Assessing potential nutrient losses in tile drained, macroporous soils over an annual cycle through conservative tracer tracking

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Outline

- Objective
- Background
  - Tile drains, Macropores, Liquid Swine Manure
- Conceptual Model
- Field Experiment
  - Design, Results, Conclusions
- Implications
  - Environmental, Economic
  - Summary

Objective

- Quantify nutrient loss to groundwater and surface-water after fall application of liquid manure on tile drained fields with macroporous soils

Location

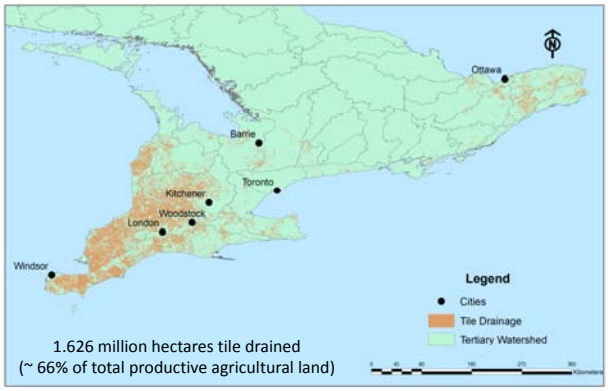
(From Waldick, Conant and Rudolph, 2009)

Background – Tile Drains

Purpose: Remove excess soil moisture
Benefits
- •Plant earlier and harvest later
- •Reduced soil compaction
- •Improved root zone aeration
- •Root zone warms earlier in spring

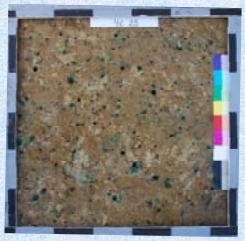
Environmental (Water Quality) Issues
- •Nitrate
- •Pathogens
- •Herbicides
- •Pesticides
- •Salts
- •Pharmaceuticals

Background: Ontario Tile Drainage



1.626 million hectares tile drained
(~ 66% of total productive agricultural land)

Background: Macroporous Soil



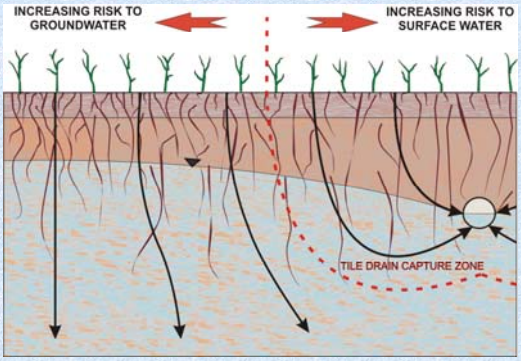
- Macropores: preferential flow paths such as:
  - root holes
  - worm burrows
  - desiccation cracks
- Macropores can significantly influence infiltration
- Common in poorly drained, structured soils requiring tile drainage

Background: Nutrient Source
e.g. liquid swine manure (LSM)

- ~ 2.9 million hogs in Ontario (Jan 2010)
- Average liquid manure ~1.9m^3/yr/hog
- LSM N content 1.79-6 kg/m3
- Annual N production 8.5-28 million kg

`Rough Estimate'
Ontario hogs produce as much nitrogen as 1.4 – 4.5 million people

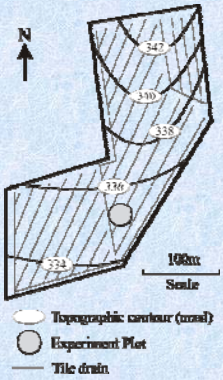
Conceptual Model
Tile Drain Capture Zone



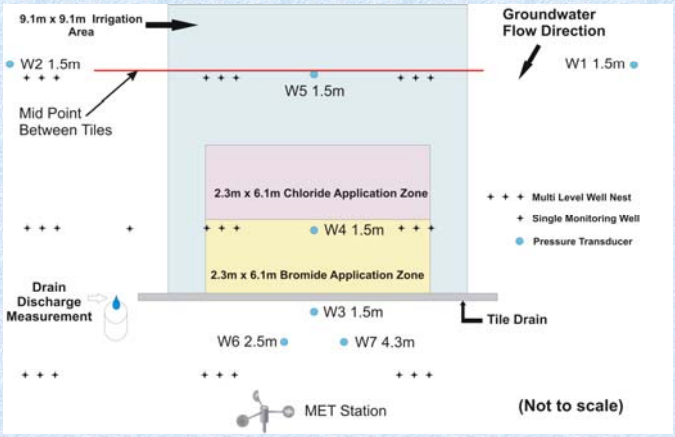
- Both vertical and lateral flow processes control tile drain dynamics

Field Site Description

- Macroporous silt loam underlain by till
- Systematically tile drained 1985
  - 12m spacing
  - 0.8m deep
- Tiles seasonally active
- Upwards hydraulic gradient



Experimental Design
Tracer Test – November 2007



Tracer Application and Irrigation

1) Wet Initial Conditions
2) Tracers (manure surrogate) applied: 2mm
3) Irrigation: 5mm/hr for 9 hours (~3yr return)

} "Bad case scenario"

Tile Monitoring

Discharge rate and tracer concentration

Inlet tube location for automatic water sampler

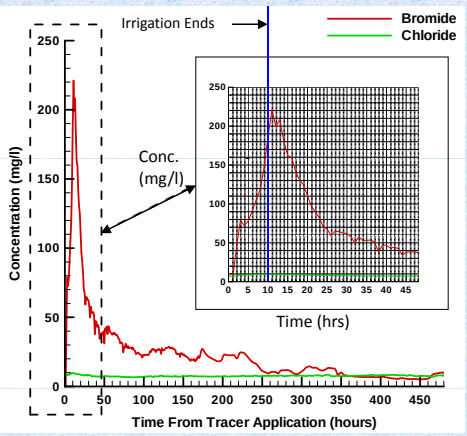
Sampling interval ranged from 15min to 24hrs

Electronic Flow Meter connected to an automatic data-logger

15min interval

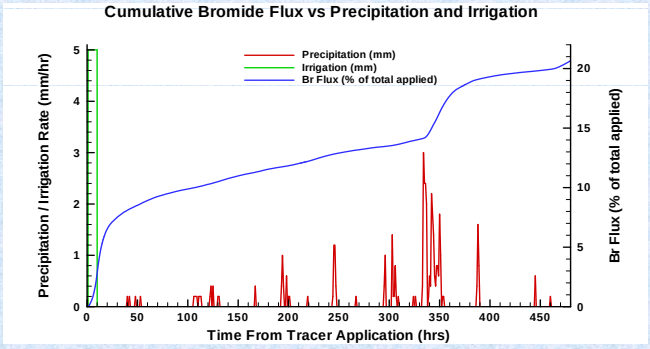
Tile drain depth ~ 80cm

Tracer Breakthrough to Tile



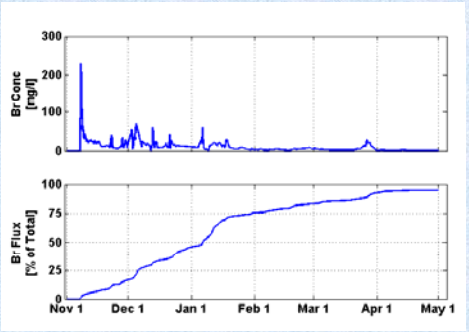
- Initial tracer arrival after 1 hr.
- Peak bromide concentrations ~11 hours after application
- No noticeable increase in chloride concentrations

Tracer Discharged Through Tile



- 7 % of the bromide tracer reached the tile within 24 hours.
- 20% of the bromide tracer reached the tile within 480 hours (20 days).
- Magnitude and duration of precipitation events influence tracer movement.

6 Month Bromide Flux



Nov 7 - 2007 to:	% Bromide Capture
Jan 1 - 2008	46
Feb 1 - 2008	76
Mar 1 - 2008	83
Apr 1 - 2008	93
May 1 - 2008	95
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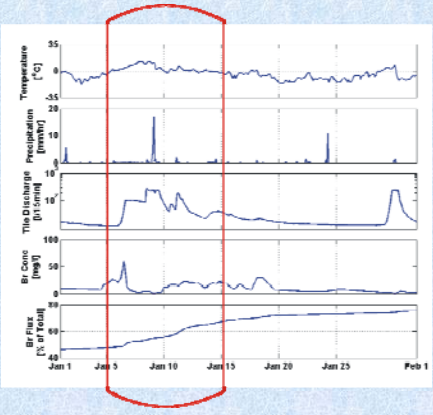
Nov 1 - 2008	98

Chloride concentrations not observed to increase above background levels.

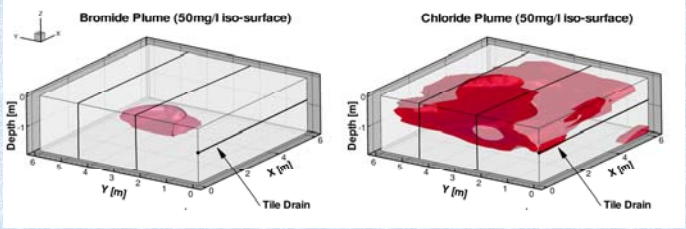
January 2008 Melt Event



- Extreme event
- Jan 5 to 15
- Average Temp: 3°C
- Precipitation: 62mm
- % of Total Bromide: 20%
- Tile discharge increased from 50 to over 1200 l/hr

Residual Tracer In Soil – Sept 2008

16 soil cores - 141 samples



Bromide
- Less than 2% of total
- Very shallow

Chloride
- Appears to have 'just' reached tile drain
- From surface to tile depth
- Background Cl complicates mass balance

Conclusions

- Macropores important in first 24-48hrs (< 10% Br)
- Winter melts are most important single event (>20% Br)
- Tile drain (surface water) primary tracer receptor
- Groundwater at this site (upwards gradient) not at risk
- Tracer applied in Nov within 2m of tile effectively gone by May
  - Equates to:
    - 33% loss at 12m tile spacing } Assuming full field coverage

Ontario Environmental Implications

- Assumptions
  - 1/3 of all LSM manure applied in fall
  - 2/3 of receiving fields are tile drained
  - 15m tile spacing
  - Our field site is typical

Nitrogen loading on surface water from fall LSM applications = 1.15 million Kg/yr

Ontario Economic Implications*

(From the farmers' perspective: Nitrogen has value)

- Assumptions
  - Lost N replaced by equivalent Urea N [$CO(NH_2)_2$]
  - Urea = $300/ton

Replacement cost of N lost to the environment from fall LSM application = $840,000/yr ($290/1000hogs)

* Guidance was obtained from: www.ext.colostate.edu/pubs/crops/00548.html

In Summary

Fall LSM application

leads to

high N losses to the environment

and there is currently

Little financial incentive for farmers to change

Ackowledgements

- **Funding**
  - Ontario Ministry of the Environment
  - Canadian Foundation for Innovation (CFI)
  - Ontario Pork
  - NSERC

NSERC CRSNG

Ontario

Canada Foundation for Innovation
Fondation canadienne pour l'innovation

ONTARIO PORK

- **People**
  - Jeff Melchin
  - Joanna Passmore
  - Julia Charlton
  - Sean Sinclair
  - Paul Johnson
  - Bob Ingelton
  - Brewster Conant
  - Andrew Wiebe
  - Cailey McCutcheon

And
Franks Aarts and Family