Modeling LNAPL Depletion at a Former Xylene Processing Facility (Germany)

by Grant R. Carey, Ph.D.

Porewater Solutions

Ottawa, Ontario, Canada

www.porewater.com gcarey@porewater.com

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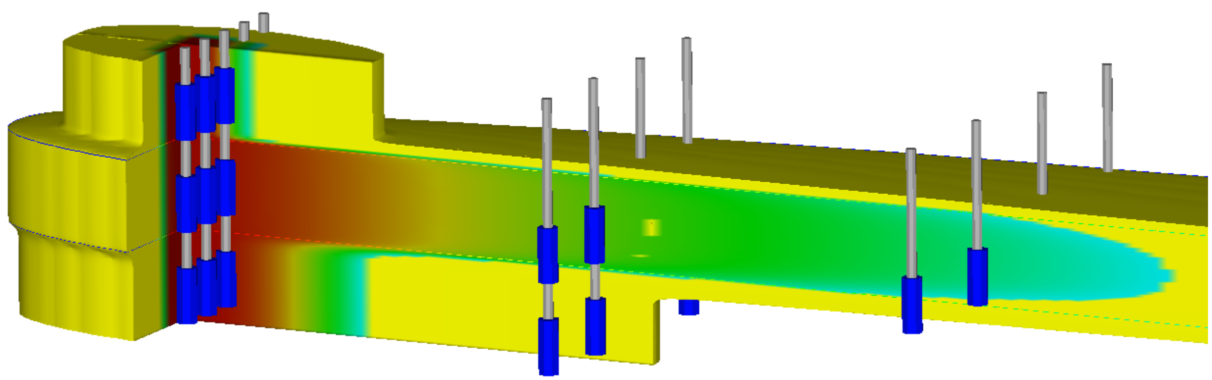
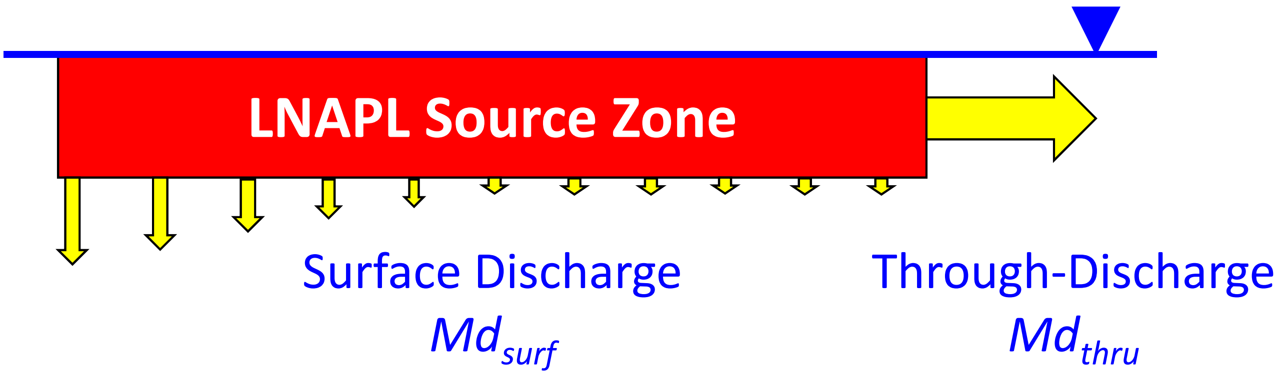


LNAPL Depletion Modeling



Schafer and Therrien (1995)
Former Xylene Processing Facility

- **Screening Model Uses**
  - Compare Timeframes
  - Refine CSM
  - Identify data gaps
  - Regulatory support
- **Critical field properties**
  - LNAPL thickness
  - Transverse dispersivity
- **Case study example**

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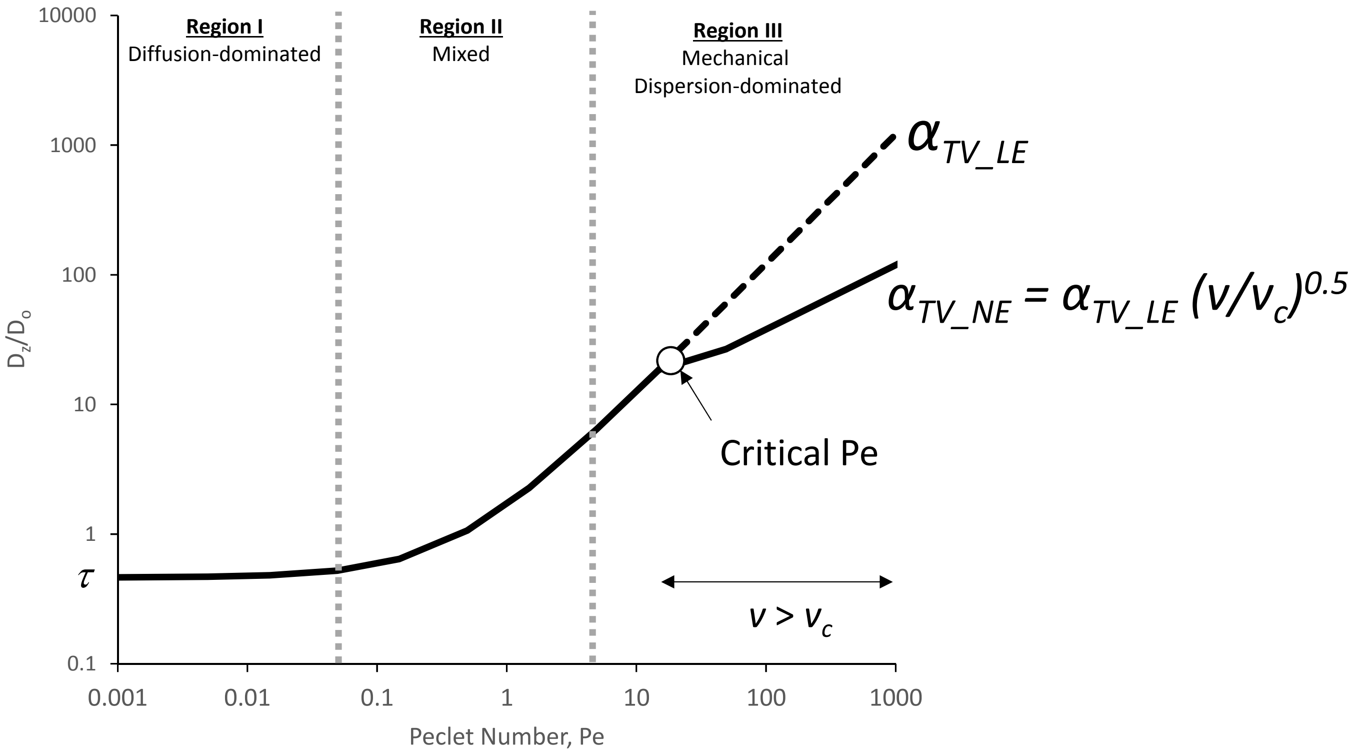
Transverse Vertical Dispersivity

Klenk and Grathwohl (2002), and Carey et al. (2018)



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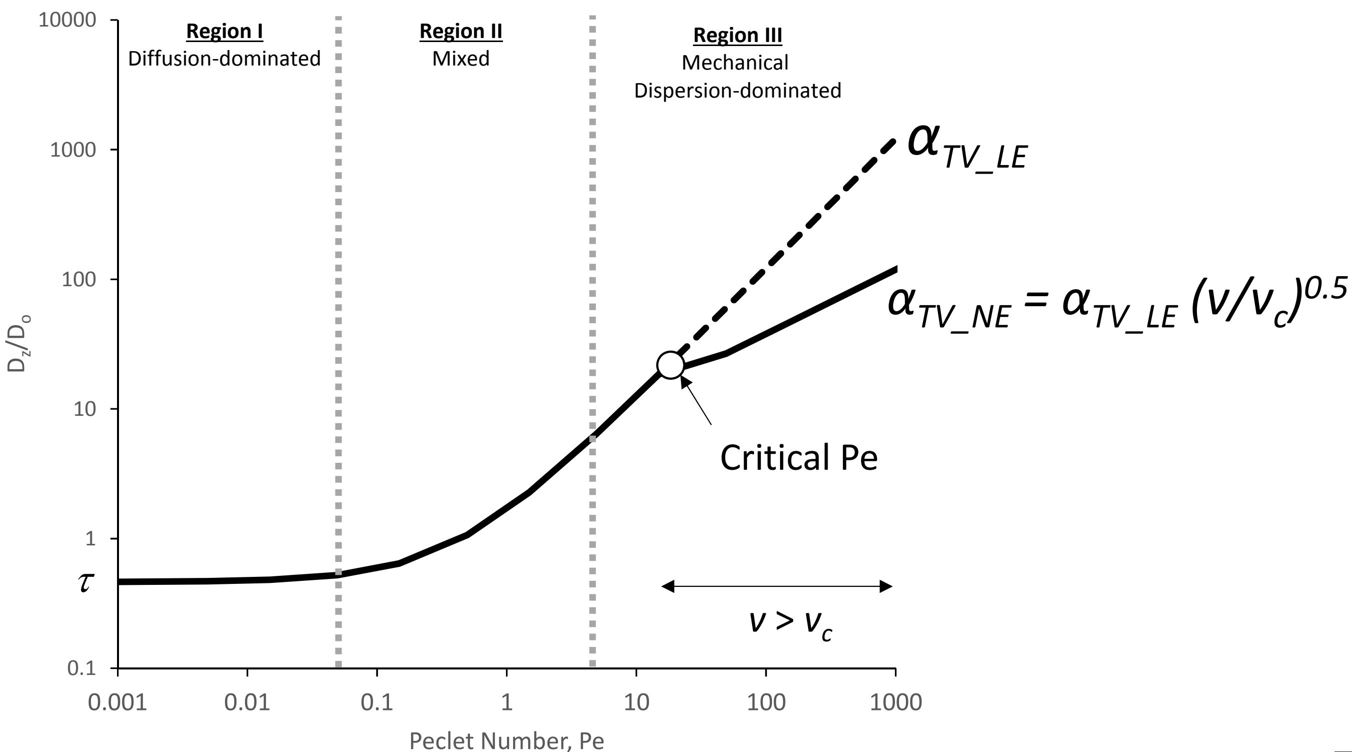
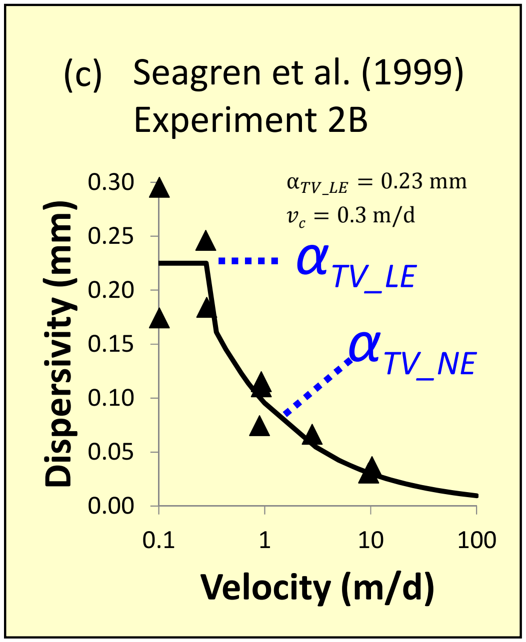
Transverse Vertical Dispersivity

Klenk and Grathwohl (2002), and Carey et al. (2018)



Carey et al. (2018)



v_c ~ 3 to 5 m/d for pool dissolution

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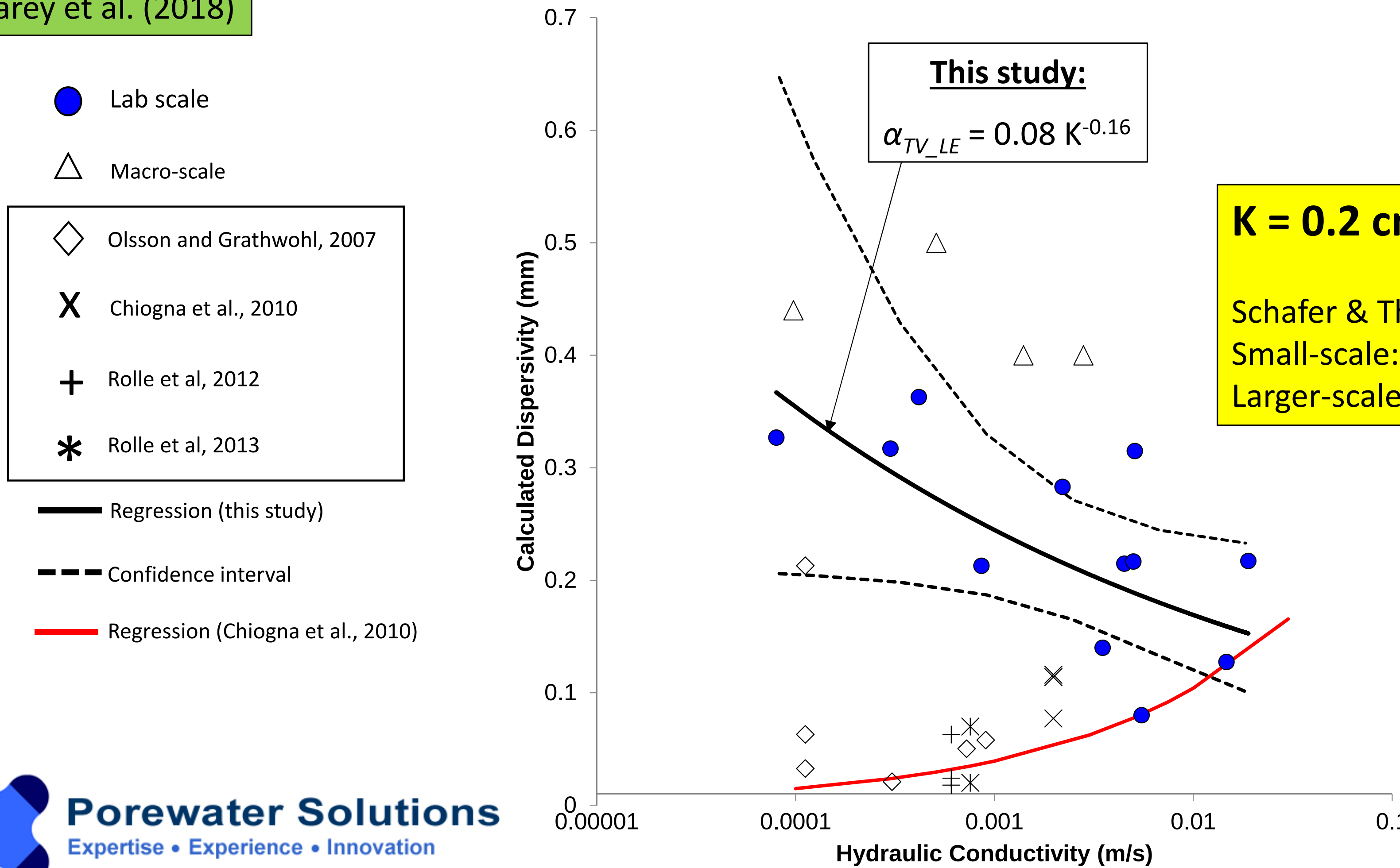
Transverse Vertical Dispersivity (LE) vs. K

Carey et al. (2018)



K = 0.2 cm/s

Schafer & Therrien: α_{TV_LE} = 10 mm
Small-scale: α_{TV_LE} = 0.22 mm
Larger-scale: α_{TV_LE} = 0.4 mm

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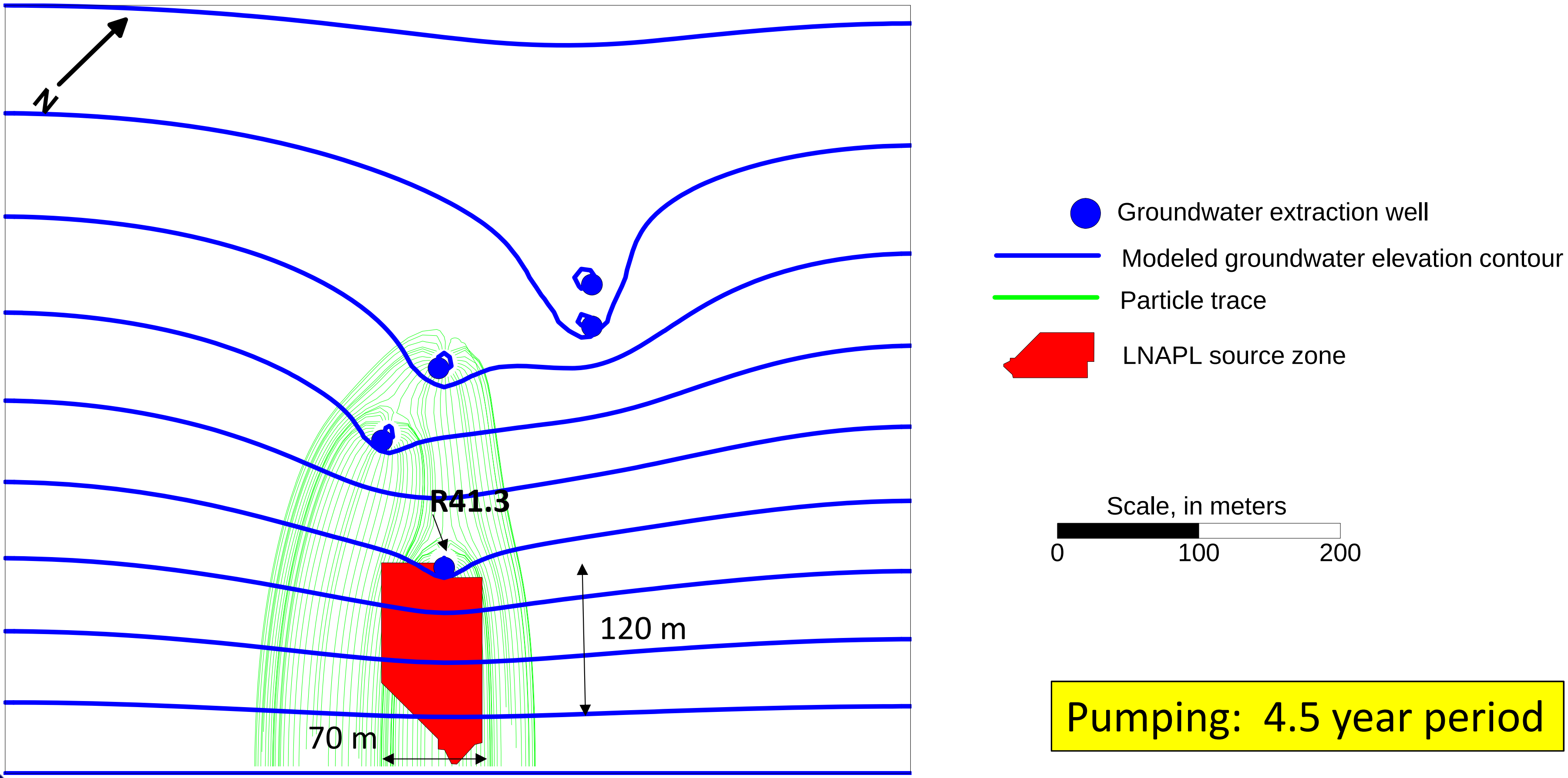
Former Xylene Processing Facility (Germany)



Pumping: 4.5 year period

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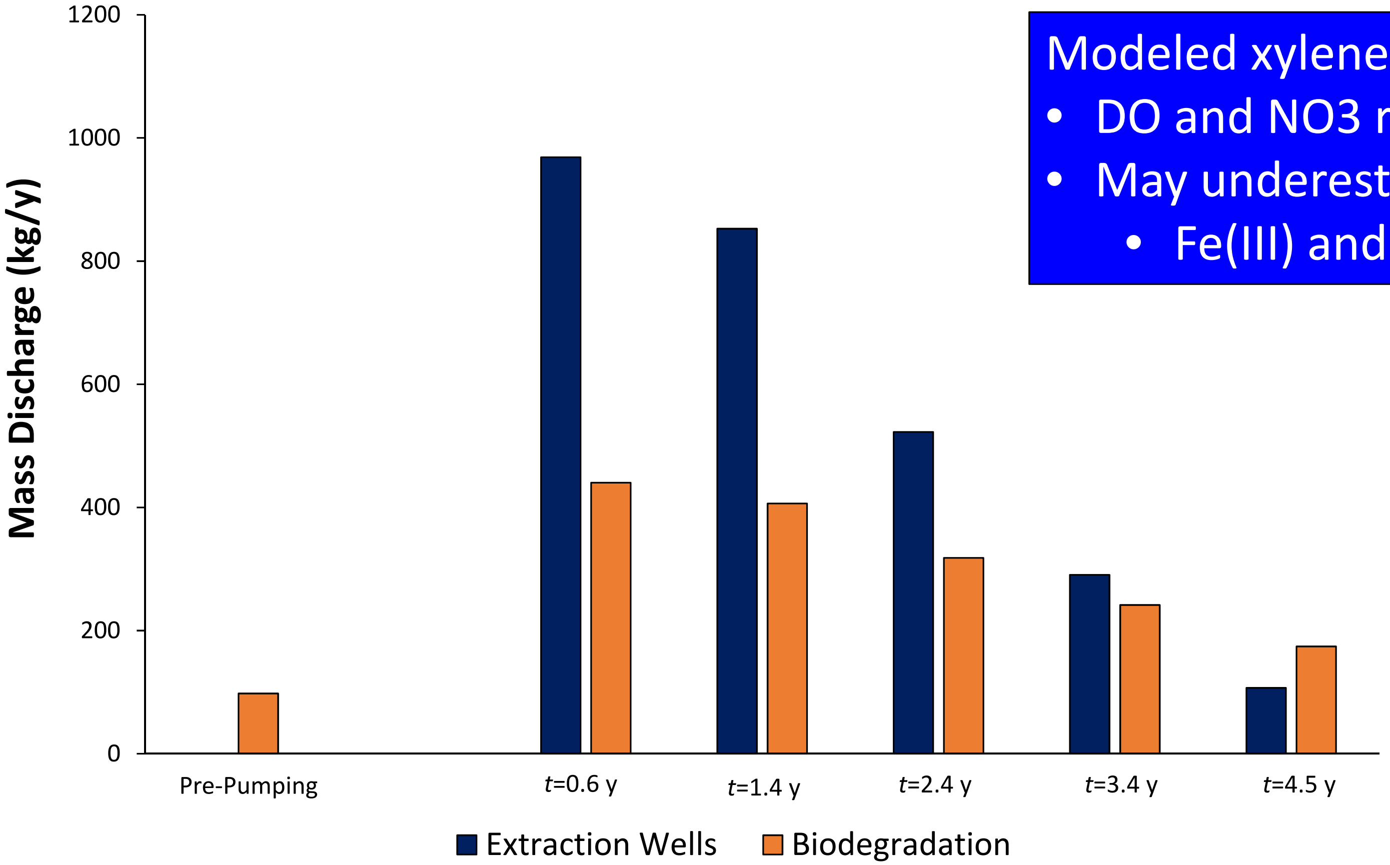
Estimated Mass Discharge Based on Schafer and Therrien (1995)



Modeled xylene biodegradation
- DO and NO3 reduction only
- May underestimate actual by 2x
  - Fe(III) and SO4 reduction

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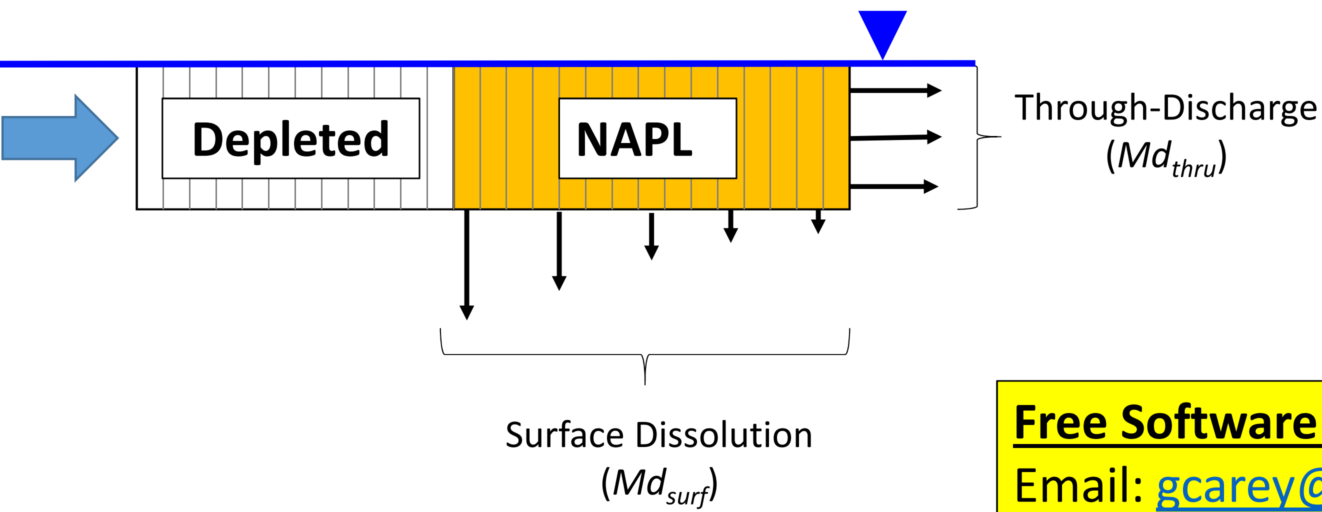
NAPL Depletion Model (NDM): Mass Discharge

Carey et al. (2014a)



Free Software:
Email: gcarey@porewater.com
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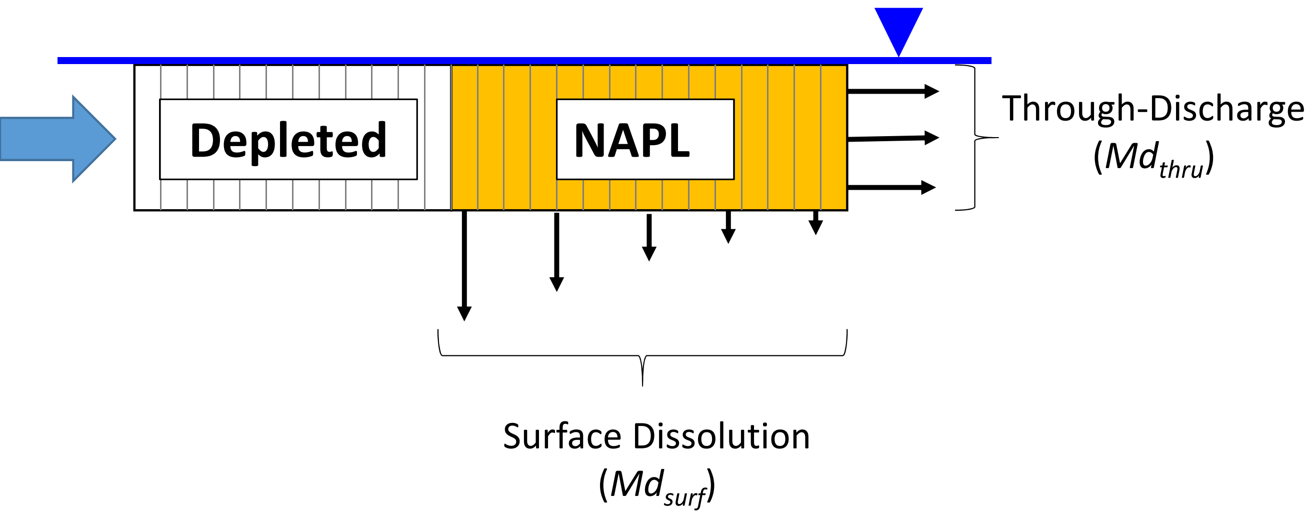
NAPL Depletion Model (NDM): Mass Discharge

Carey et al. (2014a)



Empirical Relationship (*K* in m/s)	
$\tau = 0.60\, K^{0.030}$	(i)
$\theta_t = 0.30\, \mathrm{K}^{-0.026}$	(ii)
$\theta_e = 0.41\, \mathrm{K}^{0.064}$, $\mathrm{K} \leq 1\mathrm{x}10^{-2}$ m/s	(iii)
$\theta_e = (0.29\, \mathrm{K}^{-0.026}) - 0.03$, $\mathrm{K} > 1\mathrm{x}10^{-2}$ m/s	(iv)
$\alpha_{TV} = 0.08\, \mathrm{K}^{-0.16}$, $v \leq v_c$	(v)
$\alpha_{TV\_NE} = 0.08\, \mathrm{K}^{-0.16}\, (v_c/v)^{0.5}$, $v > v_c$	(vi)
$\alpha_{aw} = 0.112\, (100\, K)^{0.211}$	(vii)
$n = 13.14\, (100\, K)^{0.246}$ $\mathrm{K} \geq 1\mathrm{x}10\text{-}4$ m/s	(viii)
$S_{wr} = 0.015\, (100\, K)^{-0.218}$	(ix)

Carey et al. (2015a,b,c)

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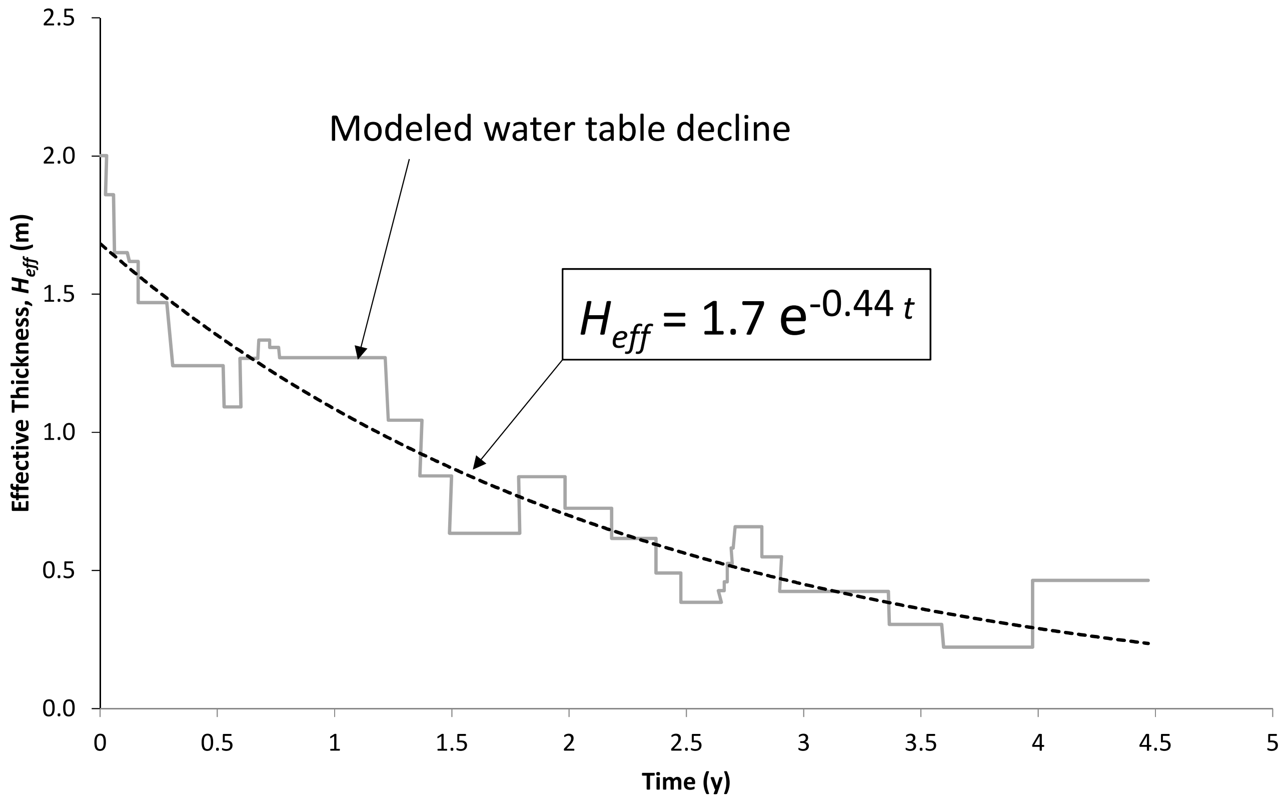
Saturated Source Zone Thickness vs. Time



Note: Effective thickness of the LNAPL source zone was determined based on an assumed source zone bottom elevation of 19.75 m, and the fluctuating water table elevation. t=0 corresponds to May 1, 1988.

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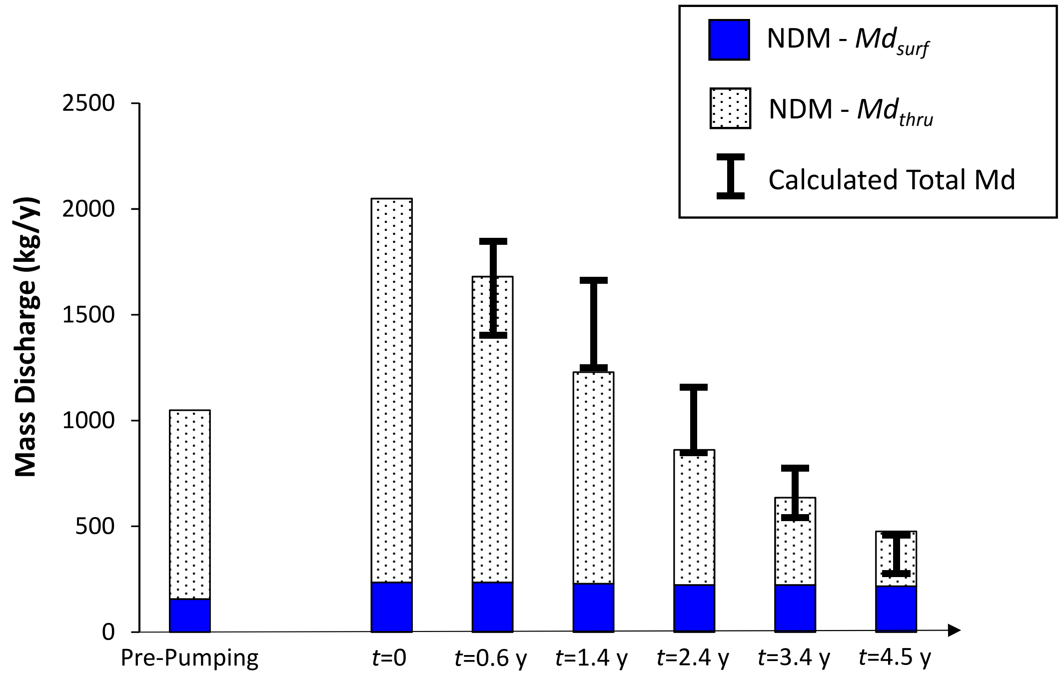
Modeled and Estimated Mass Discharge



Notes:

1. Groundwater extraction system started at t=0.

2. Md = mass discharge.

3. Range in calculated total Md is based on the potential difference between including and excluding xylene biodegradation under manganogenesis, ferrogenesis, and sulfate reduction.

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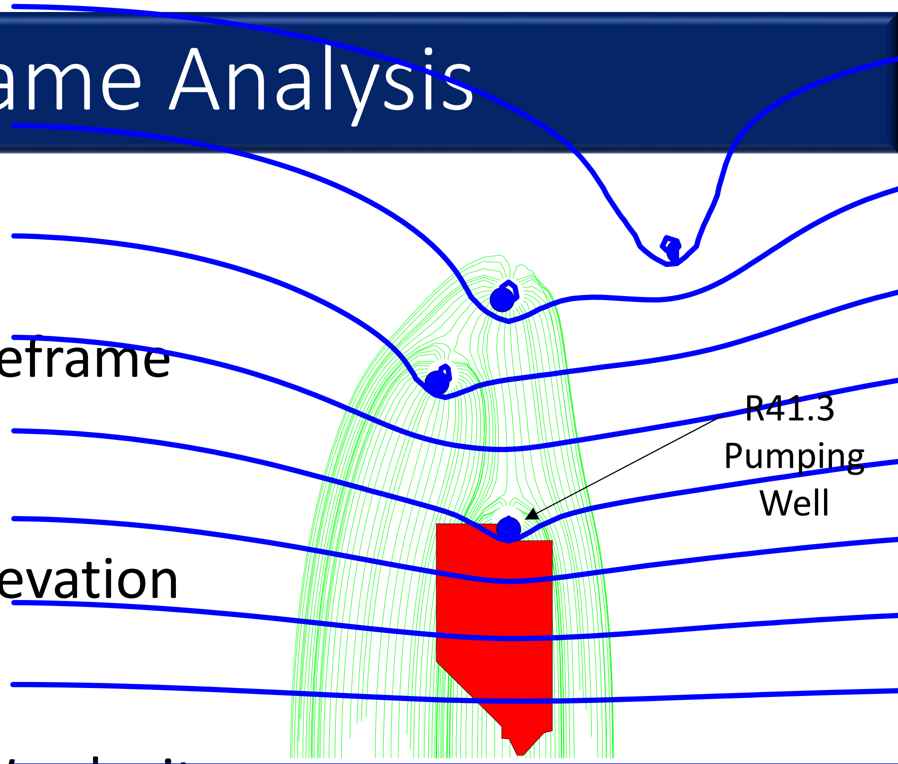
Remediation Timeframe Analysis

Goal

- Evaluate influence of Q on depletion timeframe

Approach

- Assume constant, average water table elevation
  - Source zone 0.85 m thick below water table
- Evaluate influence of increasing Q on GW velocity
- Model LNAPL depletion for each scenario



Scenarios
Q=0 (MNA)
Qx1 (system design)
R41.3 Qx2
R41.3 Qx4

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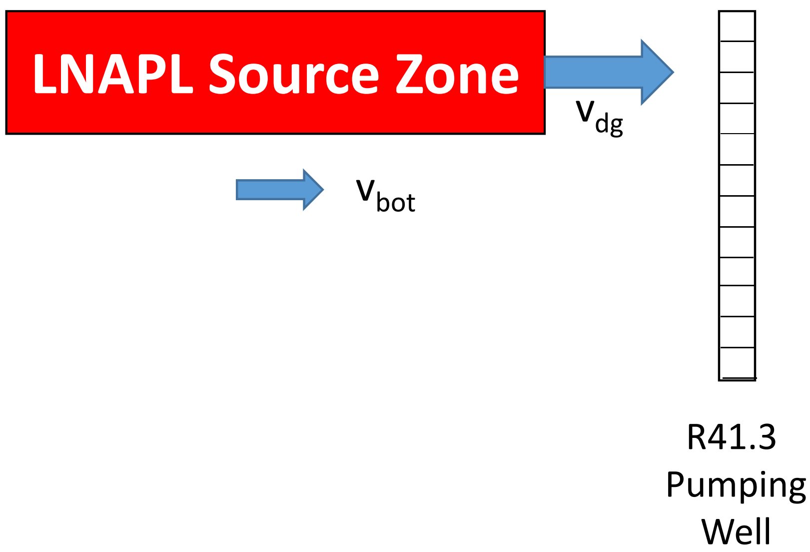
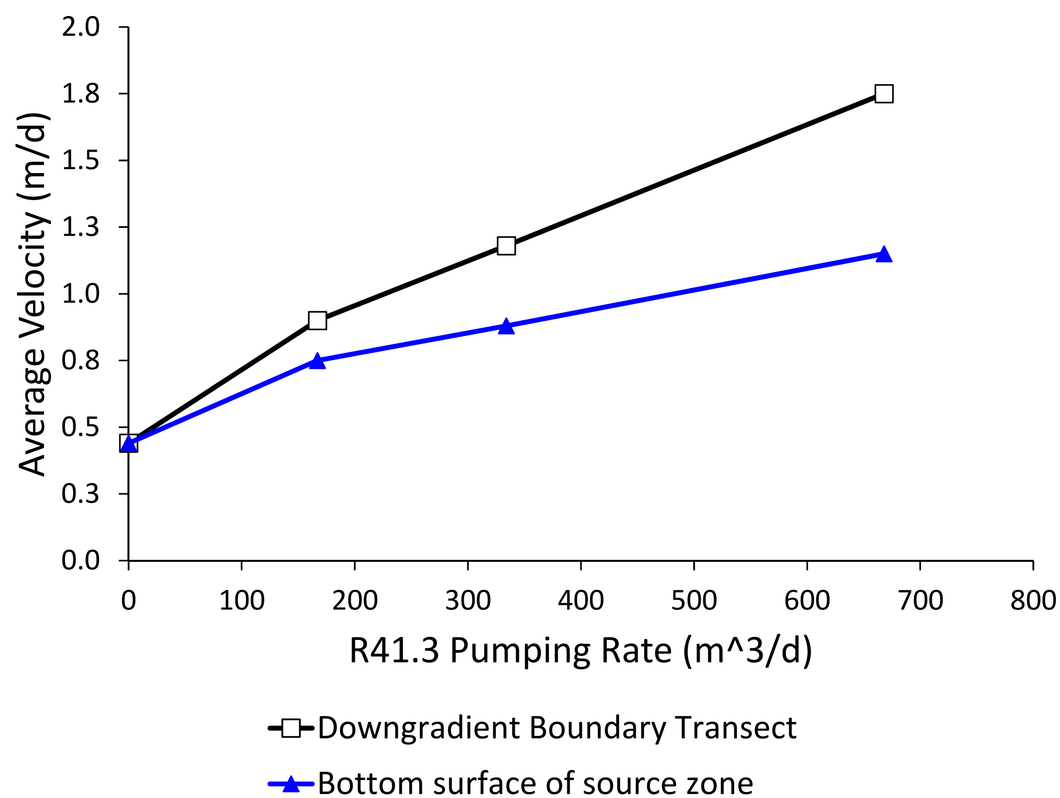
Velocity vs. Pumping Rate





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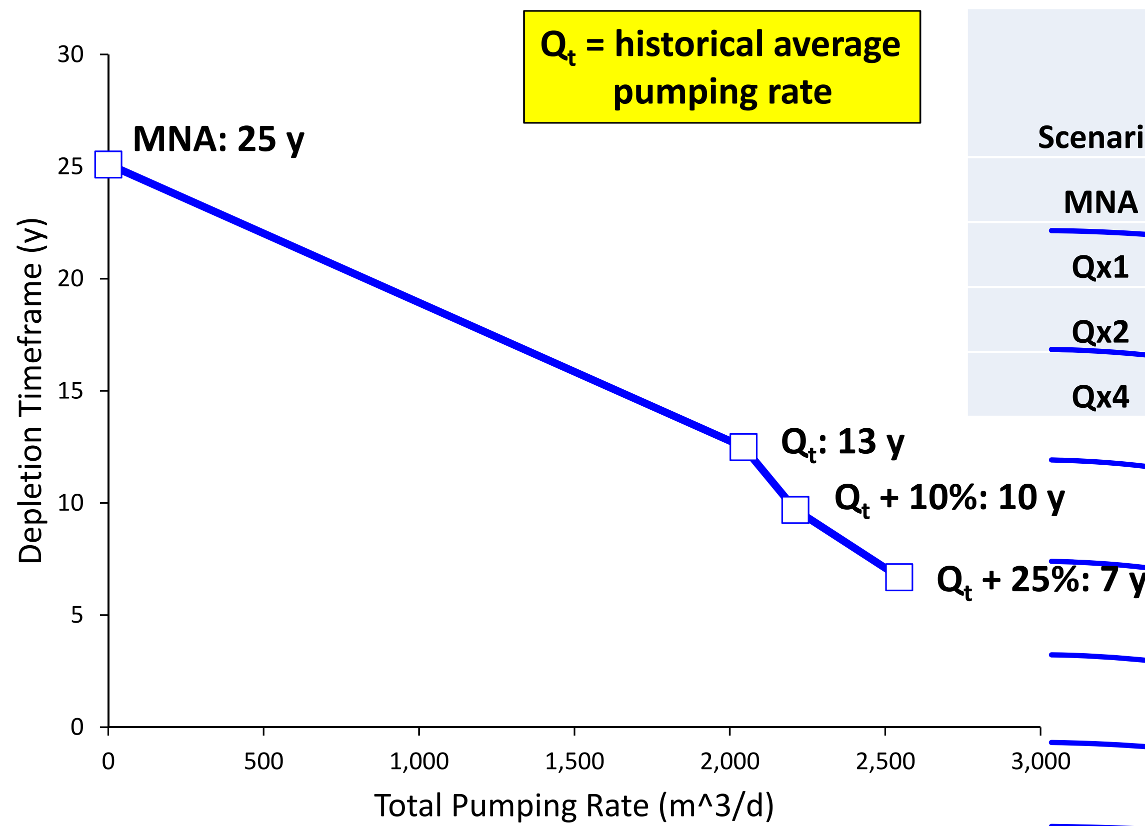
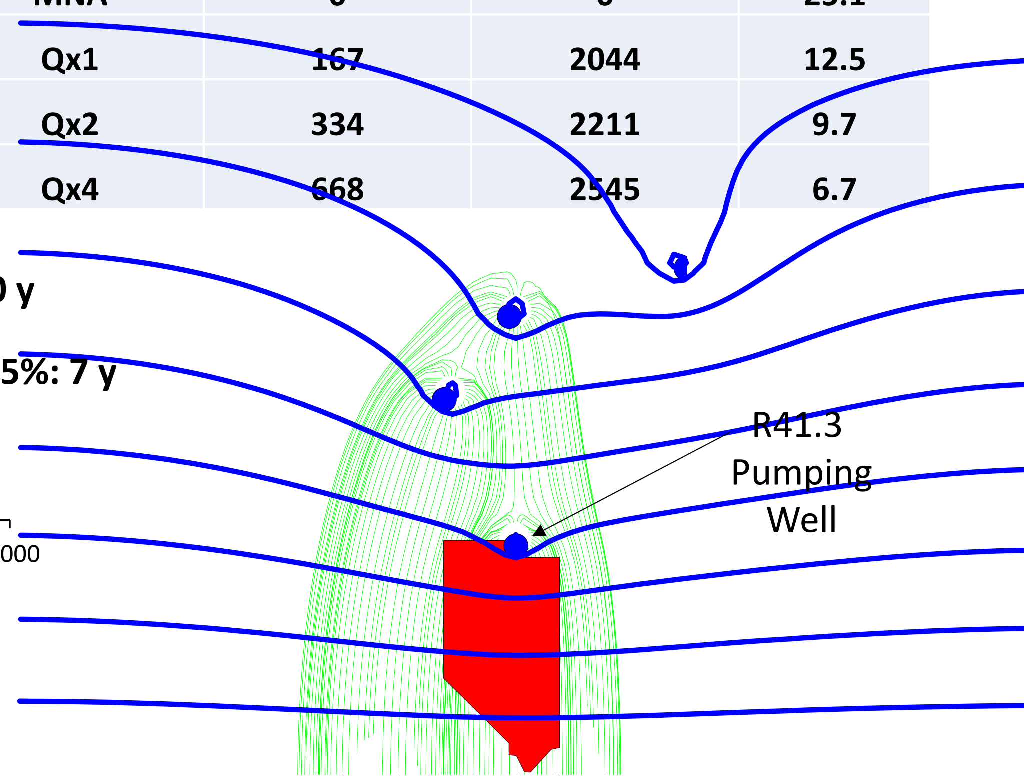
Note: Pumping rates at extraction wells R41.2, R41.4, R41.6, and R41.8 were simulated to be constant for all scenarios where the R41.3 well pumping rate was greater than zero.

Depletion Timeframe vs. Total Pumping Rate



Scenario	R41.3 Pumping Rate (m^3/d)	Combined Pumping Rate (m^3/d)	Remediation Timeframe (y)
MNA	0	0	25.1
Qx1	167	2044	12.5
Qx2	334	2211	9.7
Qx4	668	2545	6.7



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Summary

- Transverse dispersivity based on K
- Model matched estimated mass discharge vs. time
  - Without any input calibration
- MNA may be appropriate if no receptors at risk
- Increased pumping rate at R41.3
  - Small incremental cost
  - Large reduction in remediation timeframe

Questions

Grant Carey, Ph.D.
Porewater Solutions

613-270-9458
gcarey@porewater.com
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