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In-Situ Treatments using Nano-Scale Zero-Valent Iron Implemented in North America and Europe

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Presentation Outline

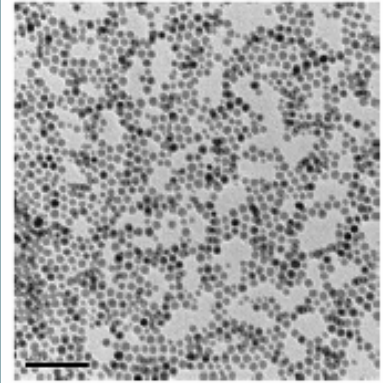
- Overview of ZVI technology
- NZVI treatment implementation steps
- Results
- Conclusions

Iron Filings

- Cost Considerations
- Specific surface $\sim 500 \text{ m}^2/\text{kg}$
- Typical quantities needed - Several metric tones

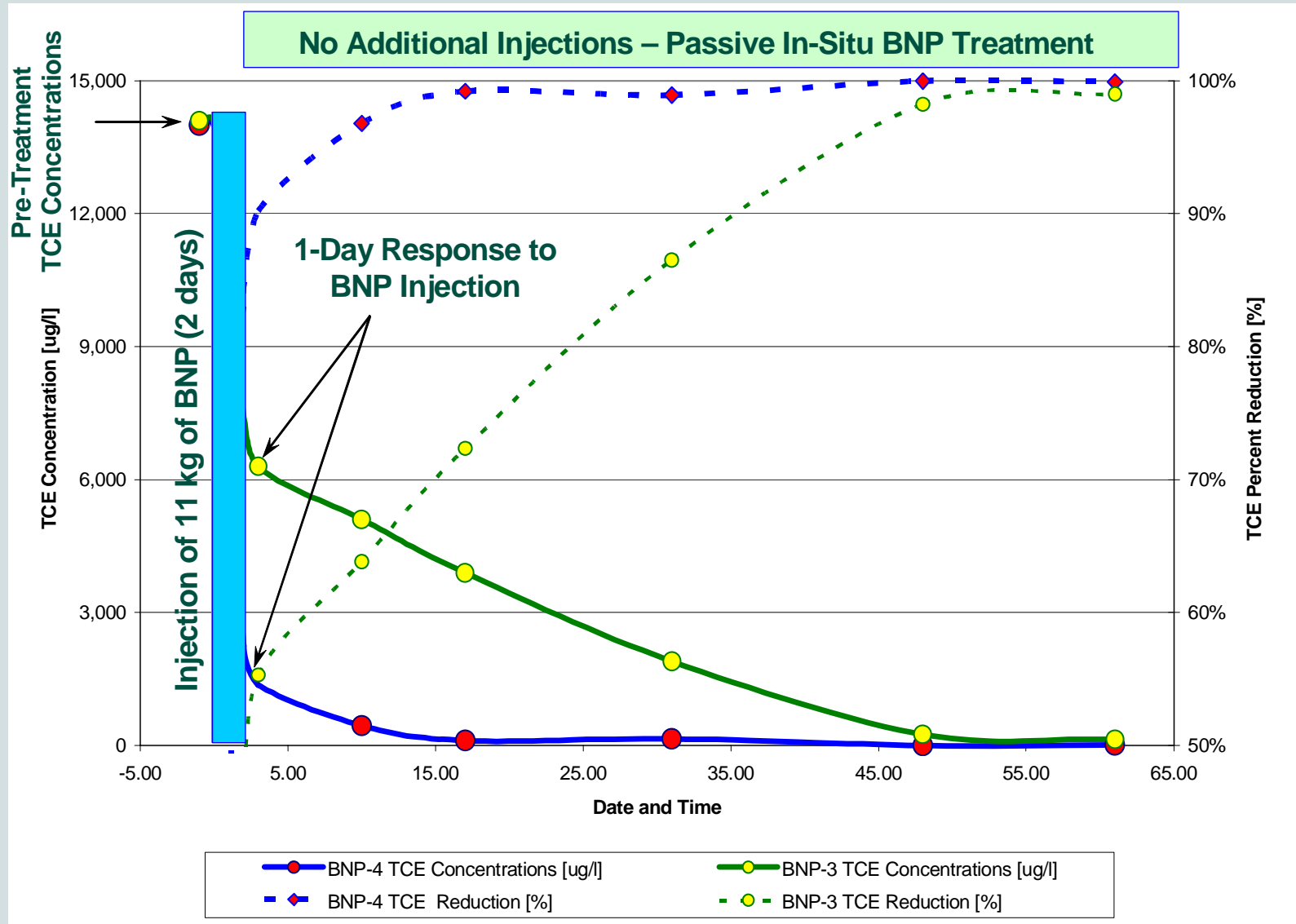


Nanoscale Zero-Valent Iron Particles



- Lehigh University
- Iron particles with palladium coatings (BNP)
- Nanoscale zero-valent Iron (NZVI)
- Specific surface for 50-60 nm ~ 25,000 m²/kg
- Specific surface for 2-5 nm ~ 142,000 m²/kg
- Treatment of:
 - Chlorinated solvents
 - Cr⁶⁺, etc.

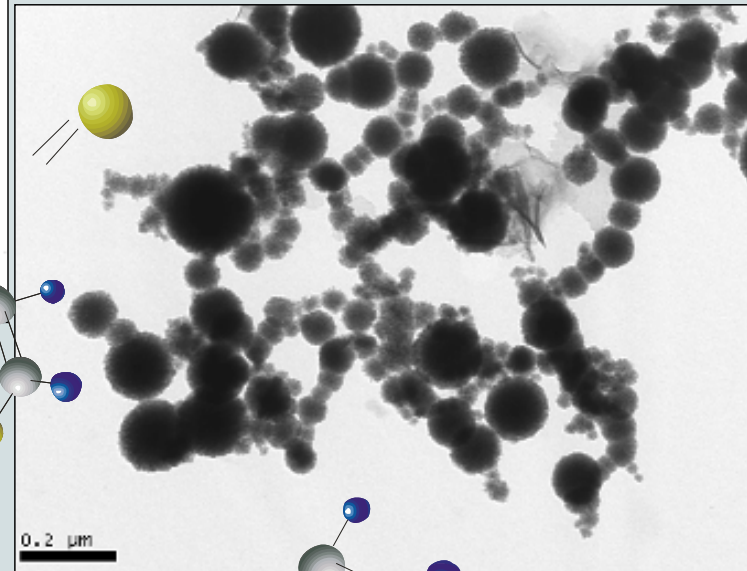
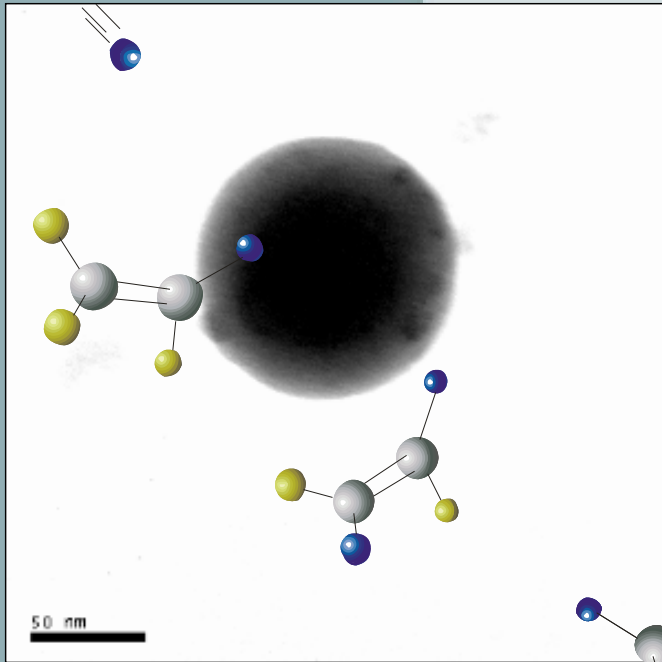
TCE Reduction, BNP-4 and BNP-3



Nanoscale Zero-Valent Iron Particles

- NZVI water slurry (no additives)
- Subsurface placement by gravity feed
- No special well construction needed
- Fast reaction time – real time monitoring and reactant dosage
- Minimum design requirements / permit level design
- Does not eliminate anaerobic bacteria activity
- Flexible remedial system that can be modified with time

Nanoscale Particles



NZVI Injection Equipment



NZVI Injection Equipment



NZVI Injection Equipment



NZVI Injection Equipment



Field Monitoring Equipment



Field Monitoring Equipment



Parametric sensors



Data logger

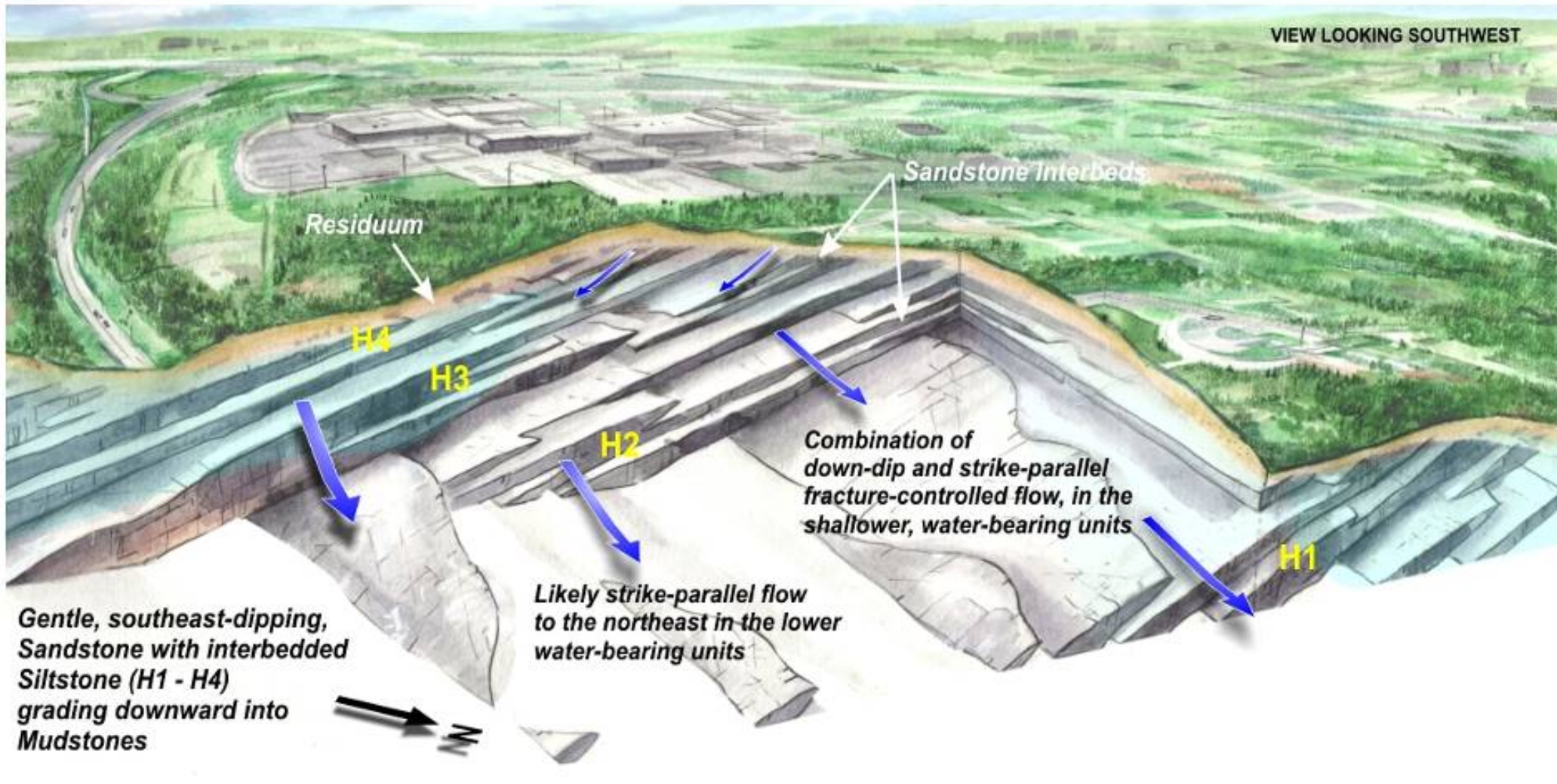


Trench for cables



Injection System

Conceptual Geologic and Hydrogeologic Model



Project Team

➤ USA

- Florin Gheorghiu
- Christian Mace
- Dr. Ramesh Venkatakrishnan
- Allen Kane
- Steve Finn
- Randy White
- Dr. Todd Rees
- Bob Glazier
- Bob Stetkar
- Dr. Bill Diesing
- Peter Swinick
- Dr. Wei-xian Zhang
(Lehigh University)

➤ Australia

- Dave Thomas

➤ Canada

- Steve Desrocher
- Tom Grimminck

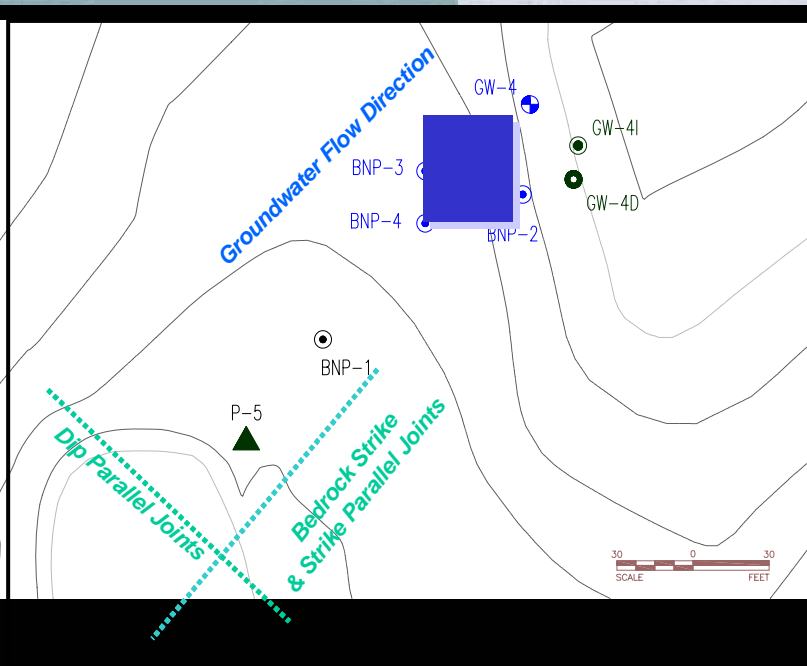
➤ Europe

- Michael Pupeza
- Dr. Graham Norris
- Dr: Miroslav Cernik
(Aquatest Czech Republic)

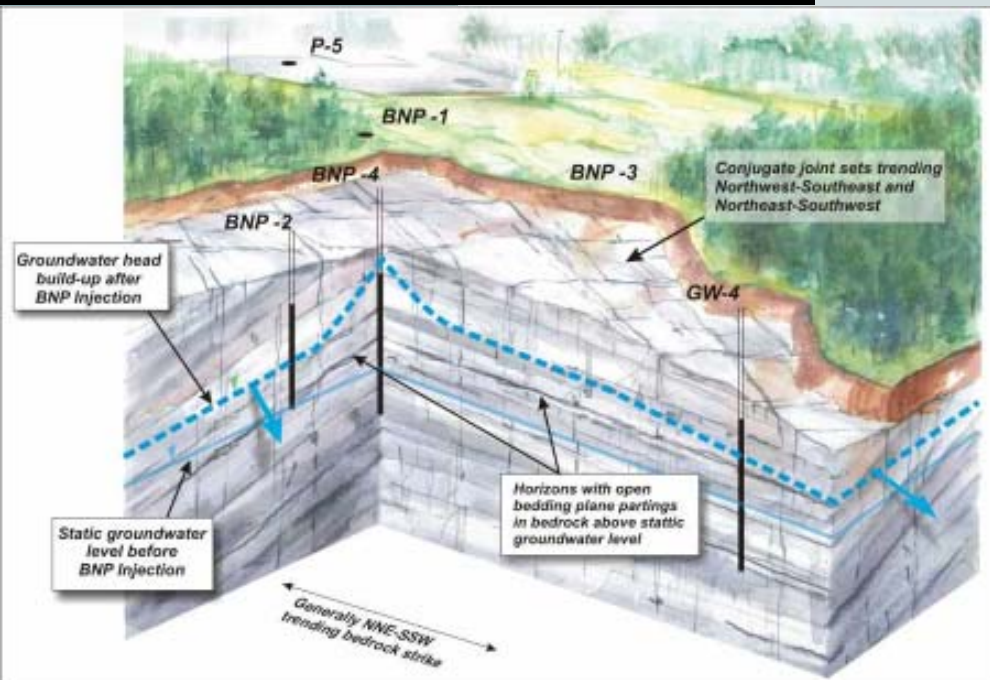
Clients

- Dr. Rainer Domalski
 - Ruetgers Organics Corporation
(Salem, Ohio Site)
- Other Confidential
Clients.....

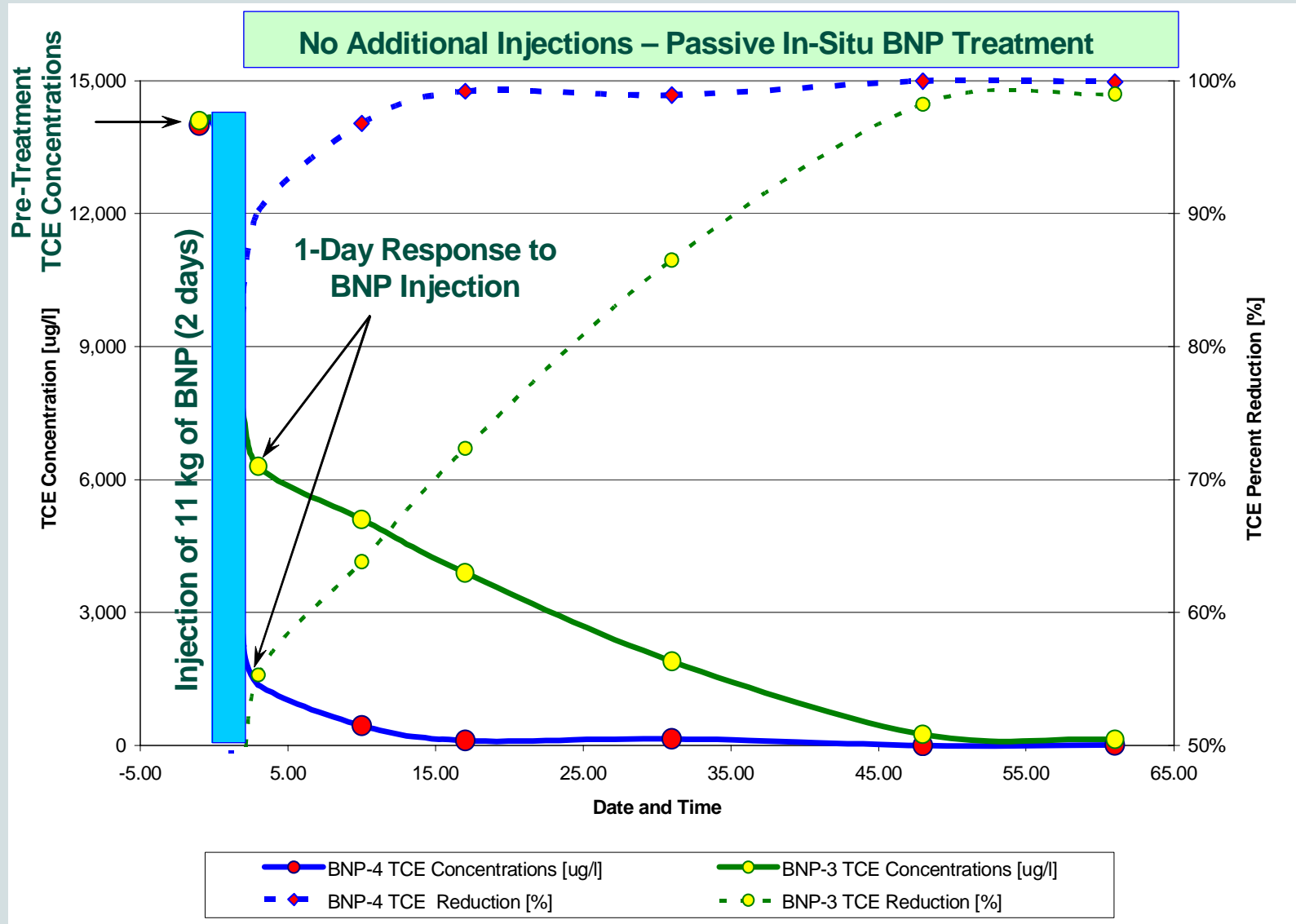
Test Design



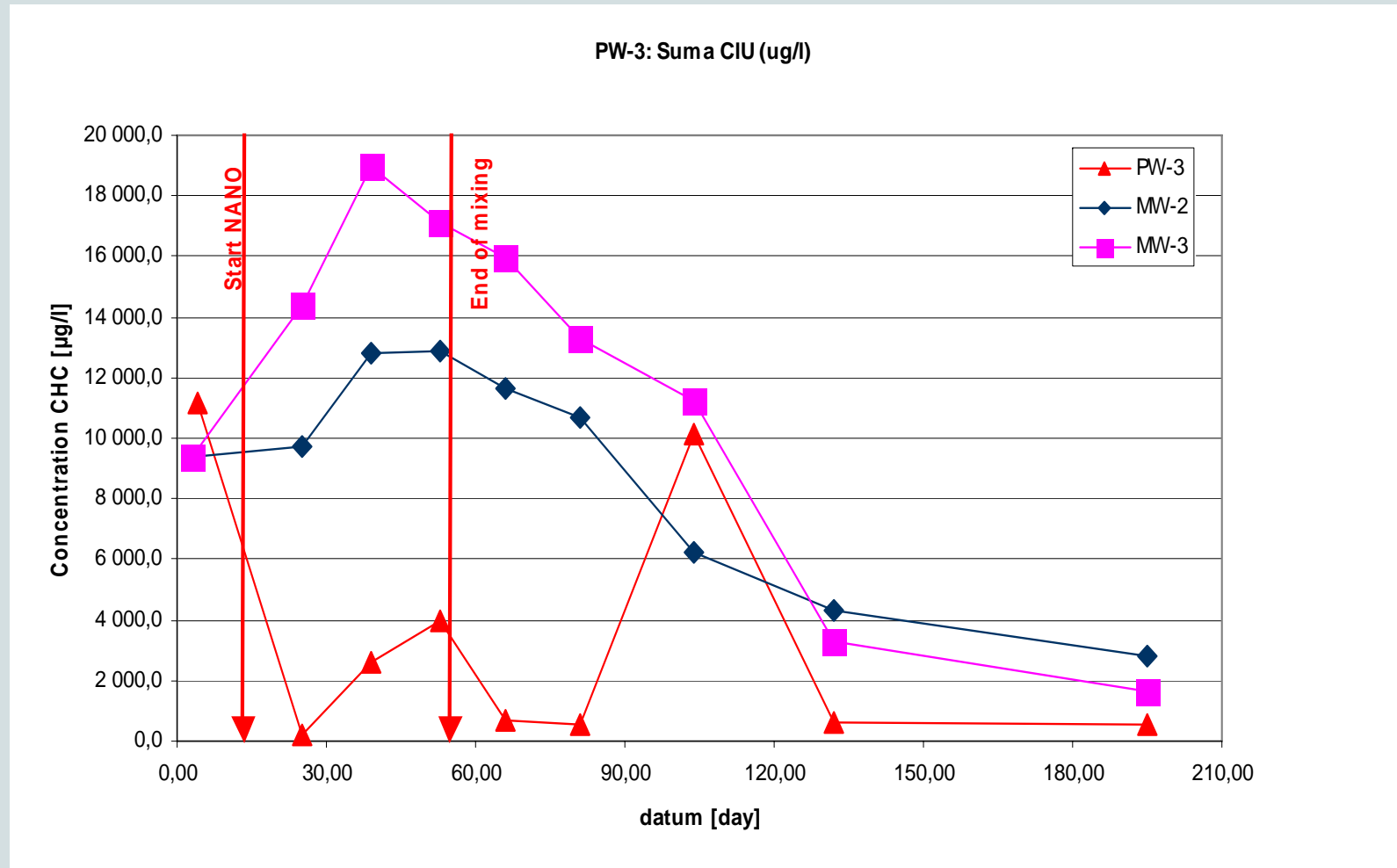
- Geology: fractured interbeds of sandstone / siltstone
- Total **BNP** slurry volume = 6,050 l
- **BNP** mass injected: 11.2 kg
- Injection Well BNP-4
- Monitoring Wells
 - BNP-3: 6.5 m north of BNP-4
 - BNP-2: 13 m northeast of BNP-4
 - GW-4: 21 m north-northeast of BNP-4



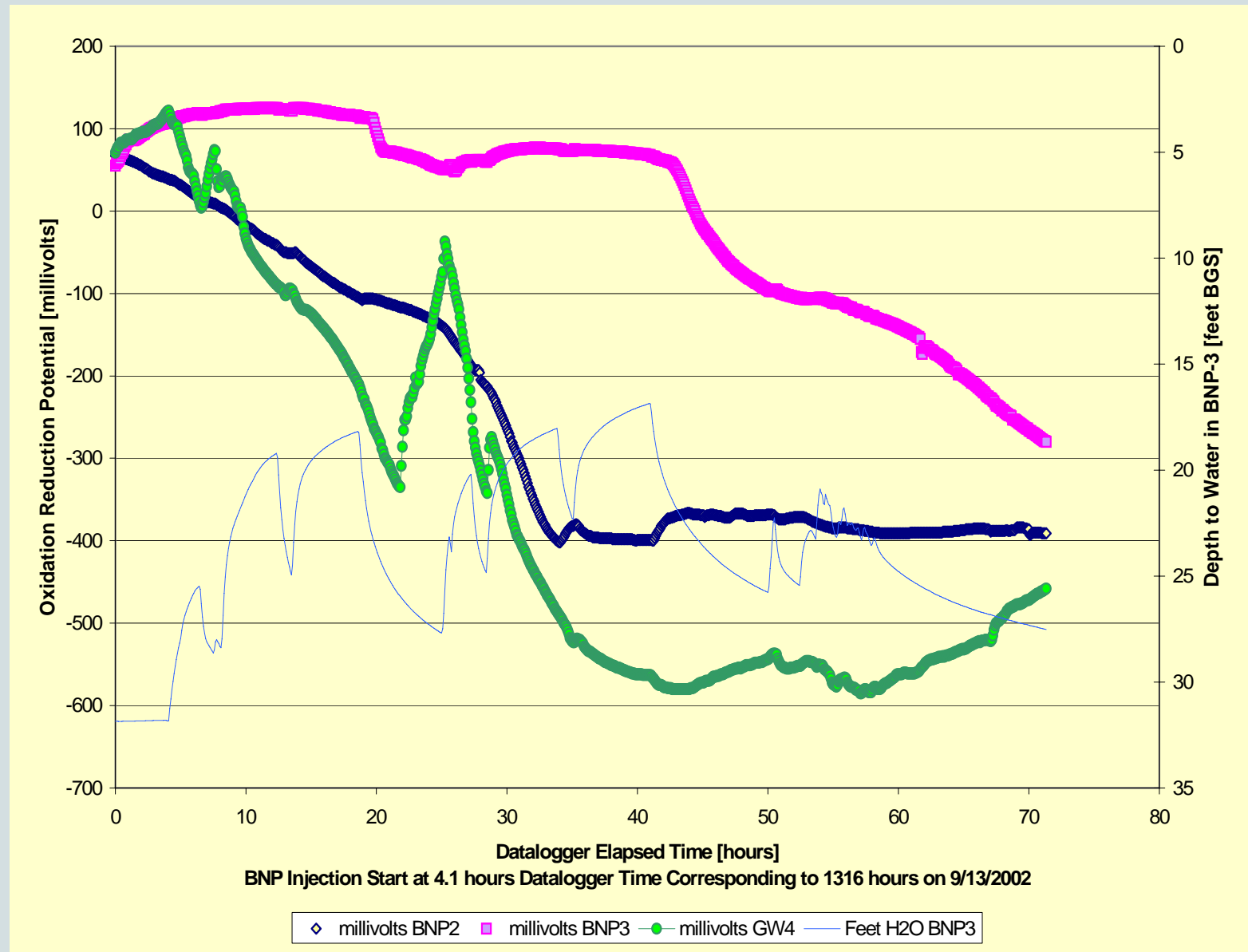
TCE Reduction, BNP-4 and BNP-3



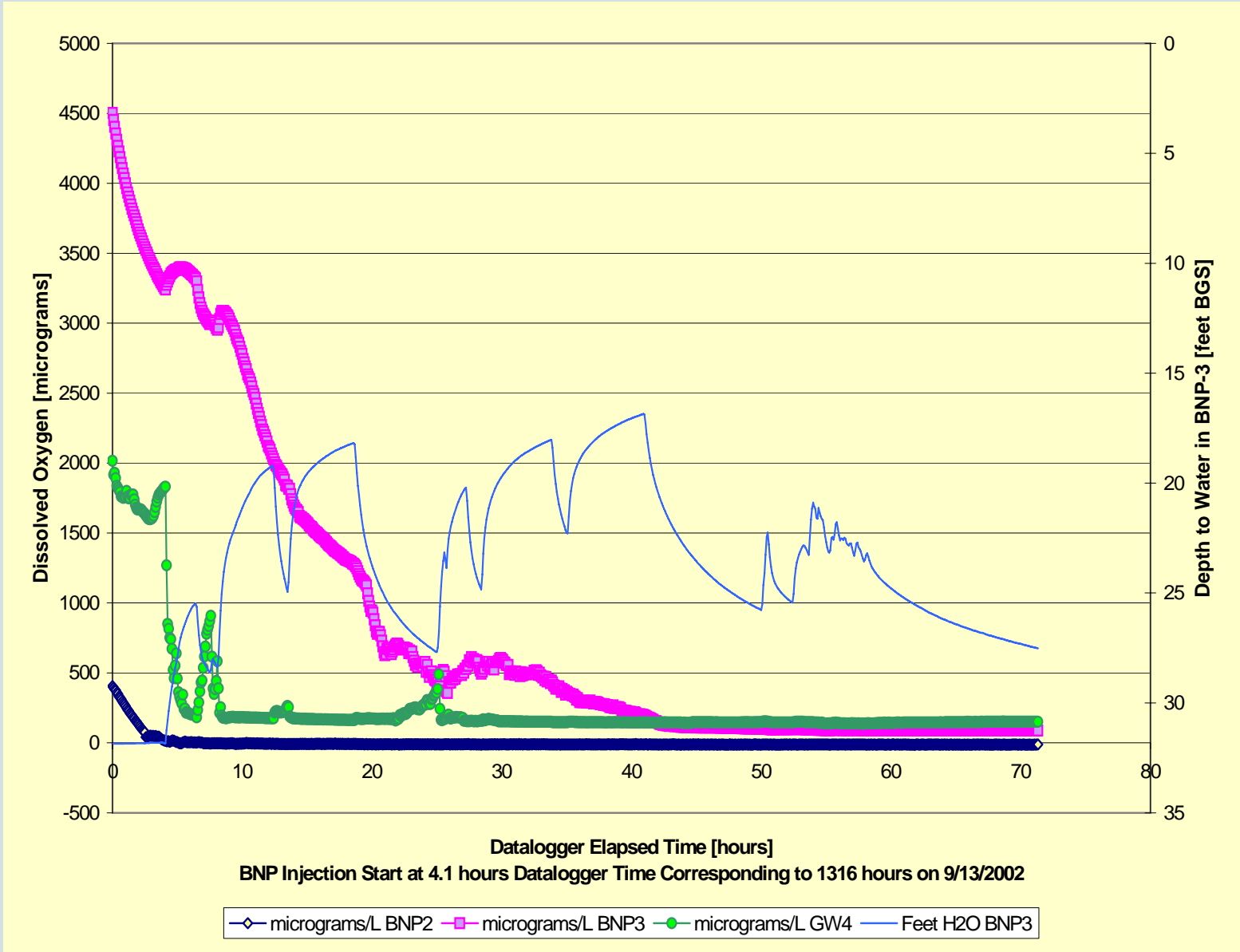
Test Results Czech Republic



ORP vs. Time



DO vs. Time



Pre- and Post-Injection Eh – pH Conditions

Eh-pH Diagram for BNP Pilot Test (triangle is injection well)

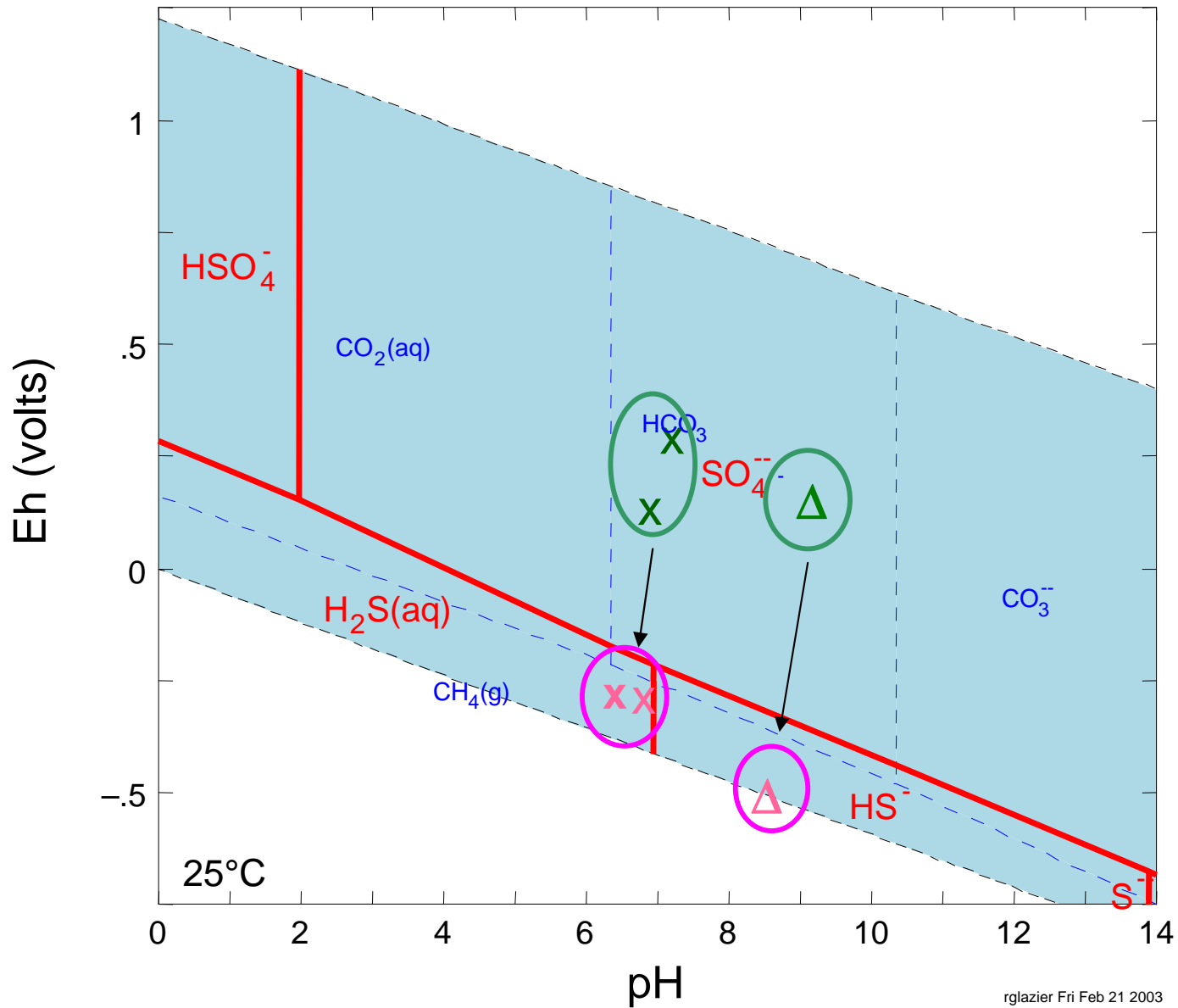
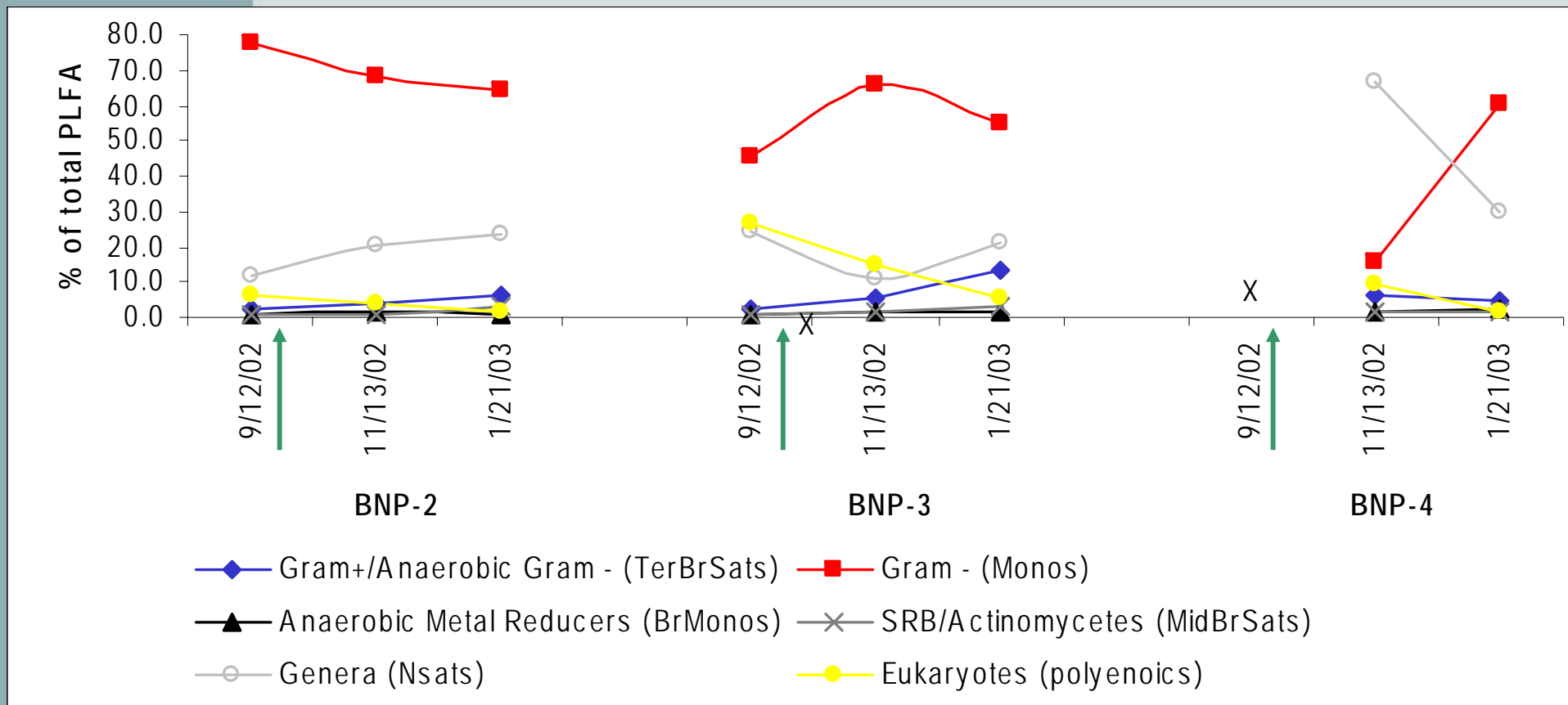


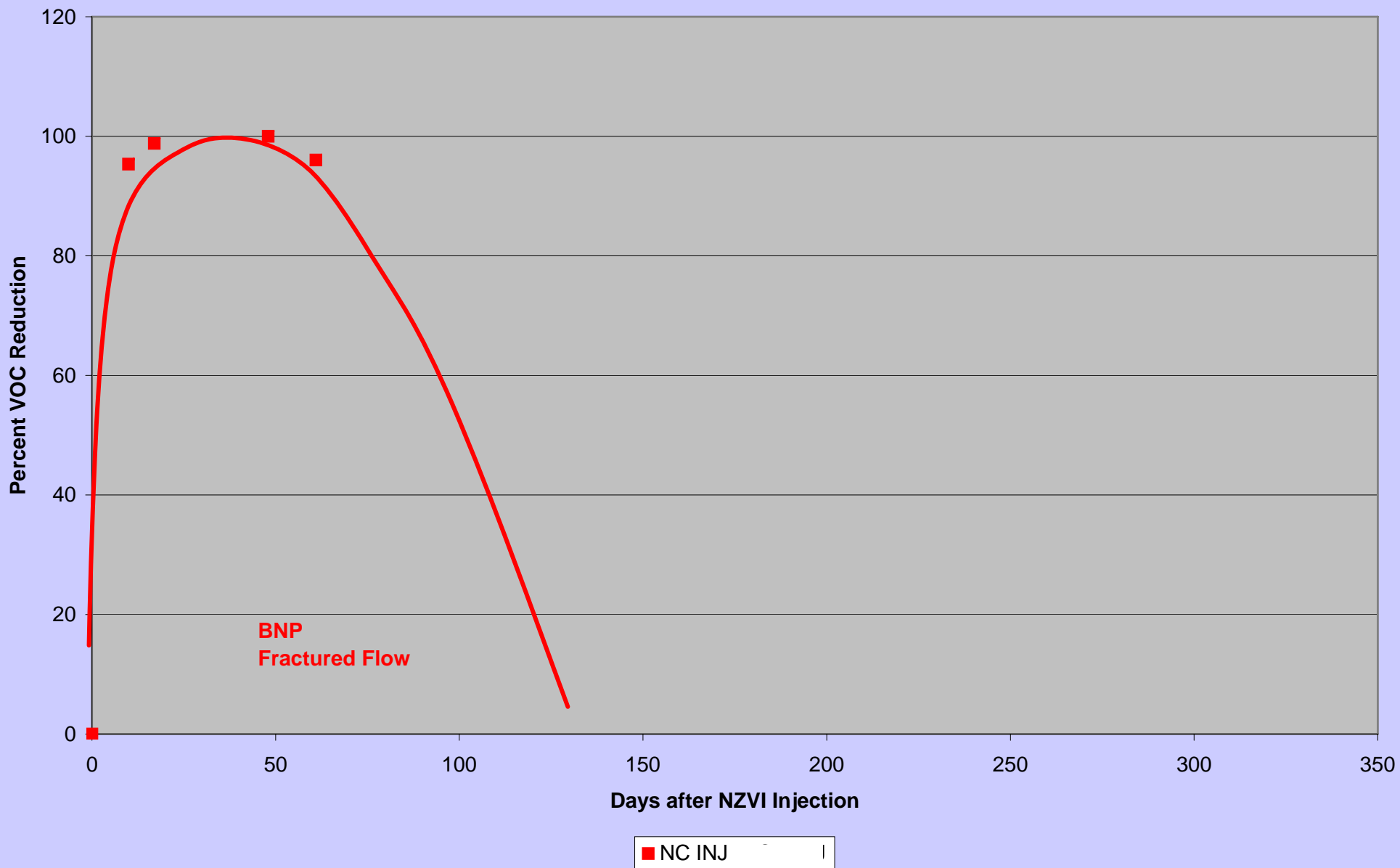
Diagram S^Q. T = 25 °C, P = 1.013 bara (atm) = 10^{-3.689}, a [H₂O] = 1, a [HCO₃⁻] = 10^{-2.222}, (speciates)Suppressed: Sulfur-Rhmb



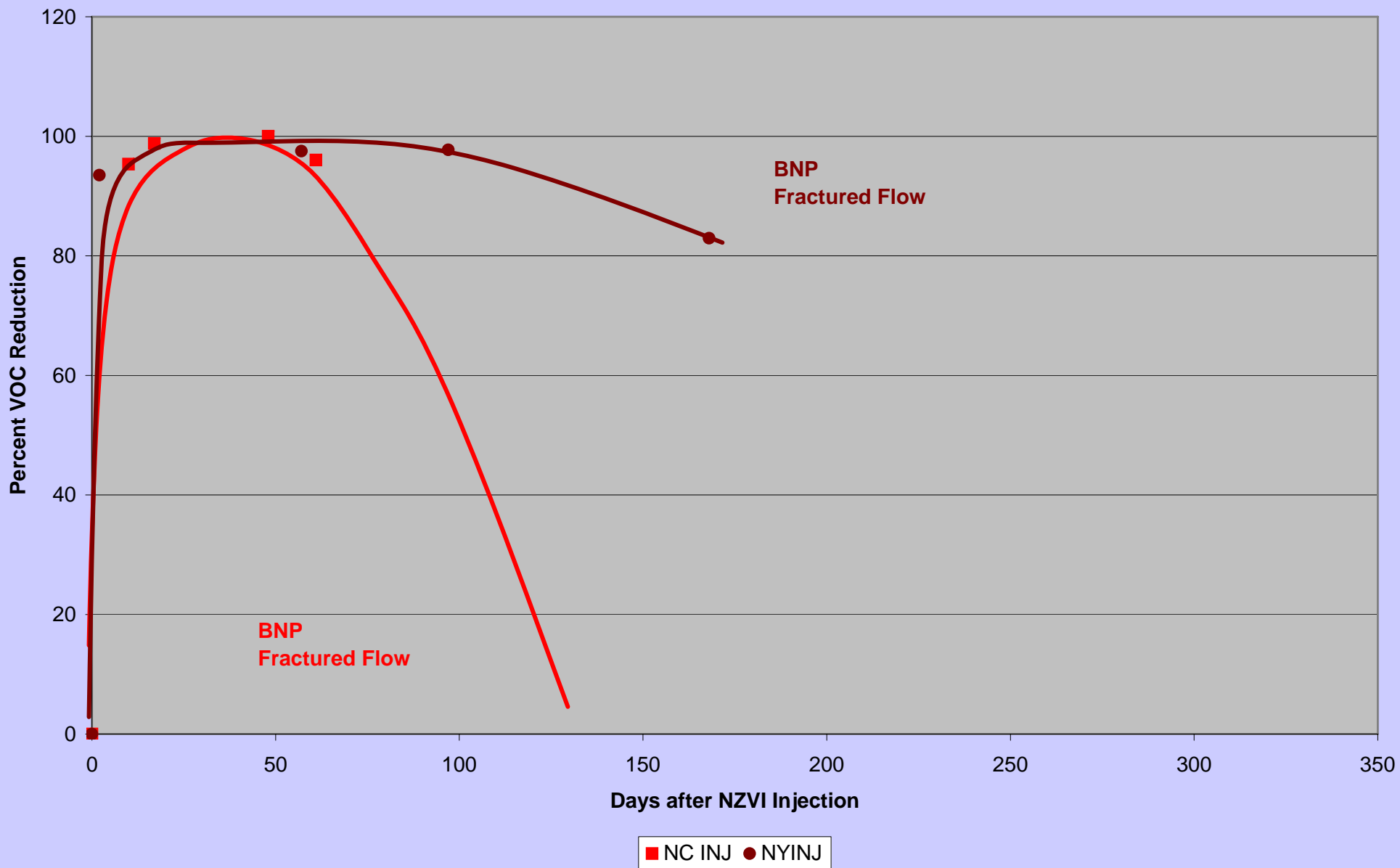
Microbial Community Structure



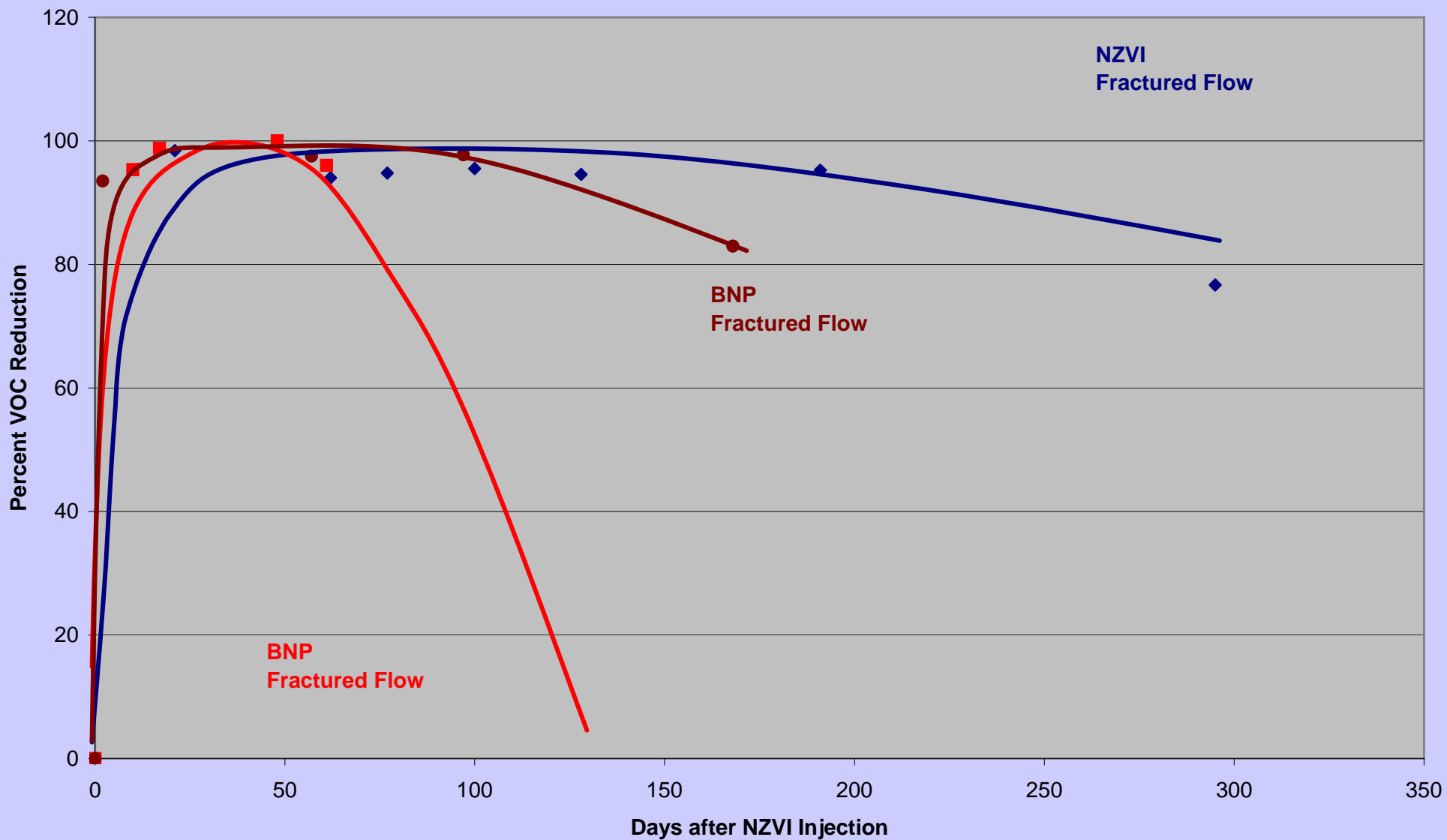
Percent VOC Reduction in Injection Wells



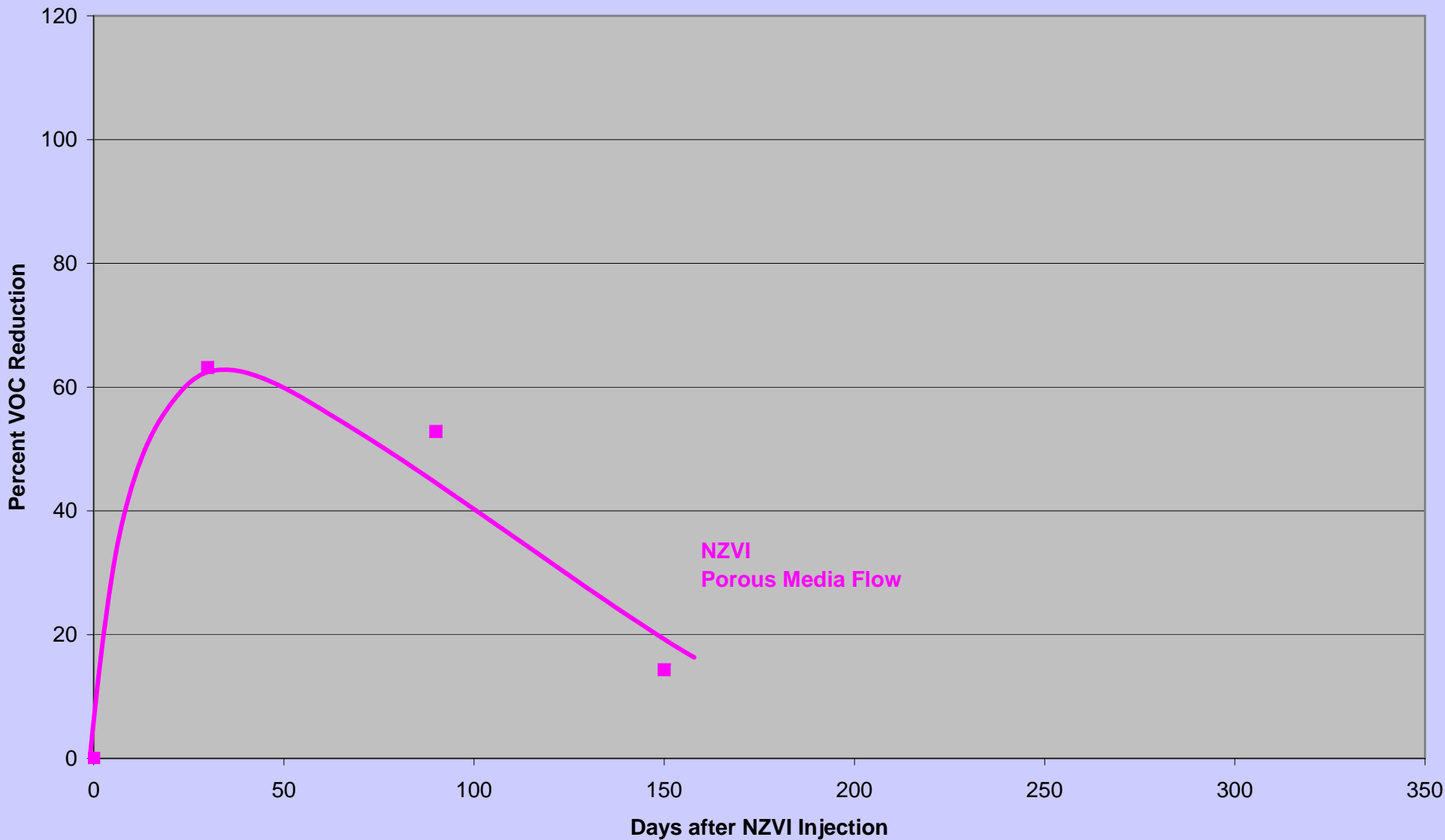
Percent VOC Reduction in Injection Wells



Percent VOC Reduction in Injection Wells

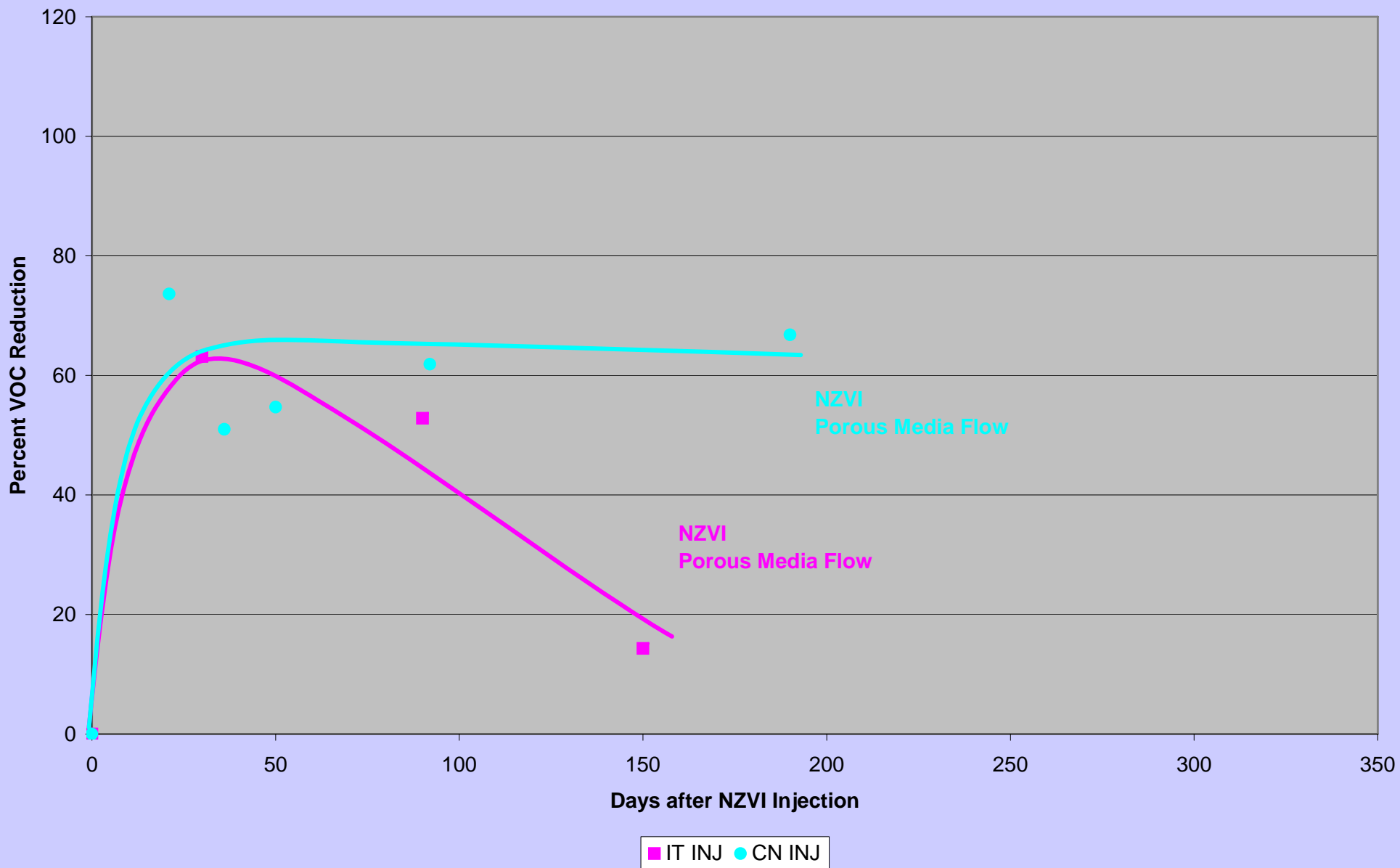


Percent VOC Reduction in Injection Wells

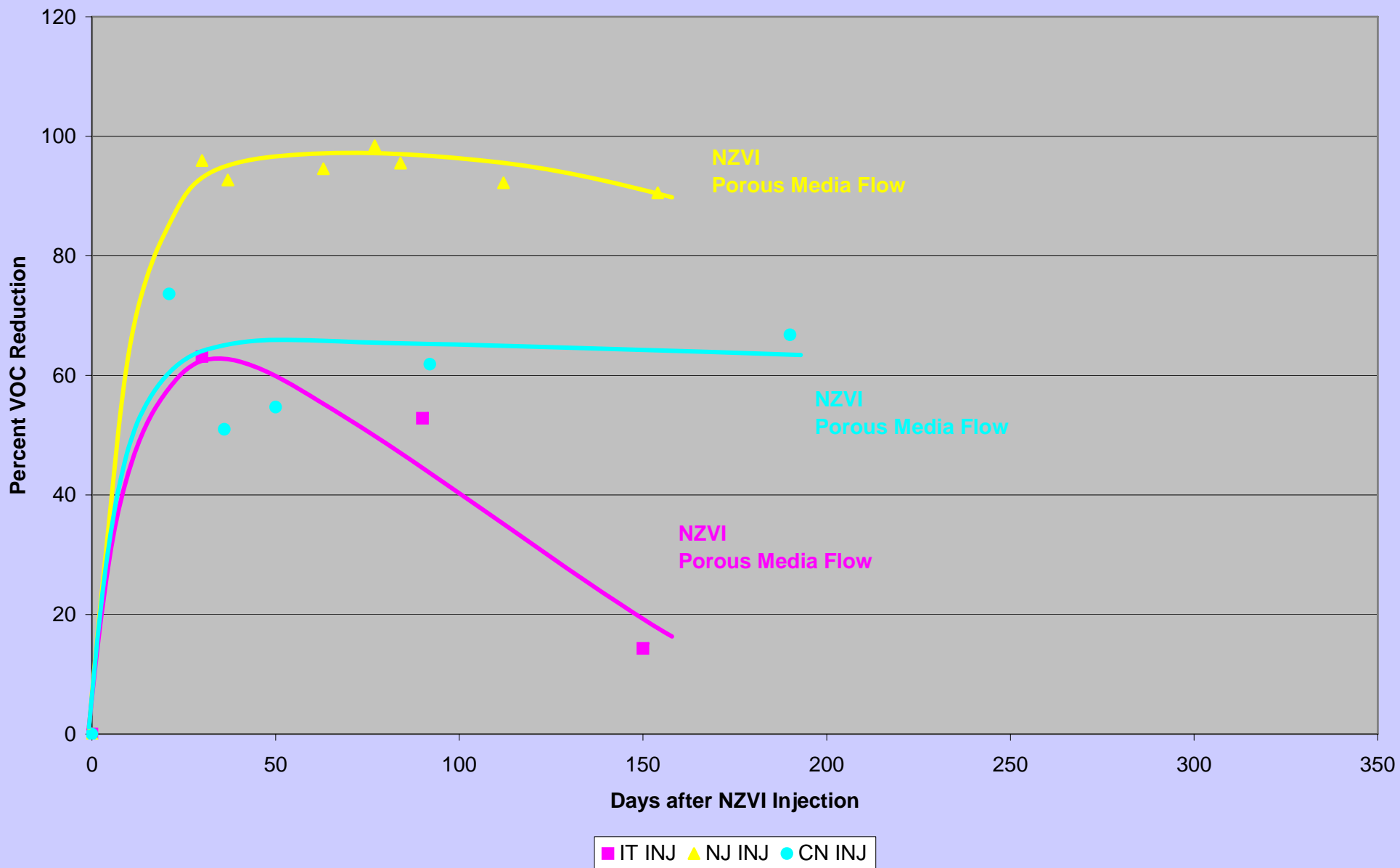


■ IT INJ

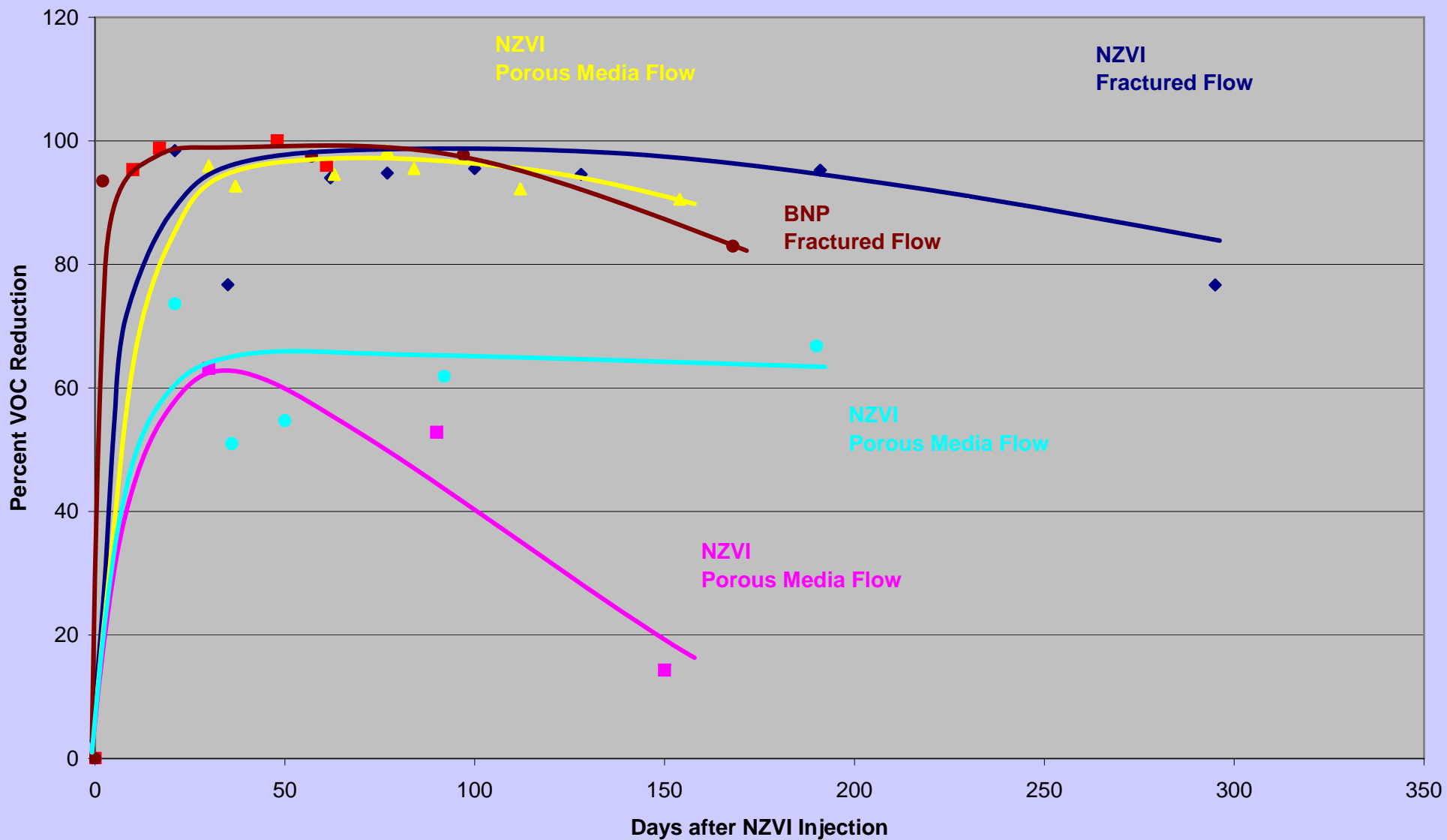
Percent VOC Reduction in Injection Wells



Percent VOC Reduction in Injection Wells

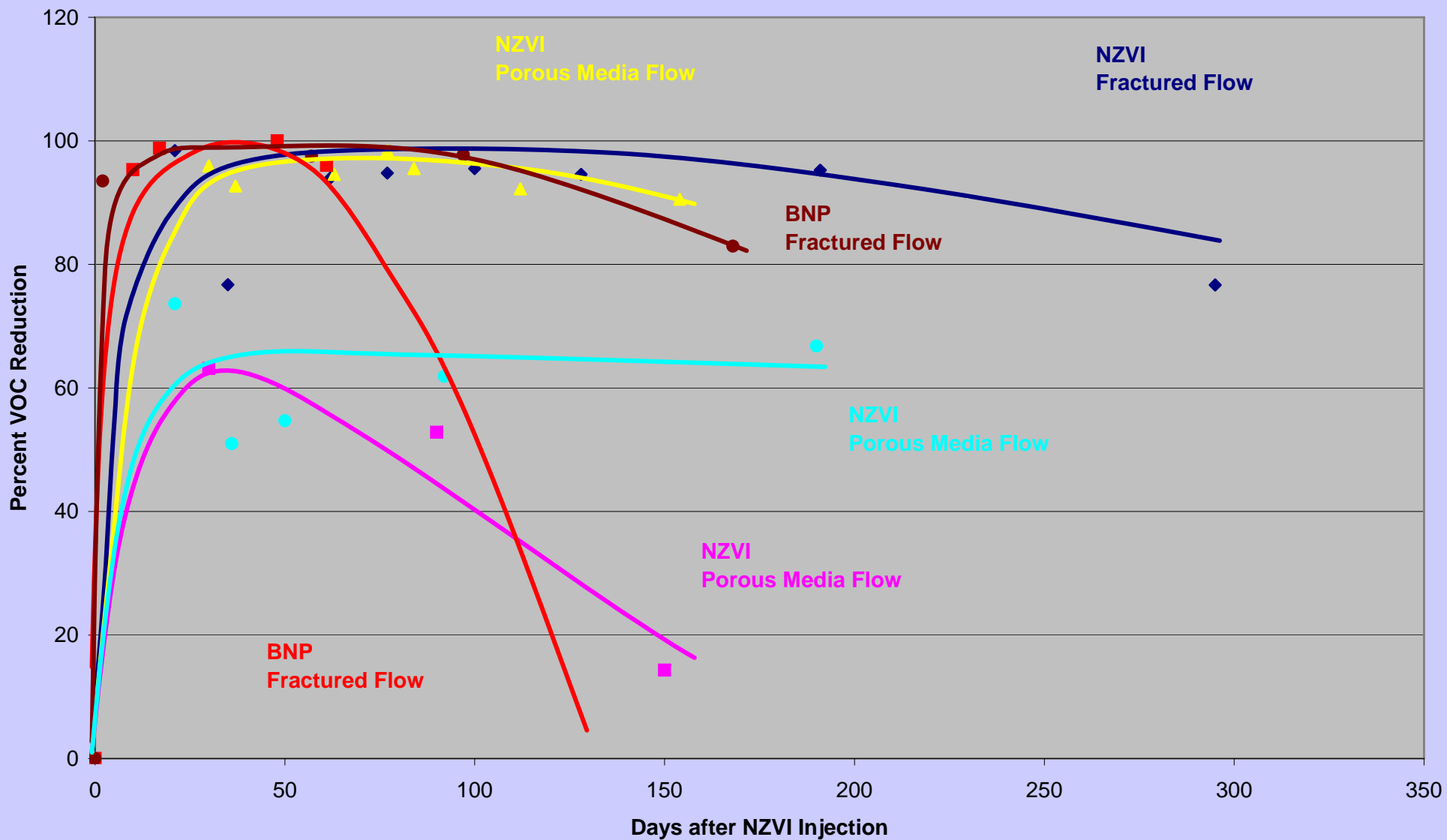


Percent VOC Reduction in Injection Wells



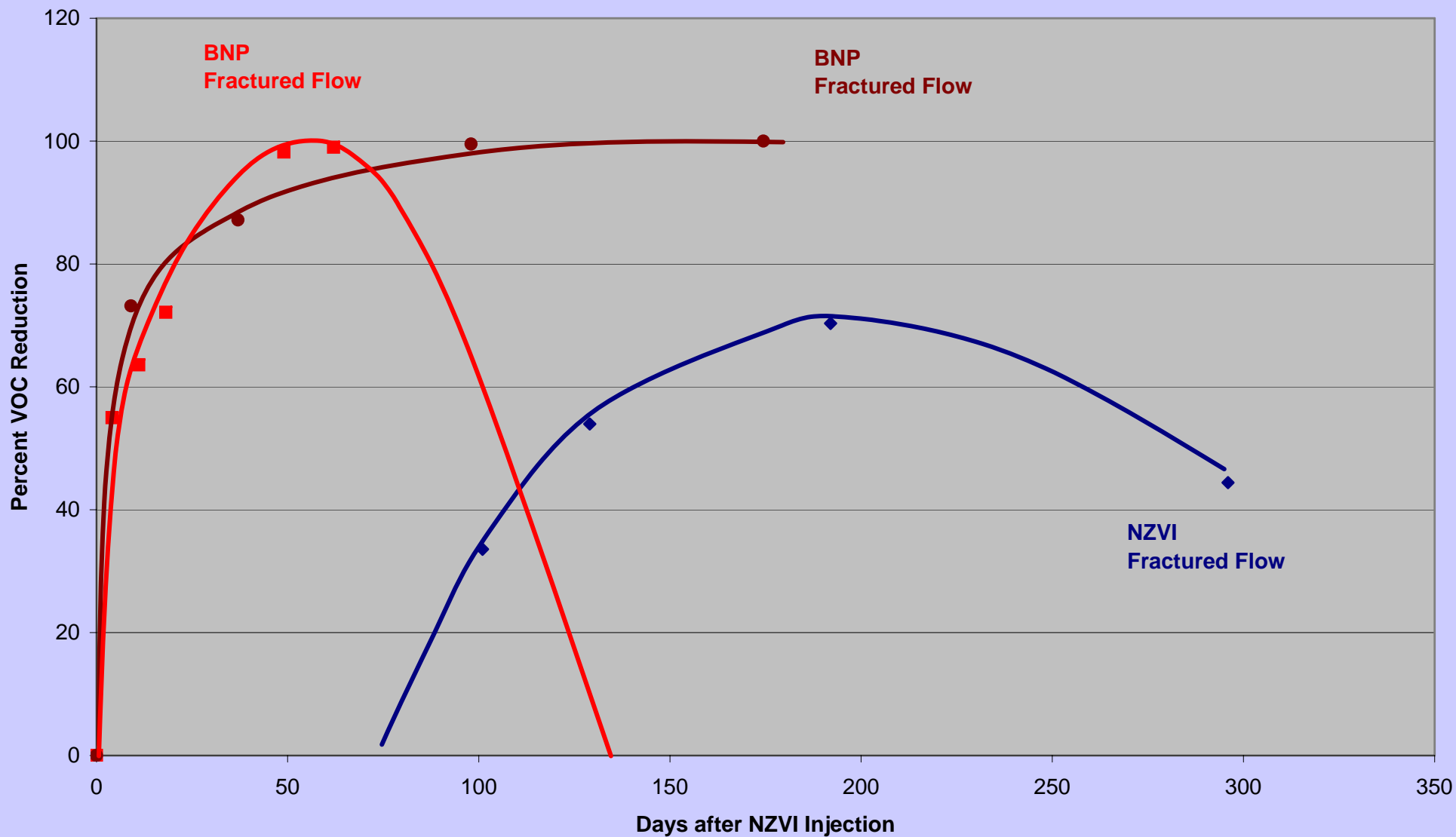
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Percent VOC Reduction in Injection Wells



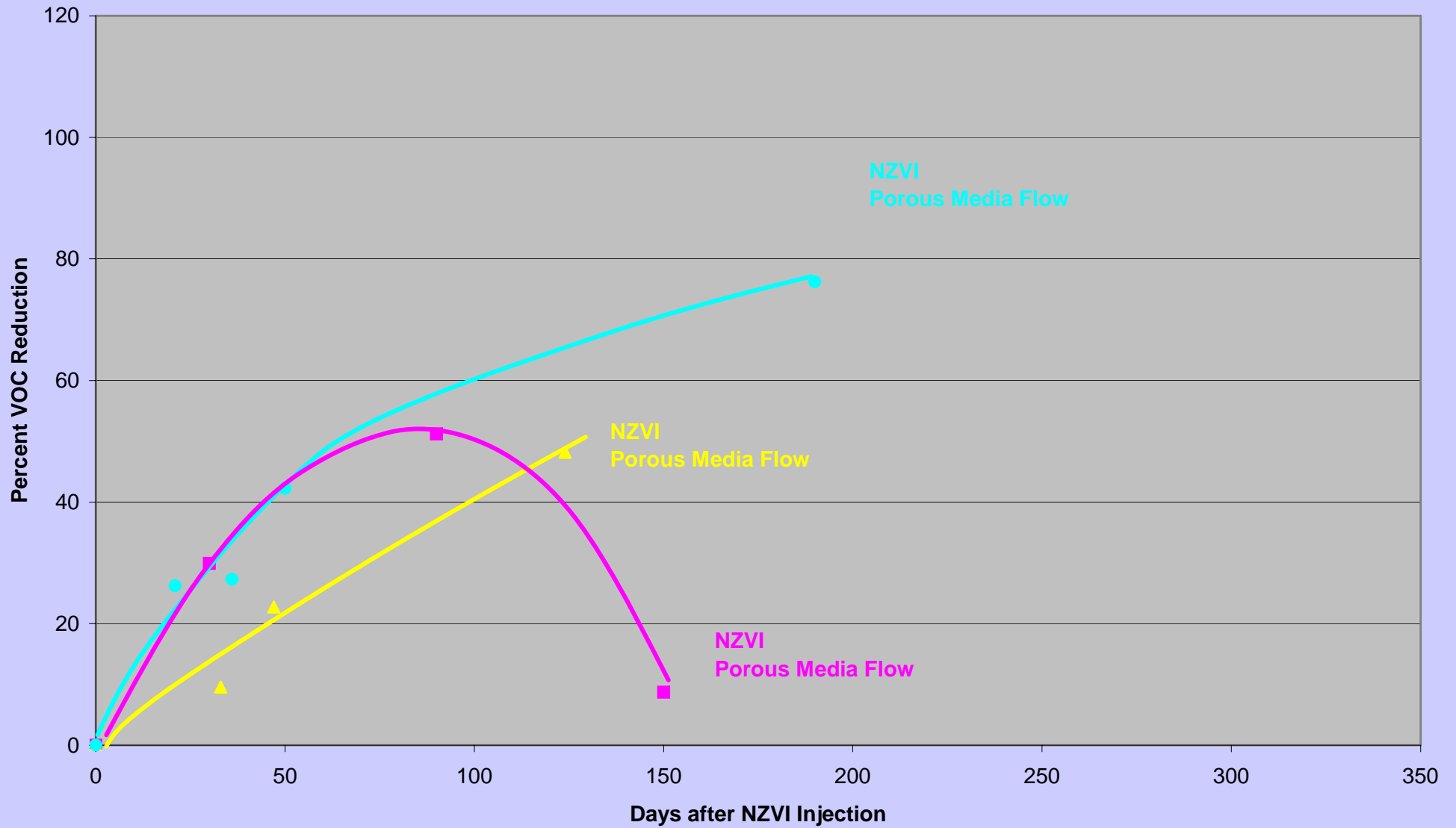
◆ CZ1 INJ ■ IT INJ ▲ NJ INJ ● CN INJ ■ NC INJ ● NYINJ

Percent VOC Reduction in Monitoring Wells

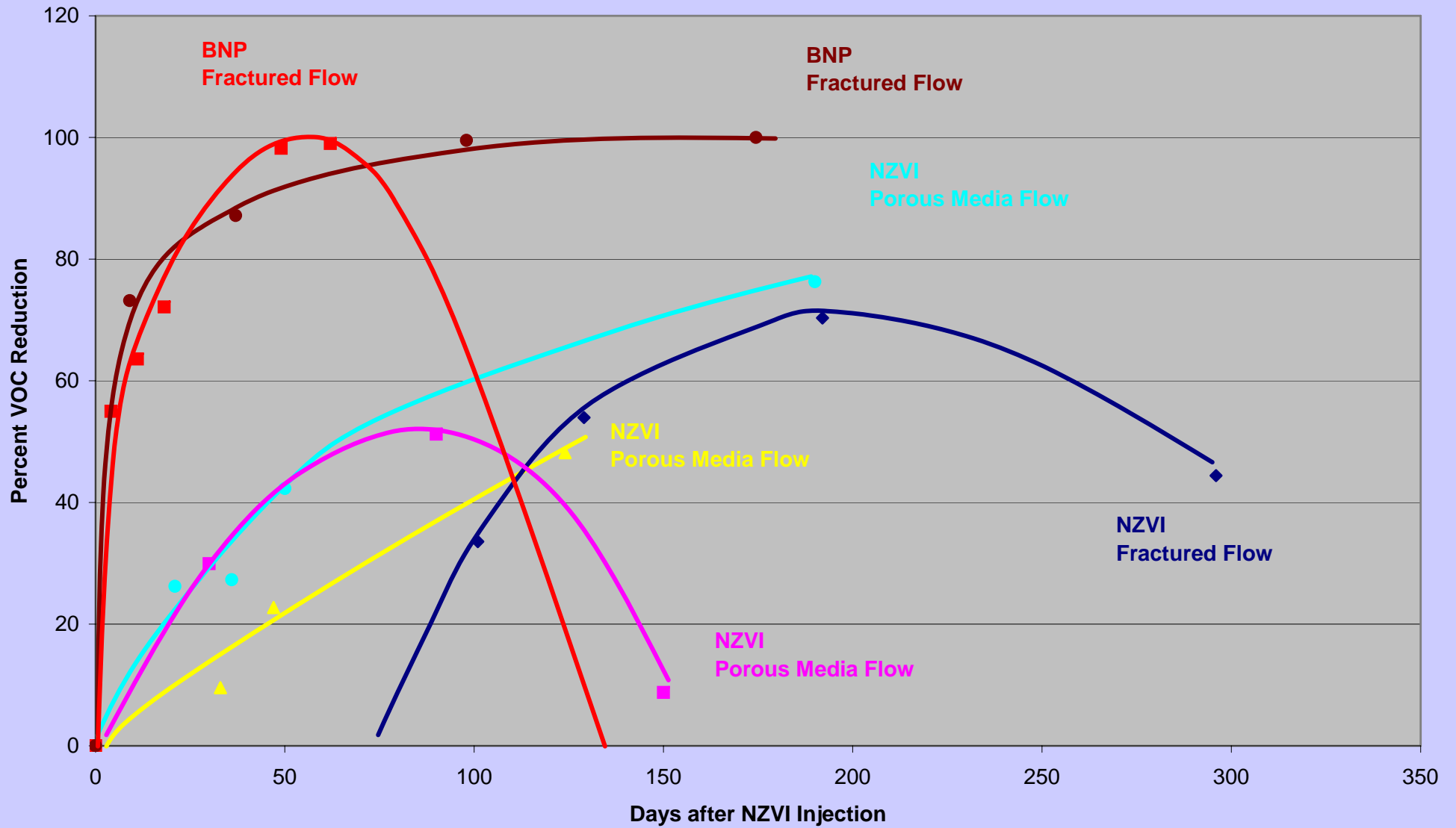


◆ CZ1 MW ■ NC MW ● NY MW

Percent VOC Reduction in Monitoring Wells



Percent VOC Reduction in Monitoring Wells



◆ CZ1 MW ■ IT MW ▲ NJ MW ● CN MW ■ NC MW ● NY MW

Implementability



Implementability



Conclusions

- Dramatic decrease of VOC concentrations over short time in fractured bedrock aquifers
- Slower but steady decrease of VOC concentrations in primary porosity aquifers
- Iron particles travel with groundwater, quicker in fractured media, slower in unconsolidated sediments
- Persistence of VOC treatment over a long period of time (BNP react quicker but are spent more rapid, NZVI react slower but have longer effect)
- Does not eliminate anaerobic bacterial activity