Demonstrating Nanoremediation in the Field
- The NanoRem Test Sites -

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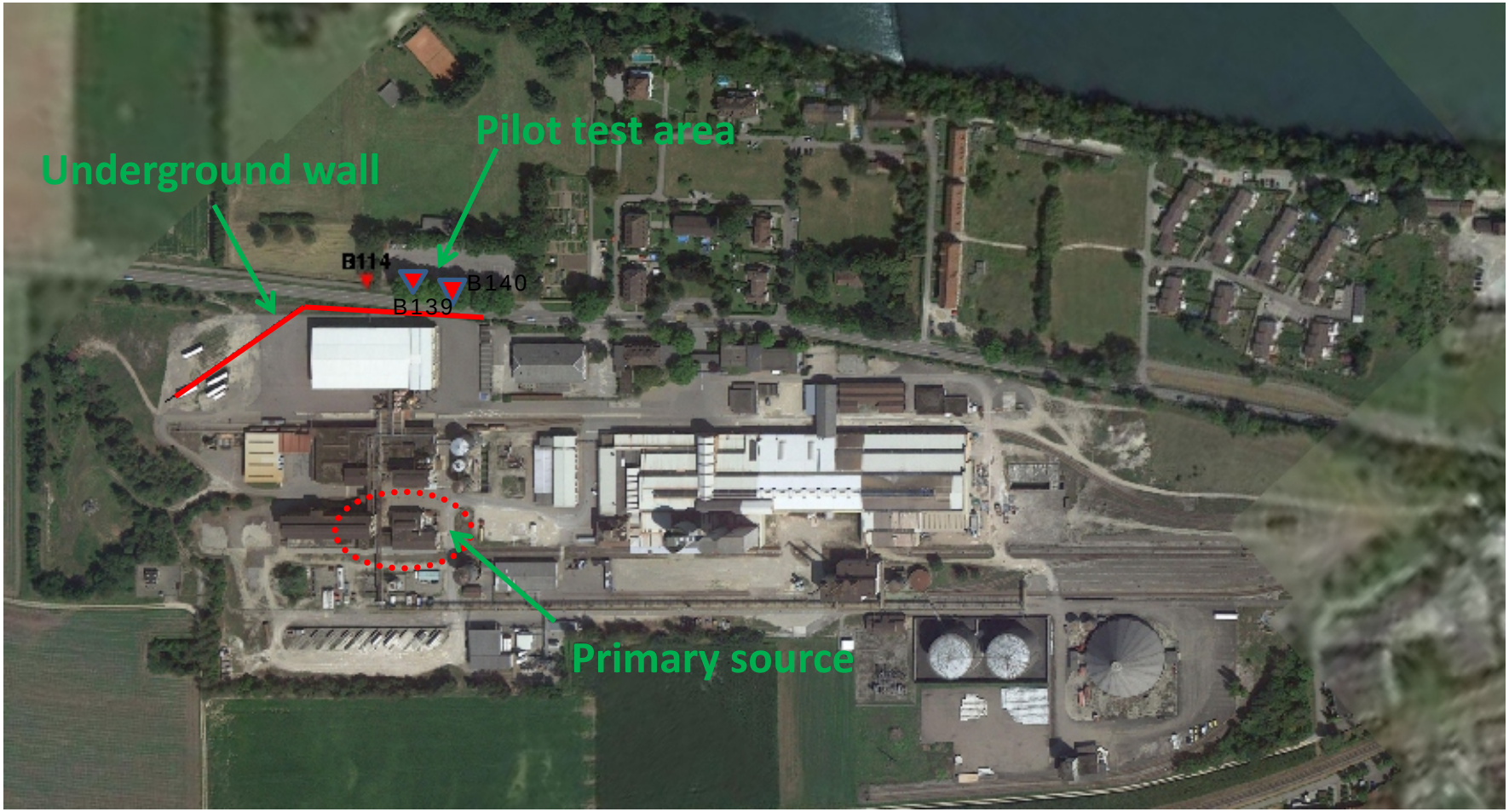
Objectives of NanoRem Field Sites

- Testing of emerging NP applications.
- Optimisation of NPs and tools.
- Determination of degradation products at field conditions.
- Application of appropriate injection technologies for varying hydrogeology.
- Alleviation of the current lack of validated field scale performance data for end-users and regulators.

NanoRem Pilot Sites

Site	Country	Site Primary Investigator (SPI)	Target Cont.	NP-Type (Producer)	Reaction Principle	Aquifer
Zurzach	CH	**Solvay (Schweiz) AG**	CHC	nZVI, milled (UVR-FIA)	Reduction/ Sorption	Layered alluvial
Spolchemie 1	CZ	**Aquatest**	CHC	nZVI, stabilized (NANOIRON)	Reduction	alluvial
Spolchemie 2	CZ	**Aquatest**	BTEX	Iron-Oxide (HMGU / UDE)	Oxidation/ microb. Enhancement	alluvial
Barreiro	PO	**GeoPlano**	HM	nZVI, tbd (NANOIRON)	Immobilisation	alluvial
Bizkaia	ES	**Tecnalia**	HM	nZVI, tbd (NANOIRON)	Reduction/ Immobilisation	alluvial
Besor-Secher	IS	**Negev, BGU**	CHC	Carbo-Iron® (SciDre)	Reduction	fractured
Balassagyarmat	H	**Golder**	CHC	Carbo-Iron® (SciDre)	Reduction	coarse alpine

Zurzach, Switzerland



Zurzach, Conceptual Site Model

Treatment of the secondary source with FerMEG 12 (milled nZVI). Five new injection well and three monitoring wells installed within the NanoRem test area

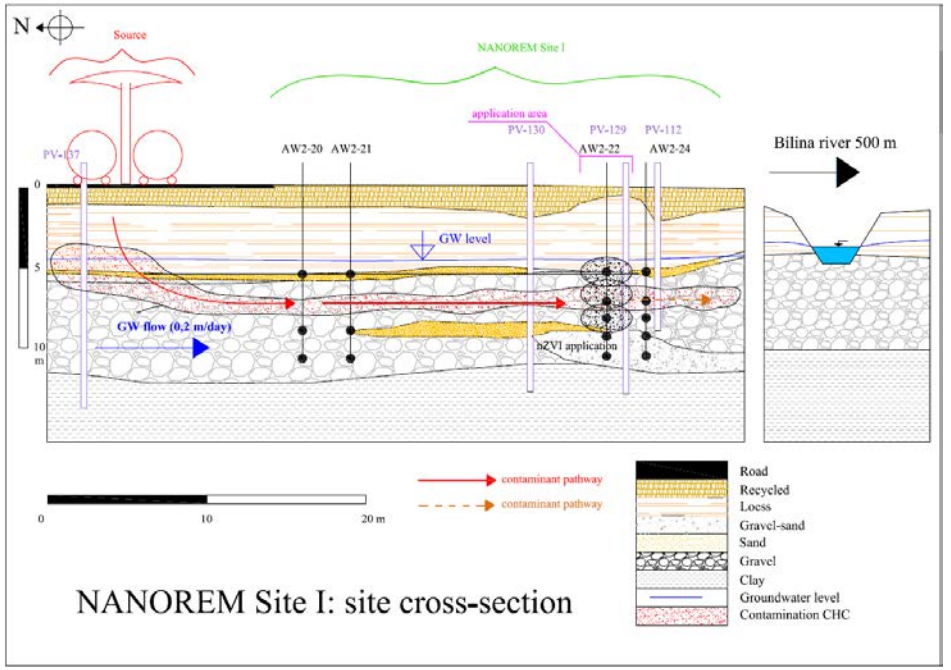
Zurzach, Status

- Conceptual Site Model Available ✓
- Permit Available ✓
- Monitoring Strategy Completed ✓
- Monitoring Installed ✓
- Injection of NP ✓
- Longterm Performance Monitoring) (✓)
- Report / CL:AIRE-NanoRem Bulletin ☒

Spolchemie DNAPL, CZ

Spolchemie DNAPL Conceptual Site Model

- Area 10 x 20-30 m, Groundwater table 4-5 m below surface
- Aquifer, quarternary, sand, gravel, 6-7 m thickness
- Source: production, storage and distribution of DNAPL (PCE, PCM); bounded by Permeable Reactive Barrier
- Groundwater flow velocity ca 0,2 m/d (behind the wall)
- Outside PRB, DNAPL is far from the site
- Dissolved plume, spreading by the groundwater
- Residual phase unlikely, no pools
- Back diffusion unlikely
- Bílina river is the final receptor

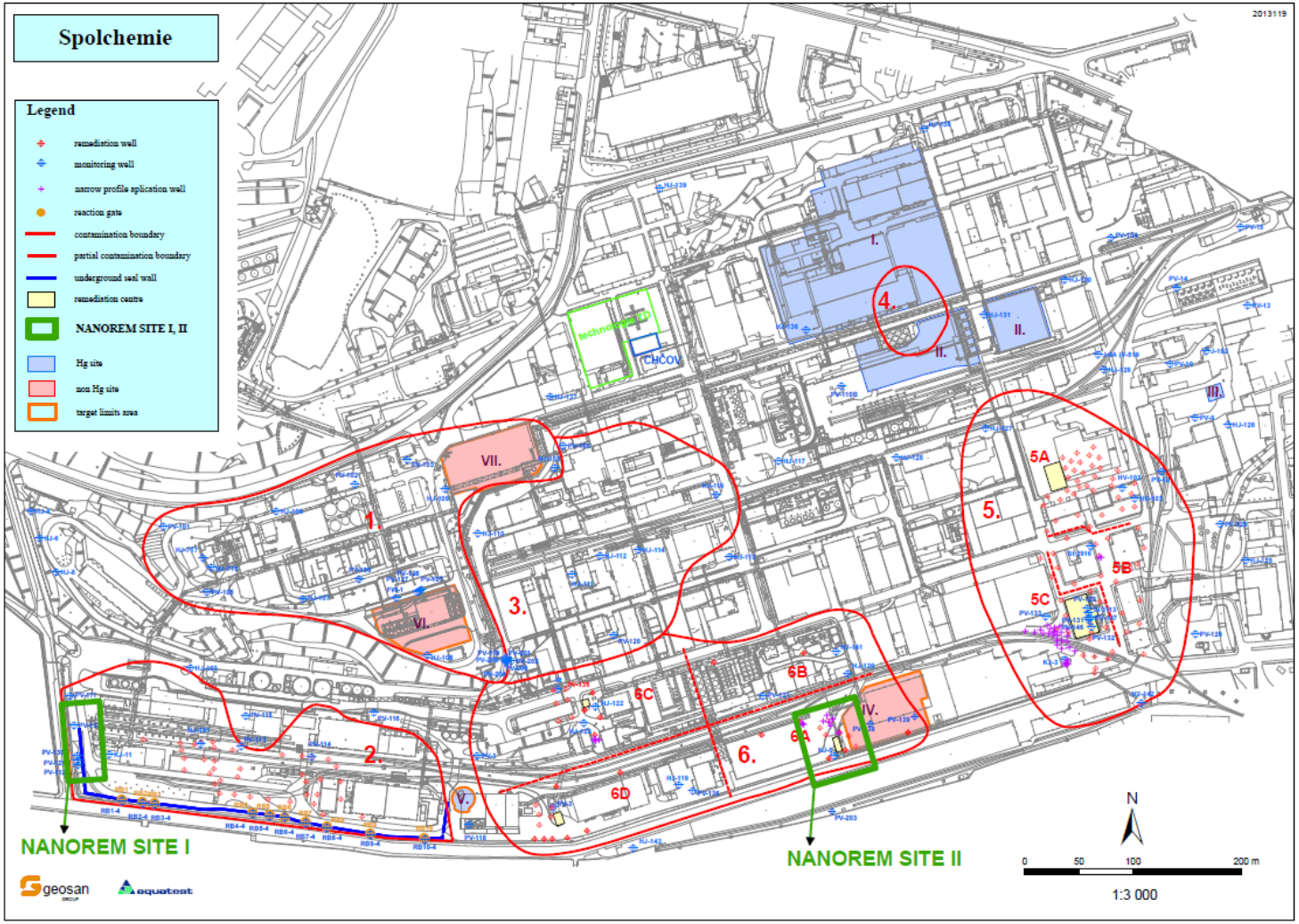


NANOREM Site I: site cross-section

Spolchemie DNAPL, Status

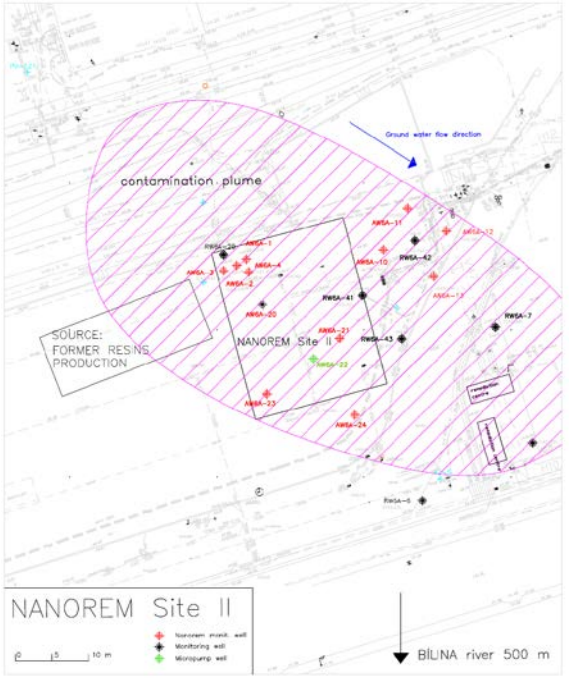
- Conceptual Site Model Available ✓
- Permit Available ✓
- Monitoring Strategy Completed ✓
- Monitoring Installed ✓
- 1st Injection of NP ✓
- 2nd Injection of NP ☒
- Longterm Performance Monitoring ✓
- Report / CL:AIRE-NanoRem Bulletin ☒

Spolchemie LNAPL, CZ



Spolchemie LNAPL Conceptual Site Model

- Area 20 x 20-30m
- Groundwater table 4-5 m below surface
- Aquifer, quarternary, sand, gravel
- Groundwater flow velocity ca 0,9 m/d
- 6-7 m thickness
- main contaminants BTEX
- former production of synthetic resins (burned out) and storage tanks in northwest from the site
- Free phase, residual phase and dissolved contamination in highly mobile layer of aquifer



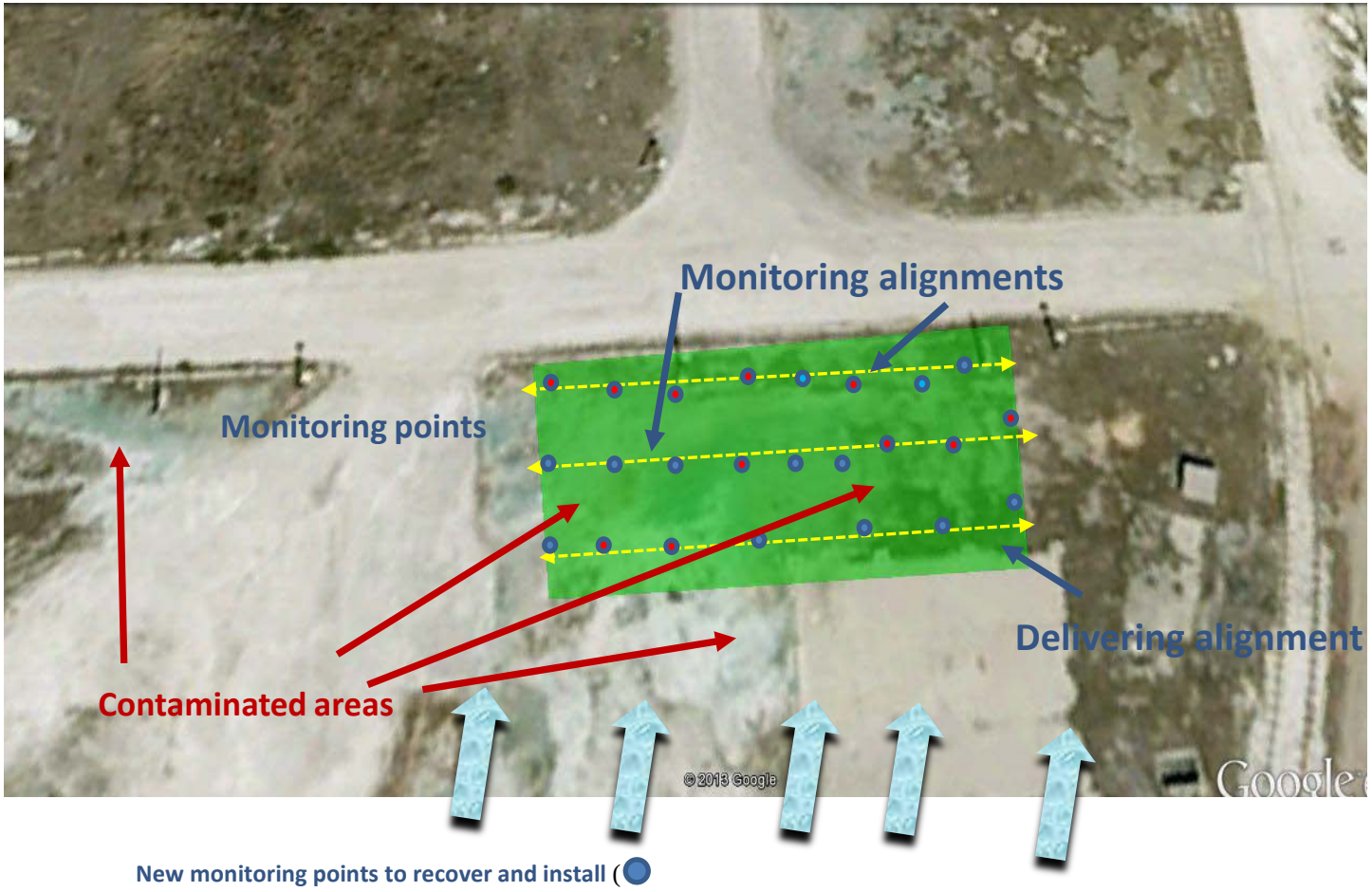
Spolchemie LNAPL, Status

- Pilot Area Selected ✓
- Conceptual Site Model Available ✓
- Permit Available ✓
- Monitoring Strategy Completed ✓
- Monitoring Installed ☒
- 1st Injection of NP ✓
- 2nd Injection of NP ☒
- Longterm Performance Monitoring ☒
- Report / CL:AIRE-NanoRem Bulletin ☒

Barreiro, Portugal

- Old 340ha industrial area which is now being dismantled
- The owner is a semi public institution
- Different types of contaminants
- Study area is contaminated by heavy metal, sulphates, nitrates
- Semi confined aquifer
- Sedimentary formations, composed by layers of sands, silts and clays

Barreiro – Remediation Concept

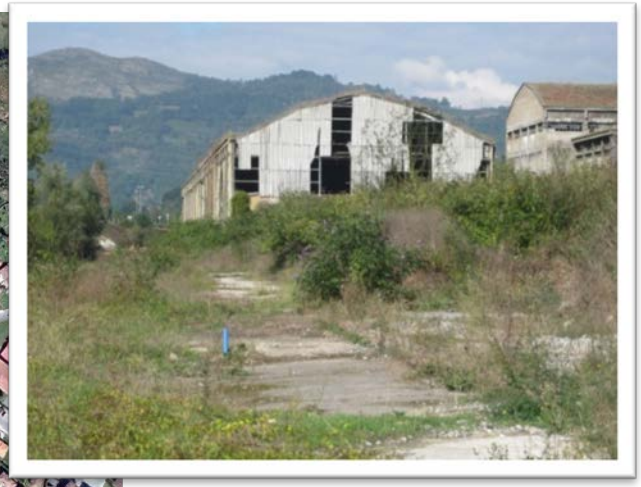


- Remediation by creating an active barrier composed by several piezometer where the NP's will be delivered
- Total quantity will be delivered into the different upstream Pz pipes (manually or automatically)

Barreiro, Status

- Conceptual Site Model Available ✓
- Permit Available ✓
- Monitoring Strategy Completed ☒/✓
- Monitoring Installed ☒/✓
- Injection of NP ☒
- Longterm Performance Monitoring ☒
- Report / CL:AIRE-NanoRem Bulletin ☒

Nitrastur, Spain



SITE INVESTIGATIONS PERFORMED TO DATE:

- Date unknown: **14 boreholes** (P1- P14), all fitted (currently 7 operative).
- 2009 DEC: **109 trial pits, 20 boreholes** (S01 – S20), all fitted (currently 12 operative), 316 soil samples, 20 groundwater samples, analysis: heavy metals and TPHs.
- 2011 AITEMIN: **1 borehole** (N-1), pumping tests, hydrogeological model outlined.
- 2013 UNIOVI: currently using as demo site for other R&D project **(Life+ 2012-2015)**, portable XRF screening, 5 soil samples, 12 groundwater samples from previous piezometers and 2 surface water samples → cooperation opportunity?

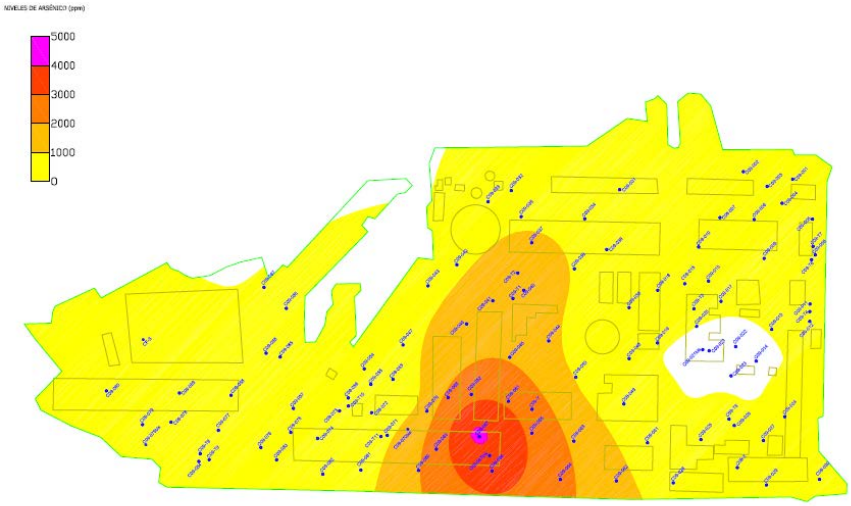
➔ **Good overall characterization (6 SP/1Ha)**

Nitrastur – Remediation Concept

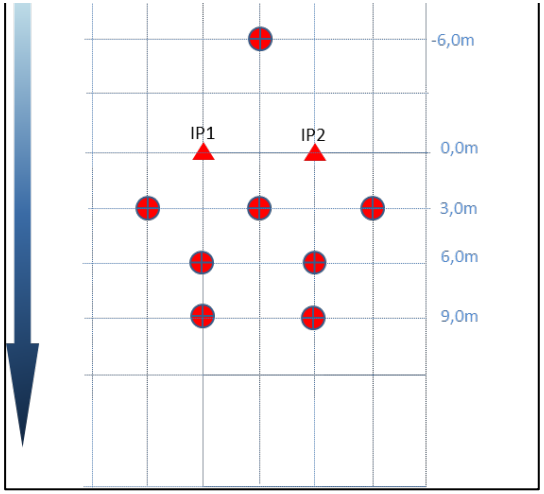
ARSENIC IN SITU NANOREMEDIATION IN GROUNDWATER

Goethite (from NanoIron or HMGU/UDE) and n**ZVI (Nanofer Star)** tested in laboratory by TULib:

- Concentration of solved arsenic decreases significantly in the treatments using both goethites;
- Concentration of dissolved As is also reduced when reacting with nZVI (NanoferStar).
  → more reactive than goethites, mobility issues still challenging



- Pilot test area: 12m x 15m, in flat, cleared area. Former NH3 zone.
- Nº monitoring wells: 8, Nº injection wells: 2 – 6 m spaced.
- **3 m** spaced* (1 upgradient, 7 downgradient). Down 1m into Shale (7 to 8 mbgl).
- Injection in open boreholes



Nitrastur, Status

- Conceptual Site Model Available ✓
- Permit Available ✓
- Monitoring Strategy Completed ✓
- Monitoring Installed ✓
- Injection of NP ☒
- Longterm Performance Monitoring ☒
- Report / CL:AIRE-NanoRem Bulletin ☒

Balassagyarmat, Hungary

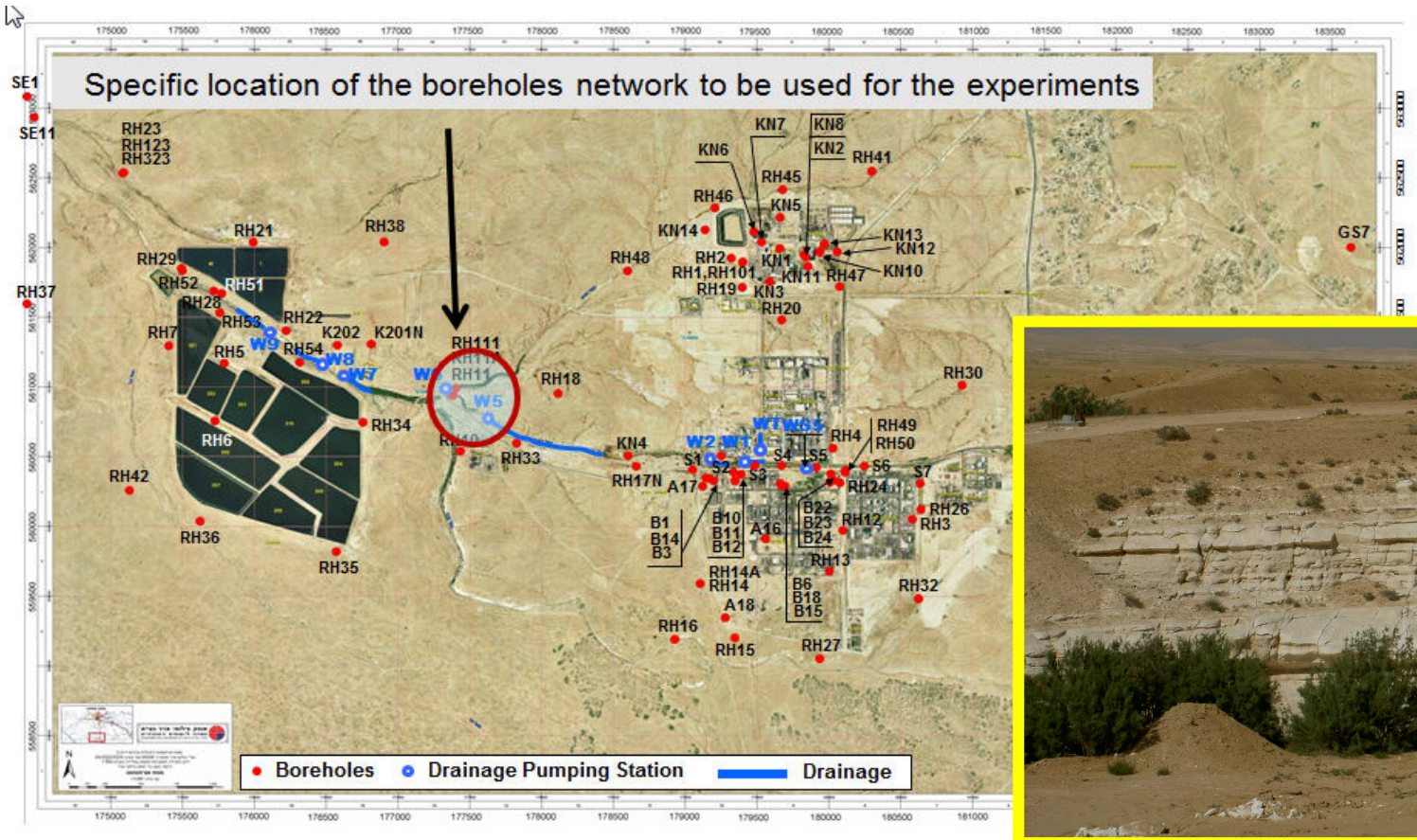
Balassagyarmat Conceptual Site Model

- 2005 site evaluation updated based on reference date measurement in 12/2013
- Determination of current hydraulic and hydrochemical site conditions: 9 wells suitable for sampling and hydraulics measurements
- Groundwater sampling and data logging of physico-chemical parameters (pH, temperature, conductivity, RedOx, Oxigen). Chemical characterization of ground-water at all wells (analysis of 66 organic and inorganic parameters each)
- Results: In general the in 2005 described hydraulic situation with a groundwater flow in NNW direction was confirmed, the current contamination spreading was outlined.
- Due to geology, hydrogeology and hydro-/geochemistry the Balassagyarmat site has been evaluated as useable for nano particle application

Balassagyarmat, Status

- Pilot Area Selected ✓
- Conceptual Site Model Available ✓
- Permit Available ✓
- DL 10.1 Report on Site Selection ✓
- Monitoring Strategy Completed ✓
- Monitoring Installed ☒ (✓)
- Injection of NP ☒
- Longterm Performance Monitoring ☒
- Report / CL:AIRE-NanoRem Bulletin ☒

Besor-Secher, Israel



Neot Hovav size is 23.7 km^2, of which 8km^2 are used and the rest is designated for future industrial factories.
Currently there are 21 factories and industrial facilities on site.

Annual precipitation ~180 mm

Besor-Secher
Conceptual Site Model

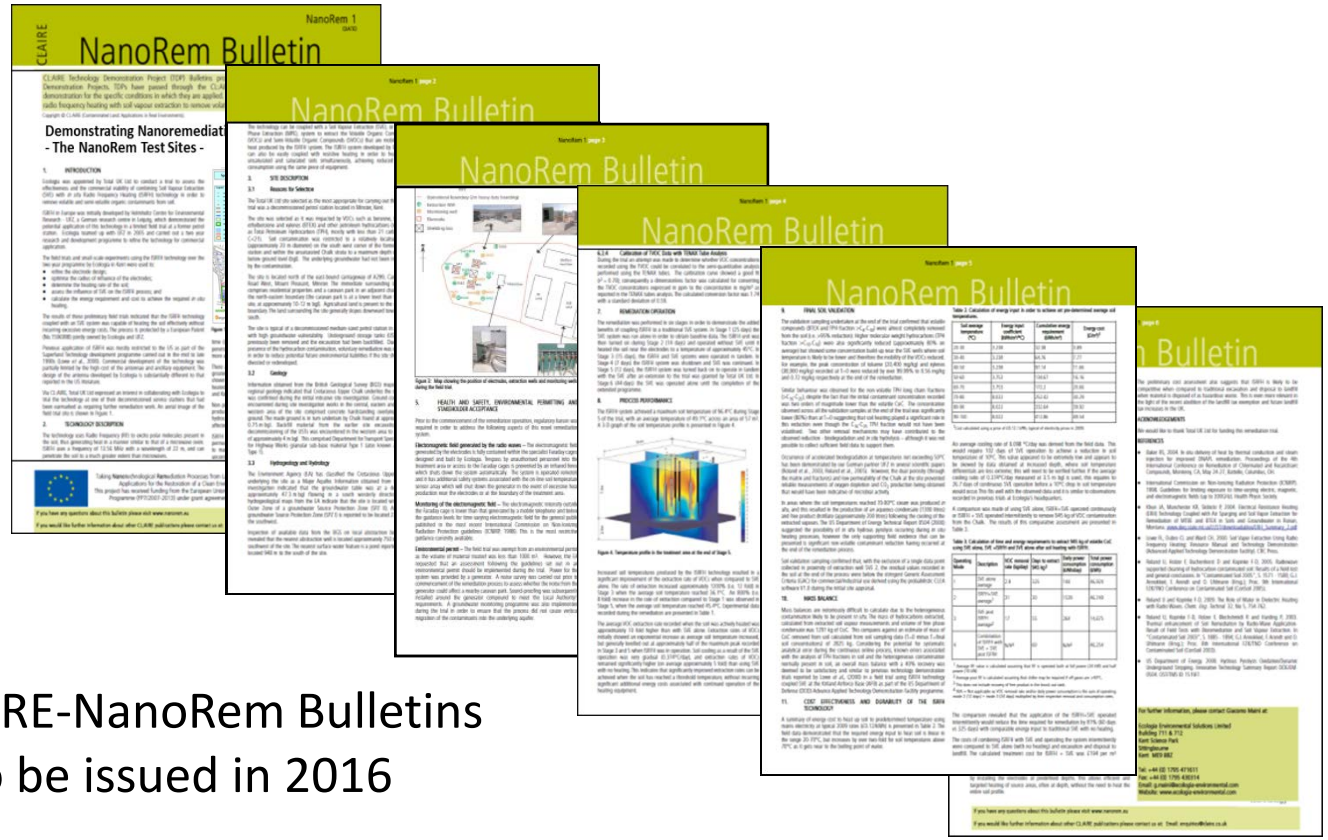
- Hydraulically active network of boreholes penetrating the fractured chalk aquifer.
- Tracer test done at the site 11 years ago showed very high recoveries.
- Previous work done in this pilot site can give us good estimation about hydraulic properties conceptual and numerical model available for the specific site.
- Focus in NanoRem is mainly on particles transport mechanism and potential utilizing the unique fractured hydraulically connected system at the site, on which many hydrological parameters are known.

Besor-Secher, Status

- Conceptual Site Model Available ✓
- Permit Available ✓
- Monitoring Strategy Completed ✓
- Monitoring Installed ✓
- Injection of NP ✓
- Longterm Performance Monitoring n.a.
- Report / CL:AIRE-NanoRem Bulletin ☒

More Information on NanoRem Sites

AQUACONSOIL Poster Session
→ Detailled info on each site



CL:AIRE-NanoRem Bulletins
→ To be issued in 2016

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