Linkages between agricultural practices and the quality of groundwater

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Environment and Climate Change Canada

Watershed Hydrology and Ecology Research Division

Water Science & Technology Directorate

Science and Technology Branch

Agriculture and Agri-Food Canada

Environmental Health

Research and Development (Coastal Region)

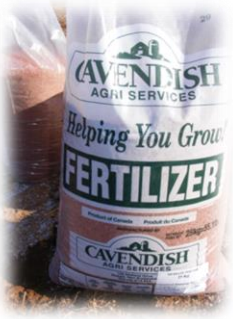
Fredericton Research and Development Centre

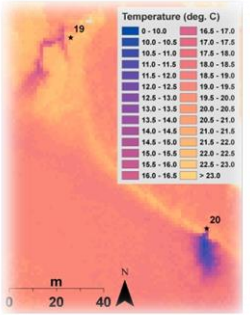
Science and Technology Branch

Geotop Seminar - February 23rd, 2017

Research program

- **Focus**
  - Assessment of the impacts of agricultural practices on groundwater quantity and quality
- **Research areas**
  - Nutrients in groundwater
  - Coupling soil/ unsaturated – saturated zone processes
  - Groundwater – surface water interactions
- **Highlights**
  - Numerical modelling of water and nutrient (nitrogen) transport
  - Potato production systems
  - Fractured bedrock (and till)





Departmental mandate

- **AAFC (APH Strategy 2015 – 2018 Draft Action Plan)**
  - Understanding chemical, physical and biological processes that lead to N and P losses from agricultural lands (into surface, groundwater and atmosphere) (Priority 1)

- **ECCC (ECCC Science Strategy 2014 – 2019)**
  - Understand and track the origin, fate and impact of critical contaminants in the environment (air, water, wildlife) (…) (Science Goal)

EC-AAFC joint research

ECCC: Canadian Centre for Inland Waters (CCIW)

Burlington, Ontario

AAFC: Fredericton Research and Development Centre (FRDC)

Fredericton, New Brunswick

- Supports the “Principle of Linkages” (EC SP) and the “Partnering for Impact” strategic goal (AAFC S&I Strategy)
- Reduces the cost/effort of implementing departmental mandates
- Allows direct access to resources (e.g. funding, technical support, scientific expertise) of both departments

CCIW, Burlington, ON (ECCC)

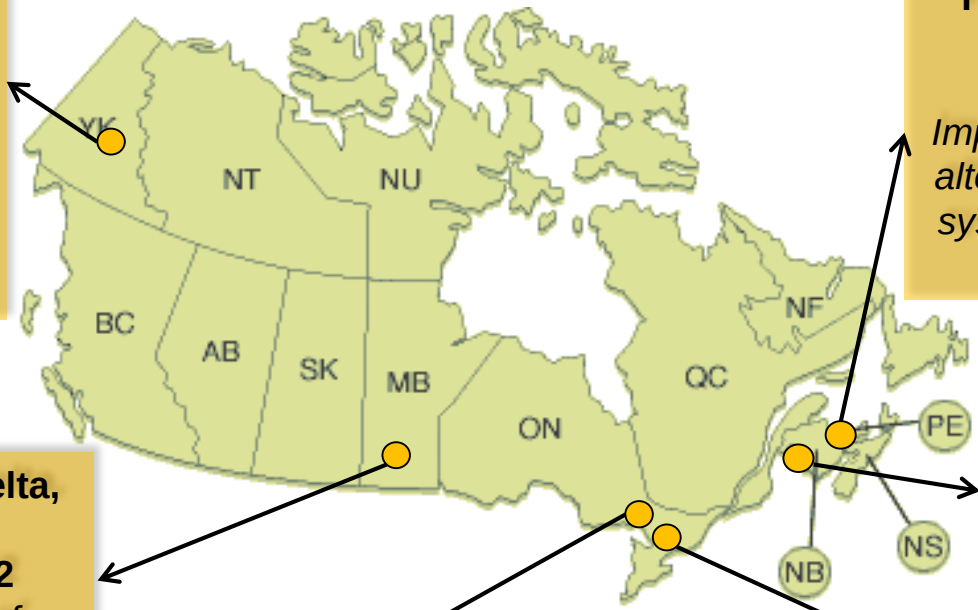
- 600 staff (ECCC, DFO, CCG, RCMP)
  - 3 groundwater scientists
- Main areas of research:
  - Sources, fate and impacts of nutrient and other contaminant loading on aquatic ecosystems (sediment, groundwater, surface water)
  - Algal blooms & biota
  - Emerging contaminants

FRDC, Fredericton, NB (AAFC)

- 12 scientists

- Main areas of research:
  - Potato germplasm enhancement
    - e.g. develop new varieties, gene mapping
  - Crop protection
    - e.g. early detection of viruses and pests, pest control
  - Enhancing the environmental performance of potato production systems
    - e.g. soil science, erosion, surface and groundwater research

Research Projects



Sites TBD
ECCC CCA
Impact of climate change on subsurface flow in permafrost

Harrington, PE (AAFC Experimental Farm)
AAFC GF2
Impact of conventional and alternative potato cropping systems on nitrate loading to groundwater

Black Brook Watershed, NB
AAFC GF2
Linkage between land use and groundwater quality

Assiniboine Delta, MB (TBA)
ECCC LWBI2
Significance of groundwater contribution to N and P loading to Lake Winnipeg

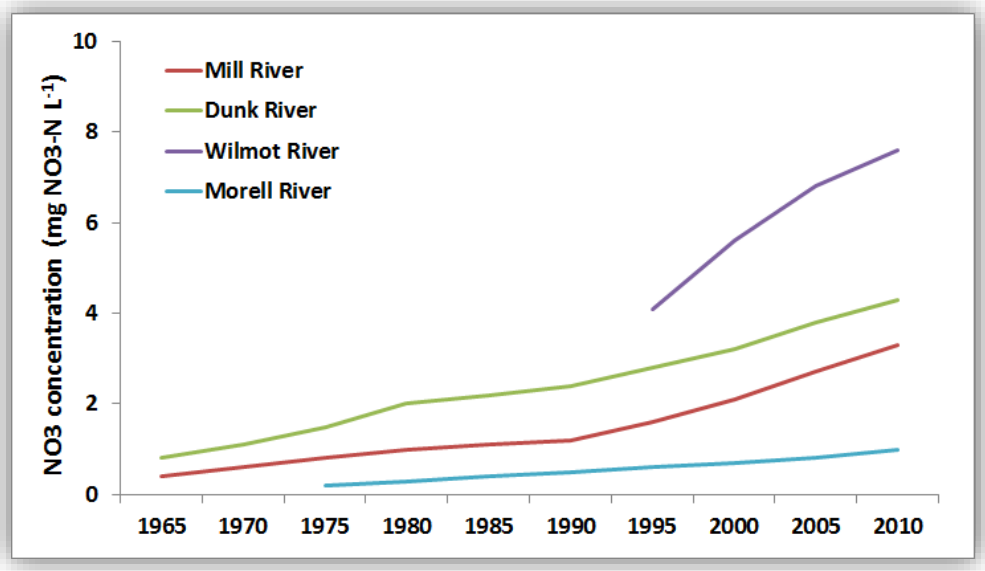
Nottawasaga River
ECCC-CCIW, LSGBI
Groundwater mediated nutrient loads to surface waters

Belle Park (former landfill)
ECCC, Kingston Municipality
Role of phreatophytes in capturing contaminated groundwater seepage

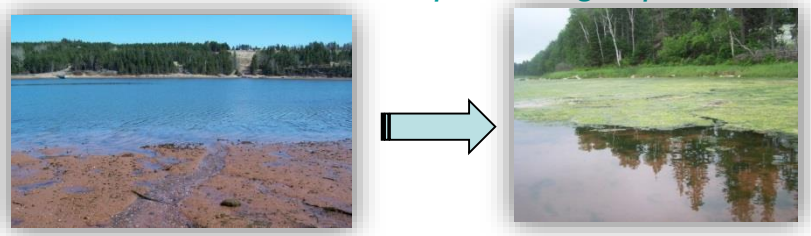
PEI Context

- Potatoes are the most important agricultural commodity and have been linked to increasing groundwater contamination

- Quality of groundwater is critical for PEI since groundwater
  - is the sole source for drinking water
  - has significant contributions to surface water



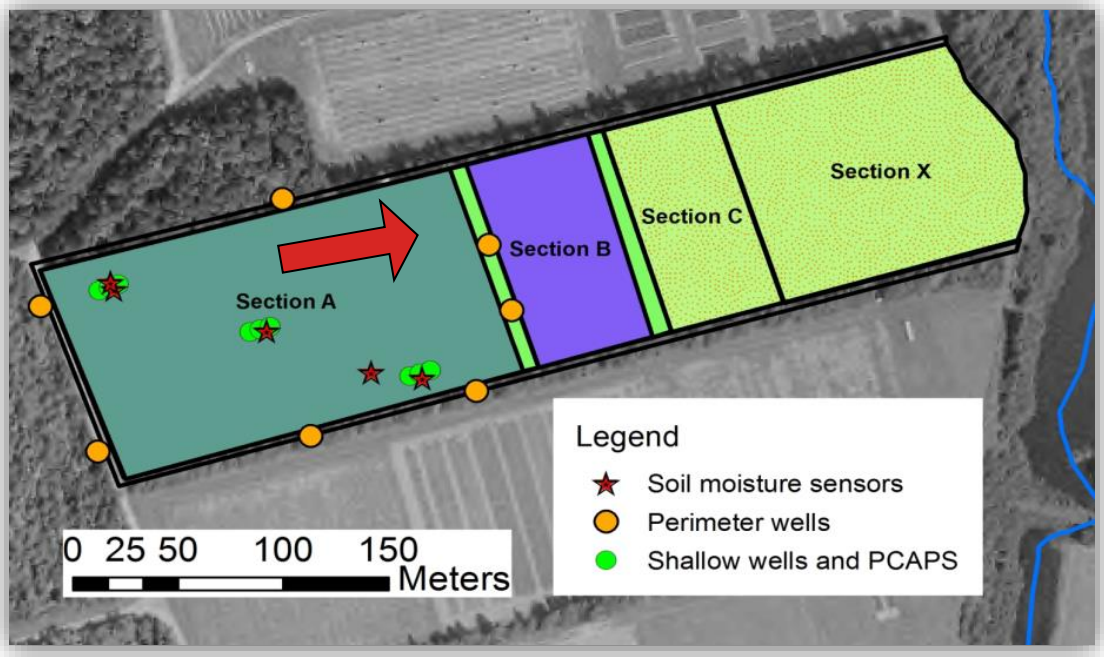
http://www.gov.pe.ca



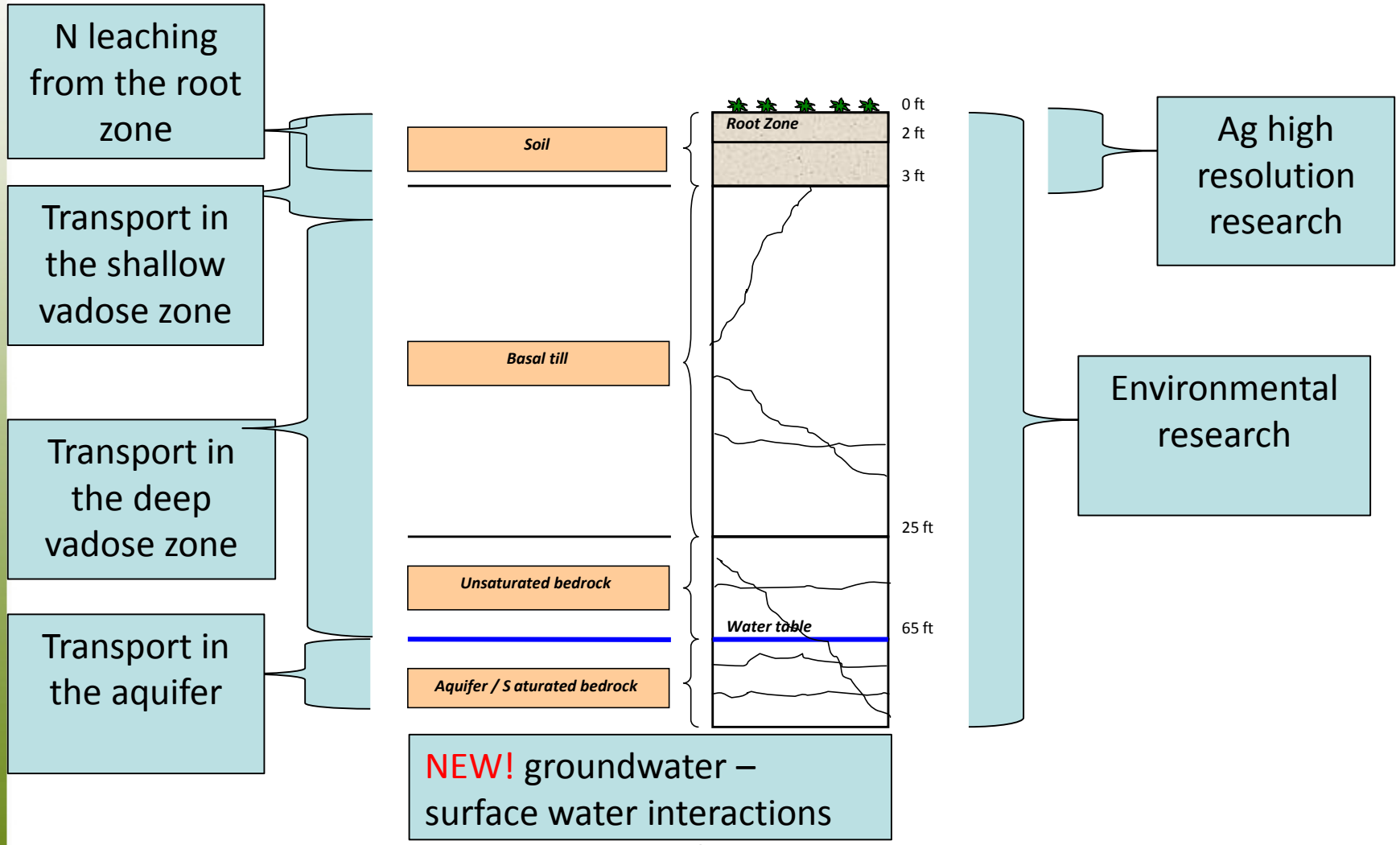
Fish kills and anoxic events have been reported in the recent past

Study site – HEF, Field 355, PEI

- 2.4 ha, AAFC experimental farm (Charlottetown)
- Gentle slope
- Topographic high and forested area up-gradient
- Field under a 3-year potato rotation
- Fractured sandstone bedrock

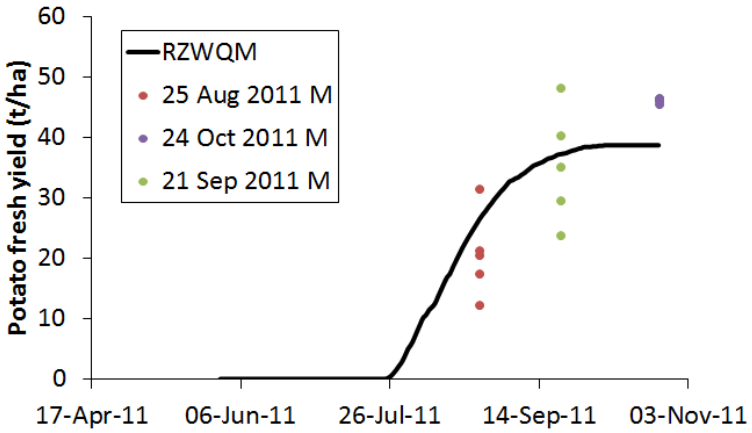


Project-based research components

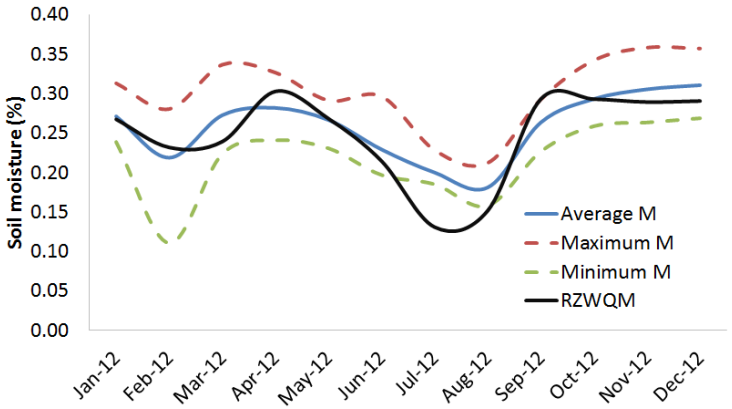


N leaching from the root zone

- RZWQM - Root Zone Water Quality Model (USDA-ARS)
  - 1D, Flow, N cycling, plant growth in soil
  - 2011-2014 daily

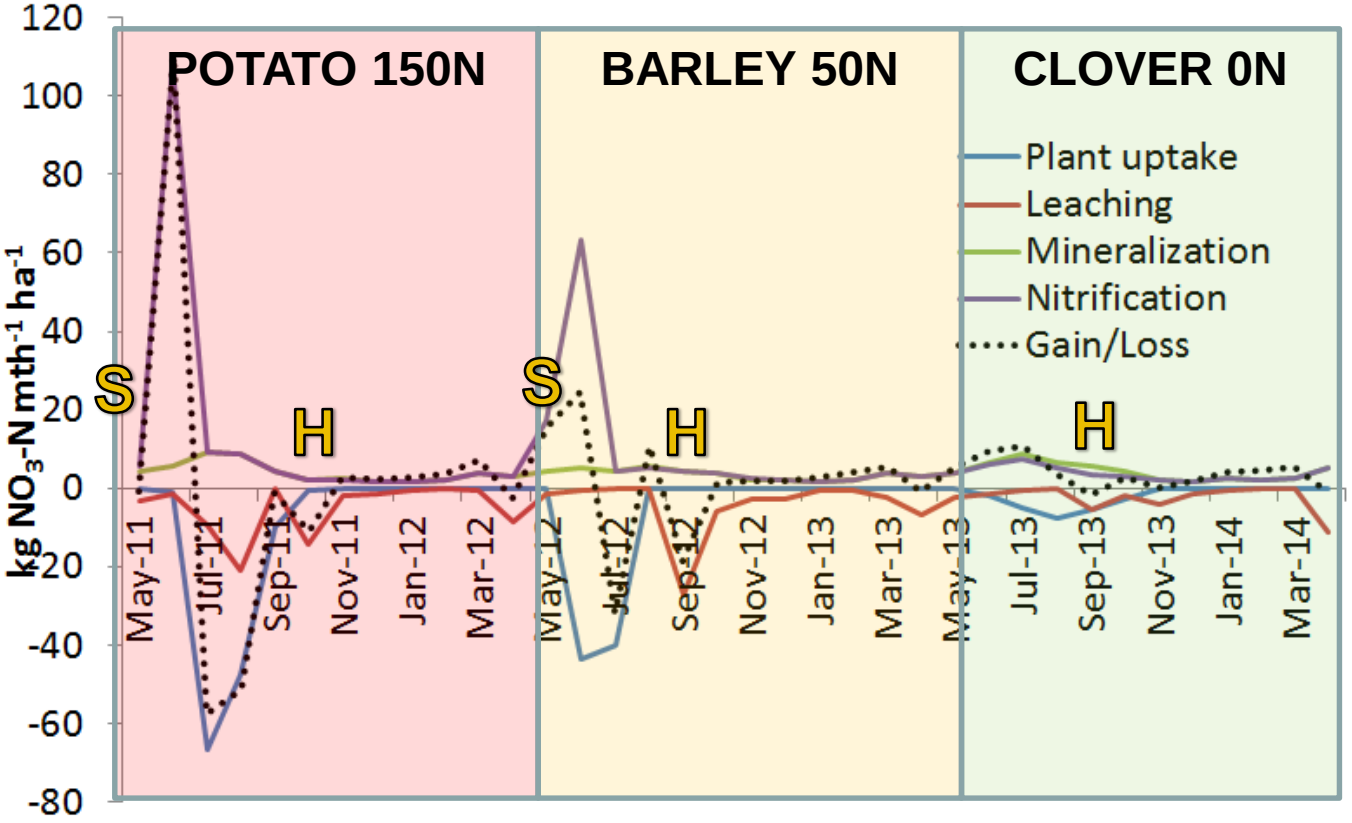


Calibration (biomass)



Calibration (soil moisture)

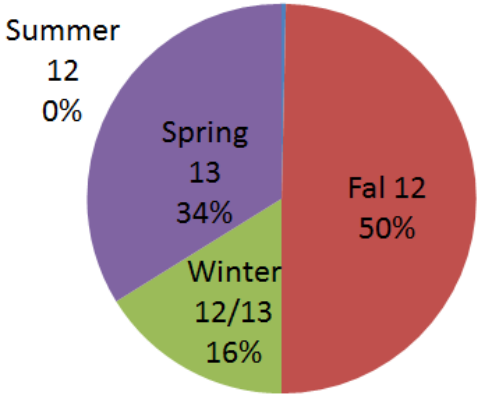
RZWQM: N gains and losses



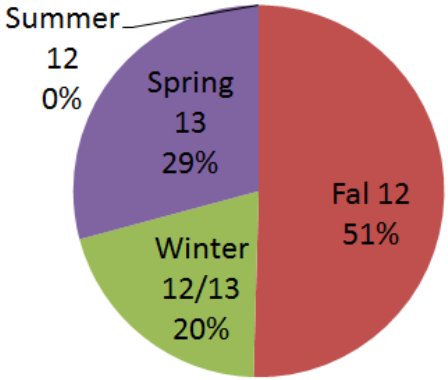
Period	Crop	Pl. upt.	Leach.	Nitrif.	Miner.	Volat.
2011/12	potato	125.7	63.5	152.6	49.5	8.7
2012/13	barley	83.4	50.1	113.4	42.7	4.5
2013/14	clover	22.9	29.5	45.0	52.6	0.0

Seasonal drainage and loading

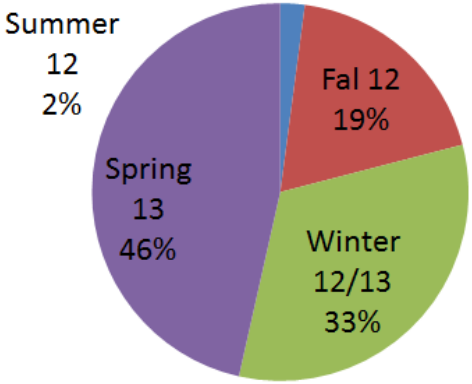
- Drainage / Recharge



RZWQM

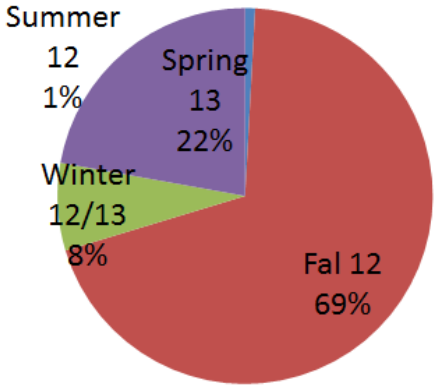


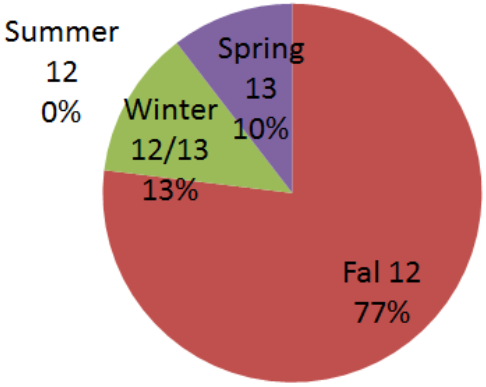
PCAPs

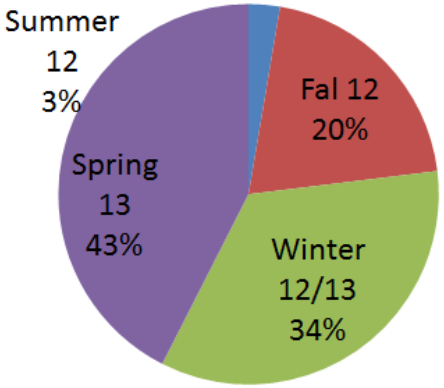


High N wells

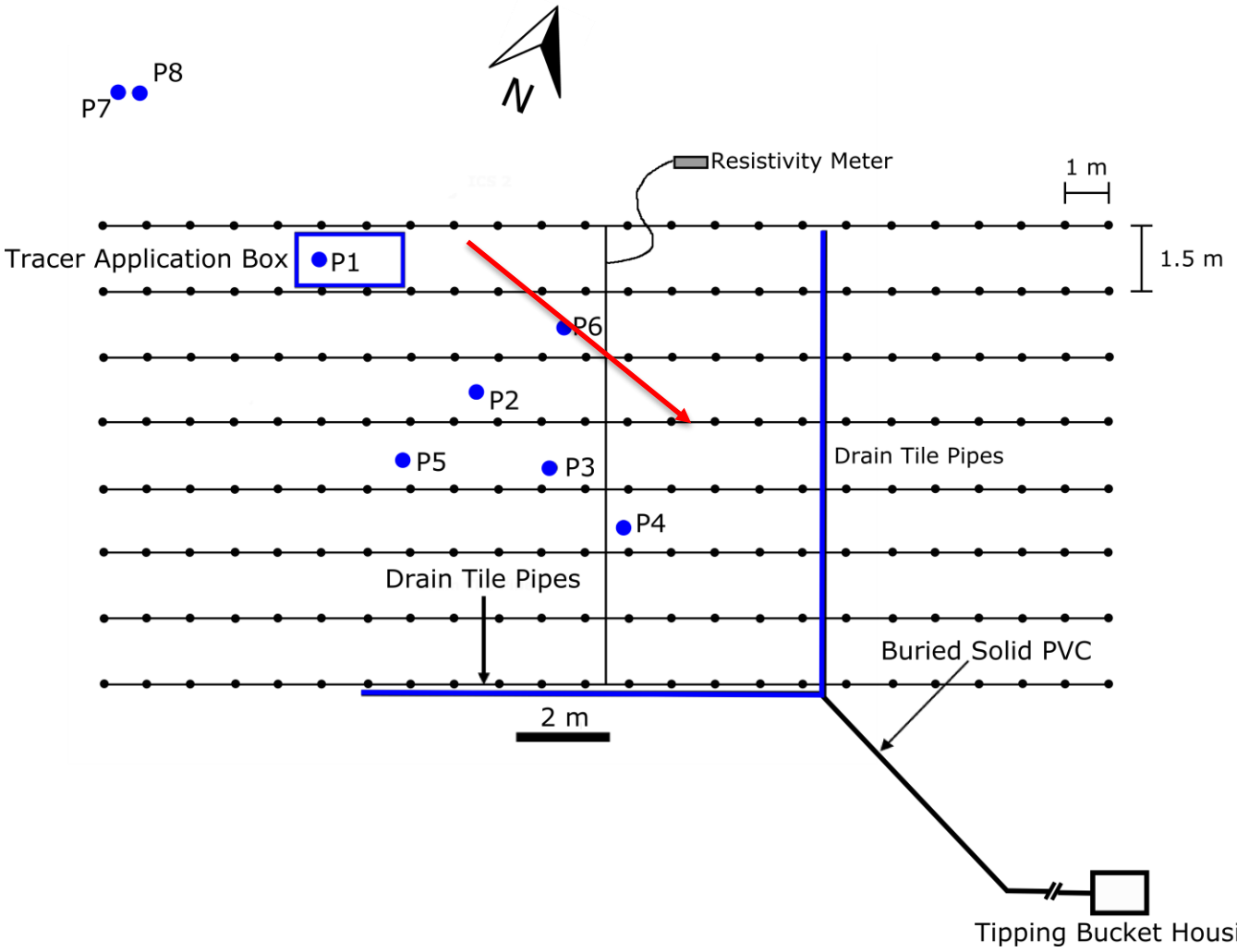
- Leaching / loading





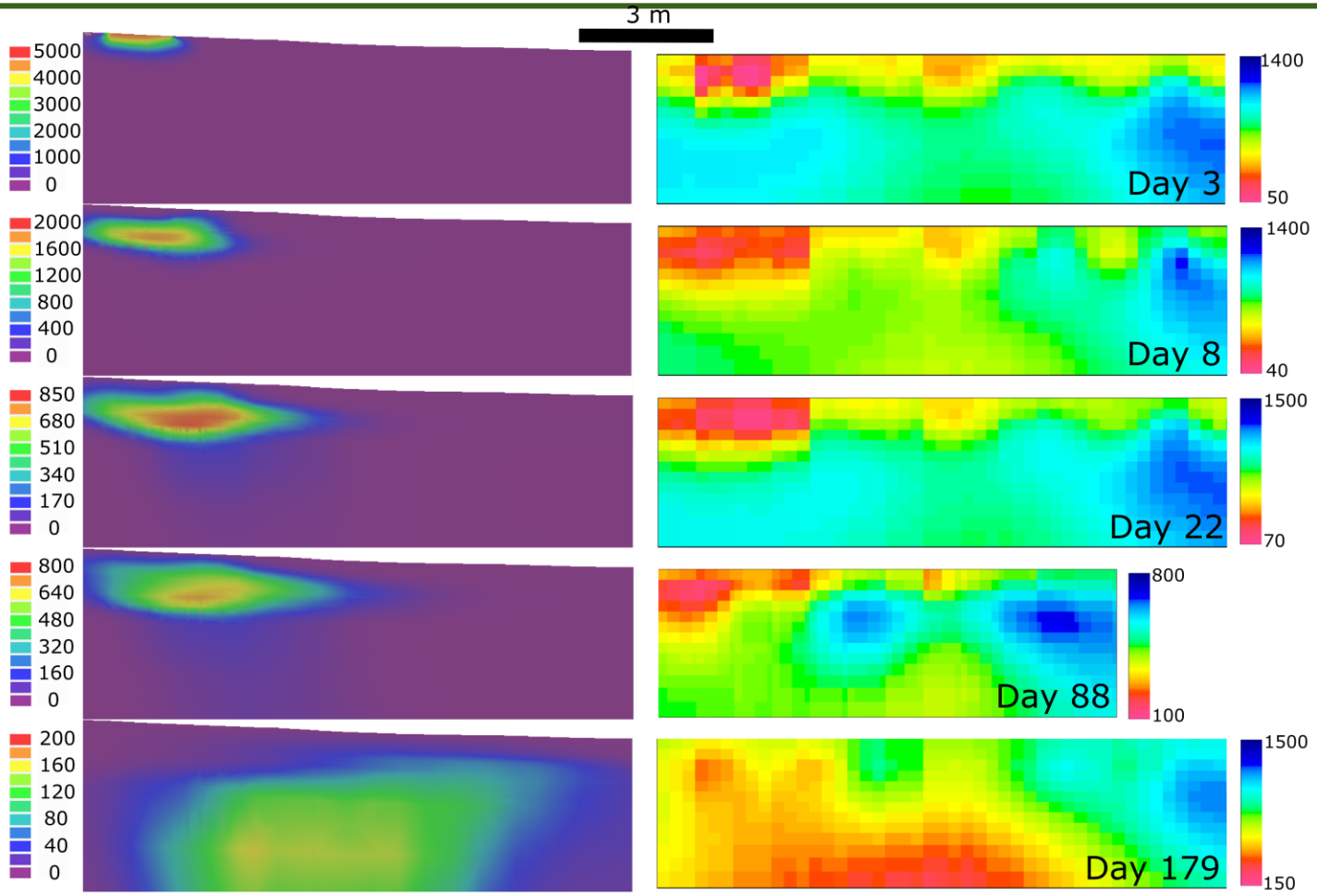


Shallow vadose zone - setup

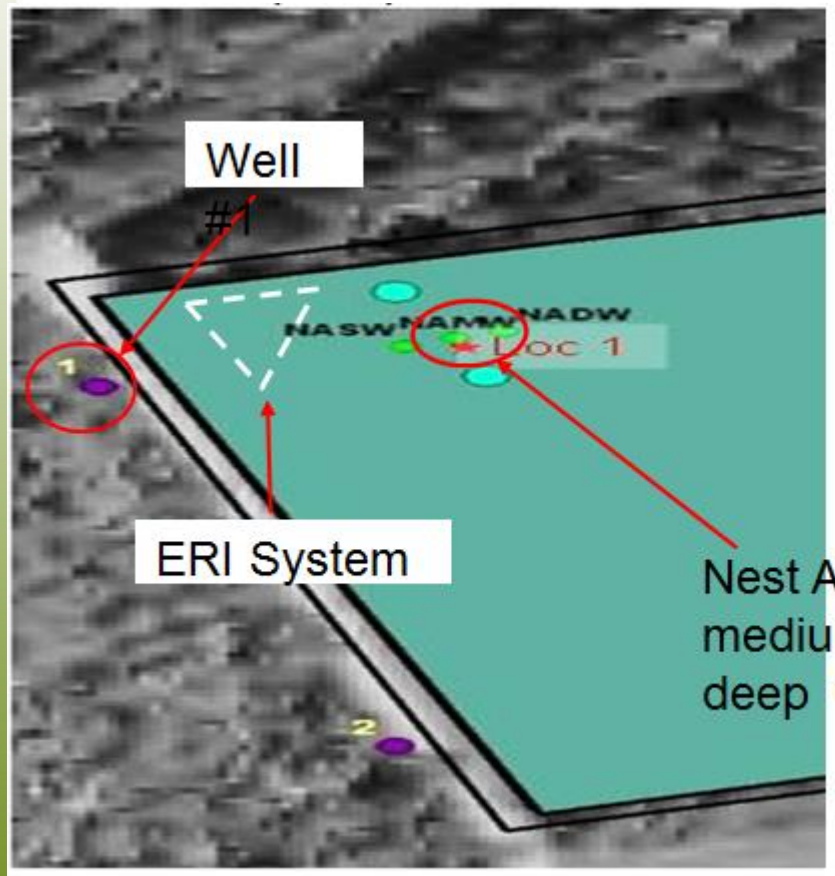


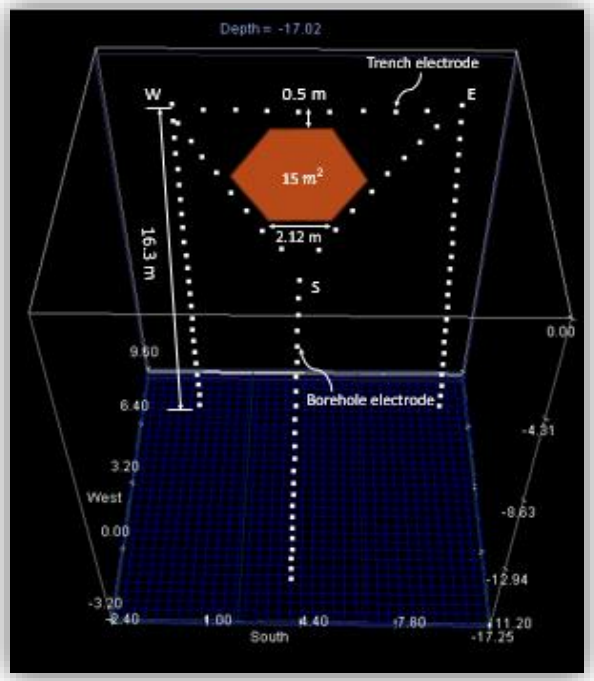
Simulated Concentration Vs. Resistivity

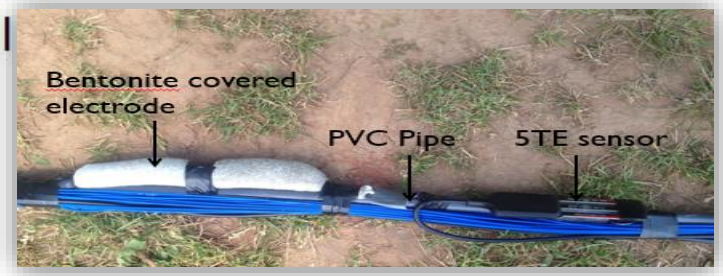
SWB + FEFLOW (conc.) Inverse modelling (resistivity)



Deep vadose zone – setup (ERI)

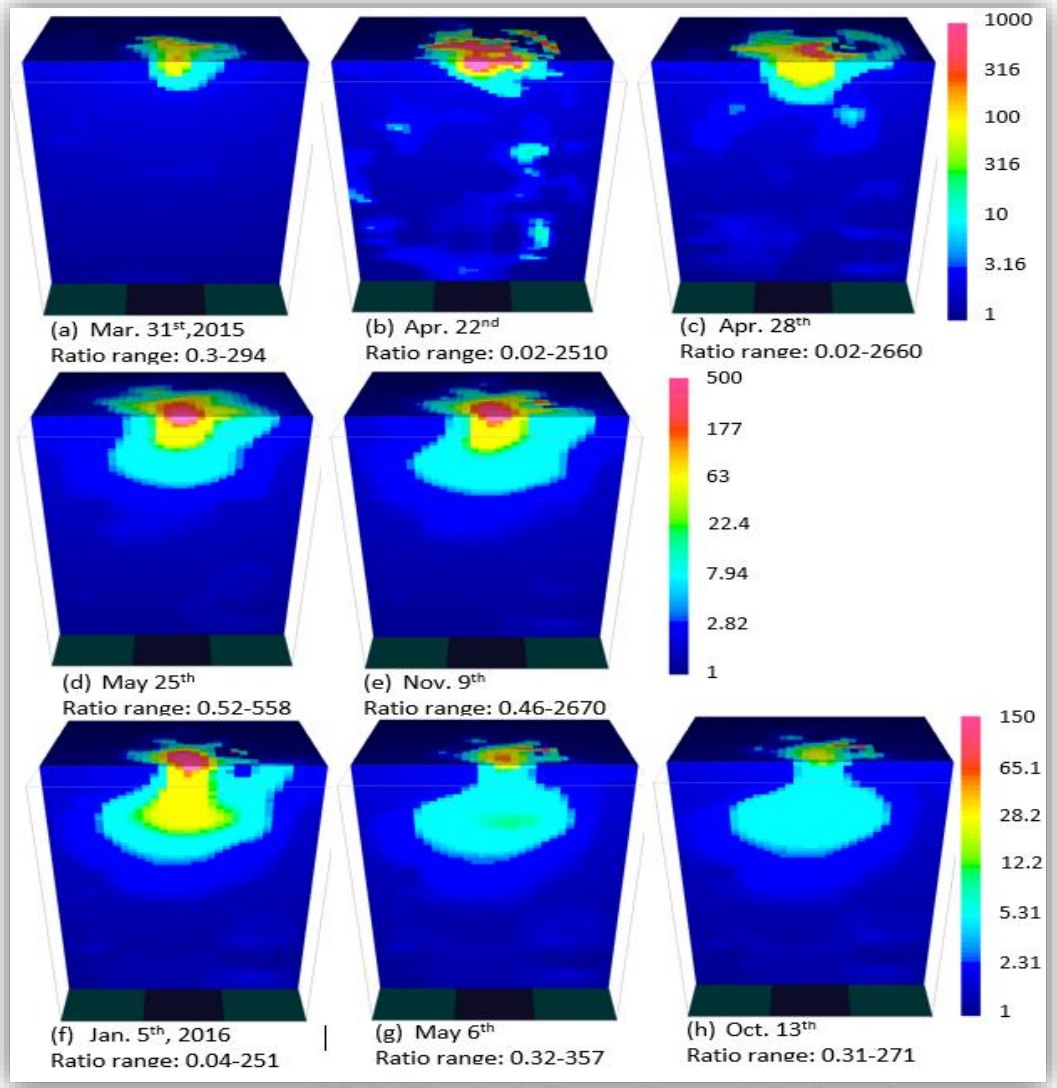




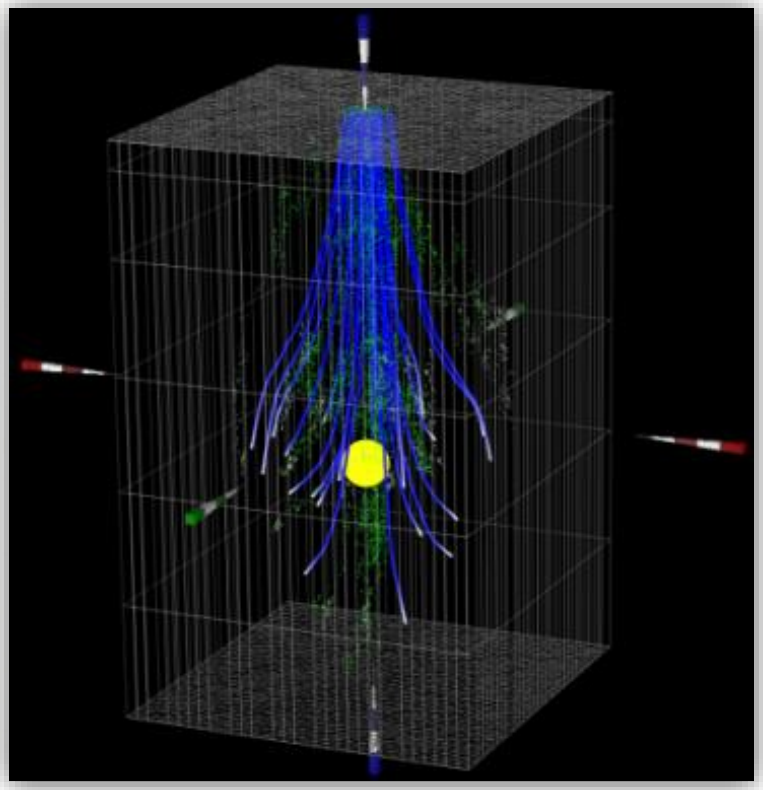


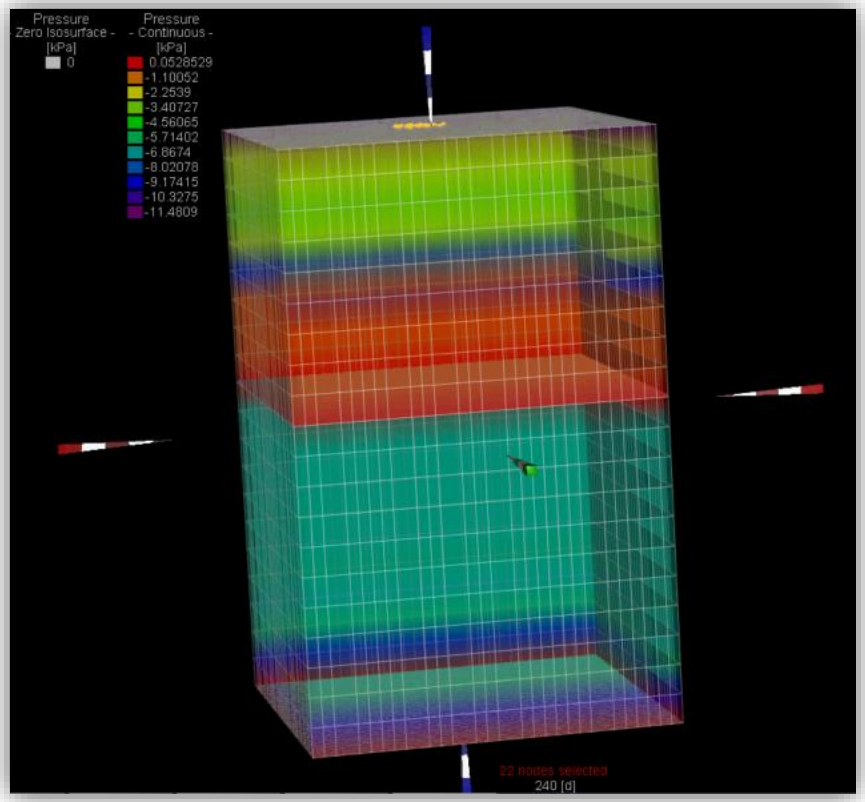
Electrical Resistivity Imaging (ERI)

- Sub-horizontal layers of alternating resistivity (till)
- Tracer percolated to 3.5 m in 46 days
- Little evidence of bulk matrix flow below 3.5 m
- Preferential percolation paths (i.e. fractures)



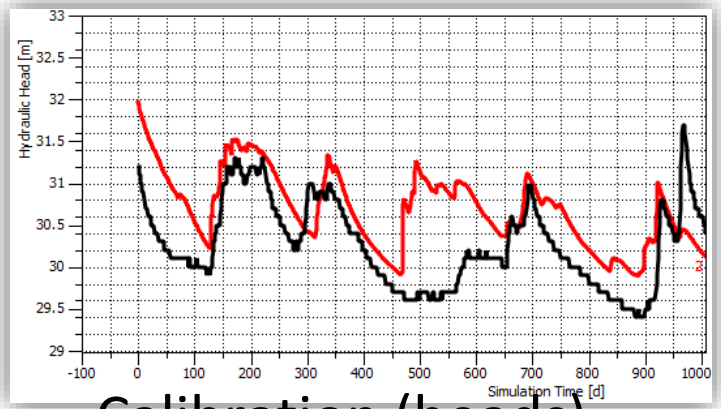
Particle tracking (FEFLOW)



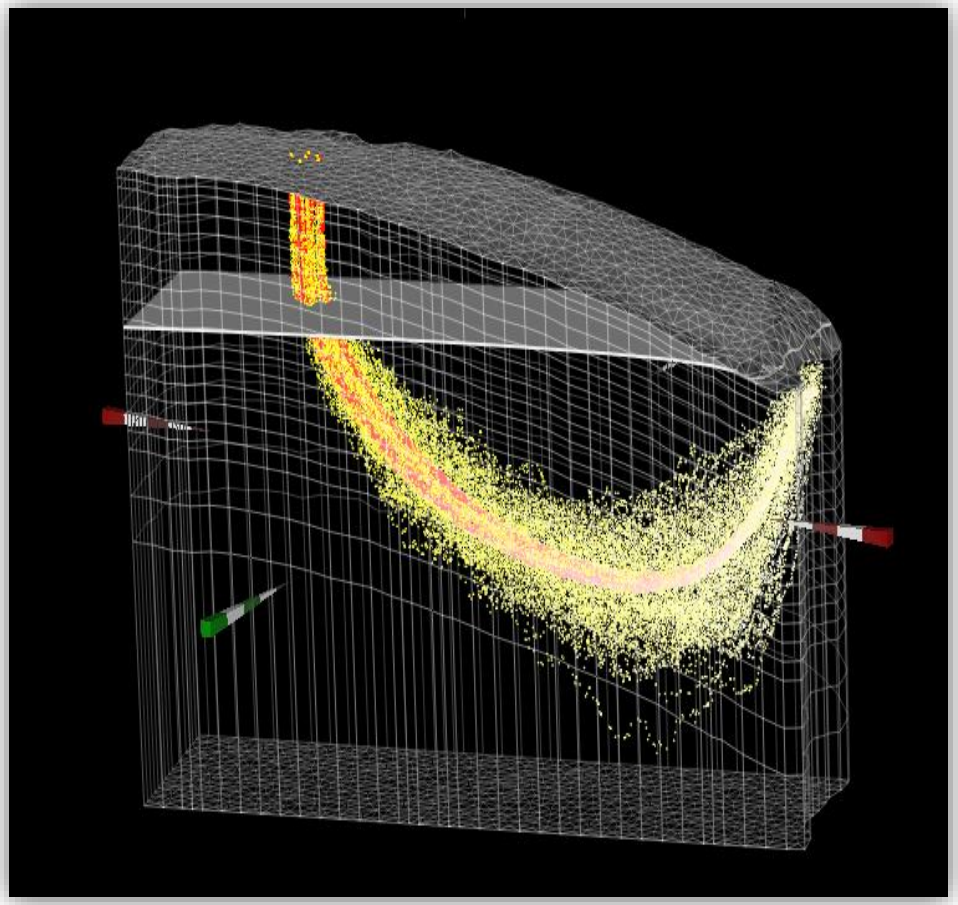


Saturated zone - FEFLOW

- Finite Element subsurface FLOW system
  - 3D, Flow, N transport/fate
  - Unsaturated – saturated flow modelling
  - 2001-2014 daily



Calibration (heads)

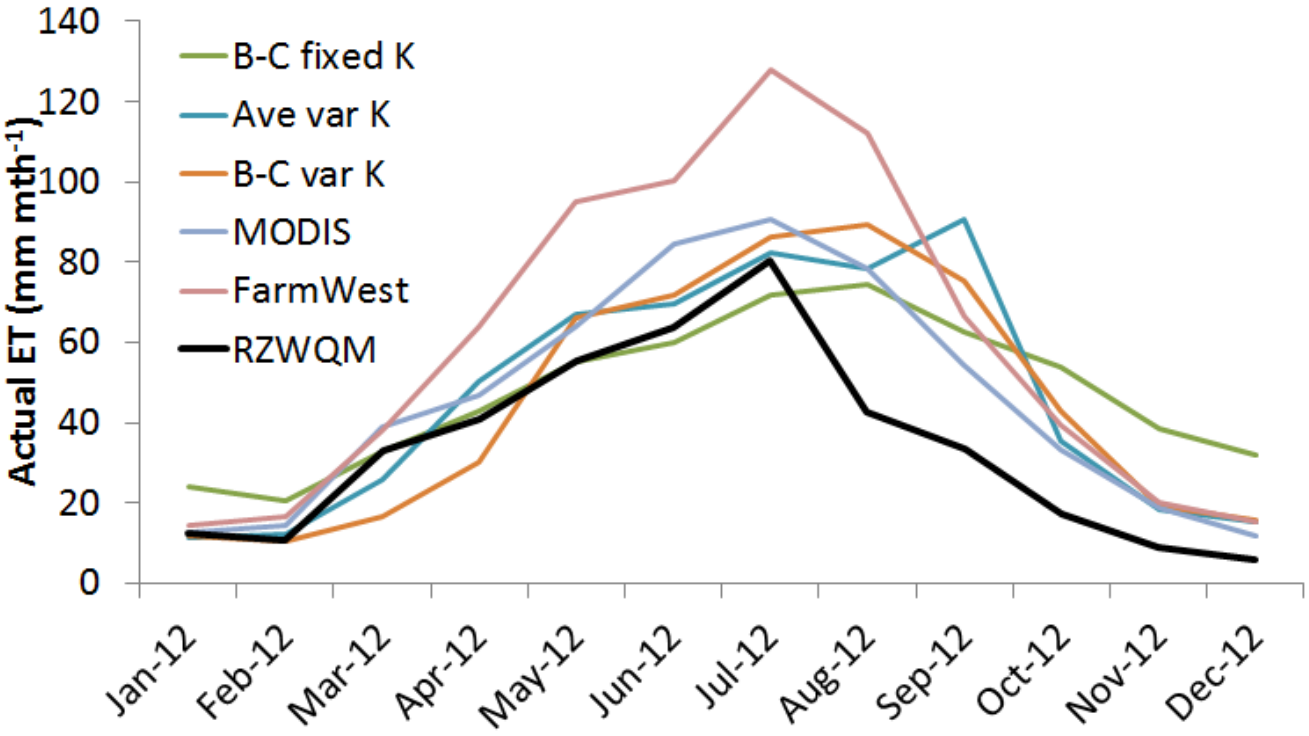


Groundwater-surface water interface

- HEF Field 355
- GWSWI biogeochemically active
- Denitrification at the stream-groundwater interface
- Push-pull tests of (isotopically enriched N)

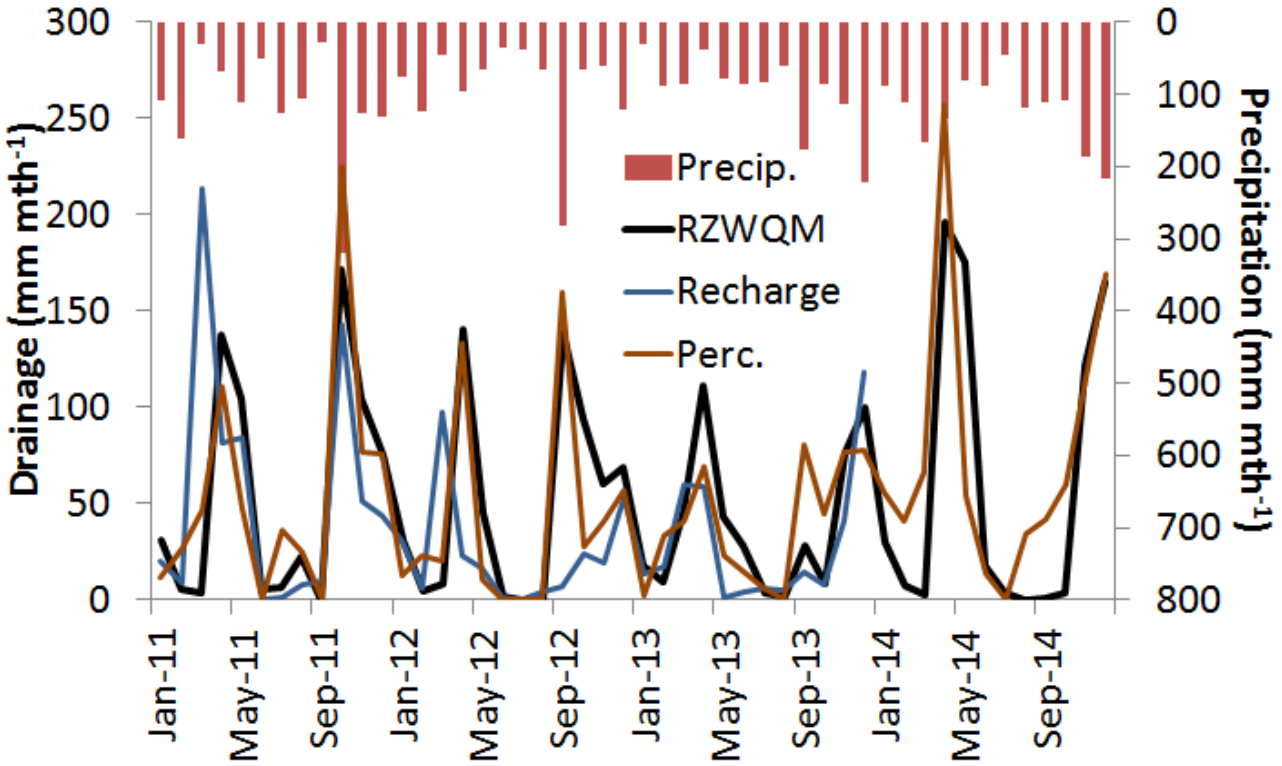
Evapotranspiration (ET)

- Comparable with ET resulted from the water balance calculations
- RZWQM ET (2011 – 2014): 487 mm yr^{-1} vs 415 to 556 mm with other methods
- R^2 (Average vs RZWQM; 2011-2014): 0.75



Seepage, Percolation, Recharge

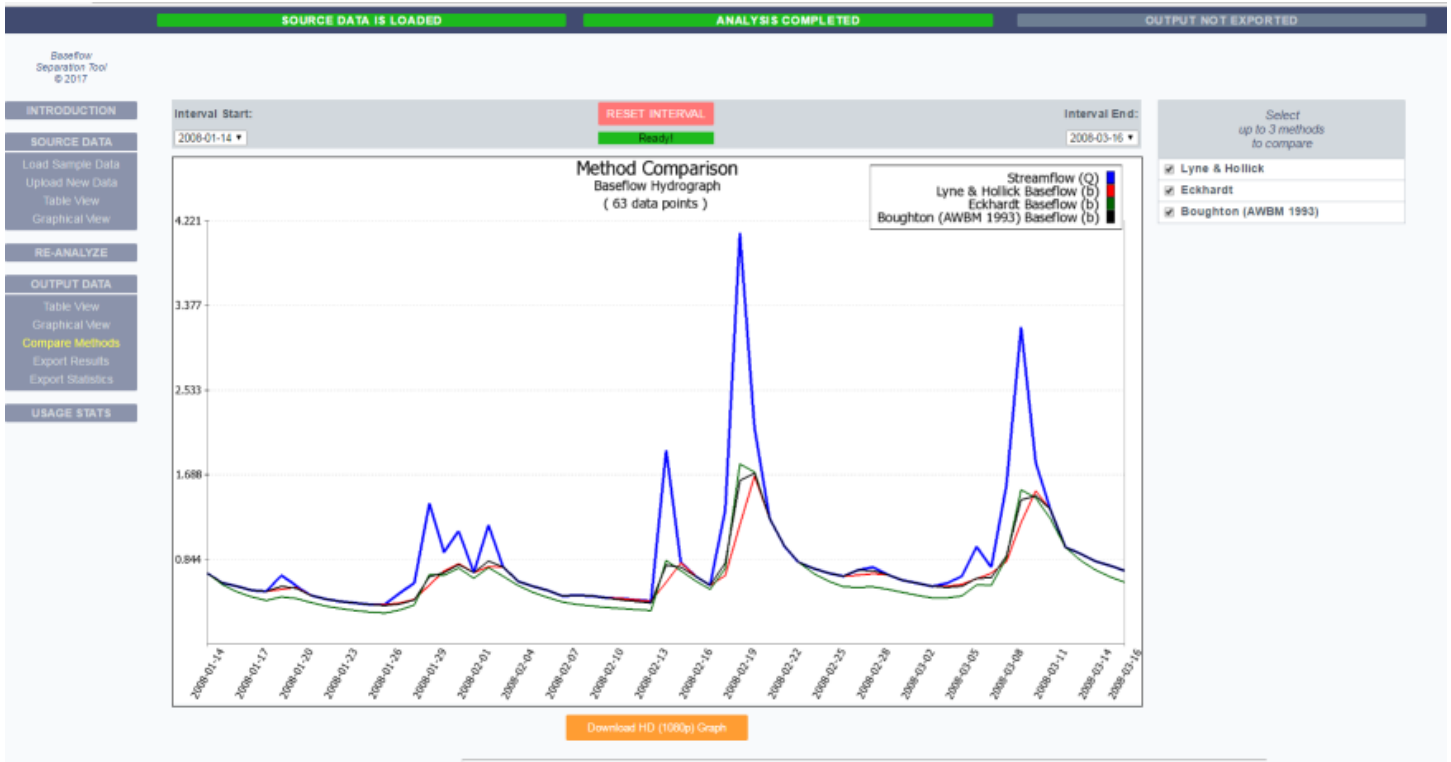
- Moderate correlation (R^2 = 0.67) between RZWQM seepage and percolation from water balance
- Significant “drainage” events in Mar-Apr and Sep-Nov



Averages for 2011-2013		
RZWQM	Perc.	Rech.
577.6	544.3	430.5

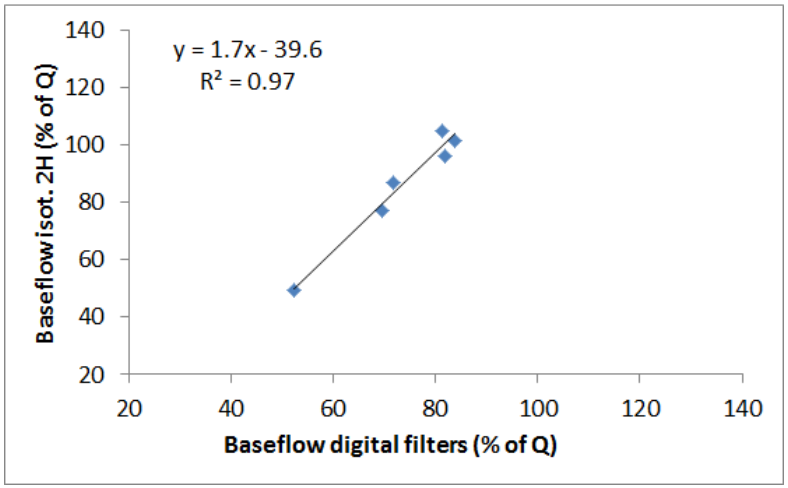
Hydrograph separation: digital filters

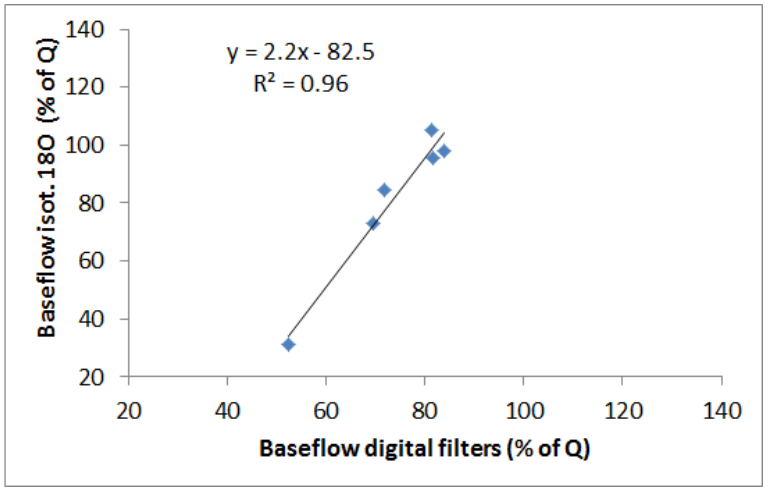
- Baseflow separation tool: 10 algorithms



Hydrograph separation: geochemical tracers

Date	%gw hyd sep	%gw 2H	%gw 18O	%gw cond	%gw Cl	%gw NO3-N	%gw Ca	%gw Mg	%gw SO4	%gw PO4
25-Jun-08	81.4	105.0	105.1	n.a.	72.1	72.9	80.9	62.8	78.8	n.a.
28-Oct-08	52.4	49.4	31.3	n.a.	43.4	29.7	57.5	47.4	35.3	n.a.
17-Sep-09	81.7	95.9	95.5	58.4	91.9	75.3	92.0	60.5	74.9	n.a.
20-Oct-09	71.8	86.9	84.4	65.8	92.5	79.0	82.6	61.0	86.9	n.a.
04-Aug-10	83.9	101.4	98.0	74.0	97.3	80.9	98.6	74.9	104.3	n.a.
08-Nov-10	69.7	77.2	73.0	72.9	67.4	58.5	89.8	70.8	47.0	n.a.
Average	73.5	86.0	81.2	67.8	77.4	66.1	83.6	62.9	71.2	n.a.
NRMSE		0.270	0.219		0.225	0.228	0.293	0.475	0.230	n.a.
Correl		0.966	0.958	0.035	0.693	0.842	0.746	0.509	0.686	n.a.
Stdev	12.0	18.1	26.7	9.4	19.8	20.8	20.4	10.0	22.9	





Black Brook Watershed (BBW)

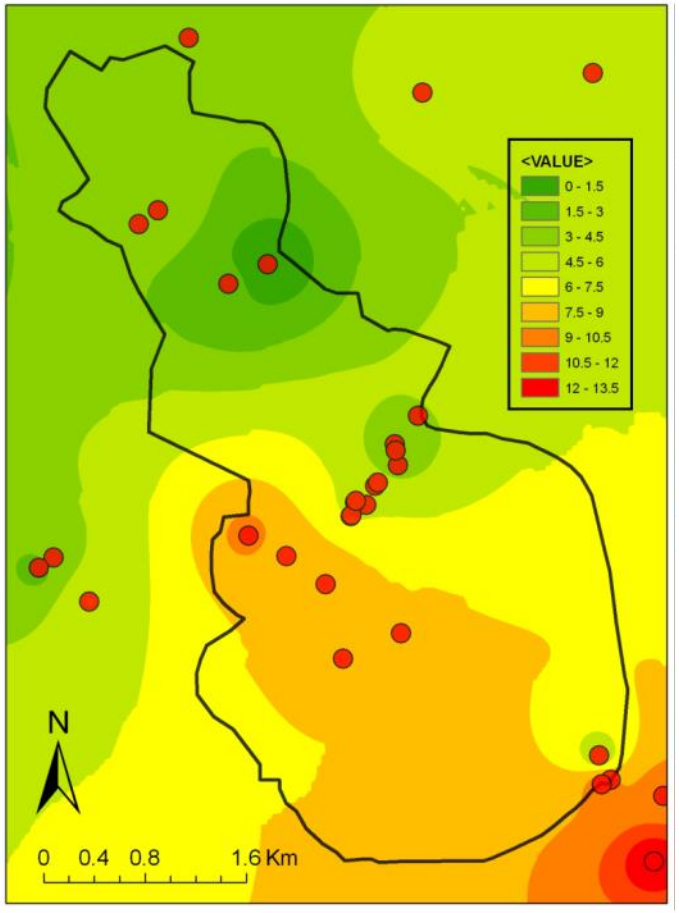
- 14.5 km^2
- Hilly landscape
- 65% agricultural land
- Climate
  - 1100 mm yr^{-1} precipitation (30% snow)
  - 3.5 ^oC average air temperatur
- Fractured shale bedrock; insignificant matrix porosity

Nitrate concentrations

- 82% of the samples above the guideline for protection of aquatic life (2.5 mg NO3-N l^{-1})

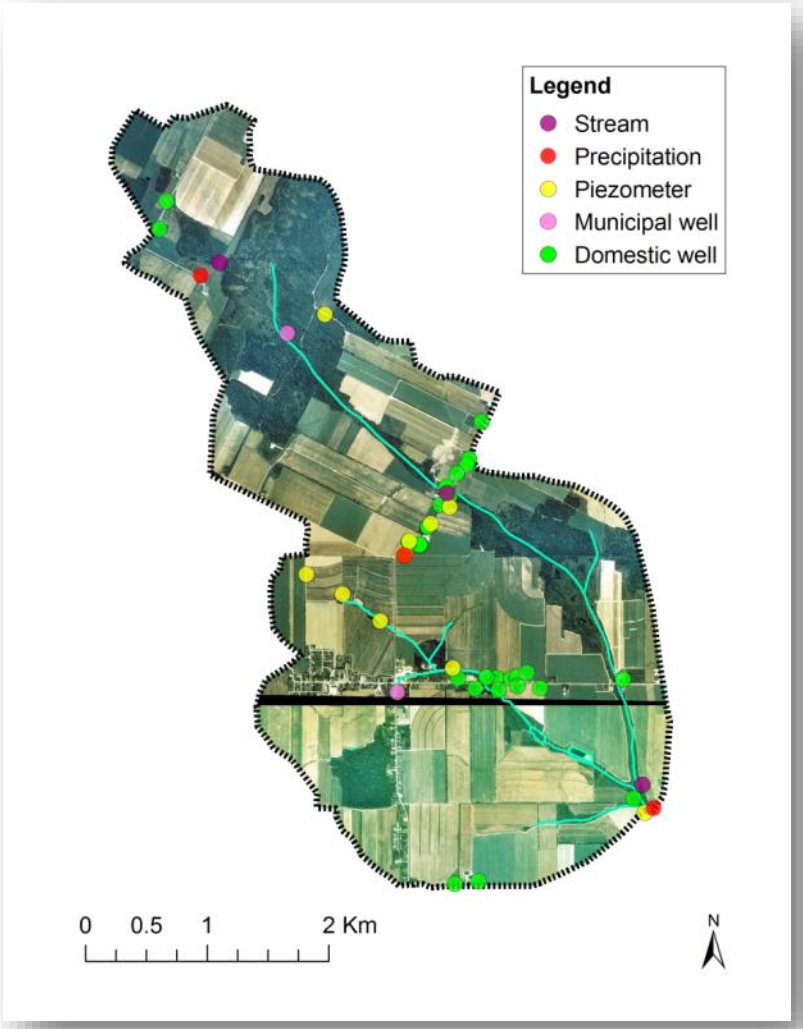
- 19% of the samples above the MAC for nitrate in drinking water (10 mg NO3-N l^{-1})

	mg NO3-N l^{-1}
Average	5.8
Maximum	20.6



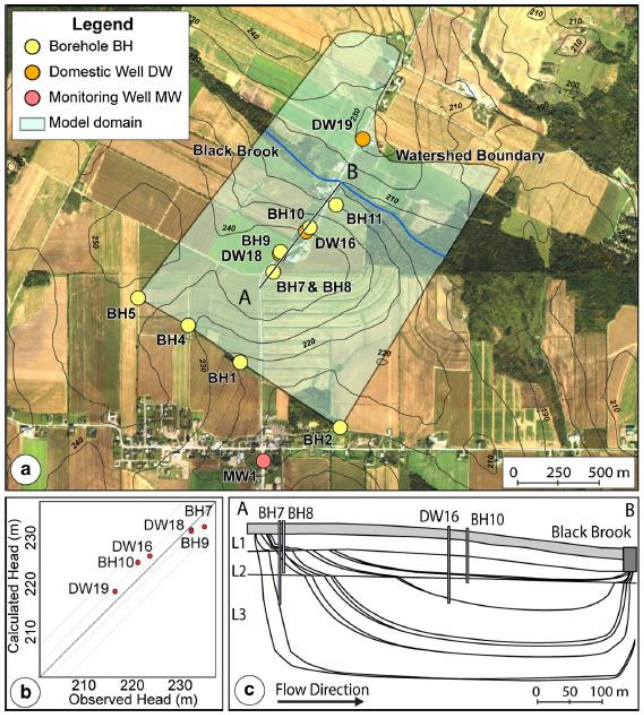
Monitoring and sampling

- Ground water monitoring wells
  - 35 wells
    - 11 piezometers
    - 5 municipal wells
    - 19 domestic wells
  - Monitoring
    - Continuously for water level
    - Monthly for nitrate
    - Seasonal basis for major ions, water and nitrate isotopes

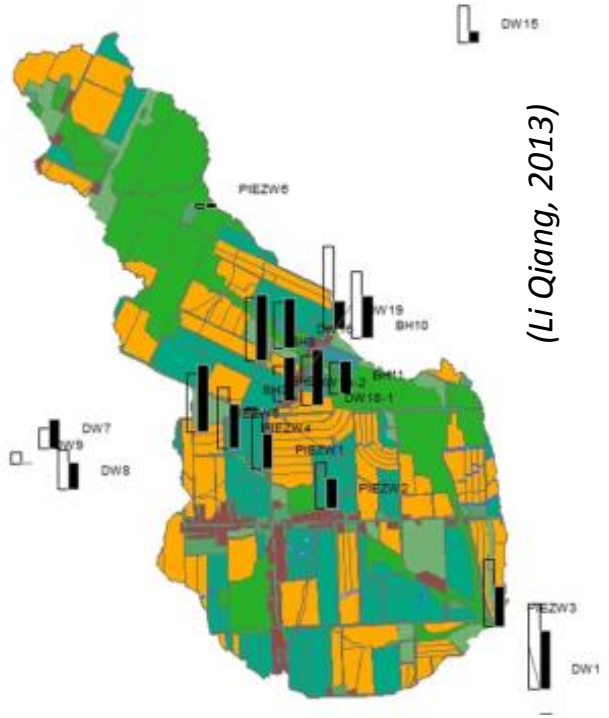


Numerical modelling

- Use findings for refinement of existing models



(DesRoches et al, 2014)



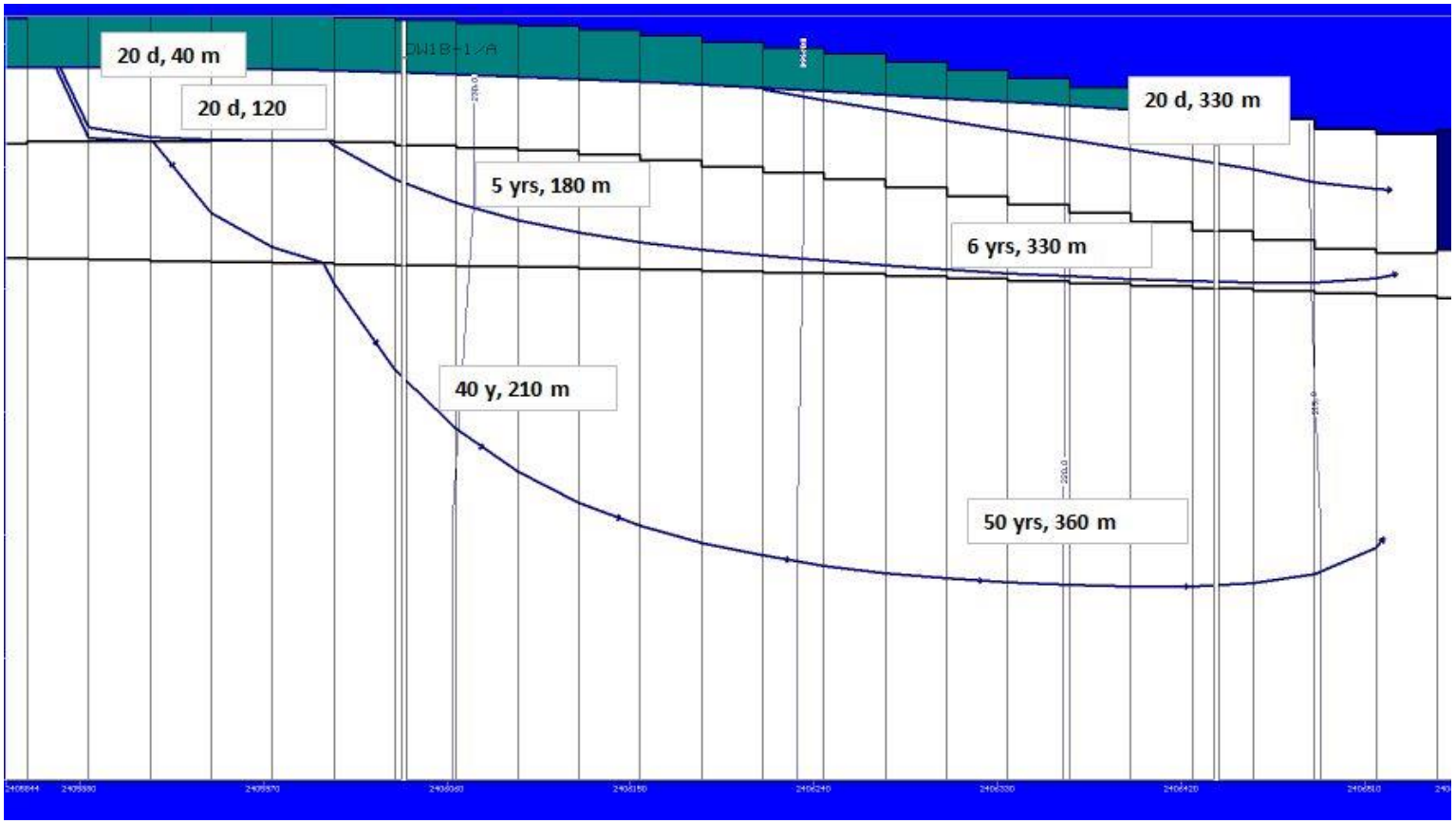
(Li Qiang, 2013)

High resolution, reduced scale

Lower resolution, watershed scale

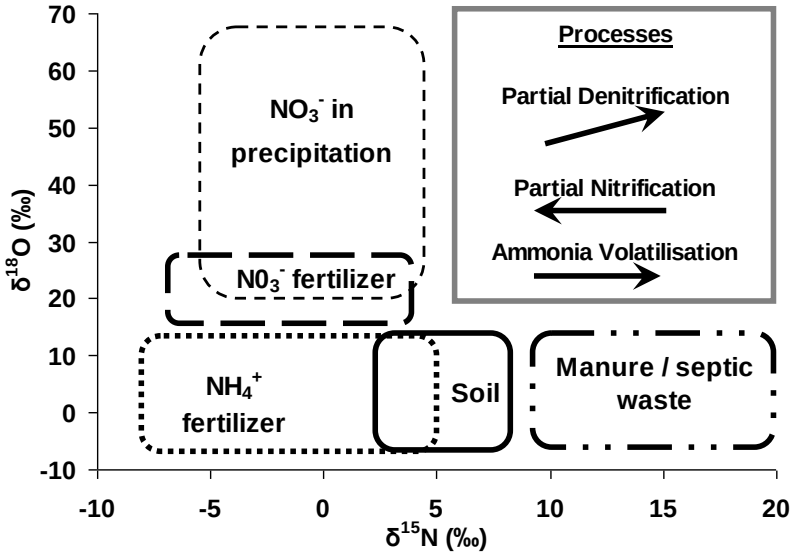
Particle tracking (MODFLOW)

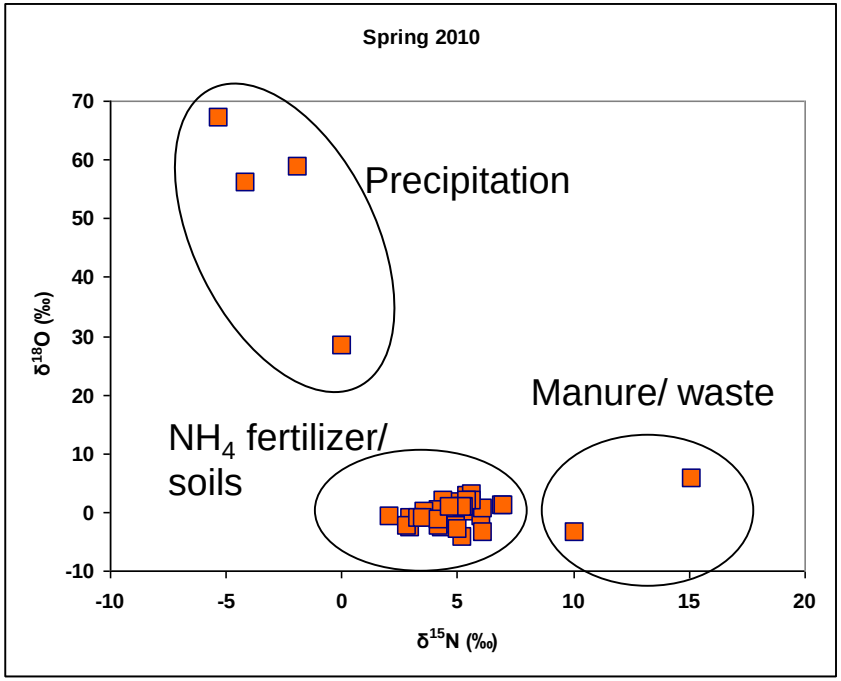
0 m



200 m

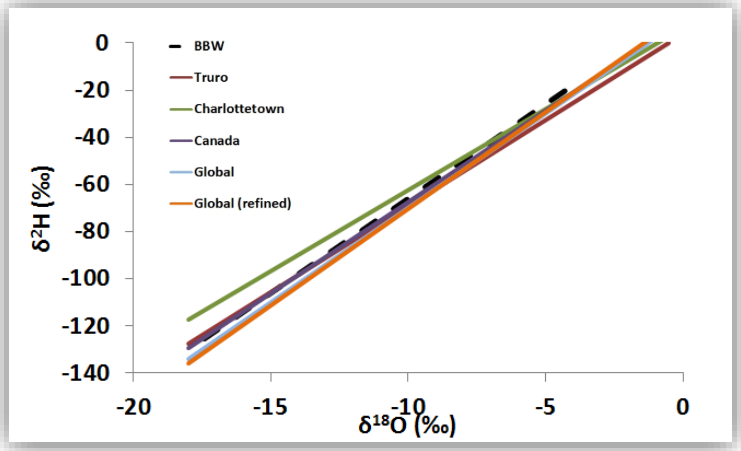
Tracers: ^{15}N & ^{18}O in Nitrate

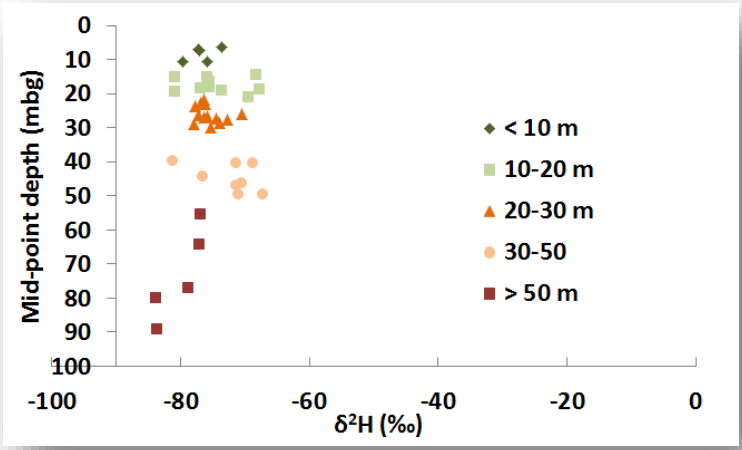




Tracers: water isotopes

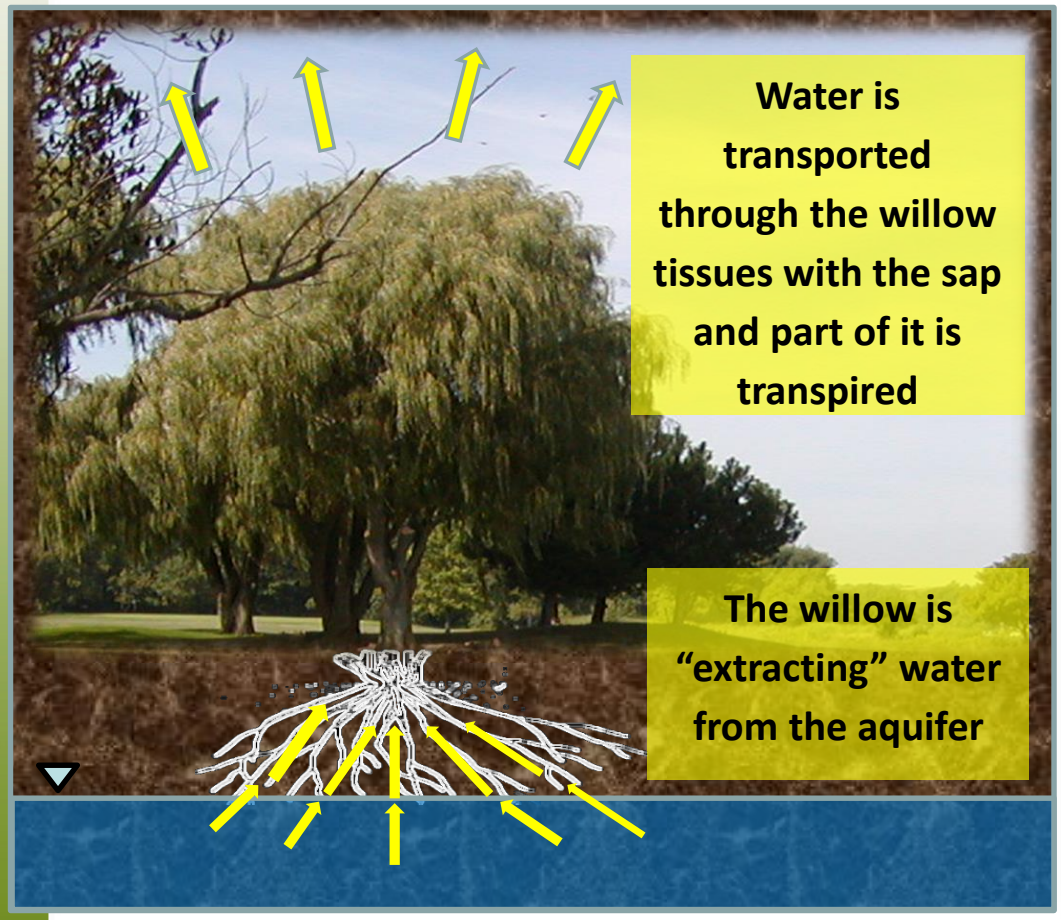
- Precipitation
  - No spatial variation at watershed scale
  - Significant seasonal and short-term (i.e. event) variation
- Groundwater
  - Derived from local modern precipitation; muted seasonal variations
  - Aquifer waters are well mixed
  - Rapid infiltration/ percolation (no evaporative losses)
  - Main source for streamflow on both annual (~80%) and event (min. ~50%) basis
  - Spring snowmelt is the most significant contributor to recharge
  - Slightly depleted water in the deepest wells

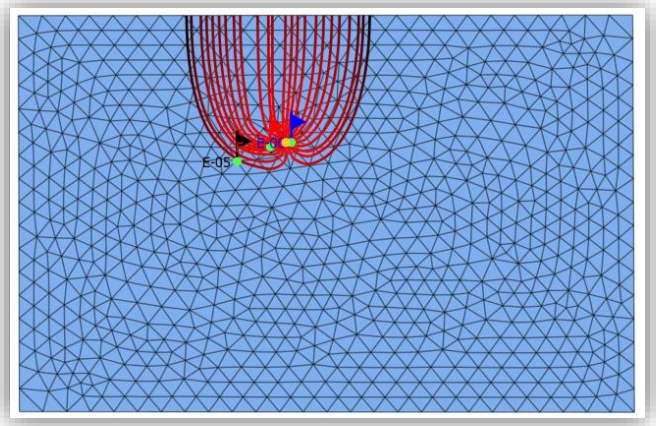


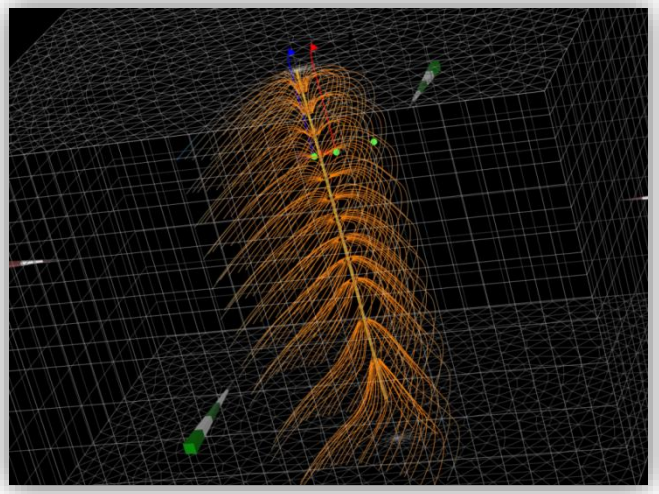


Groundwater remediation - phreatophytes

- 3.7 m^3/d validated groundwater extraction / pumping rate







Acknowledgements

- Research funded through
  - AAFC (SAGES, GF & GF2)
  - Environment Canada (A-base)

- Collaborators:
  - Bernie Zebarth, Mark Grimmett, Li Sheng, Judith Nyiraneza, Yefang Jiang, Vernon Rodd, John Spoelstra, Dale van Stempvoort and others

- Technical support:
  - Mona Levesque, Rick Allaby, Sylvie Lavoie, Sandy Jenkins, Lionel Stevens, Zisheng Xing, Irene Power, Ambrose Malone, John Voralek, Greg Bickerton and others

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