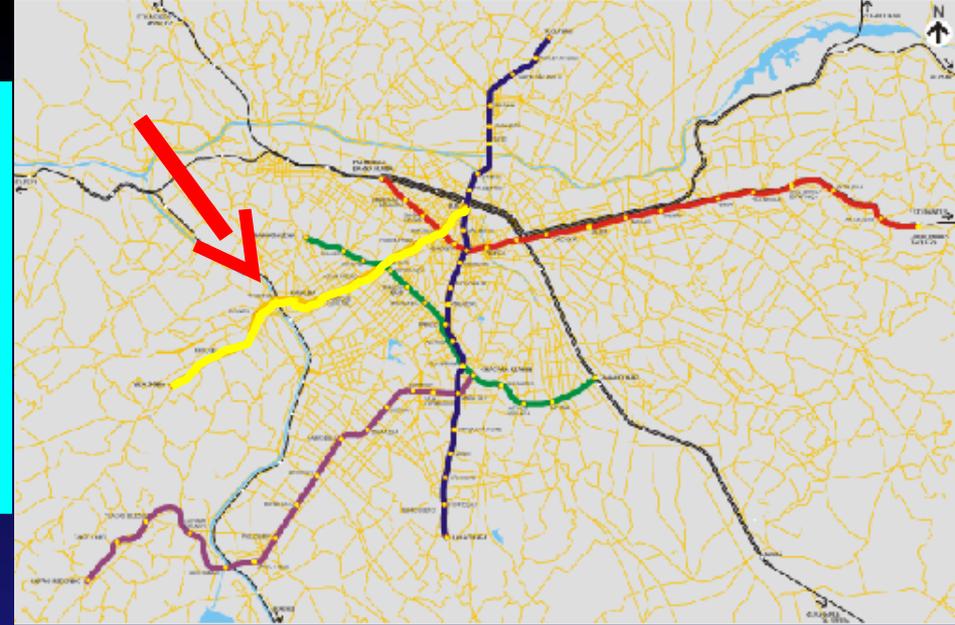


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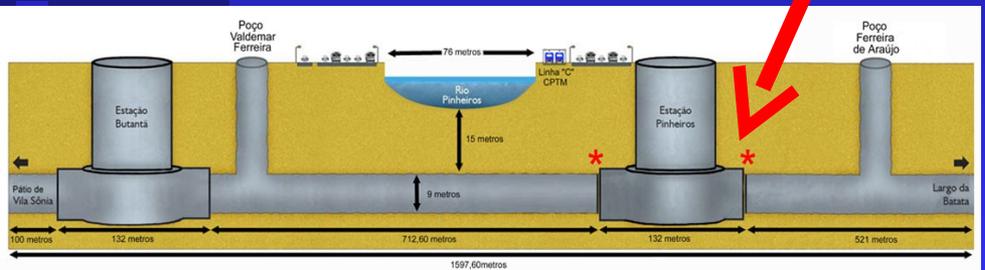
- Introduction
- IPT Investigation Work and Report
- Main IPT Report Findings
- Conclusions and Recommendations



Introduction: SP Metro Line 4

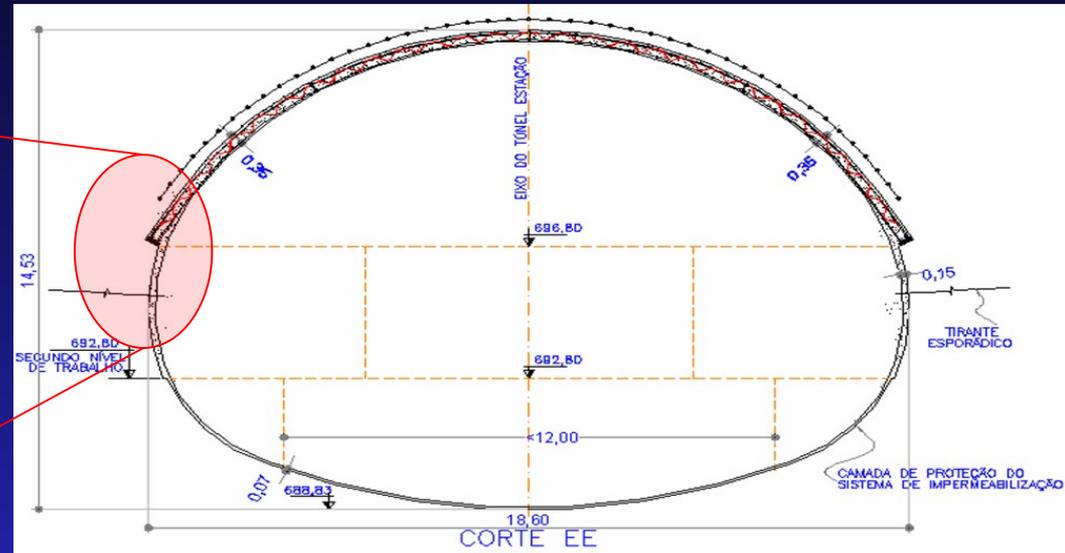
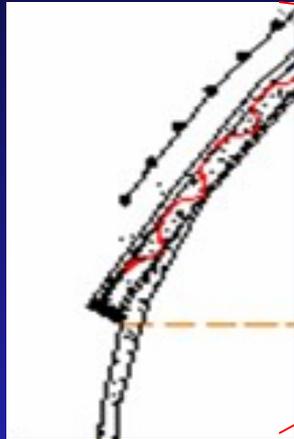


Introduction: Pinheiros Station



Introduction: Pinheiros Station

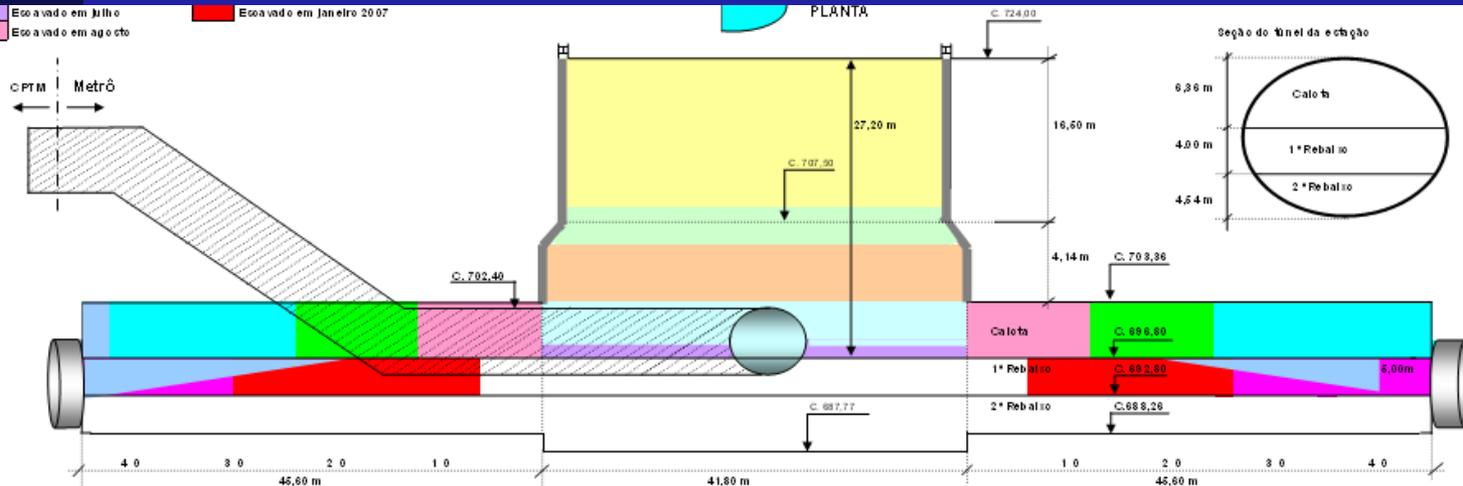
→ Design and Construction



■ Ecoavado em julho
■ Ecoavado em agosto

■ Ecoavado em Janeiro 2007

PLANTA



Introduction: Pinheiros Station Accident

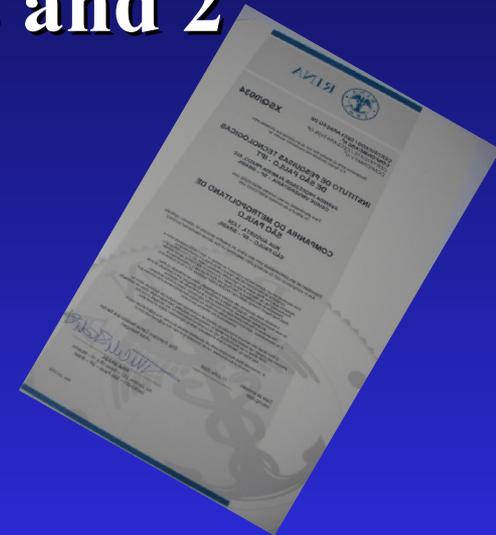


- Occurred on 12/01/2007
- During the bench excavation, very close of arriving to the shaft
- First failure signs ~14h30
- Daylight collapse at 14h54
- **Enormous material damages and 7 fatalities**
- **IPT commissioned the technical investigation**

IPT Investigation Work and Report

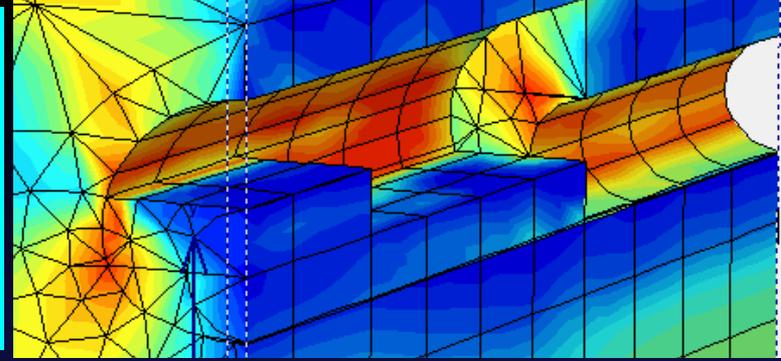


- IPT Commission (team of in-house specialists)
- Board of Consultants (4 Brazilians and 2 foreigners)
- Independent Auditing Firm (Rina International)
- Desk Studies
- Following-up of the collapse debris excavation
- Interviews with involved staff from all parties



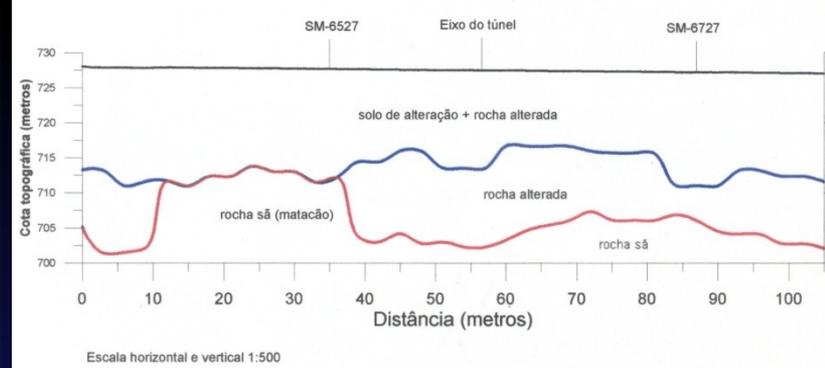


IPT Main Report (06 June 2008)

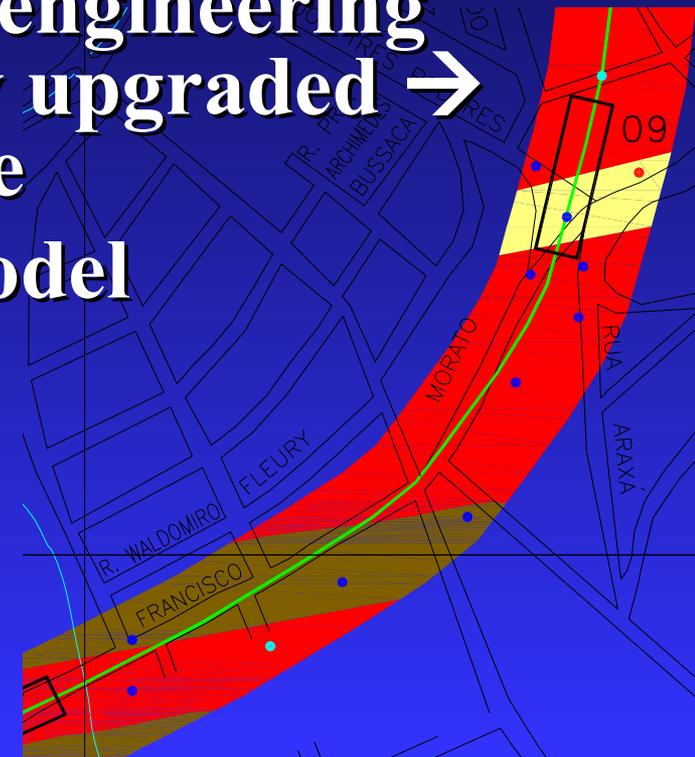


- **Chapters 1-3: Introduction, objectives & scope**
- **Chapter 4: Urban tunnelling**
- **Chapter 5: Trends in contractual practices**
- **Chapter 6: Pre-bidding knowledge**
- **Chapter 7: Contractual aspects of Line 4**
- **Chapter 8: Design and construction**
- **Chapter 9: Collapse**
- **Chapter 10: Mechanism and causes**
- **Chapter 11: Conclusions and Lessons**

IPT Main Report: Pre-Bidding



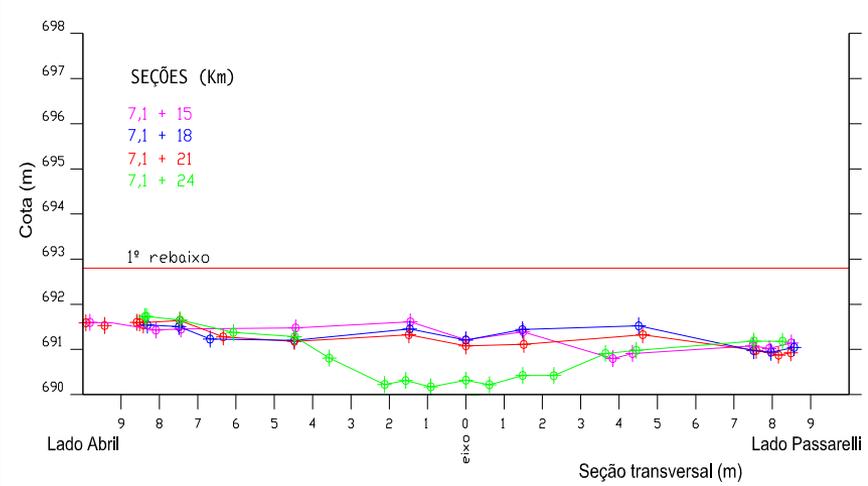
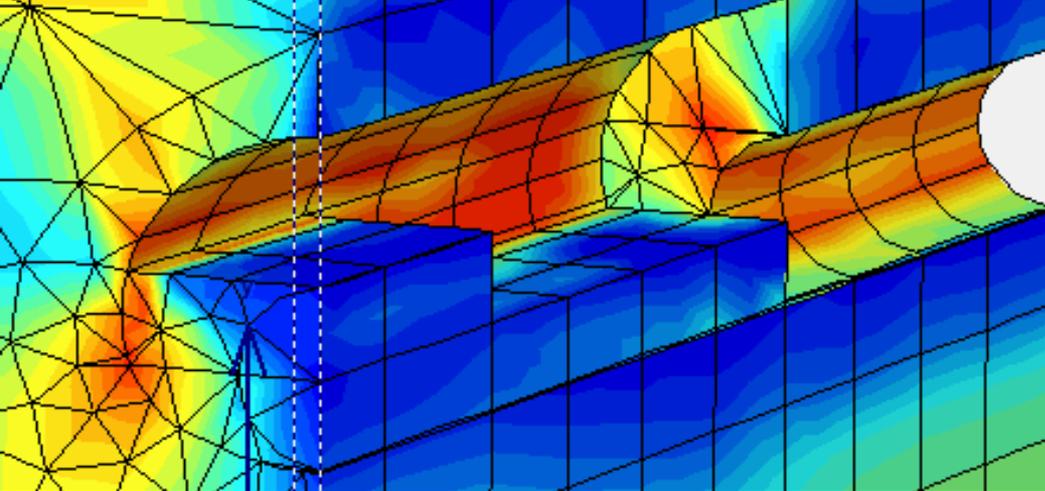
- 10 years of studies till bidding
- the amount of geological and geotechnical investigation and the level of engineering design had been continuously upgraded → very reasonable and adequate
- Geological-geomechanical model
 - Hasui (1993)
 - IPT (1997)
 - Figueiredo Ferraz (2001)



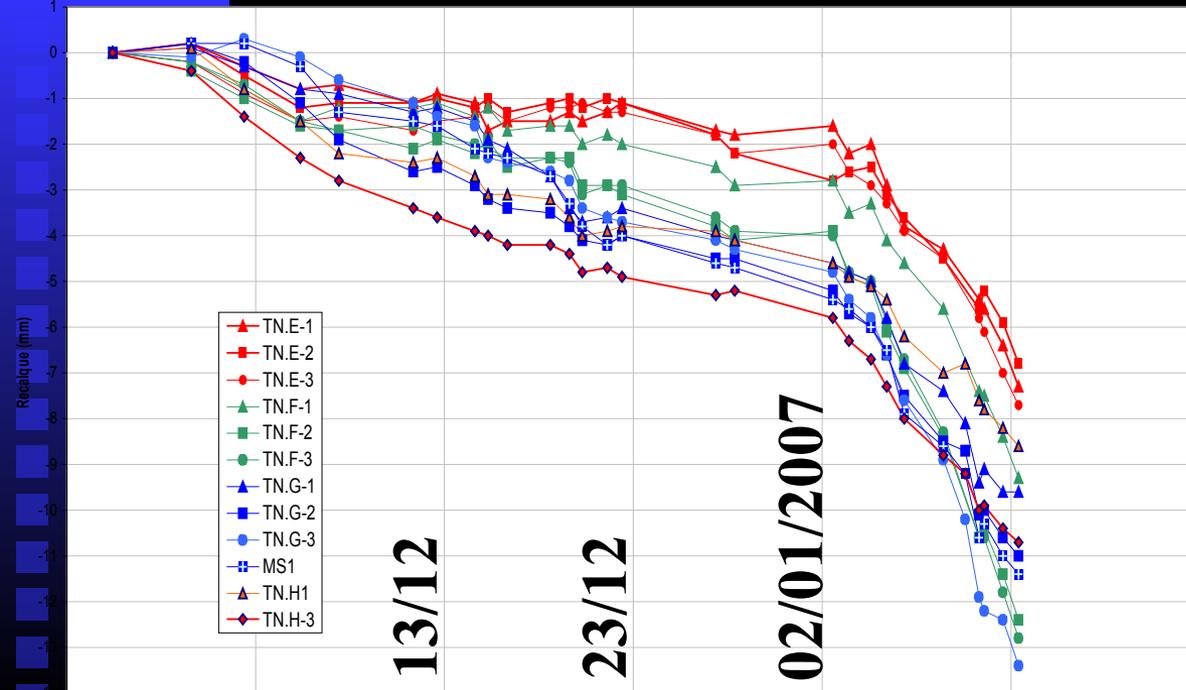
IPT Main Report: Design & Construction

- **GGM for construction**
- **Design**
 - **Geomechanical model adopted**
 - **Assumptions and calculations**
 - **Instrumentation and threshold values**
- **Construction**
 - **Quality control based on self-certification**
 - **Instrumentation data**
 - **Management (contingency and emergency actions)**



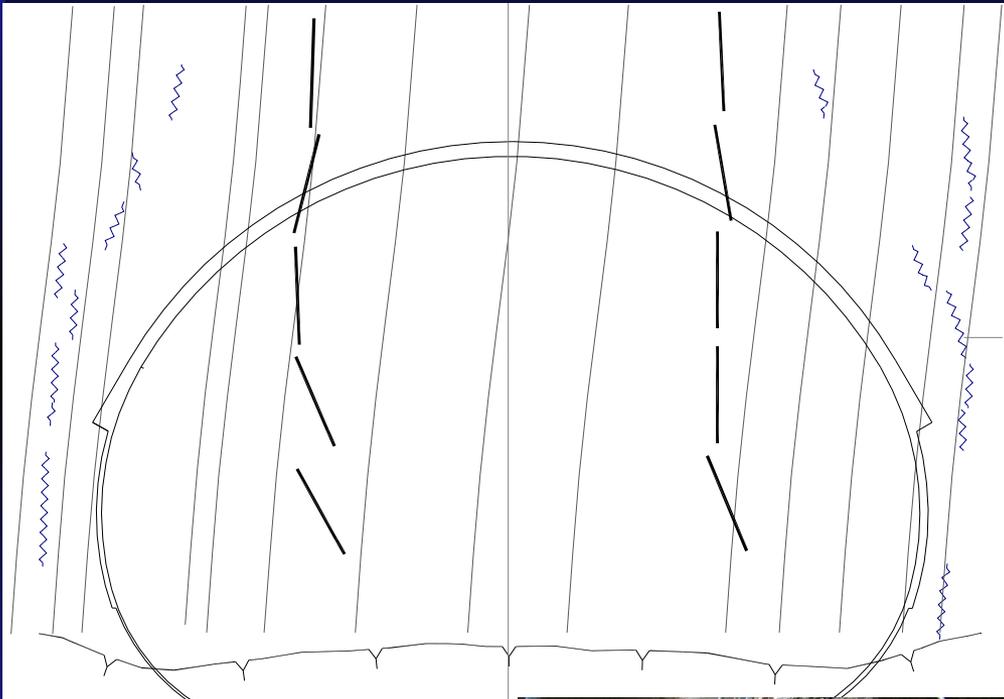


Collapse



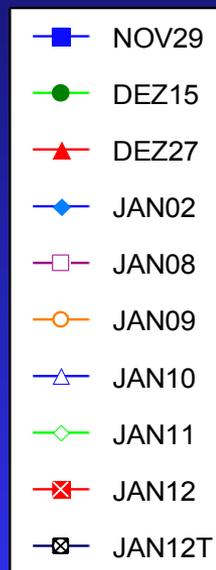
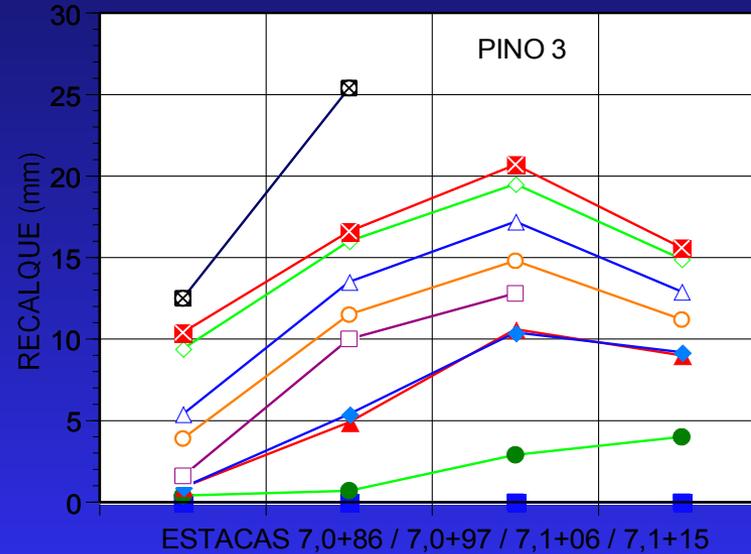
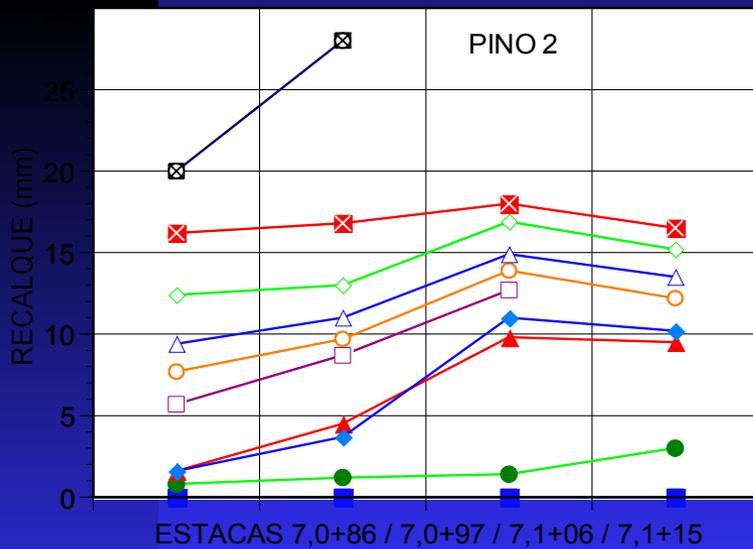
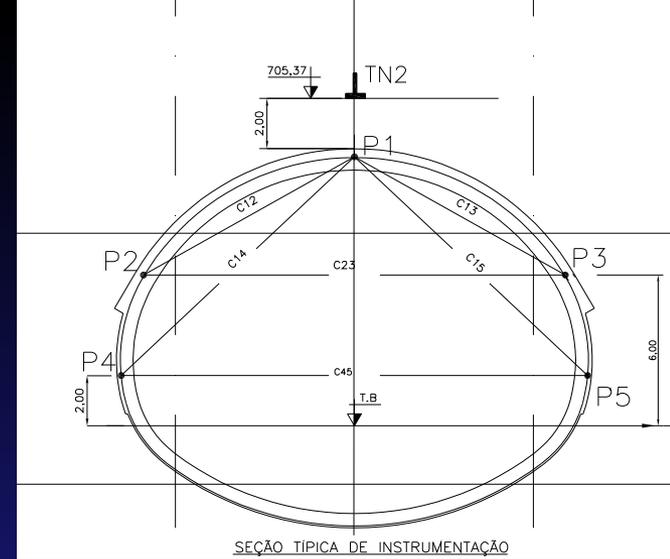
Instrument	Position	Forecasted (mm)	Observed on 11/01/07 (mm)	Observed / Forecasted
Extensometer	Axis	-0,7	-11	17
	Lateral Wall	-0,7	-12	19
Convergence Pins (Settlement)	Axis	-0,7	-7	10
	Upper	-0,9	-20	22
	Lower	-0,5	-7	13
Convergence	△ P2-P3	-0,2	-21	95

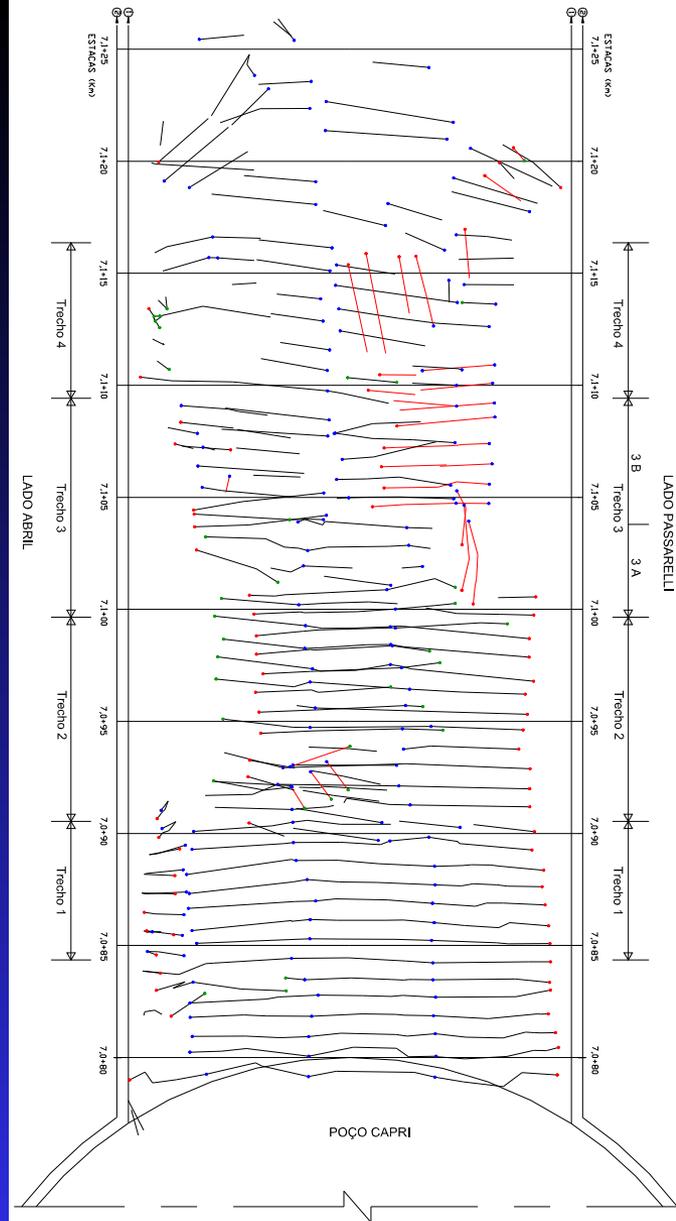
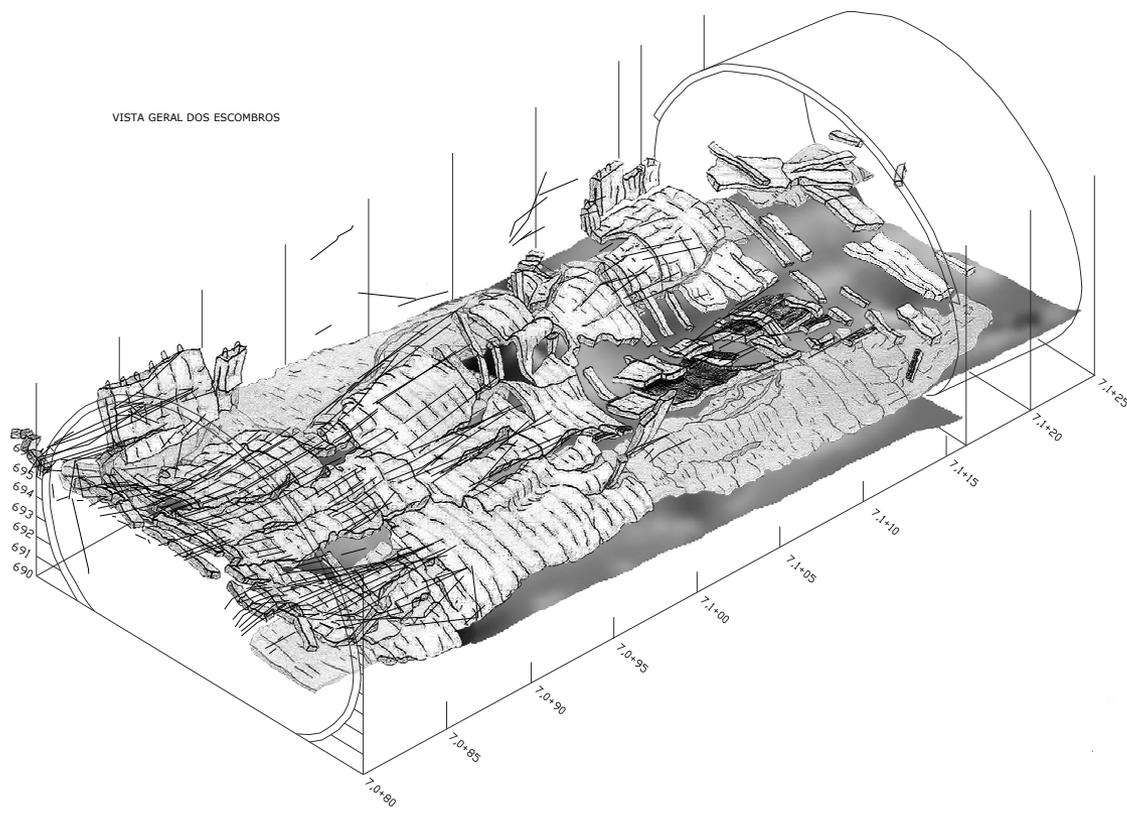
Main Report Findings: Collapse Evidences



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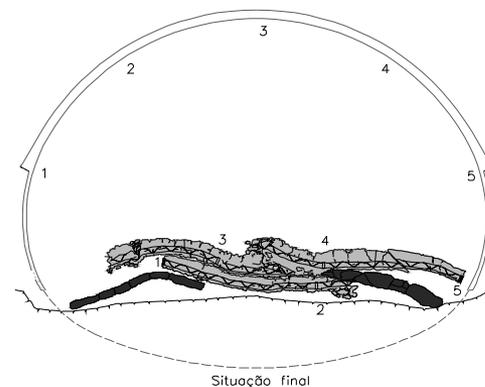
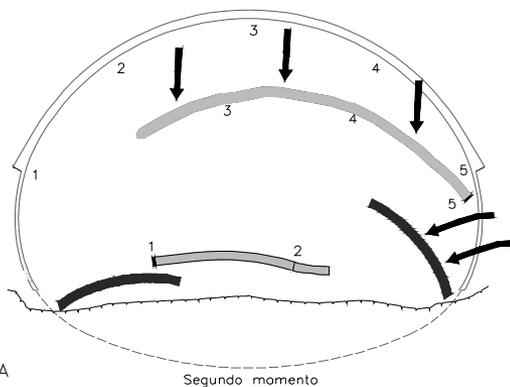
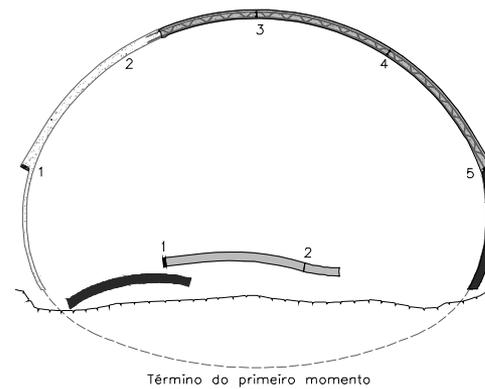
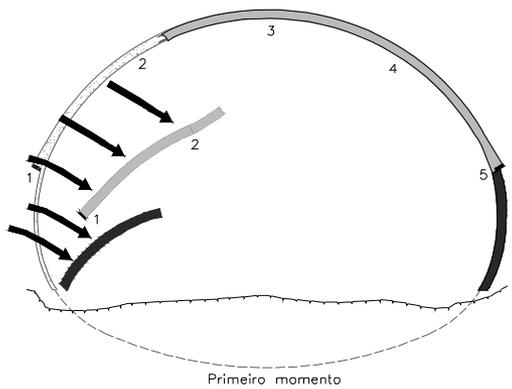
Instrumentation evidences





Main Report Findings: Collapse Evidences

■ Debris position evidences

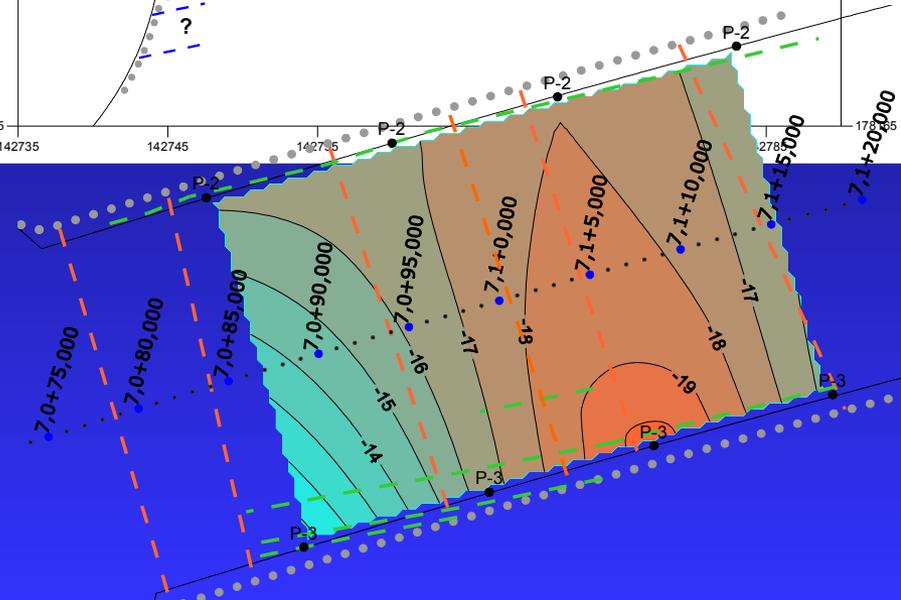
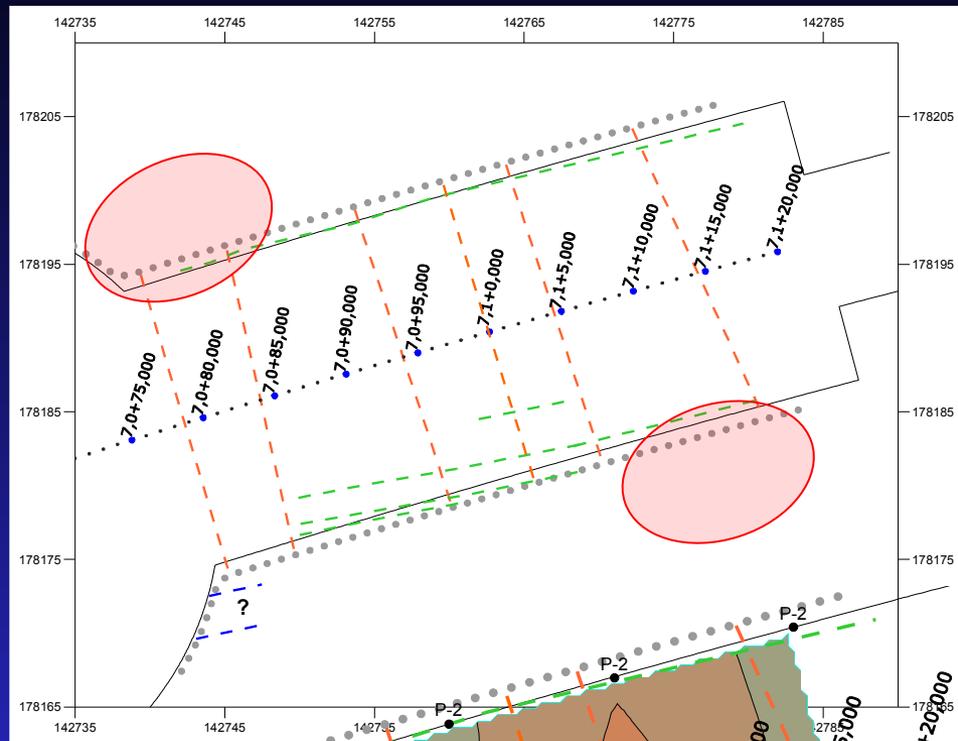
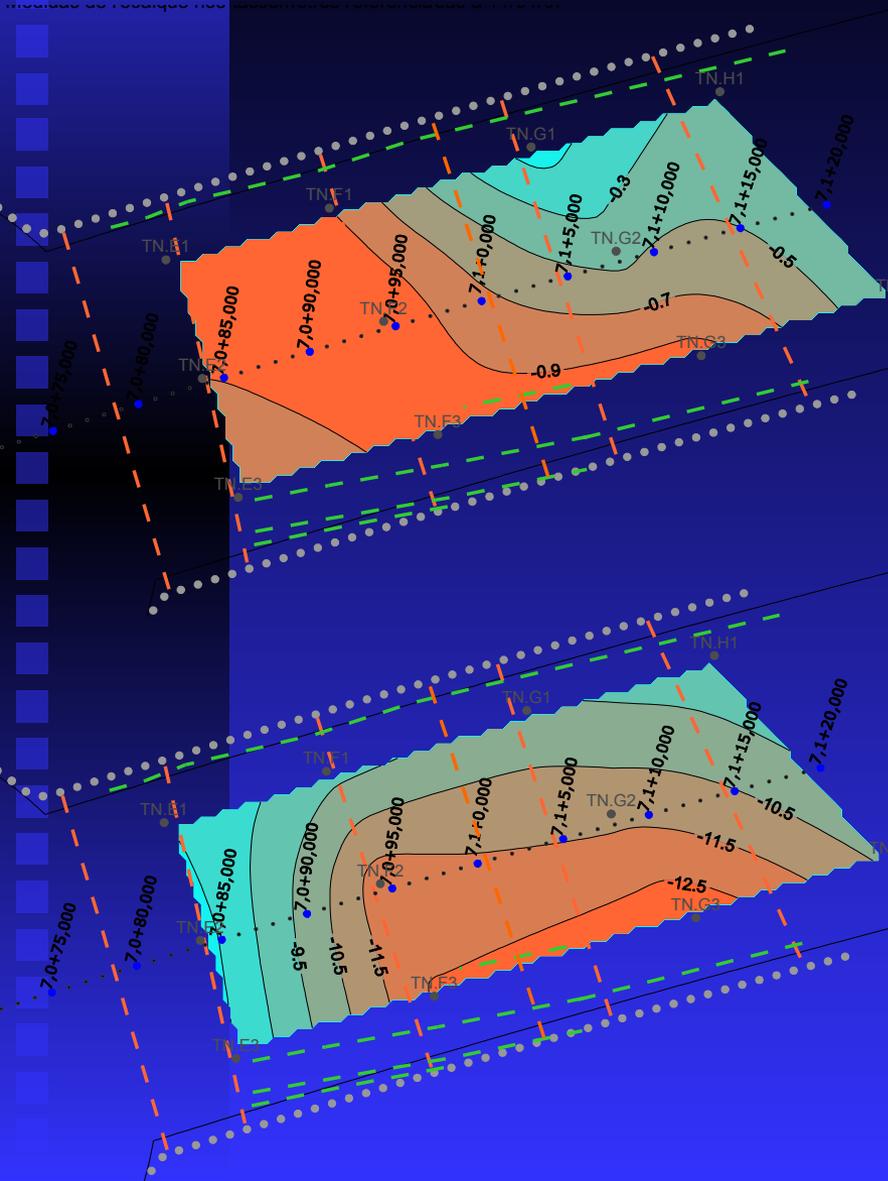


LEGENDA

- ➔ Indicação dos movimentos
- ▬ Parede do rebaixo
- ▬ Calota



Main Findings: Collapse Mechanism



Main Report Findings: Risk Factors and Causes

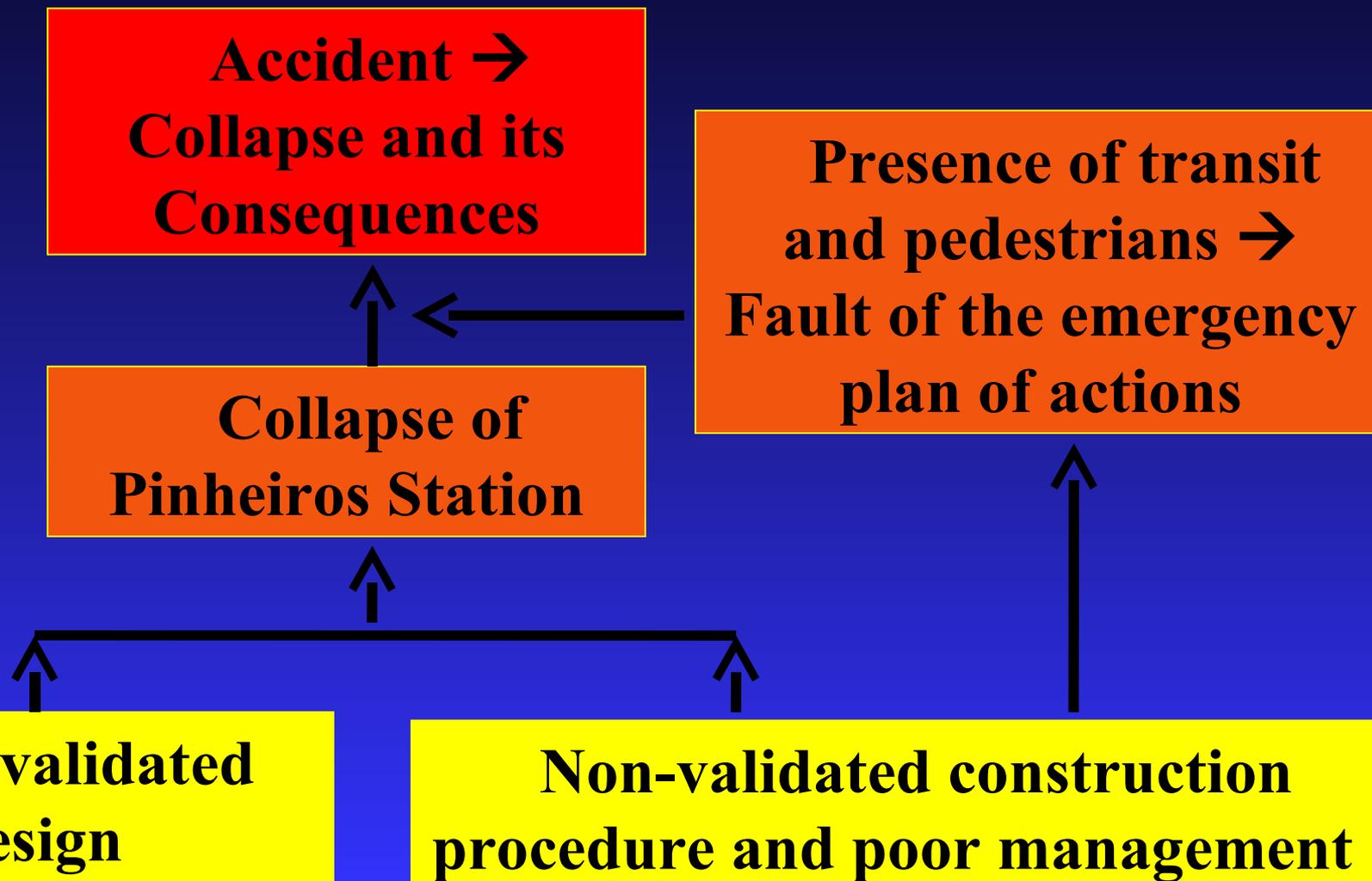
■ Non-Validated Design

- Oversimplified geomechanical model
- Structural tunnel model
- Assumptions and completeness of calculations and simulations
- No definition of threshold values for monitoring
- Deficient GG mapping
- Deficient analysis and interpretation of monitoring data
- No evidence of back-analyses and design validation

■ Non-Validated Construction Procedure

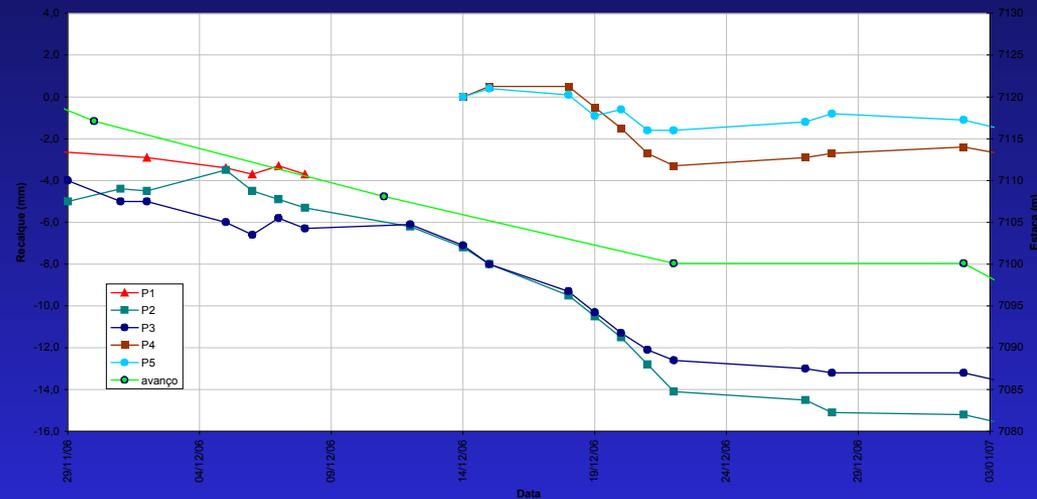
- Change of excavation direction
- Increase of bench height
- Change of blasting scheme
- Deficient quality control
- Increase of excavation rate
- Deficient construction management (lack of bolts)
- No decision to stop works
- Deficient plans of contingency and emergency actions

Main Report Findings: Risk Factors and Causes

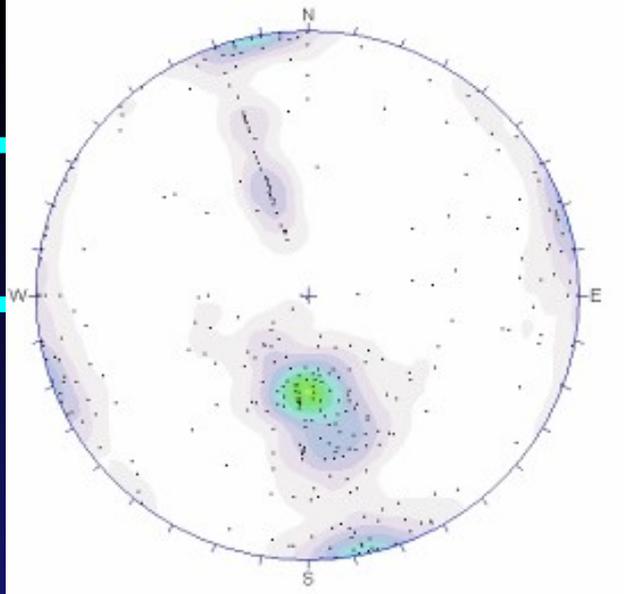


Risk Factors and Causes: Foreseeability and Other Aspects

- Different ground conditions
- Excessive rain
- Seismic activity
- Pipe leakage
- Foreseeability
 - Clear under good practice of engineering
 - Misty by faults in several engineering processes



Conclusions



- Geological model complex but data was fully disclosure → no major changes → by no means claim based on Different Ground Conditions
- Causes are related to faults in engineering processes (design and construction) → systemic fault process
- Lessons and recommendations to engineering and contractual arrangements

Recommendations for Future Contractual Arrangements



- **Keep fair balance among quality, schedule and costs**
- **Mix of technical and performance specifications
→ quality control**
- **Independent auditing and full disclosure of control parameters → owners must keep control**
- **Incorporate risk management and risk sharing**