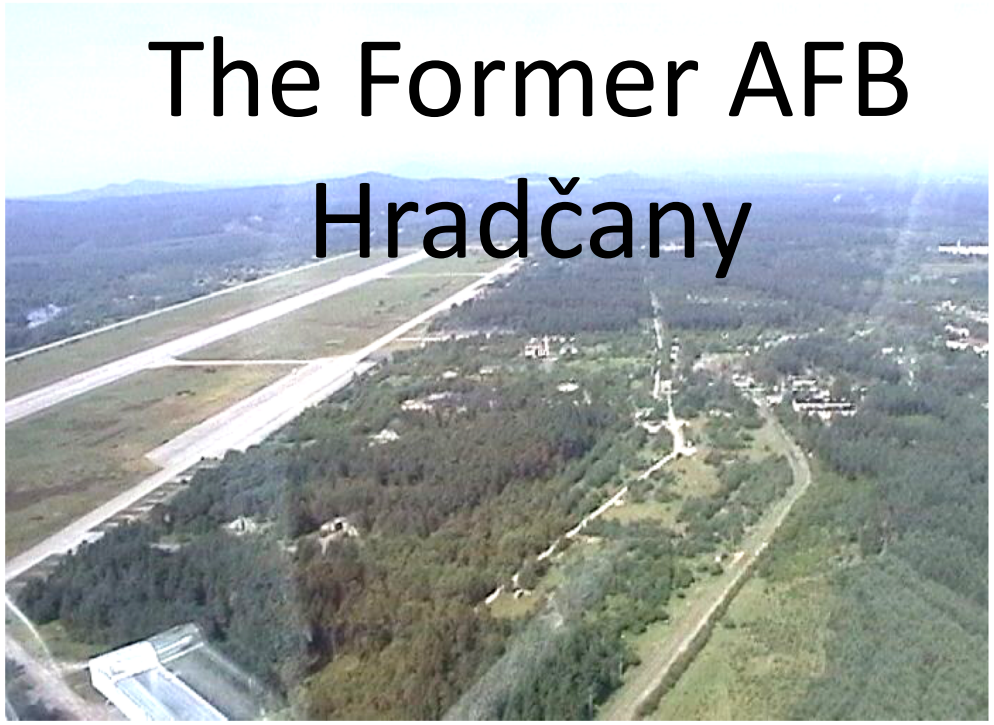
TECHNICAL UNIVERSITY OF LIBEREC
Centre for Nanomaterials, Advanced Technologies and Innovation

Major Natural and Technological Factors Affecting Efficiency of Bioremediation of Jet-Fuel in Sedimentary Bedrock

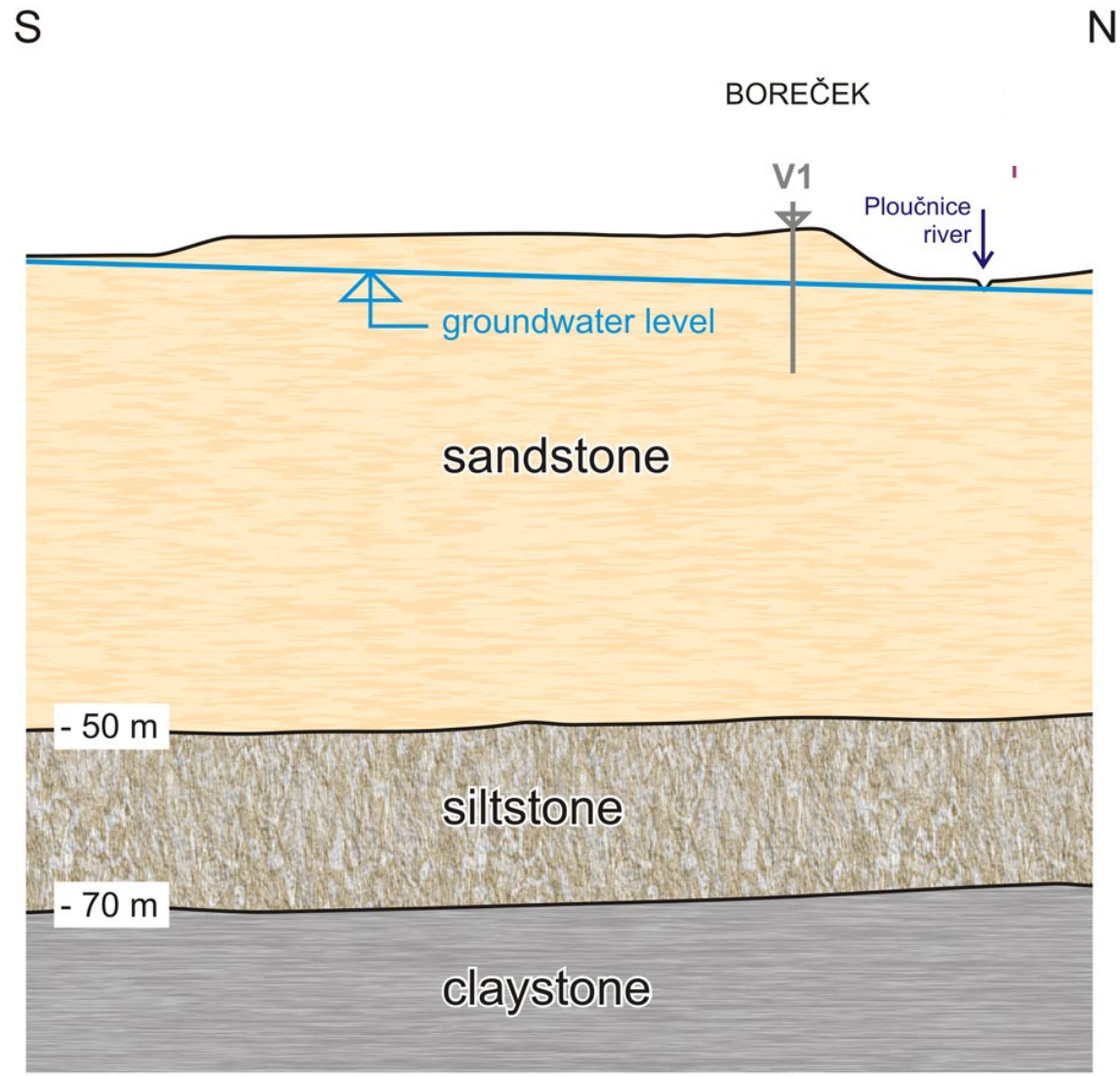
Jiřina Macháčková, Stanislava Prokšová, Ferdinand Herčík

The Former AFB Hradčany



- Site in the Northern Bohemia, Czech Republic
- Founded by Nazi in 1940, later operated by the Czechoslovak Army, from 1968 till 1991 by the Soviet Army
- The most western army airport of Warsaw Treaty (so-called Eastern Block) during the Cold War, intensively operated in eighties during the Cold War escalation

Site Geology



- Sedimentary complex of the Bohemian Cretaceous Basin
- Overlaid with Quaternary river terrace (2-5 m)
- GWL 4-10 m bgs
- The aquifer has been main and intensively used drinking water source in wide vicinity of the site

Clean-Up History I.

1986 - free oil phase started to seep from the river bank to the river, first sign of an environmental damage

1987 – 2002 hydraulic barrier operation in order to prevent contamination spreading to surface water

1991 – Soviet Army withdrawal from CZ

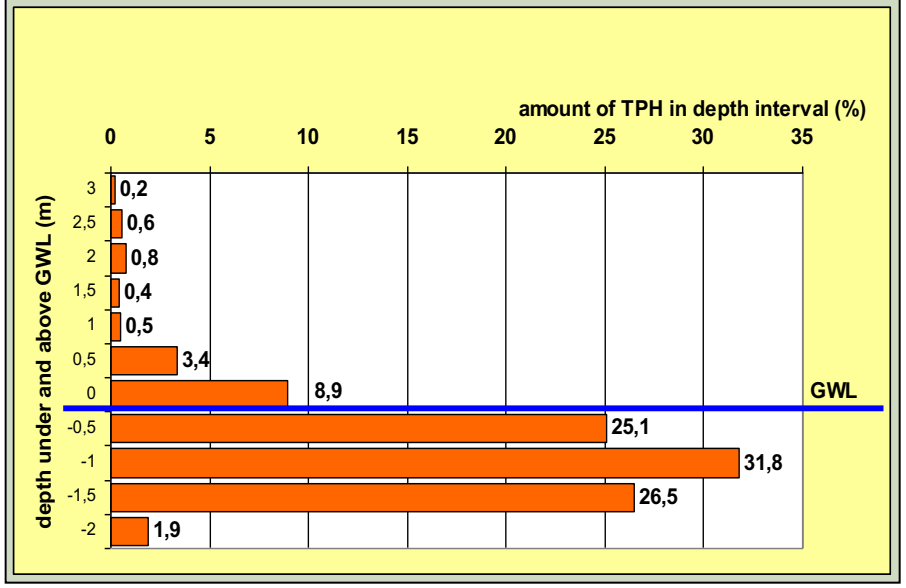
1991 – 1996 – first more detailed surveys of contamination extent and venting/bioventing testing

Clean-up History II.

- 1996 – risk assessment, setting of clean-up goals
  - TPH (IR) 5 000 mg/kg soil
  - TPH (IR) 5 mg/L GW, BTEX (GC) 1 mg/L GW,
  - detectable free oil phase absent on GWT
- 1997 – 2012 – full-scale clean-up
  - 1997 – 2008 – active operation of technology
  - 2009 – 2012 – site closure - rebound monitoring, evaluation of reaching of the goals, risk assessment of residual contamination

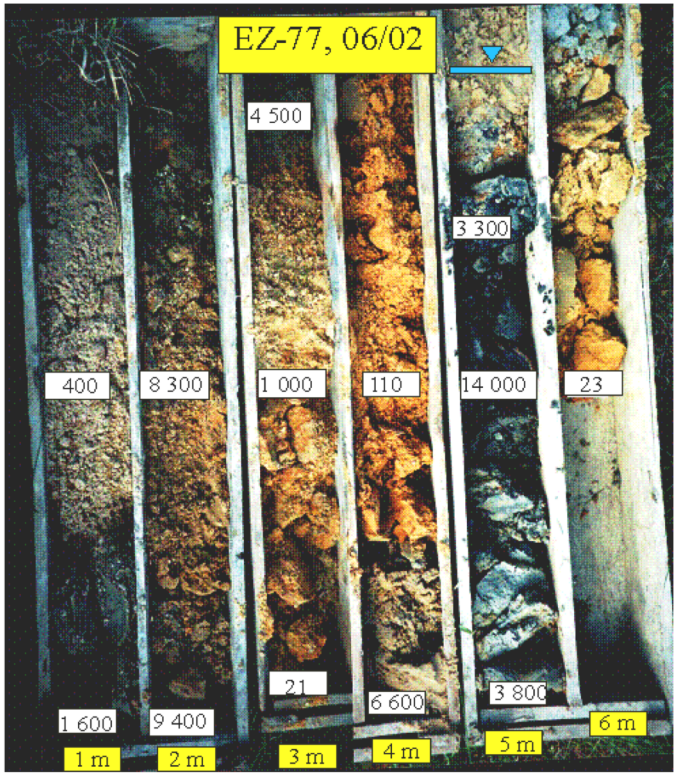
Contamination extent (2000)

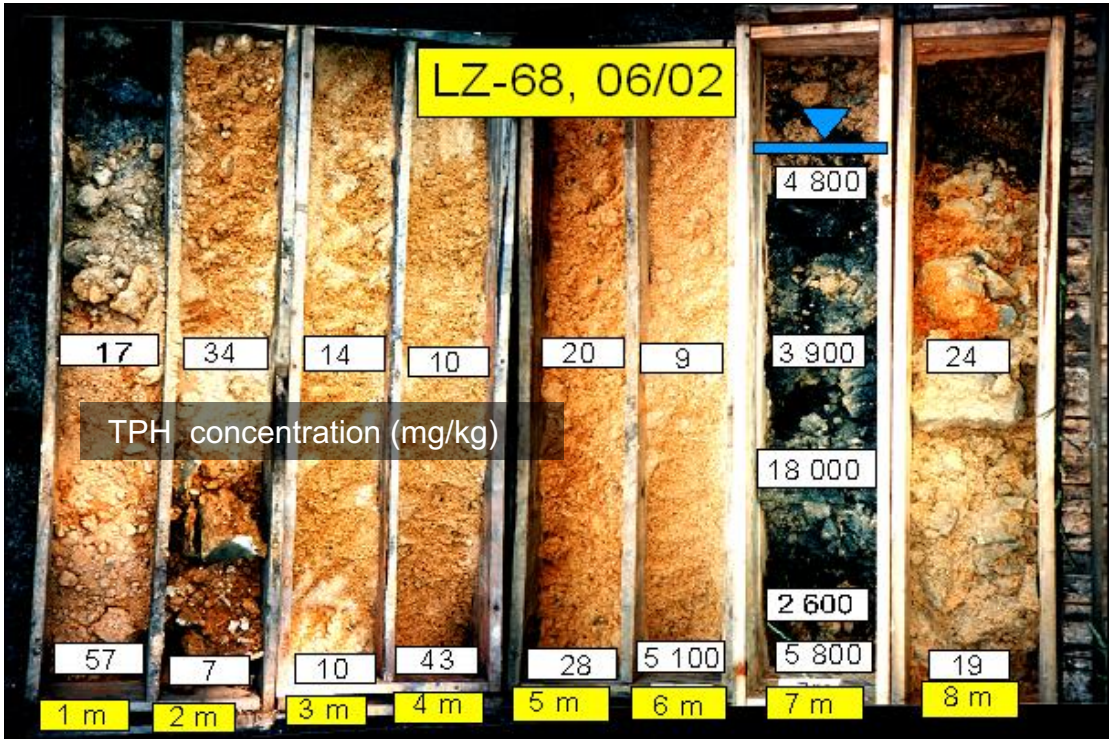
- 7 150 metric tons released to subsurface (mass estimation based on soil sampling)
- Semi-volatile fraction, mainly jet fuel, admixture of gasoline, diesel
- 28.3 ha of contaminated soil and groundwater
- LNAPL present at 80% of the area with thickness up to 90 cm
- Contamination bounded to two different geological environments – eastern plume formed in loose Quaternary deposits, former river bed, western plume formed in consolidated Cretaceous sandstones



Contaminant distribution in soil profile

Maximum of contamination bounded to layer 1,5 m under groundwater table (soil sampling result in area of 11 ha)

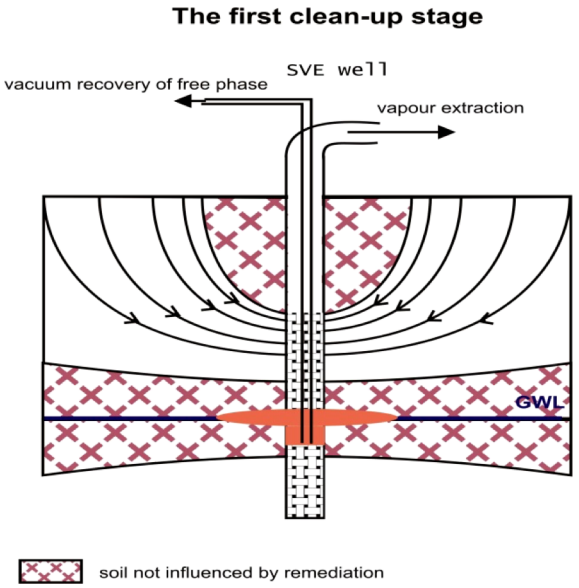




Clean-up technology - combination of several methods

I. Stage

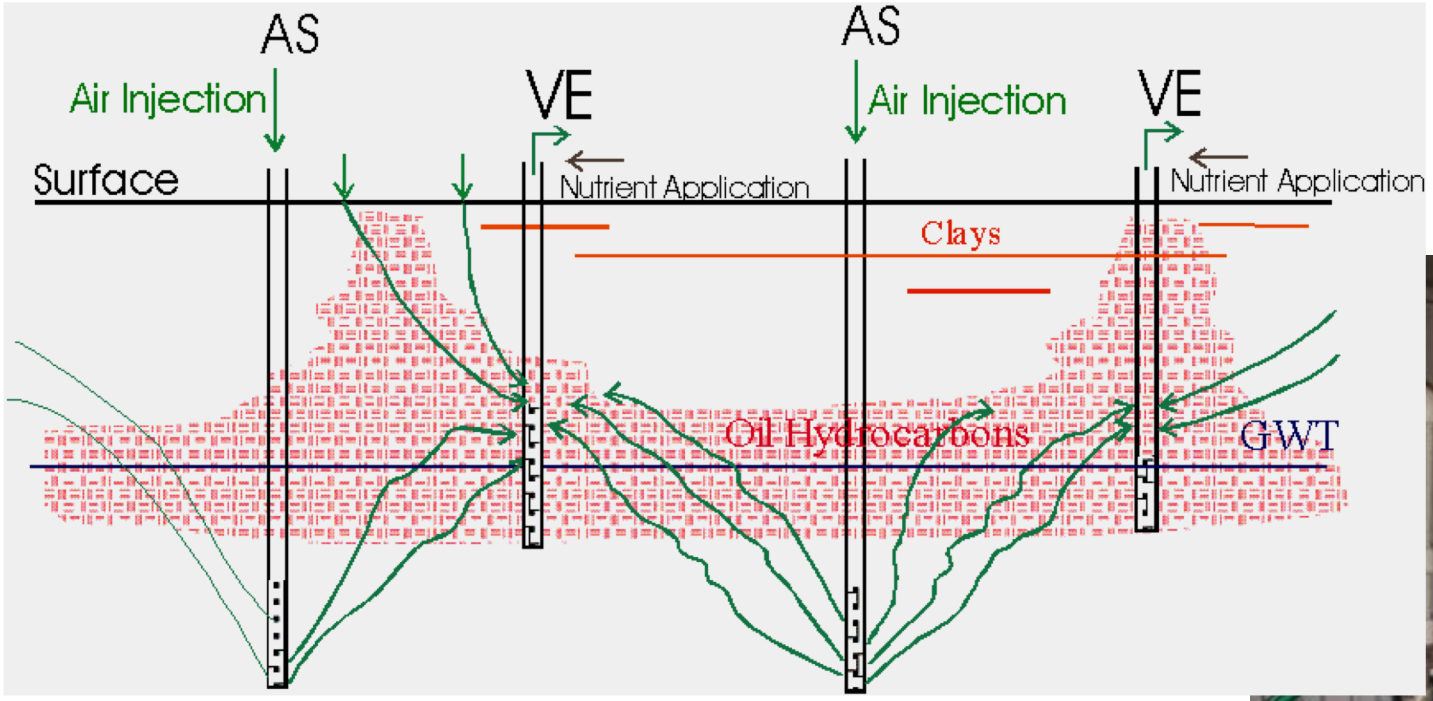
- Soil vapor extraction + vacuum oil phase extraction – removal of extractable LNAPL
- 1 – 2 years in the source zone



II. Stage

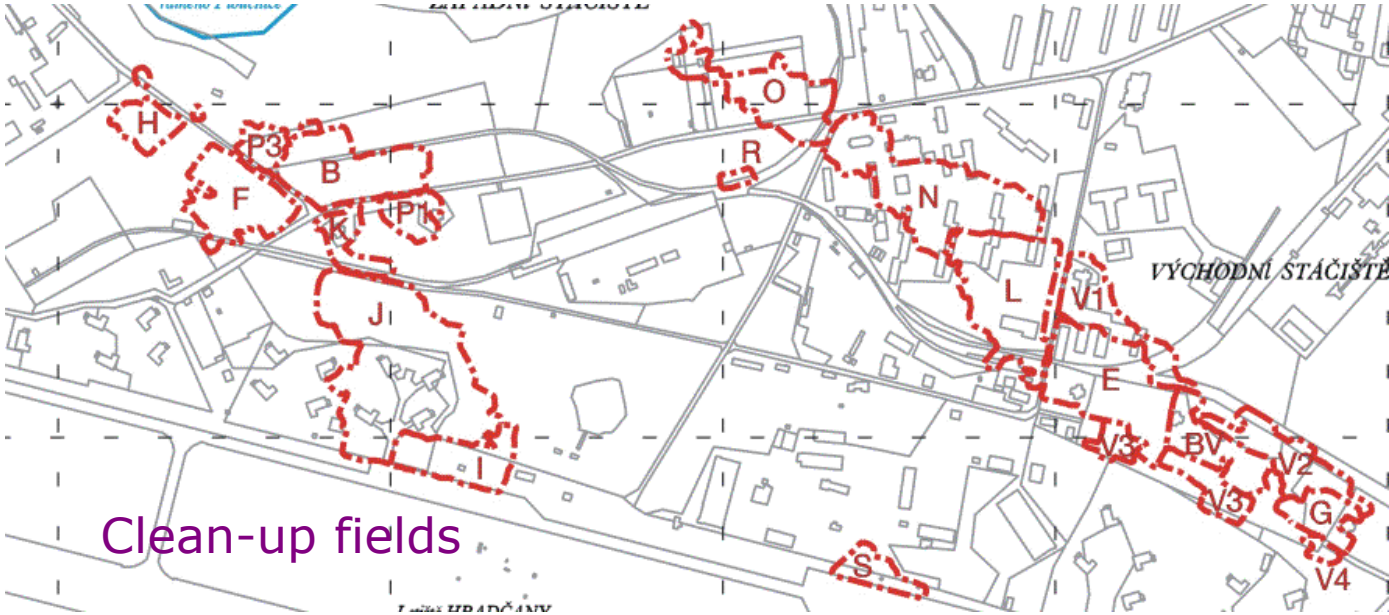
- *In situ* aerobic biodegradation
- stimulation of indigenous aerobic bacteria
- Oxygenation of soil and groundwater (venting, air sparging)
- Naturally very low nutrient content periodical application of nutrients (N,P,K)
- 2 – 6 years, based on initial contamination

The schematic layout of biodegradation technology



Clean-up Fields

- 28.3 ha put consequently under operation in 1997- 2005
- Area divided into clean-up fields (0.5 – 2 ha)
- 1650 air sparging wells, 1350 venting wells
- 60 compressors, 25 blowers, about 100 km of various piping



Clean-up fields

The Clean-up Efficiency

- Monitoring of extracted air - O_2, CO_2, volume

  Monthly - quantification of TPH biodegraded, based on stochiometry

  $$\mathbf{C_{10}H_{18} + 14{,}5\ O_2 \longrightarrow 10\ CO_2 + 9\ H_2O}$$

- Background respiration (uncontaminated area 2.3 t/ha/year)
- Point respiration testing of soil and groundwater

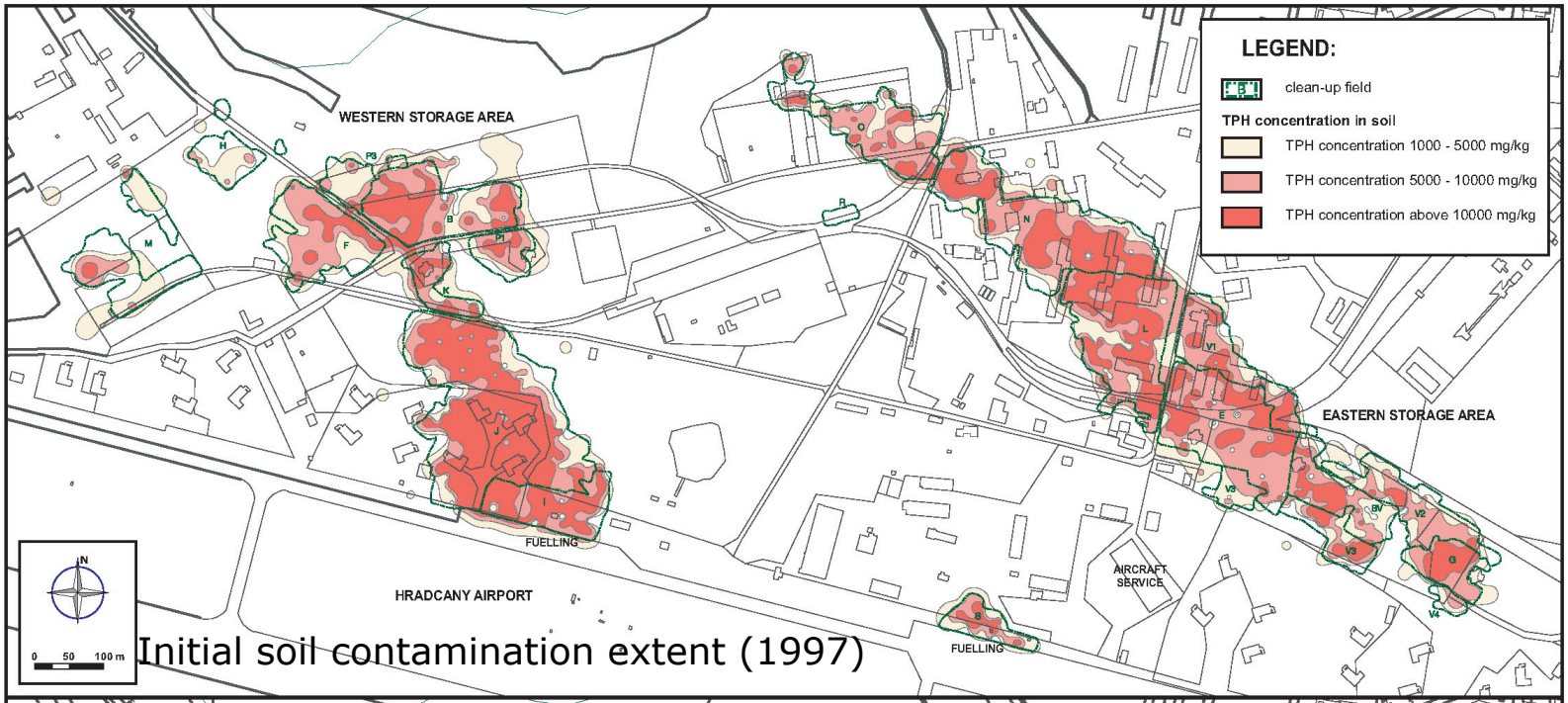
  1 – 2 times a year

- Control soil sampling

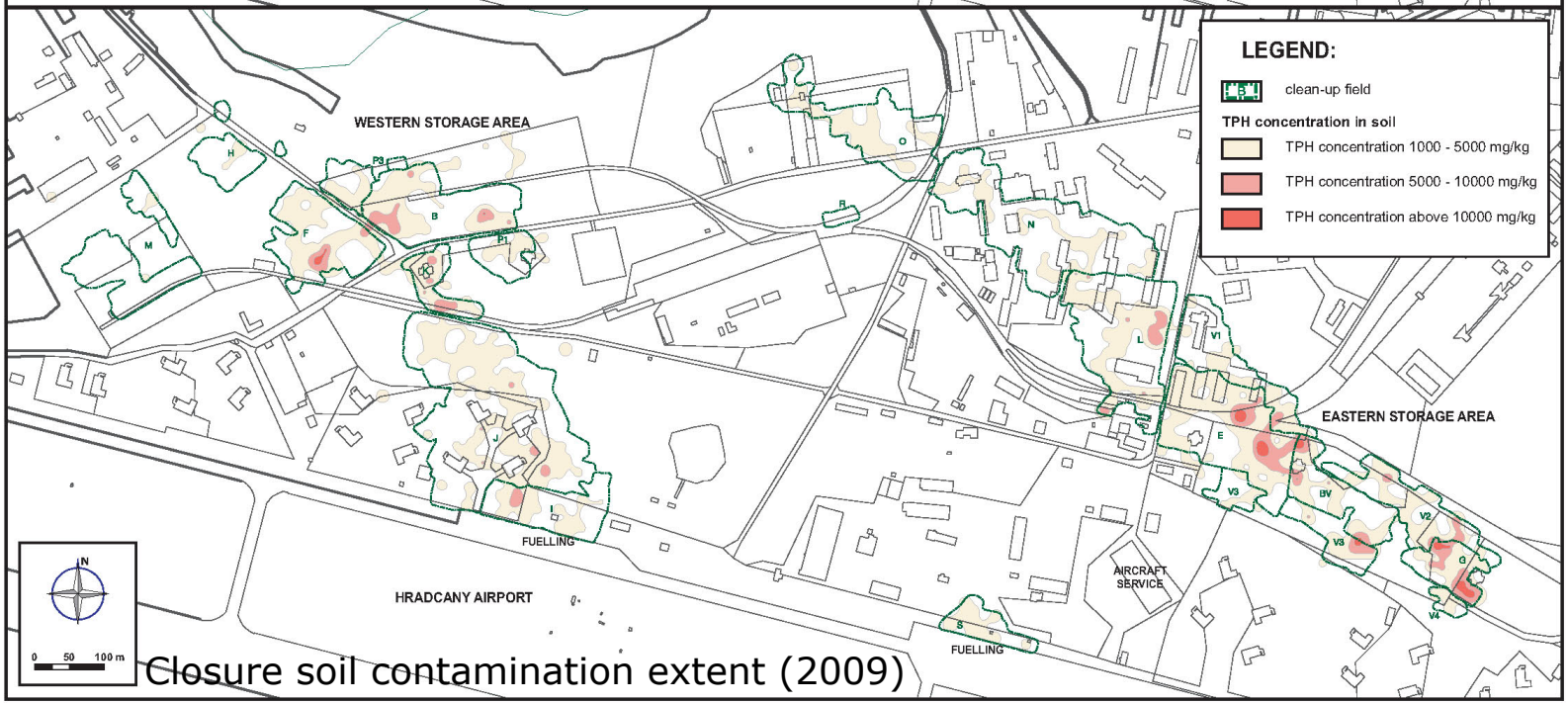
  2- 4 year period, quantification of TPH mass

- Groundwater sampling, LNAPL monitoring

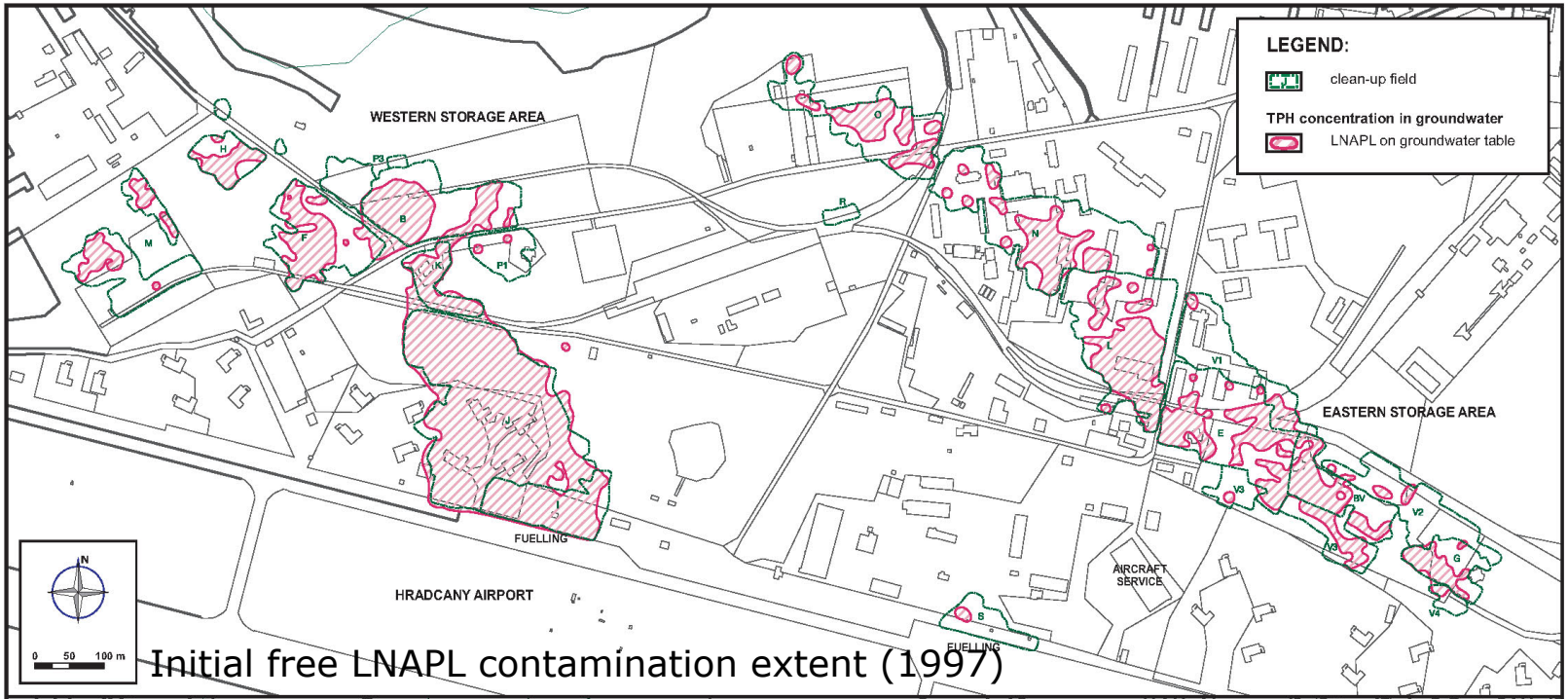
  1 -2 times a year



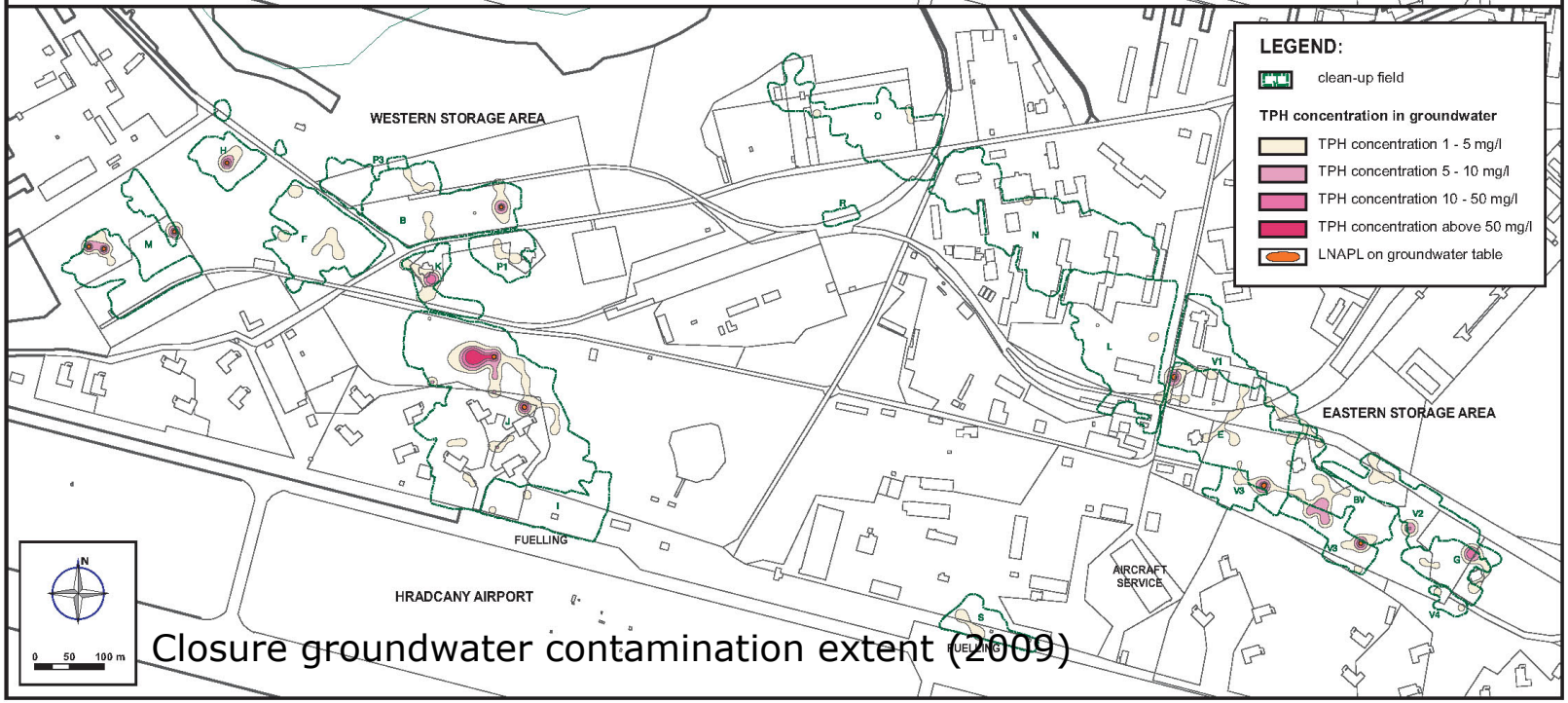
Initial soil contamination extent (1997)



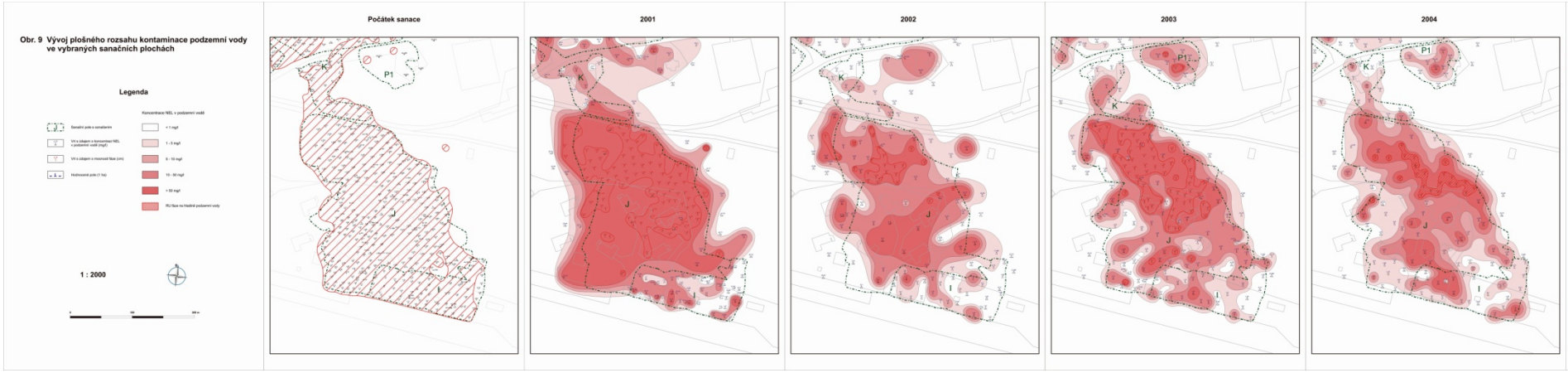
Closure soil contamination extent (2009)

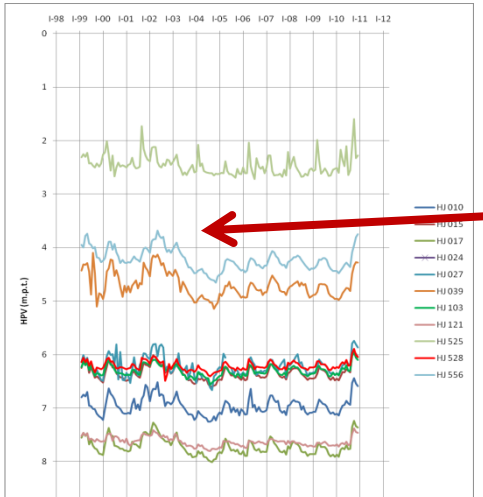


Initial free LNAPL contamination extent (1997)



Closure groundwater contamination extent (2009)

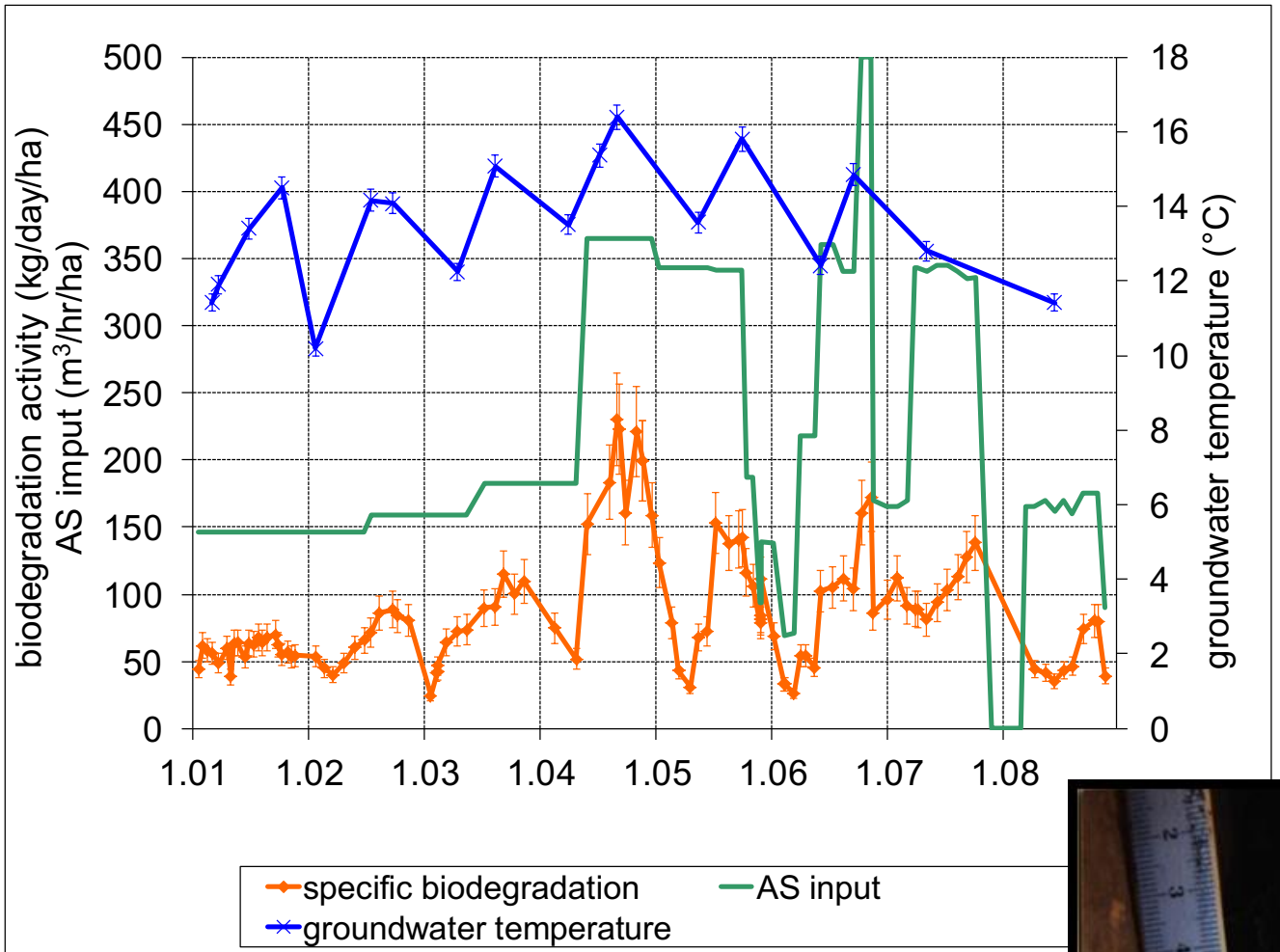




Closure monitoring

- 2003 – extremely dry year, rebound of LNAPL

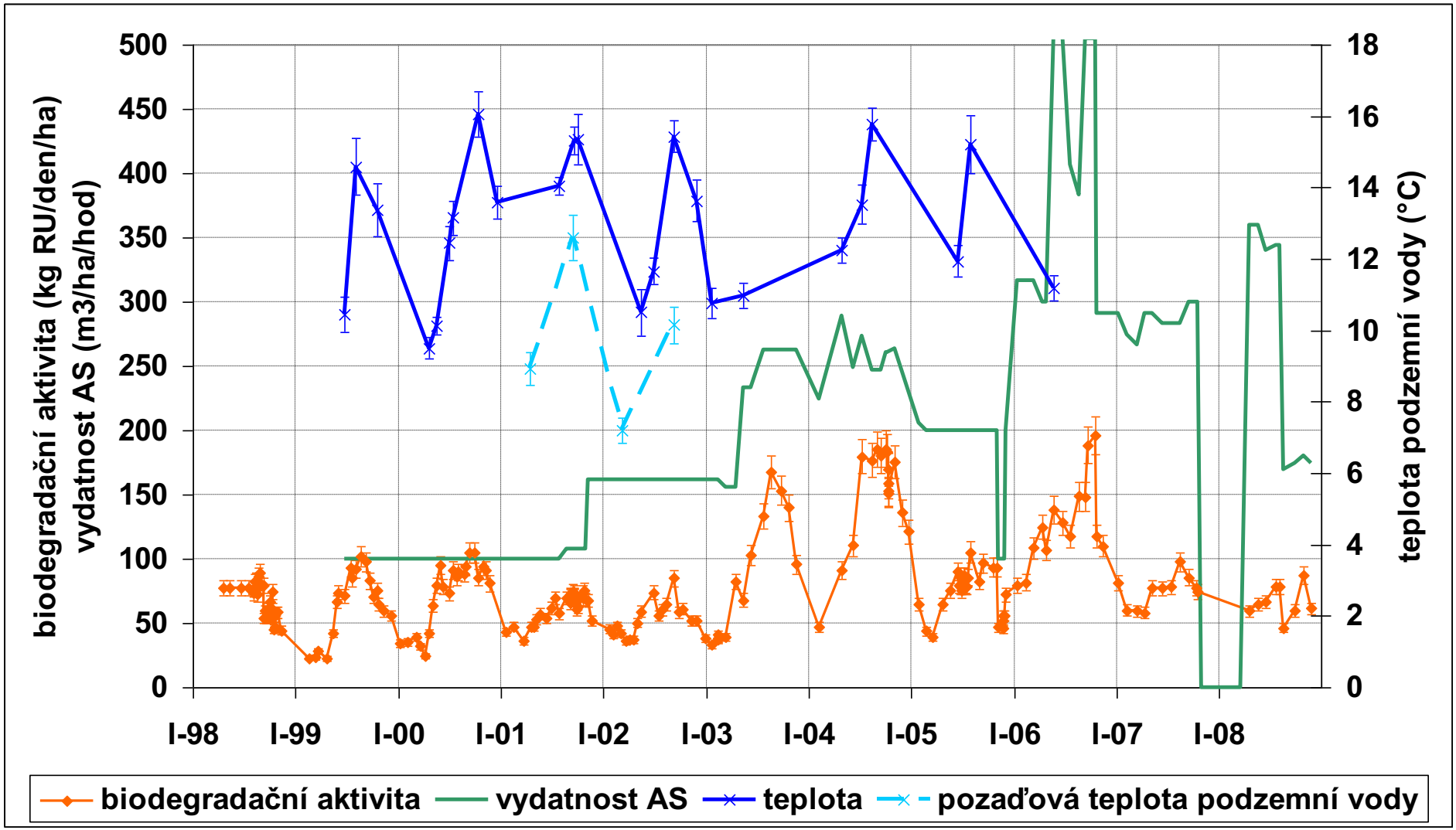
Biodegraration Activity in the L Field (2,5 ha)



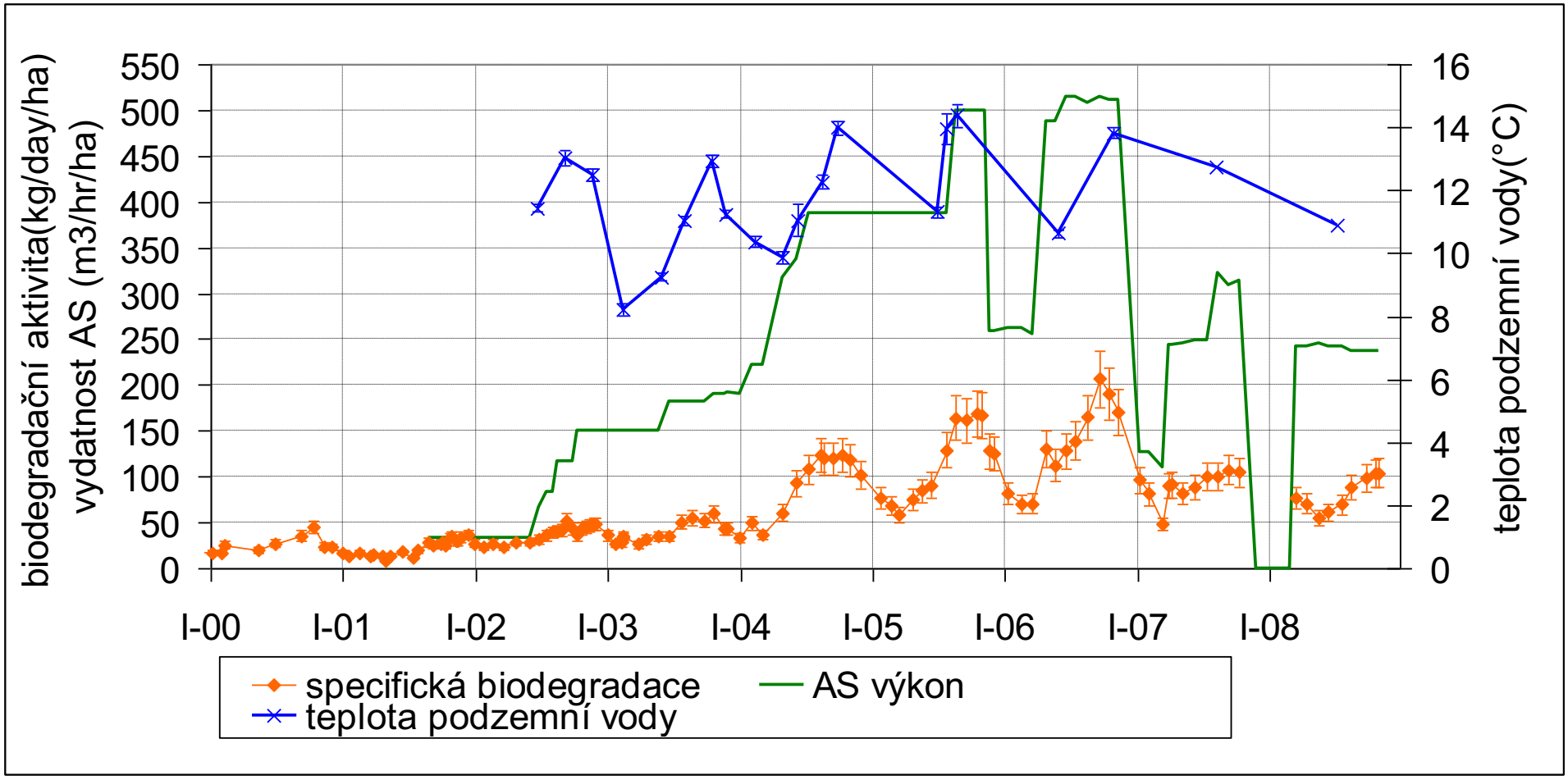
Soil Core 0.5 m under GWL (2002)

During clean-up a crucial role of air sparging intensity for reached biodegradation was observed
Annual fluctuation of bioactivity wa sobserved together with seasonal fluctuation of groundwater temperature

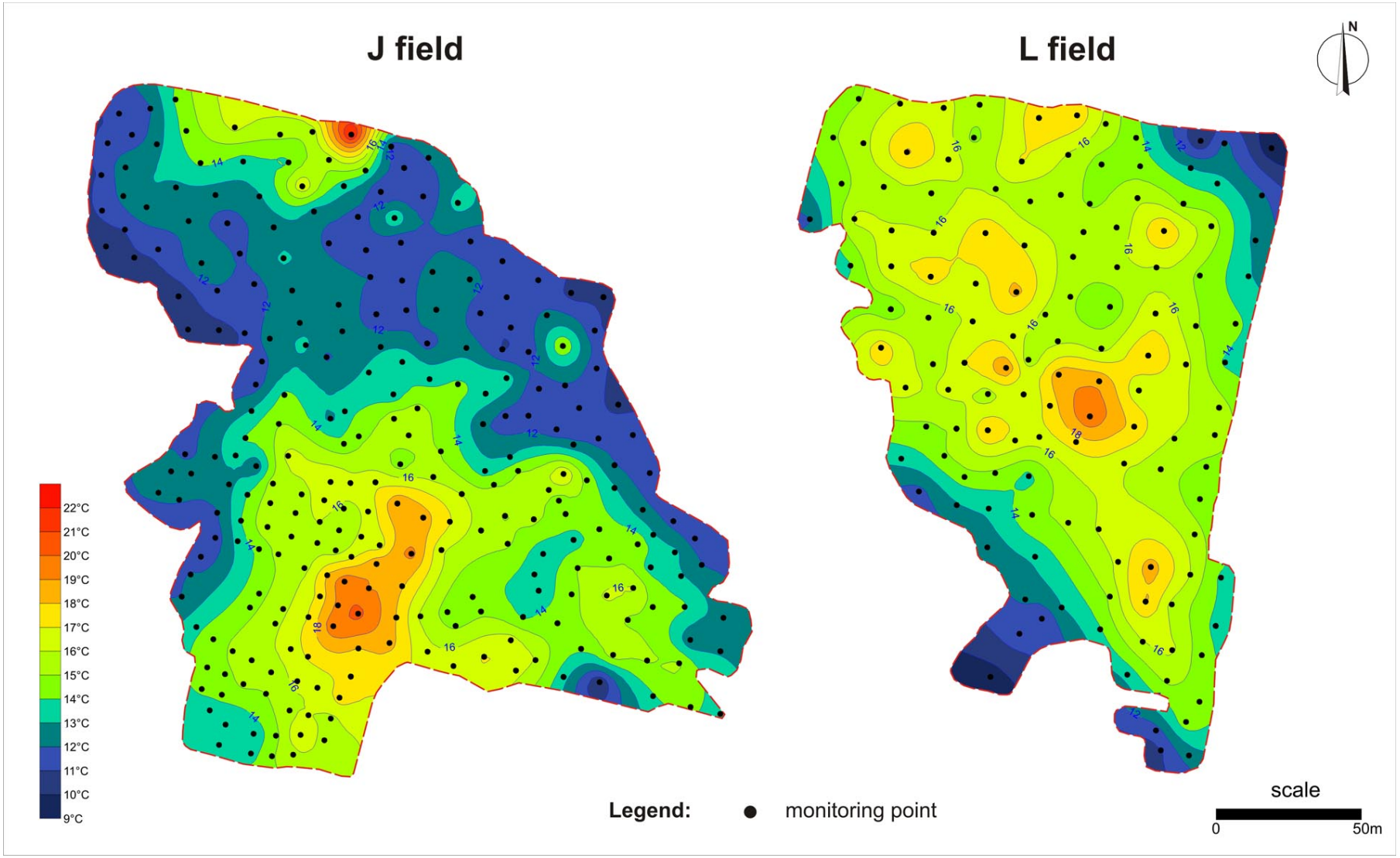
Biodegradation Activity in the I Field (1,4 ha)



Biodegradation Activity in the J Field (4,9 ha)

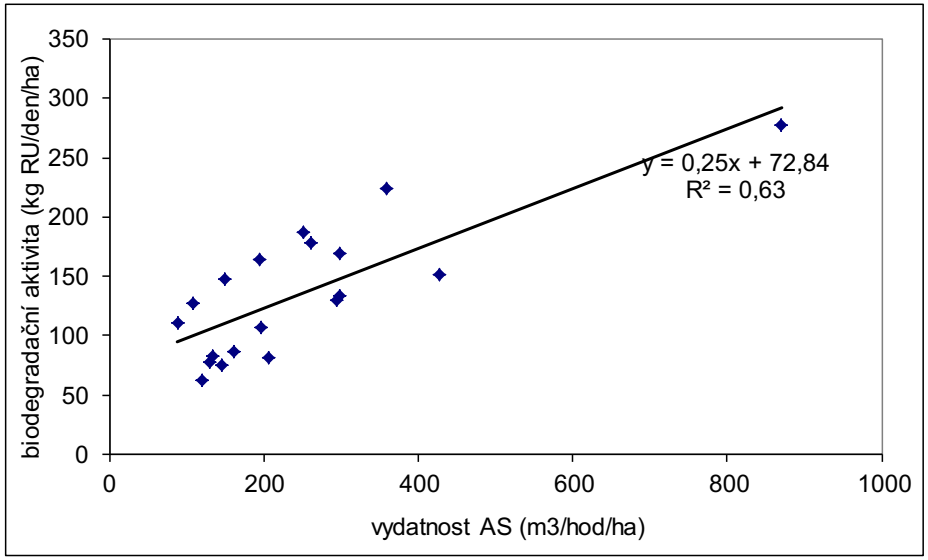


Groundwater temperature in summer 2004 (in-situ monitoring)

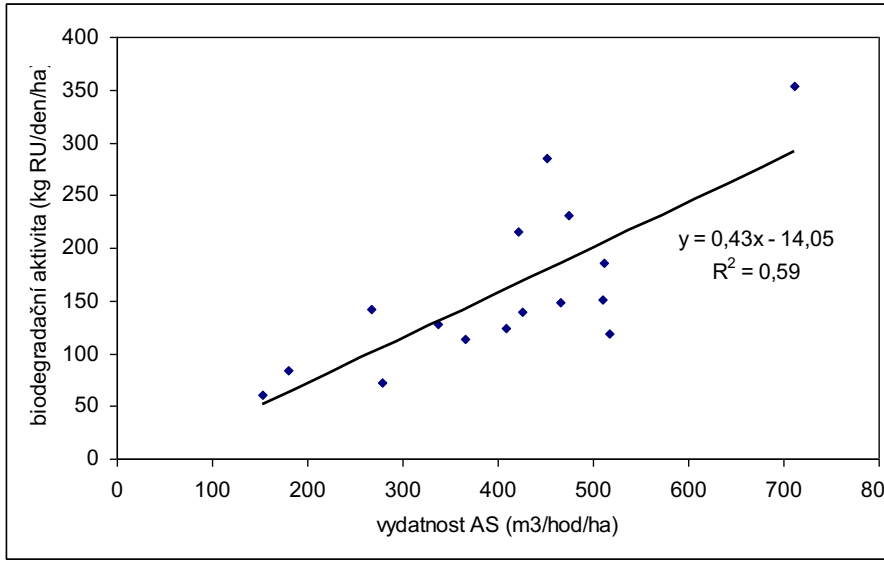


J field – southern part operated for 3 years, northern for four months in 2004
L field – whole field operated for four years in 2004

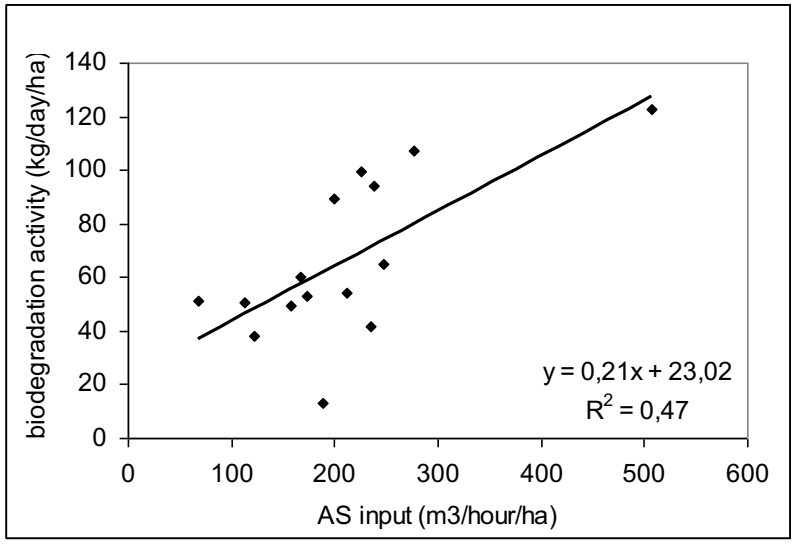
Correlation between AS input and biodegradation rate



2004

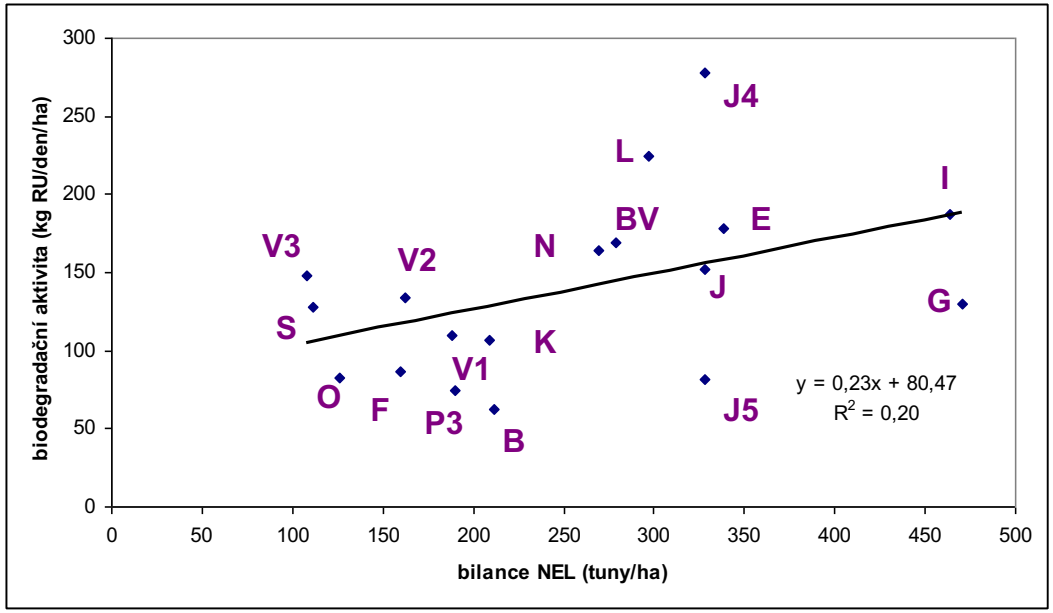


2006



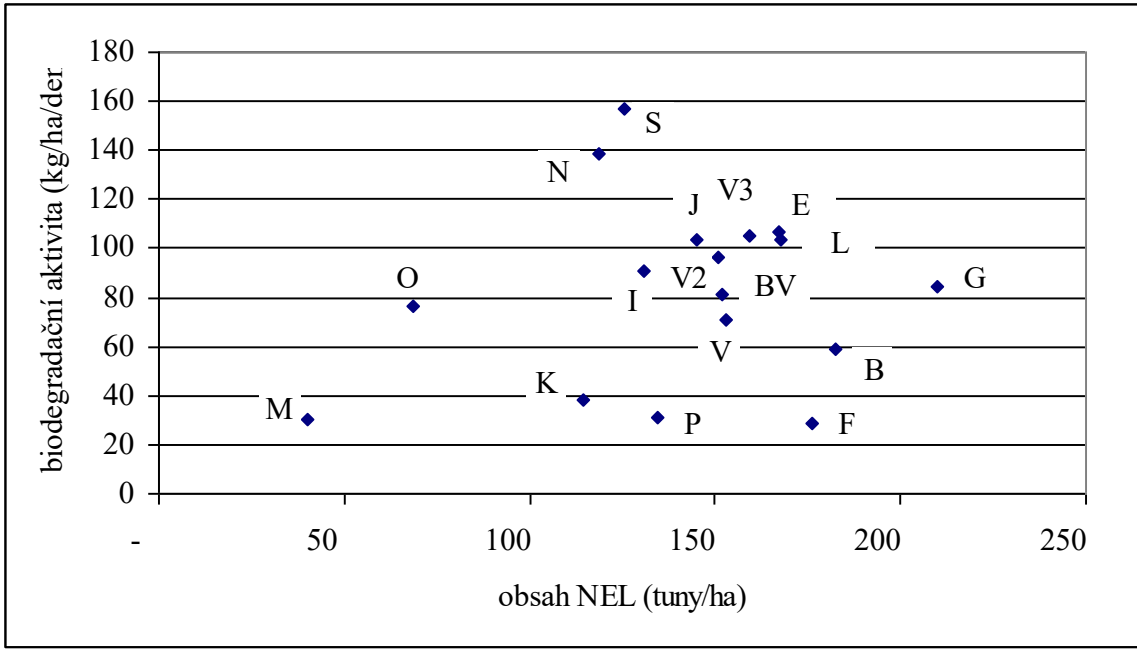
2008

Correlation between TPH content and bioactivity



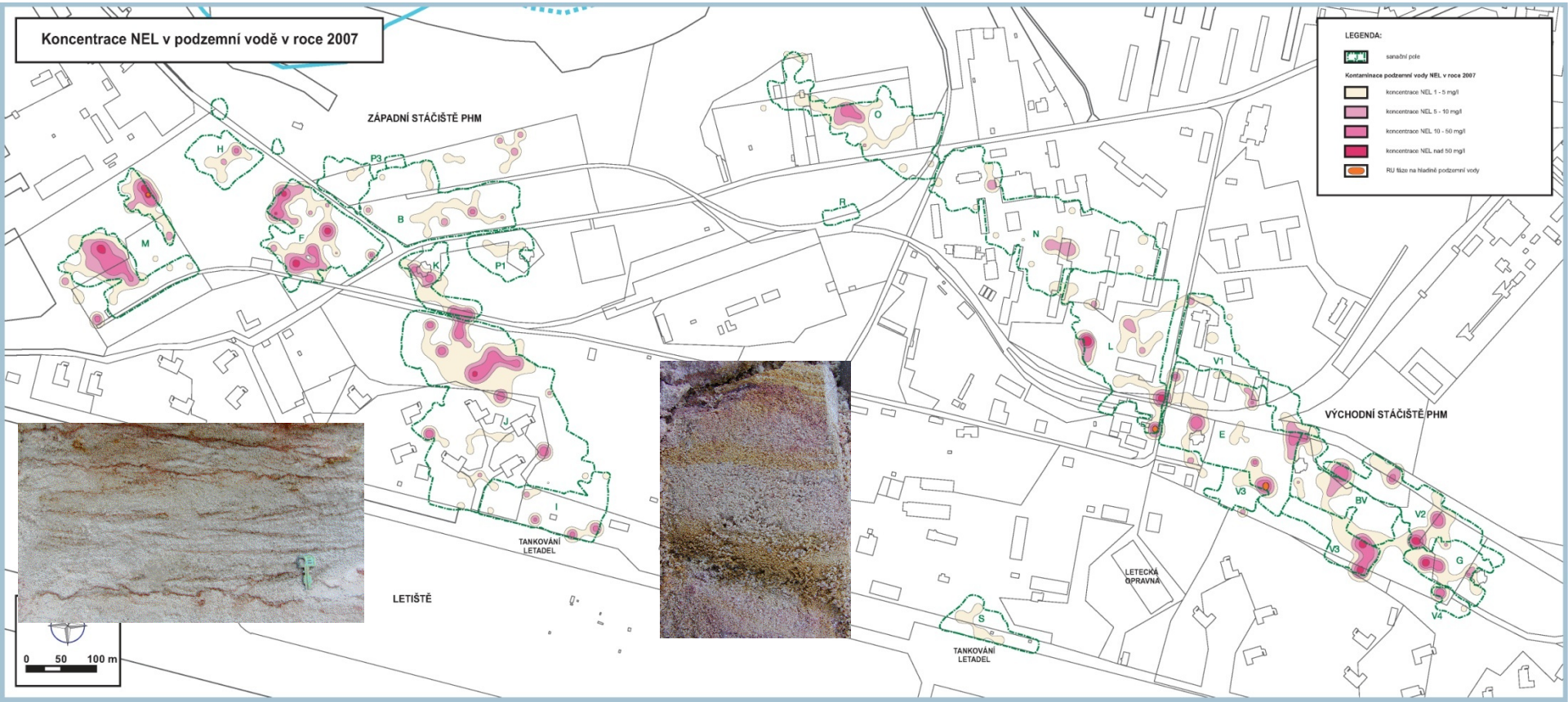
2004

2007

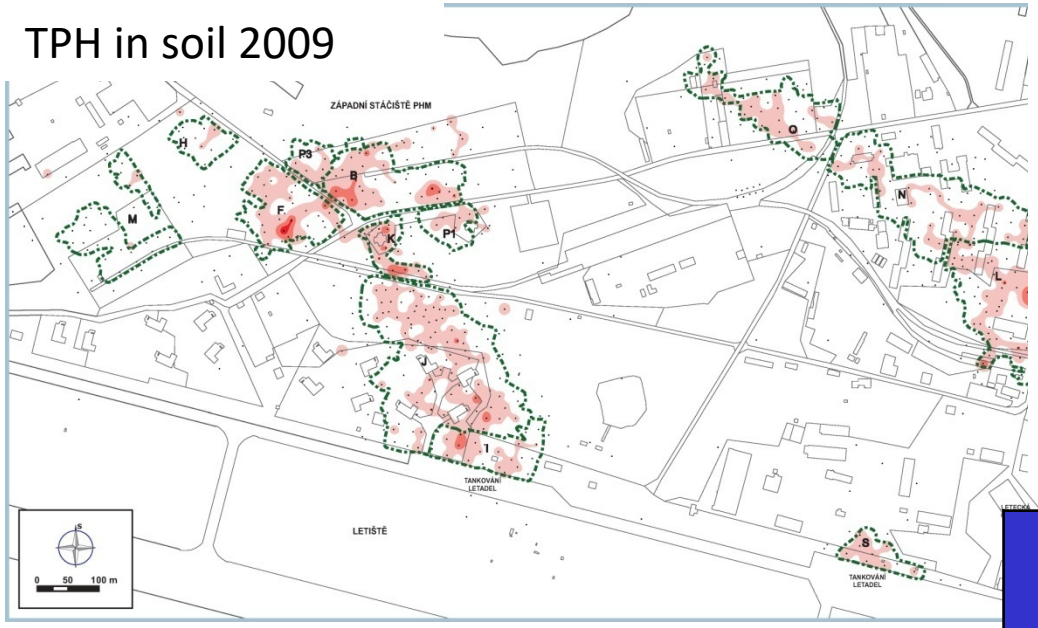


Influence of geological structures

Very consolidated, discrete layers (thickness to 1 m) in fields B, F, K, north of J – troubles with reaching of goals / rebounding (Spring 2007, after first winter shut-down consolidated layers – residual contamination bounded to them



TPH in soil 2009



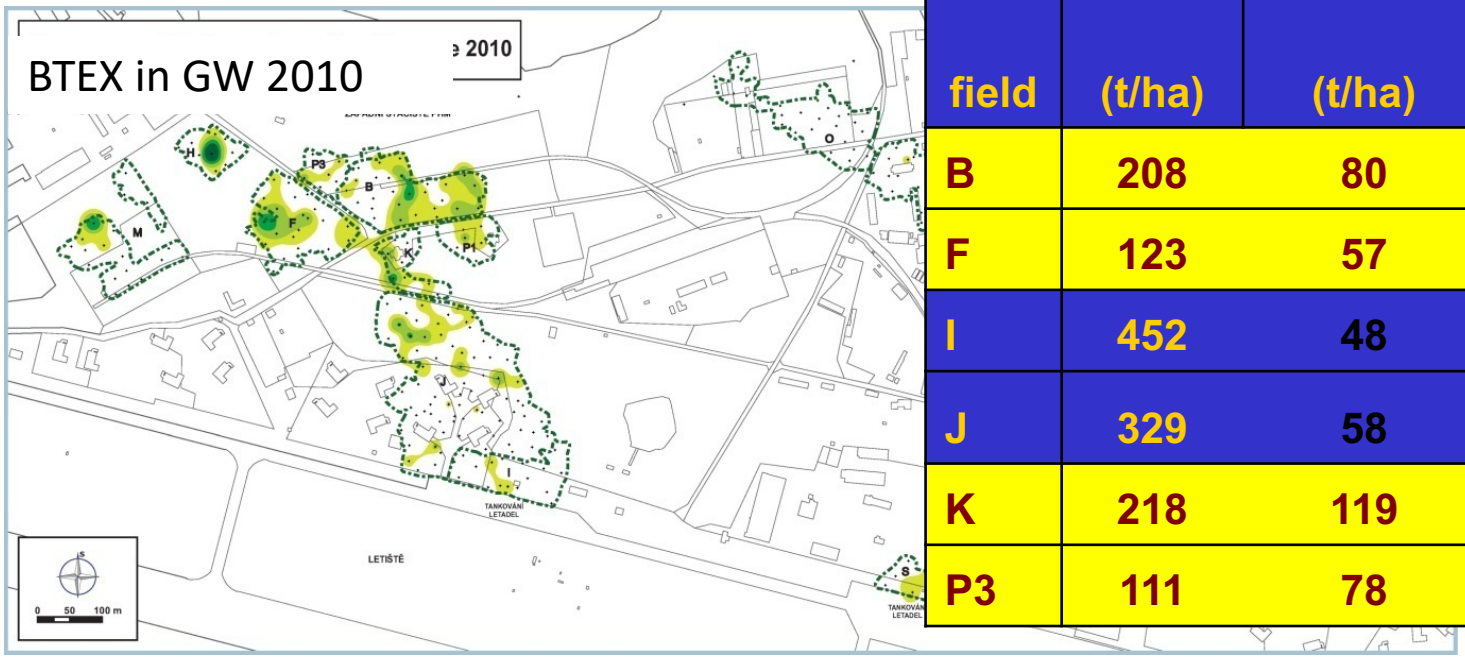
2 years after shutdown of technology operation

Consolidated layers - source of BTEX

Typical AS problem – less permeable layers were not fully remedied

Sufficient attenuation processes to hold goal

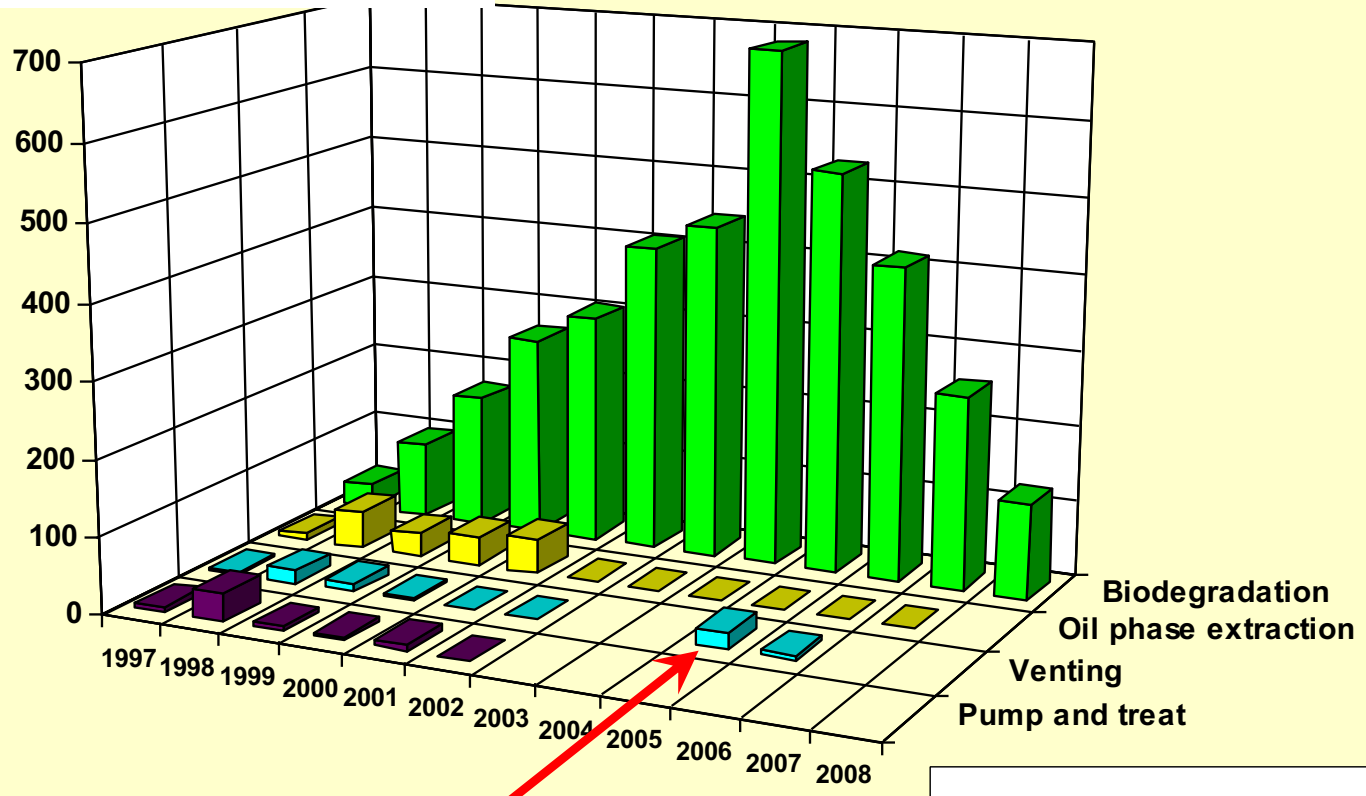
BTEX in GW 2010



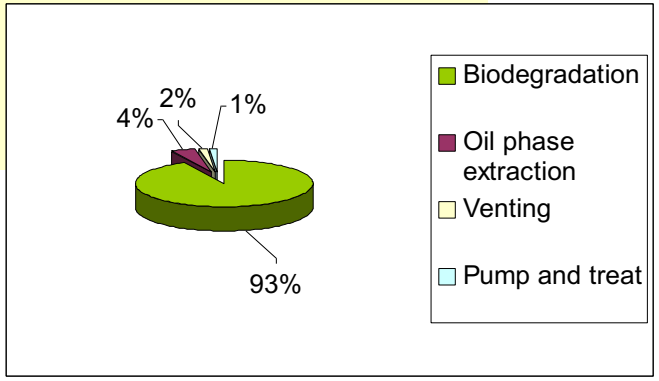
field	Initial TPH (t/ha)	Closure TPH (t/ha)	decrease %
B	208	80	62%
F	123	57	53%
I	452	48	89%
J	329	58	82%
K	218	119	46%
P3	111	78	30%

Overall result of clean-up methods

TPH removal – metric tons per year



Start of field M remediation – gasoline storage



Conclusions – Factors influencing biodegradation rates

- Main technological factor was amount of air injected by AS
- Main natural factor was fluctuation of groundwater temperature
- Intensive biodegradation heighted GW temperature
- Contamination content influenced biodegradation rates after removal of 80% of contamination
- Less permeable geological structures influenced remedial result in the part of the site

Publications with more detailed info

- Macháčkova J., Wittlingerova Z., Vlk K., Zima J., Linka A.: Comparison of Two Methods for Assessment of In Situ Jet-Fuel Remediation Efficiency, DOI 10.1007/s11270-007-9507-9, Water Air Soil Pollut, 2008, vol 187, pages 181-194/ Springer

- J. Masak , J. Machackova , M. Siglova , A. Cejkova , V. Jirku (2003) : Capacity of the Bioremediation Technology for Clean-Up of Soil and Groundwater Contaminated with Petroleum Hydrocarbons , Journal of Environmental Science and Health, Volume 38, Number 10 / Taylor & Francis

- Jirina Machackova, Zdena Wittlingerova, Kvetoslav Vlk & Jaroslav Zima (2012): Major factors affecting insitu biodegradation rates of jet-fuel during large-scale biosparging project in sedimentary bedrock, Journal of Environmental Science and Health, Part A: Toxic/Hazardous Substances and Environmental Engineering, 47:8, 1152-1165

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Reg. č.: CZ.1.07/2.4.00/31.0189

Questions?

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