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# Trap&Treat BOS200® Case Studies

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*In-Situ Services Team Leader*
*Ejlskov A/S*

# Case Study #1

# Injection Design and Injection Layout Map

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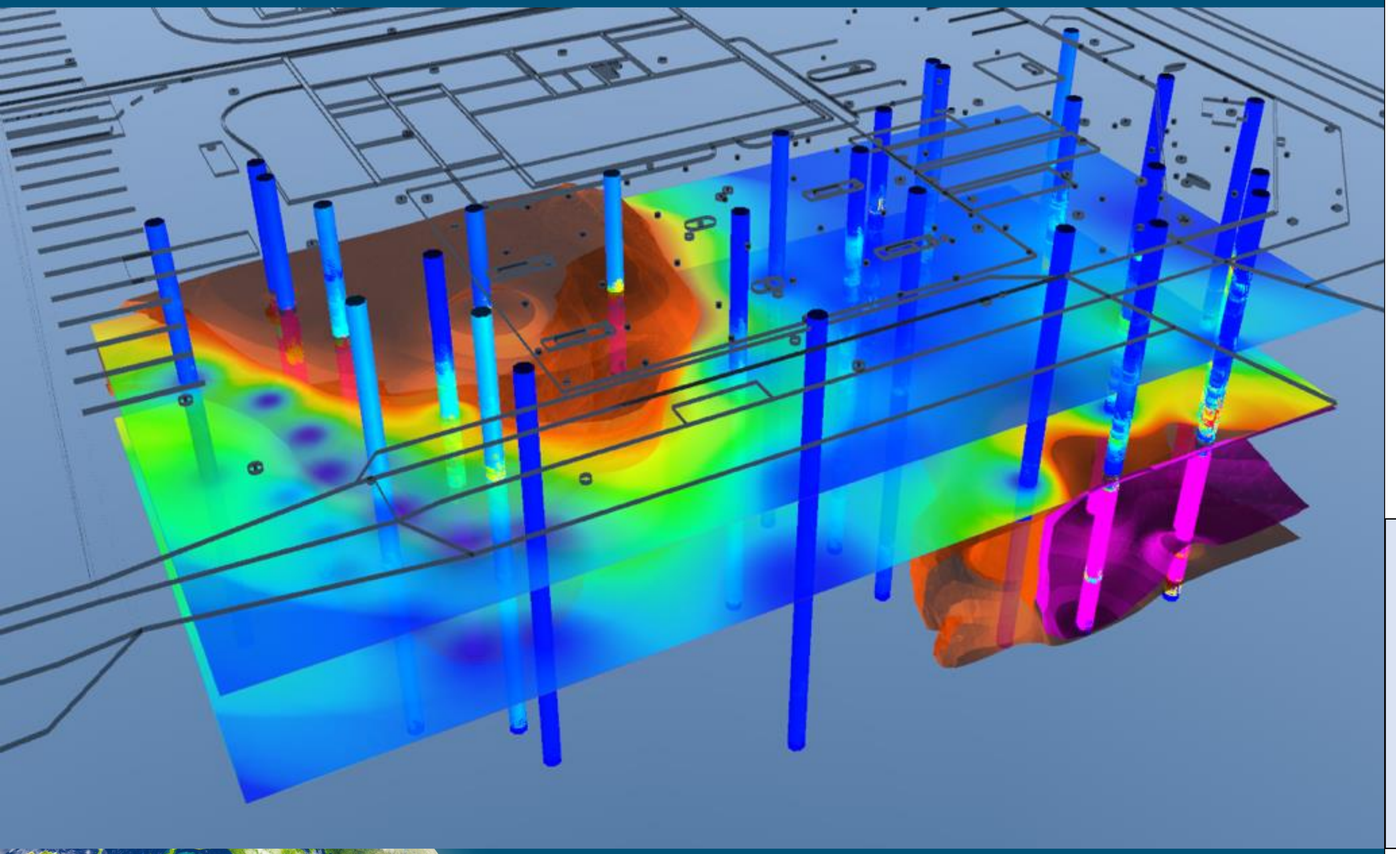
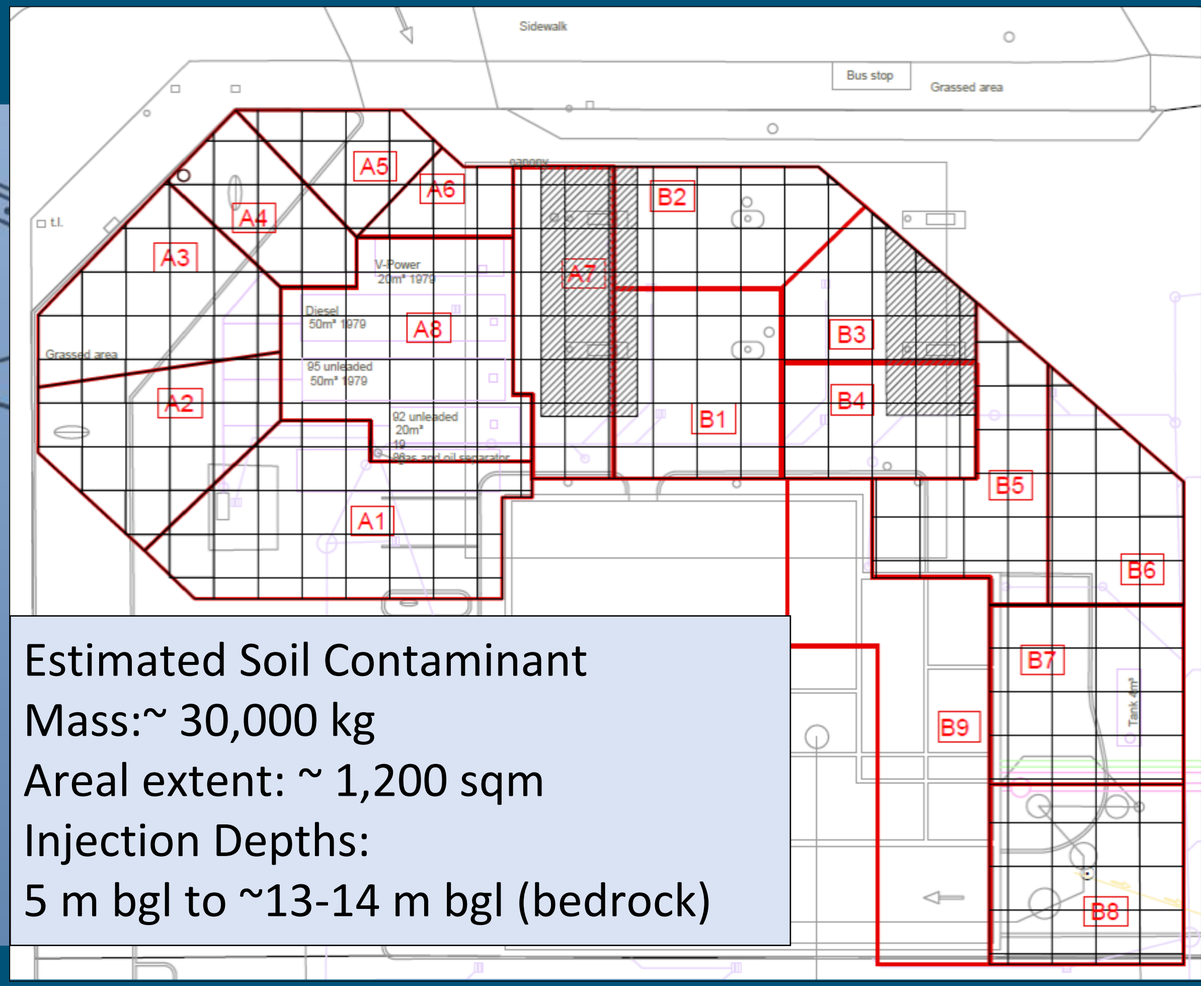
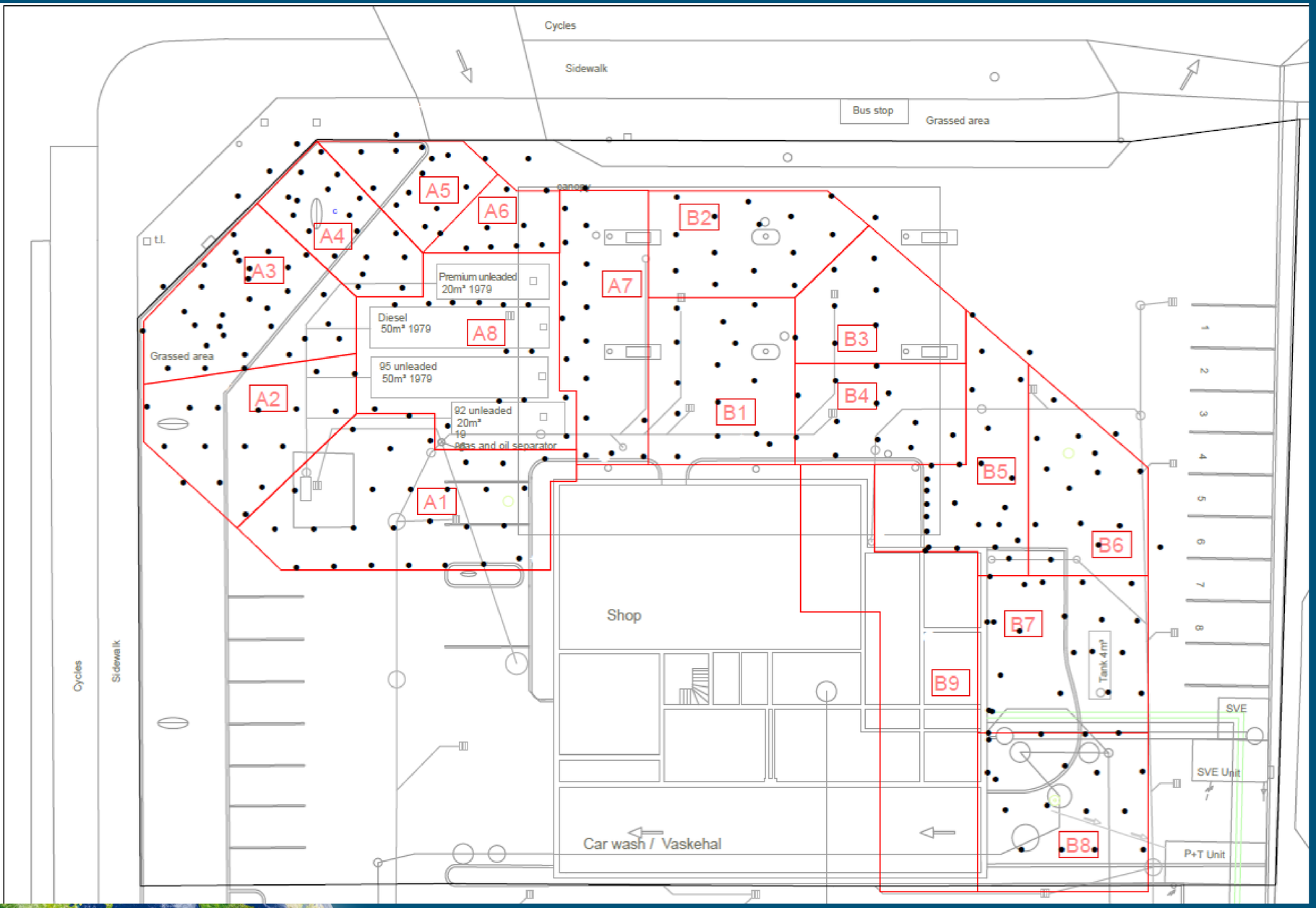





Estimated Soil Contaminant
Mass:~ 30,000 kg
Areal extent: ~ 1,200 sqm
Injection Depths:
5 m bgl to ~13-14 m bgl (bedrock)

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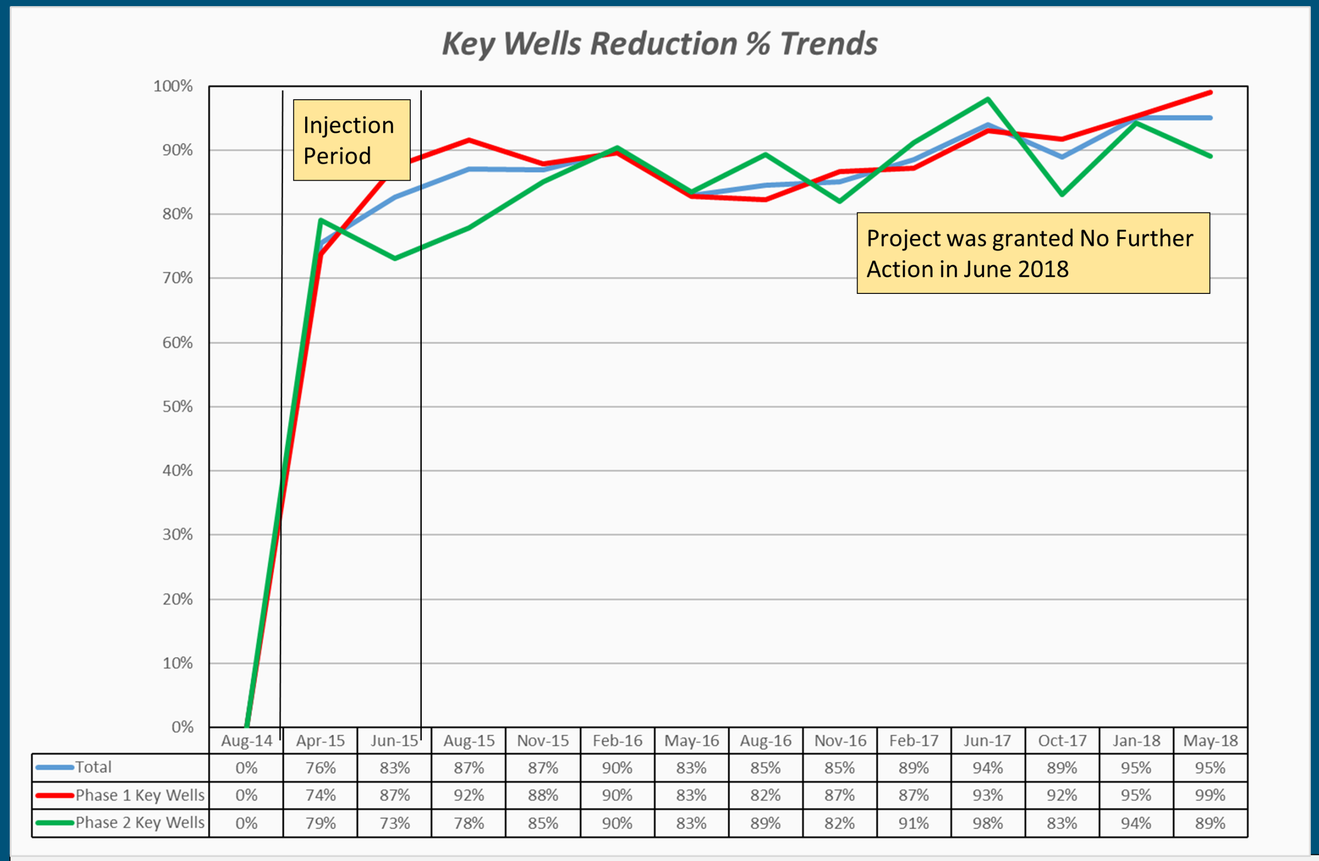
# Injection Points Map

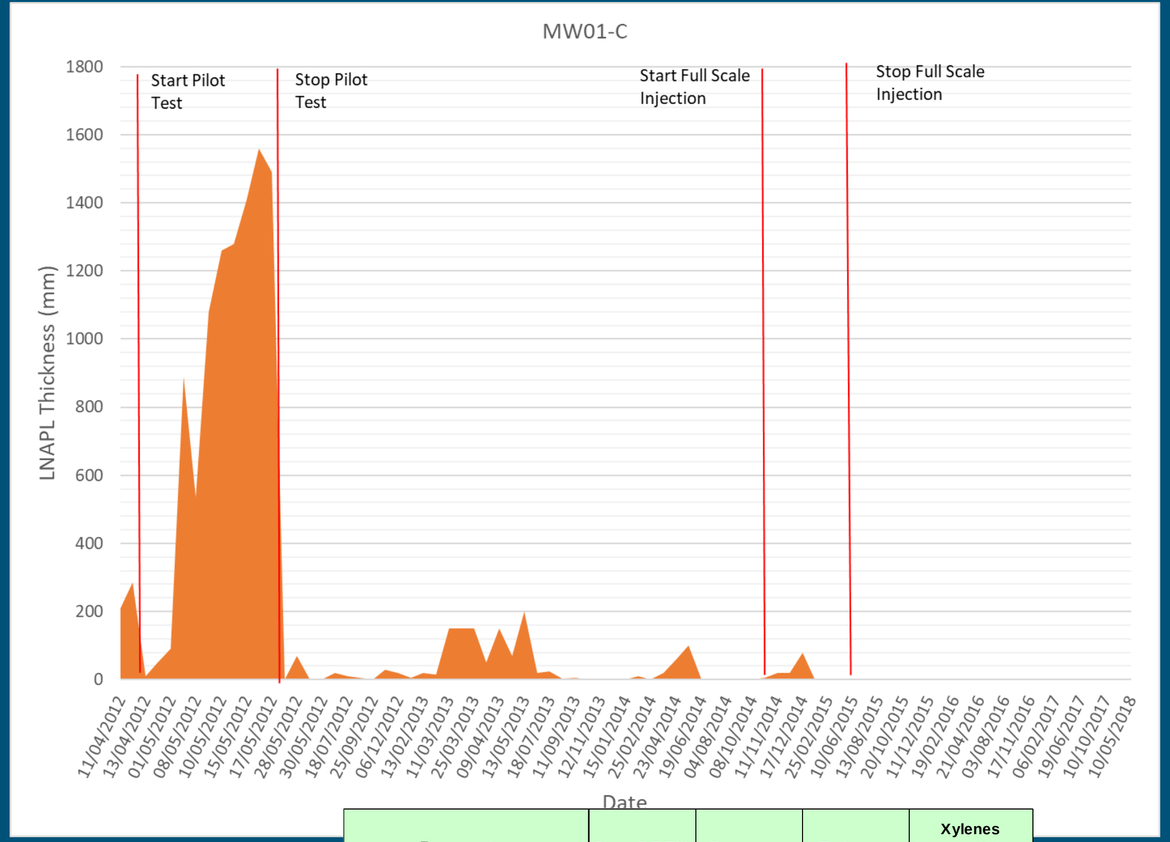
Two Phases of works were carried out:

- Phase 1 from October to December 2014 (station operational)
- Phase 2 from March to May 2015 (station closed)
- Approx. 287 injection points and 72,000 kg of BOS200® injected

# Source and plume treatment – Copenhagen (Active Gas Station) – Case Study – Performance Based Contract




| | Aug-14 | Apr-15 | Jun-15 | Aug-15 | Nov-15 | Feb-16 | May-16 | Aug-16 | Nov-16 | Feb-17 | Jun-17 | Oct-17 | Jan-18 | May-18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 0% | 76% | 83% | 87% | 87% | 90% | 83% | 85% | 85% | 89% | 94% | 89% | 95% | 95% |
| Phase 1 Key Wells | 0% | 74% | 87% | 92% | 88% | 90% | 83% | 82% | 87% | 87% | 93% | 92% | 95% | 99% |
| Phase 2 Key Wells | 0% | 79% | 73% | 78% | 85% | 90% | 83% | 89% | 82% | 91% | 98% | 83% | 94% | 89% |



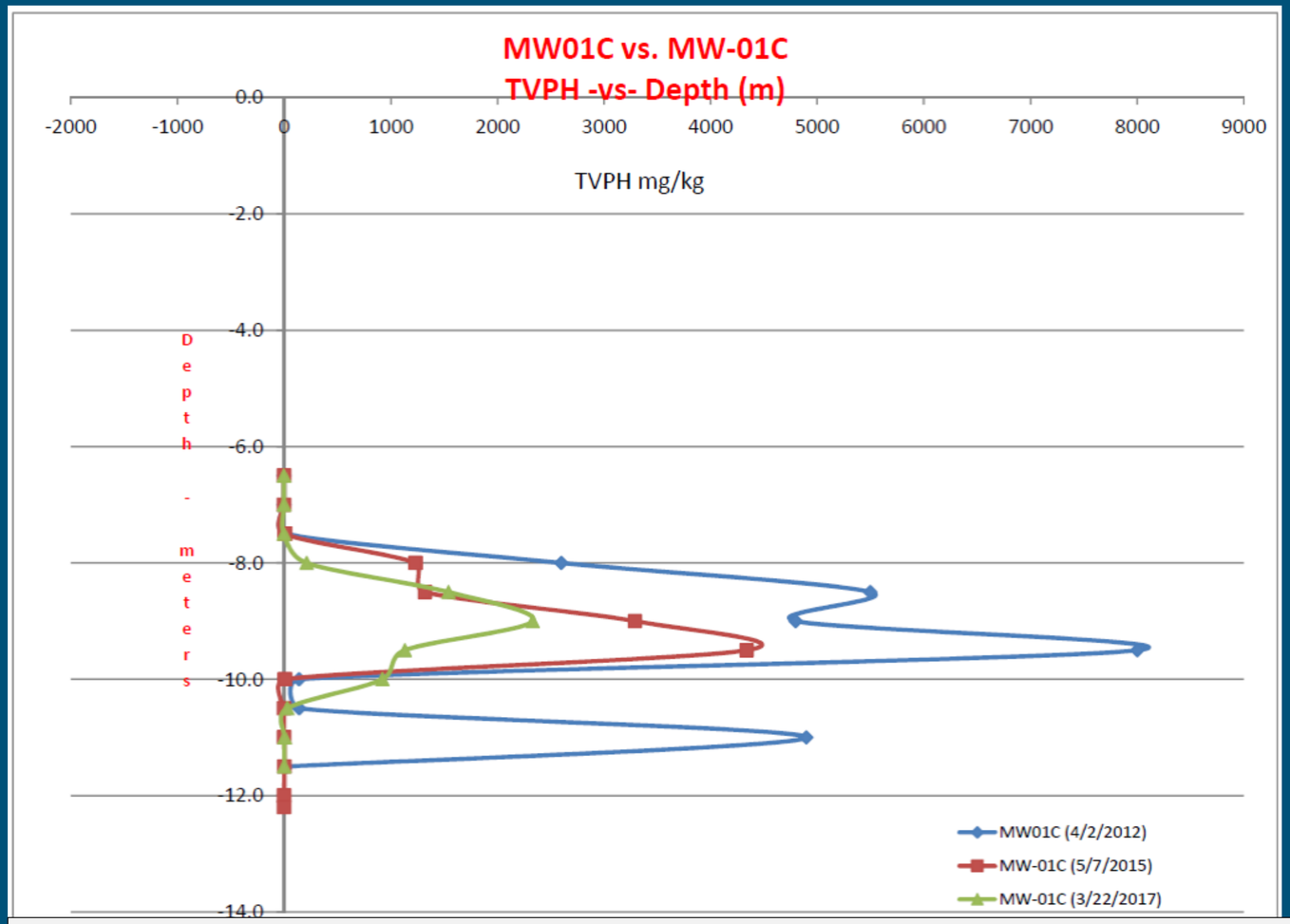

| Parameter | | Sum BTEX | Benzene | Toluene | Xylenes (o+m+p-Xylene +Ethylbenzene) |
|---|---|---|---|---|---|
| Quality Critera | | - | 1 | 5 | 5 |
| Well | Date | µg/l | µg/l | µg/l | µg/l |
| KB2-B | Feb 2013 | 4,321 | 4,200 | 2 | 119 |
| KB2-B | Mar 2013 | 4,900 | 4,800 | < 1,9 | 77 |
| KB2-B | May 2013 | 344 | 330 | < 1 | 14 |
| KB2-B | Aug 2013 | 385 | 373 | <1,2 | 12 |
| KB2-B | Nov 2013 | 264 | 260 | < 2 | 4 |
| KB2-B | Feb 2014 | 359 | 340 | < 2 | 19 |
| KB2-B | May 2014 | 221 | 210 | < 2 | 9 |
| KB2-B | Aug 2014 | 100 | 96 | 0.11 | 6 |
| KB2-B | Dec 2014 | 360 | 350 | 0.28 | 13 |
| KB2-B | Feb 2015 | 310 | 280 | 5.5 | 24 |
| KB2-B | Mar 2015 | 440 | 420 | 1 | 19 |
| KB2-B | Jul 2015 | 205 | 200 | < 3 | < 1,6 |
| *KB2-B* | *Aug 2015* | *105* | *98* | *< 5* | *< 2,4* |
| KB2-B | Feb 2016 | 48 | 42 | < 6 | < 3,8 |
| KB2-B | May 2016 | 12 | 10 | <2 | < 0,9 |
| KB2-B | Aug 2016 | 12 | 9 | < 2 | < 1,1 |
| KB2-B | Nov 2016 | 10 | 7 | < 2 | < 0,9 |
| KB2-B | Jan 2017 | 41 | 7 | 17 | 17 |
| KB2-B | May 2017 | 16 | 14 | 1 | 0.37 |
| KB2-B | Oct 2017 | < 0,01 | < 0,01 | < 0,01 | < 0,04 |
| KB2-B | Jan 2018 | 22 | 22 | 0.15 | 0.79 |
| KB2-B | May 2018 | 0.16 | 0.041 | <0.02 | 0.12 |

Above – overall trends of monitoring wells (Benzene % reduction trends are shown) part of the performance-based contract – from LNAPL concentrations to below site-specific criteria in less than 3 years (1.5 m LNAPL well cleaned to ND levels)

On the right – the importance of removing a migration pathway. Limestone aquifer GW well not addressed by injections. Removal of contaminant migration pathway from the upper soils allowed passive reduction of BTEX concentrations

NO FURTHER ACTION granted by local authorities in June 2018 – Largest EU retail site for the client

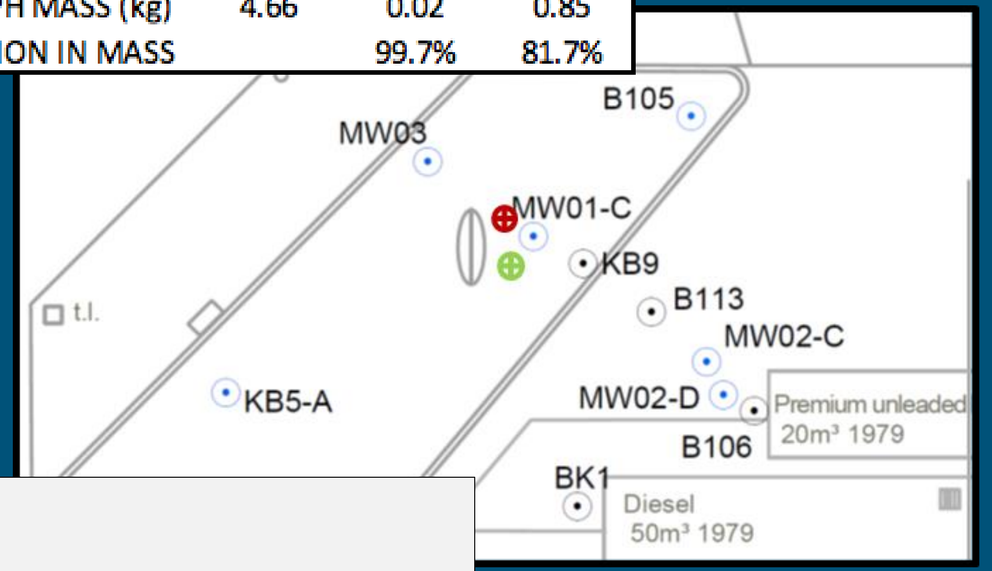
# Active Gas Station (Copenhagen) – Performance Based Contract




## Validation Soil Sampling

| VADOSE ZONE | | | |
|---|---|---|---|
| SAMPLING EVENT | 2012 | 2015 | 2017 |
| TOTAL TVPH MASS (kg) | 18.62 | 9.07 | 4.88 |
| % REDUCTION IN MASS | | 51.3% | 73.8% |

| SATURATED ZONE | | | |
|---|---|---|---|
| SAMPLING EVENT | 2012 | 2015 | 2017 |
| TOTAL TVPH MASS (kg) | 4.66 | 0.02 | 0.85 |
| % REDUCTION IN MASS | | 99.7% | 81.7% |




Soil Validation Data from LNAPL location requested by client.

Evaluation based on high resolution soil samples from within the same square meter off the original location sampled in 2012.

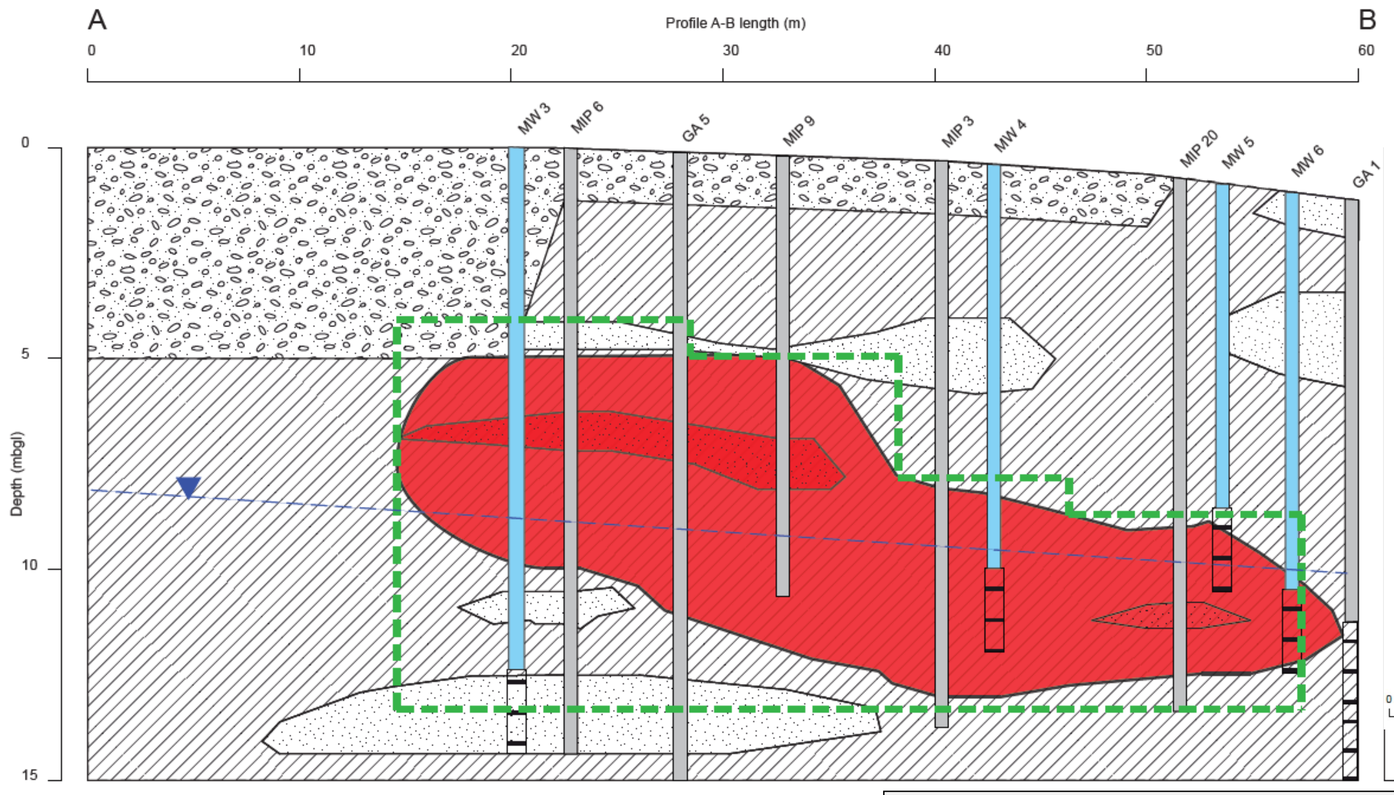
Sampling events conducted 3 years post initial pilot test (2012) and 2 years after completion of 2015 full-scale event.

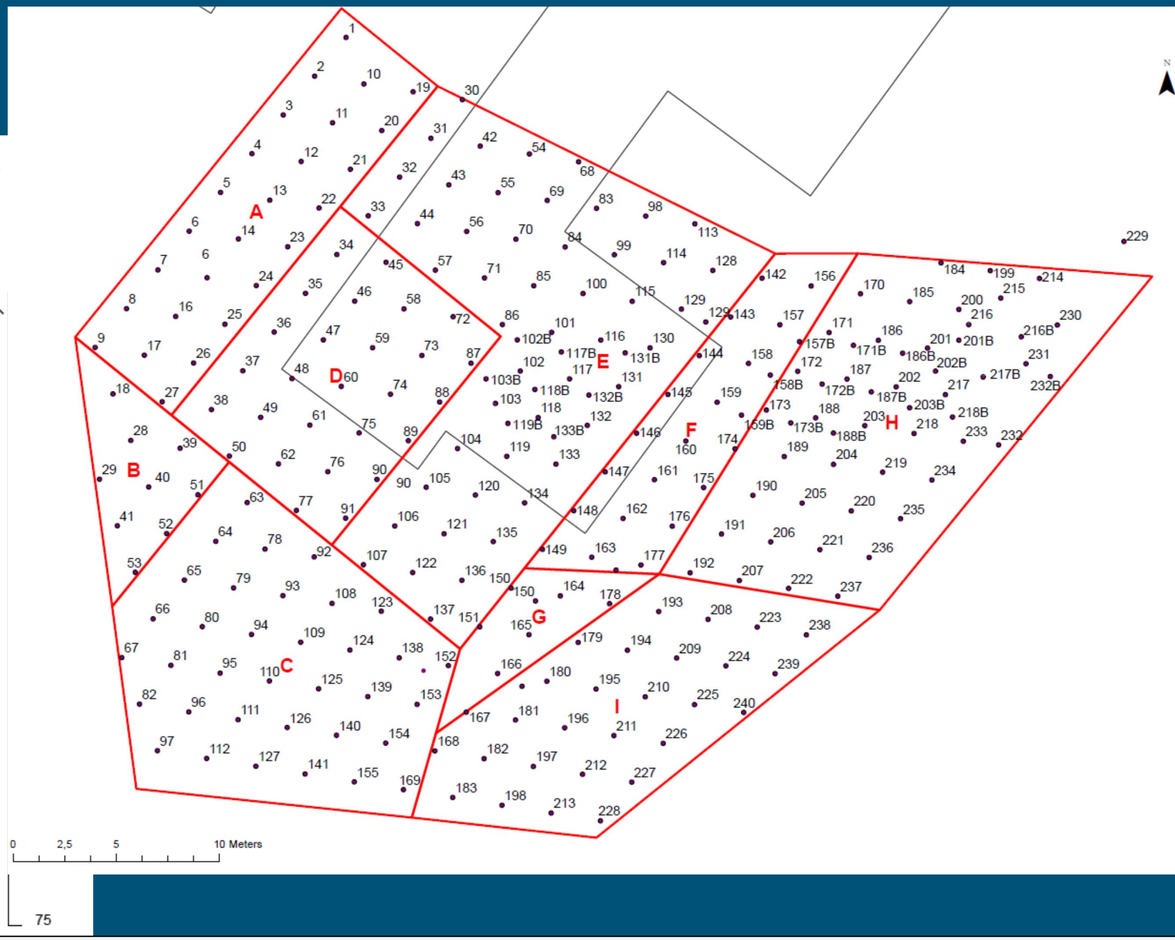
Mass reduction evaluation based on “contaminant mass” evaluation on a cubic meter basis around each soil sample.

By June 2018 MW01-C GW well went from 150 cm LNAPL in 2012 to ND level of Benzene.

# Case Study #2

# CSM– Post Remedial Design – Injection Summary




## Legend

- Approximate groundwater level
- Groundwater flow
- Excavation backfill
- Moraine clay
- Sandy lenses
- MIP or soil core
- Well
- Screened interval in well
- Bulk contaminated mass
- BOS 200 zone of injection

RDC: 20+ MIP Locations performed to 15-20 m bgl - 200 soil samples (50 cm intervals)

Design: Surgical remediation design with 9 specific subareas and injection profiles

In-Situ: 267 injection points from 4 to 15 m bgl within one single injection round (June to August 2015) - Approx. 60,000 kg of BOS200 installed (incl. additional slow release electron acceptor amendments)

Follow-Up: Performance Monitoring (Groundwater and Soil Validation)

# Active Gas Station (Finland) – Guarantee Based Contract

## Groundwater Performance Monitoring

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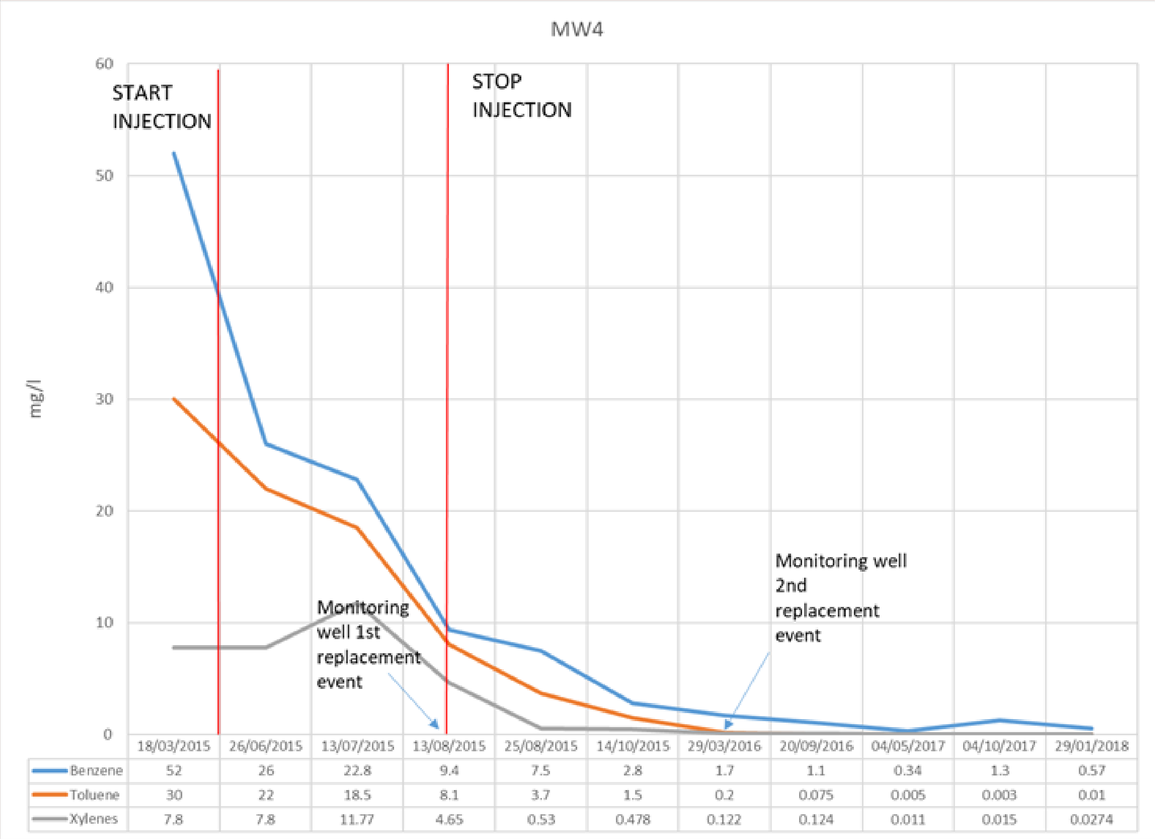
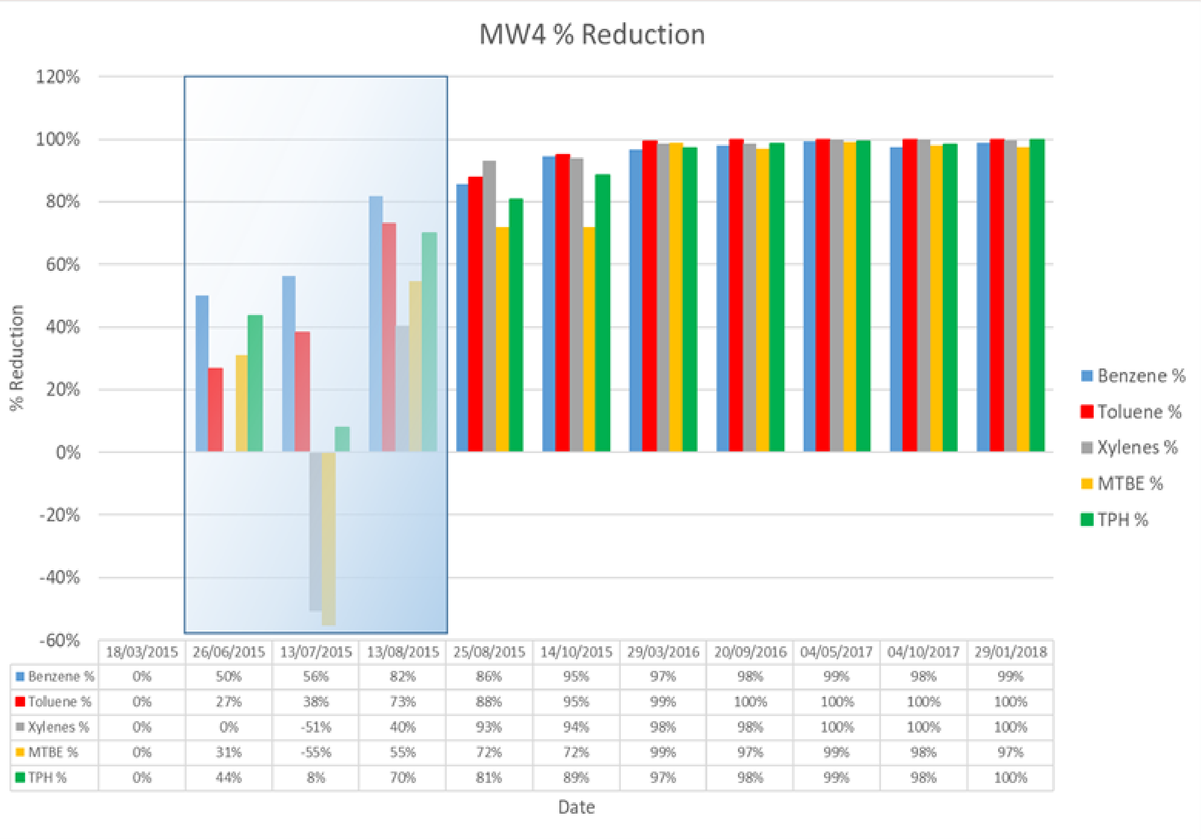



| | 18/03/2015 | 26/06/2015 | 13/07/2015 | 13/08/2015 | 25/08/2015 | 14/10/2015 | 29/03/2016 | 20/09/2016 | 04/05/2017 | 04/10/2017 | 29/01/2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Benzene | 52 | 26 | 22.8 | 9.4 | 7.5 | 2.8 | 1.7 | 1.1 | 0.34 | 1.3 | 0.57 |
| Toluene | 30 | 22 | 18.5 | 8.1 | 3.7 | 1.5 | 0.2 | 0.075 | 0.005 | 0.003 | 0.01 |
| Xylenes | 7.8 | 7.8 | 11.77 | 4.65 | 0.53 | 0.478 | 0.122 | 0.124 | 0.011 | 0.015 | 0.0274 |




| | 18/03/2015 | 26/06/2015 | 13/07/2015 | 13/08/2015 | 25/08/2015 | 14/10/2015 | 29/03/2016 | 20/09/2016 | 04/05/2017 | 04/10/2017 | 29/01/2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Benzene % | 0% | 50% | 56% | 82% | 86% | 95% | 97% | 98% | 99% | 98% | 99% |
| Toluene % | 0% | 27% | 38% | 73% | 88% | 95% | 99% | 100% | 100% | 100% | 100% |
| Xylenes % | 0% | 0% | -51% | 40% | 93% | 94% | 98% | 98% | 100% | 100% | 100% |
| MTBE % | 0% | 31% | -55% | 55% | 72% | 72% | 99% | 97% | 99% | 98% | 97% |
| TPH % | 0% | 44% | 8% | 70% | 81% | 89% | 97% | 98% | 99% | 98% | 100% |

# Active Gas Station (Finland) – Guarantee Based Contract

## Groundwater Performance Monitoring

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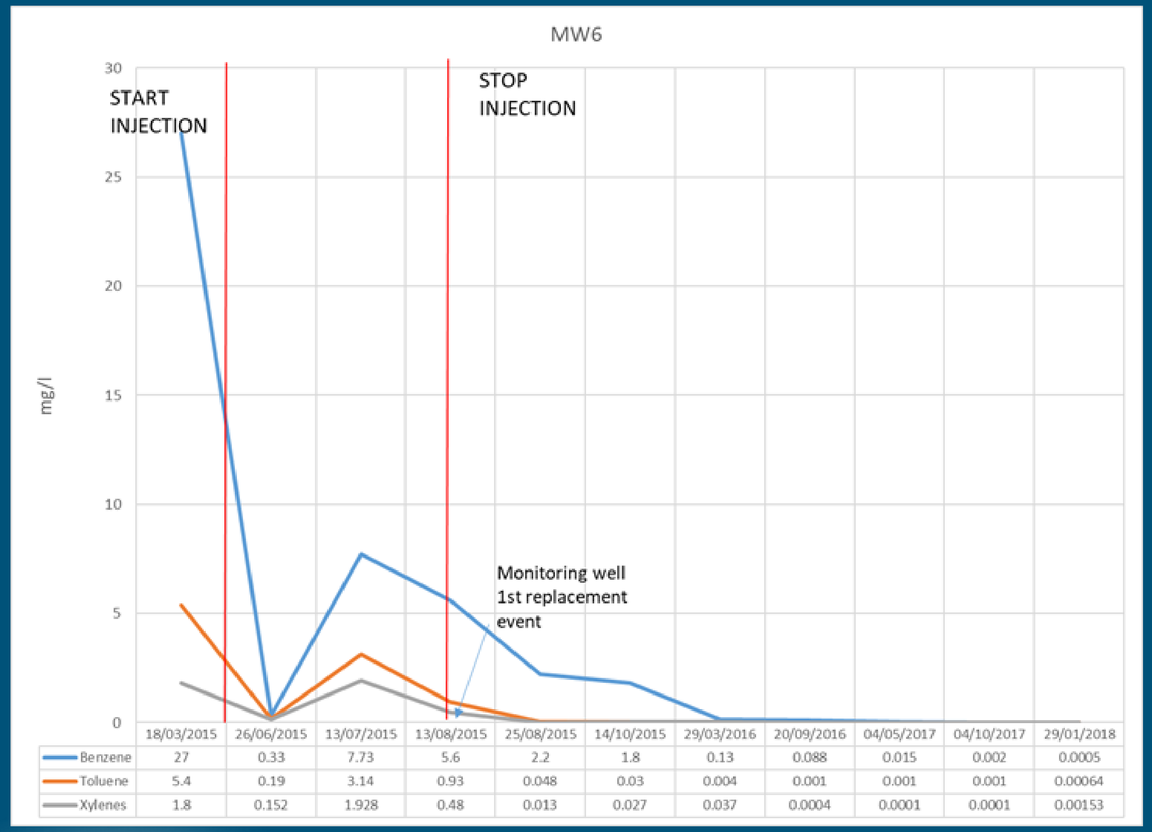
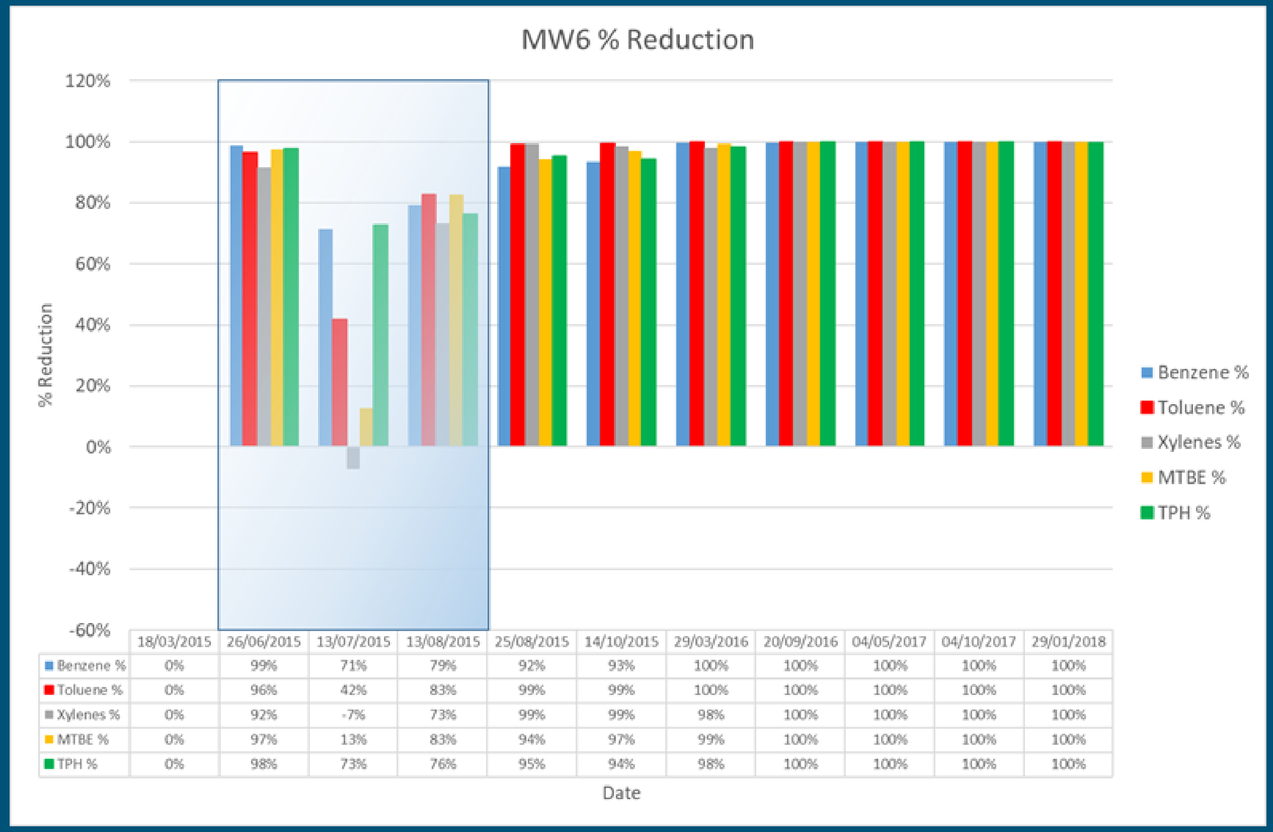



| | 18/03/2015 | 26/06/2015 | 13/07/2015 | 13/08/2015 | 25/08/2015 | 14/10/2015 | 29/03/2016 | 20/09/2016 | 04/05/2017 | 04/10/2017 | 29/01/2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Benzene | 27 | 0.33 | 7.73 | 5.6 | 2.2 | 1.8 | 0.13 | 0.088 | 0.015 | 0.002 | 0.0005 |
| Toluene | 5.4 | 0.19 | 3.14 | 0.93 | 0.048 | 0.03 | 0.004 | 0.001 | 0.001 | 0.001 | 0.00064 |
| Xylenes | 1.8 | 0.152 | 1.928 | 0.48 | 0.013 | 0.027 | 0.037 | 0.0004 | 0.0001 | 0.0001 | 0.00153 |




| | 18/03/2015 | 26/06/2015 | 13/07/2015 | 13/08/2015 | 25/08/2015 | 14/10/2015 | 29/03/2016 | 20/09/2016 | 04/05/2017 | 04/10/2017 | 29/01/2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Benzene % | 0% | 99% | 71% | 79% | 92% | 93% | 100% | 100% | 100% | 100% | 100% |
| Toluene % | 0% | 96% | 42% | 83% | 99% | 99% | 100% | 100% | 100% | 100% | 100% |
| Xylenes % | 0% | 92% | -7% | 73% | 99% | 99% | 98% | 100% | 100% | 100% | 100% |
| MTBE % | 0% | 97% | 13% | 83% | 94% | 97% | 99% | 100% | 100% | 100% | 100% |
| TPH % | 0% | 98% | 73% | 76% | 95% | 94% | 98% | 100% | 100% | 100% | 100% |

**LNAPL Site Closed in 3-½ years post injection (1 µg/l Benzene required)**

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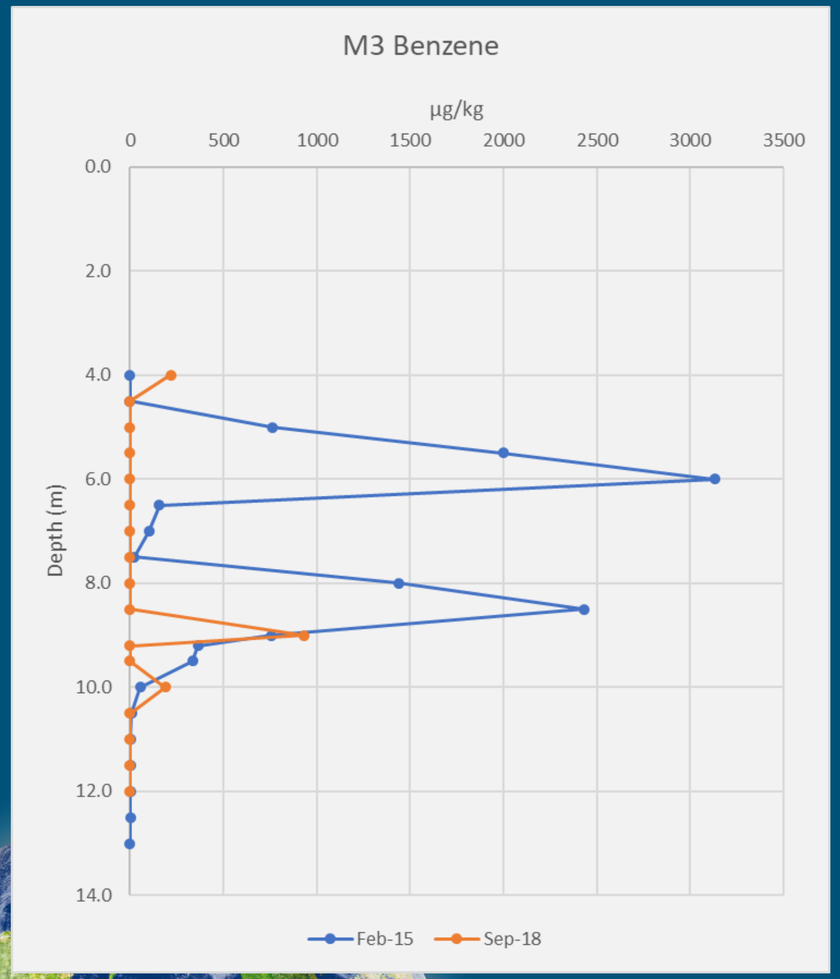
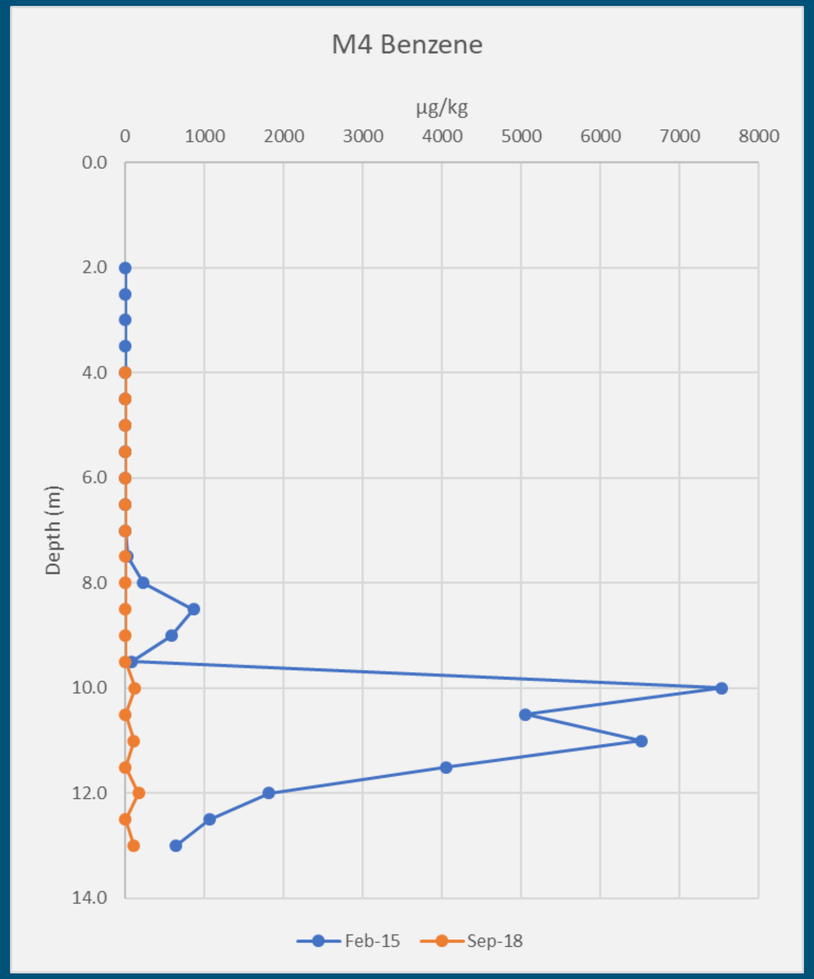
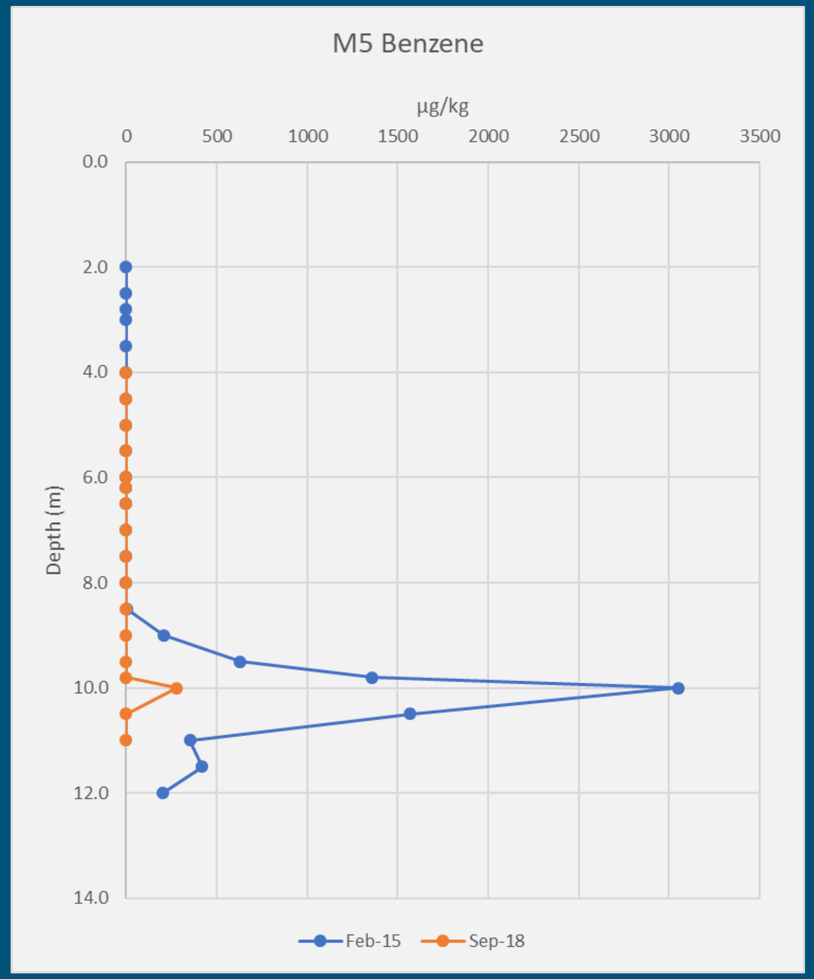
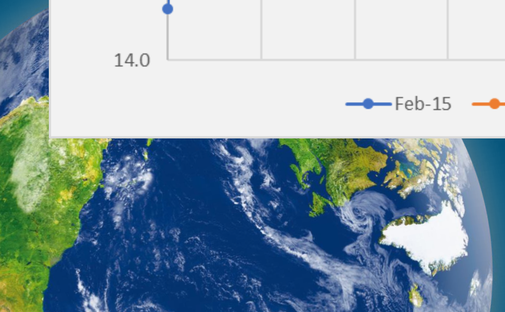
# Active Gas Station (Finland) – Guarantee Based Contract

## Performance Monitoring – Soil Validation



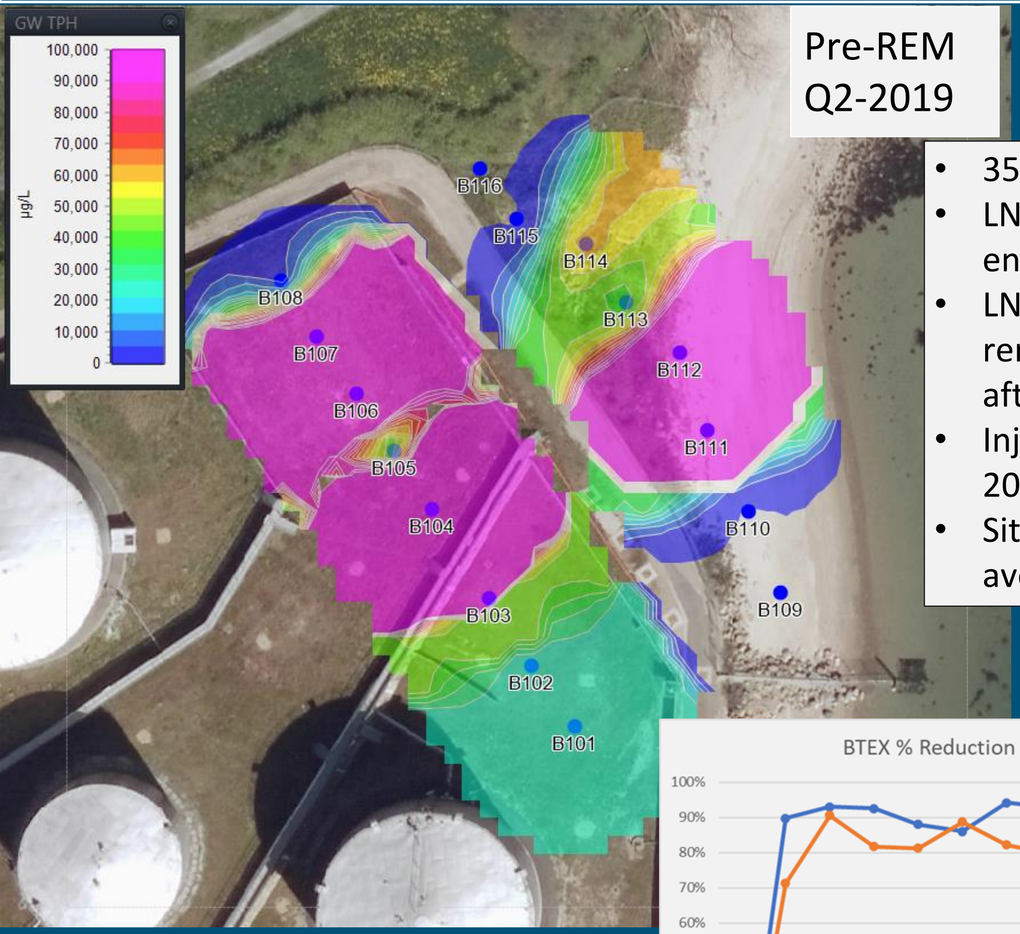



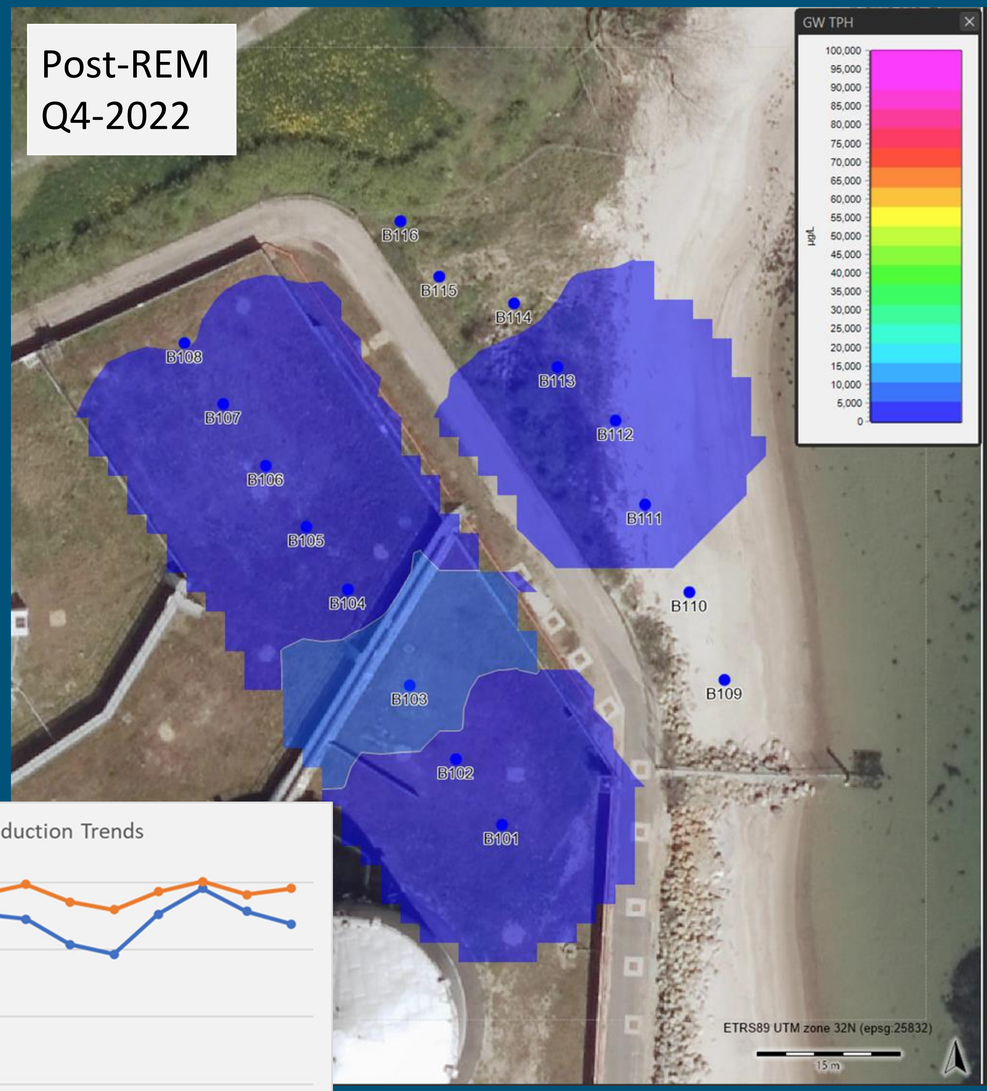
# Case Study #3

# Source and barrier treatment – LNAPL Case Study

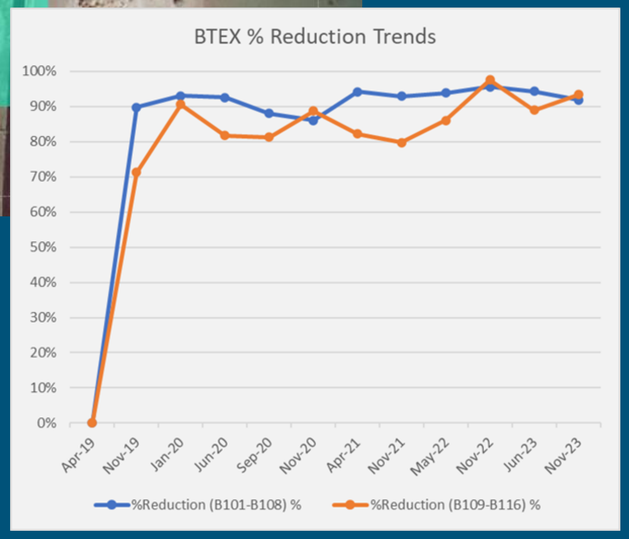


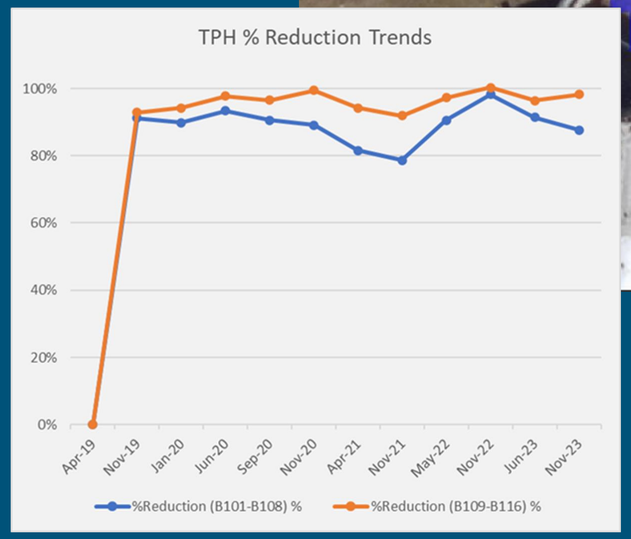

Pre-REM
Q2-2019

- 35 m3 Xylene Spill in 1985
- LNAPL pushing towards marine environment
- LNAPL observed in few wells prior to remediation start no longer observed after remediation completion
- Injection completed across Q3-Q4 2019
- Site specific criteria to be met on average on-site and off-site




Post-REM
Q4-2022



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# Source and barrier treatment – LNAPL Case Study

Soil Data Overview Pre- and Post Remediation

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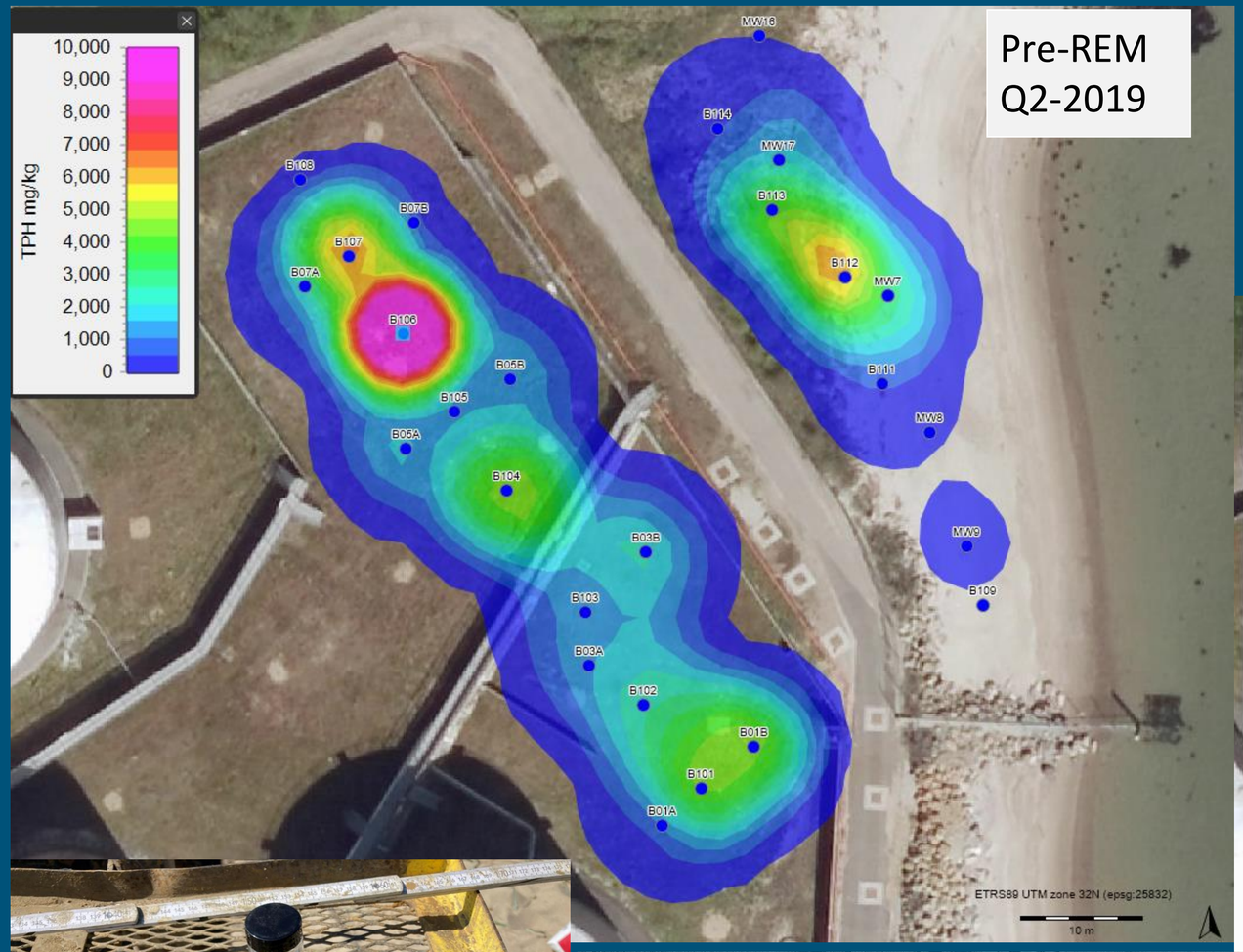
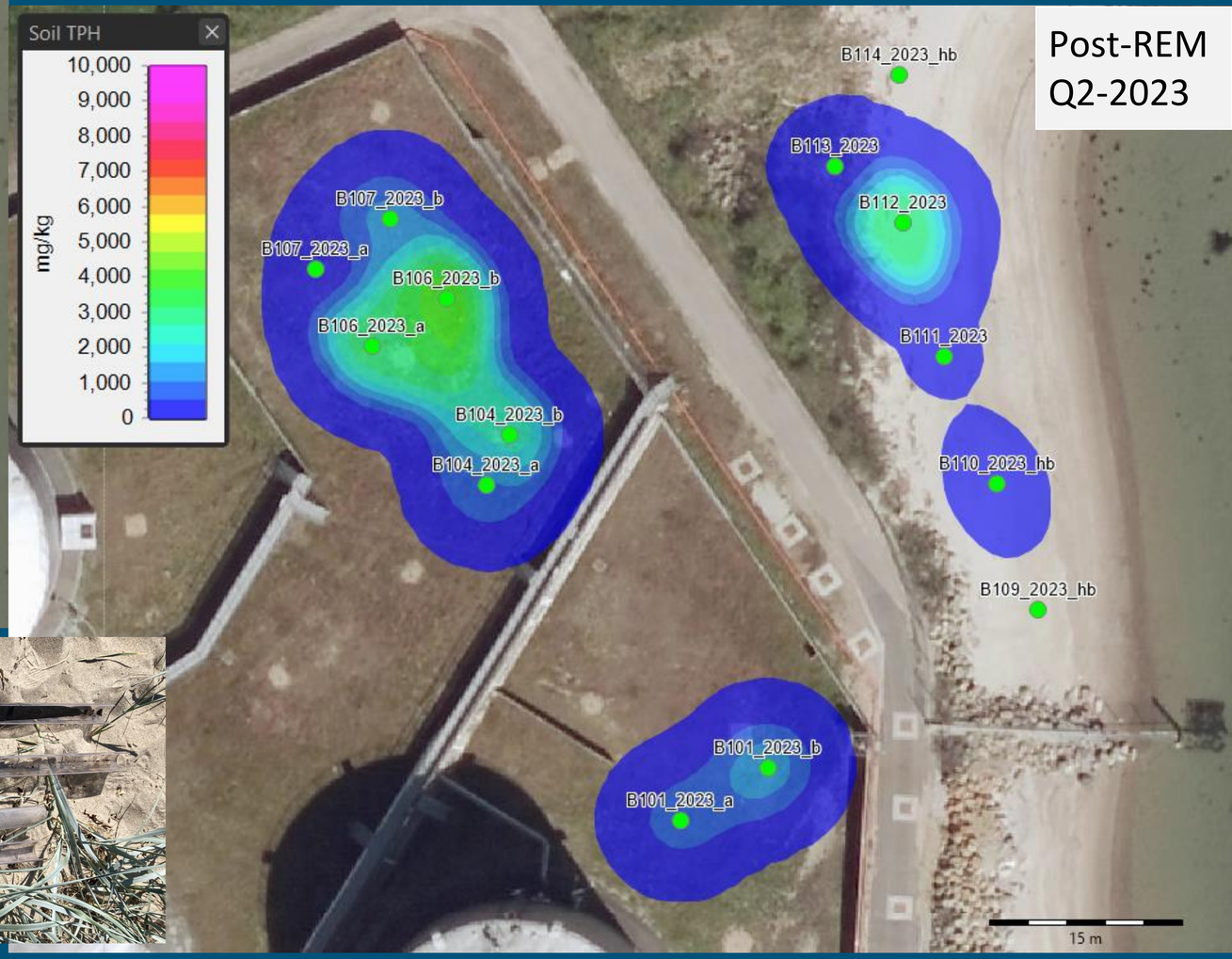
Soil validation data from the June 2023 event showed a reduction in the TPH soil contaminant mass of approx. 70% compared to pre-remediation soil concentrations (5,000 kg of TPH degraded within 36 months)

Pre-REM Q2-2019

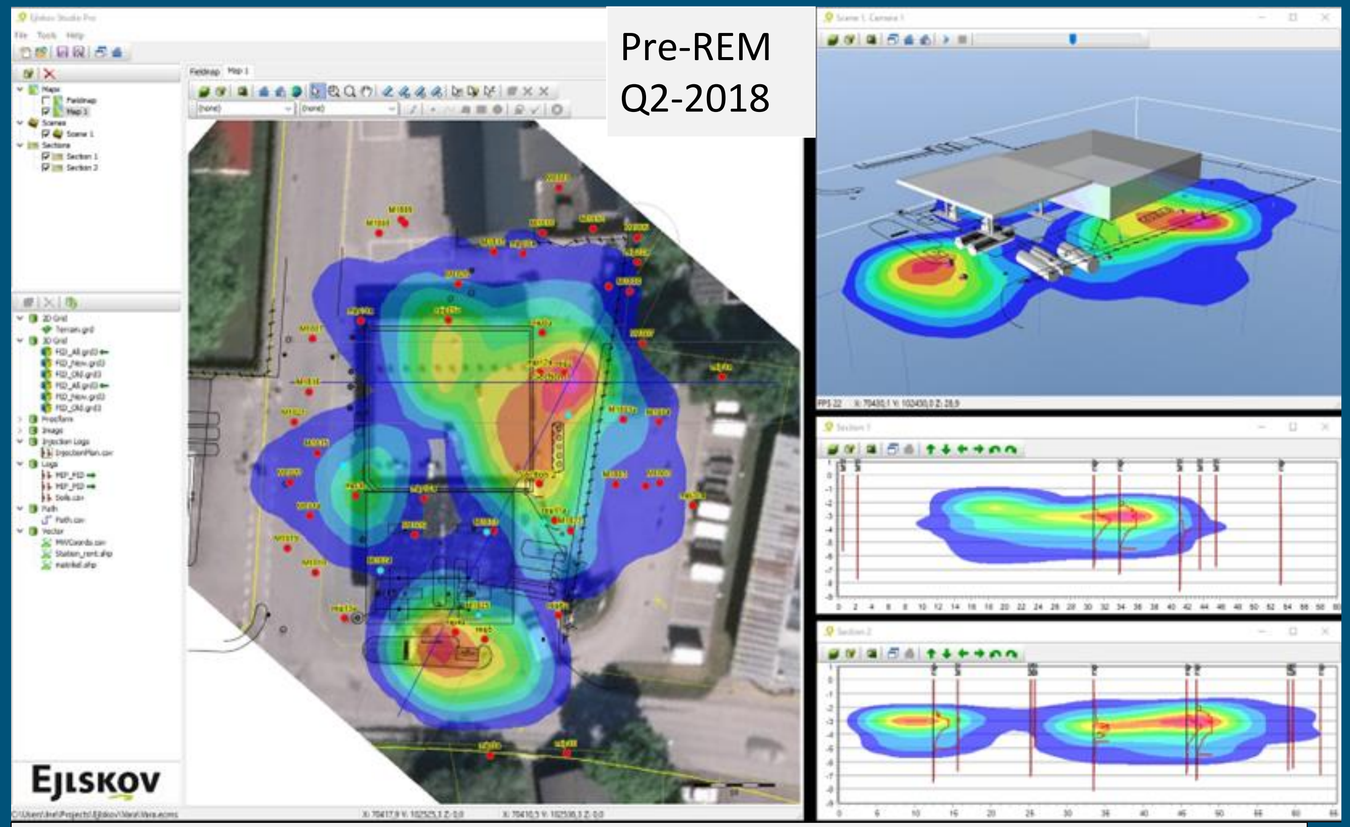


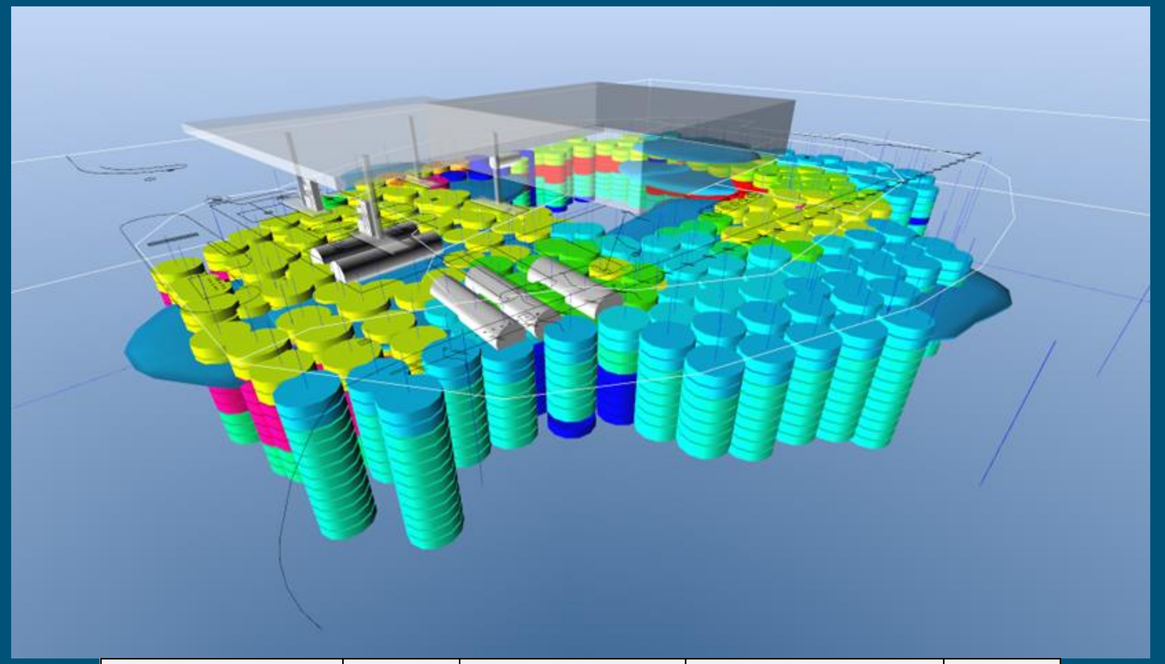
Post-REM Q2-2023



# Case Study #4

# Active Gas Station Sweden – LNAPL Plume Treatment



| ELEMENT | SAMPLE | Medelkoncentrationen | Medelkoncentrationen | Reduction |
|---|---|---|---|---|
| Sampling Date | | 2018-07-26 | 2022-01-10 | % |
| alifater >C5-C8 | µg/l | 929 | 66.5 | 93% |
| alifater >C8-C10 | µg/l | 236 | 50.0 | 79% |
| alifater >C10-C12 | µg/l | 22 | 10.0 | 55% |
| alifater >C12-C16 | µg/l | 20 | 10.0 | 50% |
| alifater >C16-C35 | µg/l | 44 | 25.0 | 43% |
| aromater >C8-C10 | µg/l | 2098 | 36.8 | 98% |
| aromater >C10-C16 | µg/l | 10 | 5.0 | 50% |
| aromater >C16-C35 | µg/l | 1 | 2.5 | -150% |
| bensen | µg/l | 3459 | 1.5 | 100% |
| toluen | µg/l | 4414 | 4.3 | 100% |
| etylbensen | µg/l | 654 | 5.0 | 99% |
| xylener, summa | µg/l | 4140 | 18.2 | 100% |
| PAH, summa L | µg/l | 38 | 2.5 | |
| PAH, summa M | µg/l | 0.36 | 0.1 | |
| PAH, summa H | µg/l | 0.08 | 0.0 | |
| MTBE | µg/l | 367 | 0.1 | 100% |
| MEDELVÄRDE reduktion samtliga | | | | 63% |
| MEDELVÄRDE reduktion >åtgärdsmål | | | | 96% |

- Injections completed in Q3 2018
- 266 injection points across entire active gas station
- Approx. 30,000 kg of BOS200® installed incl. supplemental electron acceptors
- Plume containment – reduction as main goal based on site specific criteria (long term re-evaluation of risks)

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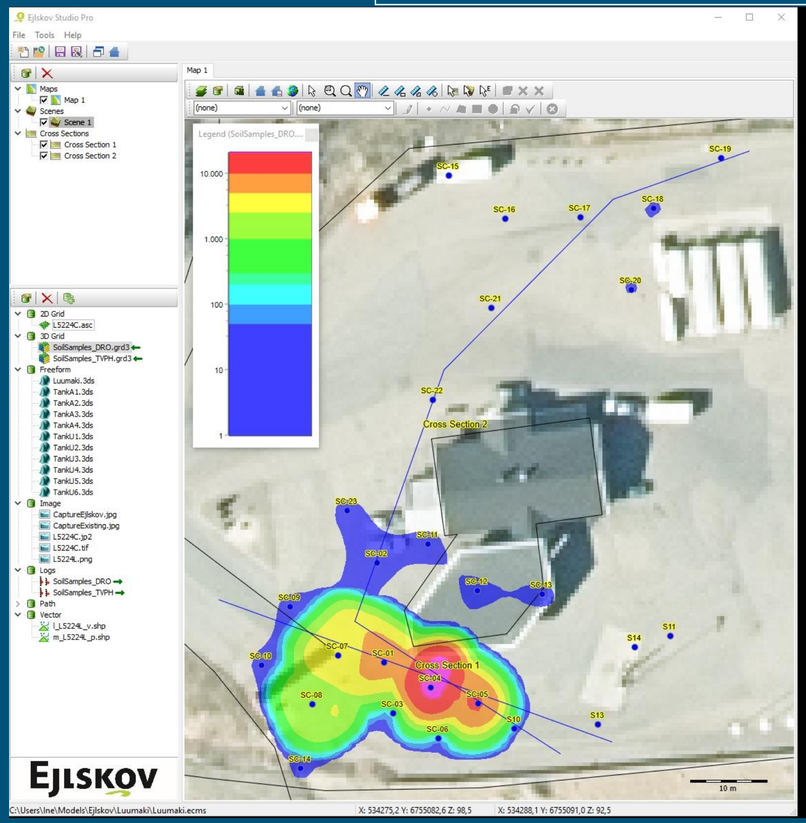
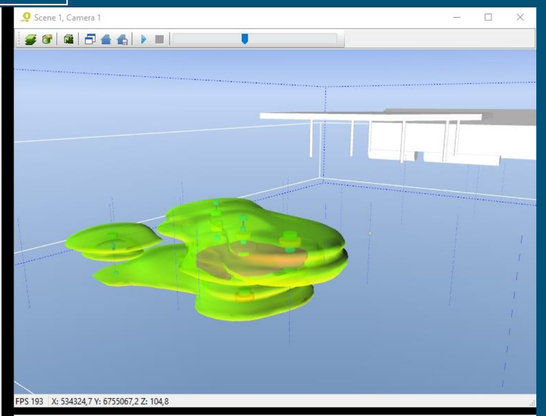
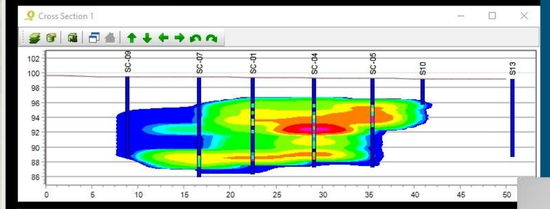
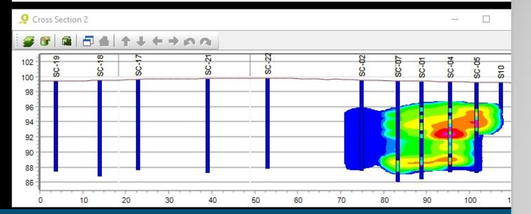
# Case Study #5

POST-REMEDIAL DESIGN

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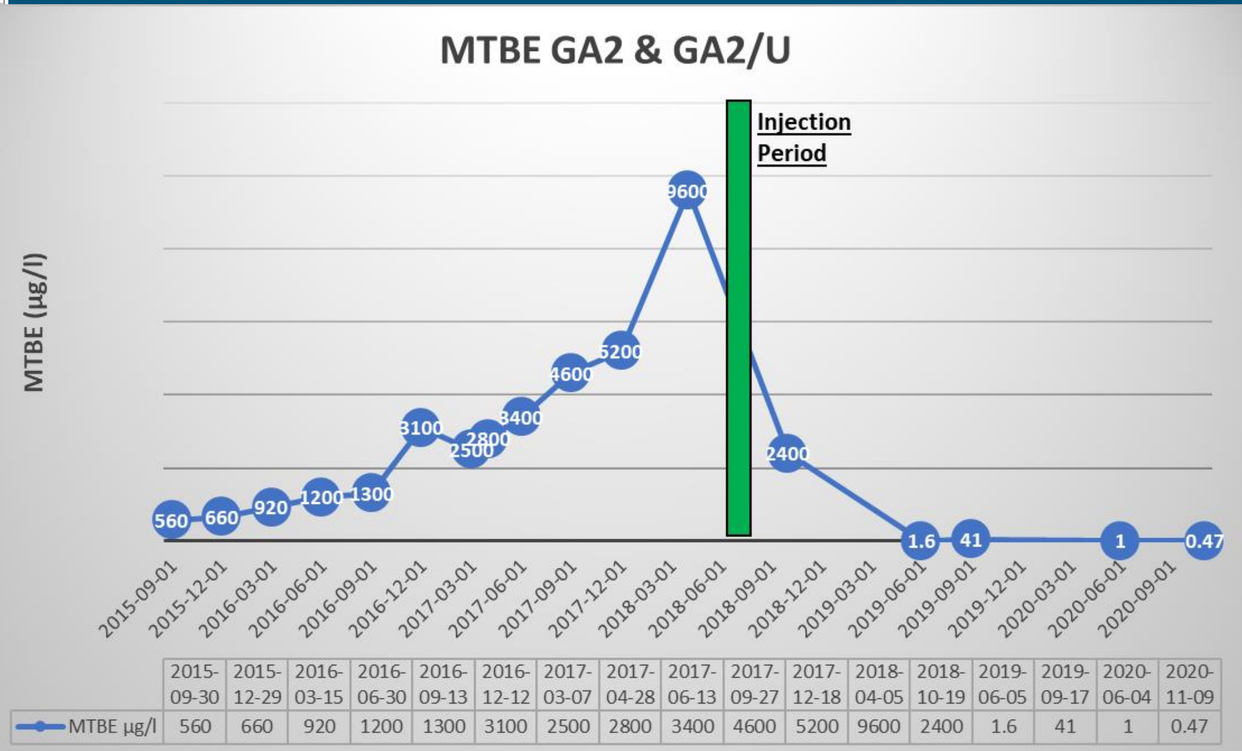
# Residual LNAPL – MTBE Risk Removal (Case Study) – South East Finland

- 425 soil samples analysed free of charge – Sept 2017
- In-situ remediation completed in May - June 2018
- Pre-drilling followed by Direct Push injections (11 m of dry sands to go through)
- Site closed in Q2 2021 – compliance point results on the right




| | 2015-09-30 | 2015-12-29 | 2016-03-15 | 2016-06-30 | 2016-09-13 | 2016-12-12 | 2017-03-07 | 2017-04-28 | 2017-06-13 | 2017-09-27 | 2017-12-18 | 2018-04-05 | 2018-10-19 | 2019-06-05 | 2019-09-17 | 2020-06-04 | 2020-11-09 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MTBE µg/l | 560 | 660 | 920 | 1200 | 1300 | 3100 | 2500 | 2800 | 3400 | 4600 | 5200 | 9600 | 2400 | 1.6 | 41 | 1 | 0.47 |

# Case Study #6

# Case Study – Gas Station Off-Site Plume Mitigation

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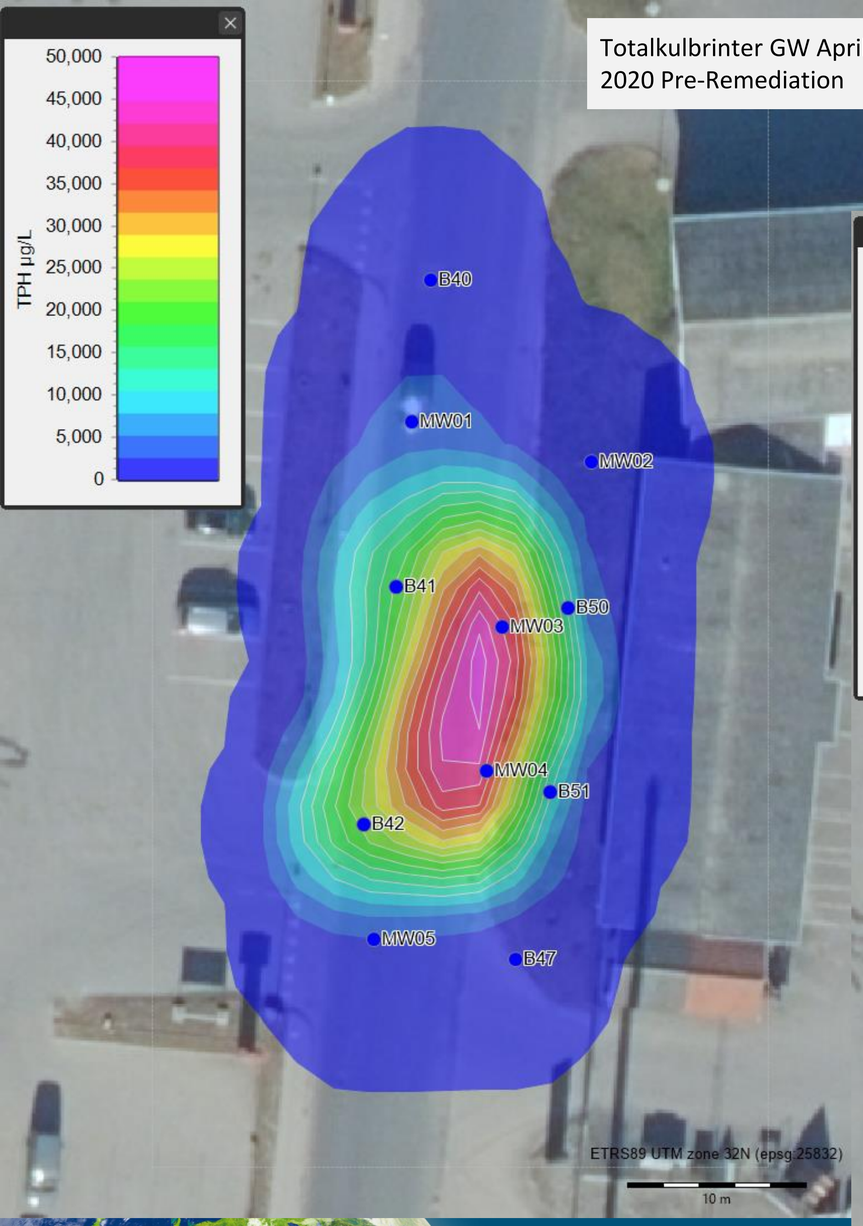
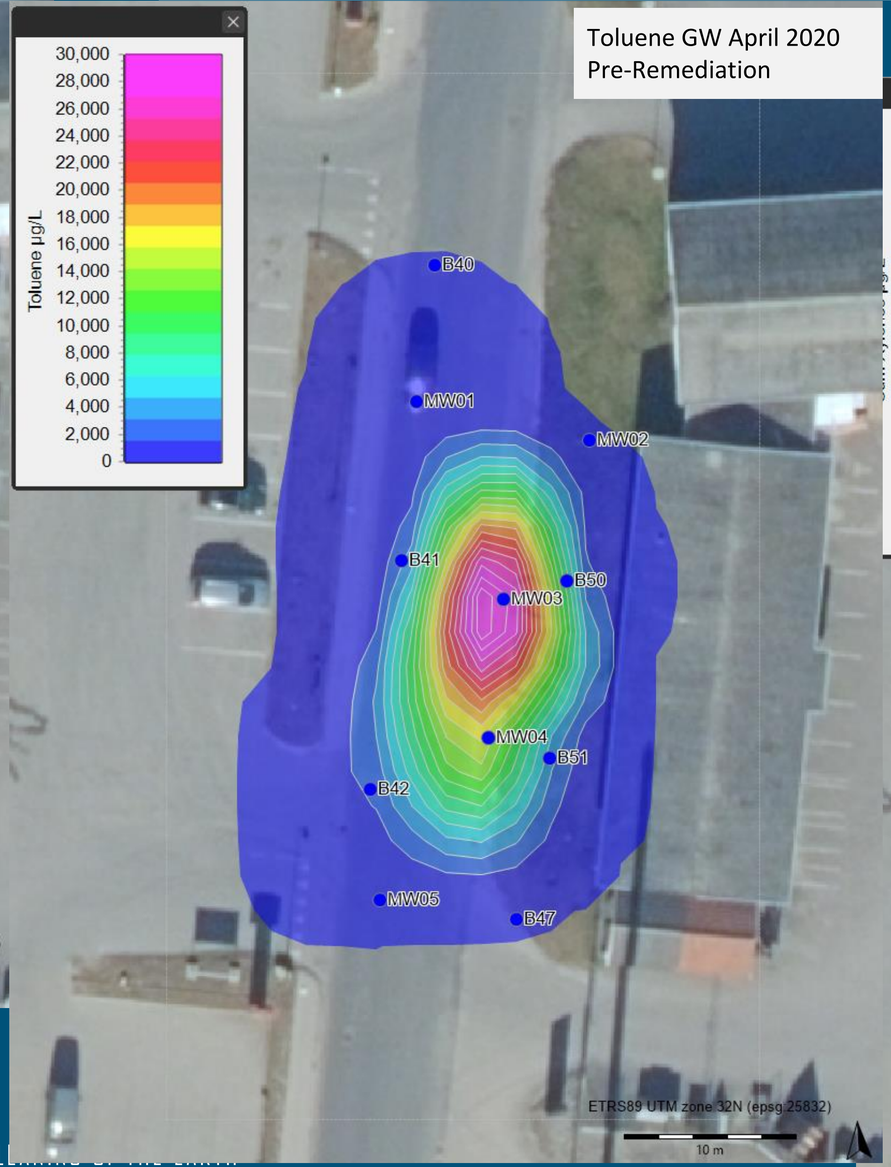
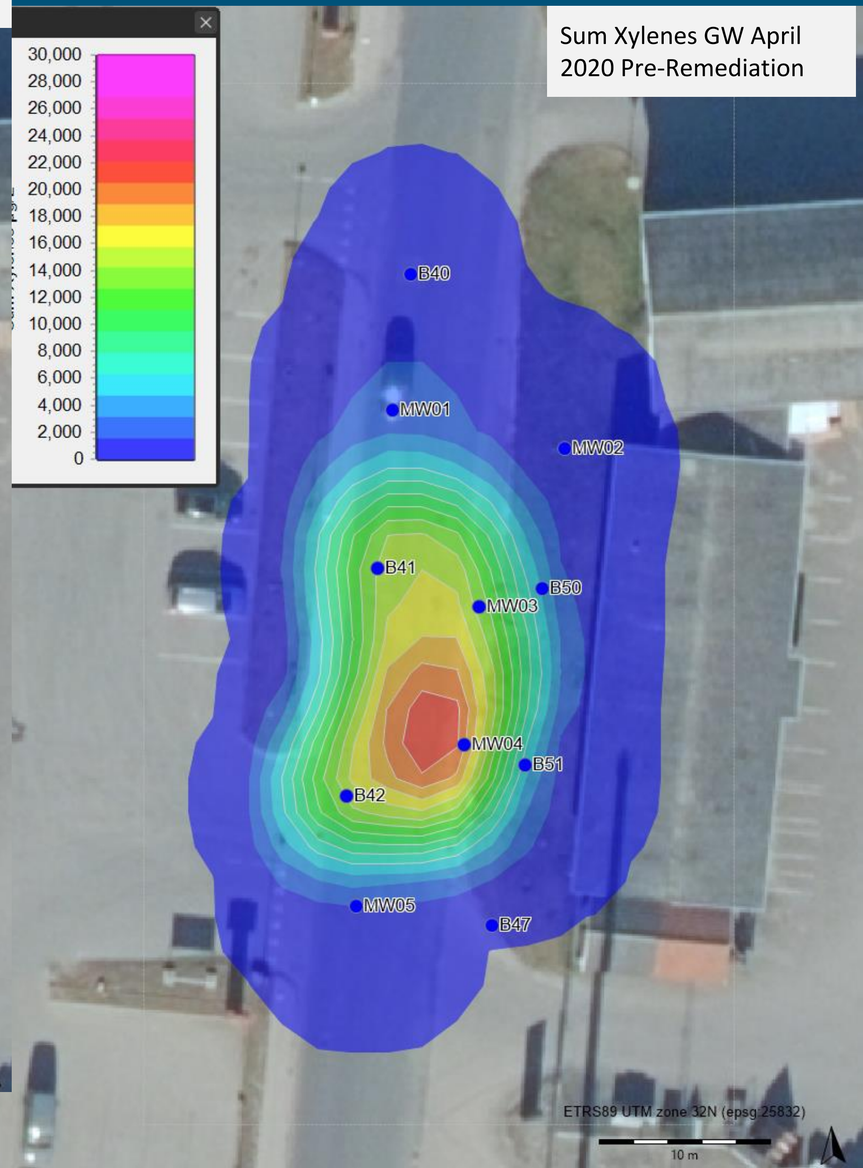
Totalkulbrinter GW April 2020 Pre-Remediation




Toluene GW April 2020 Pre-Remediation




Sum Xylenes GW April 2020 Pre-Remediation



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# Case Study – Gas Station
# Off-Site Plume Mitigation

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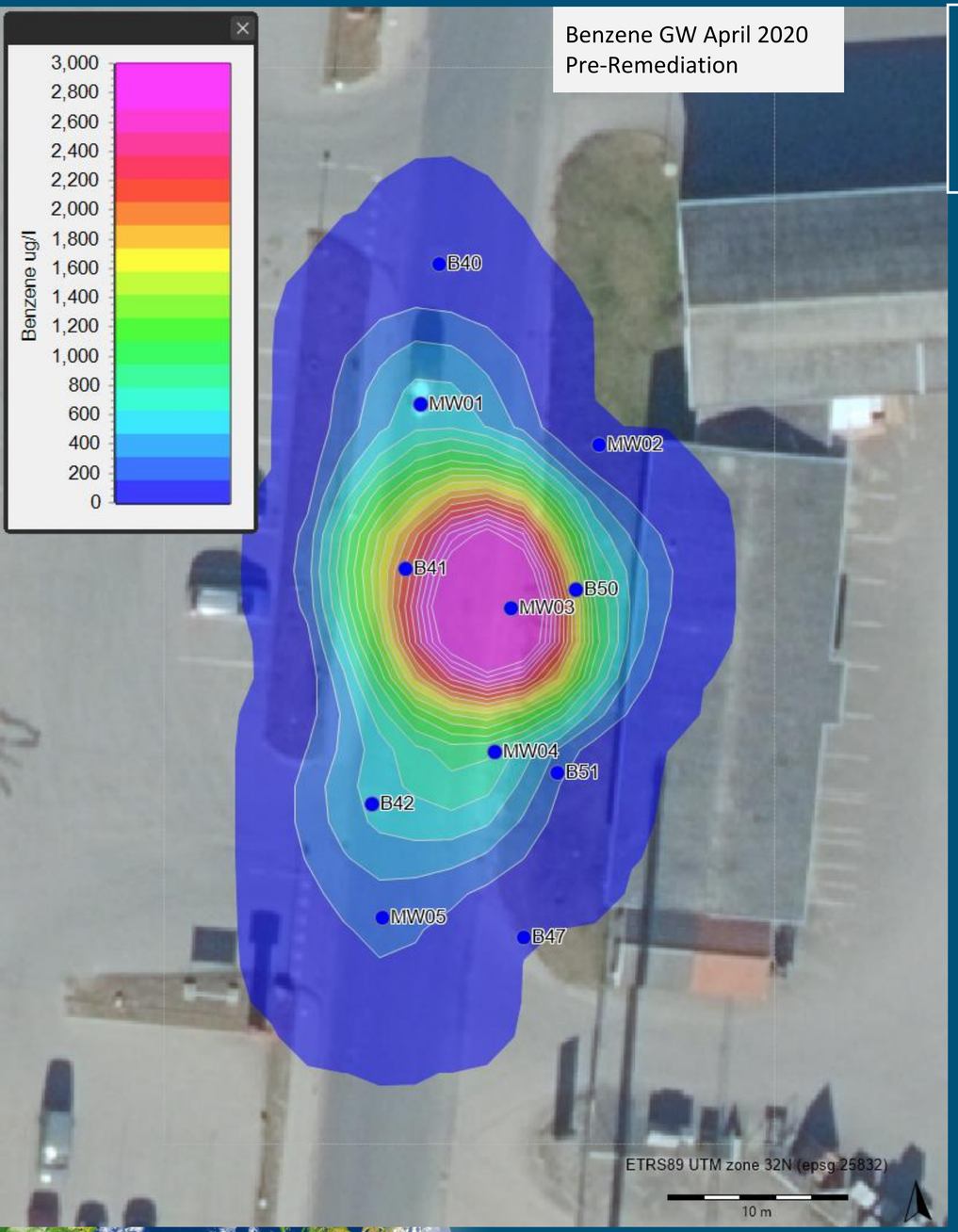


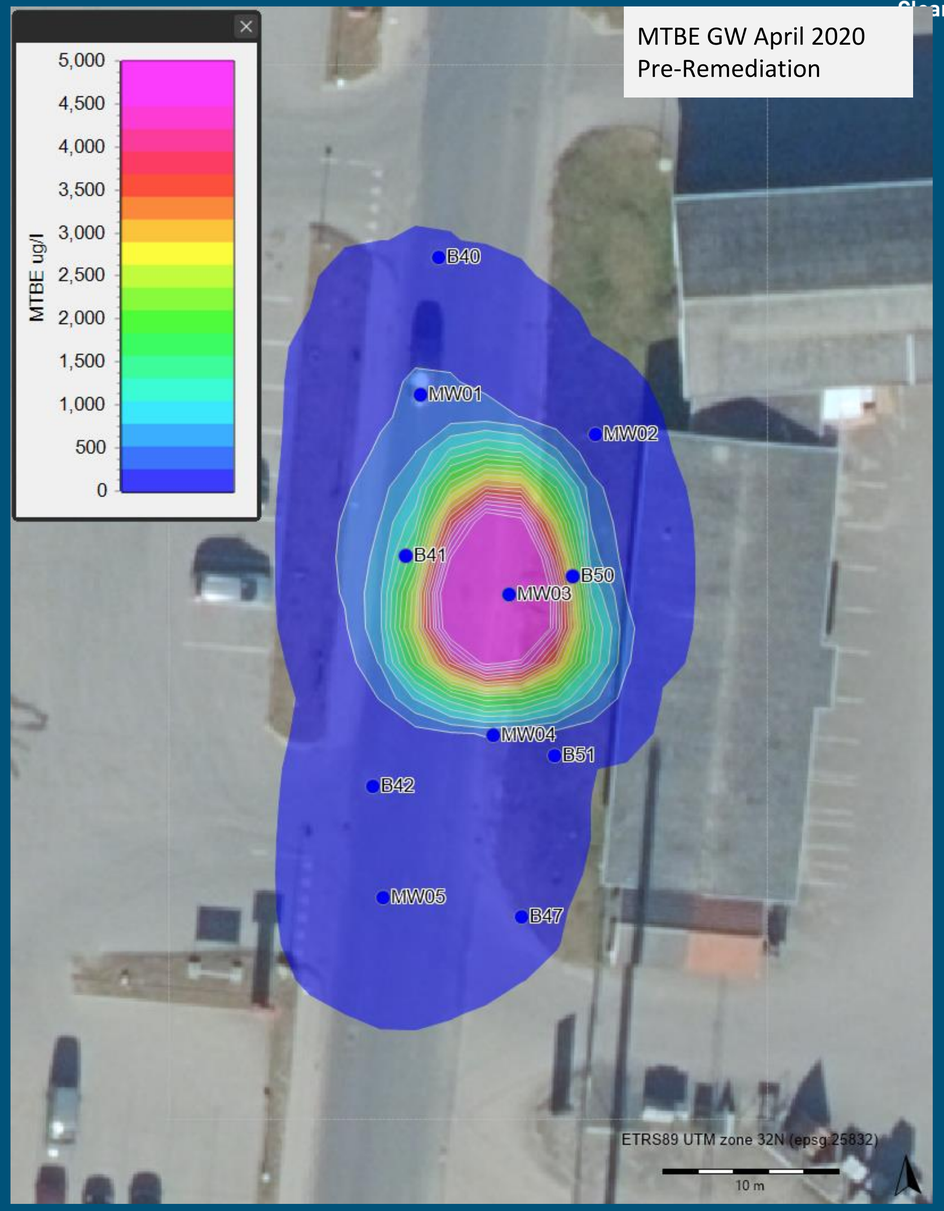

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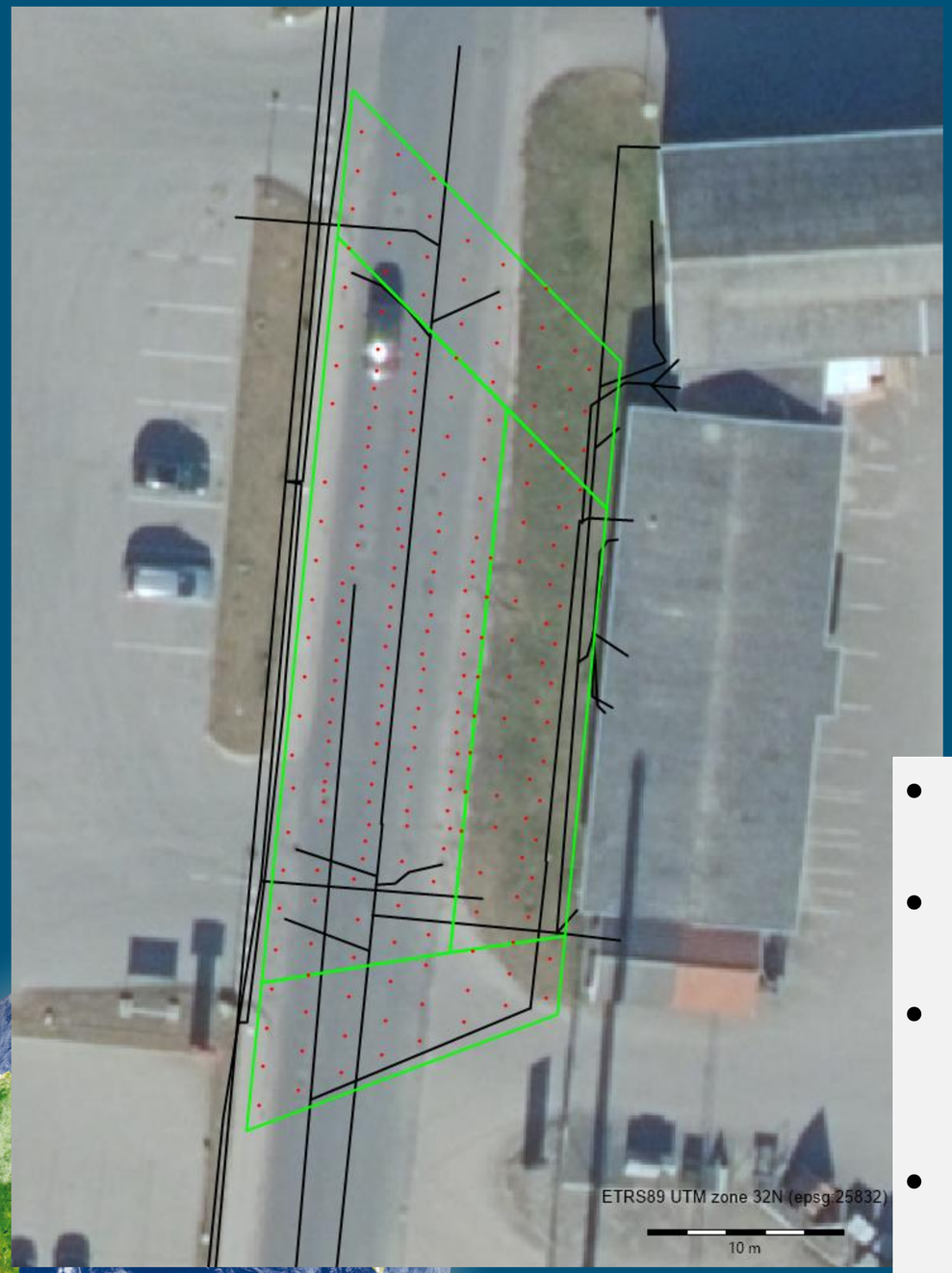
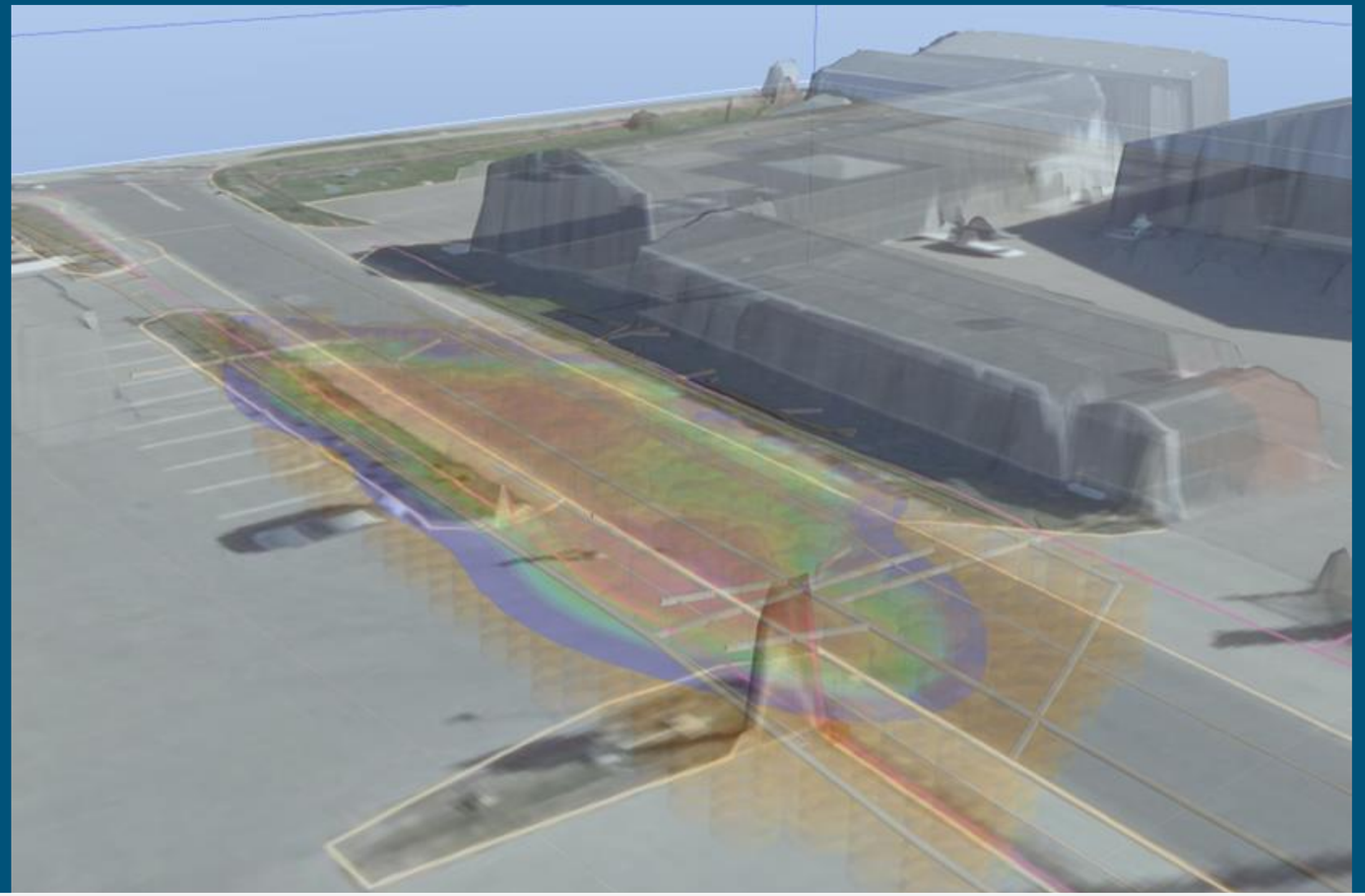
# Summary of Injection Works



- Total of 238 injection points (April 14th to May 14th 2020)
- Injection depth varying from 1.5 m bgl to 7 m bgl
- Total of 29,000 kg of BOS200® and supplemental slow release terminal electron acceptors
- >80% soil contaminant mass reduction measured via high resolution soil validation event in December 2023

# Post Remediation Overview

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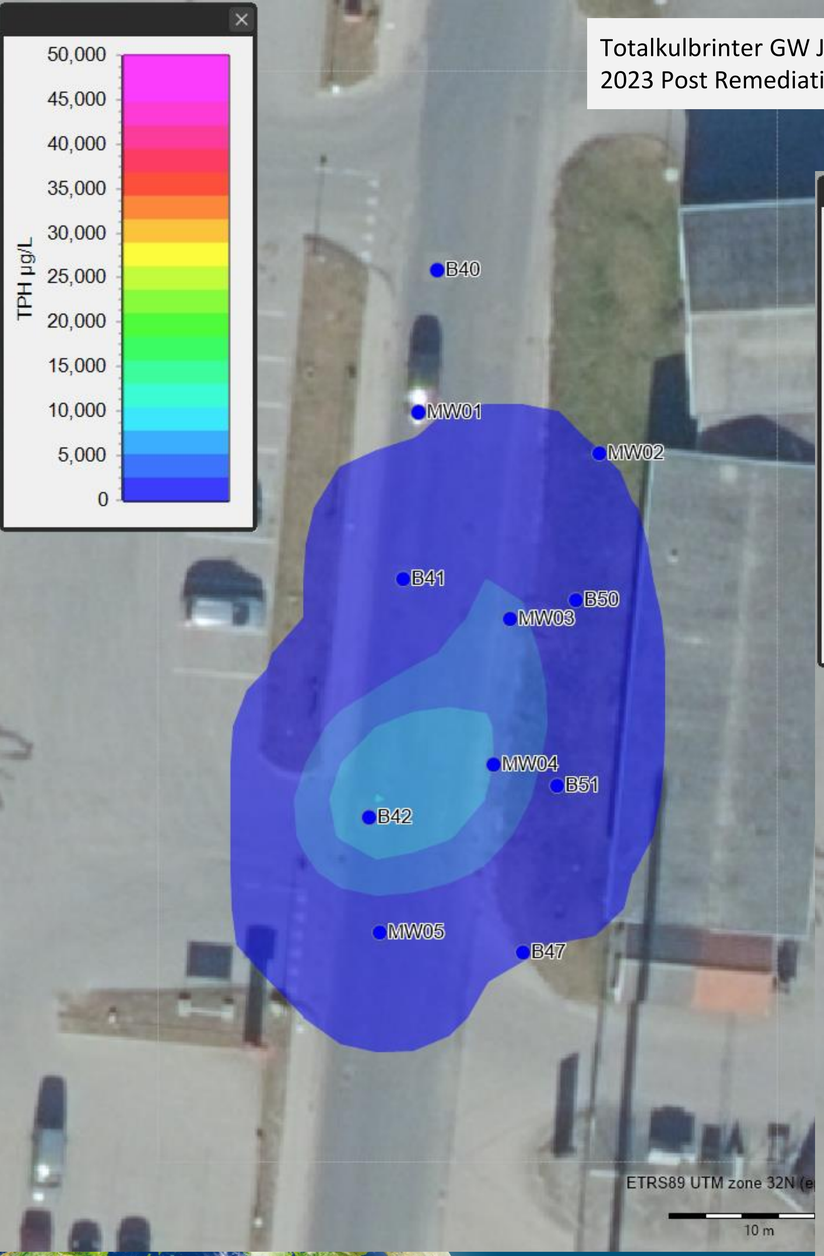
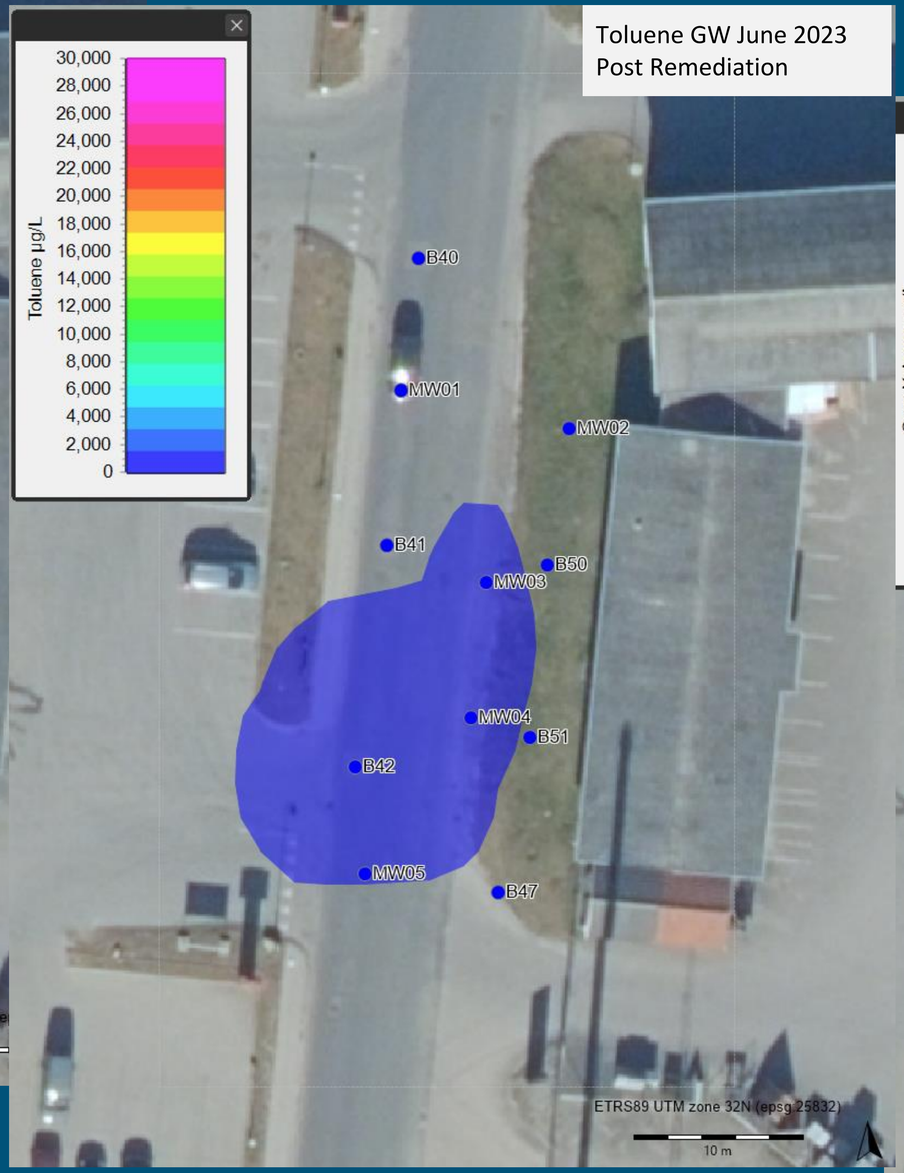
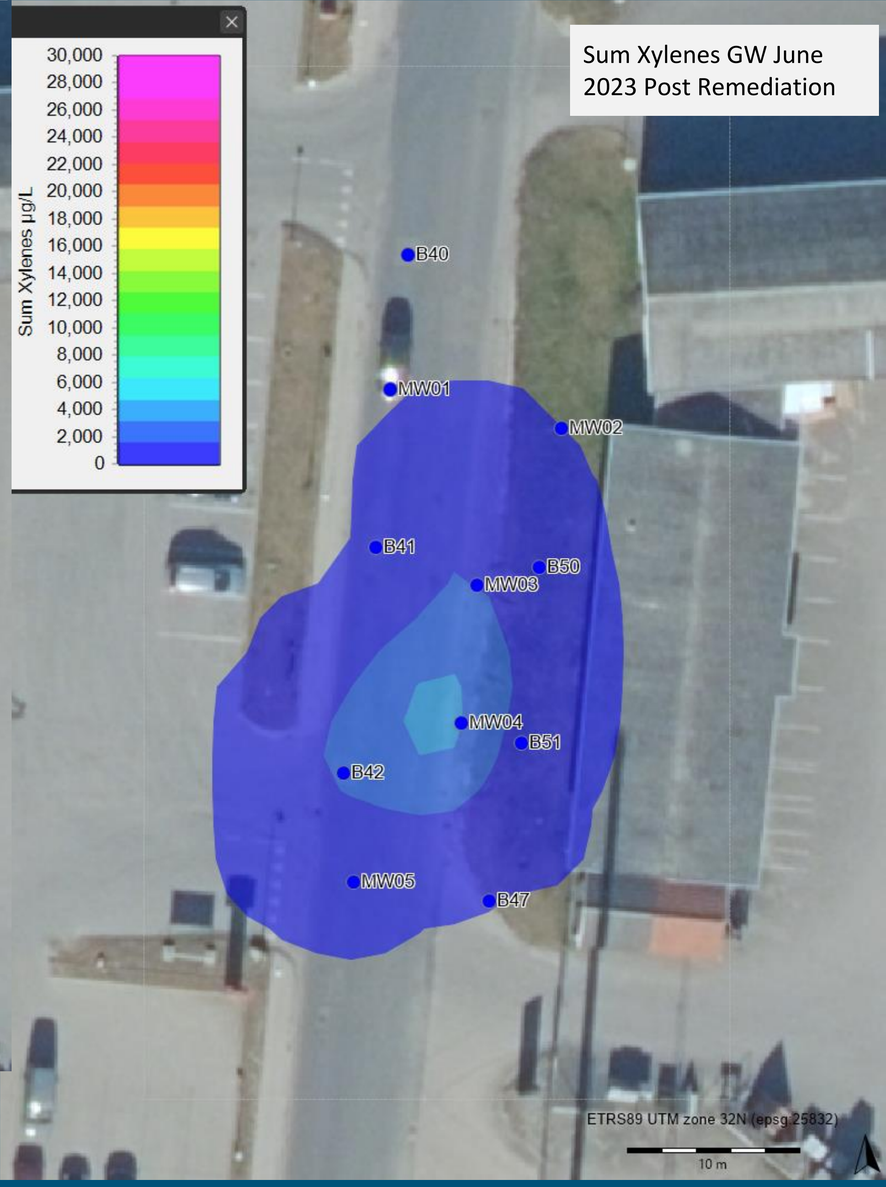
Totalkulbrinter GW June 2023 Post Remediation




Toluene GW June 2023 Post Remediation




Sum Xylenes GW June 2023 Post Remediation



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# Post Remediation Overview

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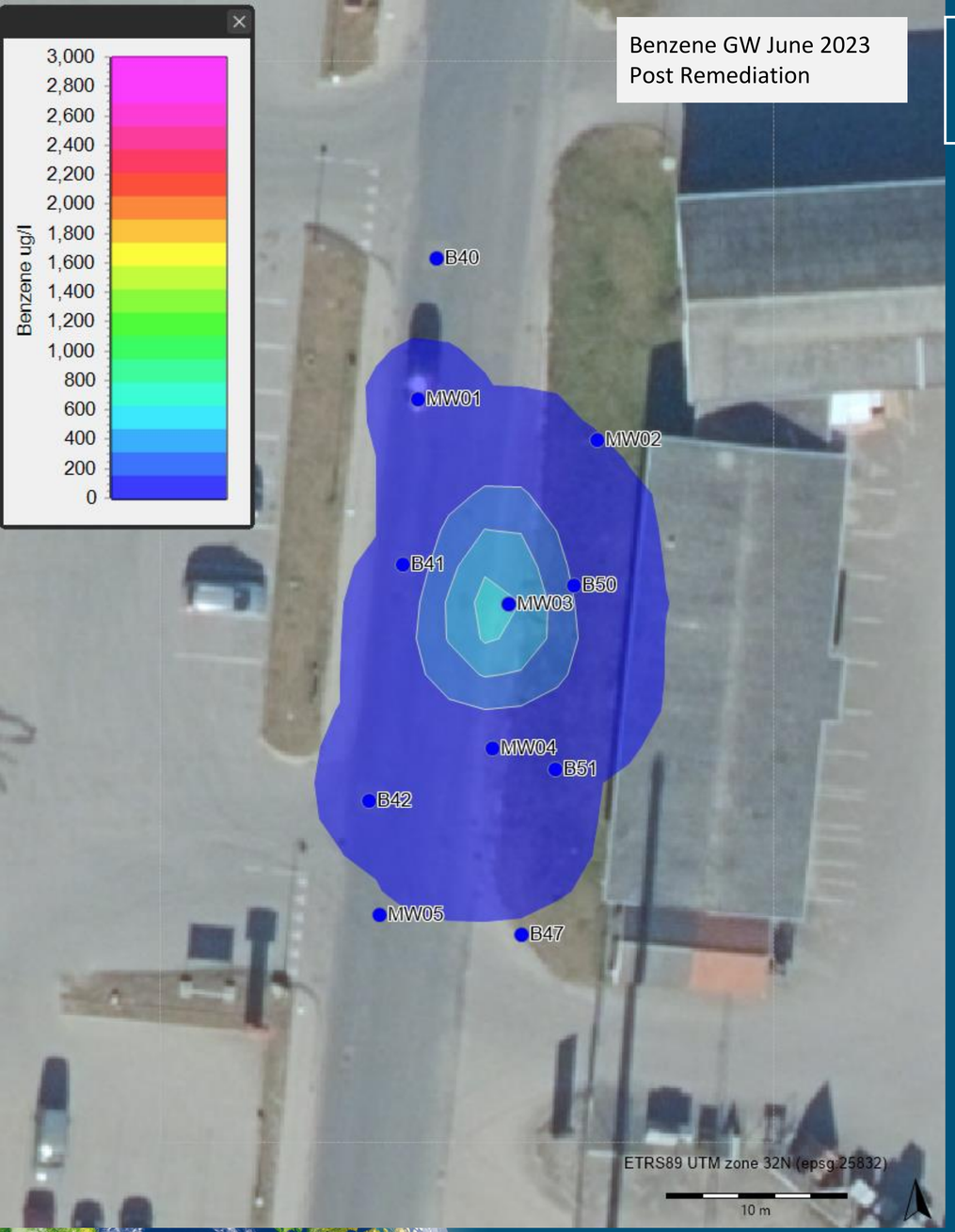
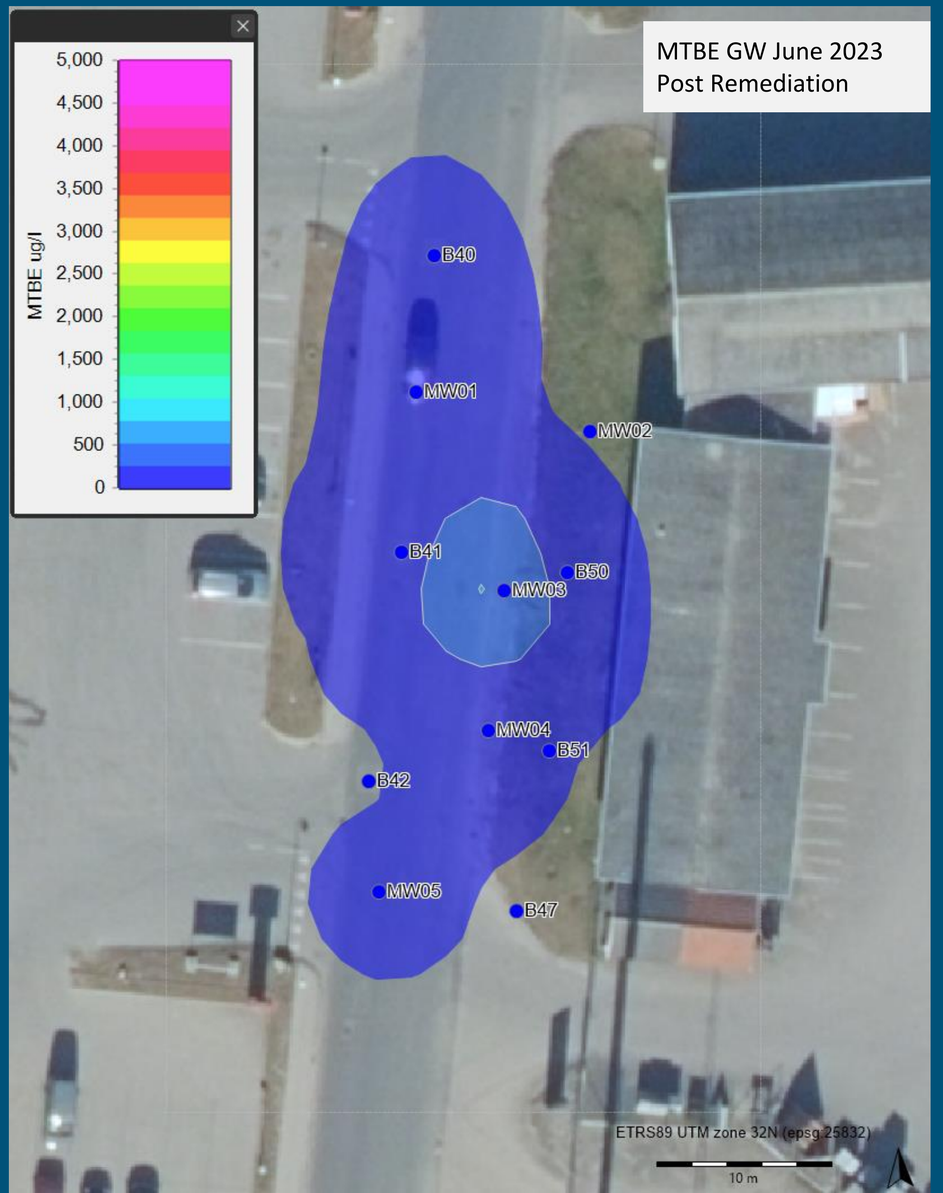
Benzene GW June 2023
Post Remediation




MTBE GW June 2023
Post Remediation



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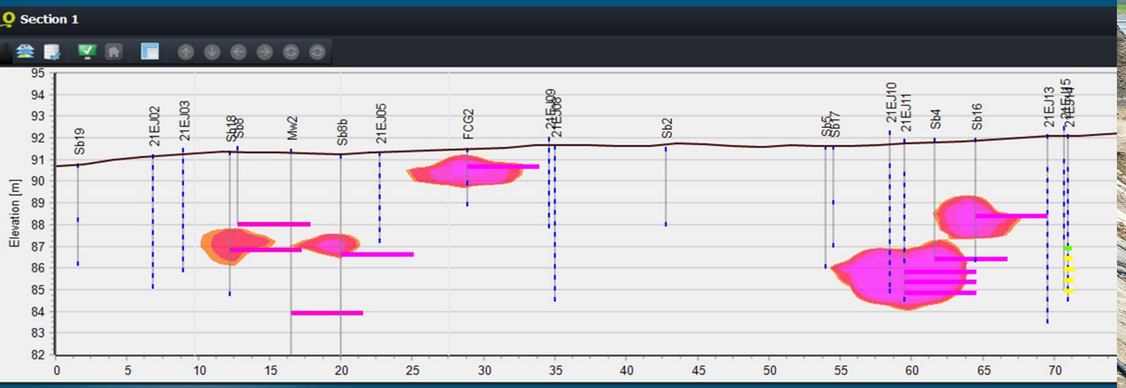
# Case Study #7

# Remediation Solution – Soil mixing / blending

Remediation solution / application:

- Excavation pits can be open in small areas (e.g. 5 x 5 m) and slowly advanced to depth with a bucket excavator
- Soil from the clean top layers can be temporarily stock-piled on site
- When contaminated layers are reached, BOS100® / CAT100 / BOS200® slurry and additional terminal electron acceptors or donors can be added to the formation and soil mixed by use of bucket excavator or power mixers
- The contaminated soil can always be mixed inside the excavation pit
- Clean top-soil is compacted at completion of soil mixing operations



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# Case Study – TPH Soil Contamination – Soil Mixing

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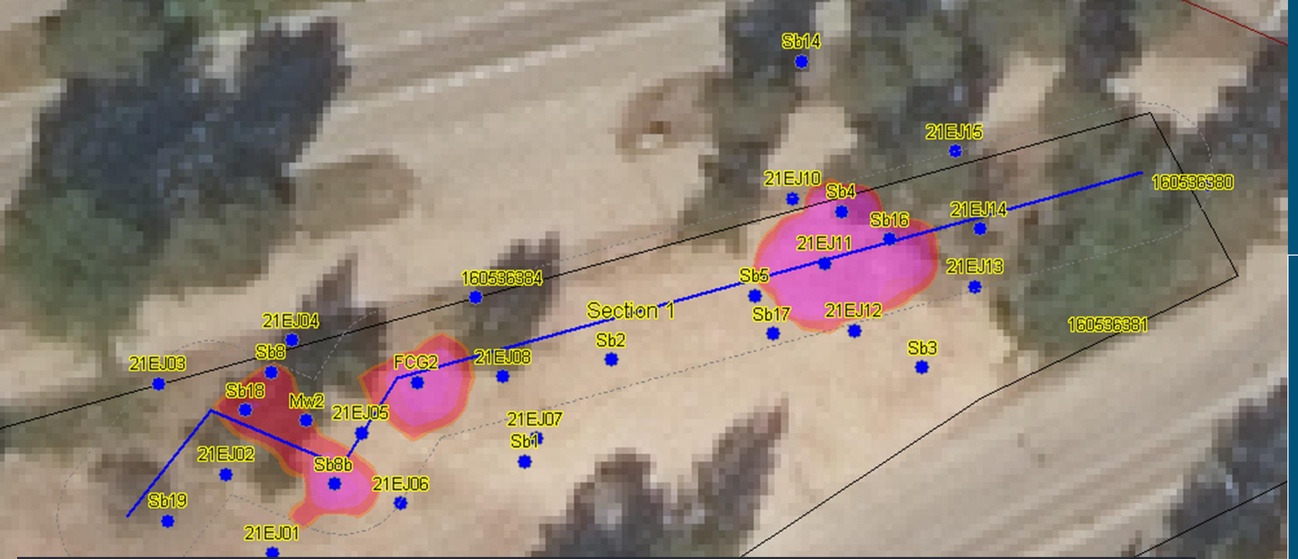
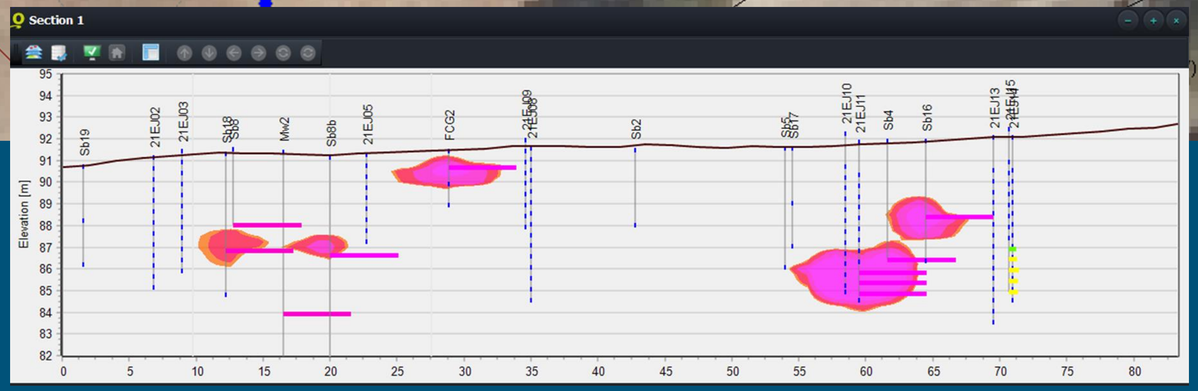
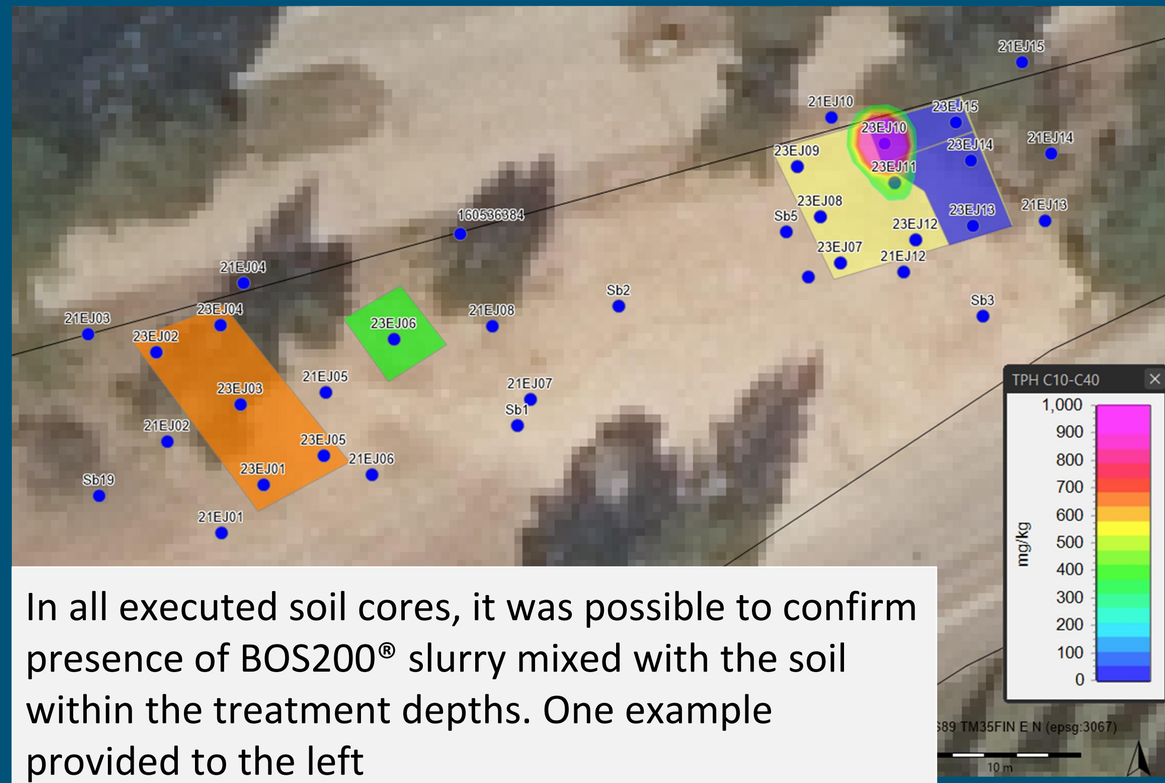
On the left – Soil contamination prior to BOS200® treatment
Below – Soil condition after soil validation 24 months post treatment (colored areas showing treatment zones)
95% TPH mass reduction measured by collection of high-density soil data compared to pre-remediation soil data






In all executed soil cores, it was possible to confirm presence of BOS200® slurry mixed with the soil within the treatment depths. One example provided to the left