OBSERVATIONAL APPROACH IN TUNNELLING-

NECESSITY OF TIMELY MONITORING BY INSTRUMENTATION

by

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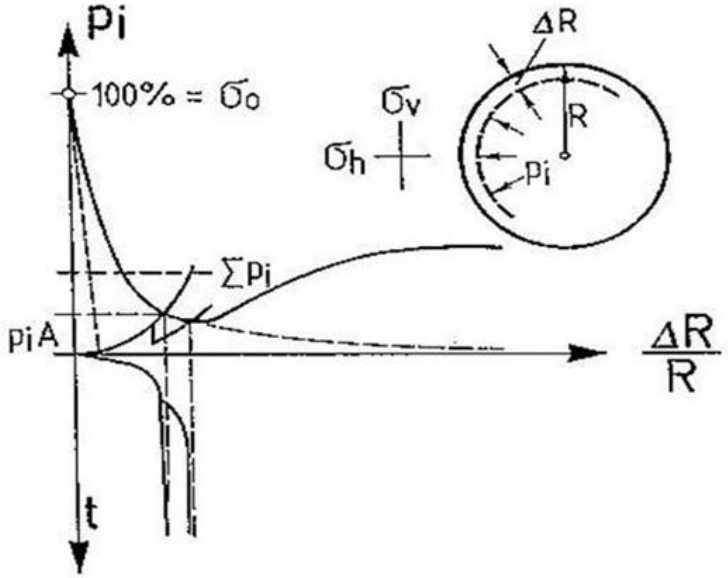
AGENDA

1. NATM - HISTORY, BACKGROUND, PRINCIPLES
2. INSTRUMENTATION & MONITORING
3. OBSERVATIONAL APPROACH
4. TYPES OF MONITORING IN NATM TUNNELLING
5. SOFTWARE PRODUCING EVALUATION REPORTS WITH INTEGRATED INFORMATION
6. CONCLUSION

NATM

THE NEW AUSTRIAN TUNNELLING METHOD FOLLOWS A CONCEPT WHERE THE ROCK MASS SURROUNDING THE EXCAVATION IS CONSIDERED AS LOAD BEARING STRUCTURE BY ACTIVATION OF A STRESS BEARING ROCK MASS ARCH.

OPTIMIZING SUPPORT REQUIREMENTS

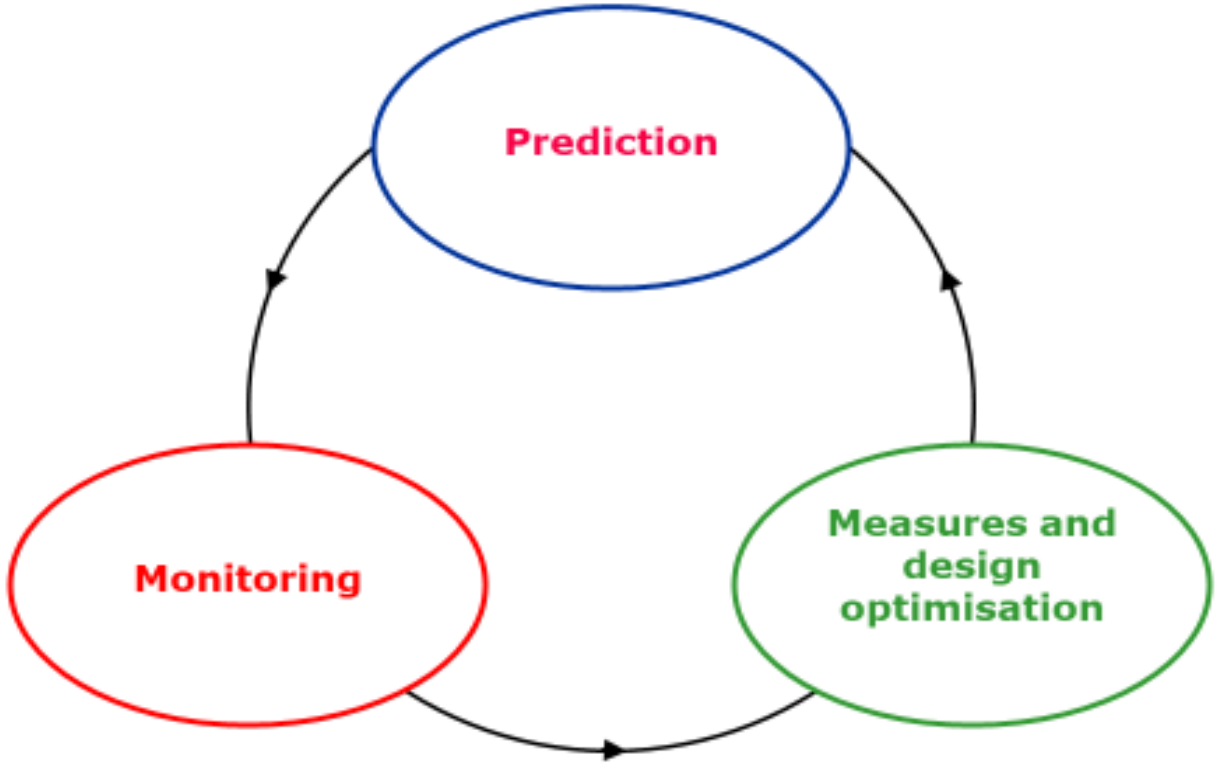


- The Fenner-Pacher curve shows the relationship between the deformation ΔR/R and required support resistance Pi. Simplistically, the more deformation is allowed, the less resistance is needed. In practice, the support resistance reaches a minimum at a certain radial deformation, and support requirements increase if deformations become excessive.
- Fenner-Pacher-type diagrams can be generated to help evaluate the support methods best suited to the conditions.

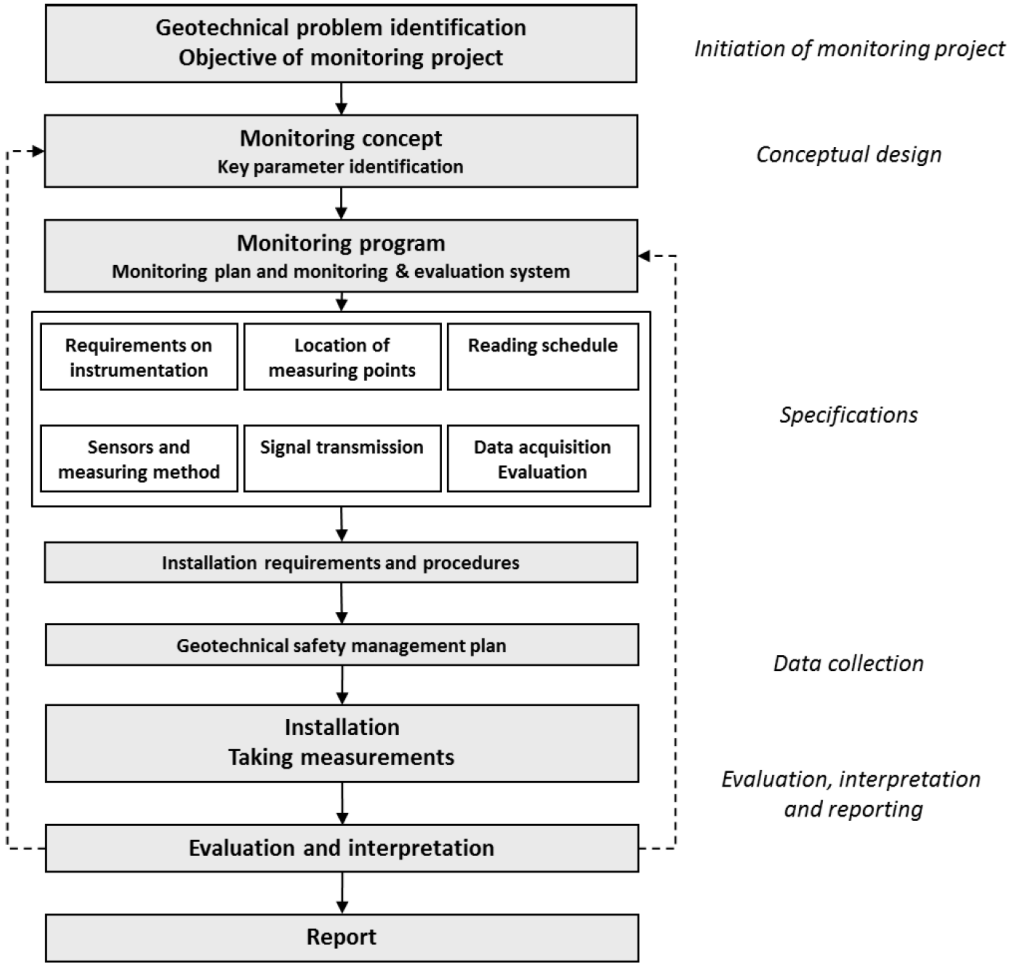
NATM PROCESS

- FIRST FLEXIBLE, THIN SUPPORT TO ALLOW ROCK MASS THE POSSIBILITY OF DEFORMATION TO REDUCE ROCK PRESSURE
- AFTER REDUCTION OF ROCK PRESSURE INSTALLATION OF FINAL SUPPORT
- OPTIMIZATION OF THIS PROCESS BY MEANS OF OBSERVATION AND MONITORING
- WATERPROOFING BEFORE INSTALLATION OF FINAL LINING

Instrumentation & Monitoring <–> Observational Method



Development of an instrumentation program

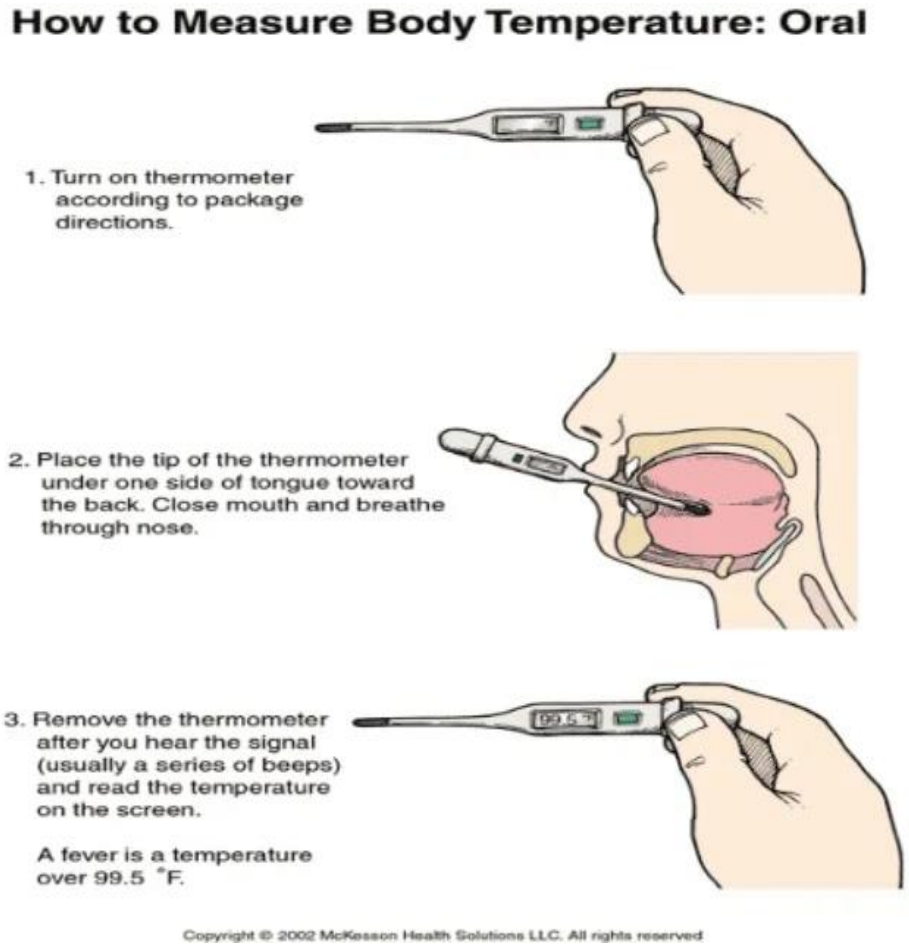


I & M produce huge loads of data:

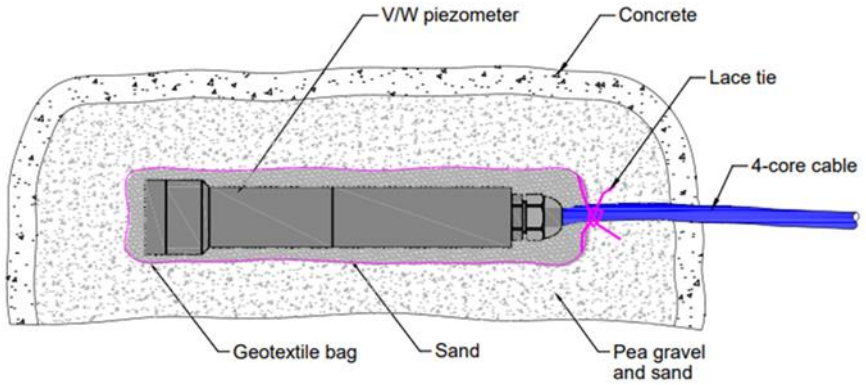
We use instruments but do not make use of instruments

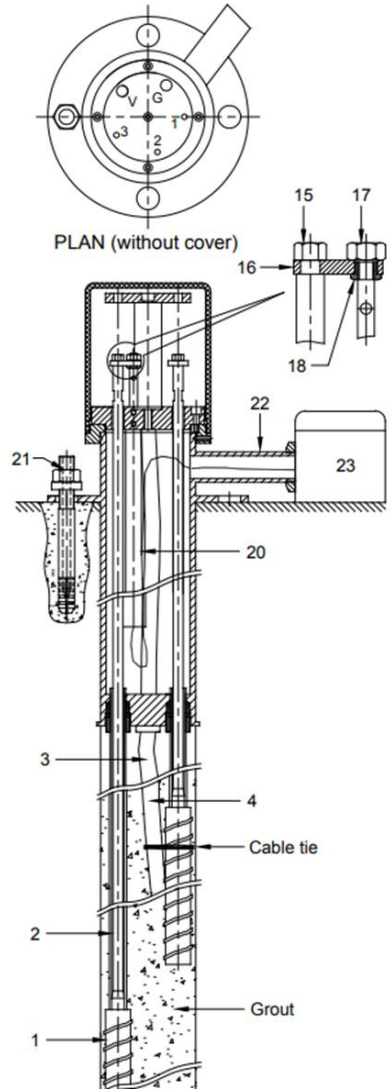
- Faith in instruments
- Use of Monitoring Software

Cityringen, Metro Copenhagen	
Type of instrument	No. of measurem. 4 years of construction
Geodetic (Levelling, 3D)	78.653.534
Borehole Instruments (Inclinometer, Extensometer)	1.099.265
Other Geotechnical Instrumentation (Strain Gauges, Load Cells, Tilt Meter, Liquid Levelling, Crack Meter)	40.689.833
Water Level and Pore Pressure	103.241.337
Water Properties (Chemical Analysis, Performance Parameters Water Management)	44.184.157
Others	12.383.043
TOTAL	280.251.169



How to measure Blood Pressure


V/W piezometer
Concrete
Lace tie
4-core cable
Geotextile bag
Sand
Pea gravel and sand


PLAN (without cover)
15
17
16
18
22
23
21
20
3
4
Cable tie
2
Grout
1

Geotechnical Instrumentation:

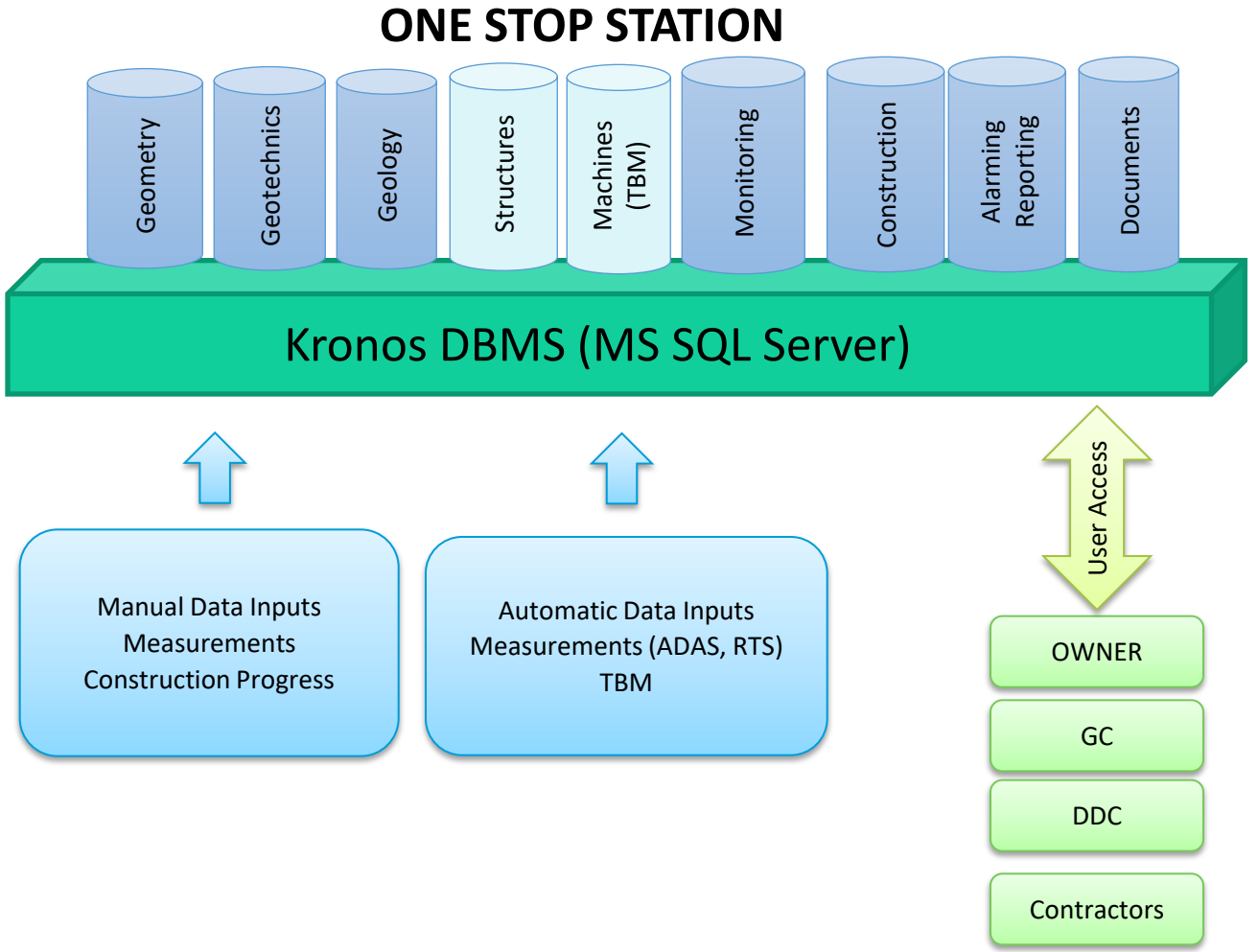
Commonly ignored aspects

- Identification of requirements and development of instrumentation program
- Importance of specifications of instruments
- Importance of methodology of installation
- Pre-dispatch, pre-installation & post installation inspections
- Observing data regularly as per prescribed methodology
- Through appropriate Software, Presentation of the data in near real-time, and making available integrated information, automated alarming and simultaneous reporting to various groups of users
- The corrective actions
- Abandoning approach to instruments as just a formality

Tunnelling Asia' 2022

Workshop on

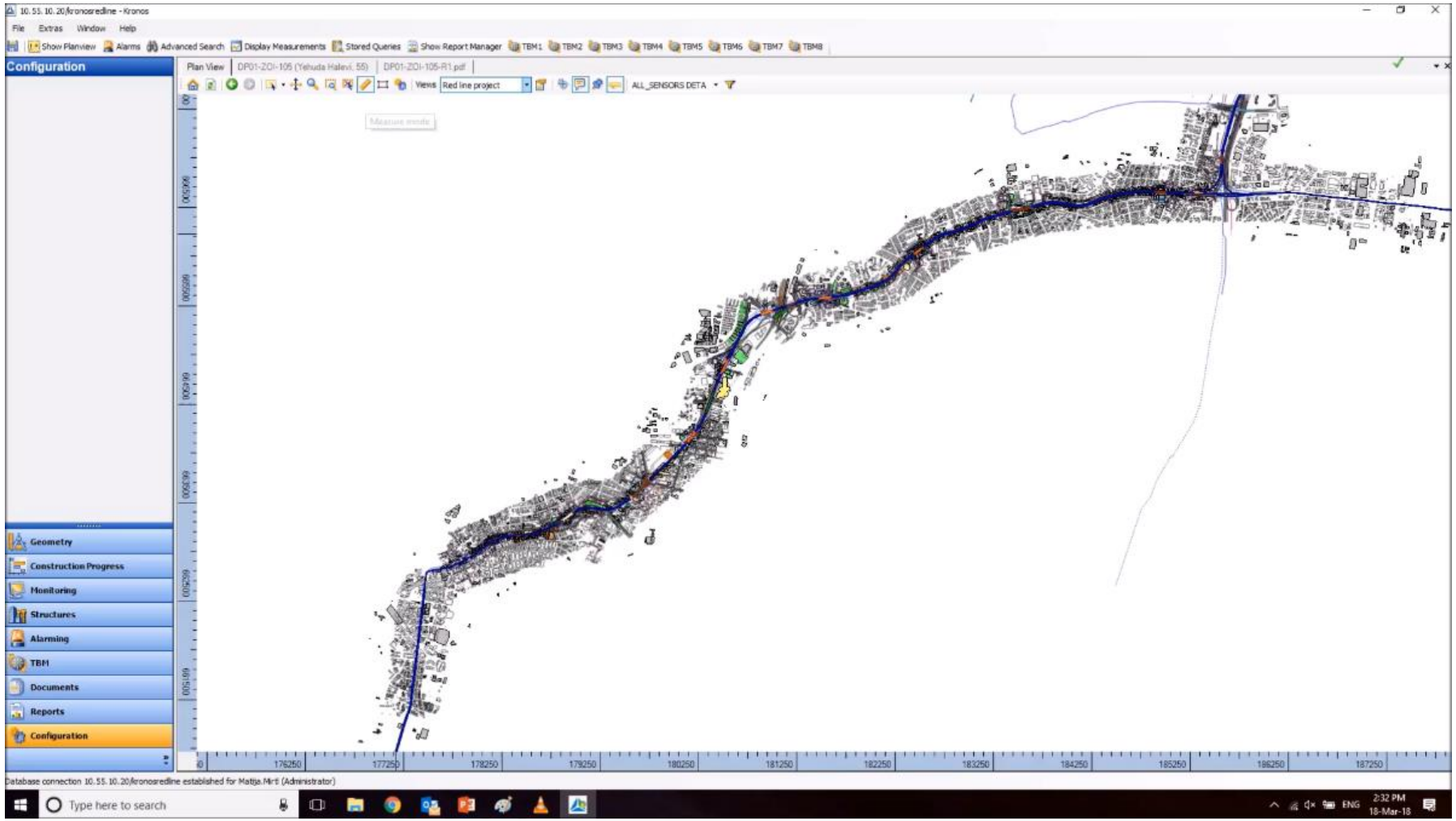
Observational Approach in Tunnelling: Evolvement, Issues and Challenge



June 24th – 25th 2022, Mumbai, India

ACCESSIBLE FROM PLAN VIEW OR MENU BAR

- PAN, ZOOM AND MEASURE FUNCTION
- CONSTRUCTION PROGRESS INCLUDING
- LIVE MODE OF REFRESHING CHANGING DATA
- COMPLETE BUILDING INFORMATION
- ALL MEASURING SENSOR INFORMTION AFTER PROCESSING
- GRADUATED SYMBOLS
- POINT SELECTION DIRECTLY FROM PLAN VIEW


Configuration
Geometry
Construction Progress
Monitoring
Structures
Alarming
TBM
Documents
Reports
Configuration
Plan View
Red line project
ALL_SENSORS DETA

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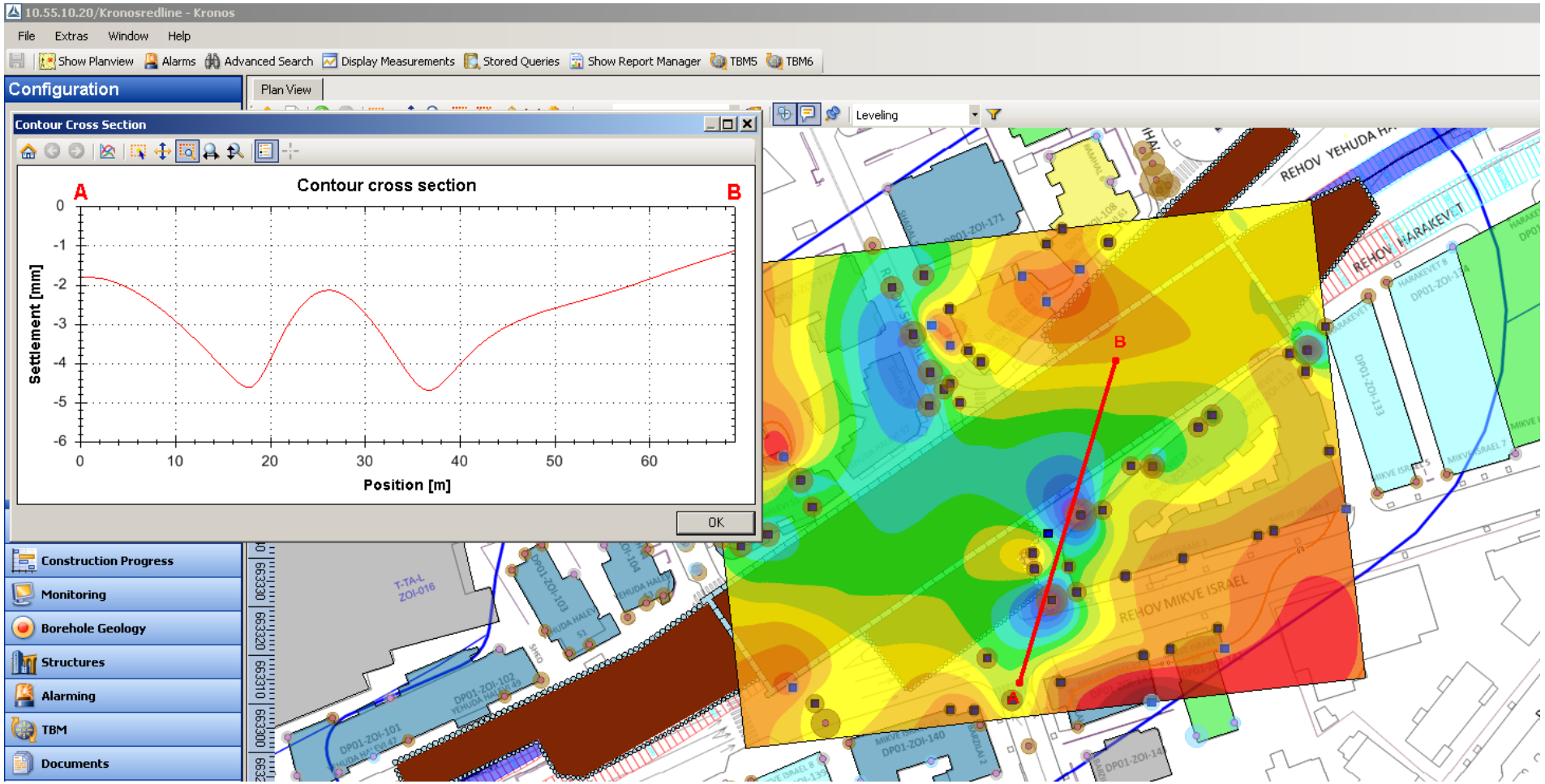
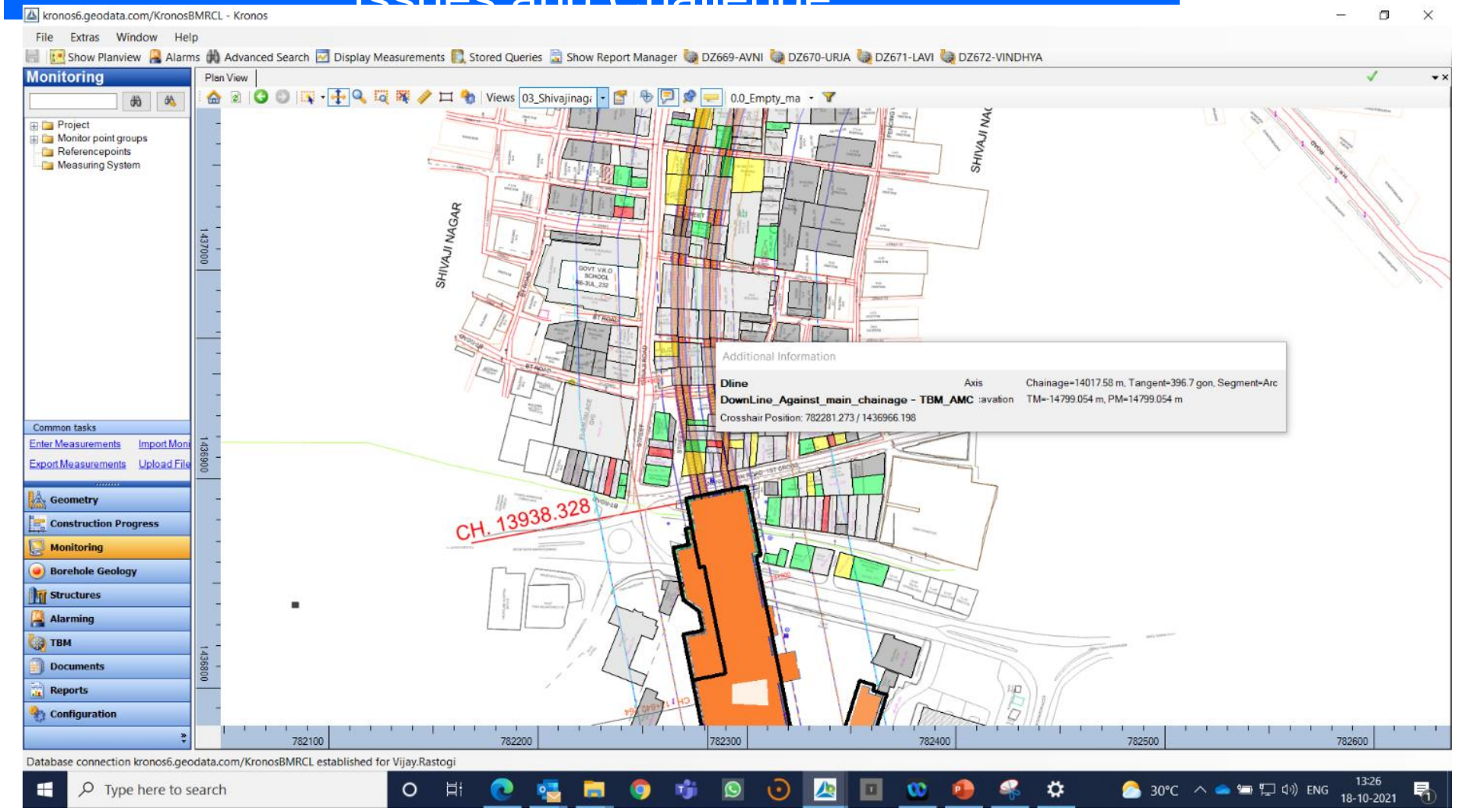
Workshop on

Observational Approach in Tunnelling: Evolvement, Issues and Challenge



GROUND SETTLEMENT IN REALTIME


kronos6.geodata.com/KronosBMRCL - Kronos
File Extras Window Help
Show Planview Alarms Advanced Search Display Measurements Stored Queries Show Report Manager DZ669-AVNI DZ670-URJA DZ671-LAVI DZ672-VINDHYA
Monitoring
Project
Monitor point groups
Referencepoints
Measuring System
Common tasks
Enter Measurements
Export Measurements
Geometry
Construction Progress
Monitoring
Borehole Geology
Structures
Alarming
TBM
Documents
Reports
Configuration
Plan View
Views 03_Shivajinag
0.0_Empty_ma
SHIVAJI NAGAR
Additional Information
Dline Axis Chainage=14017.58 m, Tangent=396.7 gon, Segment=Arc
DownLine_Against_main_chainage - TBM_AMC :avation TM=-14799.054 m, PM=14799.054 m
Crosshair Position: 782281.273 / 1436966.198
CH. 13938.328
1437000
1436900
1436800
782100
782200
782300
782400
782500
782600
Database connection kronos6.geodata.com/KronosBMRCL established for Vijay.Rastogi
Type here to search
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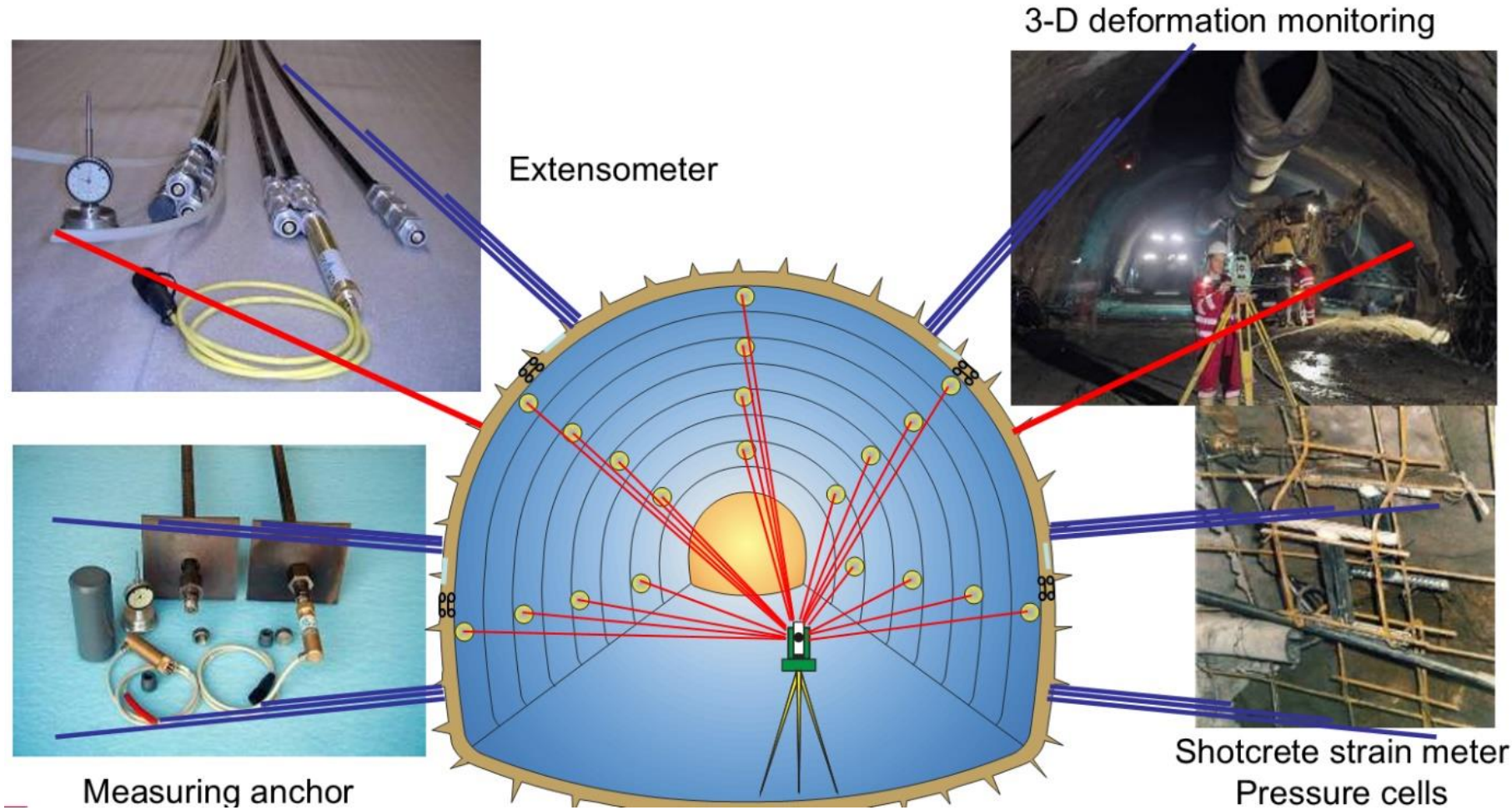
ENG
13:26
18-10-2021

TYPES OF MONITORING FOR NATM

Geodetic Monitoring

TYPES OF MONITORING FOR NATM

Geoetechnical Monitoring



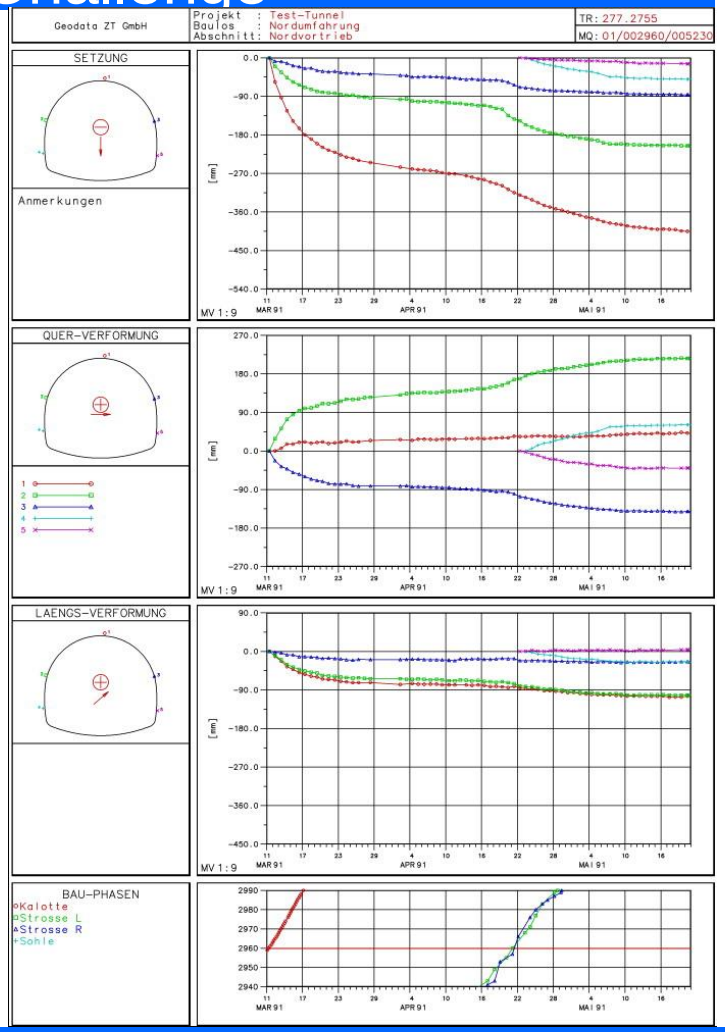
NATM EVALUATION METHODS

Table 5. Value of evaluation methods with regard to specific questions [58]

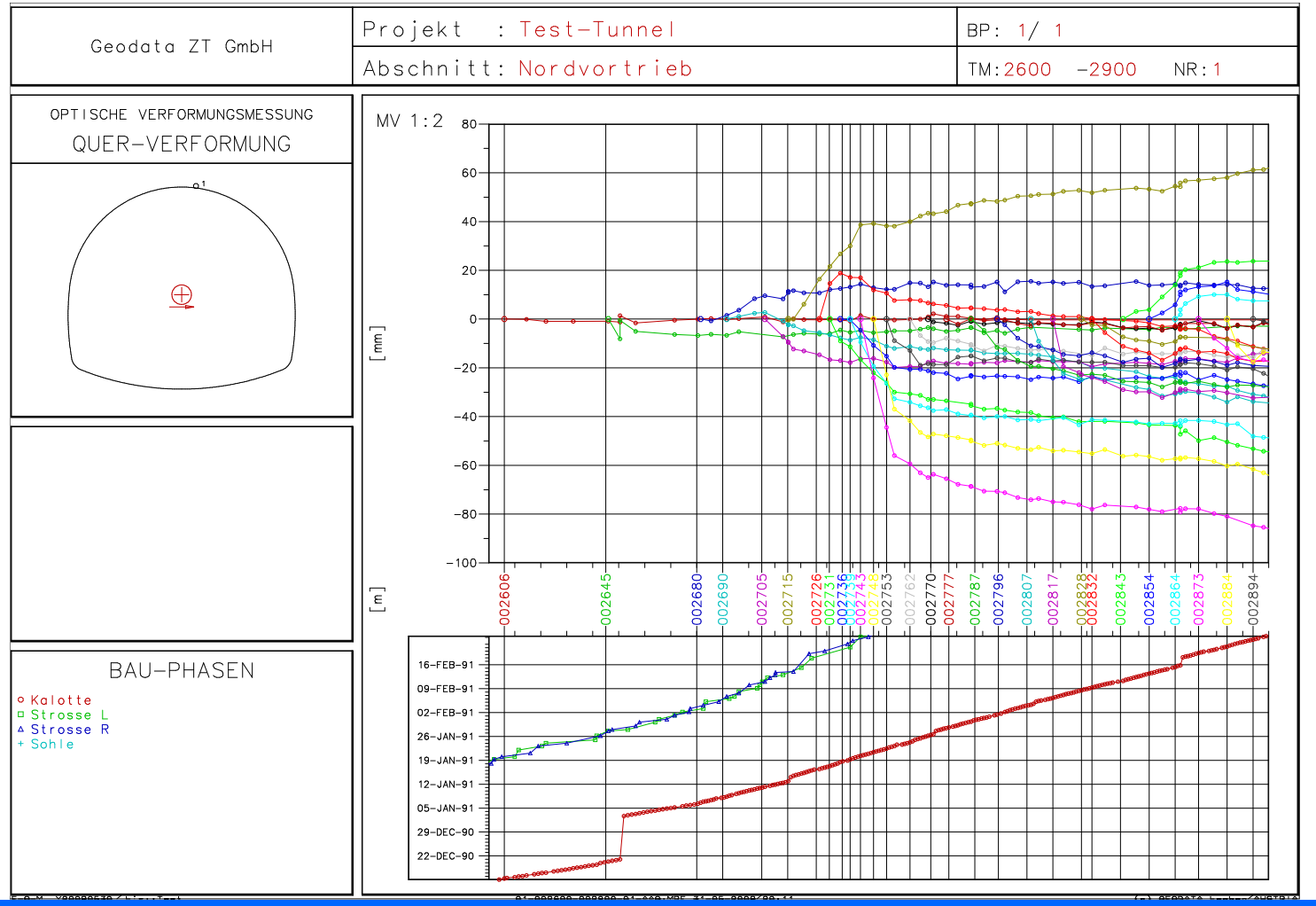
Value of evaluation methods ■ very valuable □ limited value - no value	Evaluation target					
	Stabilisation process	Prediction of displacements	Stress distribution longitudinal	Detection of weak zones outside profile; kinematics	Prediction ahead of face	Estimate of lining stress intensity
Time-displacement	■	■	-	□	-	■
Distance-displacement	■	■	-	□	-	■
Deflection lines, trends	□	-	■	□	□	-
Trends of relative displacement values	-	-	-	■	-	-
Vectors in cross section	-	-	-	■	-	■
Vectors in longitudinal section	-	-	■	■	■	-
Spatial vector orientation	-	-	■	■	■	-
Lining utilisation plot	-	-	-	□	-	■
Surface settlement plot	□	-	□	□	□	-

Time displacement diagrams-3D-displacement measurements (displacement/time)

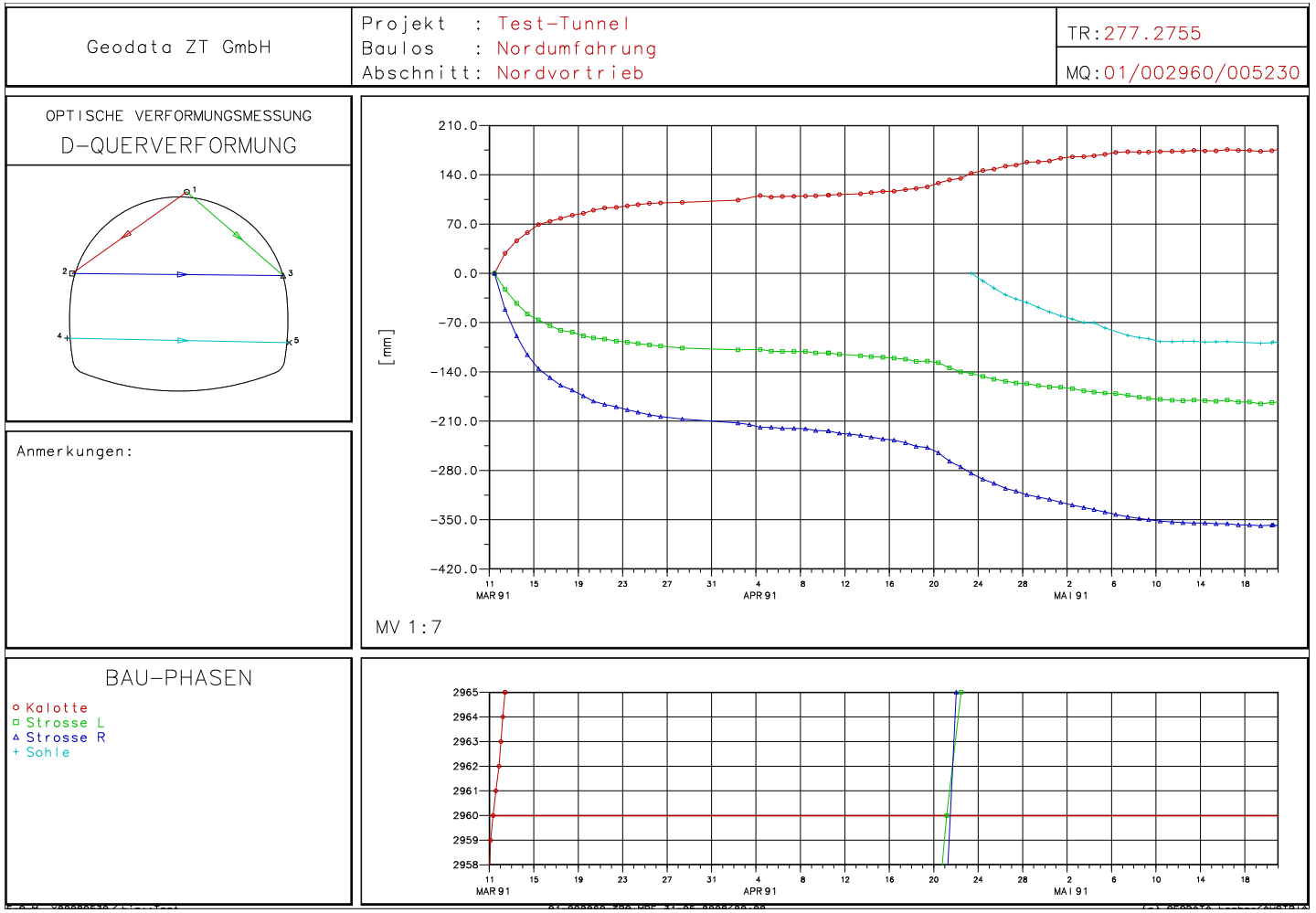
(***Geo-mechanical relevance**: useful for assessment of time dependent components of displacement and stabilization of construction steps)*



Lateral displacement – one certain point in different cross-sections

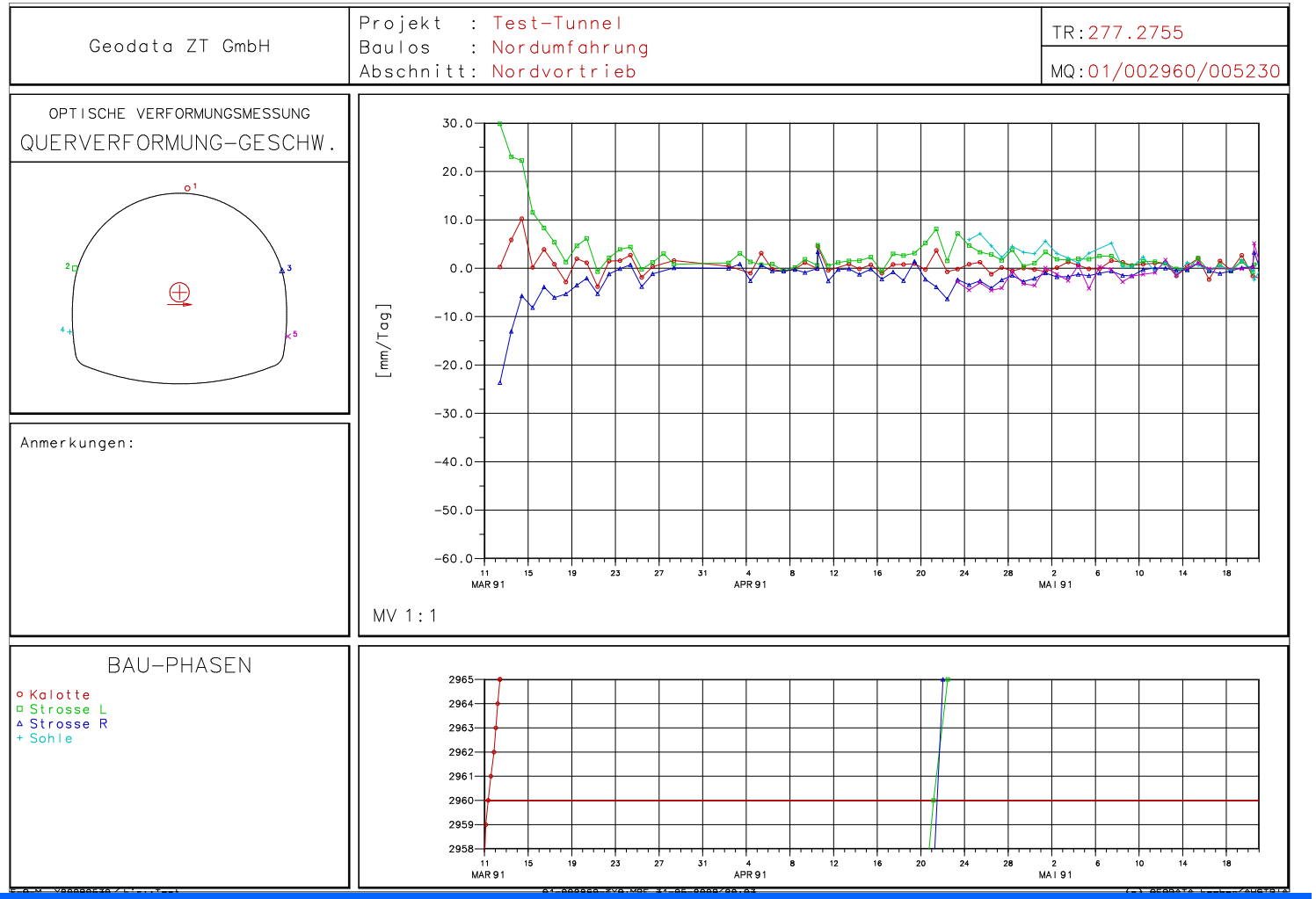


Convergence between several points in a cross-section versus time

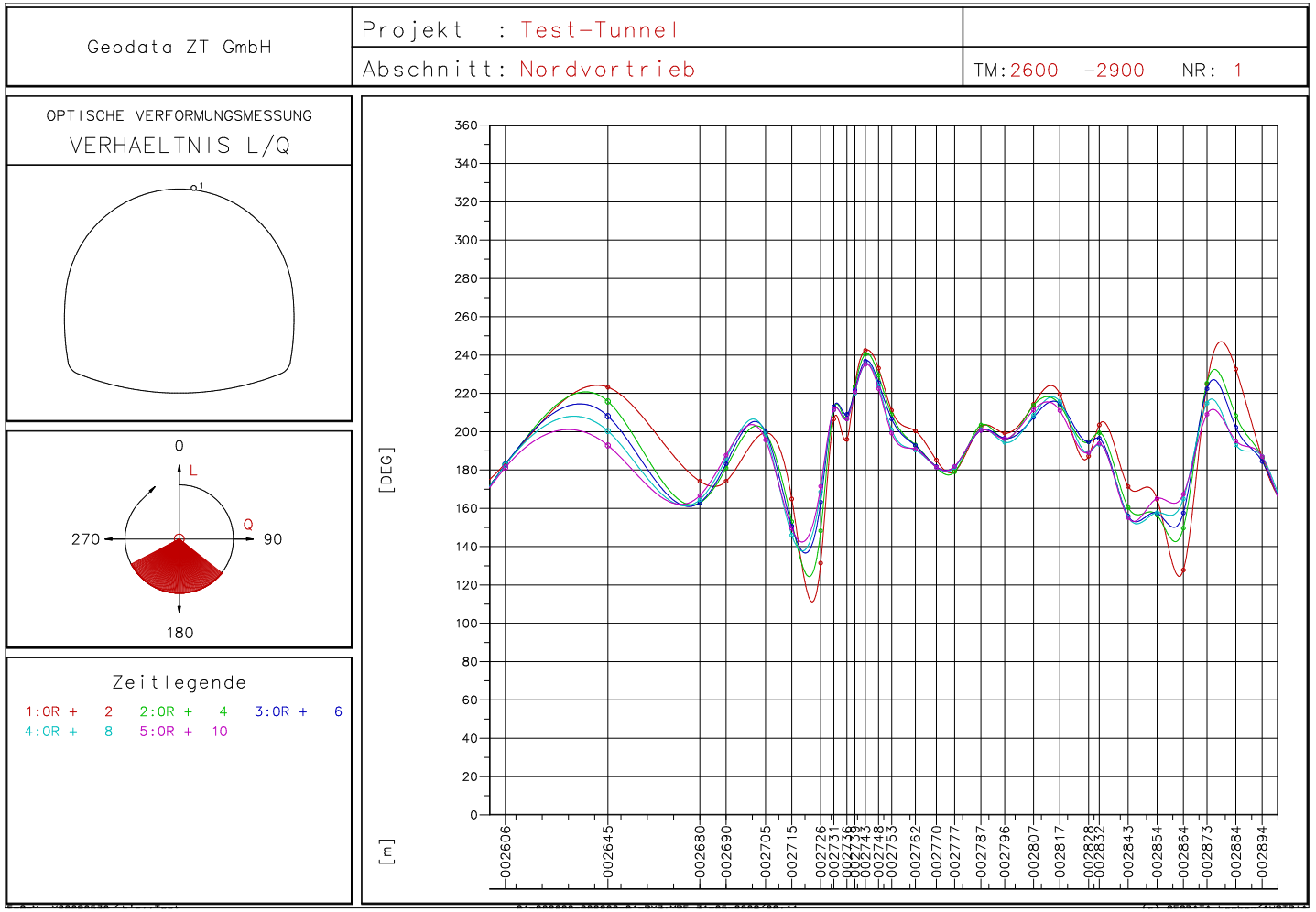


Speed of lateral displacement versus time – all points of a cross-section

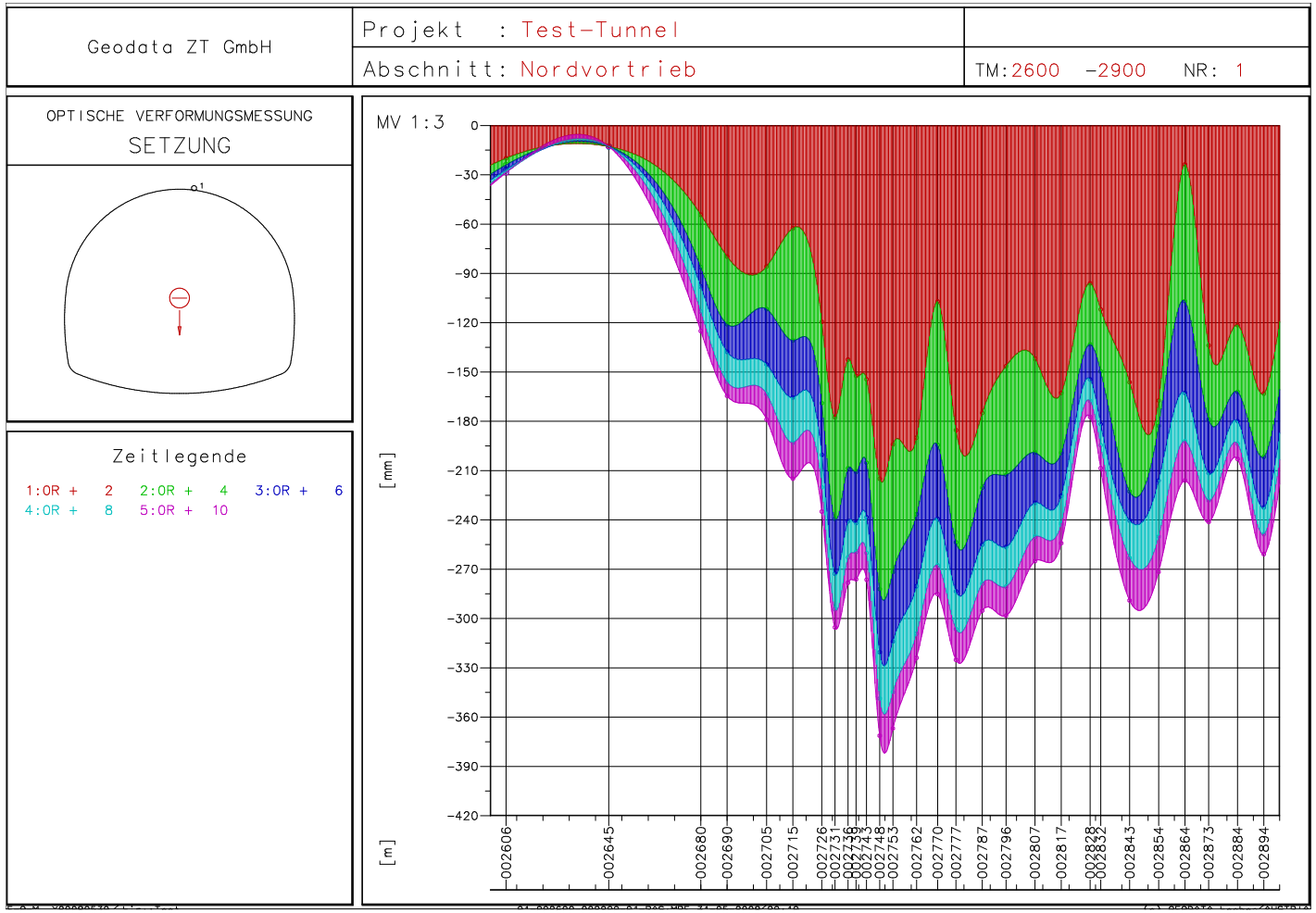
*(**Geo-mechanical relevance**: useful for assessment of time dependent components of displacement and stabilization of construction steps)*



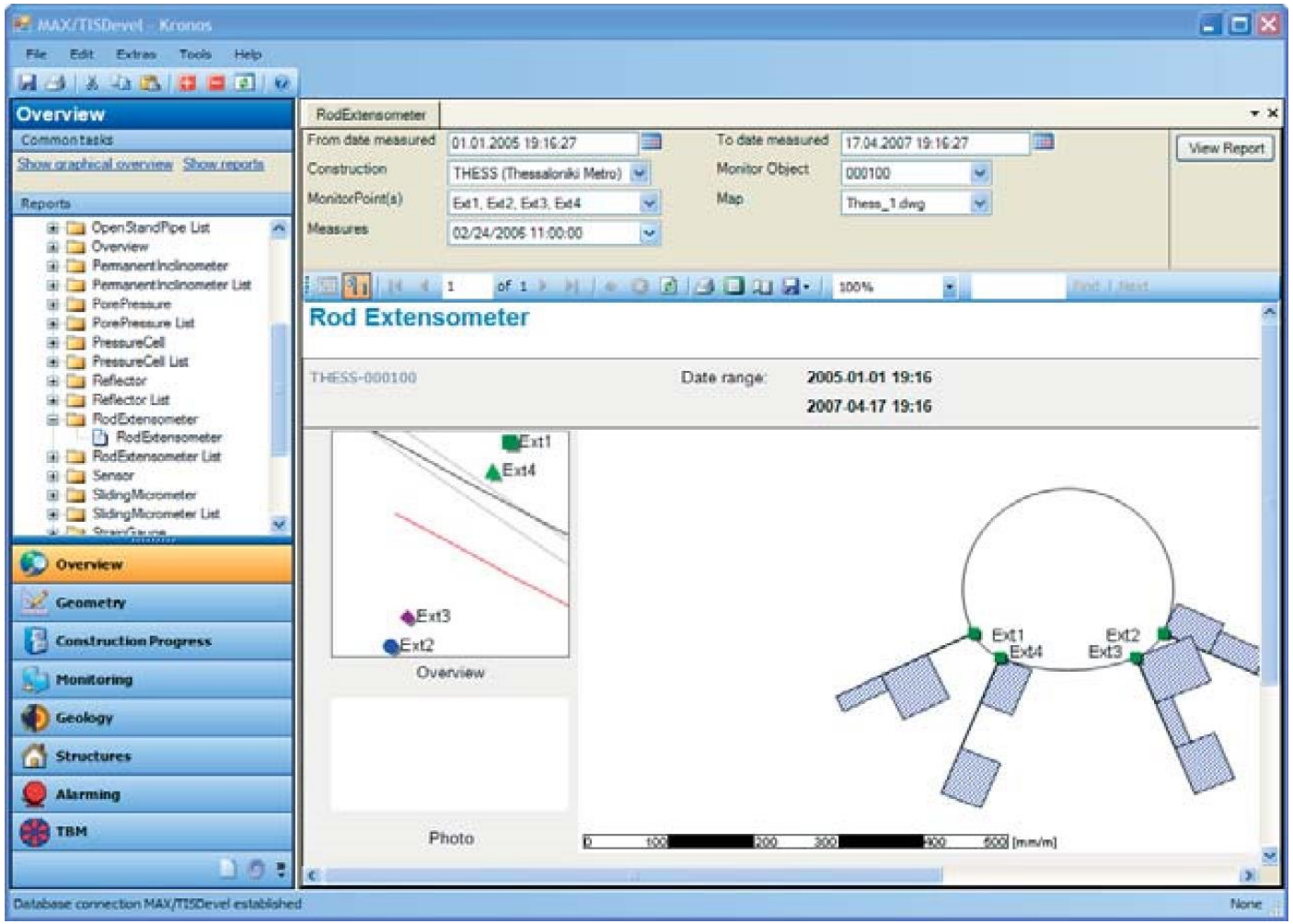
Relation between longitudinal and lateral displacement of a certain point in different cross-sections at certain time differences related to the zero-reading



Settlement of a certain point in different cross-sections at a certain time difference related to the zero-reading

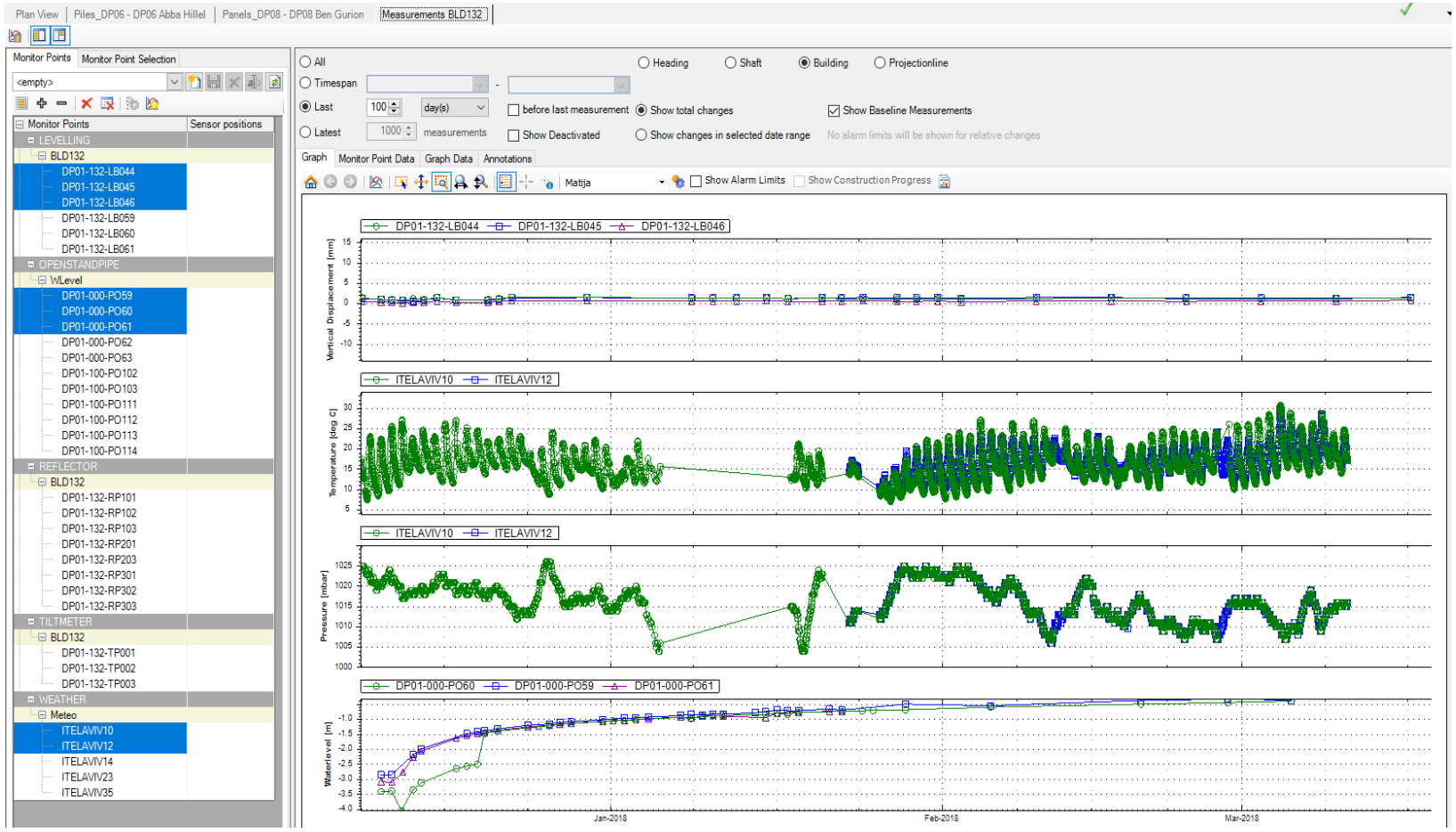


Data presentation of a 3-pt extensometer



ALL MONITORING DATA

- ***Browser based multiuser access to data visualization***
- ***Different sensor types***
- ***Selection of points from plan view***
- **Access to data from monitoring section**
- ***Graphical and tabular visualization of results***
- Combination of different sensor types on same graph
- Graph smoothing options
- Numerous graph options for showing measurement data
- Relative and absolute displacements
- Construction progress visible on the graphs
- Monitoring point annotations
- Depth related graphs (inclinometer, ext.)



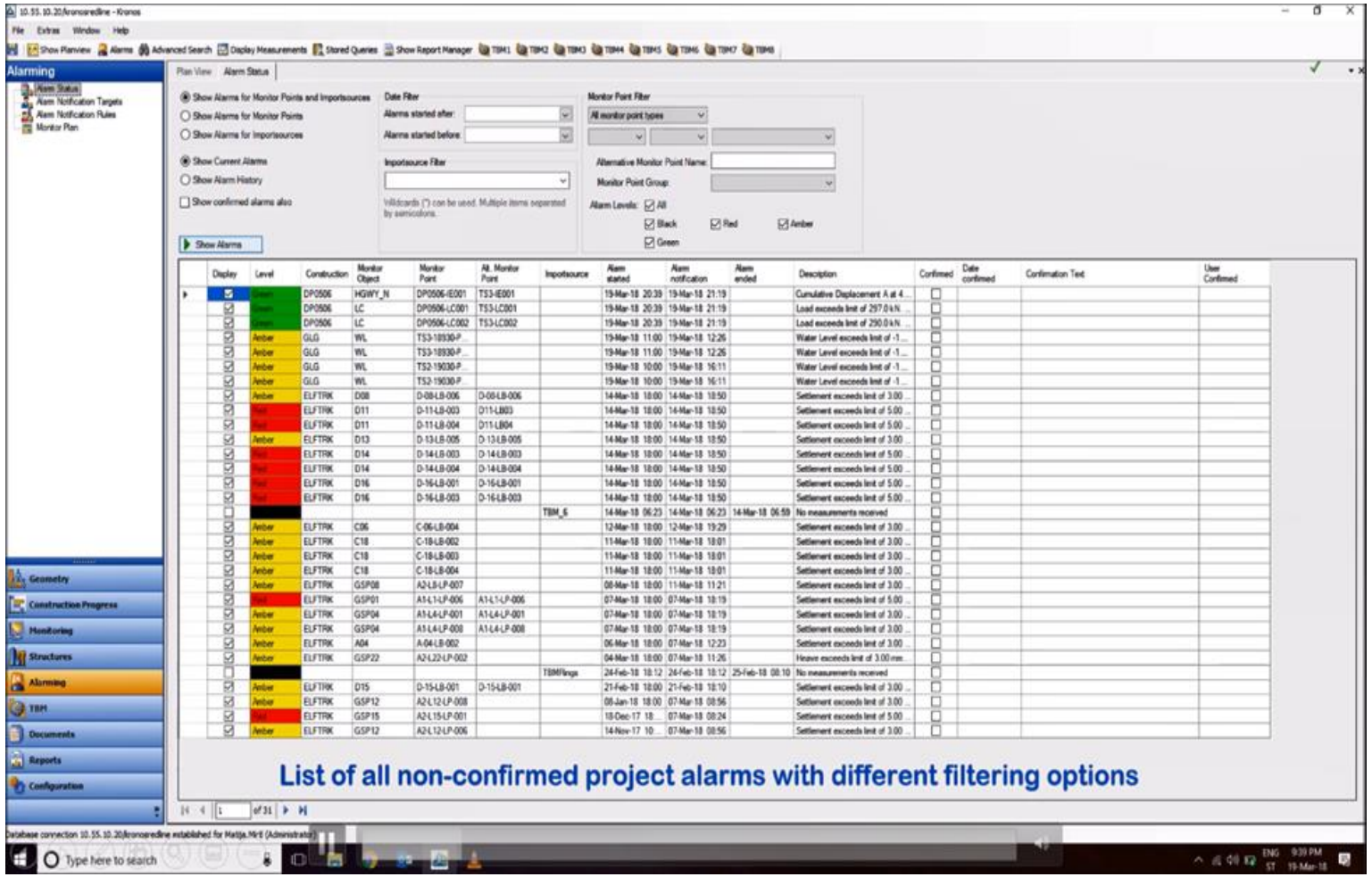
EXTENSIVE ALARMING FUNCTIONS

ALARM LIMITS

- **ALERT, ACTION, ALARM**

KIND OF ALARMS

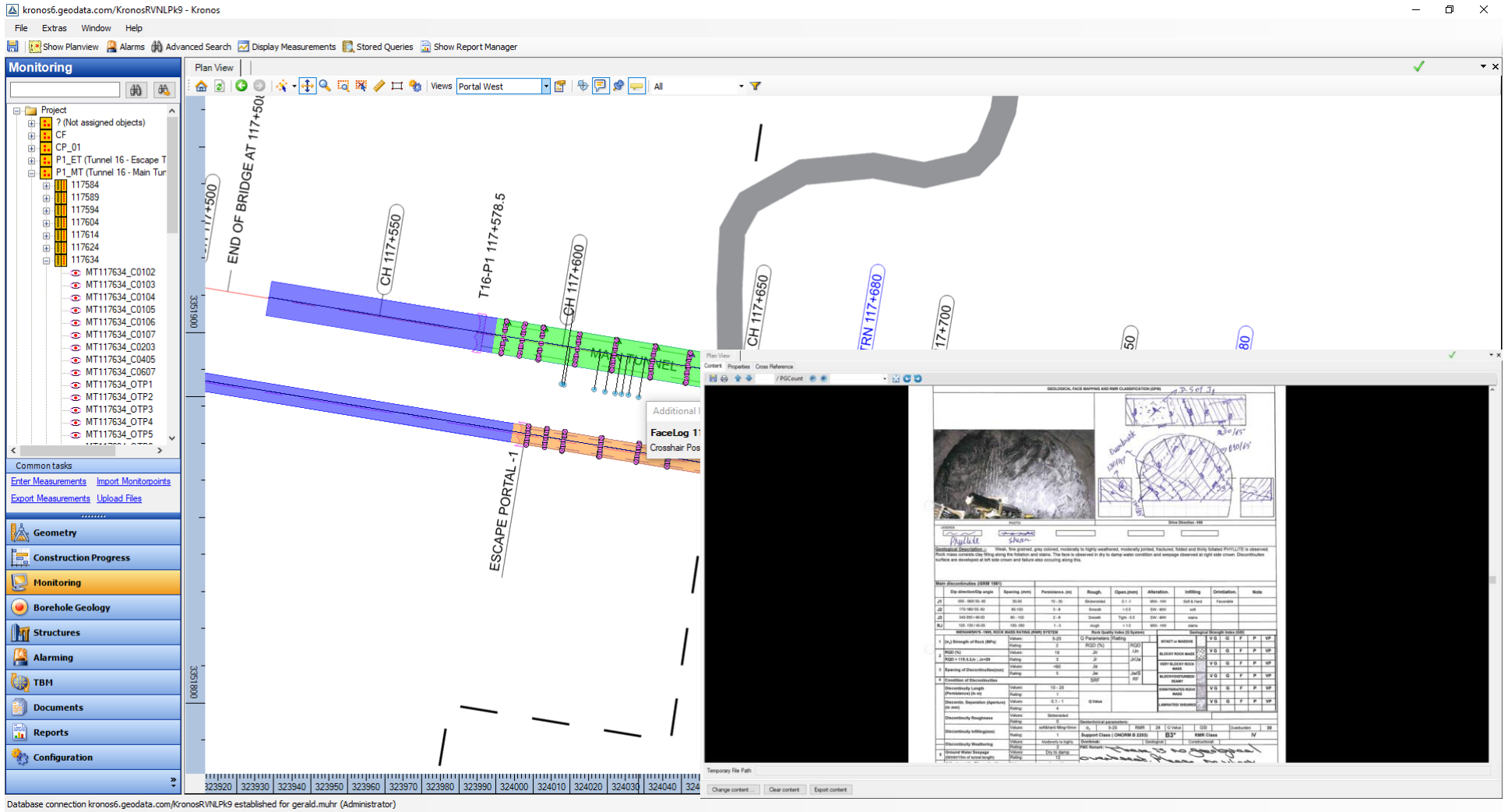
- **VALUE ALARMS**
- **OUT OF RANGE ALARMS**
- **RATE ALARMS**
- **FREQUENCY ALARMS**


Alarming
Show Alarms for Monitor Points and Importsources
Show Alarms for Monitor Points
Show Alarms for Importsources
Show Current Alarms
Show Alarm History
Show confirmed alarms also
Show Alarms
Date Filter
Alarms started after:
Alarms started before:
Importsource Filter
Monitor Point Filter
Alternative Monitor Point Name:
Monitor Point Group:
Alarm Levels: All Black Red Amber Green
Display
Level
Construction
Monitor Object
Monitor Point
Alt. Monitor Point
Importsource
Alarm started
Alarm notification
Alarm ended
Description
Confirmed
Date confirmed
Confirmation Text
User Confirmed
Geometry
Construction Progress
Monitoring
Structures
Alarming
TBM
Documents
Reports
Configuration
List of all non-confirmed project alarms with different filtering options

GEODATA

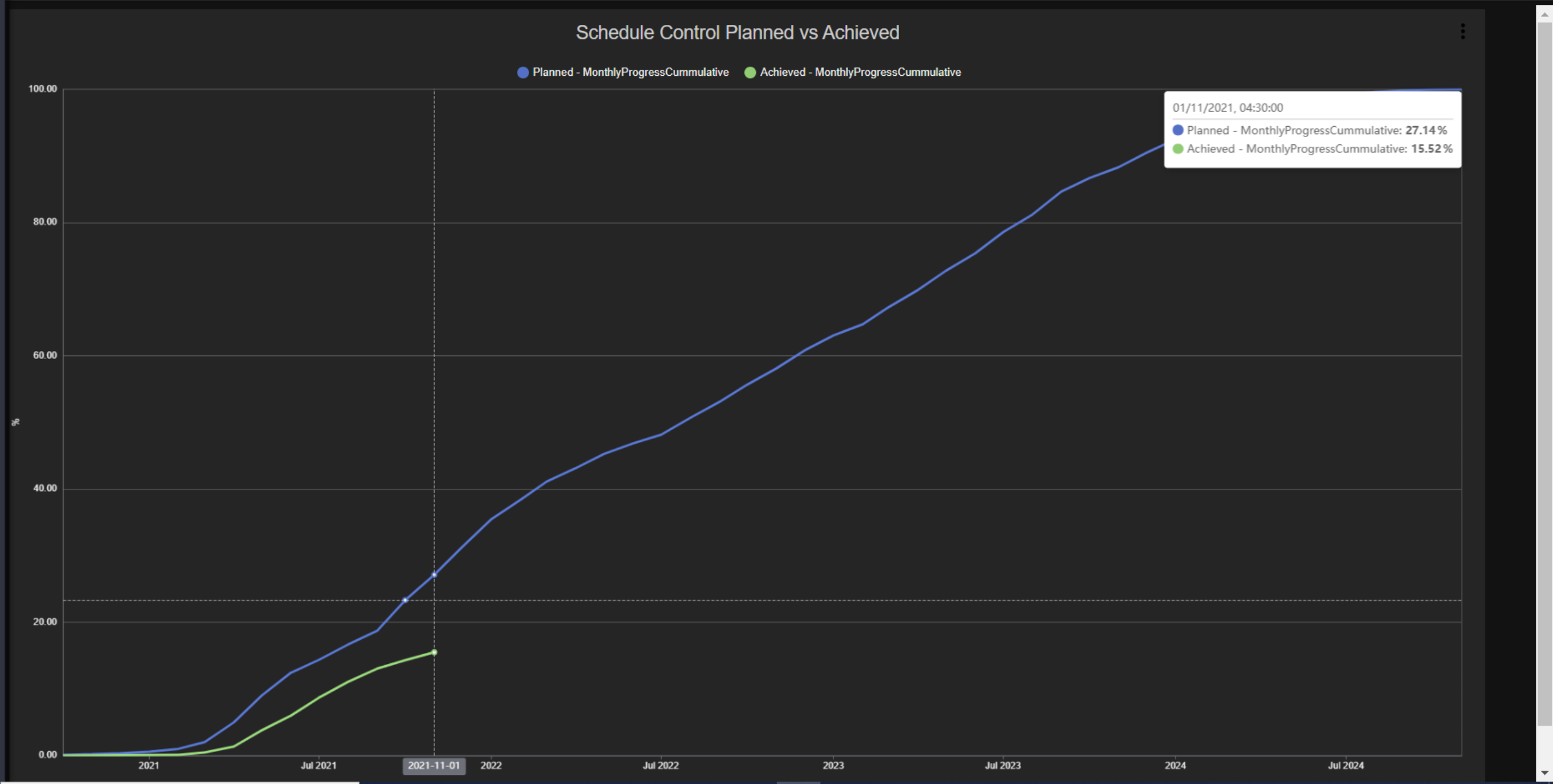
Geographical Marker enables attachment of any document to any point on the axis

CONSTRUCTION STATUS AND SITE DOCUMENTATION

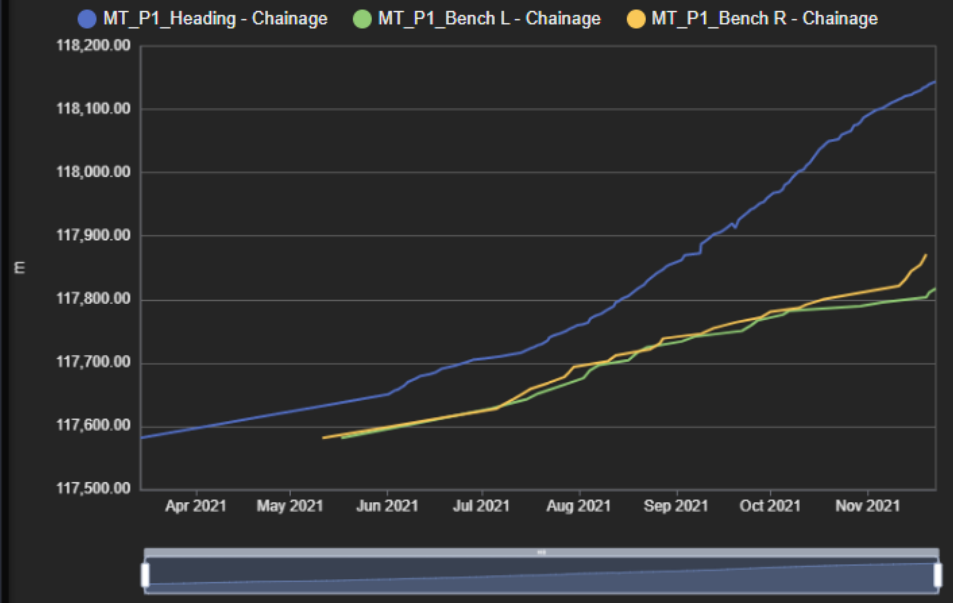


WE TURN DATA INTO INFORMATION

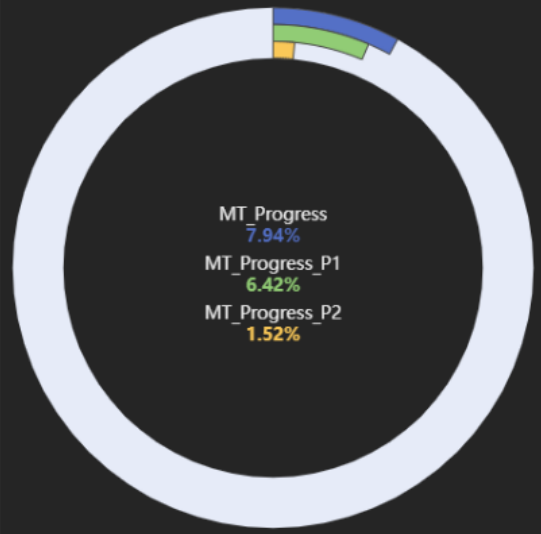
www.geodata.com


Schedule Control Planned vs Achieved
Planned - MonthlyProgressCummulative
Achieved - MonthlyProgressCummulative
100.00
80.00
60.00
40.00
20.00
0.00
%
01/11/2021, 04:30:00
Planned - MonthlyProgressCummulative: 27.14 %
Achieved - MonthlyProgressCummulative: 15.52 %
2021
Jul 2021
2021-11-01
2022
Jul 2022
2023
Jul 2023
2024
Jul 2024

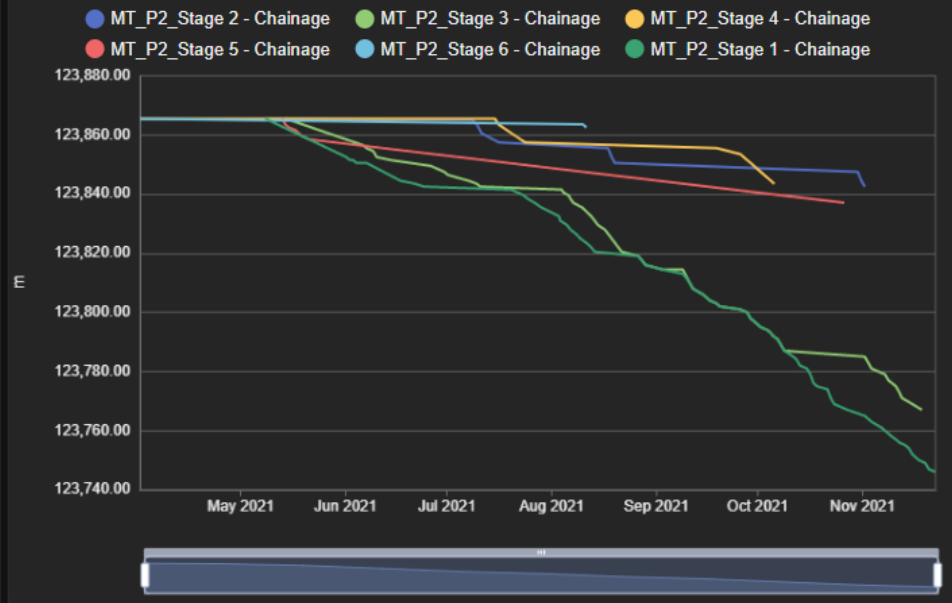
MT Portal West P1 - Construction Progress (Chainage)



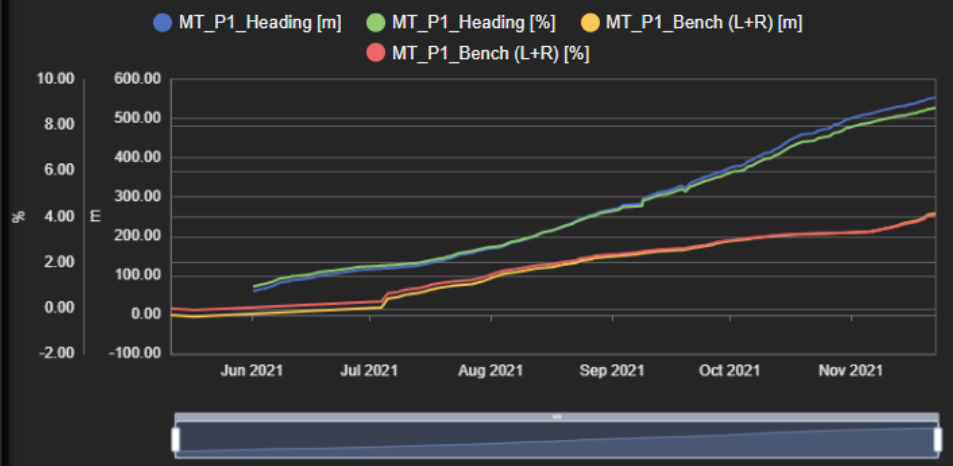
MT Progress



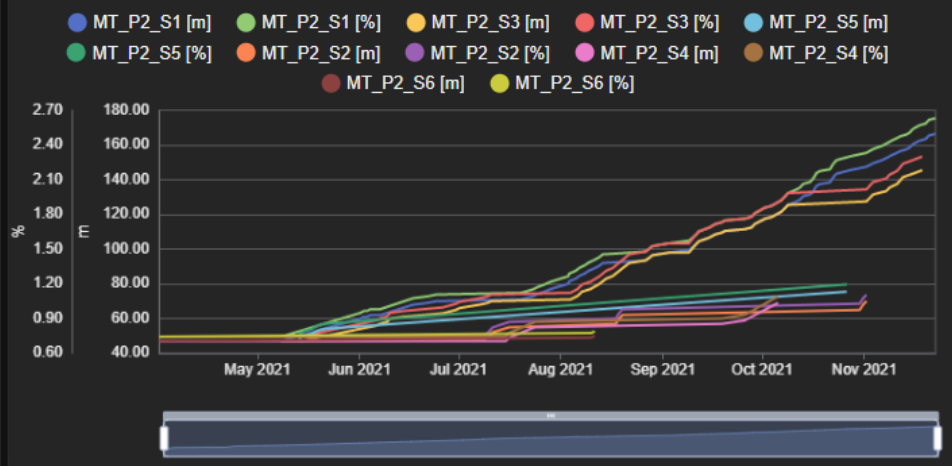
MT Portal East P2 - Construction Progress (Chainage)

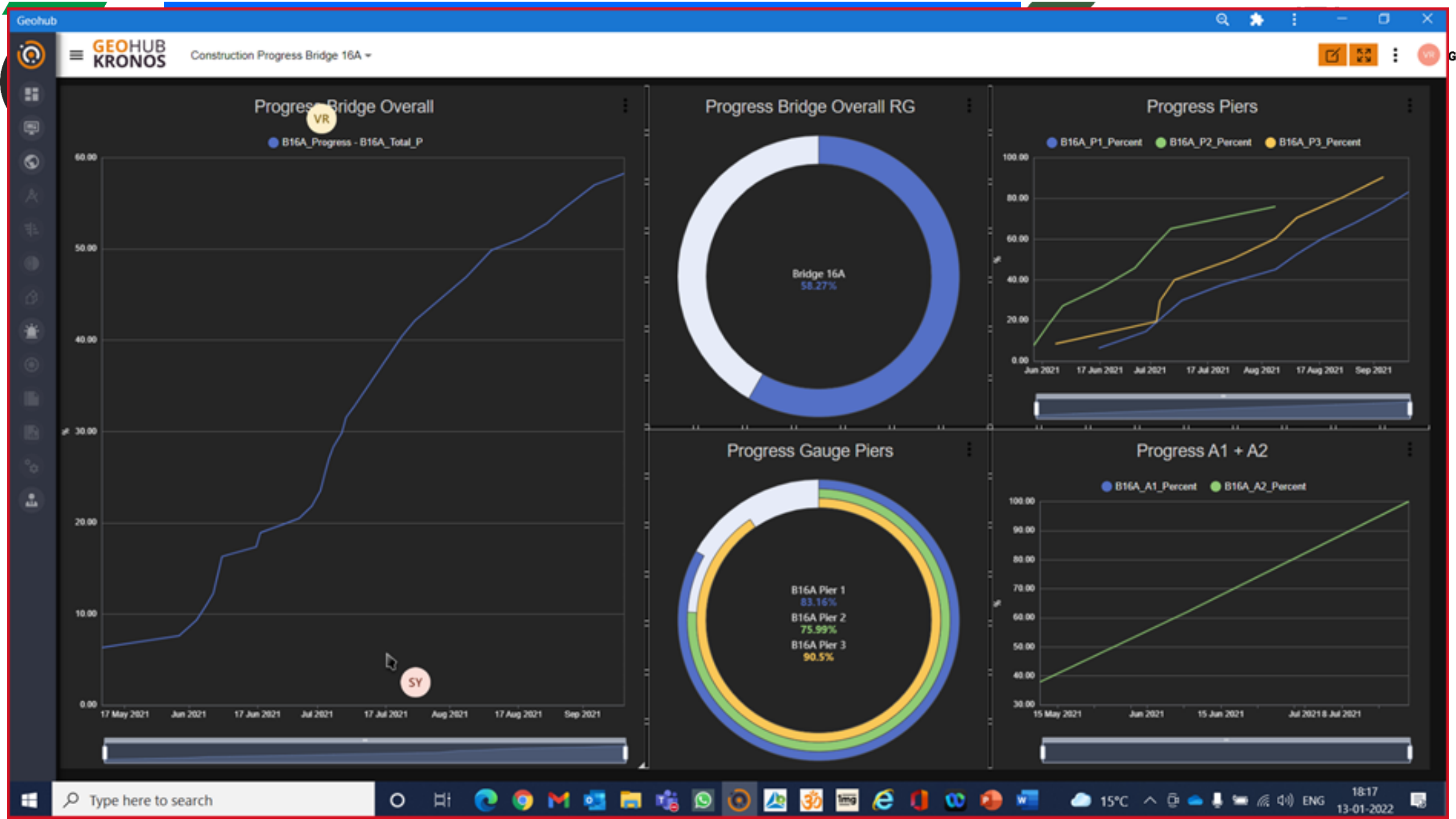


MT Portal West P1 - Heading



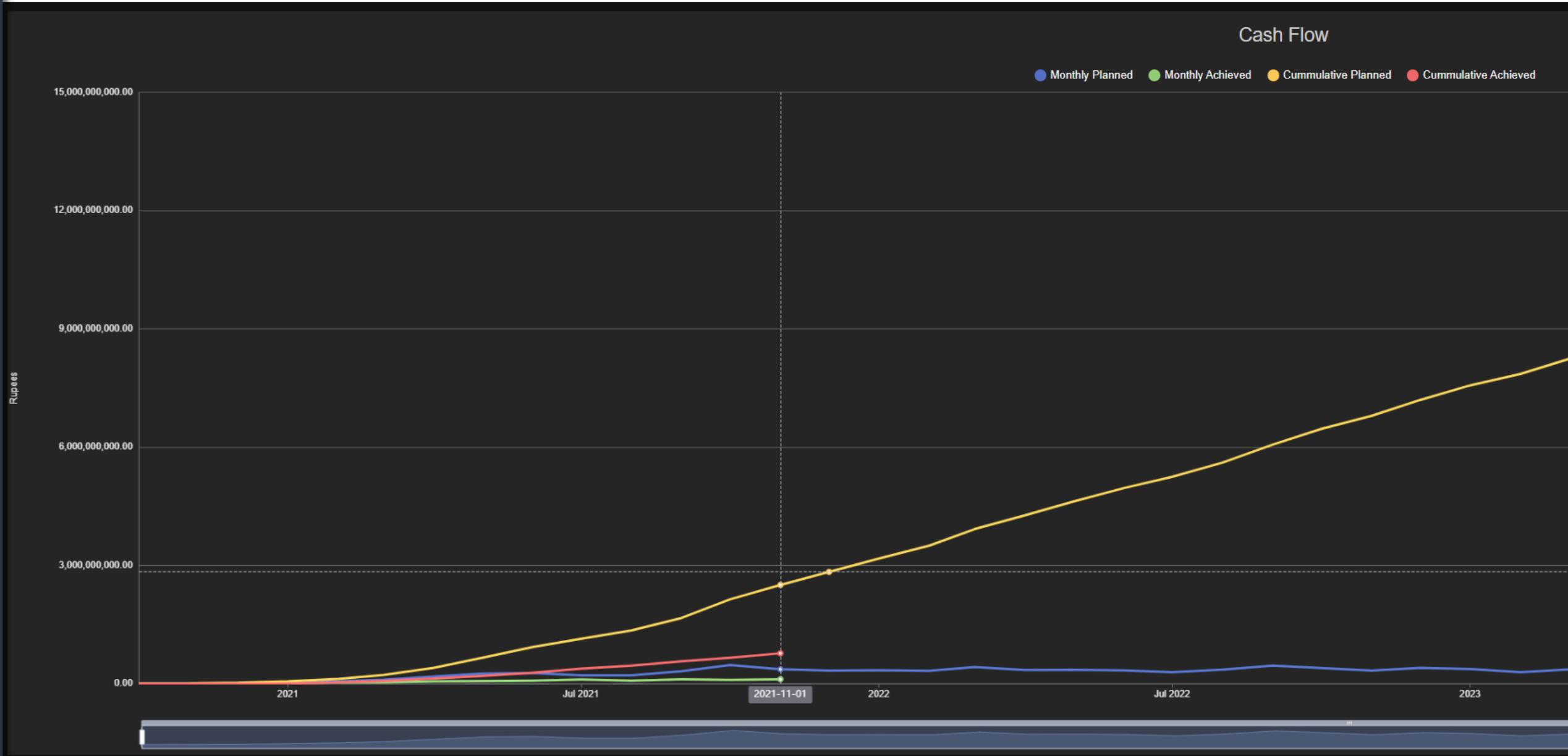
MT Portal East P2 - Heading




Geohub
GEOHUB KRONOS
Construction Progress Bridge 16A
Progress Bridge Overall
B16A_Progress - B16A_Total_P
60.00
50.00
40.00
30.00
20.00
10.00
0.00
17 May 2021
Jun 2021
17 Jun 2021
Jul 2021
17 Jul 2021
Aug 2021
17 Aug 2021
Sep 2021
VR
SY
Progress Bridge Overall RG
Bridge 16A
58.27%
Progress Piers
B16A_P1_Percent
B16A_P2_Percent
B16A_P3_Percent
100.00
80.00
60.00
40.00
20.00
0.00
Jun 2021
17 Jun 2021
Jul 2021
17 Jul 2021
Aug 2021
17 Aug 2021
Sep 2021
Progress Gauge Piers
B16A Pier 1
83.16%
B16A Pier 2
75.99%
B16A Pier 3
90.5%
Progress A1 + A2
B16A_A1_Percent
B16A_A2_Percent
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
15 May 2021
Jun 2021
15 Jun 2021
Jul 2021
8 Jul 2021
Type here to search
15°C
ENG
18:17
13-01-2022

GEOHUB KRONOS

Cost Control Project



CONCLUSION

- In NATM, observational approach in instrumentation and monitoring is used. Making use of geotechnical/geodetic instruments ensures economy in construction material, safety, and efficiency of construction.

- Digital technology is a must for monitoring. Only that will ensure timely and efficient decision making.

- Digital monitoring must be made a part of technical specifications and insisted upon. Presently, even where is a part of the tender, specifications, it is not insisted upon.

Thanks for your attention !

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Mob 98390873032