Monitoring Urban Tunnelling

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Modern cities have an increasing demand for underground infrastructure despite high building density and complex geology.

Naturally all tunnels require:

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Modern cities have an increasing demand for underground infrastructure despite high building density and complex geology.

Naturally all tunnels require:

- Installation of a stable, enduring and water-tight structure

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Modern cities have an increasing demand for underground infrastructure despite high building density and complex geology.

Naturally all tunnels require:

- Installation of a stable, enduring and water-tight structure.
- Boxes and Shafts usually in built up areas
- No harmful effects on the surrounding structures

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Measuring settlements after the event is not an option .

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Lining mistake Cairo

Monitoring omitted from this section of the works

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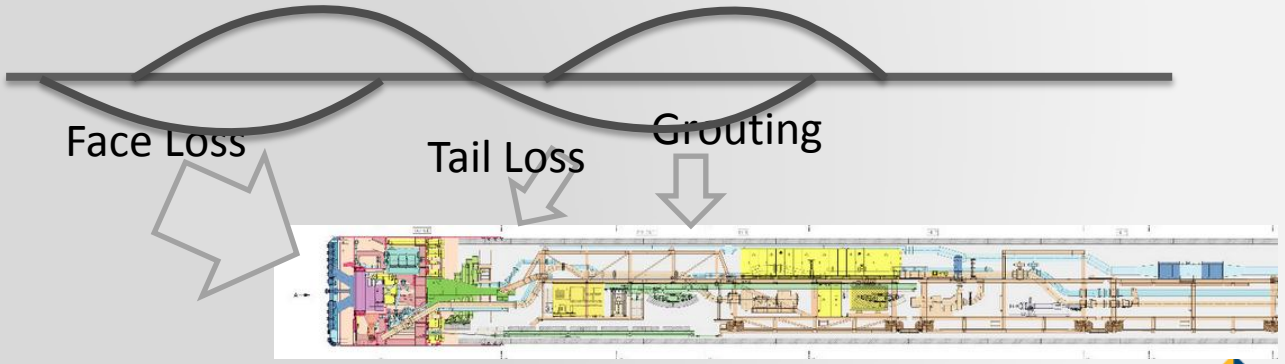
Settlements arise from the installation of a tunnel for three reasons.

A difference between the volume necessary to house the tunnel and lining, and the volume of the void created during excavation. This produces tail loss, to the rear of the shield.

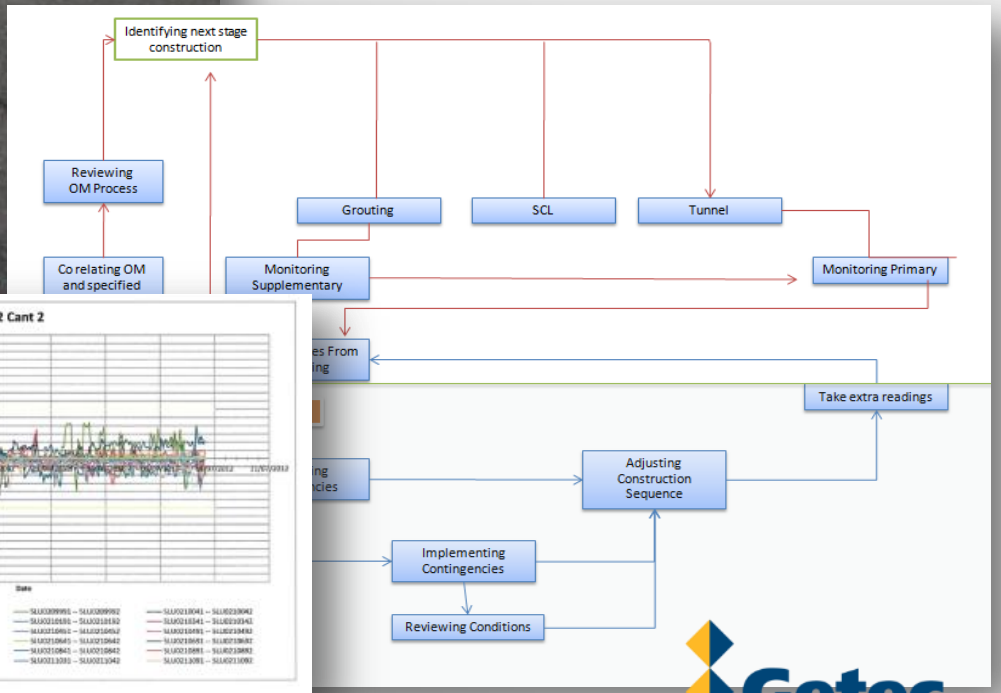
Excavation also reduces the horizontal stresses at the tunnel face, leading to soil deformations and face losses.

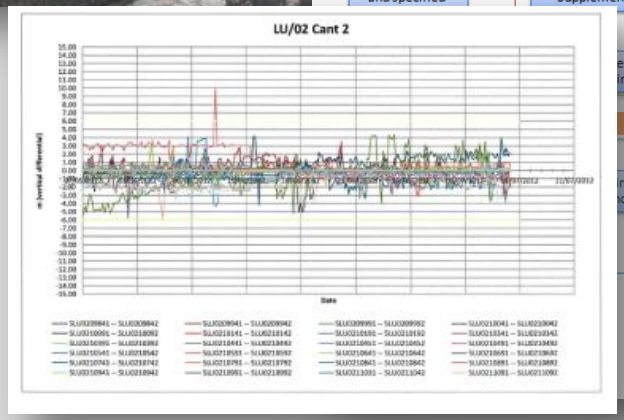
Longer term movements occur due to changes in pore pressures initiated by the installation of the tunnel. These soil movements around the tunnel lead to (smaller) movements at the surface.



Tunnel Boring Machine (TBM)

A monitoring system needs to be sophisticated, systematic and provide meaningful data to inform.





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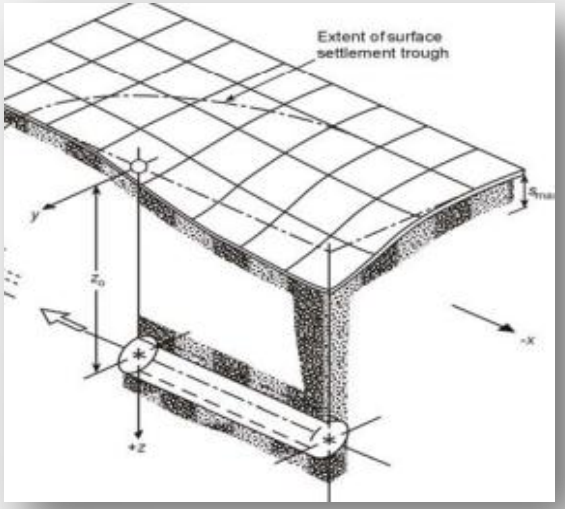
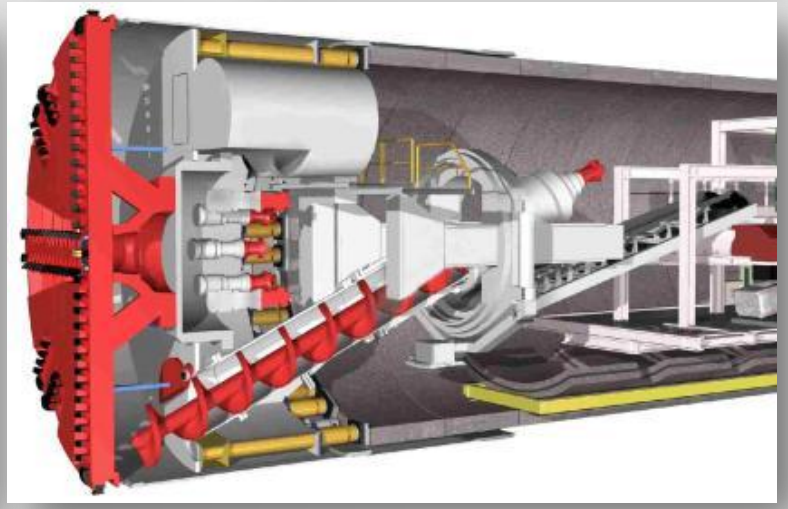
Modern urban tunnelling requires a master plan for settlement control:

1) Thorough design of the key parameters
   - *settlement expected*
   - *face support pressure*
   - *-medium design*
   - *-grout pressure calculation*
   - *-grout mix design*





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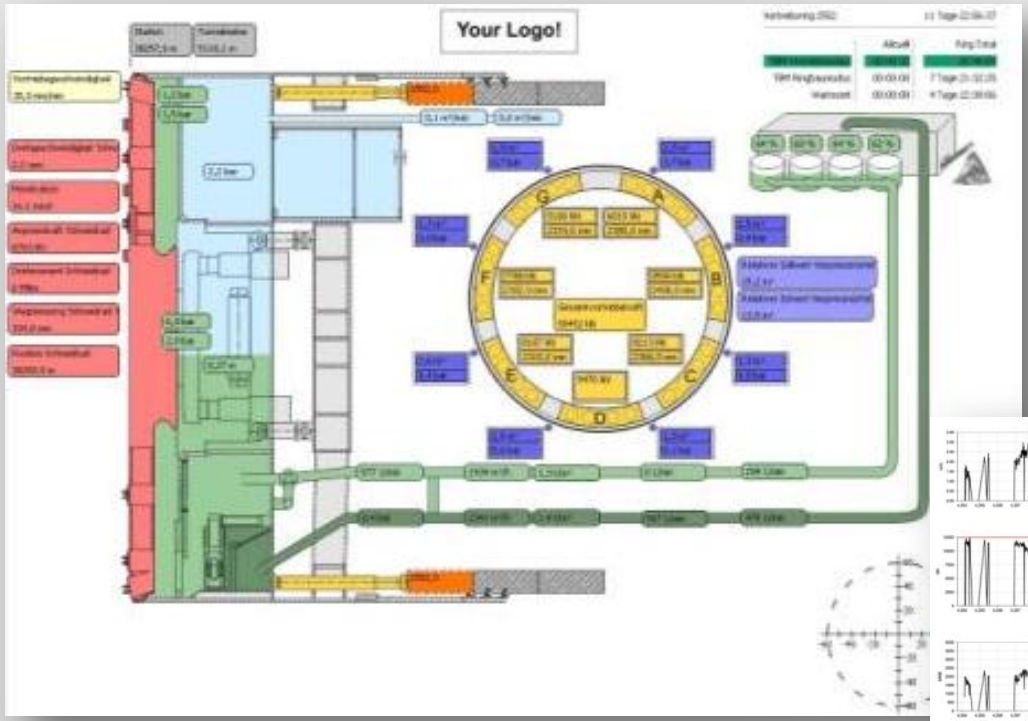
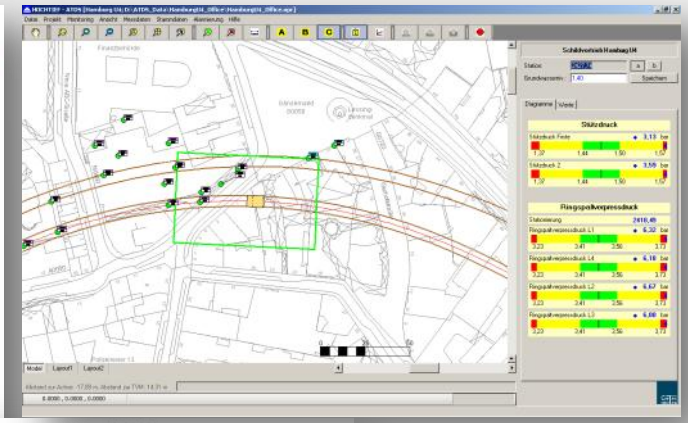
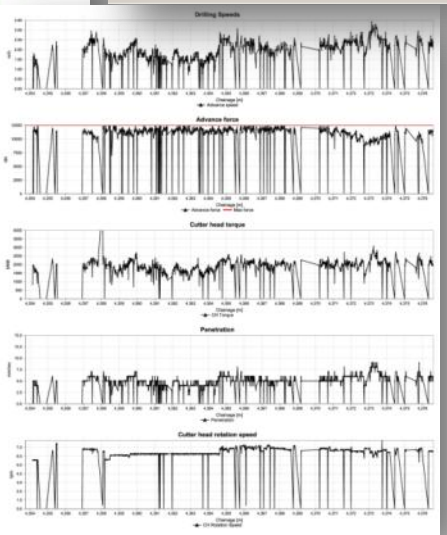
Modern urban tunnelling requires a master plan for settlement control:

1) Thorough design of the key parameters

2) Monitoring and recording of the TBM operational parameters in real time
   - *advance force, torque, penetration, slurry circuit, grout pressure and volume*







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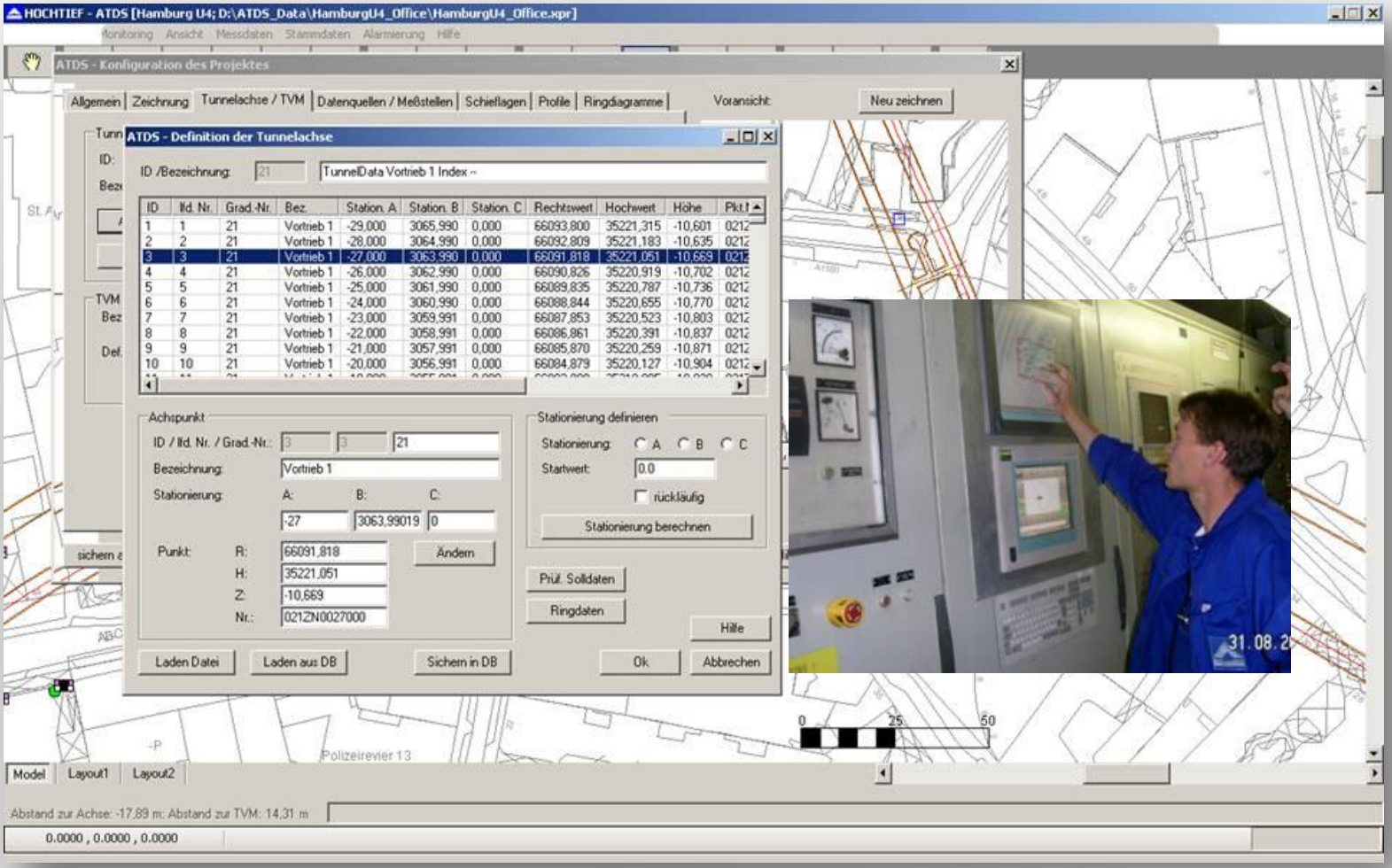

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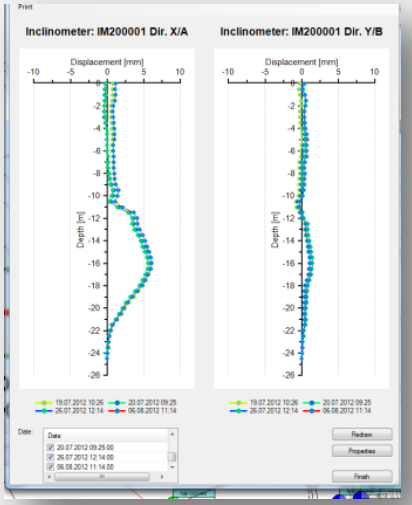
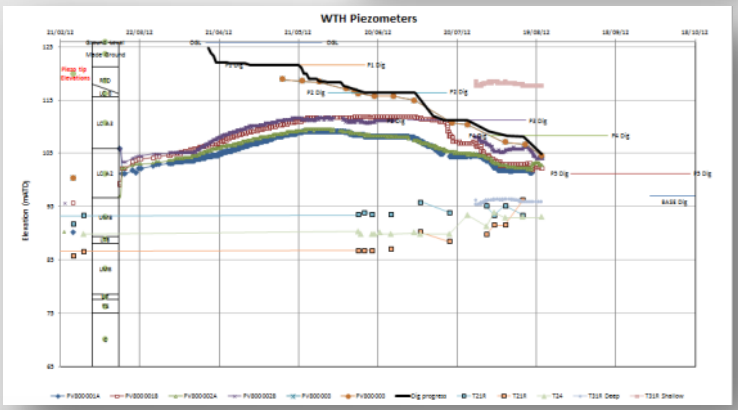
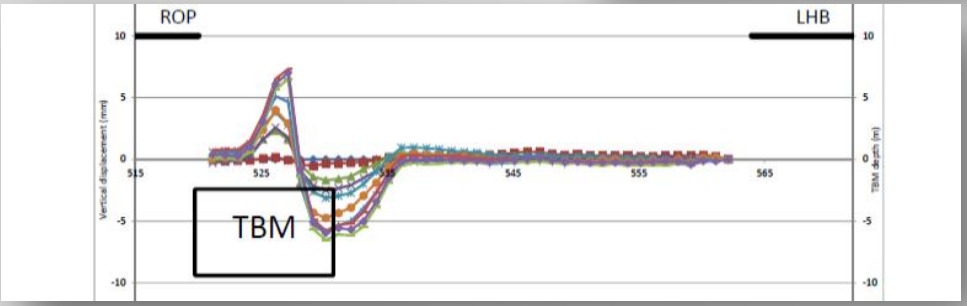
Modern urban tunnelling requires a master plan for settlement control:

1) Thorough design of the key parameters
2) Monitoring and recording of the TBM operational parameters in real time
3) Real time monitoring of the effects on the surroundings
   - surface settlements
   - below surface settlements
   - translations and rotations
   - groundwater
   - construction activities

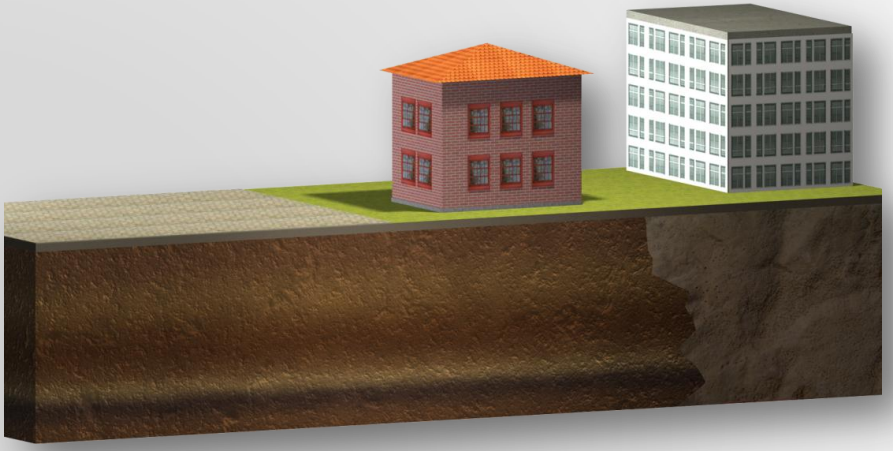






You require instrumentation and monitoring for the following reasons

Safety
Client's undertaking to stakeholders
Risk Mitigation
Asset protection
Efficiency
Design check
Value Engineering
Insurance



Too much – Too little
Fit for purpose
Cost vs Results

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Hydrostatic Water Level Systems (settlement)

Automatic Total Stations (settlement and tilt)

Precise level monitoring (settlement)

Inclinometers (tilt)

Shape Array (Tilt and Convergence)

Displacement transducers (crack and Sewer monitoring)

Strain transducers (structural stresses)

Load cells and pressure pads (stresses in SCL lining)

Peizometer (pore water pressures)

Extensometers (subsurface compression and elongation

Electrolevels (Tilt)

Noise and Vibration

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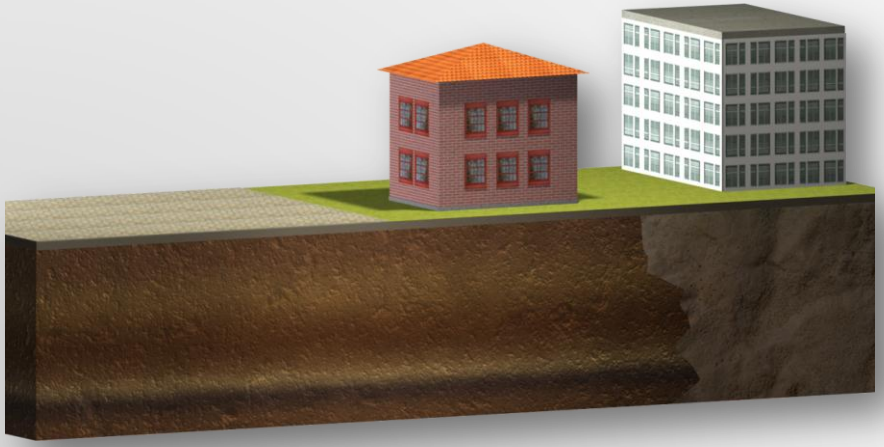
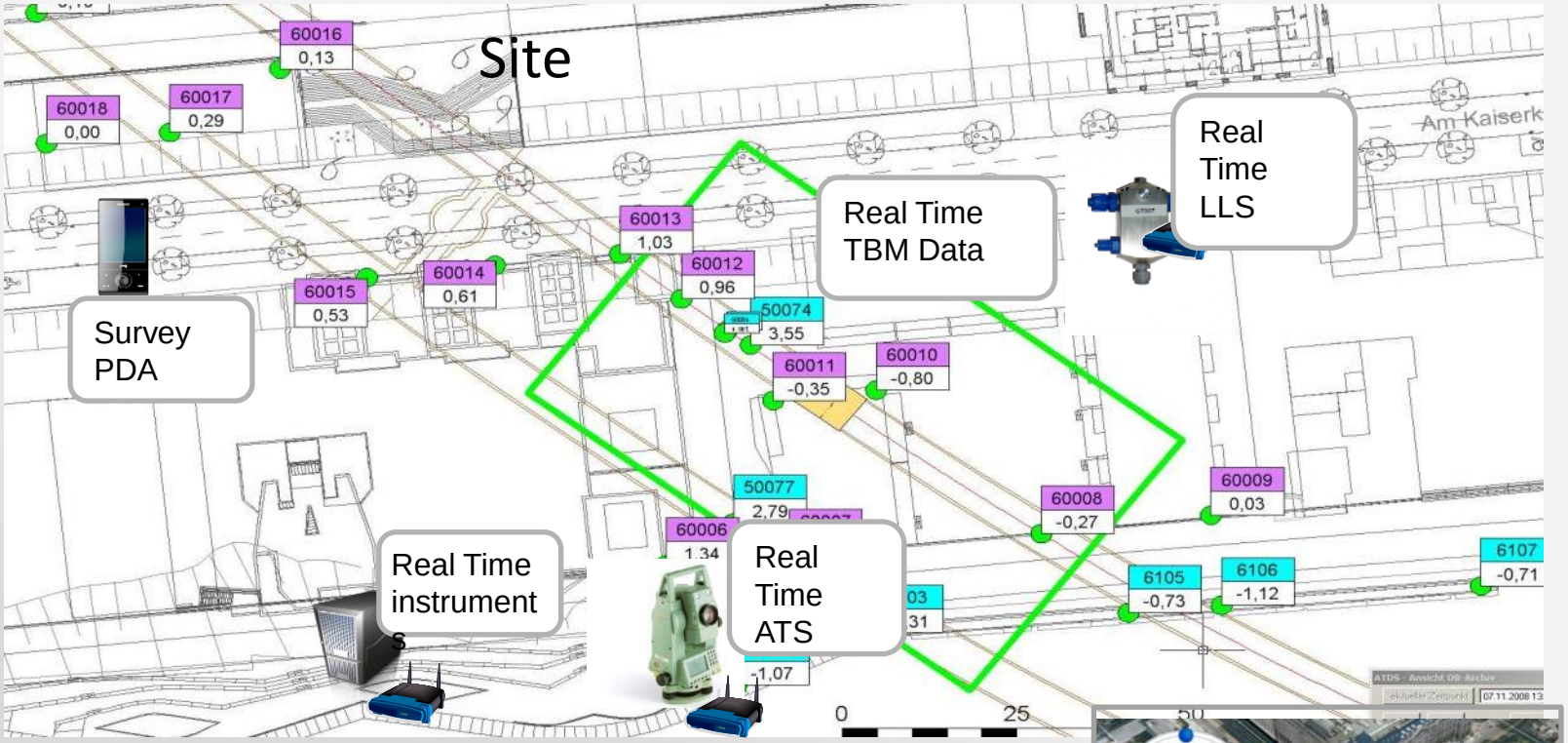
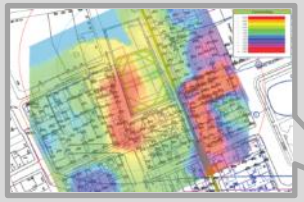
Install and take readings well in advance so that you have no surprises when you don’t need them.



- Building Behaviour
- Temperature effects
- Efficiency of Instruments and Monitoring Teams





FTP

Central Server

Archival in AGS

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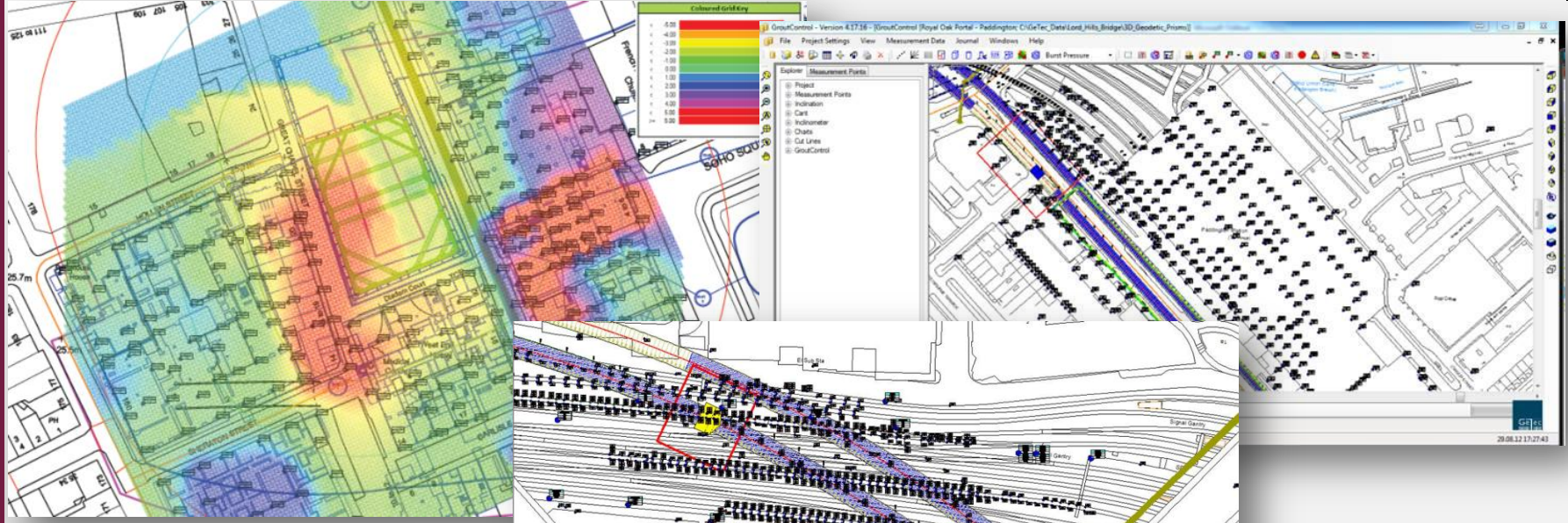

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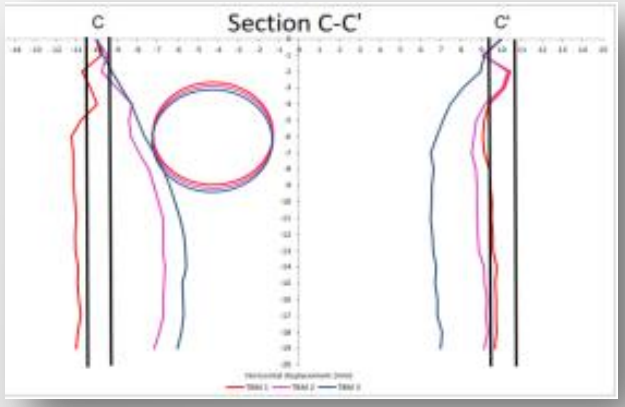
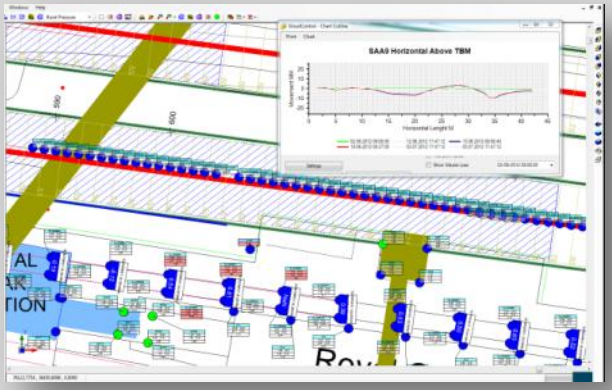
Modern urban tunnelling requires a master plan for settlement control:

1) Thorough design of the key parameters
2) Monitoring and recording of the TBM operational parameters in real time
3) Real time monitoring of the effects on the surroundings
4) Mitigation measures in case critical risks are detected
   - Back-analysis of recorded data
   - Modification of TBM operation





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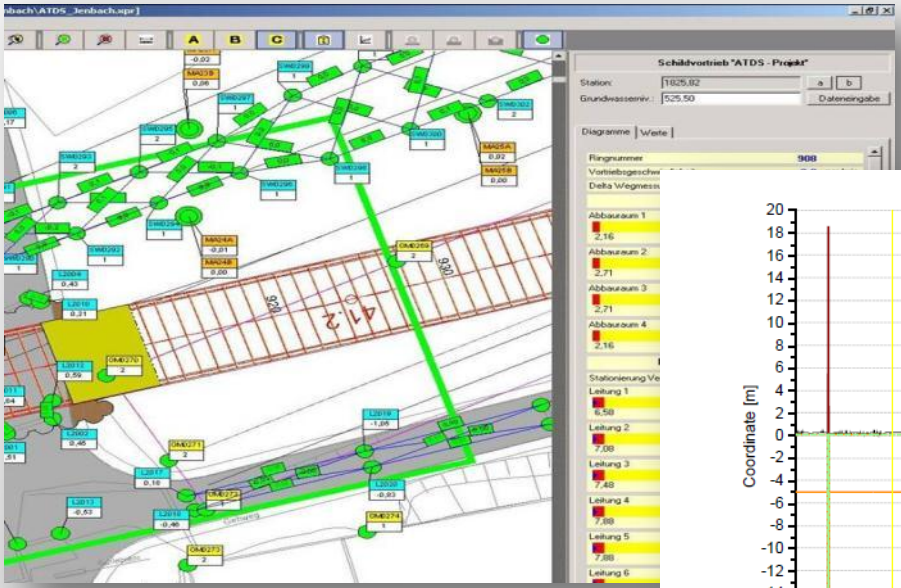

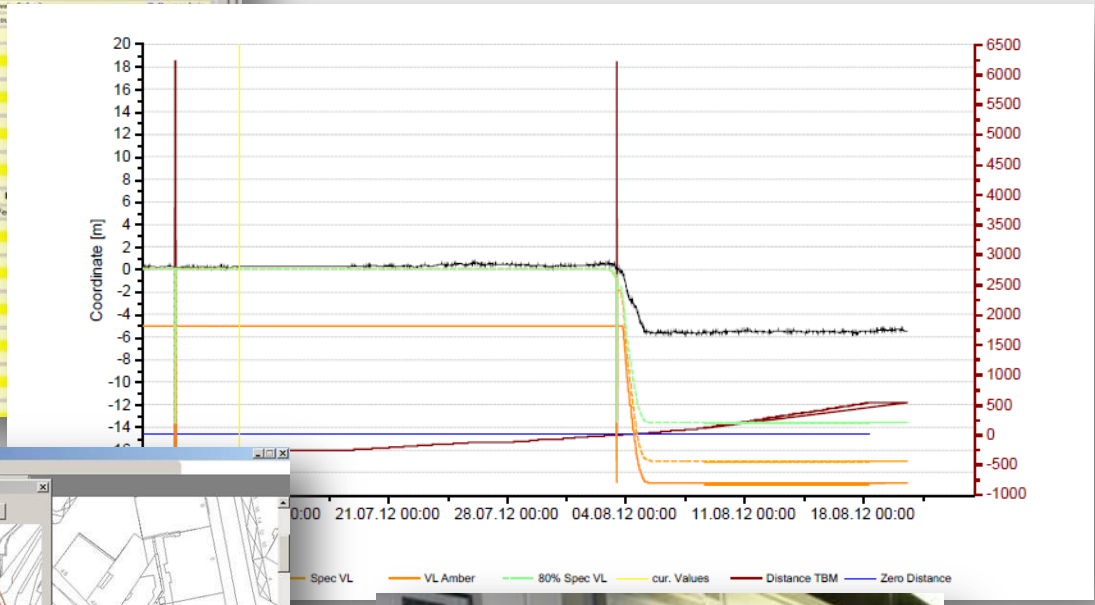

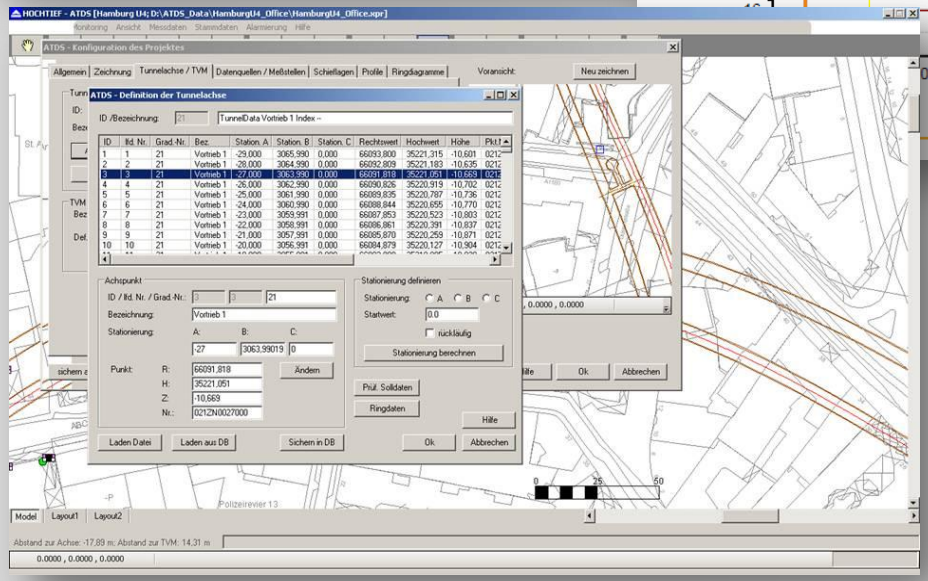

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Modern urban tunnelling requires a master plan for settlement control:

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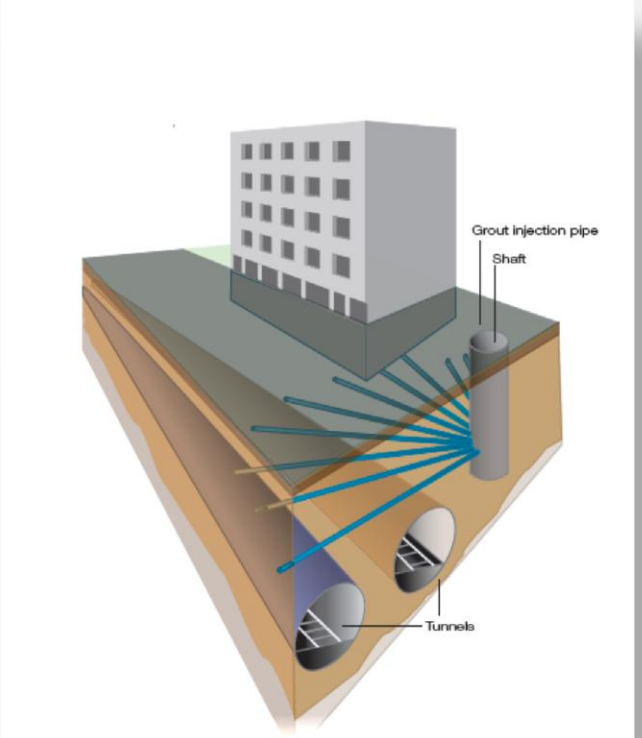
2) Monitoring and recording of the TBM operational parameters in real time
3) Real time monitoring of the effects on the surrounding
4) Mitigation measures in case of critical situations
   - Back-analysis of recorded data
   - Modification of TBM operation
   -Contingency measures



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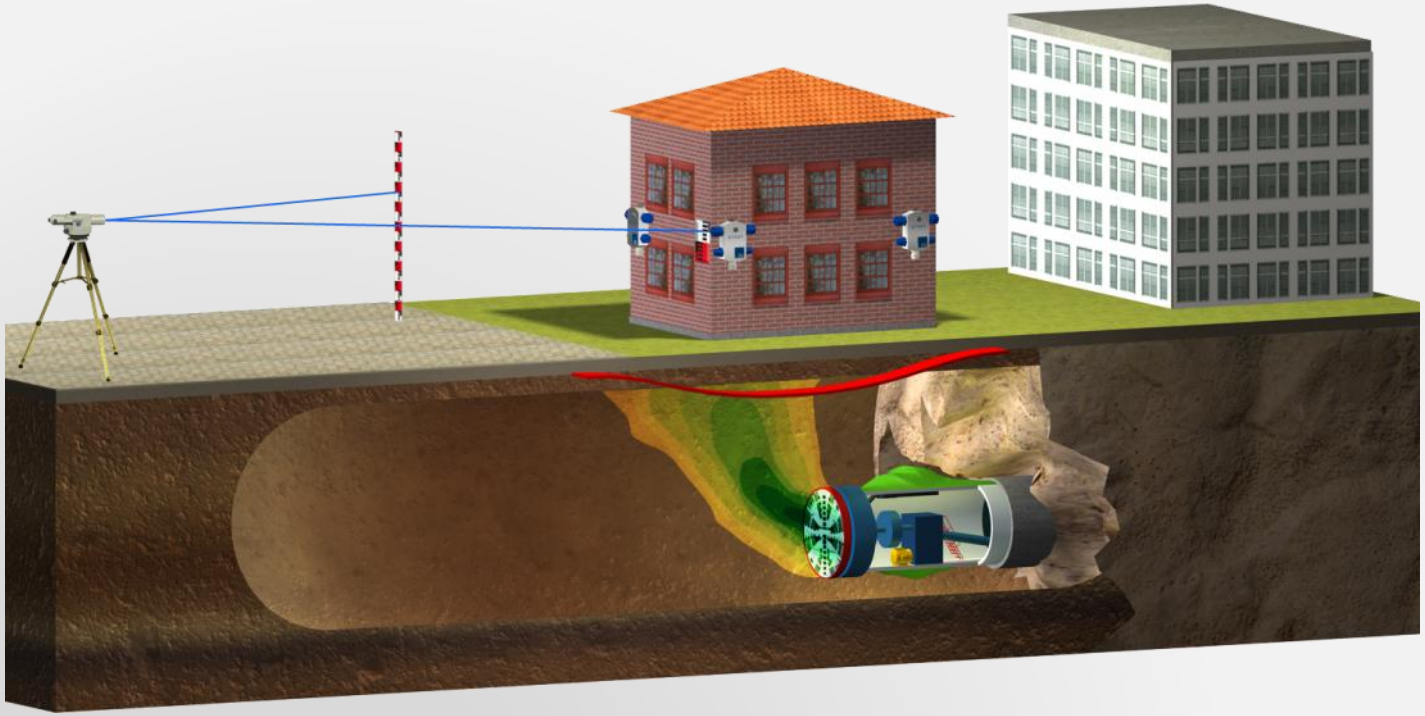

Jacking
Infill
Propping
Underpinning
Ground freezing
Grouting

Key Elements to successful monitoring

- Invest in a database and monitoring system that is compatible with all end users.
  - TBM
  - Spray Concrete Lining
  - Excavation
  - Stakeholders , Utilities and Archival

- Ensure that the monitoring system is expandable.
  - Latest technology , GIS, 3D
  - BIM
  - Construction Data
  - Public

- Good control of each construction operation
  - Shift Review Groups
  - Technical Meetings & Technical Groups
  - Clear Plan of Action
  - **Communication**

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Key Elements to successful monitoring

- Specify instrumentation that is going to give value
  - Cost against information
  - Good data comes from a good instrument that has been installed well
  - Decide what is really required to be measured
  - Excavations
  - Stakeholders , Utilities and Archival
  - Accuracy

- Use new technology & thinking

  - Be bold, trials, bespoke configuration, research
  - Observational Method
  - Training

- Feedback
  - Designers - Good Data will save money
  - Value Engineering
  - Case Studies, Papers, media
  - Improved specifications

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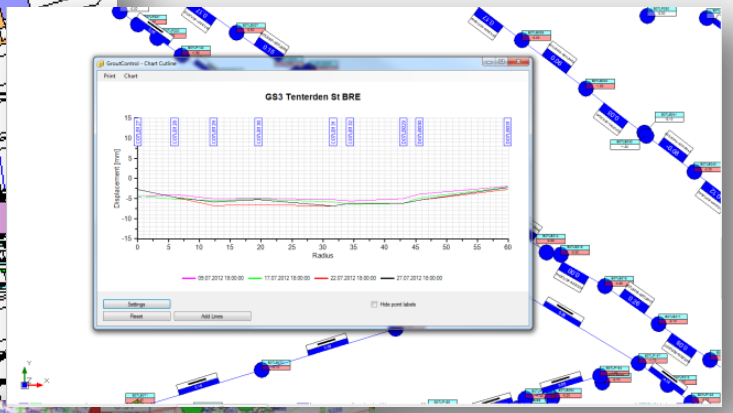
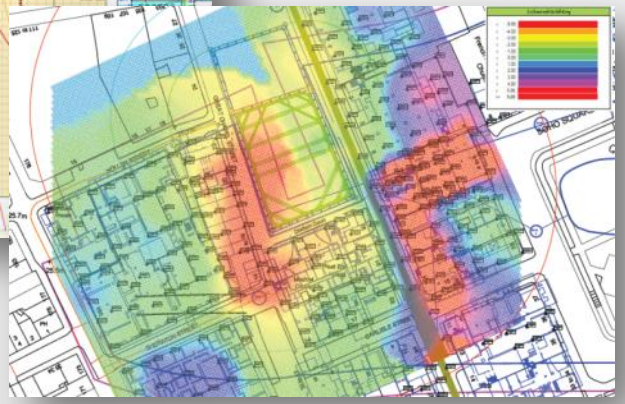
Now and the future

Software
CIM & BIM
Instruments

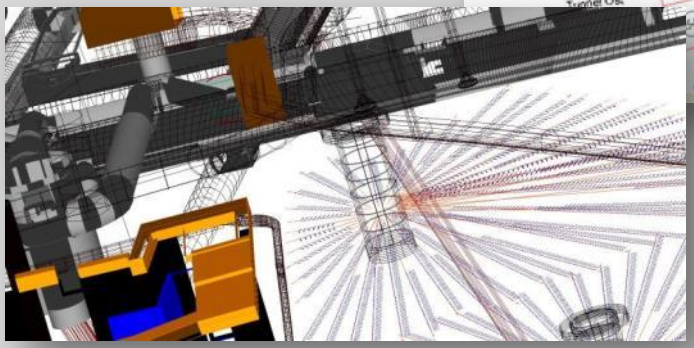


Slopes and Distortions

Real time information



Contours



3D viewing

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AGS Converter

Convergence Apps for Phones & I Pads

Google Earth integration 3 D

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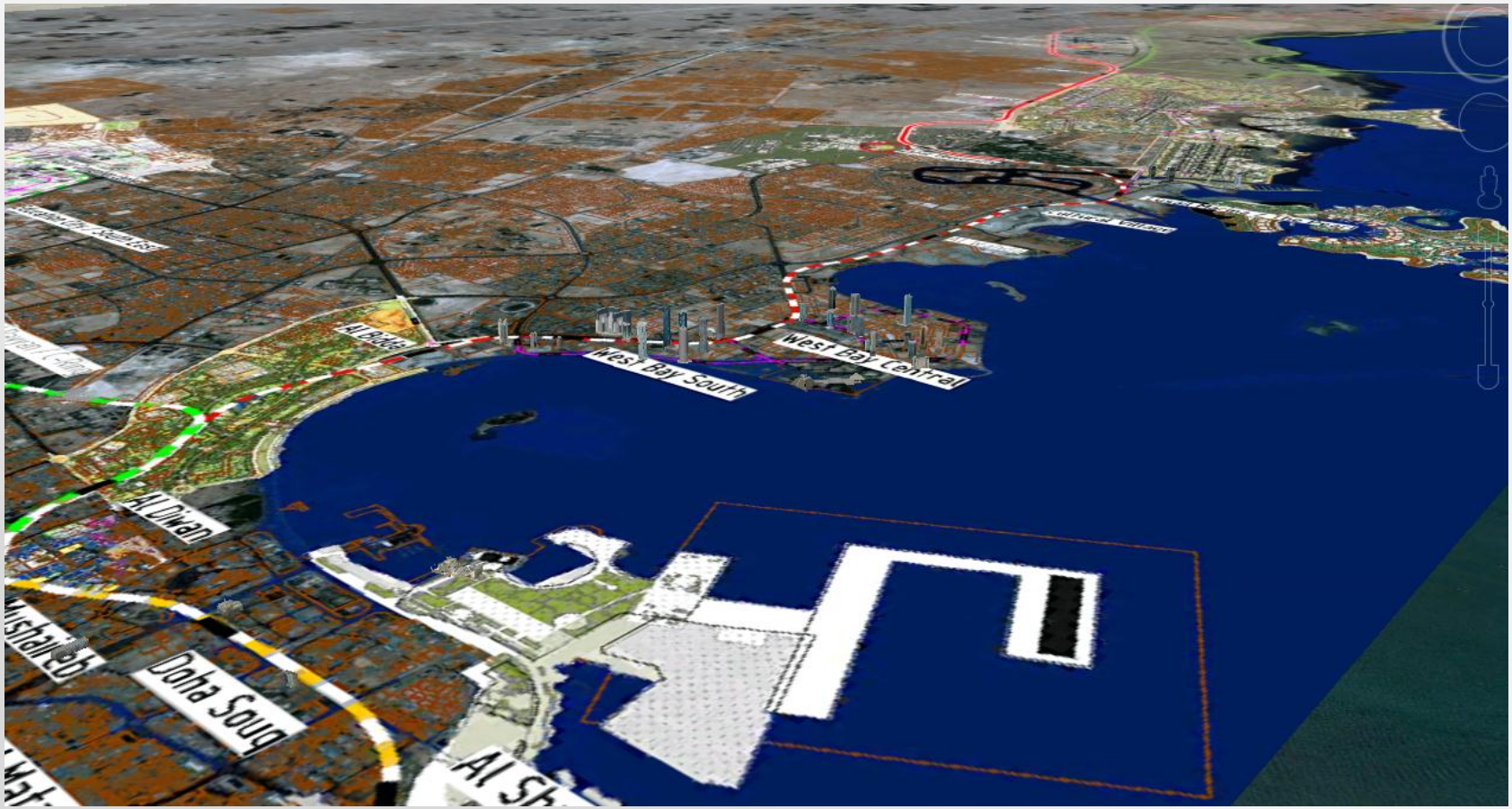

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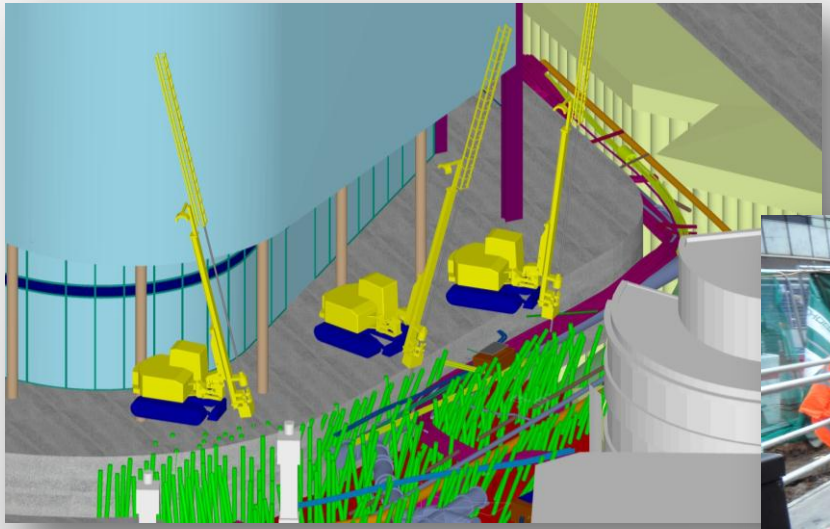

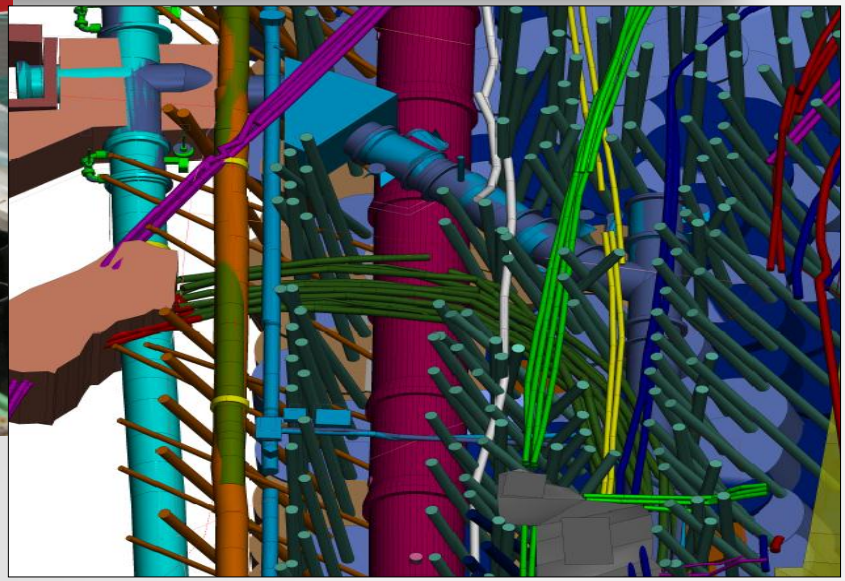

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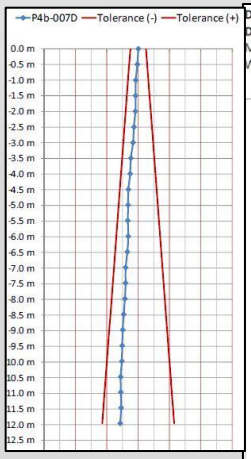

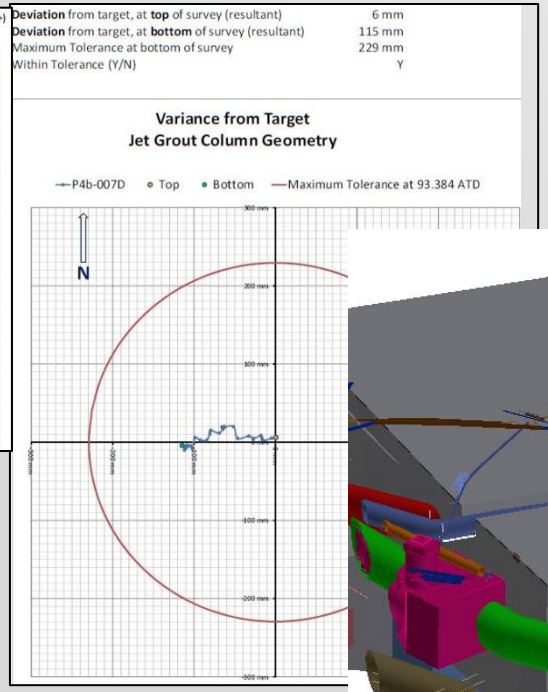

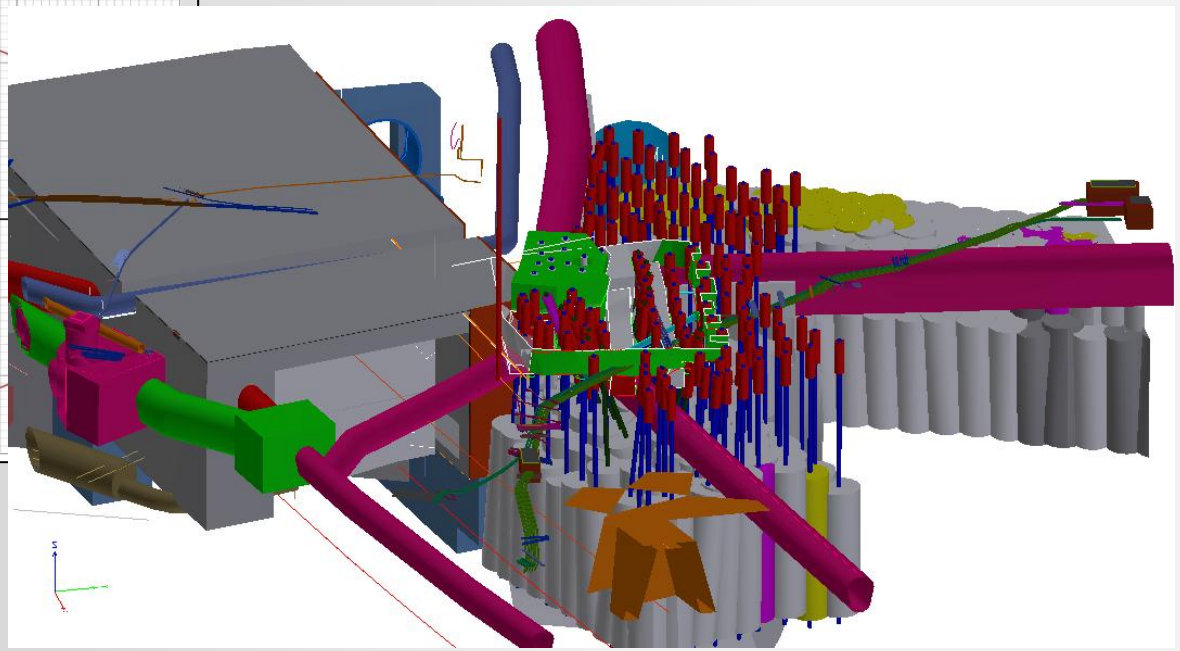

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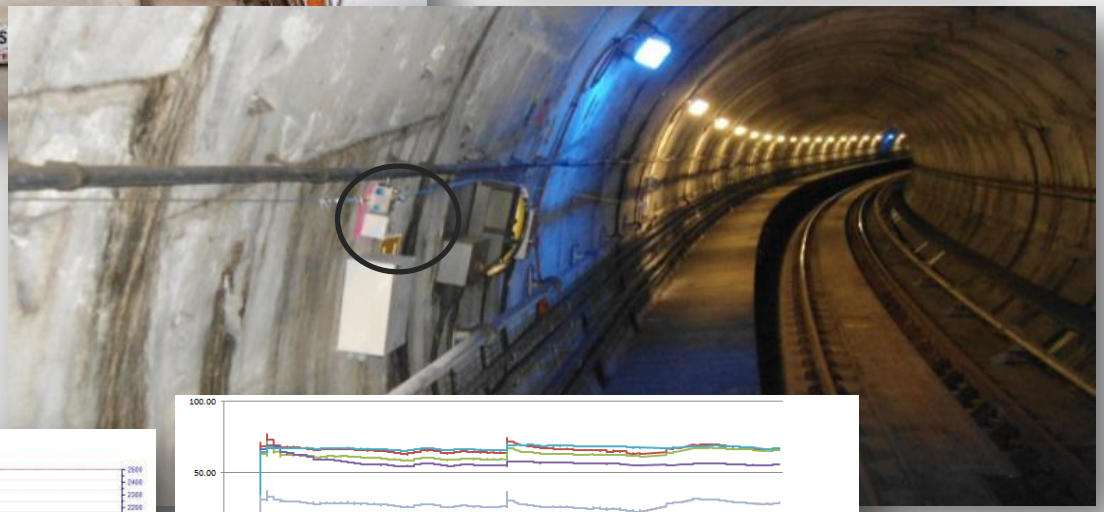

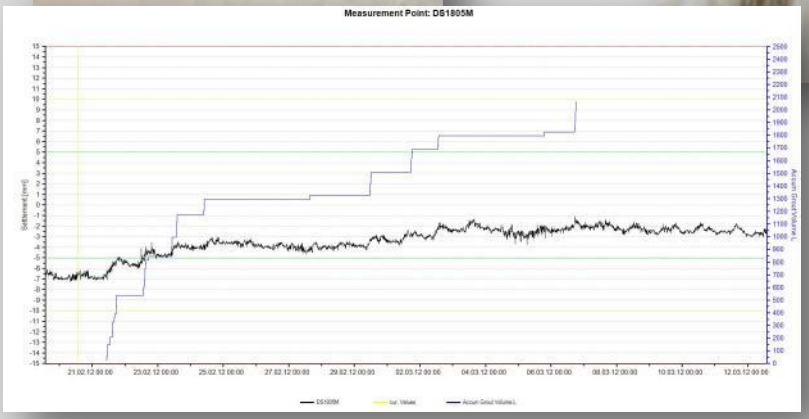

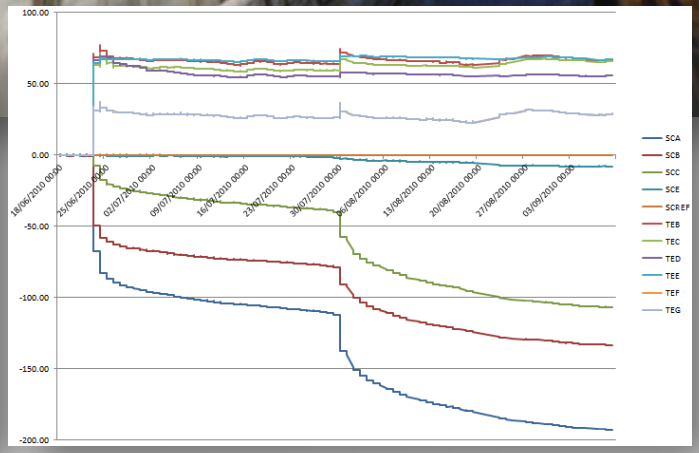

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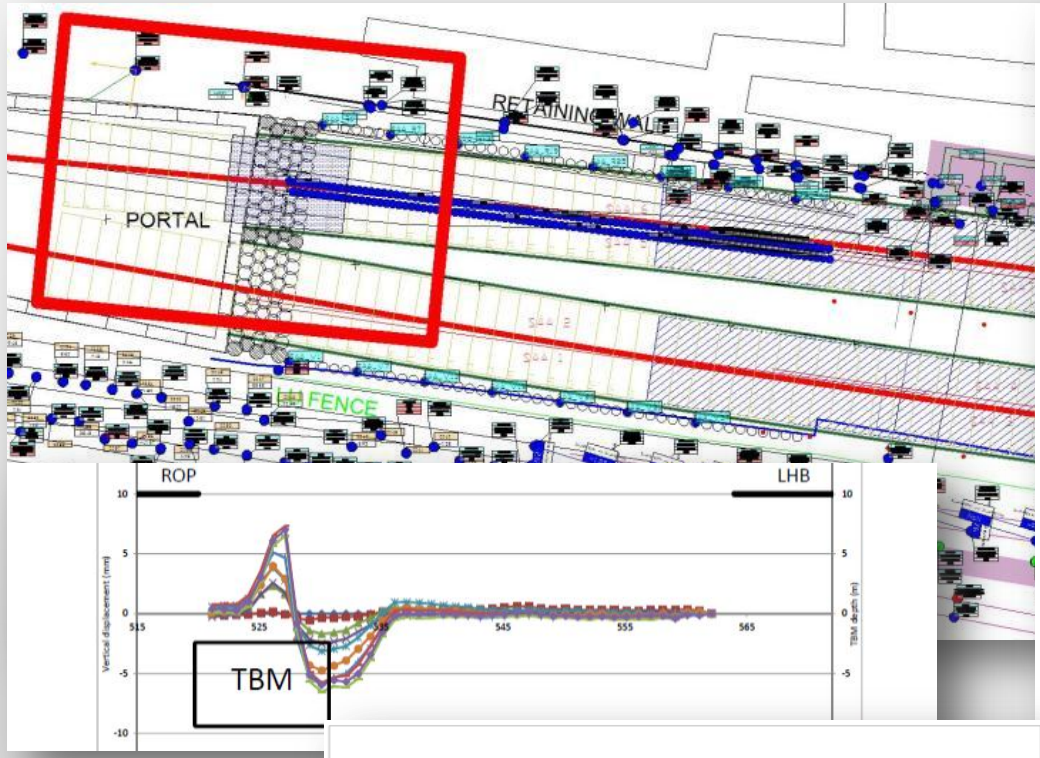

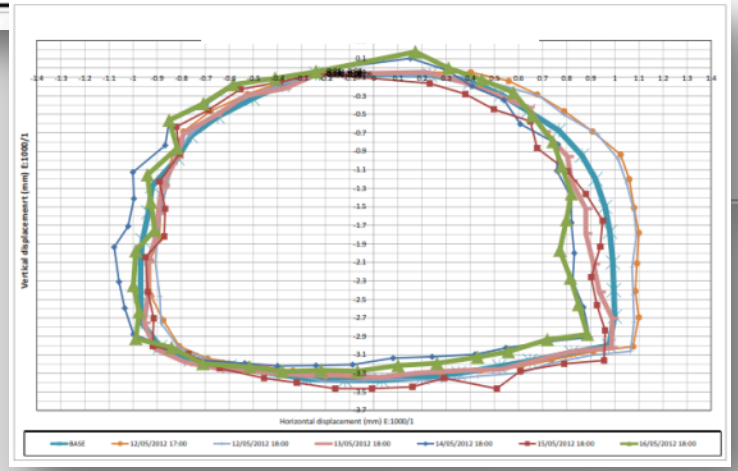

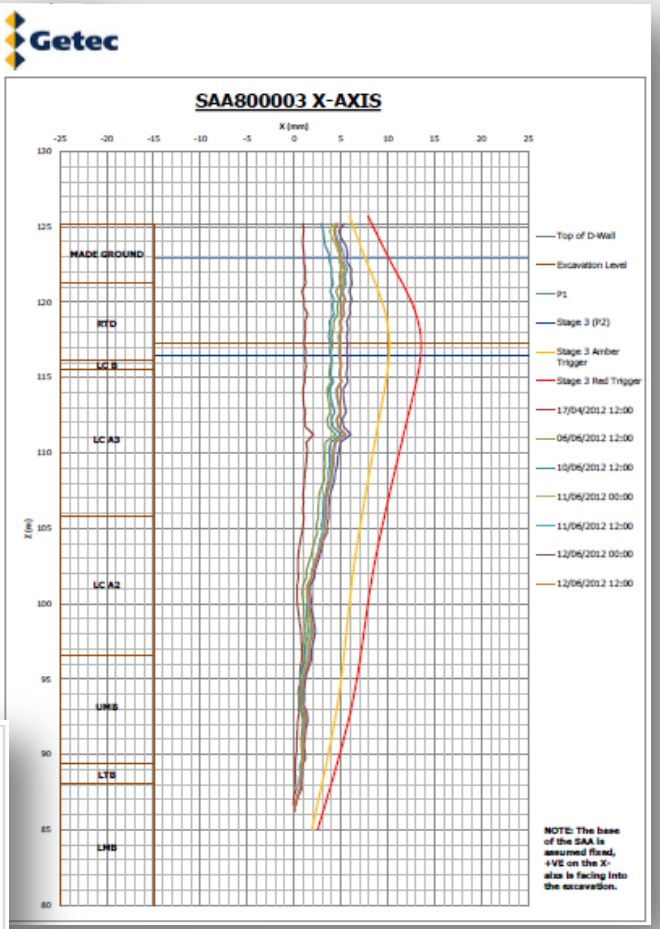

Vertical and Horizontal deflection measurements SAA

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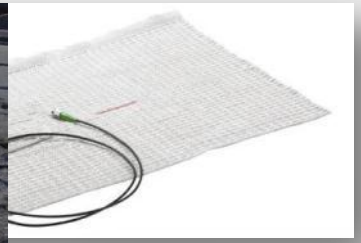

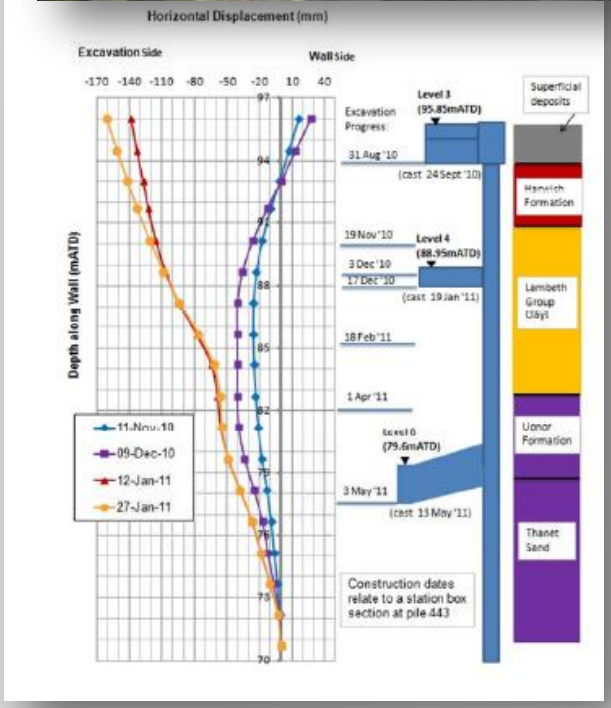

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Essentials for settlement control:

- Instrumentation & Monitoring companies give free advice ! Use it.
- Thorough engineering design
- Continuous monitoring before, during and after execution
- Have robust methods and routines of reporting data .
- Integration of all available data into one system .Real time information and visualisation at any location including the TBM data and construction data
- Flexibility (software, specification, ideas, value engineering)
- Everything moves- its how you interpret and manage that movement
- Keep it simple and communicate effectively
- Observe trends and look for clues outside the confines of your site

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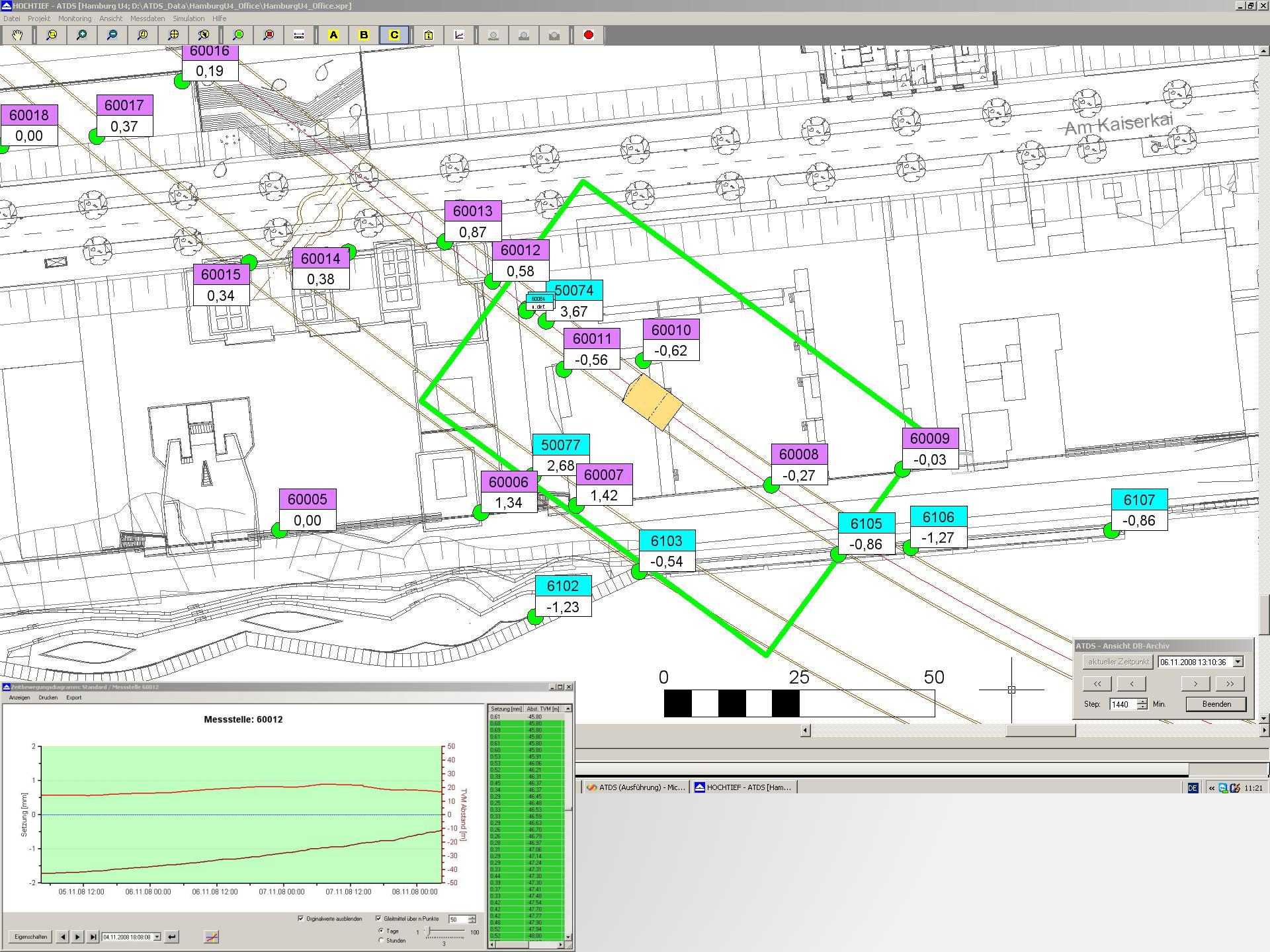
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ATDS - Ansicht DB-Archiv
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06.11.2008 13:10:36
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1440
Min.
Beenden
Zeitbewegungsdiagramm: Standard / Messstelle 60012
Anzeigen Drucken Export
Messstelle: 60012
Setzung [mm]
TVM Abstand [m]
05.11.08 12:00
06.11.08 00:00
06.11.08 12:00
07.11.08 00:00
07.11.08 12:00
08.11.08 00:00
Originalwerte ausblenden
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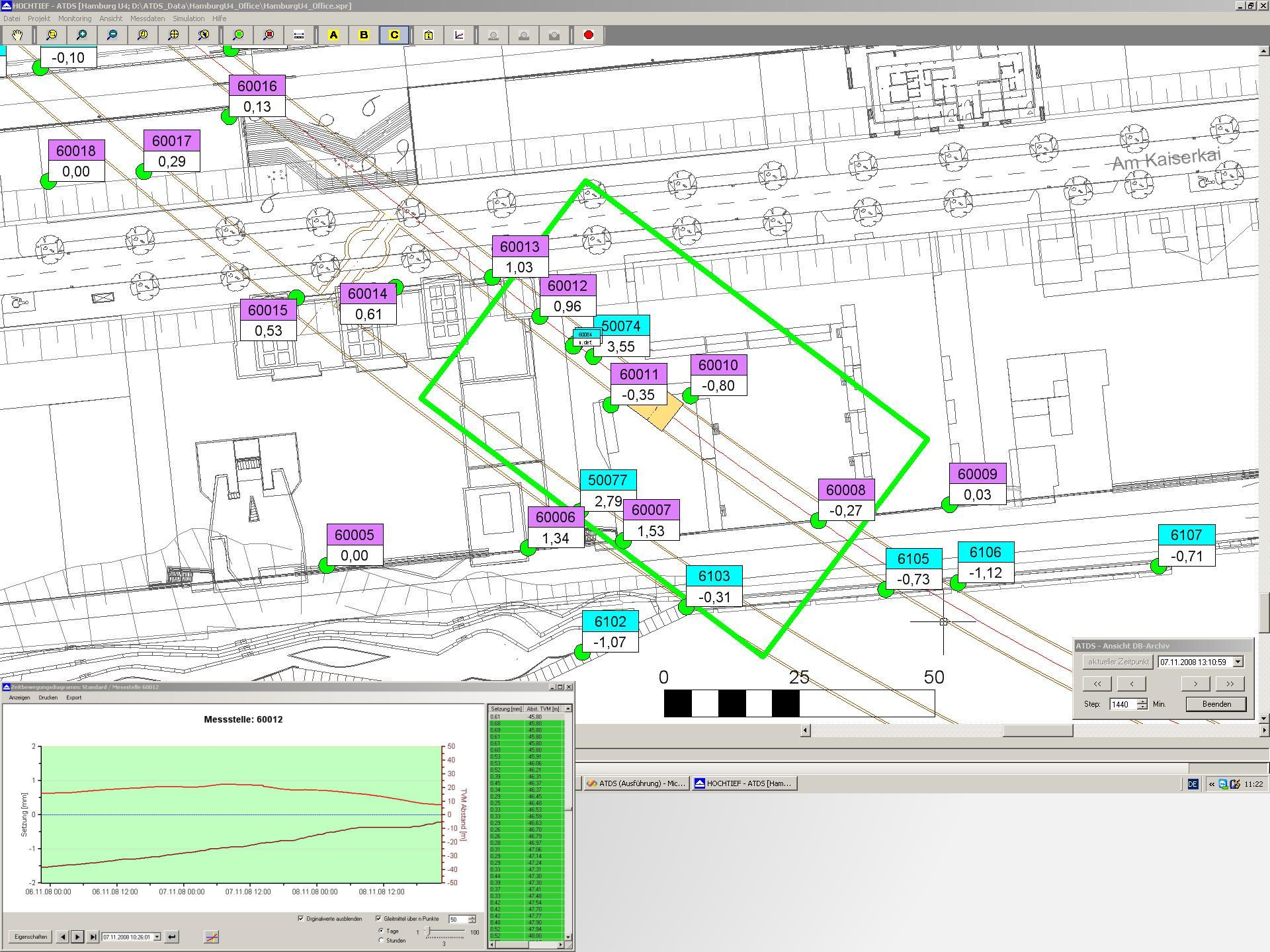
Tage
Stunden
Eigenschaften
ATDS (Ausführung) - Mic...
HOCHTIEF - ATDS [Ham...
11:21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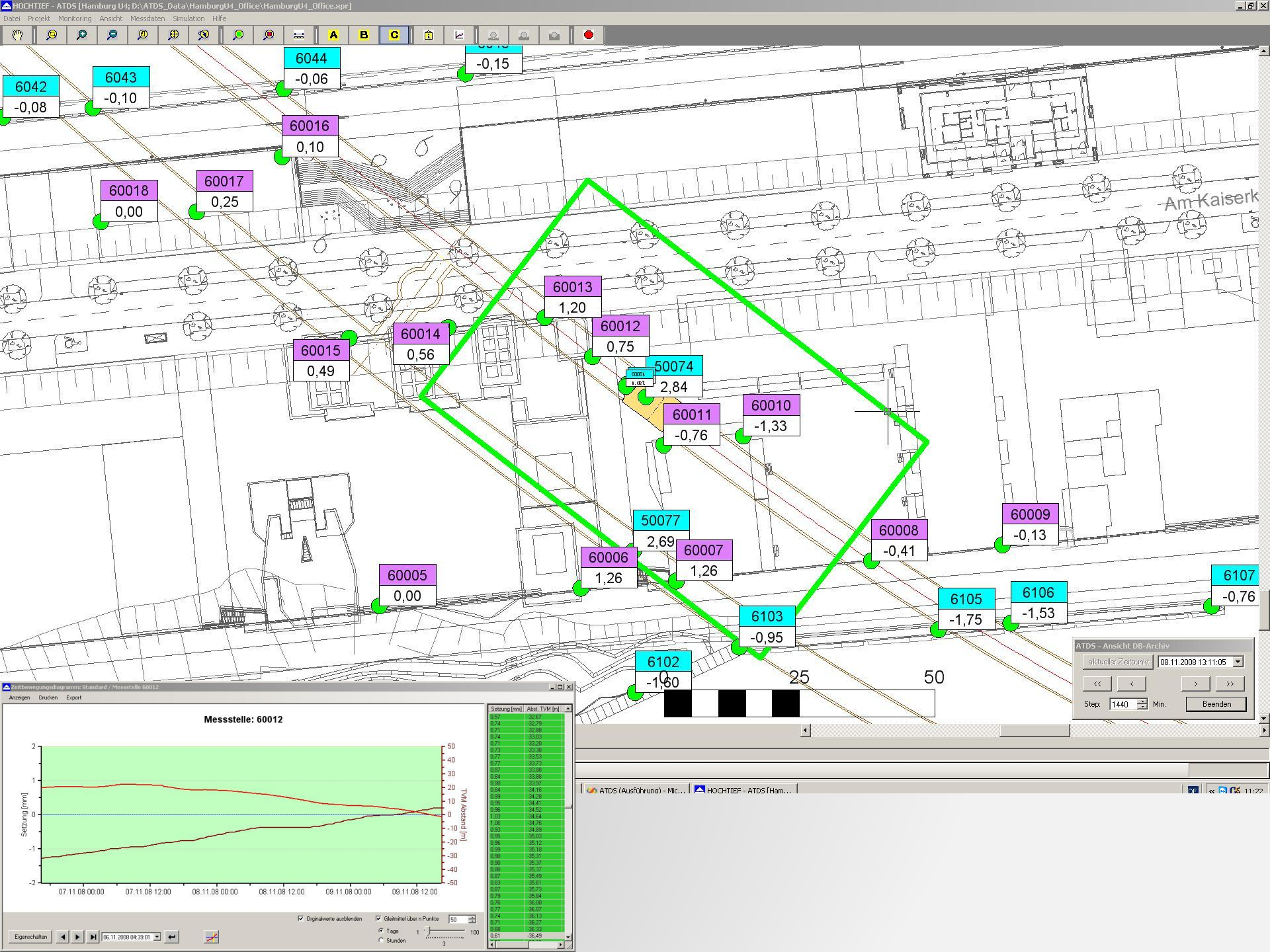
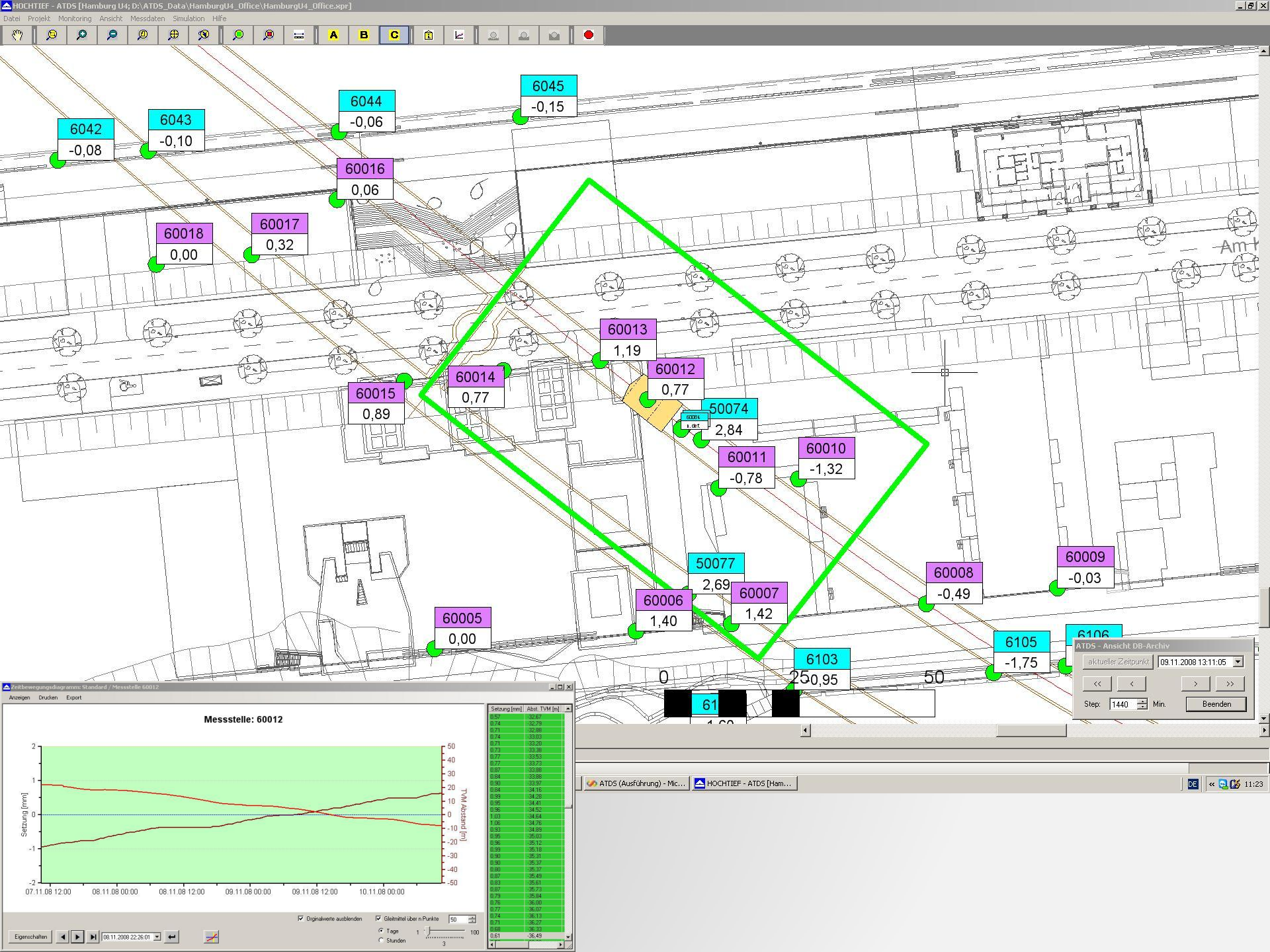
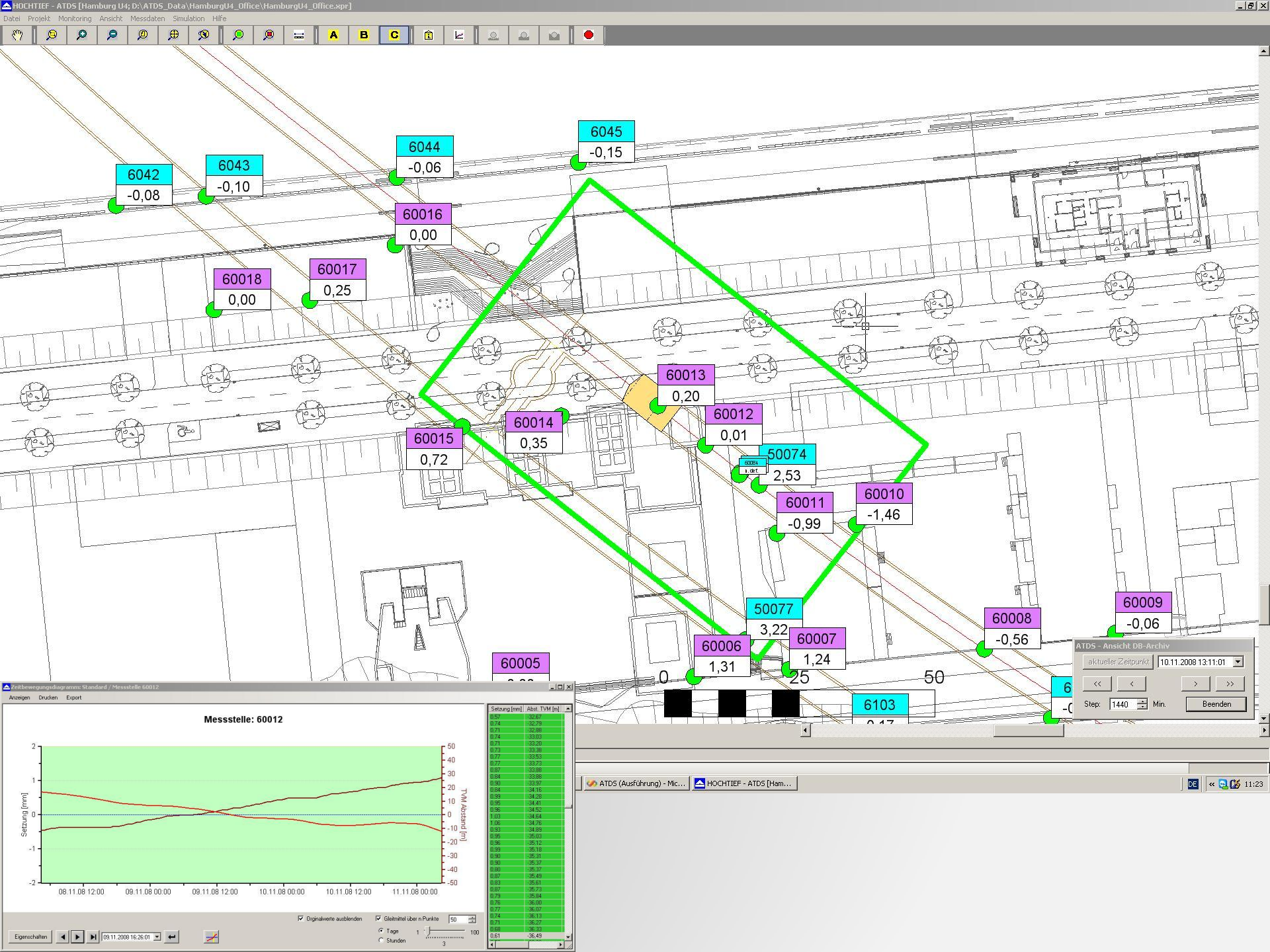
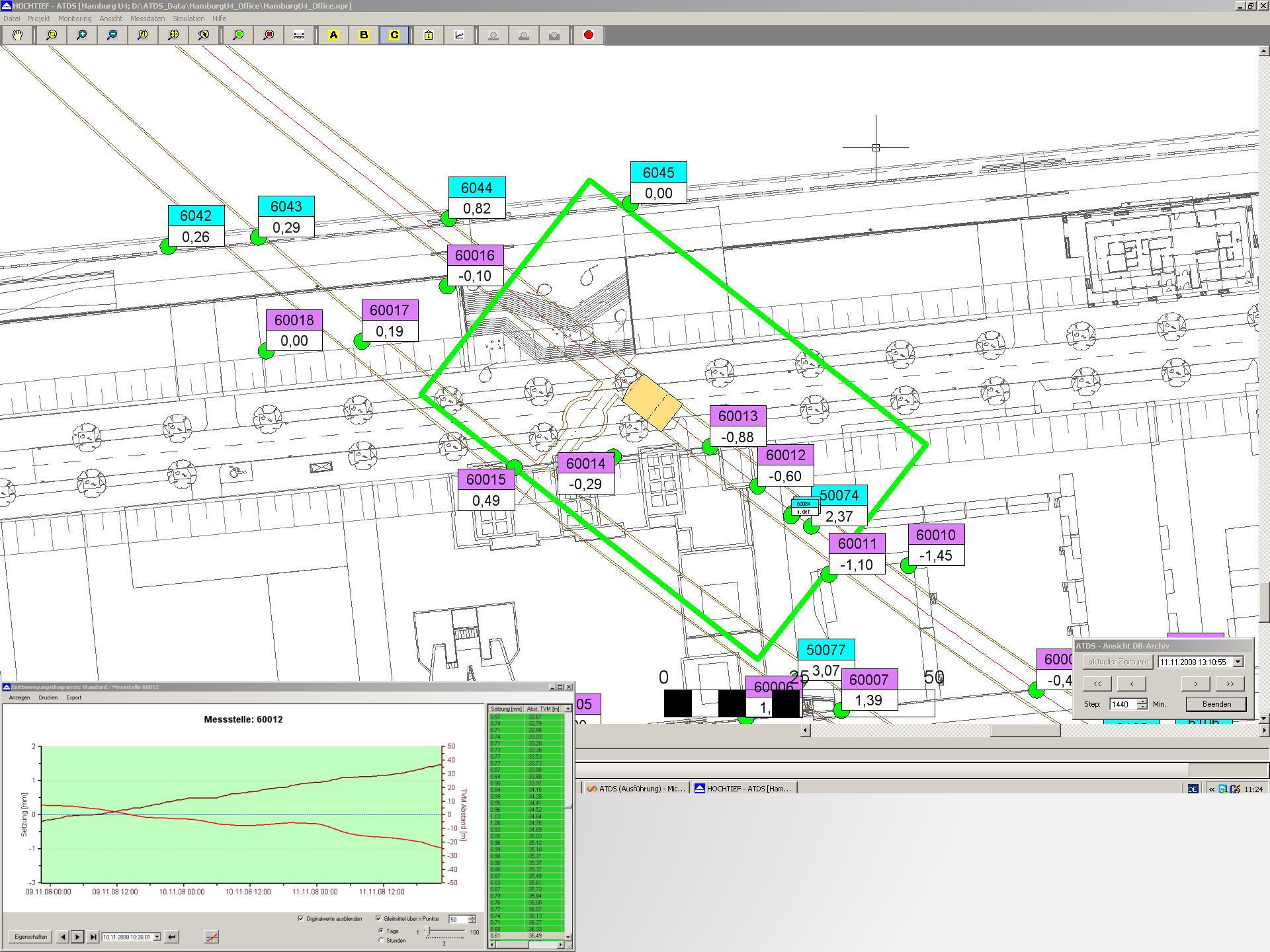
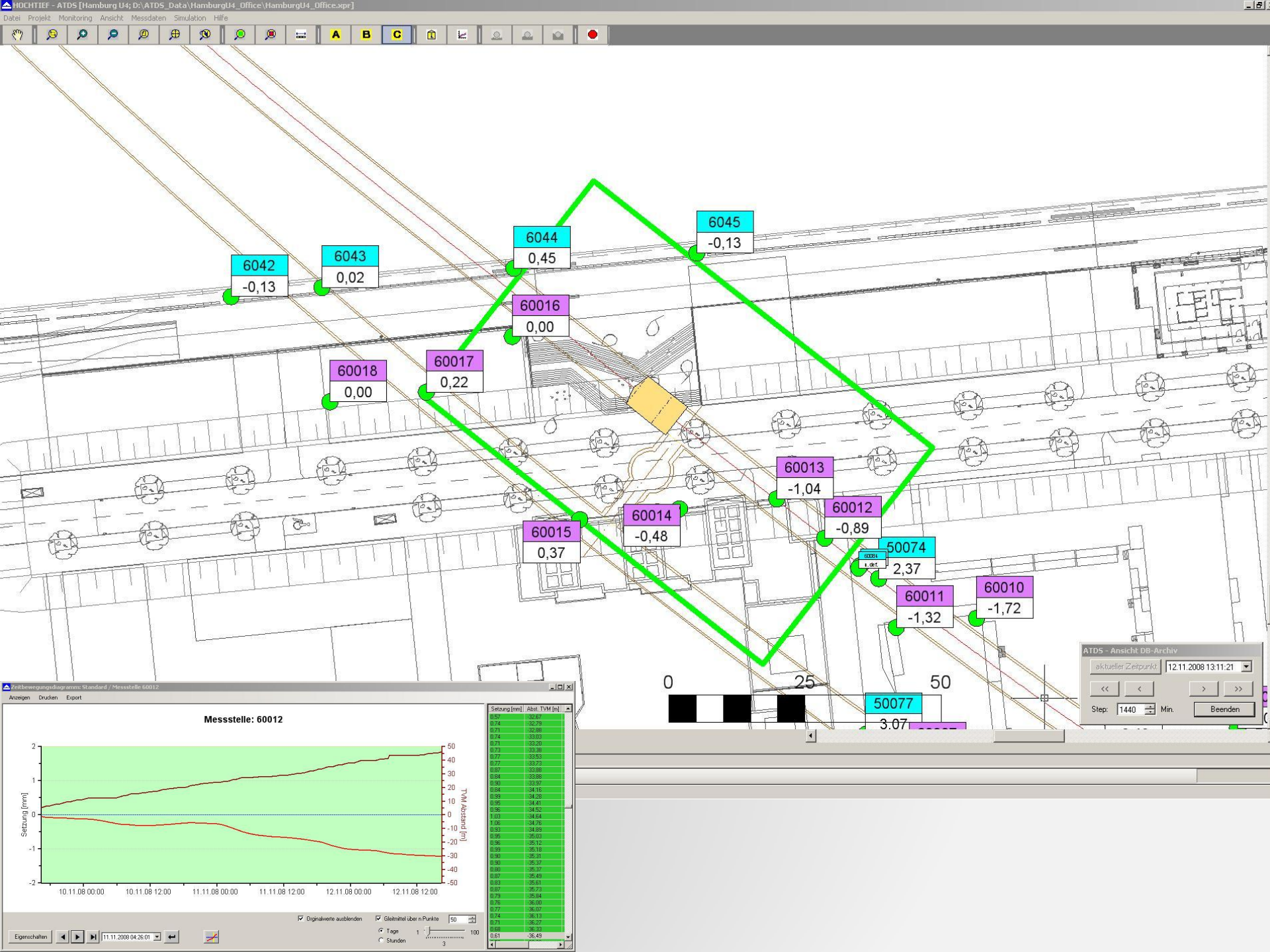
ATDS - Ansicht DB-Archiv
aktueller Zeitpunkt
07.11.2008 13:10:59
Step:
1440
Min.
Beenden
Zeitbewegungsdiagramm: Standard / Messstelle 60012
Anzeigen Drucken Export
Messstelle: 60012
Setzung [mm]
TVM Abstand [m]
06.11.08 00:00
06.11.08 12:00
07.11.08 00:00
07.11.08 12:00
08.11.08 00:00
08.11.08 12:00
Originalwerte ausblenden
Gleitmittel über n Punkte
Tage
Stunden
Eigenschaften
ATDS (Ausführung) - Mic...
HOCHTIEF - ATDS [Ham...
11:22


HOCHTIEF - ATDS [Hamburg U4; D:\ATDS_Data\HamburgU4_Office\HamburgU4_Office.xpr]
Datei Projekt Monitoring Ansicht Messdaten Simulation Hilfe
6042 -0,08
6043 -0,10
6044 -0,06
-0,15
60016 0,10
60018 0,00
60017 0,25
60013 1,20
60012 0,75
60014 0,56
60015 0,49
50074 2,84
60011 -0,76
60010 -1,33
50077 2,69
60006 1,26
60007 1,26
60005 0,00
60008 -0,41
60009 -0,13
6107 -0,76
6105 -1,75
6106 -1,53
6103 -0,95
6102 -1,60
Am Kaiserk
25
50
ATDS - Ansicht DB-Archiv
aktueller Zeitpunkt
08.11.2008 13:11:05
Step: 1440 Min.
Beenden
Zeitbewegungsdiagramm: Standard / Messstelle 60012
Anzeigen Drucken Export
Messstelle: 60012
Setzung [mm]
TVM Abstand [m]
07.11.08 00:00
07.11.08 12:00
08.11.08 00:00
08.11.08 12:00
09.11.08 00:00
09.11.08 12:00
Originalwerte ausblenden
Gleitmittel über n Punkte
Tage
Stunden
Eigenschaften
ATDS (Ausführung) - Mic...
HOCHTIEF - ATDS [Ham...


HOCHTIEF - ATDS [Hamburg U4; D:\ATDS_Data\HamburgU4_Office\HamburgU4_Office.xpr]
Datei Projekt Monitoring Ansicht Messdaten Simulation Hilfe
6042 -0,08
6043 -0,10
6044 -0,06
6045 -0,15
60016 0,06
60018 0,00
60017 0,32
60013 1,19
60014 0,77
60012 0,77
60015 0,89
50074 2,84
60011 -0,78
60010 -1,32
50077 2,69
60007 1,42
60006 1,40
60005 0,00
60008 -0,49
60009 -0,03
6105 -1,75
6103 0,95
ATDS - Ansicht DB-Archiv
aktueller Zeitpunkt
09.11.2008 13:11:05
Step: 1440 Min.
Beenden
Zeitbewegungsdiagramm: Standard / Messstelle 60012
Anzeigen Drucken Export
Messstelle: 60012
Setzung [mm]
TVM Abstand [m]
07.11.08 12:00
08.11.08 00:00
08.11.08 12:00
09.11.08 00:00
09.11.08 12:00
10.11.08 00:00
Originalwerte ausblenden
Gleitmittel über n Punkte
Tage
Stunden
Eigenschaften
ATDS (Ausführung) - Mic...
HOCHTIEF - ATDS [Ham...
11:23


HOCHTIEF - ATDS [Hamburg U4; D:\ATDS_Data\HamburgU4_Office\HamburgU4_Office.xpr]
Datei Projekt Monitoring Ansicht Messdaten Simulation Hilfe
6042 -0,08
6043 -0,10
6044 -0,06
6045 -0,15
60016 0,00
60017 0,25
60018 0,00
60013 0,20
60012 0,01
60014 0,35
60015 0,72
50074 2,53
60011 -0,99
60010 -1,46
50077 3,22
60006 1,31
60007 1,24
60008 -0,56
60009 -0,06
60005
6103
0
25
50
Messstelle: 60012
Setzung [mm]
TVM Abstand [m]
08.11.08 12:00
09.11.08 00:00
09.11.08 12:00
10.11.08 00:00
10.11.08 12:00
11.11.08 00:00
ATDS - Ansicht DB-Archiv
aktueller Zeitpunkt
10.11.2008 13:11:01
Step: 1440 Min.
Beenden
ATDS (Ausführung) - Mic...
HOCHTIEF - ATDS [Ham...
11:23


HOCHTIEF - ATDS [Hamburg U4; D:\ATDS_Data\HamburgU4_Office\HamburgU4_Office.xpr]
Datei Projekt Monitoring Ansicht Messdaten Simulation Hilfe
6042
0,26
6043
0,29
6044
0,82
6045
0,00
60016
-0,10
60018
0,00
60017
0,19
60013
-0,88
60012
-0,60
60014
-0,29
60015
0,49
50074
2,37
60011
-1,10
60010
-1,45
50077
3,07
60007
1,39
60006
1,
-0,4
0
25
50
Messstelle: 60012
Setzung [mm]
TVM Abstand [m]
09.11.08 00:00
09.11.08 12:00
10.11.08 00:00
10.11.08 12:00
11.11.08 00:00
11.11.08 12:00
ATDS - Ansicht DB-Archiv
aktueller Zeitpunkt
11.11.2008 13:10:55
Step:
1440
Min.
Beenden
ATDS (Ausführung) - Mic...
HOCHTIEF - ATDS [Ham...
11:24


HOCHTIEF - ATDS [Hamburg U4; D:\ATDS_Data\HamburgU4_Office\HamburgU4_Office.xpr]
Datei Projekt Monitoring Ansicht Messdaten Simulation Hilfe
6042 -0,13
6043 0,02
6044 0,45
6045 -0,13
60016 0,00
60018 0,00
60017 0,22
60013 -1,04
60014 -0,48
60012 -0,89
60015 0,37
50074 2,37
60011 -1,32
60010 -1,72
50077 3,07
0 25 50
ATDS - Ansicht DB-Archiv
aktueller Zeitpunkt 12.11.2008 13:11:21
Step: 1440 Min.
Beenden
Zeitbewegungsdiagramm: Standard / Messstelle 60012
Anzeigen Drucken Export
Messstelle: 60012
Setzung [mm]
TVM Abstand [m]
10.11.08 00:00
10.11.08 12:00
11.11.08 00:00
11.11.08 12:00
12.11.08 00:00
12.11.08 12:00
Originalwerte ausblenden
Gleitmittel über n Punkte
Tage
Stunden
Eigenschaften

Keeping settlement in context

Diameter = 25mm
Thickness = 1.81mm

Thank You for your Time