Geotechnical safety management for tunnels

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WHY SAFETY MANAGEMENT?

- Uncertainties in the ground model
- Spread of parameters
- Simplifications in the design

- Resulting residual risk has to be controlled and managed

UNAVOIDABLE?

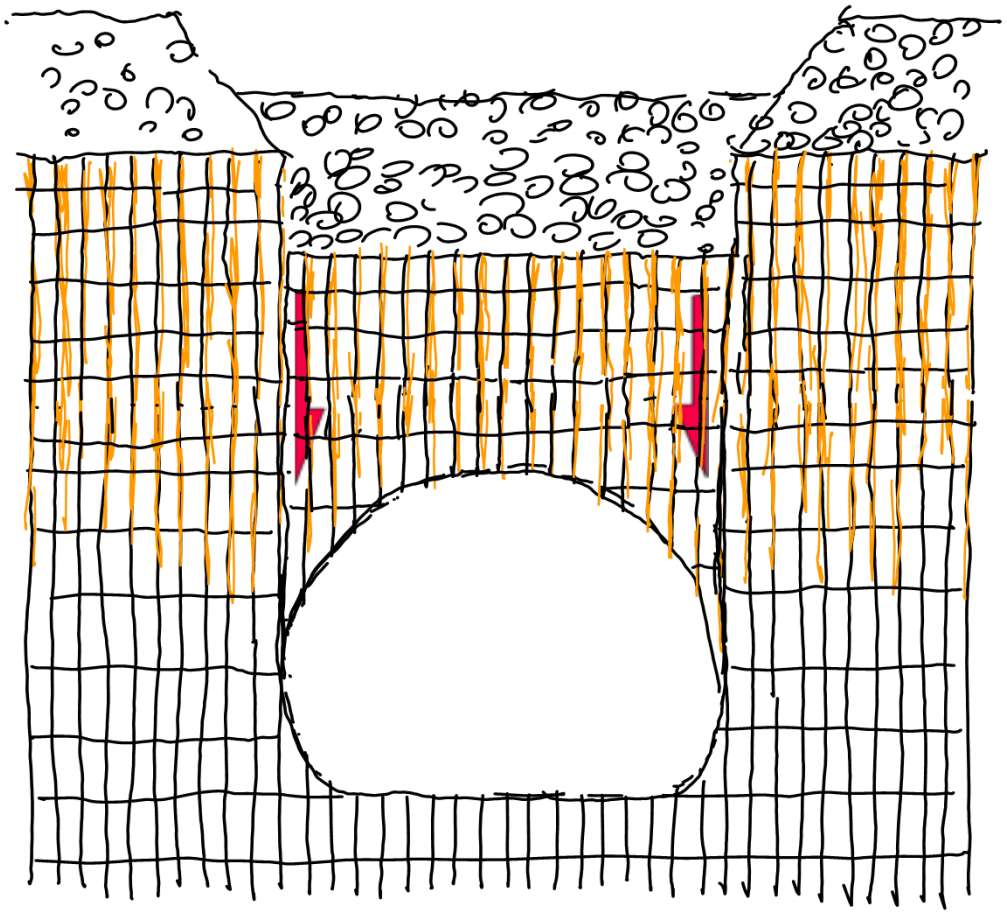
UNAVOIDABLE?

REQUIREMENTS DURING DESIGN

- Assess possible range of behaviour
- Establish acceptable limits for expected behaviour
- Assign construction measures to meet requirements
- Establish concept for assigning excavation and support to ground behaviour and boundary conditions
- Identify safety relevant issues
- Develop targeted monitoring program

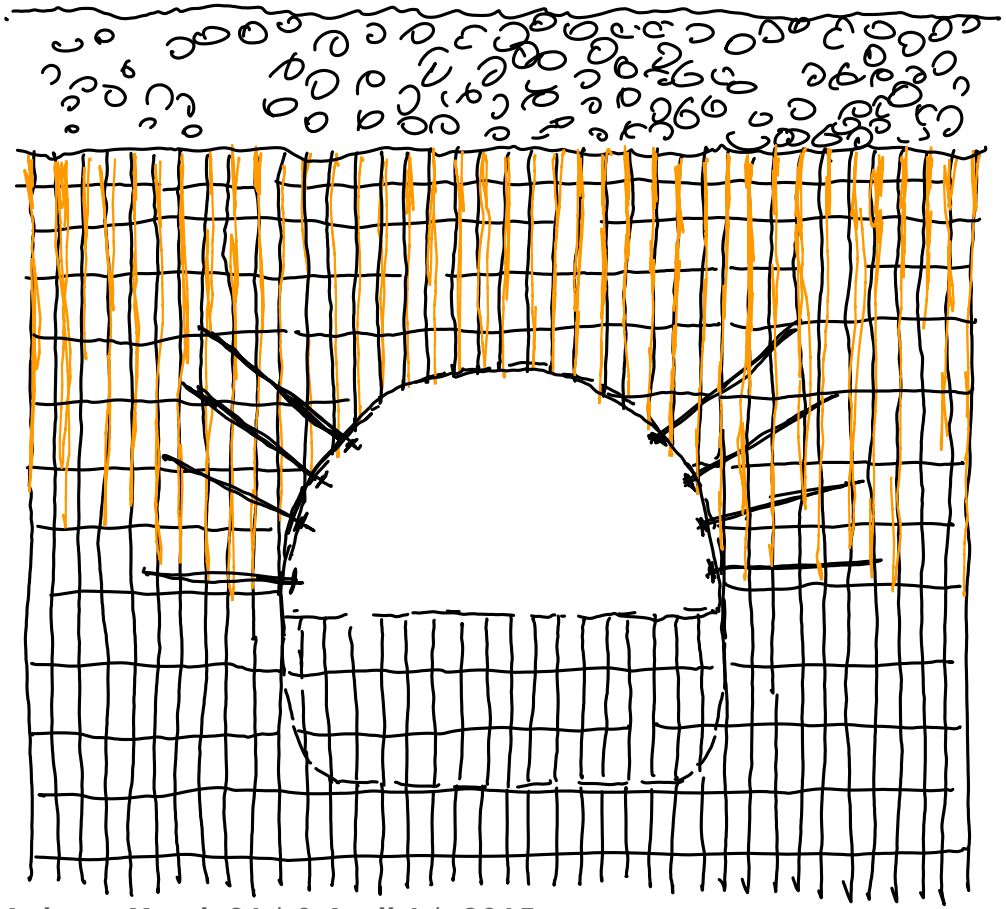
EXAMPLE: POTENTIAL BEHAVIOUR

- Potential failure mode: shearing along vertical joints



ASSIGNMENT OF EXCAVATION AND SUPPORT

- To reduce probability of shearing along vertical joints, bolting in the sidewalls and shoulders is applied

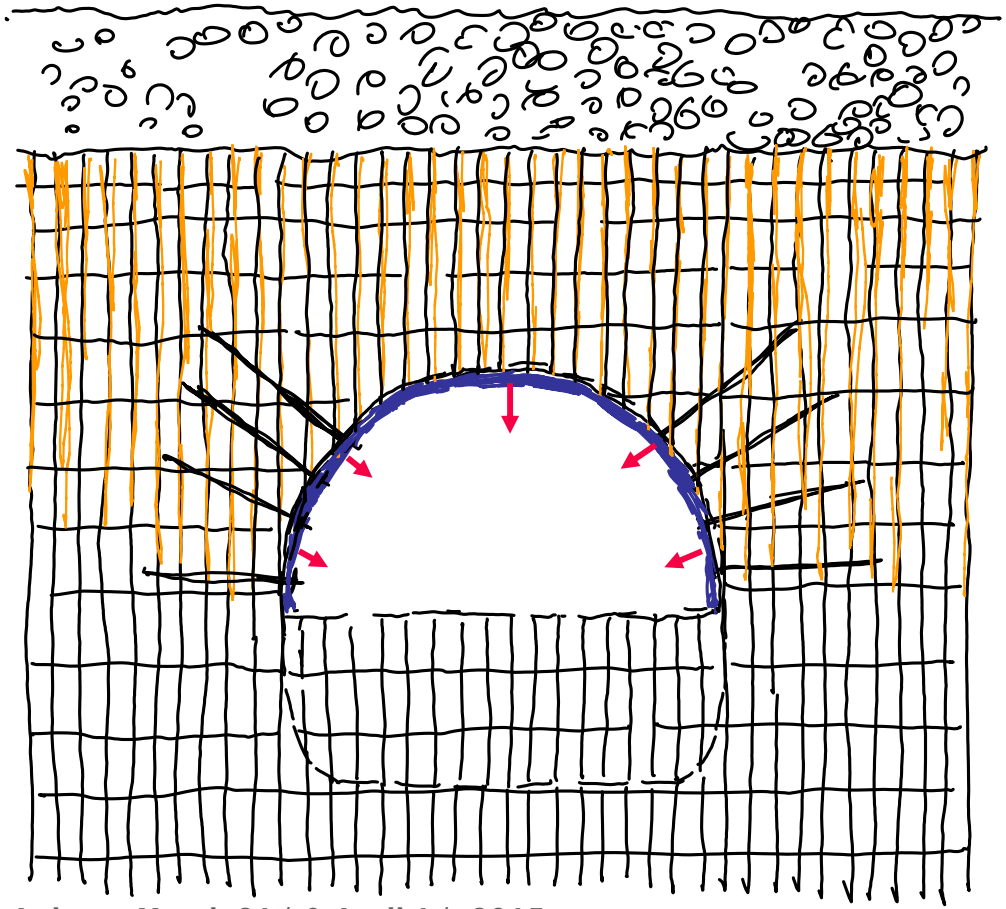


ELEMENTS OF SAFETY MANAGEMENT PLAN

- Detailed definition of expected (target) behaviour for section ahead
- Definition of parameters to be observed, observation methods, layout, reading frequency and evaluation methods
- Definition of warning and alarm levels and criteria
- Definition of contingency measures for each warning level
- Clear definition of responsibilities
- Action plan in case of reaching the alarm level
- Organisation plan and reporting structure

DEFINITION OF TARGET BEHAVIOUR

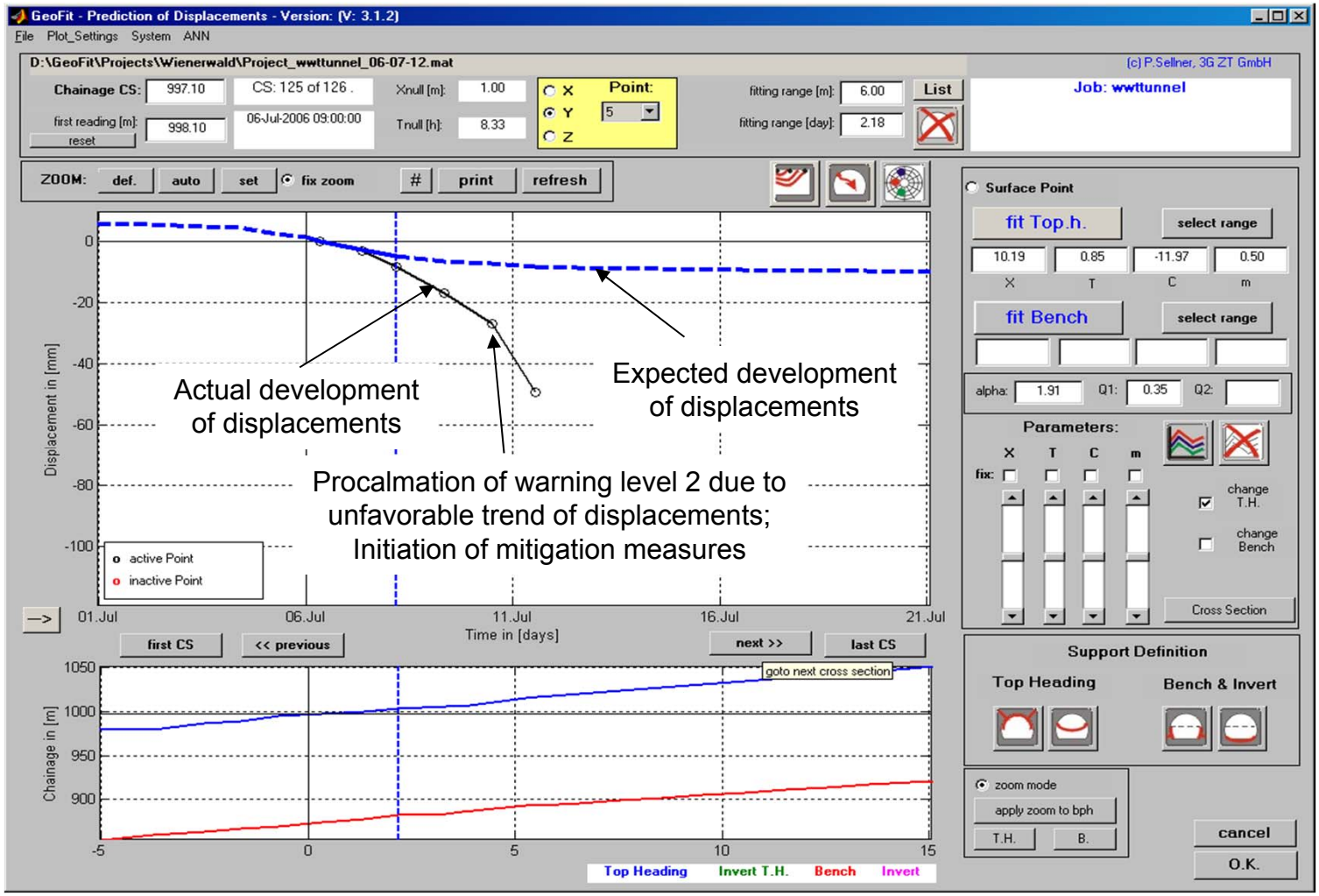
- „Normal" system behaviour can be defined by displacement characteristics or magnitudes



WARNING / ALARM CRITERIA

- Meaningful warning and alarm criteria establishment only possible, if normal behaviour is sufficiently known and defined
- Besides absolute displacement values, development and characteristics of displacements or other monitored values or observations should be defined
- Usually three levels defined:
  - Level 1: warning level reached, but no imminent stability problem
  - Level 2a: imminent stability problem, only site affected
  - Level 2b: imminent stability problem, effects on third parties expected

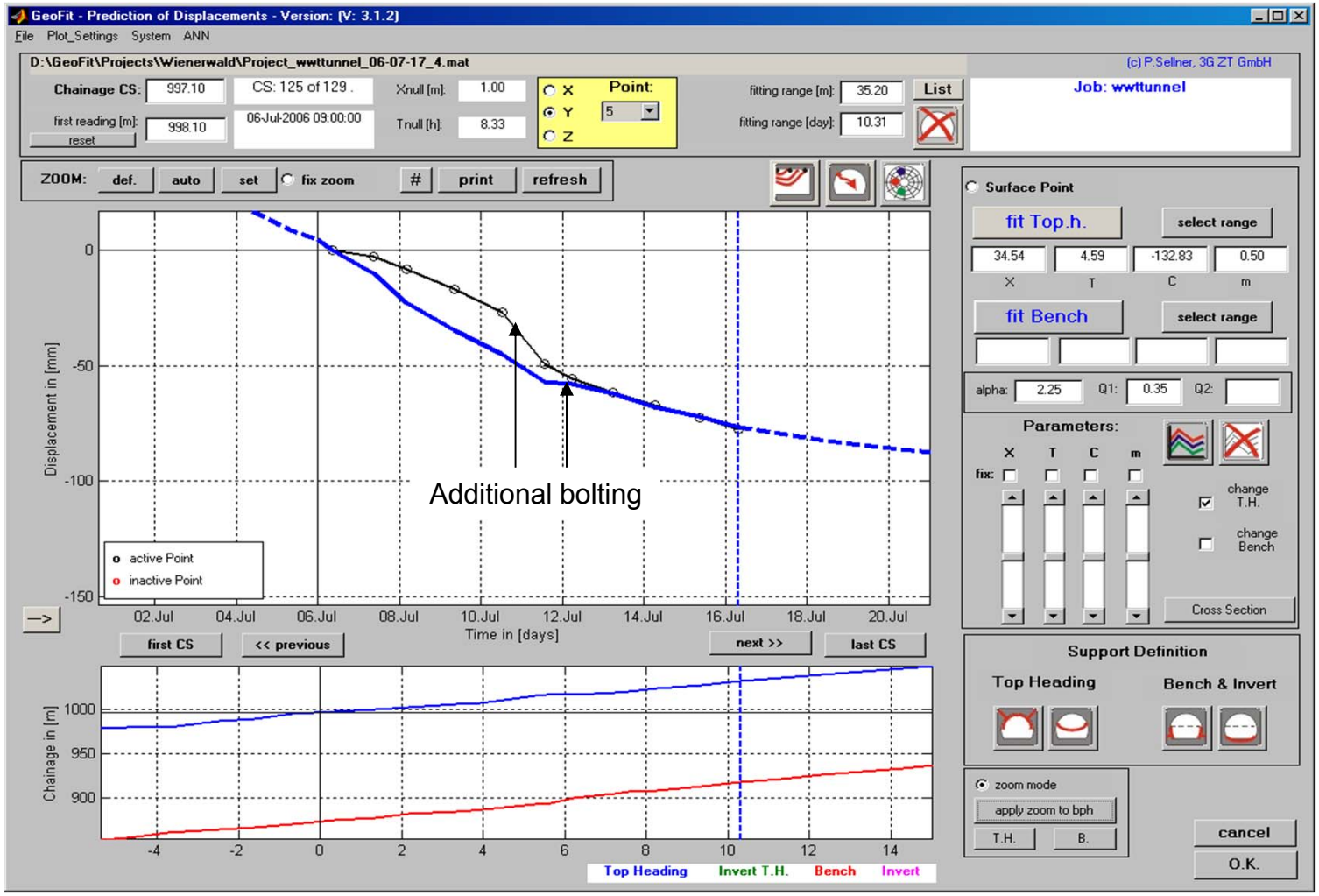
CASE HISTORY



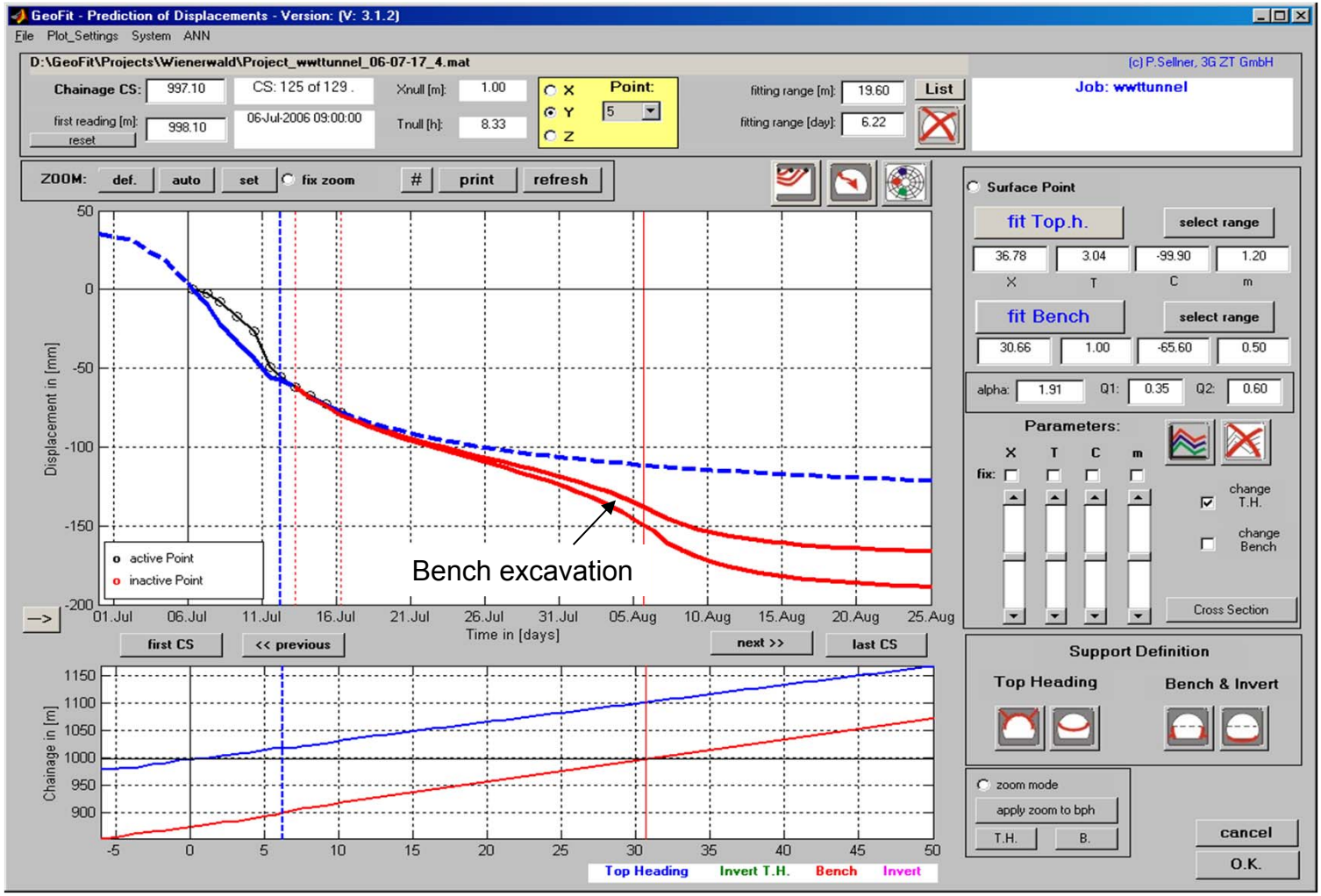
CONTINGENCY MEASURES

- Additional bolting on a length of about 20m was ordered and executed immediately
- A set of additional measures, like installation of a temporary top heading invert was prepared, should the initial mitigation measures not show satisfying effect

EFFECT OF MITIGATION MEASURES



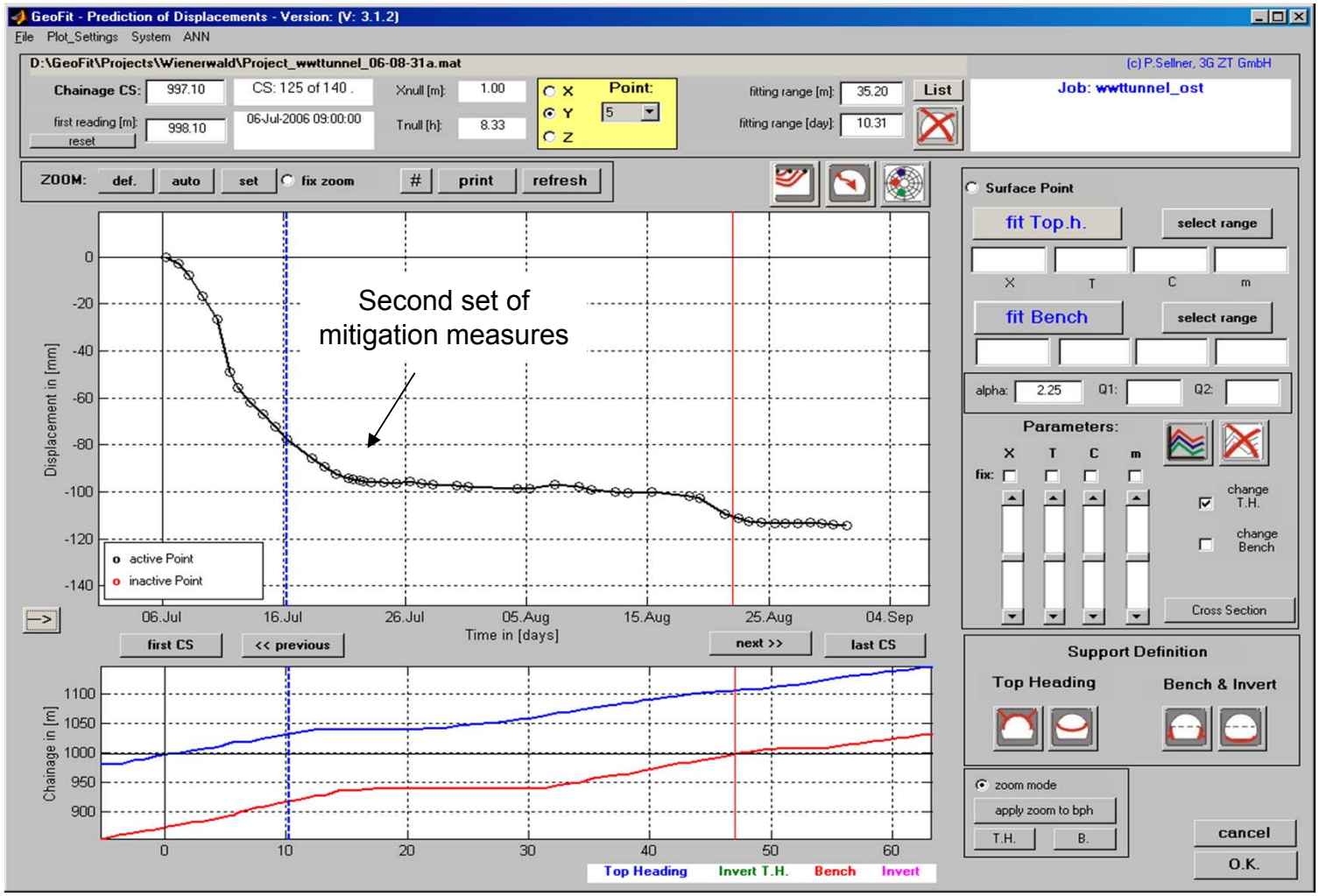
PREDICTION OF FURTHER DEVELOPMENT



FURTHER DEVELOPMENT

- Initial mitigation measures effective, but expected total displacements likely to exceed the allowed deformation
- To keep within deformation tolerance, top heading invert installed
- This measure stopped deformations practically completely

FURTHER DEVELOPMENT



CONCLUSION

- To efficiently reduce the unaviodable residual risk during tunnelling, besides a sound preparation in the design phase, a safety management procedure during construction is required
- Modern monitoring and data evaluation methods have considerably expanded the applicability of the observational approach, but cannot replace sound engineering

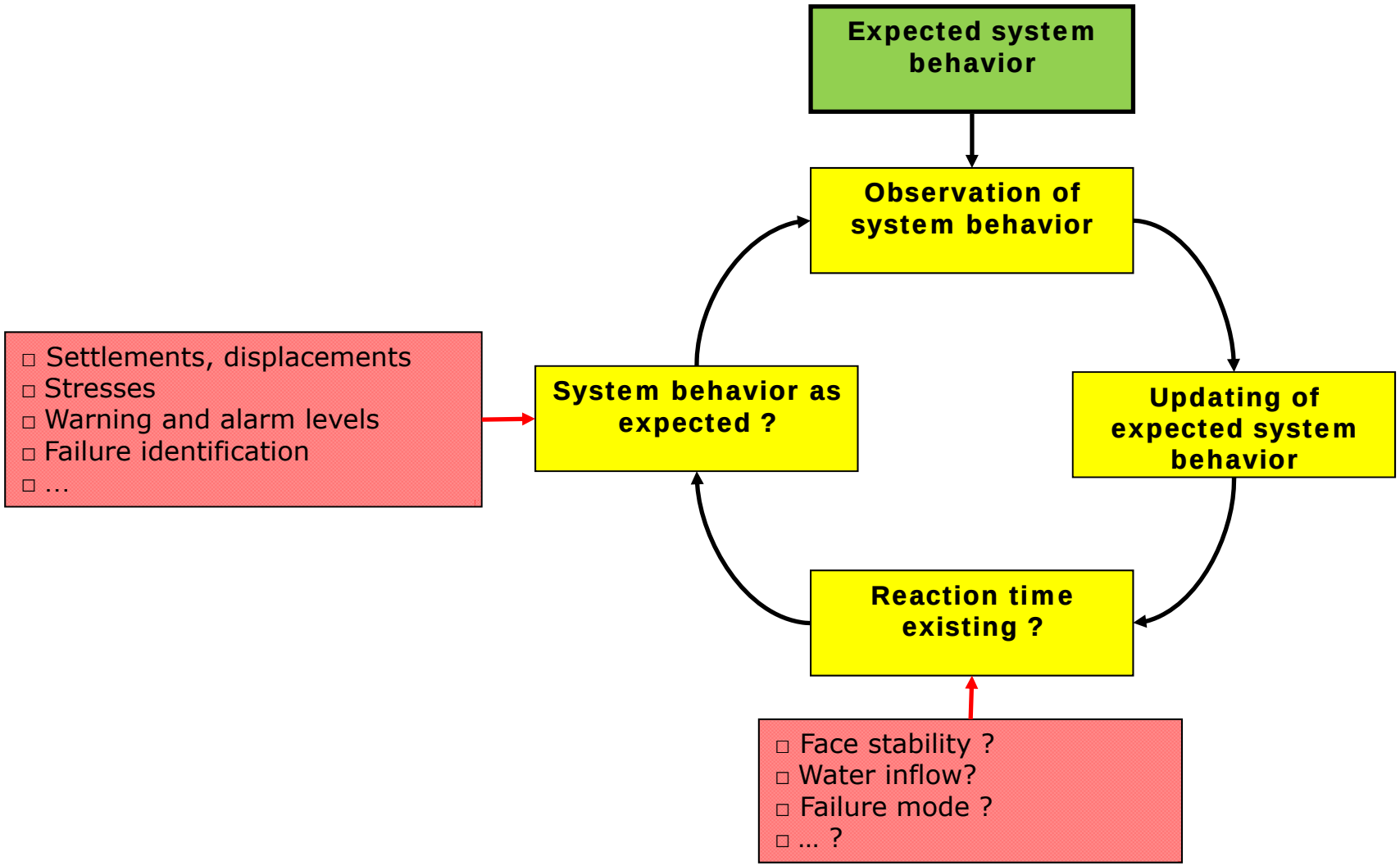
Geotechnical safety management plan

Expected/ determined system behavior

- Identification of safety relevant issues
- Definition of parameters to be observed, observation methods, layout, reading frequency, and evaluation methods
- Definition of warning and alarm levels and criteria
- Definition of contingency measures for each warning level
- Action plan in case of an alarm
- Organization plan and reporting structure
- Up-dating if necessary

Remark: this is also recommended for TBM tunneling!

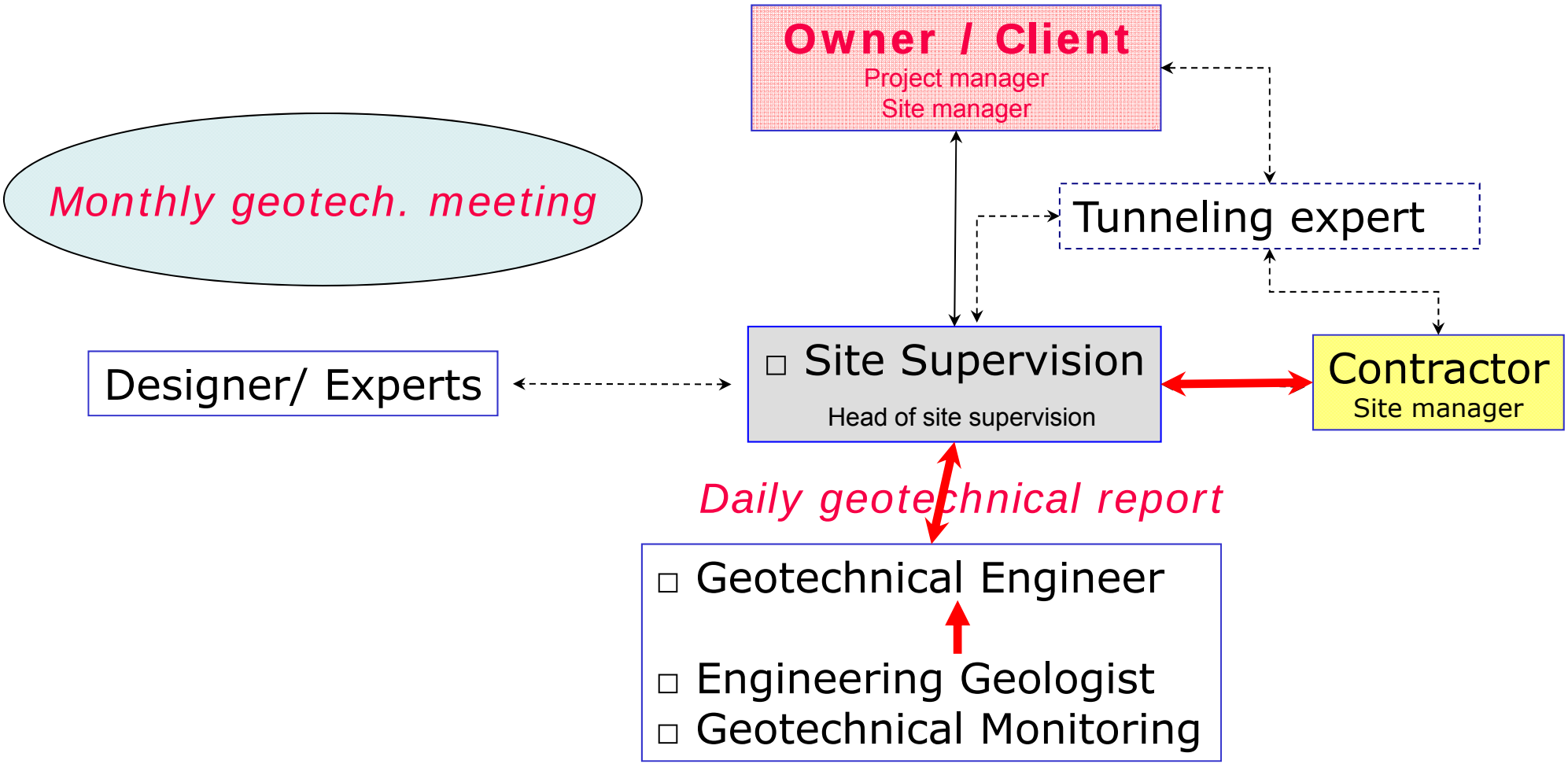
Geotechnical safety management plan – Organization plan and reporting



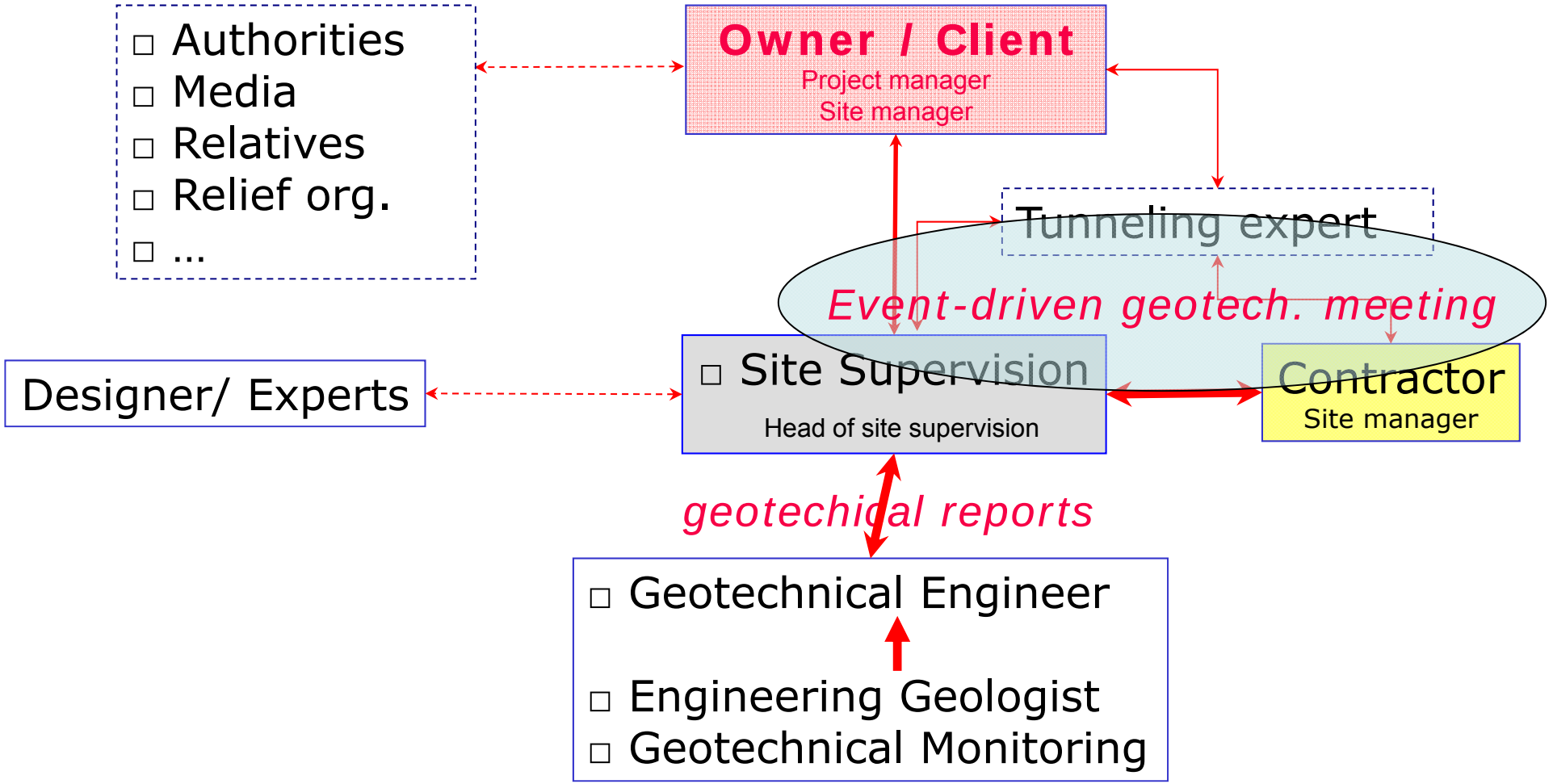
Geotechnical safety management plan - Priorities

1. Protection of public safety
2. Protection of all members of the project team
3. Protection of stability of structure

Geotechnical safety management plan – Organization plan and reporting – "NORMAL BEHAVIOR"



Geotechnical safety management plan – Organization plan and reporting – "ABNORMAL BEHAVIOR"



Many thanks for your attention!