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Remedial Site Characterization using Membrane Interphase Probe (MIP) and high resolution sampling

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Environmental Engineer / Remediation Specialist

Ejlskov A/S

- Founded in 1999 by Palle Ejlskov
- Based in Aarhus (Jutland – Denmark)
- Main business activities focused on high detailed site characterization and injection based in-situ remediation
- Currently 23 employees (Geologists, Engineers, Software developer, Field Technicians)
- Ejlskov is specialized in:
  - Soil and groundwater investigations
  - Contamination Risk evaluation towards groundwater, indoor climate and physical contact
  - Insitu Site Remediation (Trap & Treat® and other technologies)
  - Turn Key solitions to soil and groundwater contamination problems
  - Environmental risk towards groundwater, indoor climate and physical contact
  - Consulting services to local developers and authorities
  - Environmental Due Diligence and EHS Audits

Presentation Layout / Agenda

PART ONE

- Remedial Site Characterization
  - Why
  - When
  - How
- Geoprobe System
  - Introduction to the method
  - Direct Sensing
    - Membrane Interface Probing (MIP)
  - Soil Coring – Dual Tube
  - Well installation/Groundwater sampling
- 2D/3D modeling
  - 2D modeling as planning tool (Dynamic modeling)
  - Data evaluation and 3D Modeling (Final model)
- Question Time

PART TWO

- Case Studies
  1. CRT Station, Kvistgård (Denmark)
  2. Active Retail Station, Copenhagen (Denmark)
  3. Former Industrial Facility (Sweden)
- Conclusions and Lessons Learned
- Insitu Site Remediation -Trap & Treat® concept
  - BOS100®/CAT100 ® for chlorinated solvents,
  - BOS200® for Hydrocarbons, BTEX and MTBE,
  - Injection method/Installation,
- Question Time

Remedial Design Characterization

Why, When, How?

RDC Conceptual Introduction (1)

WHY & WHEN

WHY

- Collect sufficient and relevant data (soil and groundwater) to define the actual area/volume to be treated
- Narrow down to the maximum extent possible data gaps in the Conceptual Site Model (CSM)
- Collect high frequency soil data to estimate actual soil contaminant mass
- Remove uncertainties related to remediation works extent (need to, how much, how long)

WHEN

- Need to assess to a high level of certainty the contaminant mass distrubution (pre-, post- Risk Assessment)
- Insufficient data are available (saturated soil data missing)
- Client is keen in limiting the risks associated to the remediation works implementation
- Client wants a performance based / time based guarantee on the remediation contract

Remedial Design Characterization (RDC)

Initial Site Evaluation based on available data:

- Review of Existing Soil and Groundwater Data
- Well and Borehole Logs
- Saturated and Unsaturated Soil Data
- Groundwater Data – Vertical Profile
- Previous/On-going Remedial Efforts?
- Physical Site Constraints – Tank Pits, Utilities…etc.,
- Critical Receptors (Groundwater Abstraction Wells, Streams etc.)
- Develop a preliminary Site Model

To design RDC to optimize Remediation plan

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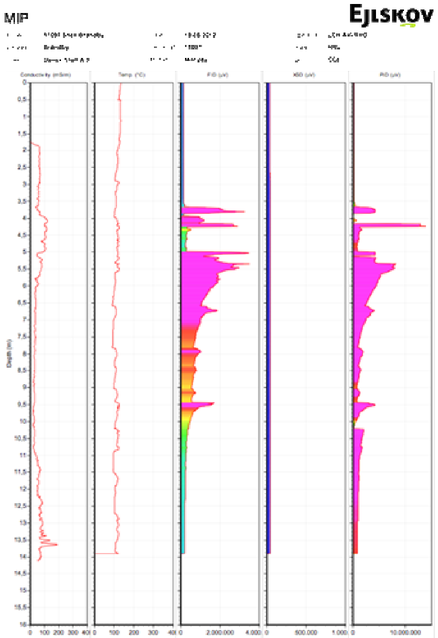
Site Investigation



HOW

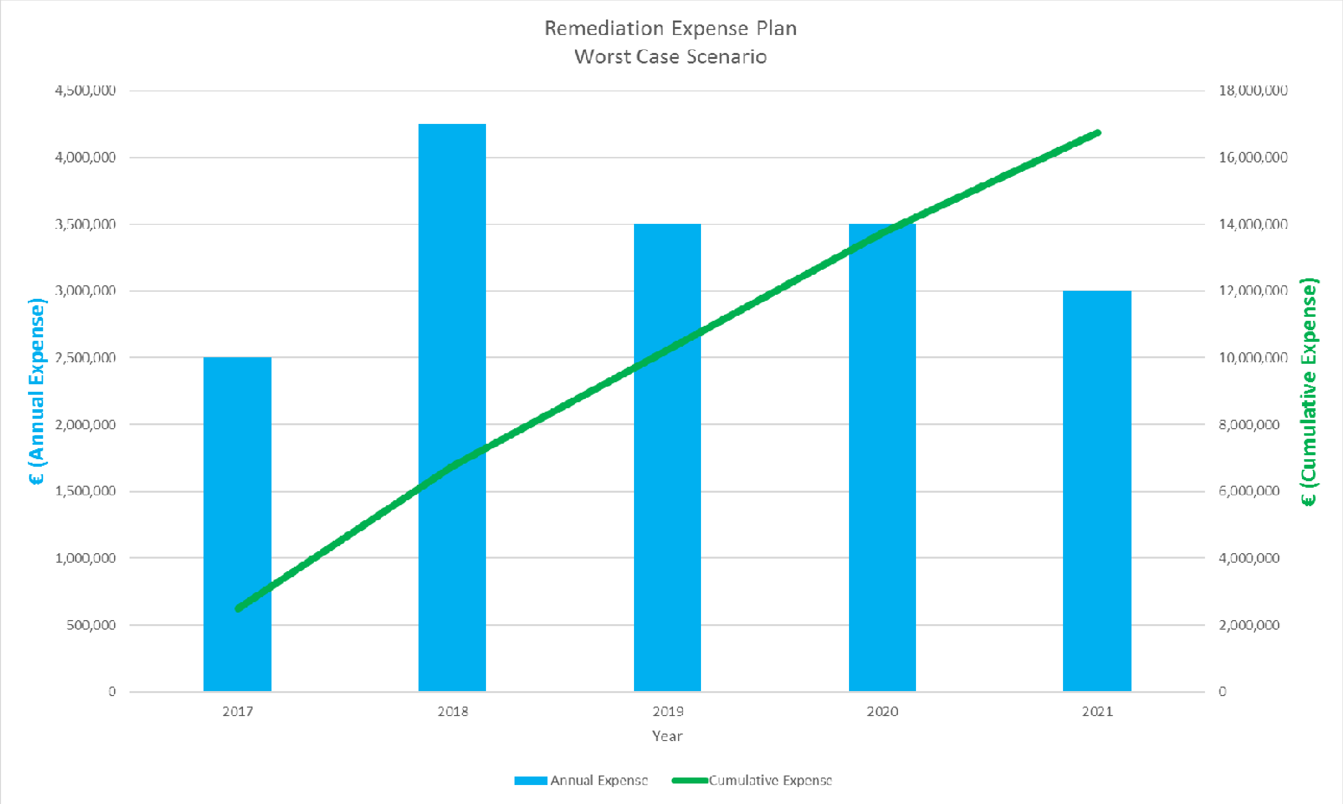
Membrane Interphase Probe

Assess real time data and modify RDC strategy

Collect relevant / high frequency soil samples

Conduct Screen Point Sampling / Install Cluster Wells

Remediation Costs Estimate



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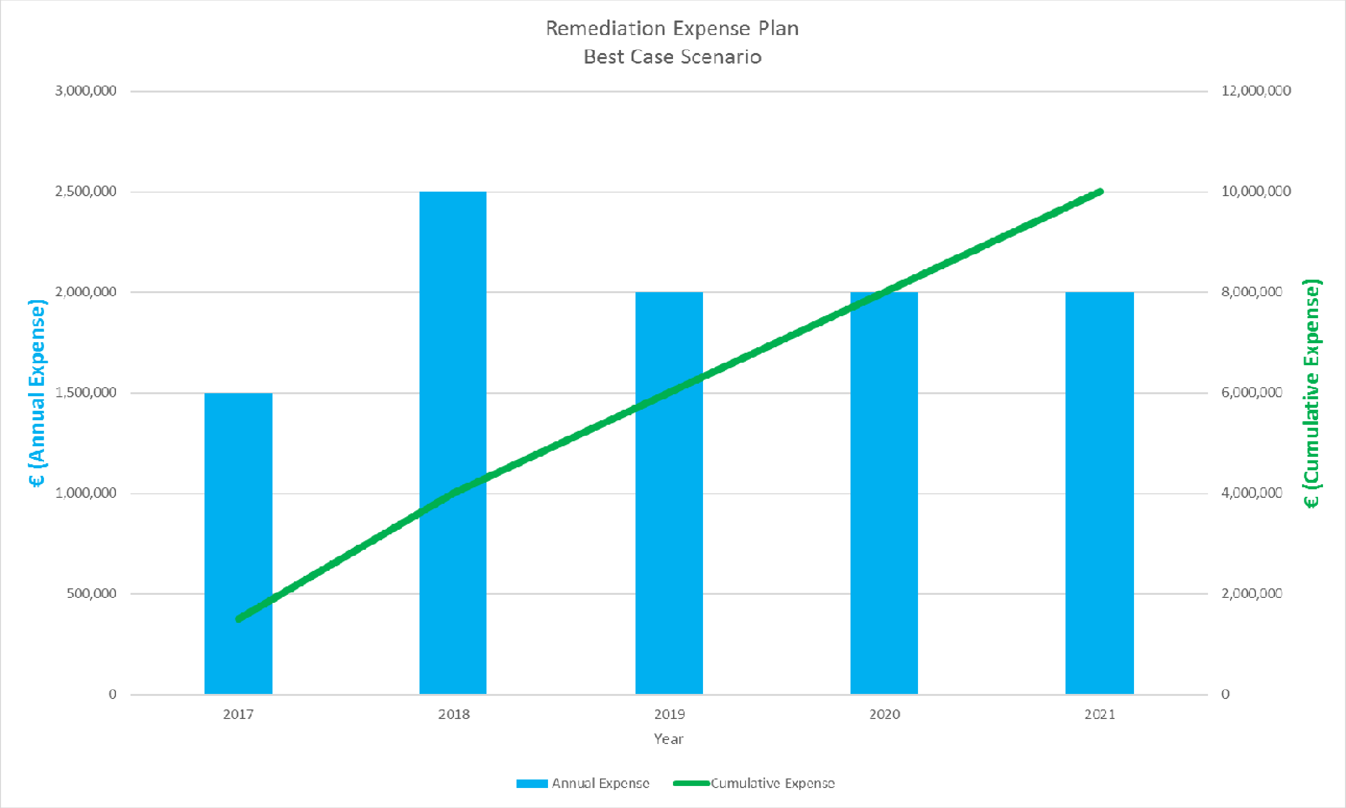
RDC Conceptual Introduction (2)

- Baseline REM cost: 25,000,000 – 30,000,000 €
- Remedial costs development driven by RDC spatial grid
- Combined RDC+REM to be split in phases based on risk / liability removal

Remediation Costs Estimate



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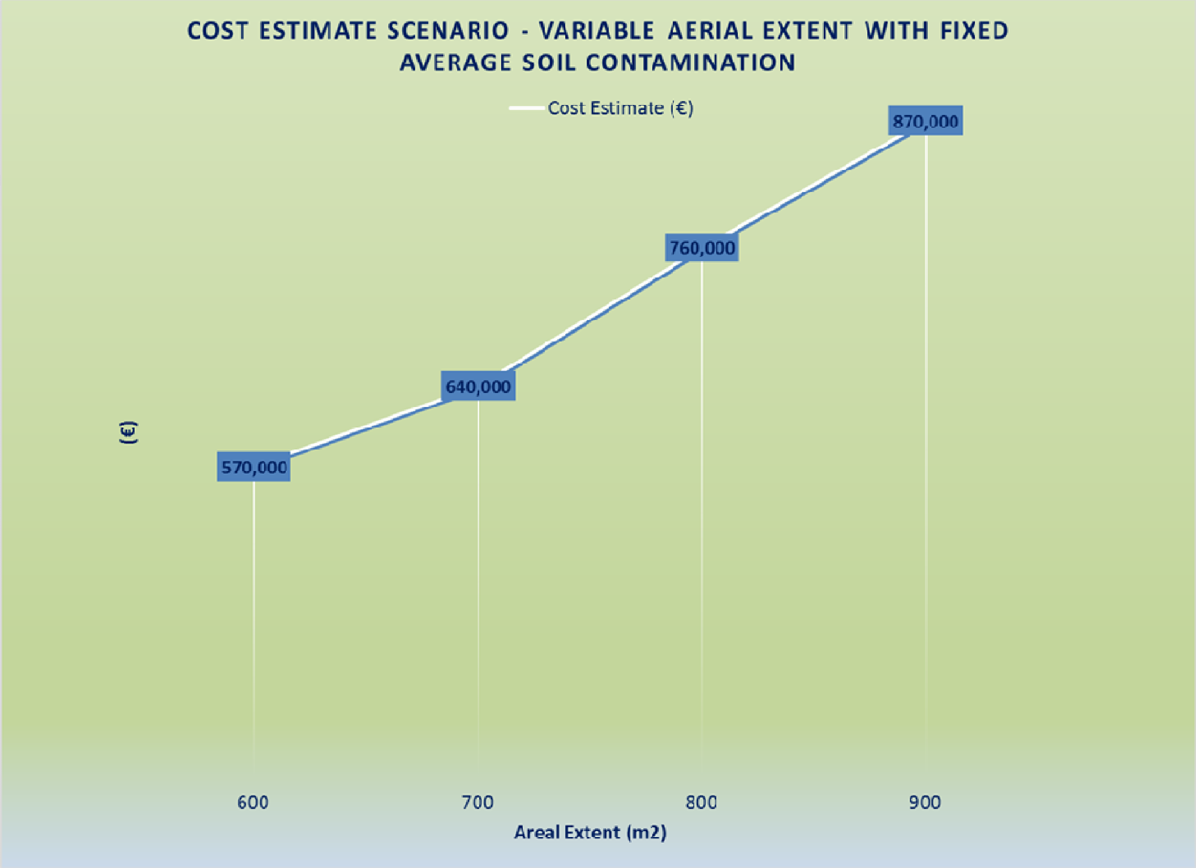
RDC Conceptual Introduction (3)

- Baseline REM cost: 25,000,000 – 30,000,000 €
- Remedial costs development driven by RDC spatial grid
- Combined RDC+REM to be split in phases based on risk / liability removal

Remediation Costs Estimate



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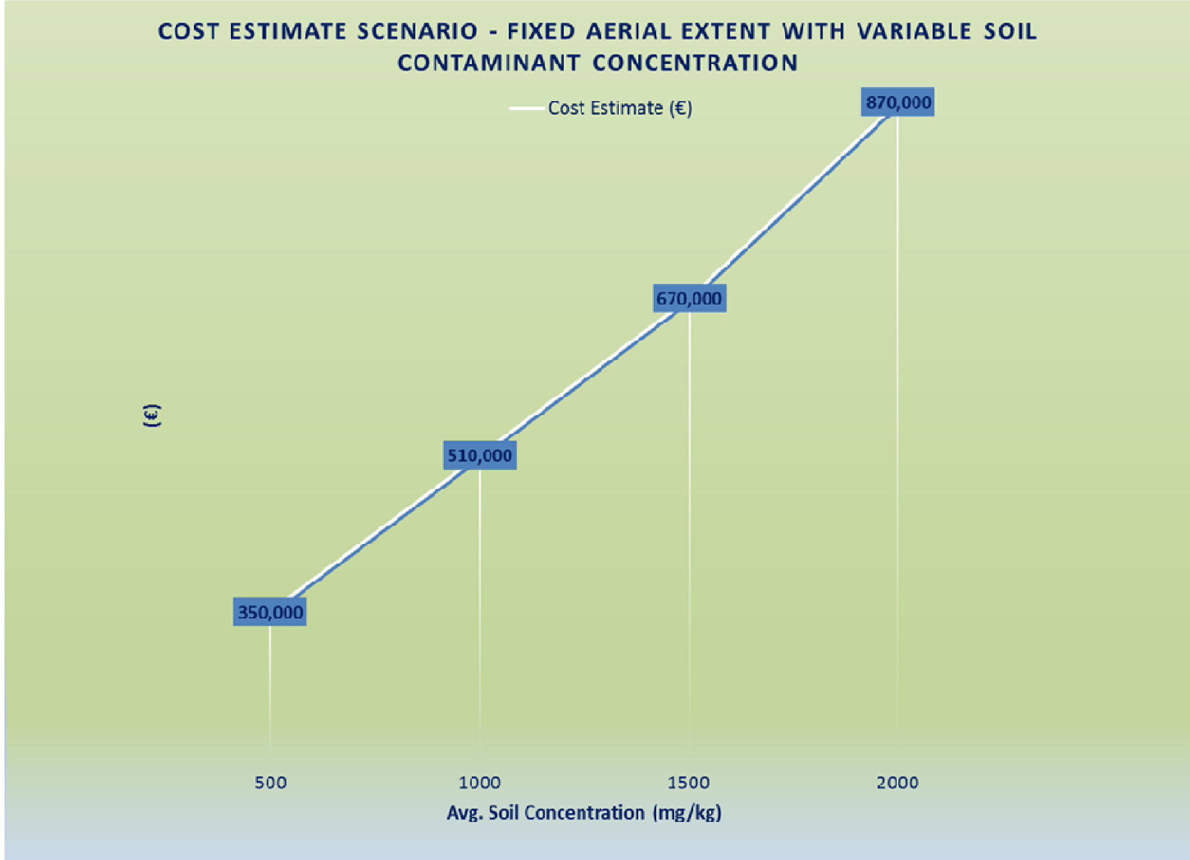
RDC Conceptual Introduction (4)

- Remedial cost development based on fixed average soil concentration and variable areal extent
- Initial estimate is generally priced towards the upper right end
- RDC generally allows for better and more refined price estimate

Remediation Costs Estimate



RDC Conceptual Introduction (5)

- Remedial cost development based on fixed aerial extent and variable average soil concentrations
- Initial estimate is generally priced towards the upper right end
- Most likely scenario compared to prev ious slide. RDC likely to show different contamination patterns

GeoProbe System

Tools, Features, Procedures



Geoprobe System

Key Features:

- Based on Direct Push Technology
  - Steel rods (1,25" – 3,25")
  - Auger drillings available (Solid-/Hollow Stem Augers)
- Penetration depth in non-consolidated sediments – 25-35 m.
  - Cannot pennetrate consoildated rock types, Bedrock, Limestone etc.
- Mobile and flexible rigs
  - Various sizes: 0,5-4,5 tons
  - Catepillar Tracks
  - Various tools (Direct Sensing, Well installation, Level specific Soil- and groundwater sampling, slug test)

Ejlskov Geoprobe Rigs

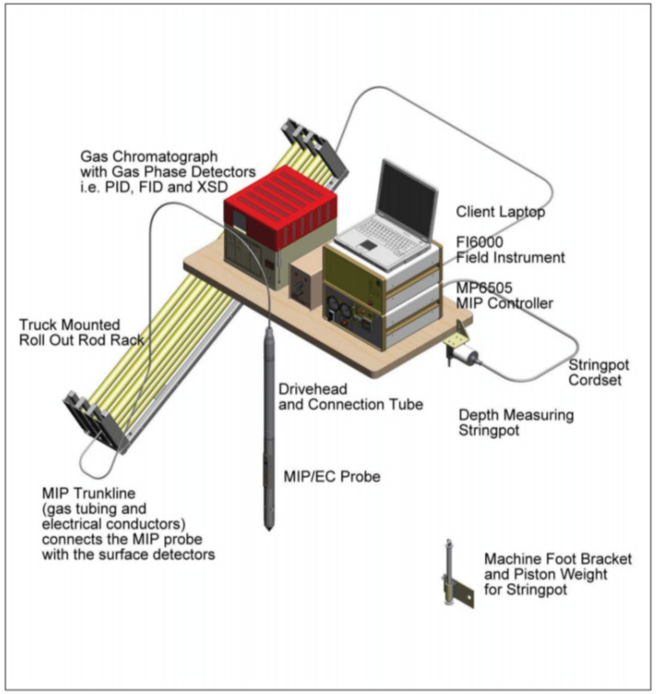
7730DT

7822DT

54DT

540MT

Membrane Interface Probe (MIP) – System set-up

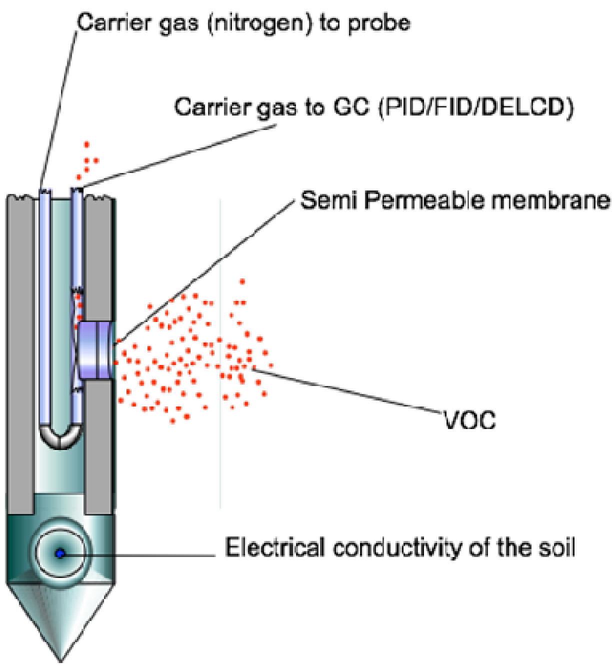


The MIP has been used extensively for mapping the extent of VOC contamination in the subsurface (vertical and horizontal).

The Membrane Interface Probe (MIP) is a screening tool with semi-quantitative capabilities As a logging tool, the MIP offers many benefits to site investigators:

- Useful for detecting and logging both chlorinated and non-chlorinated VOC contaminants.
- Works in both saturated and unsaturated soils.
- Standard tool configurations combine the MIP with at di-pol for lithology logging (Electrical Conductivity).
- Real time contaminant screening information is generated, allowing field adjustment of the site investigation. (Dynamic investigation approach)
- Relative contaminant concentration levels (signal output in µV)

Membrane Interface Probe (MIP) - Probe



- The MIP membrane is semi-permeable and is comprised of a thin film polymer impregnated into a stainless steel screen for support.
- The membrane is approximately 6.35mm in diameter. The membrane is placed in a heated block attached to the probe.
- This block is heated to approximately 90-120 ℃ as the probe is advanced into the soil. - Heating the Probe accelerates membrane diffusion while at the same time minimizing membrane absorption.
- Diffusion across the membrane is driven by the concentration gradient between the contaminated soil and the clean carrier gas behind the membrane.
- A constant gas flow of 35-45 mL/min sweeps behind the membrane and carries the contaminants to the gas phase detectors at the surface (FID,PID and XSD).
- Travel time from the membrane interface to the detector(s) is approx. 30-45sec (depending on the length of trunkline and flow rate).

Membrane Interface Probe (MIP) - Detectors

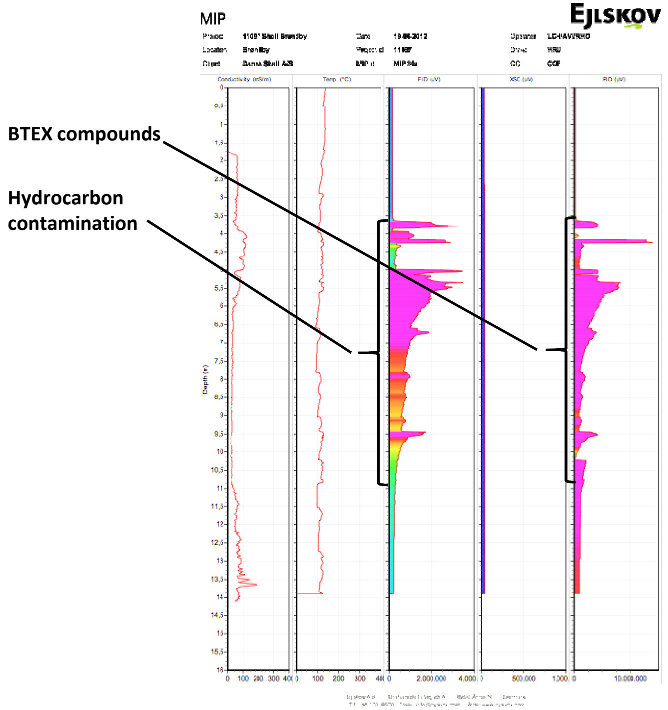
- **PID (Photo Ionization Detector)**
  Aromatic compounds like BTEX and PCE, TCE, DCE, VC……
- **FID (Flame Ionization Detector)**
  Alkanes inkl. Methane
- **XSD (Halogen Specific Detector)**
  Halogenated compounds - Cl^-, Br^-, Fl^-

- The MIP system is checked before each MIP according to the Geoprobe Standard Procedure.

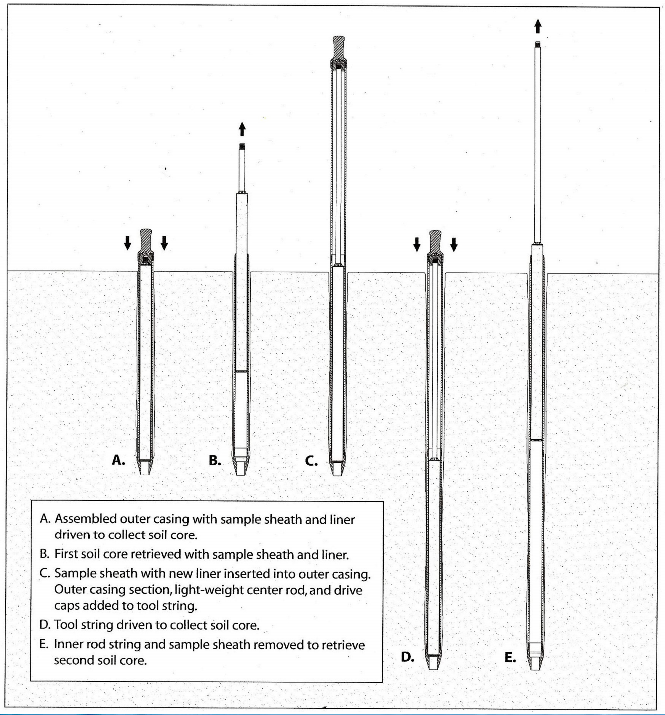
- **Detection Limits**

Detector	Detection Limit*
PID	0,2-2 ppm
FID	1-20 ppm
XSD	0,1-2 ppm

** http://geoprobe.com/mip-specifications*



Soil Coring – Geoprobe Dual Tube



- The Dual Tube method for continuous soil coring,
- Sampling of all unconsolidated soil types,
- Soil Core delivered in transparent PVC Liners (1,2 m length),
- Core Diameter: DT21 – 38 mm dia. / DT32 – 47 mm dia.
- Soil sampling from discrete sampling depth

Groundwater Screen Sampling – Geoprobe SP16

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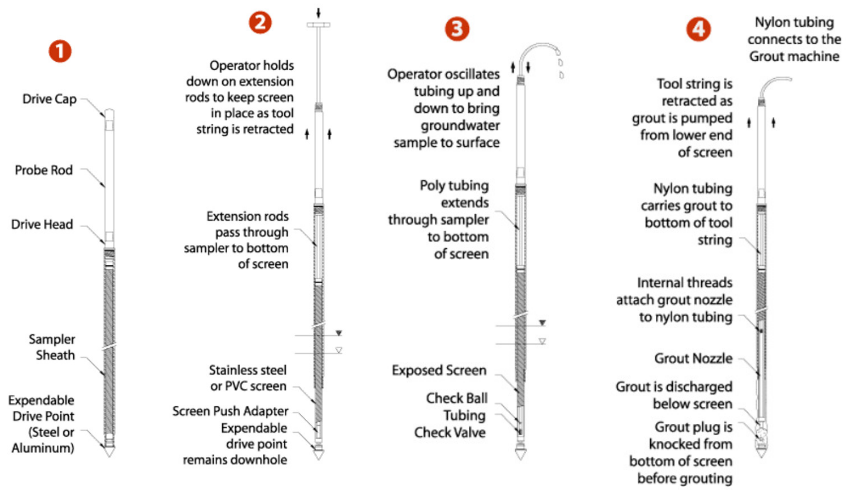
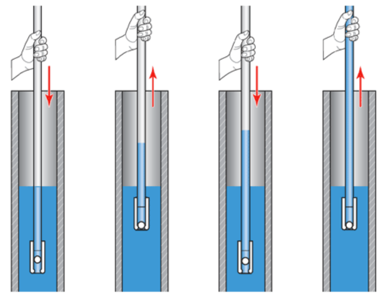
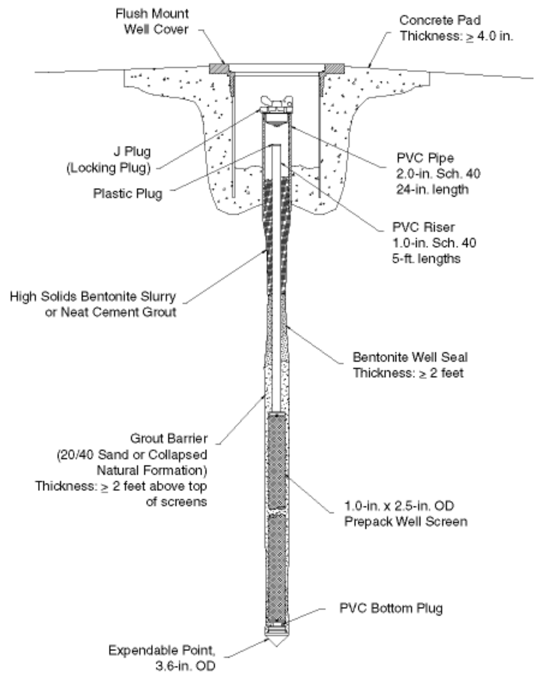


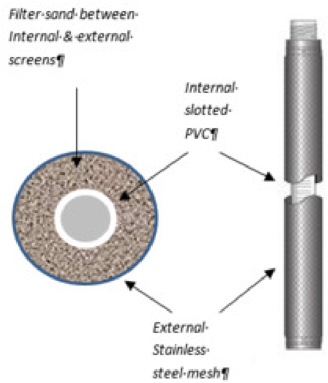
- Geoprobe Screen Point Sampler (SP16),
- Stainless steel screens (25 mm OD) – 1 meter screen length,
- Temporary well installation for discrete groundwater sampling,
- Sampling with Peristaltic pump or Inertia Pump



Well Installation – Permanent Monitoring Well



- Geoprobe Prepacked PVC screens (12,5 – 50 mm OD) (or regular standard PEHD screens <63 mm OD),
- Direct Push Installation – No handling of contaminated soil traditional auger methods,
- Prepacked screen length: 0,9-1,5 meter
  Standard PEHD screen length: 0,5-2 meters
  (Screens can be connected for extended screen interval),
- Prepacked screens ensures optimal installation of filter pack,
- Sampling with Peristaltic pump or Submersible pumps depending on internal well diameter and groundwater level.



Remedial Design Characterization

Ongoing 2D/3D Modeling and data evaluation

Active Retail Station - Denmark

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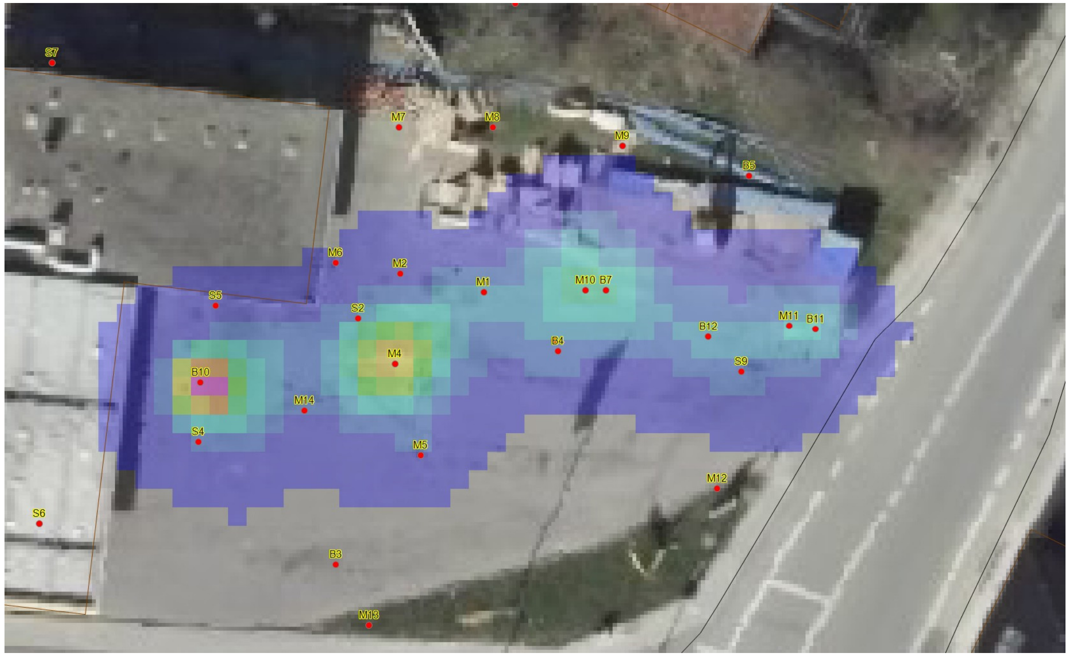
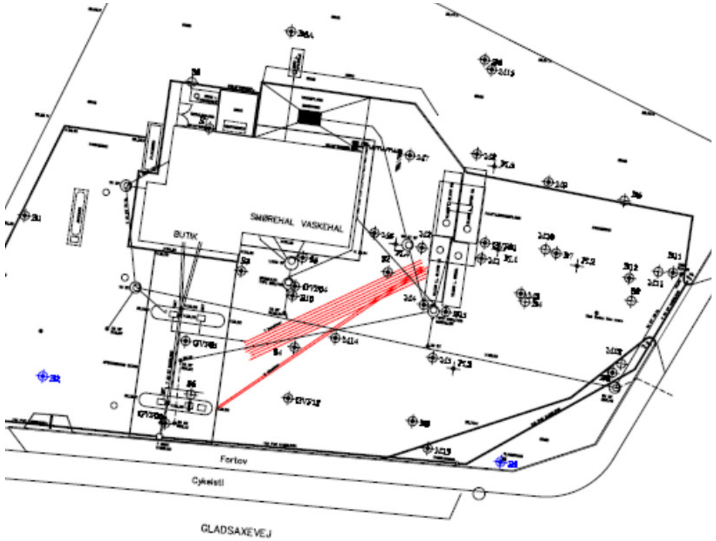
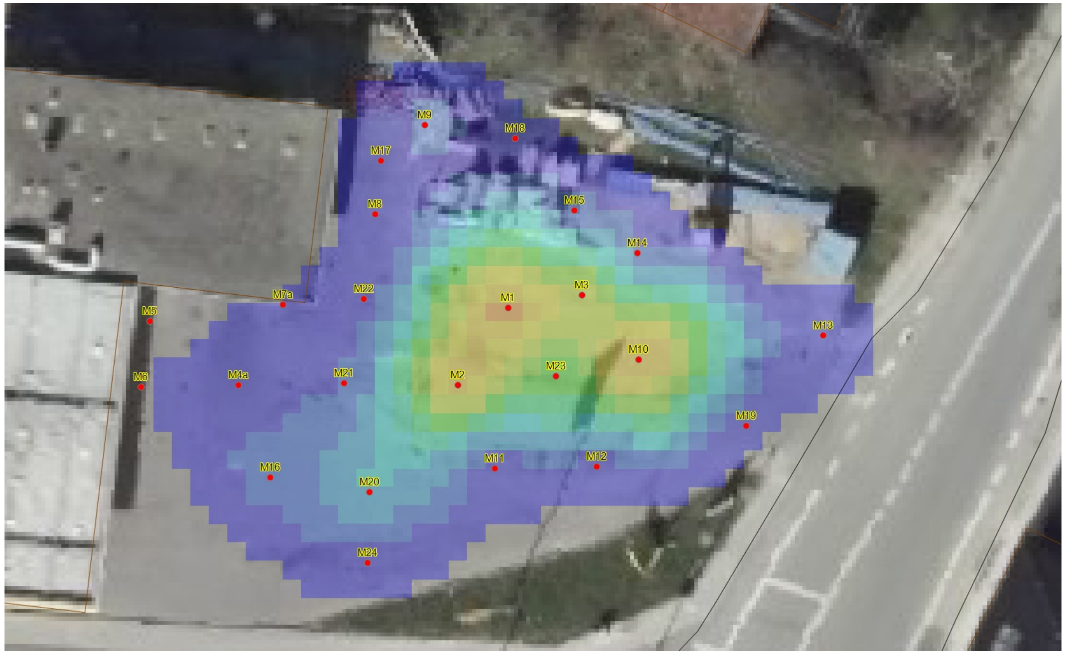


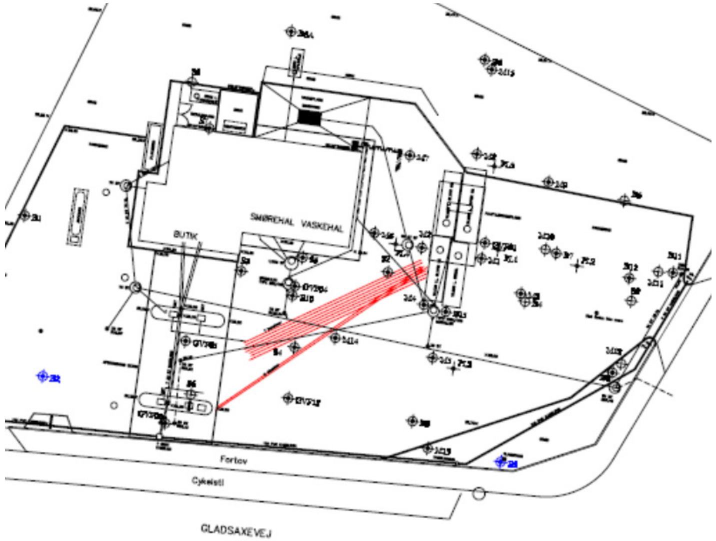
Site Example - Modelling of available data prior RDC



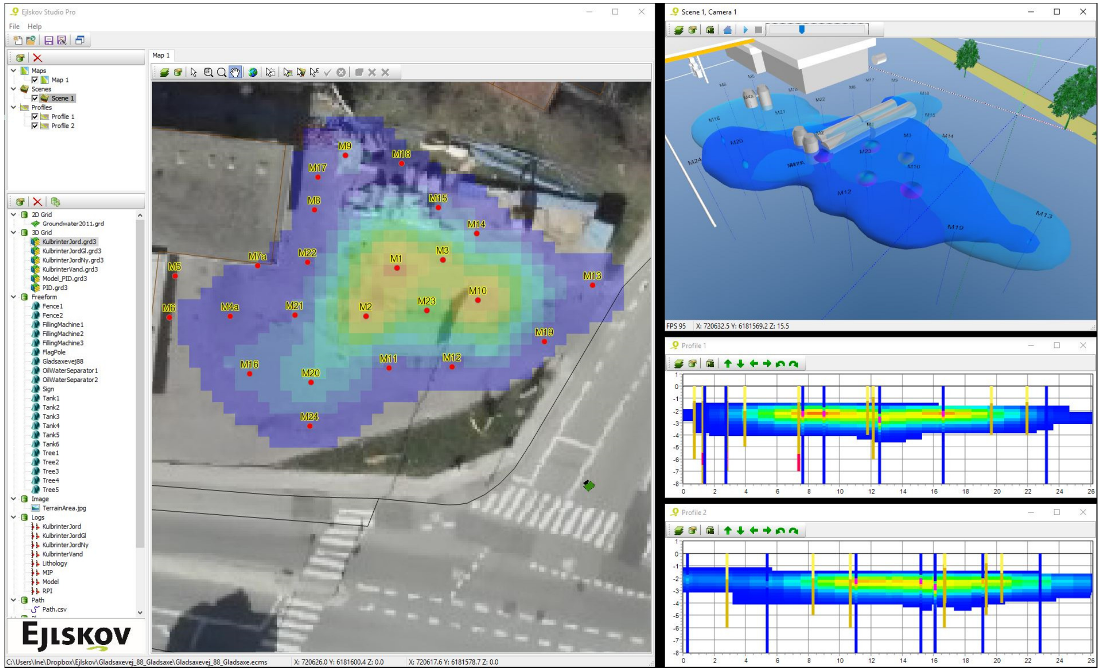
Active Retail Station - Denmark



Modelling of new data from RDC



Active Retail Station - Denmark



Final Model including 3D illustration and cross sc Modelling of available data prior RDC

RDC - Case Study (1)

CRT Station, Kvistgård, DK

Ejlskov Studio Pro

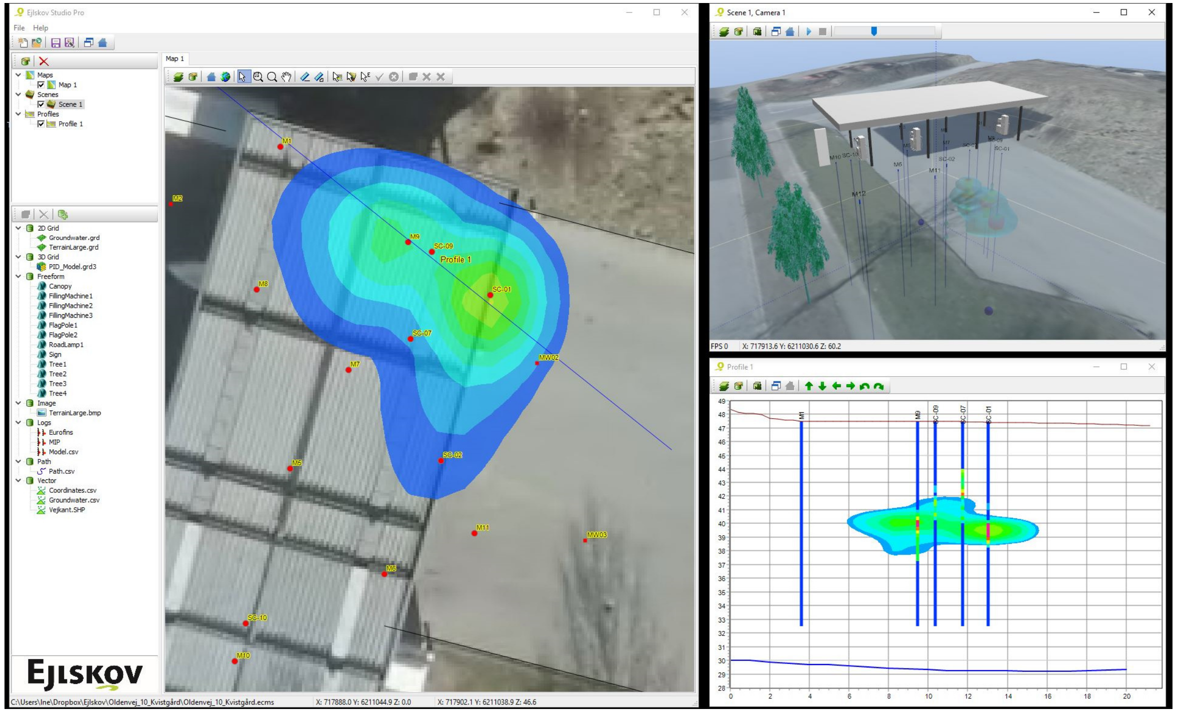
3D Mass distribution and Remedial Design Model

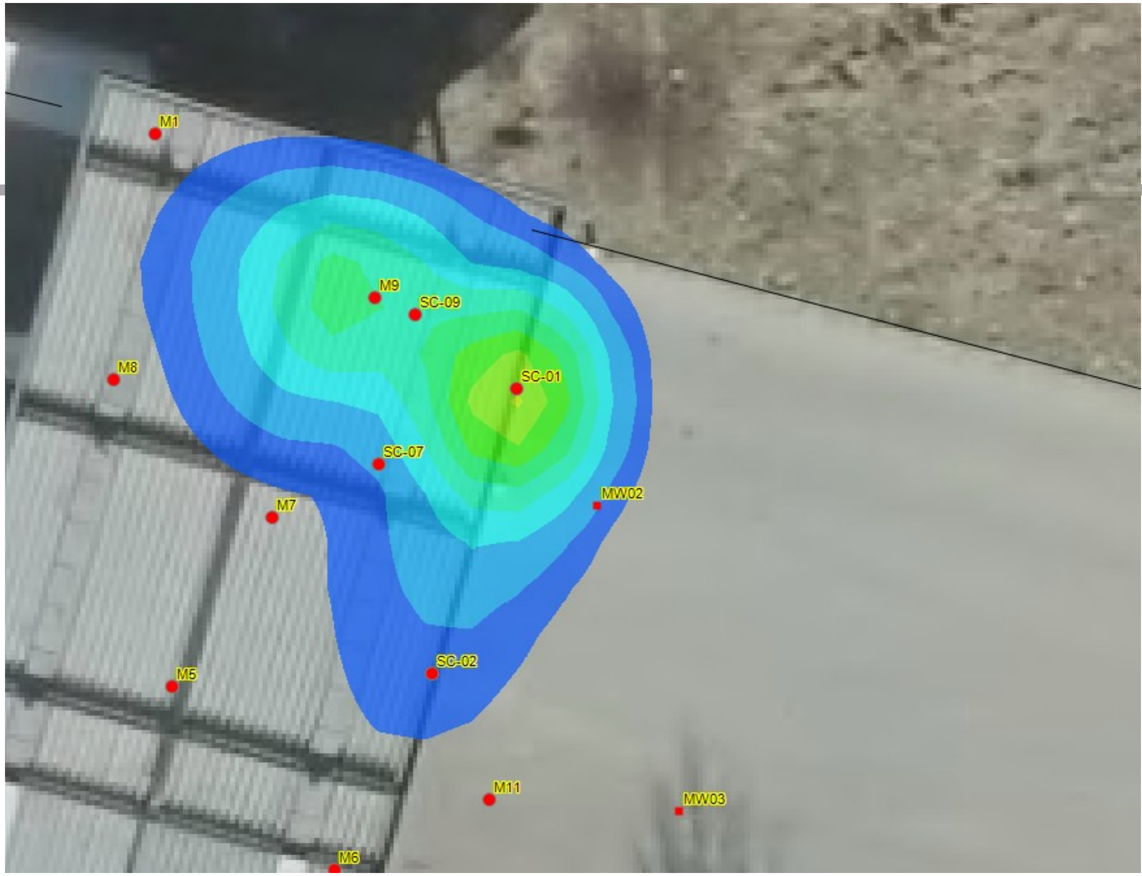
Getting the contaminant mass distribution right.

- Remedial Design Characterization (RDC)
    - For design of remediation
    - Focused on “hot” areas
        - Source Zone
        - Plume Zone

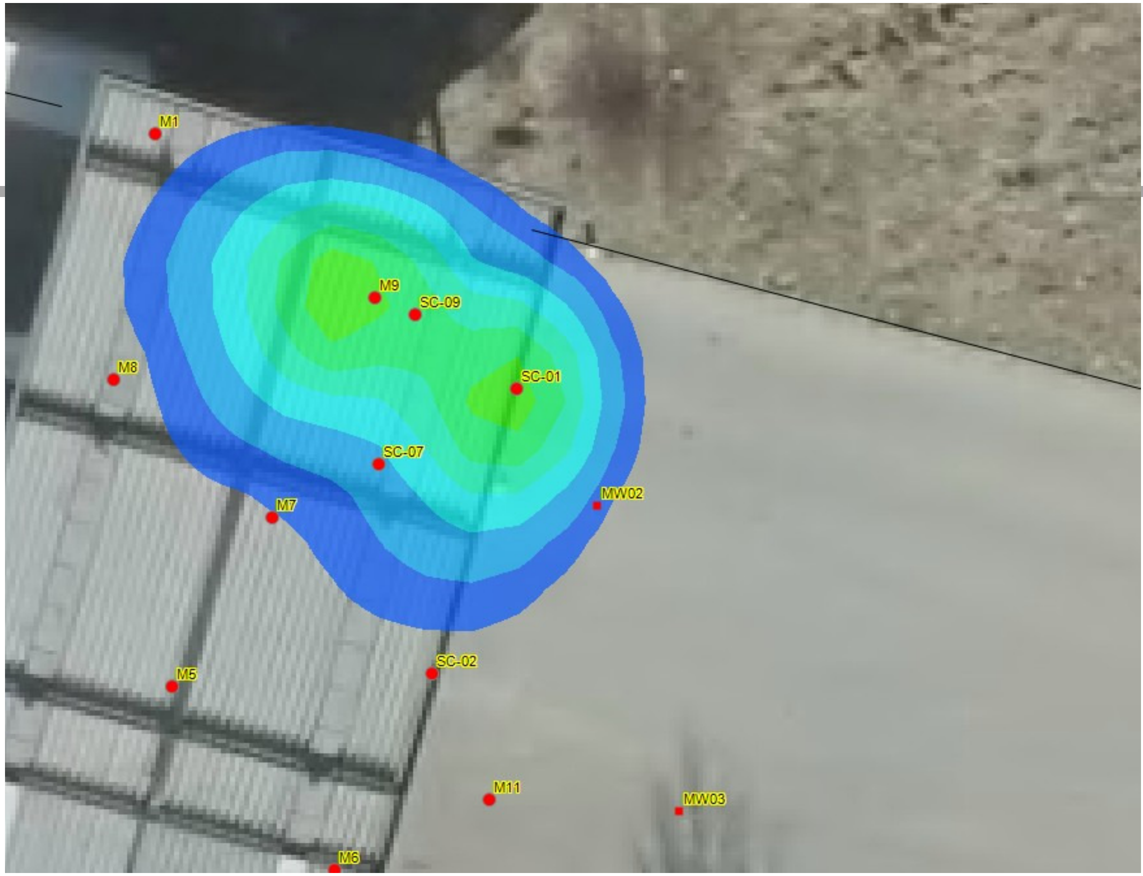
- Development of 3D contamination mass model

- Decide on the goal
    - Risk removal (still in the books)
    - Liability removal (out of the books)
    - To evaluate remedial methods



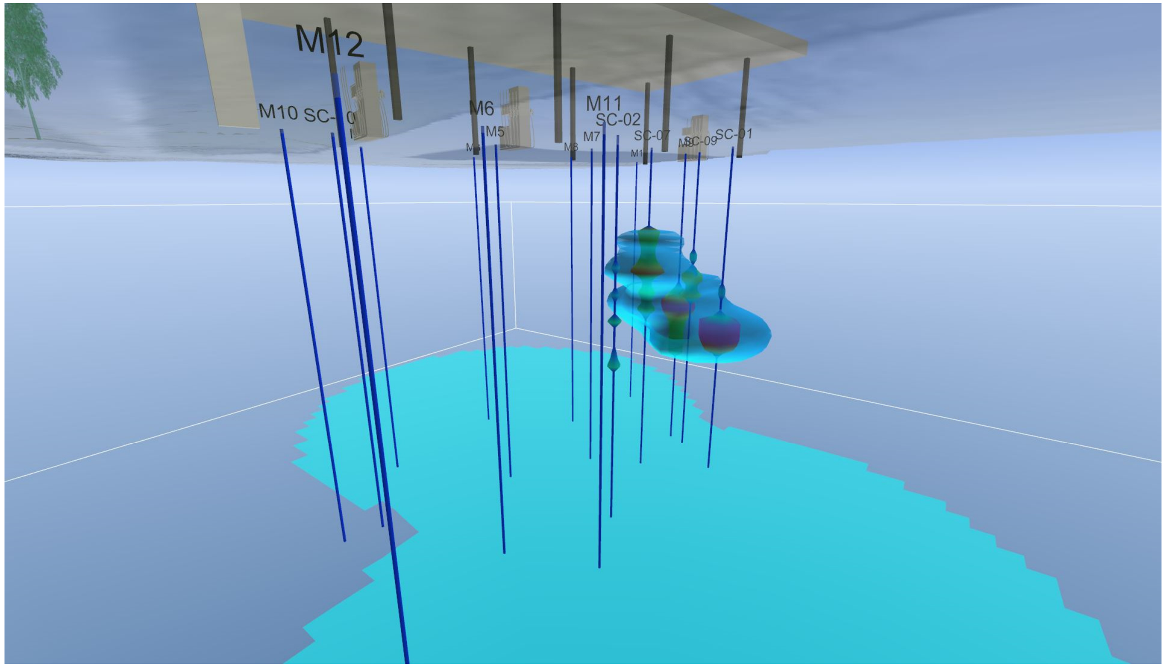


MIP 2D Model 9,5 m bgl profile

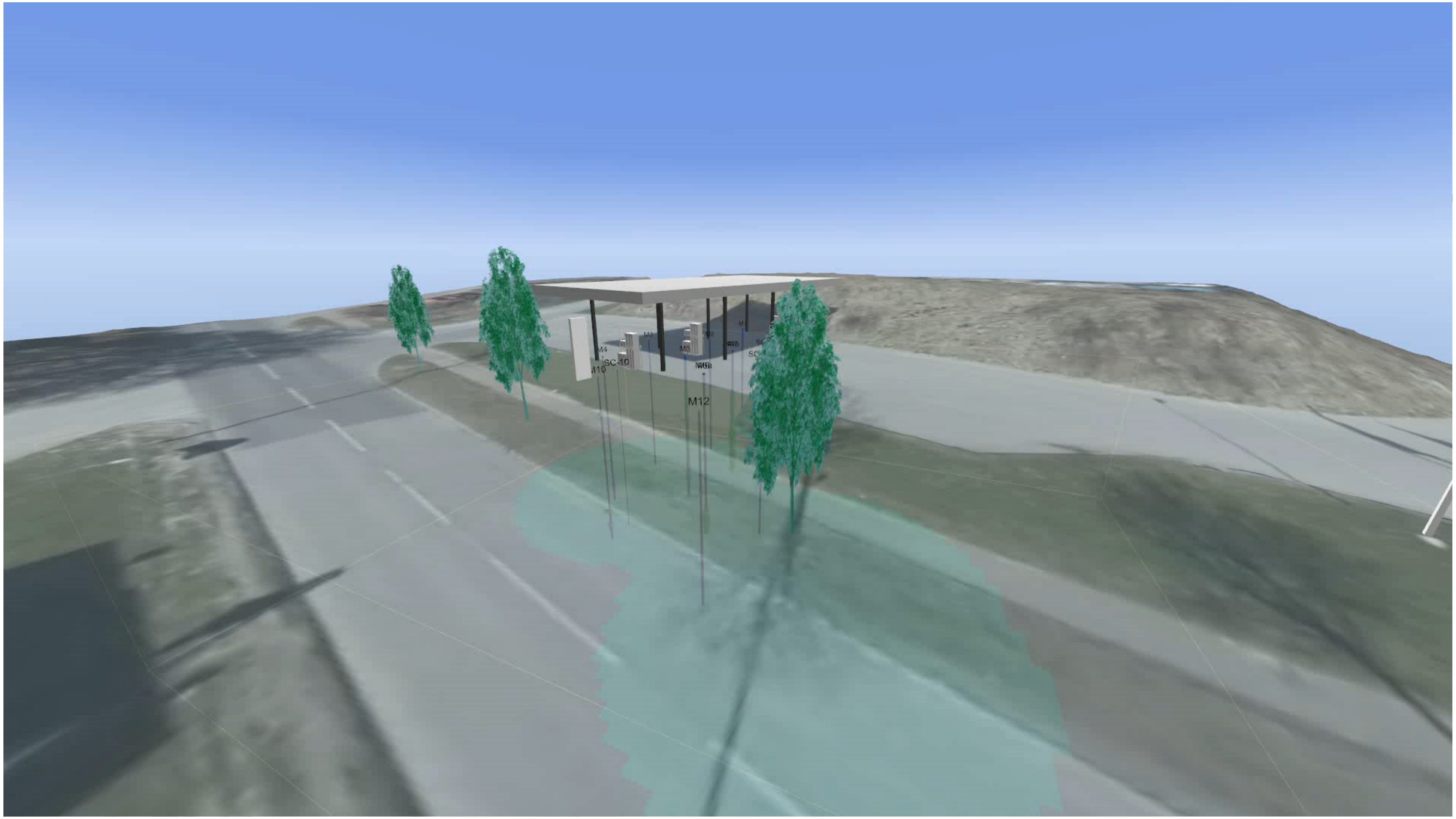


MIP 2D Model 7,5 m bgl profile

MIP 3D Model View



MIP 3D VIEW
Hydrocarbon MIP Probe Delineation and confirmatory soil sampling


M3
M4
M5
SC-10
M12

Importance of High Frequency Data

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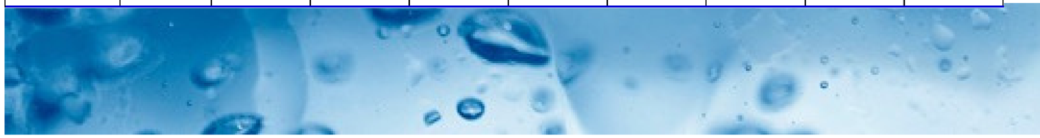
Soil Criteria Class	Sample ID	Prøvedybde m bgl	Dry Matter %	C6H6-C10 mg/kg ts.	C10-C15 mg/kg ts.	C15-C20 mg/kg ts.	C20-C35 mg/kg ts.	Sum (C10-C20) mg/kg ts.	Sum (C6H6-C35) mg/kg ts.
Klasse 4	MIP 07 SC	3,75	85	210	4900	5600	3300	10000	14000
Klasse 4	MIP 07 SC	4,0	85	280	4000	4400	2200	8400	11000
Klasse 4	MIP 07 SC	4,25	92	120	2400	2600	1400	5000	6500
Klasse 4	MIP 07 SC	4,5	92	160	3200	3500	2100	6700	9000
Klasse 4	MIP 07 SC	4,75	92	130	2600	2900	1500	5400	7000
Klasse 4	MIP 07 SC	5,0	92	200	3200	4600	2000	7800	10000
Klasse 4	MIP 07 SC	5,25	96	650	7300	8000	4200	15000	20000
Klasse 4	MIP 07 SC	5,5	96	110	1400	1400	610	2800	3500
Klasse 4	MIP 07 SC	5,75	96	9,4	480	260	110	740	860
Klasse 4	MIP 07 SC	6,0	96	14	500	140	57	630	700
Klasse 4	MIP 07 SC	6,25	95	590	11000	1100	370	12000	13000
Klasse 4	MIP 07 SC	6,5	95	290	4700	240	100	4900	5300
Klasse 3	MIP 07 SC	6,75	95	< 2	79	7,0	< 20	86	86
Klasse 4	MIP 07 SC	7,0	95	510	8200	1300	580	9500	11000
Klasse 4	MIP 07 SC	7,25	94	62	1400	250	110	1700	1800
Klasse 0	MIP 07 SC	7,5	94	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 07 SC	7,75	94	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 07 SC	8	94	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 07 SC	8,25	90	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 07 SC	8,5	90	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 07 SC	8,75	90	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 07 SC	9,0	90	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 07 SC	9,25	98	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 07 SC	9,5	98	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 07 SC	9,75	98	< 2	< 5	< 5	< 20	#	#
Klasse 4	MIP 09 SC	5,0	92	12	1100	2500	1600	3600	5200
Klasse 3	MIP 09 SC	5,25	95	< 2	6,5	18	< 20	24	24
Klasse 3	MIP 09 SC	5,5	95	< 2	7,3	16	< 20	23	23
Klasse 4	MIP 09 SC	5,75	97	61	3700	5700	3700	9400	13000
Klasse 4	MIP 09 SC	6,0	97	65	3500	5100	3300	8600	12000
Klasse 3	MIP 09 SC	6,25	96	< 2	46	41	< 20	88	88
Klasse 4	MIP 09 SC	6,5	96	100	2500	2000	860	4500	5400
Klasse 4	MIP 09 SC	6,75	95	260	4800	5100	3000	9900	13000
Klasse 4	MIP 09 SC	7,0	97	8,5	420	440	190	860	1100
Klasse 0	MIP 09 SC	7,25	95	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 09 SC	7,5	95	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 09 SC	7,75	95	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 09 SC	8,0	95	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 09 SC	8,25	90	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 09 SC	8,5	90	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 09 SC	8,75	90	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 09 SC	9,0	90	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 09 SC	9,25	91	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 09 SC	9,5	91	< 2	< 5	< 5	< 20	#	#



Ejlskov A/S , 16064, Kvistgård CRT

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Klasse 0	MIP 10 SC	2,5	89	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	3,5	96	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	4,5	98	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	5,0	96	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	5,5	96	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	6,0	98	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	6,25	98	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	6,5	98	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	6,75	98	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	7,0	93	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	7,25	93	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	7,5	93	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	7,75	93	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	8,0	96	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	8,25	90	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	8,5	90	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	8,75	90	< 2	< 5	< 5	< 20	#	#
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Klasse 0	MIP 10 SC	9,5	90	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	9,75	90	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	10,0	91	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	10,25	91	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	10,5	90	< 2	< 5	< 5	< 20	#	#
Klasse 0	MIP 10 SC	10,75	90	< 2	< 5	< 5	< 20	#	#
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Klasse 0	SC-01	4,0	74	< 2	< 5	< 5	< 20	#	#
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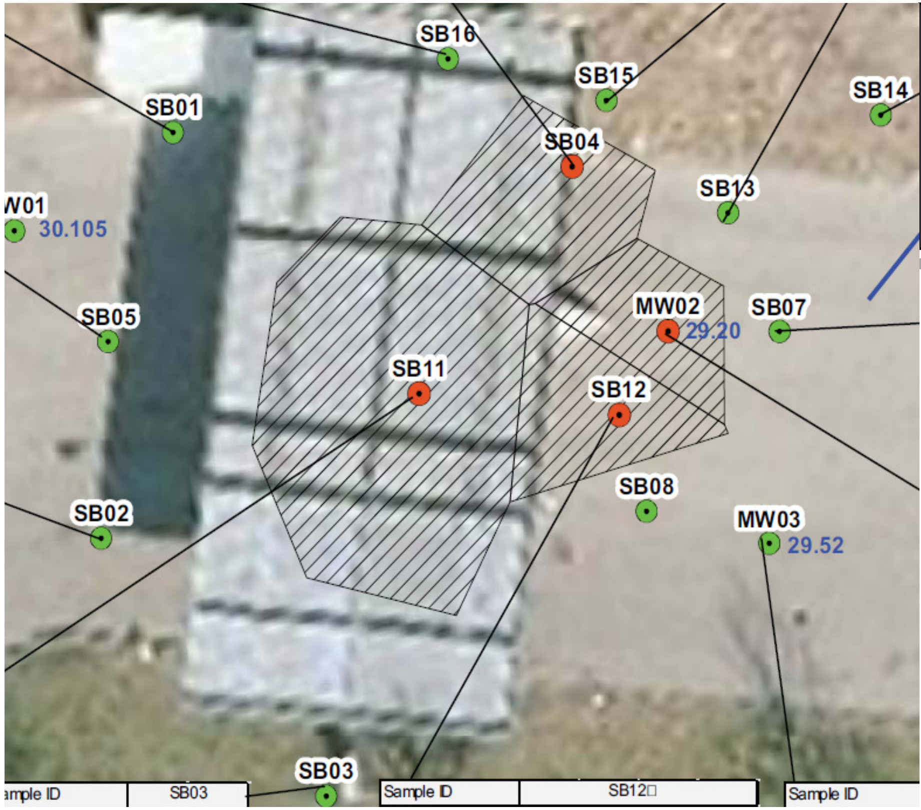
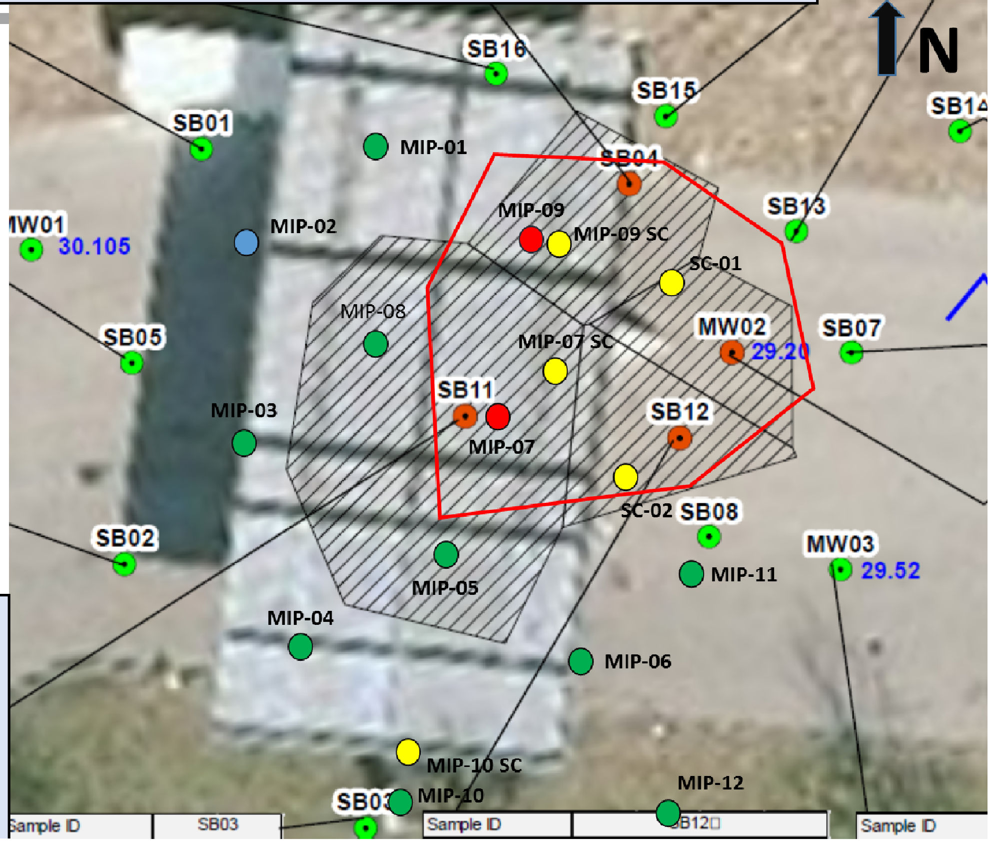
Klasse 4	SC-01	6,0	87	29	760	880	410	1600	2100
Klasse 2	SC-01	6,5	87	< 2	28	45	23	73	96
Klasse 4	SC-01	7,0	94	3,6	140	170	82	310	400
Klasse 4	SC-01	7,5	92	430	8200	8600	4000	17000	21000
Klasse 4	SC-01	7,75	92	340	5200	5500	2400	11000	13000
Klasse 4	SC-01	8,0	90	390	8500	9300	4500	18000	23000
Klasse 4	SC-01	8,25	90	360	8700	11000	5000	20000	25000
Klasse 4	SC-01	8,5	90	61	1600	2300	1000	3900	5000
Klasse 4	SC-01	8,75	88	92	5700	7800	3600	13000	17000
Klasse 4	SC-01	9,0	88	< 2	8,5	14	< 20	22	22
Klasse 3	SC-01	9,25	88	< 2	7,2	11	< 20	19	19
Klasse 0	SC-01	9,5	91	< 2	< 5	< 5	< 20	#	#
Klasse 0	SC-01	9,75	91	< 2	< 5	< 5	< 20	#	#
Klasse 0	SC-02	4,0	64	< 4	< 10	< 10	49	#	49
Klasse 4	SC-02	4,5	83	< 2	170	740	650	910	1600
Klasse 4	SC-02	5,5	83	70	1200	750	700	2000	2700
Klasse 4	SC-02	6,5	91	130	3200	770	660	4000	4800
Klasse 4	SC-02	7,5	96	7,8	270	34	30	310	350
Klasse 0	SC-02	7,75	96	< 2	< 5	< 5	< 20	#	#
Klasse 4	SC-02	8,0	96	89	1300	110	39	1400	1500
Klasse 4	SC-02	8,25	97	230	3900	1800	730	5700	6600
Klasse 0	SC-02	8,5	97	< 2	36	16	< 20	52	52
Klasse 0	SC-02	8,75	97	< 2	< 5	< 5	< 20	#	#
Klasse 0	SC-02	9,0	97	< 2	< 5	< 5	< 20	#	#
Klasse 0	SC-02	9,25	97	< 2	< 5	< 5	< 20	#	#
Klasse 0	SC-02	9,5	94	< 2	< 5	< 5	< 20	#	#
Klasse 0	SC-02	9,75	94	< 2	< 5	< 5	< 20	#	#



PRE RDC
Areal extent: ~ 200 sqm
Contamination Depths: 8 m bgl to 9 m bgl
Estimated Soil Contaminant Volume:~ 1,700 m3
Soil Disposal Costs: 310,000 €



POST RDC
Areal extent: ~ 120 sqm
Contamination Depths: 7 m bgl to 9 m bgl
Estimated Soil Contaminant Volume:~ 950 m3
Soil Disposal Costs: 175,000 €

Remedial Design Characterization

Question Time

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RDC – Case Study (2)

Active Retail Station Copenhagen (Denmark)

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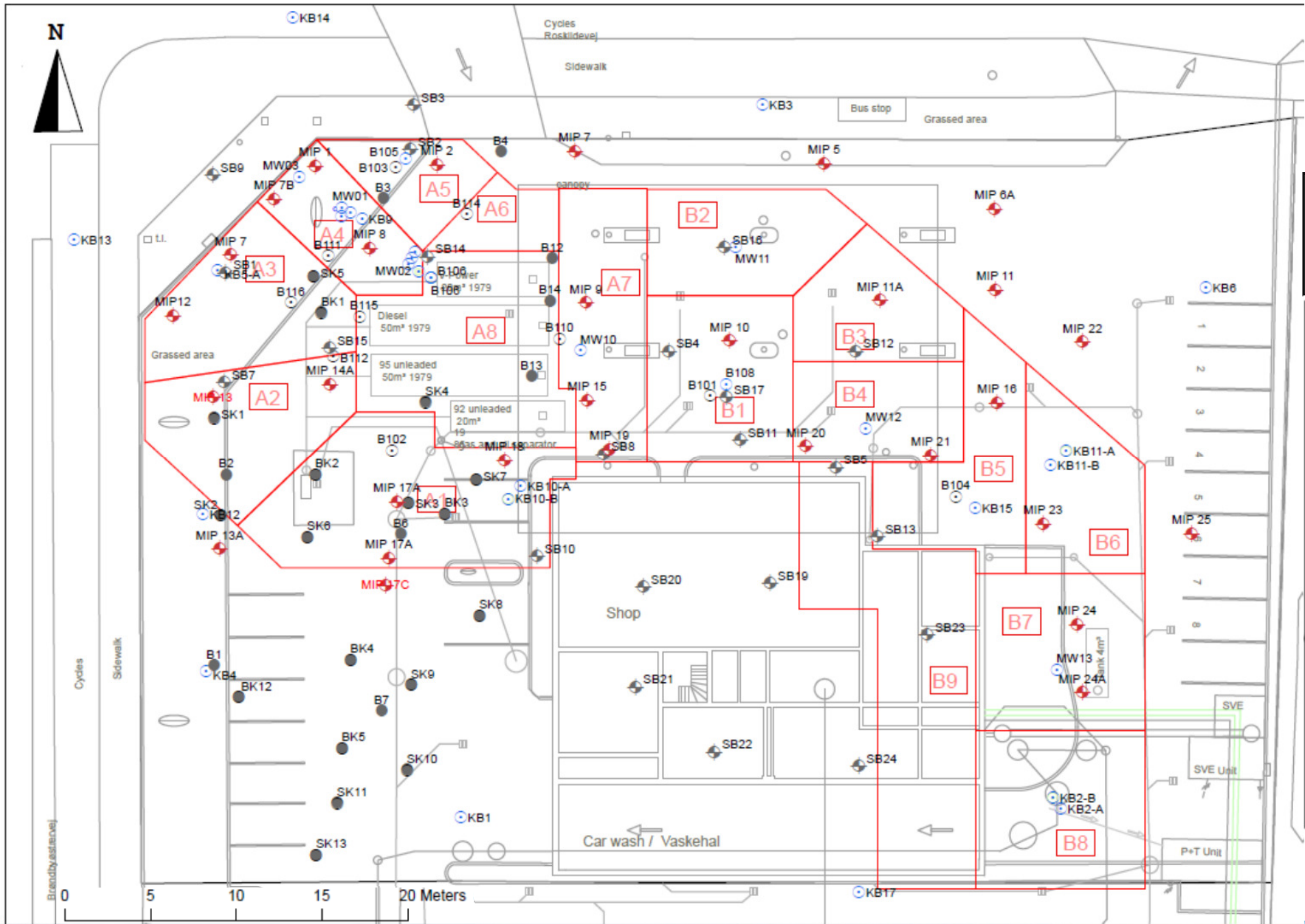
Site Historical Investigation Locations Map



Legend

- MIP investigation point
- KB01/B10x/MW01 Groundwater monitoring well: active
- B101 Former well: decommissioned (COWI 2003)
- B1 Soil boring
- SB1 Soil boring + SVE well/Boring (6 - 8 m)
- Investigation subarea

Conceptual Site Model (CSM) - 2011

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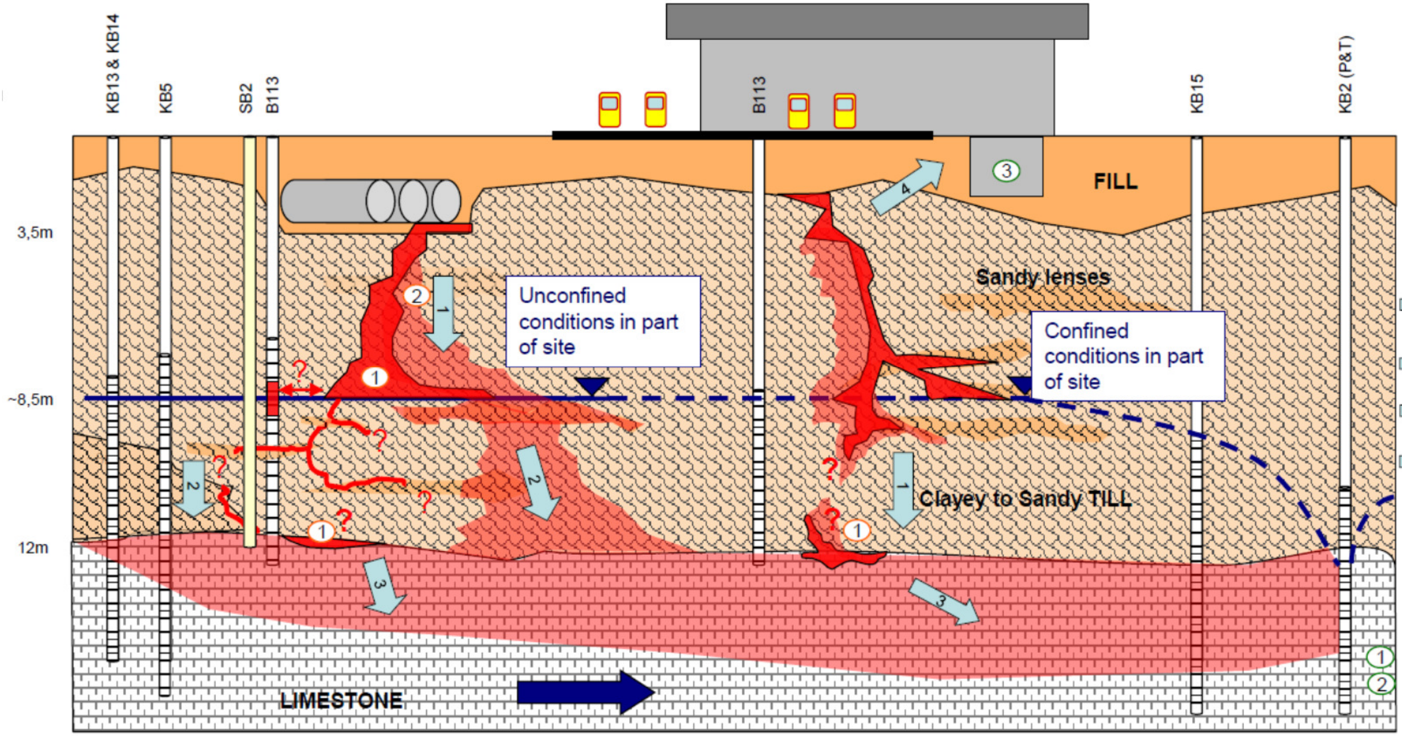


Potential Sources

1. LNAPL within the unsaturated soil matrix, preferential pathways of saturated till, and potentially trapped in limestone aquifer.
2. Residual soil contamination within unsaturated soil matrix.

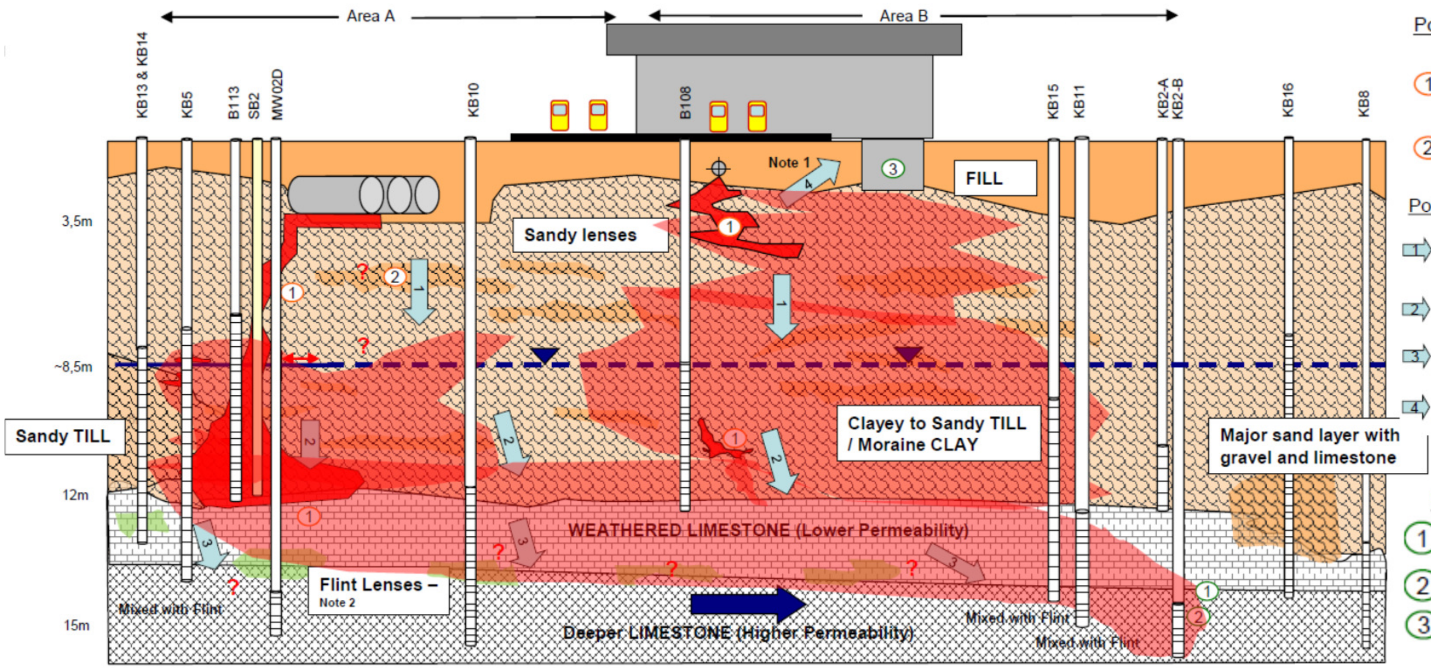
Potential Migration & Exposure Pathways

1. Vertical migration of LNAPL and dissolved contaminants (leaching) towards saturated till (unconfined) and limestone aquifer (confined conditions)
2. Transport of contaminant mass (LNAPL or dissolved) through the saturated till via preferential pathways
3. Dissolution of contaminants that may have entered and remained trapped in the limestone
4. Migration of contaminated soil vapors towards the building basement

Potential Receptors

1. Consumers of drinking water abstracted 800 m south east of the site.
2. Groundwater resource.
3. Occupants of building basement on site

Conceptual Site Model (CSM) - 2012



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Potential Receptors

1. Consumers of drinking water abstracted 800 m south east of the site.
2. Groundwater resource.
3. Occupants of building basement on site

Note 1 – VI pathway to be removed based on soil gas sampling April 2012

Note 2 – Flint understood to be found in lenses of various thickness across the area

Conceptual Site Model (CSM) - 2014

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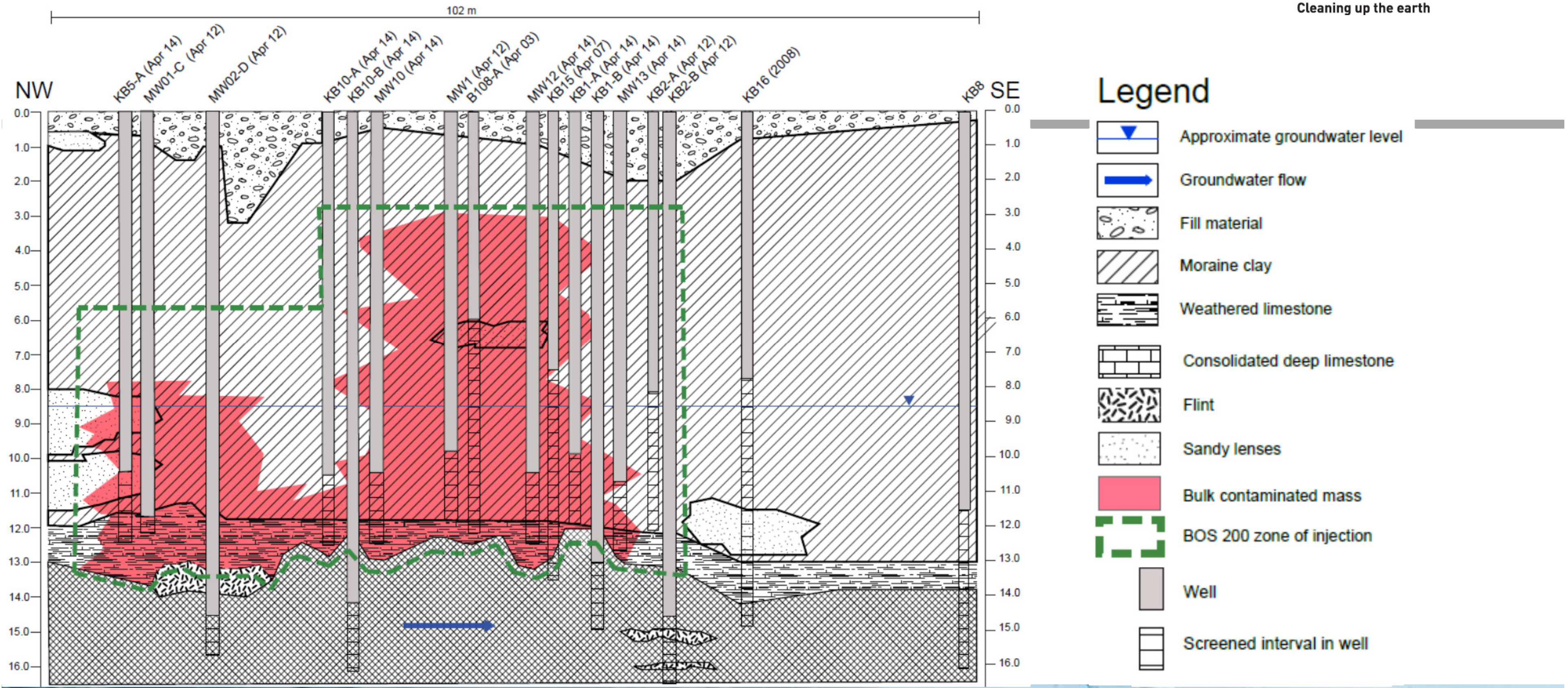

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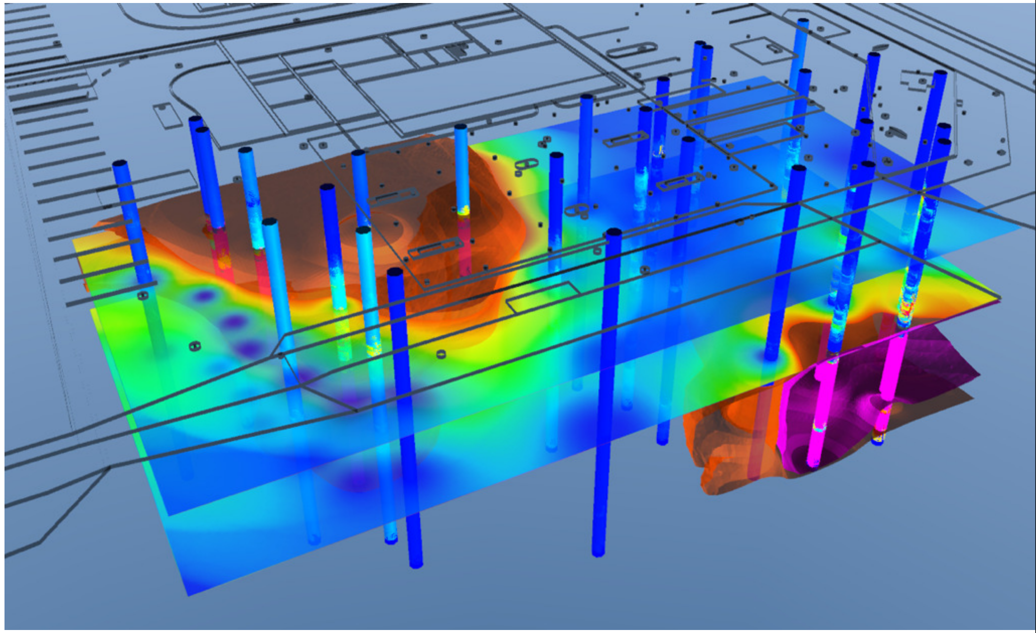
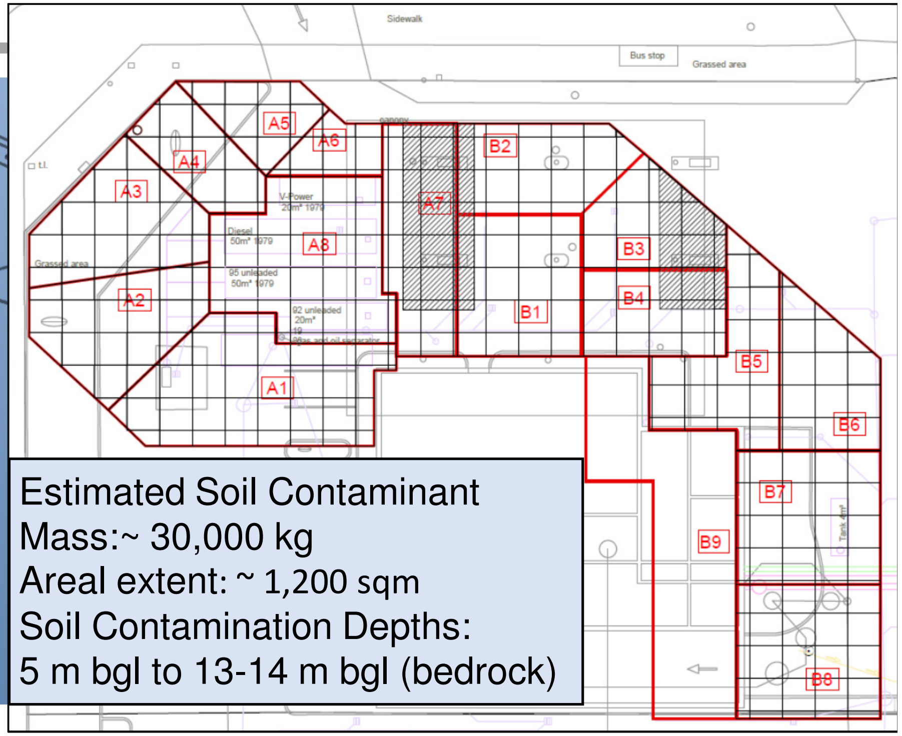
Remedial Design and Remediation Layout Map





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

RDC – Case Studies (3)

Former Industrial Facility (Sweden)

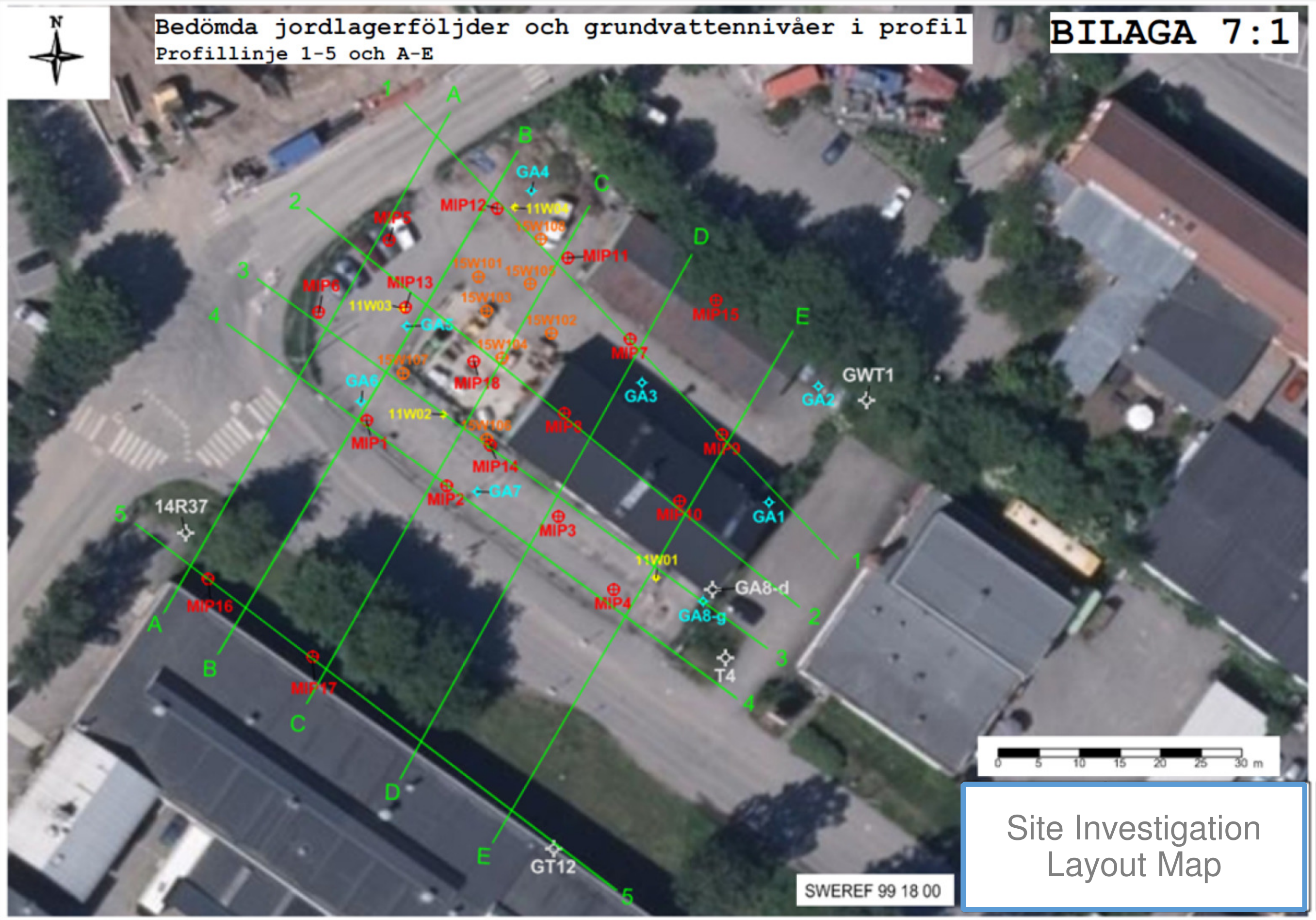
Site Background Information

The site was a former industrial dry cleaning facility located south of Stockholm.

After demolition, the site has been redeveloped to become a residential complex.

A MIP investigation was carried out on site and soil samples collected to depths of 3 m bgl (vadose zone). A series of monitoring wells were installed.

Overburden down to 3 – 3.5 m bgl was removed as part of initial phase of remediation works



Site Investigation Layout Map

MIP Investigation in this case not sided by validation soil samples to same depths of MIP points.

Soil data available to conduct remediation from 3 m bgl to bedrock not available

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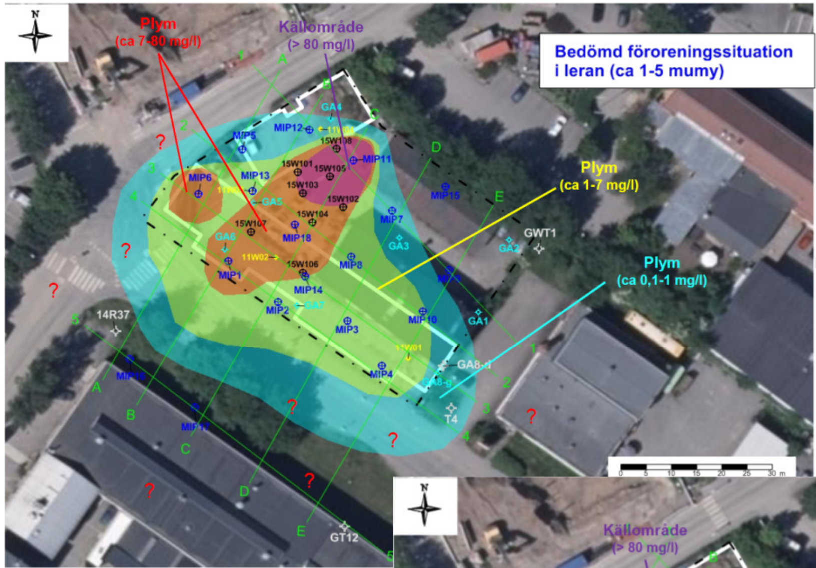
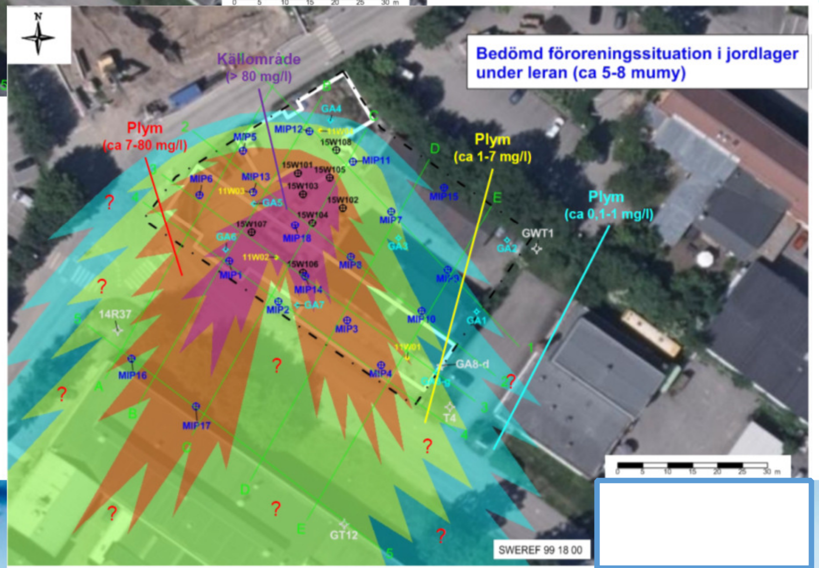
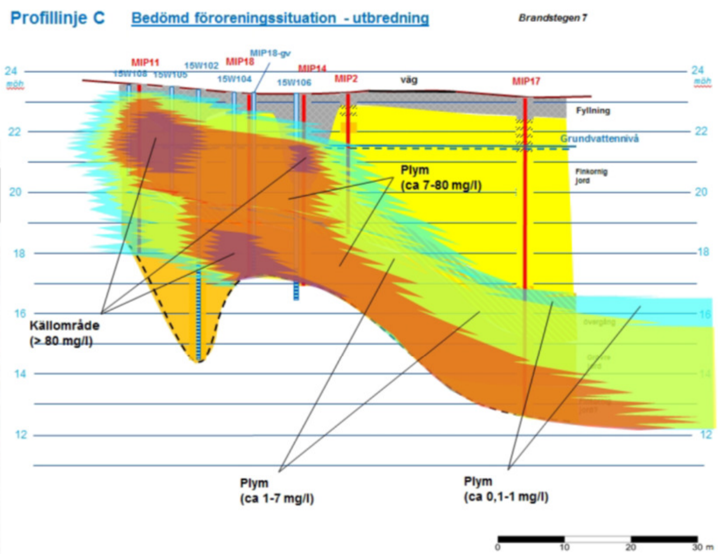
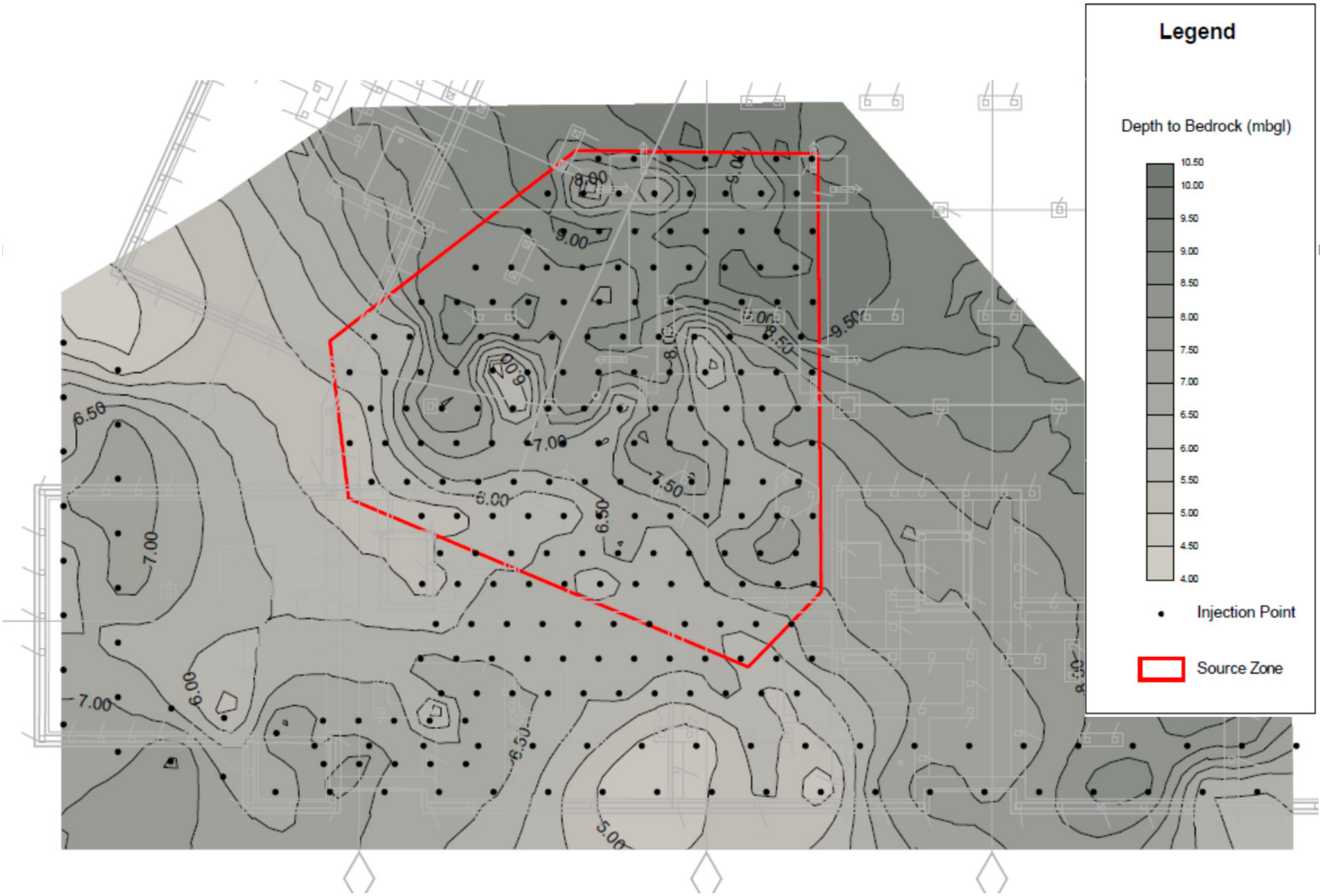
Estimated Contamination Plume









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Remediation Injection Completion Map

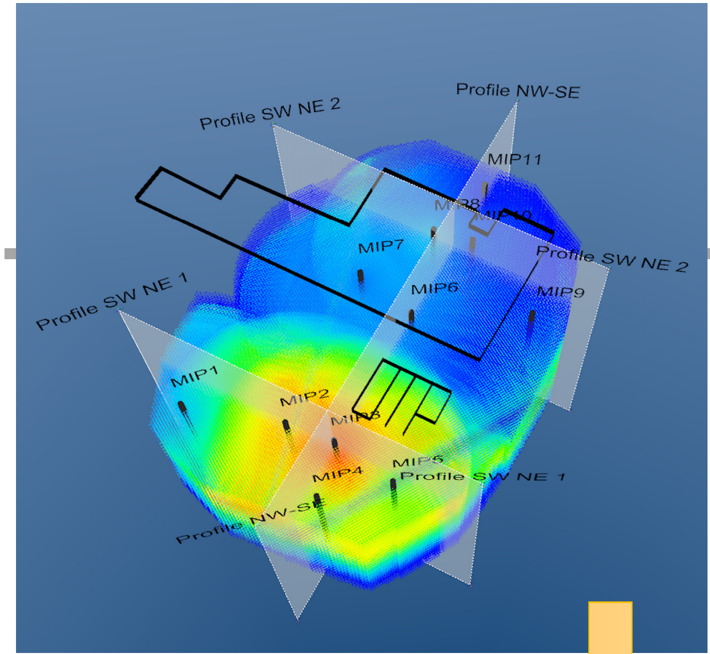
Remediation works were planned within 2 weeks and influenced by construction site activities schedule.

No detailed RDC was performed, hence leading to high level of contingency needed to reach clean up levels required by client.

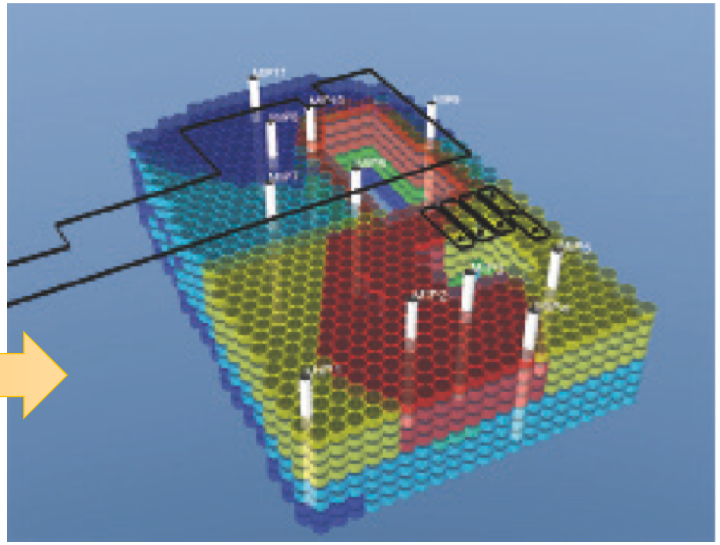
Injection treatment performed from 3.5 m bgl to bedrock.

Remedial Design Characterization

On-Going Developments



Ejlskov 3D Studio



Ejlskov 3D Studio is on a ”continuous” development process.

The software is a support tool for project managers in assessing and visualizing the contamination dynamics on site. As Ejlskov learns more from each RDC so does the software and its way of interpolating the data.

Remedial Design Characterization

Conclusions

RDC as a Remedation Tool - Why

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- Added value for long term project planning and budgeting
  - High frequency sampling ⟹ more defined and specific Conceptual Site Model
  - More specific Conceptual Site Model ⟹ more accurate remediation budget
  - More accurate remediation budget ⟹ better defined overall project costs and lifetime

- High frequency sampling advantages
  - Lead to more accurate Risk Assessment ⟹ might rule out the case with no further action
  - Allows for accurate contaminant mass assessment (amount and distribution) ⟹ more accurate (regardless of type of remedial technology) remediation budget and lifetime

- RDC is generally 5-10-15% of total remediation costs
  - Ejlskov experience of RDC costs are <0.5 - 1€/m3 of investigated soil

Insitu Site Remediation -Trap & Treat® concept

Trap&Treat® and Injection Method

BOS100® - Degradation of Chlorinated Solvents

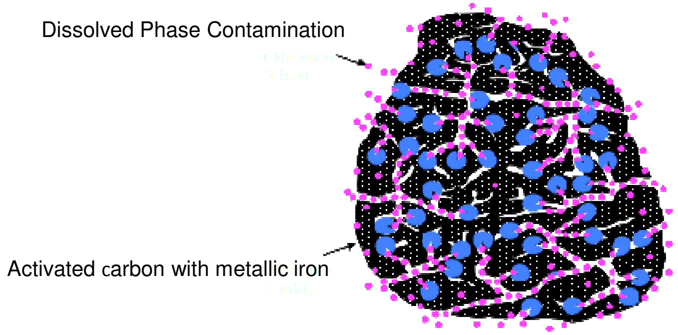
Catalyst that traps and treats through reductive dechlorination.

Specially manufactured activated carbon impregnated with elemental iron.

Substantial surface area offered by impregnated iron, BOS100®-
• 200 to 250 m2/gram compared to ZVI nano-iron powder – 20 to 40 m2/gram

Concentration of sorbed chloroethanes and substantial surface area results in rapid rates of dechlorination.

Completely non-toxic, contributing only low levels of chloride and iron to the groundwater.
Effectively controls generation of toxic daughter products, protecting groundwater throughout the treatment.



CAT100™ - Biodegradation of Chlorinated Solvents

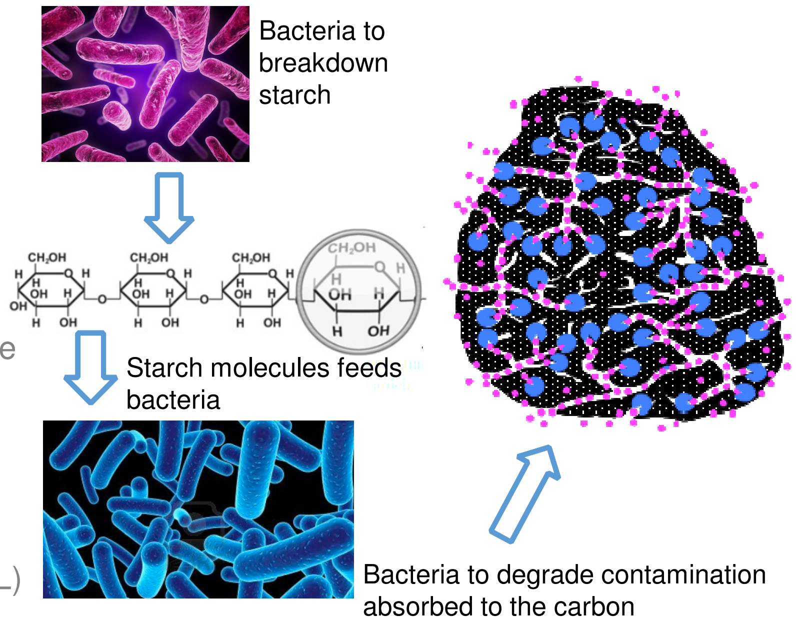
CAT100™ is a fusion of BOS100® and enhanced reductive dechlorination (ERD) to produce a technology capable of achieving results beyond the capabilities of either one alone.

Electron transfer, the heart of all contaminant degradation processes, is promoted as the contaminant binds to the metal creating an electrical connection extending throughout the carbon.

An electron pump created by slow degradation of complex carbohydrates and peptides feeds electrons to the conductor which shuttles them to the site of depletion.

In this process the metallic iron facilitates catalytic degradation of the contaminant without significant depletion of the iron.

HIGHLY EFFICIENT ON DENSE NON AQUEOUS PHASE LIQUID (DNAPL)



BOS 200®

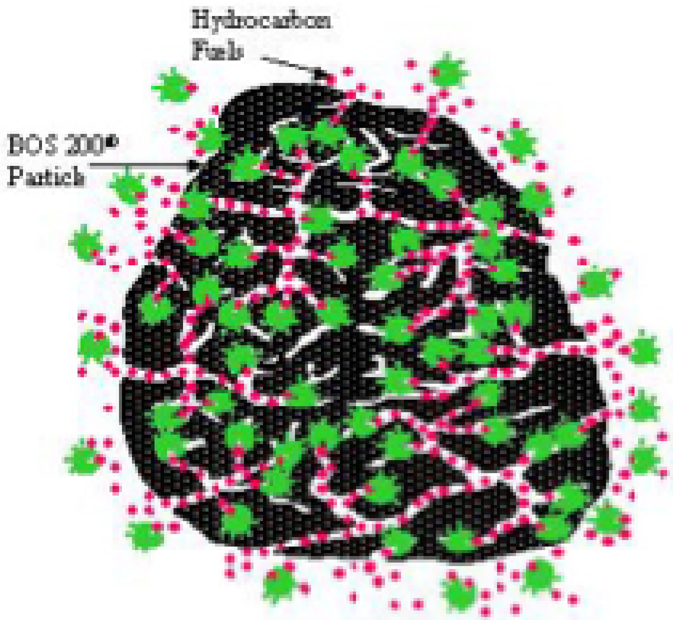
Trap & Treat® - Biodegradation of Hydrocarbons

A Carbon/Biological Based Product consisting of;

Activated Carbon Powder mixed with
- Calcium Sulfate
- Nitrate
- Phosphate
- Ammonia

Two primary treatment mechanisms take place with BOS 200®:

- First mechanism is the **“Trap”:** BOS 200® uses activated carbon to adsorb petroleum hydrocarbons.
- Biodegradation, the **“Treatment”**, is the second mechanism of BOS 200® remediation



BOS200® Key Features

- Trap&Treat® function achieved with one product
- Blend of specific bugs meant to destroy/degrade hydrocarbons present within ”reactive carbon bed” into the subsurface
- Mixing of activated carbon with fresh water and oxygen rich atmosphere guarantees the carriage into the subsurface of high quantities of dissolved oxygen
- More flexibility in targeting low or high contaminated layers and possibility to work with slurry concentrations accordingly
- Highly effective in treating LNAPL

Injection of suspended material

- Through existing wells (never recommended)
  - Very limited distribution in the contaminated zone
  - Will not address the low permeable soils/residual contaminations
  - Leading to failure
- **Through injection probes top down through hydraulic hoses**
  - **No loss of product through joints in rods**
  - **Always delivered to the injection tips**

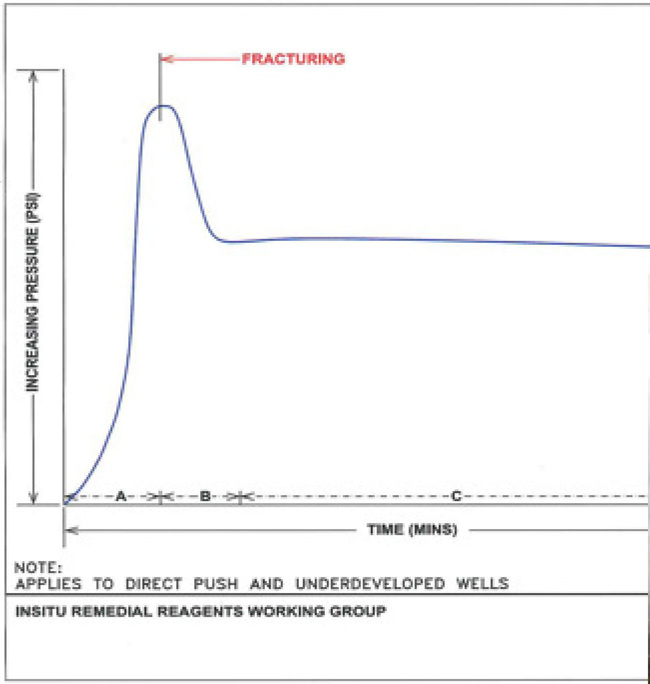
Never

Always

Installation / Injection Key Features

- Pressure, Flow, Exit Velocity
- Injection Volumes
- Distribution
- Sand vs. Clay Formations

Injection into Clays/Silts and fine sands

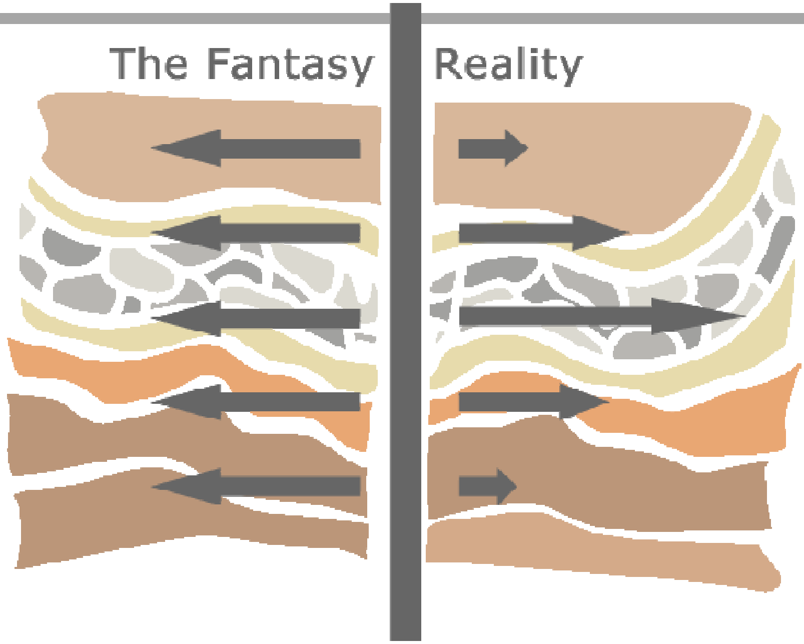


Low Flow, Low Pressure Injection

Why its not a good idea to do

Uniform Distribution

No Fracturing
ROI=f(pv,tv)



Flow follows path of least resistance

No control over injectate location

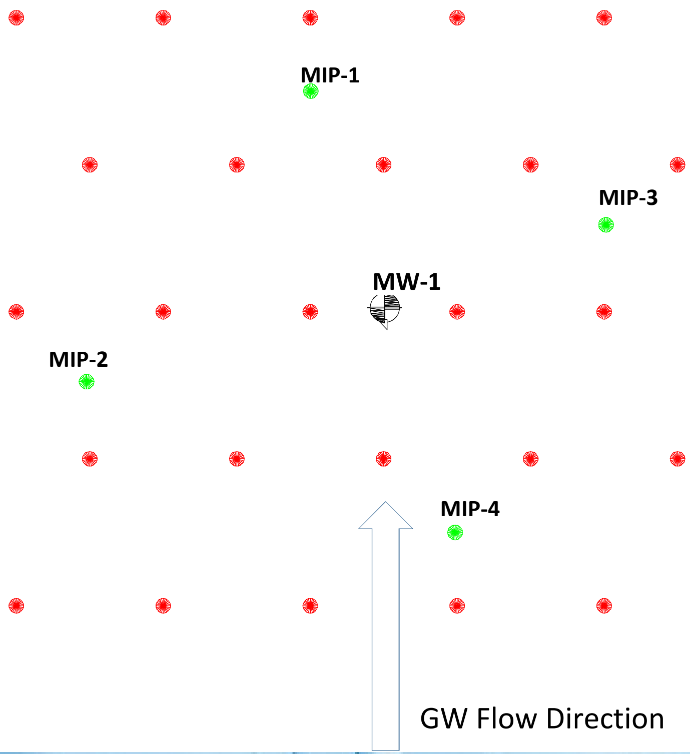
Very poor distribution likely

ROI Unknown

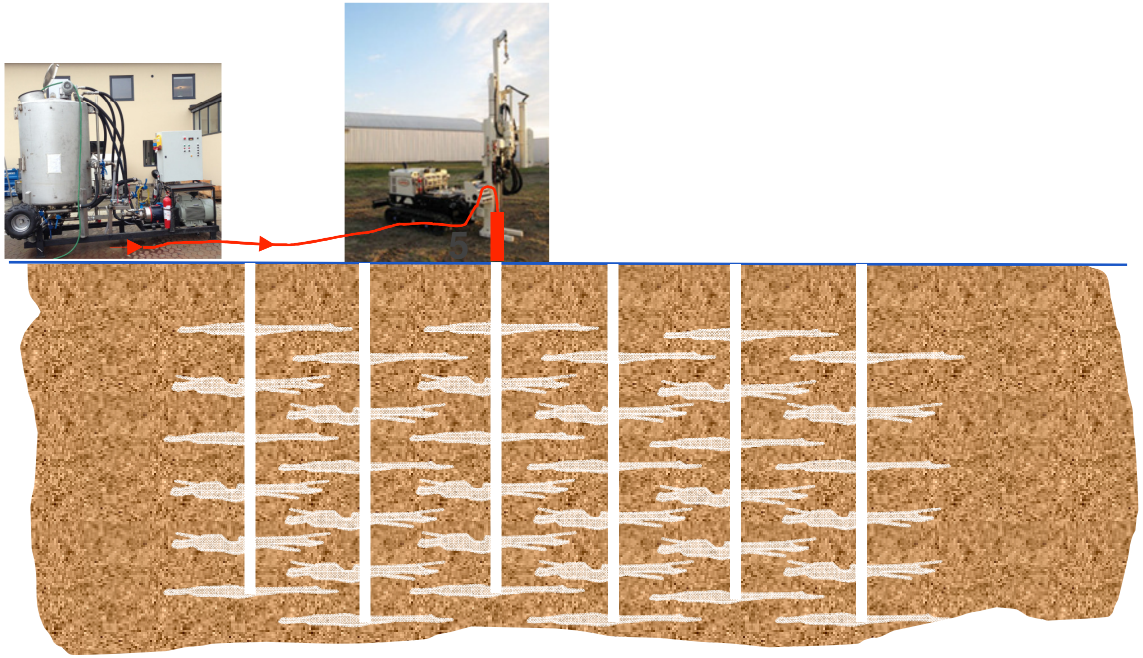
No uniform distribution

Grid Based Design

- Use triangular grid pattern
- Spacing is a function of the depth and lithology
- Spacing is tight (relative to other technologies e.g. ISCO) and ranges from 1.5 to 2.3m for most sites



Injection concept 2D



Mixing of BOS products slurry on site

Top down injections - one for every 0,5 meter

Injections (system) pressure up to 90 bar (1200 psi)

Pressure leads to soil separation - hydraulic fracking

Injection Hoses – no loss of product in rod joints

Remedial Design Characterization

Question Time


Kiitos!
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