Quantifying Phosphorus Losses from Tile Drained Agricultural Lands: Investigating the Influence of Preferential Flow

Mohamed Chikhaoui & Mark Eastman

Apurva Gollamudi, Chandra Madramootoo and Aubert Michaud

Brace Centre for Water Resources Management
Department of Bioresource Engineering

McGill University

Tile Drainage Workshop – W.H. Miner Institute
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PROBLEM

Eutrophication:

- Eutrophication of Bay Missisquoi
- Algal blooms – cyanobacteria
- Loss of recreation
- Health hazards

Non-Point Source Pollution:

- Agricultural industry
- Intensification/mechanization
    - Subsurface drainage

Subsurface Drainage:

- P transport pathway?

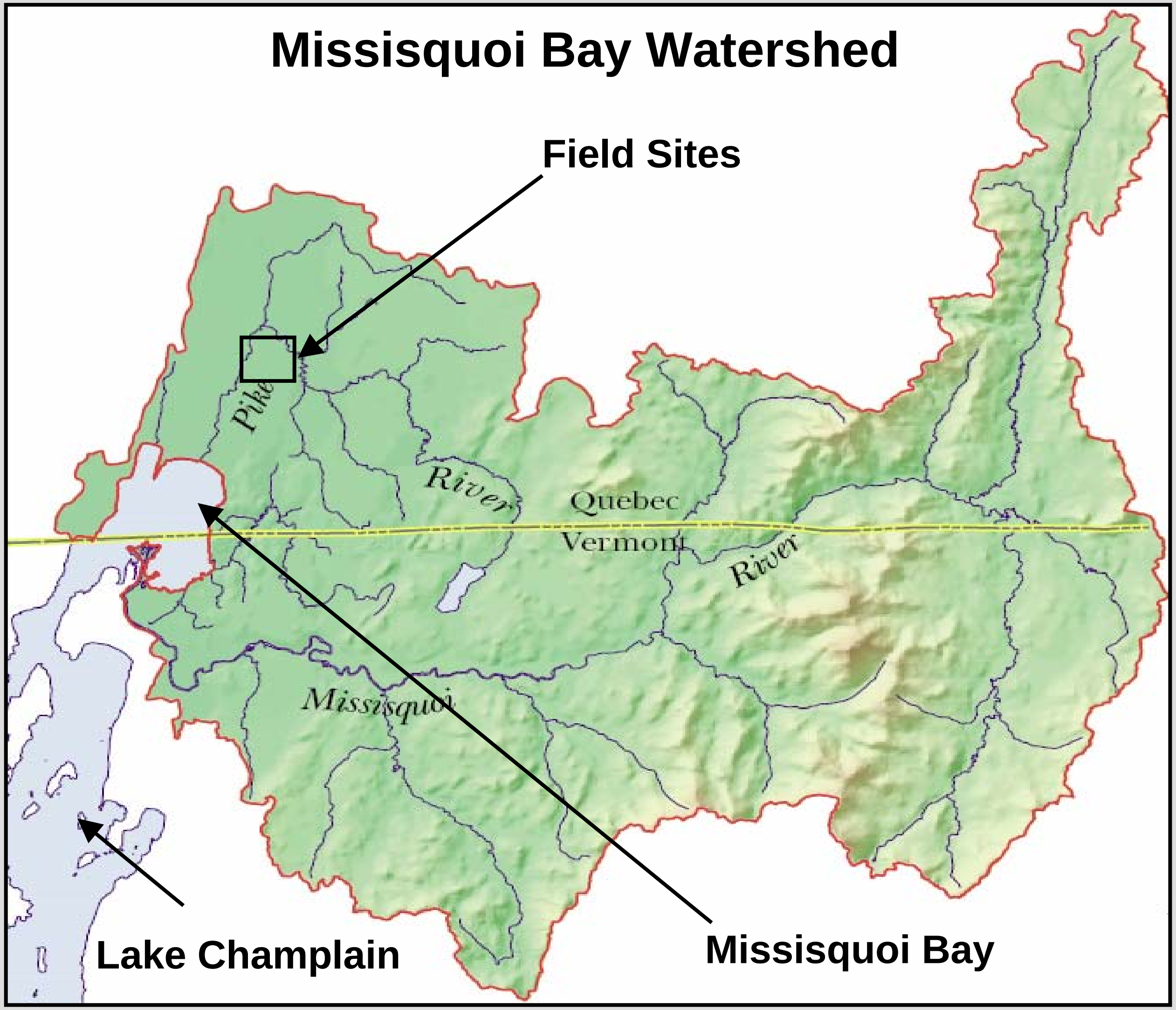
OBJECTIVES

Quantify phosphorus loss from agricultural tile drainage systems under clay loam and sandy loam soils

Identify factors which influence the risk of P loss from subsurface drained fields under clay loam and sandy loam soils

Estimation of preferential flow (bypass) contributions to tile drains

LOCATION


Missisquoi Bay Watershed
Field Sites
Pike
River
Quebec
Vermont
River
Missisquoi
Lake Champlain
Missisquoi Bay

FIELD SITES

4 Field Sites Instrumented

- 2 Subsurface Drained Sites (2000)
  - Site A (Gagnon) - Clay Loam (approx. 41% clay)
    - P-test = 145 kg ha-1, P-sat = 7%
  - Site B (Marchand) - Sandy Loam (approx. 10% clay)
    - P-test = 289 kg ha-1, P-sat = 17%

Accurate data available from 2002 onwards

INSTRUMENTATION

Surface Hydrology

- Flumes
- Ultrasonic Depth Sensors
- Pressure Transducers
- Automatic Samplers

Subsurface Hydrology

- Flow Meters
- Water Table Levelloggers
- Automatic Samplers

Depth Sensor

H - Flume

Composite Auto-Sampler

Water Table Measurement

Subsurface Flow meter

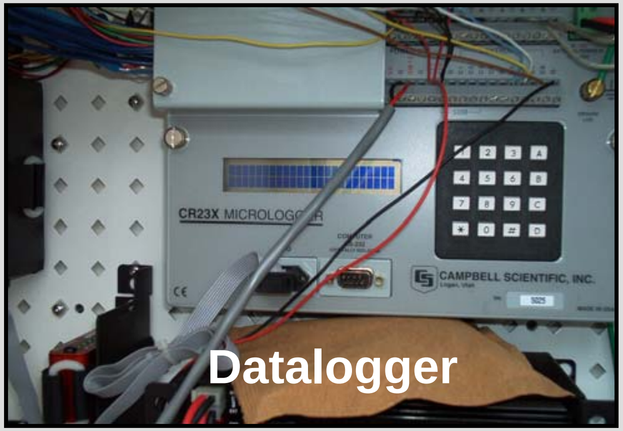
INSTRUMENTATION

Meteorological

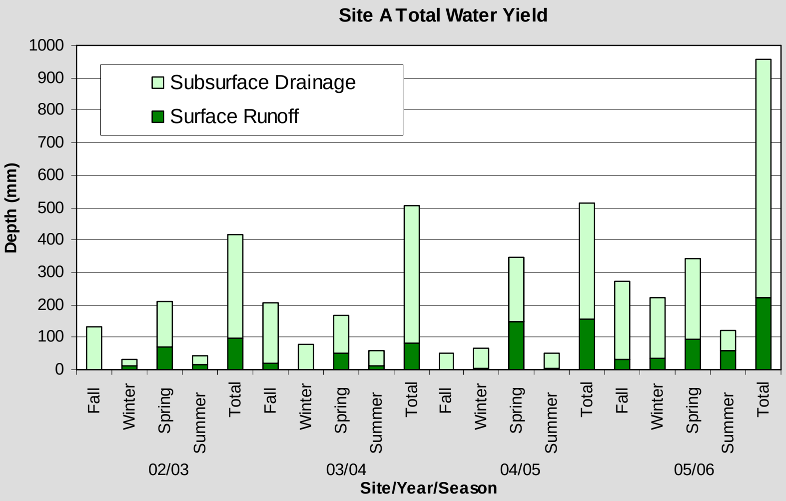
- Temperature – Air and Soil
- Rain Gauges
- Barometric pressure
- Wind Speed
- Solar Radiation

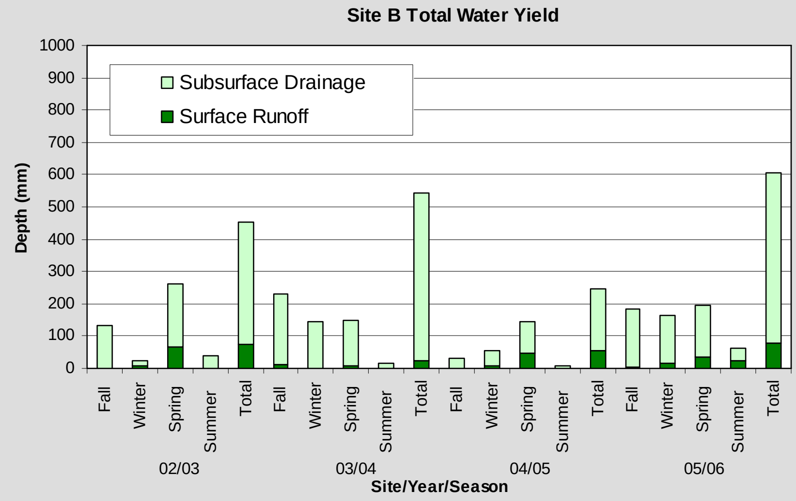
Data Storage/Access

- Data loggers
- Radios
- Modems / Cell Phones

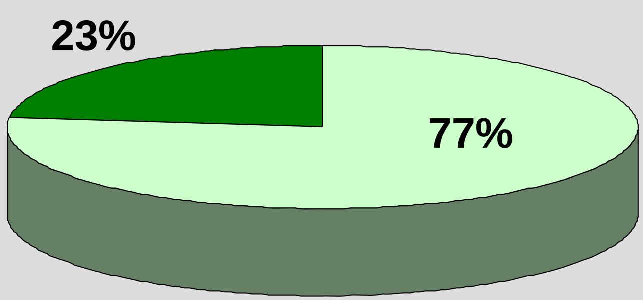


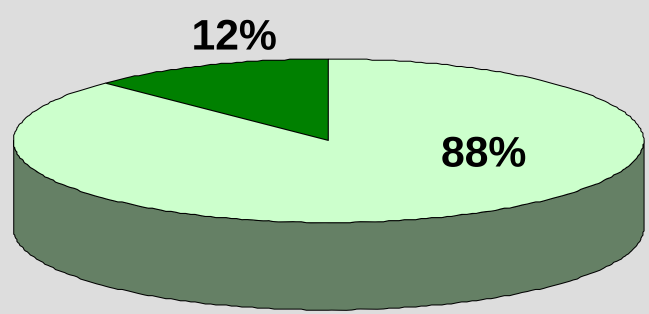
HYDROLOGY RESULTS





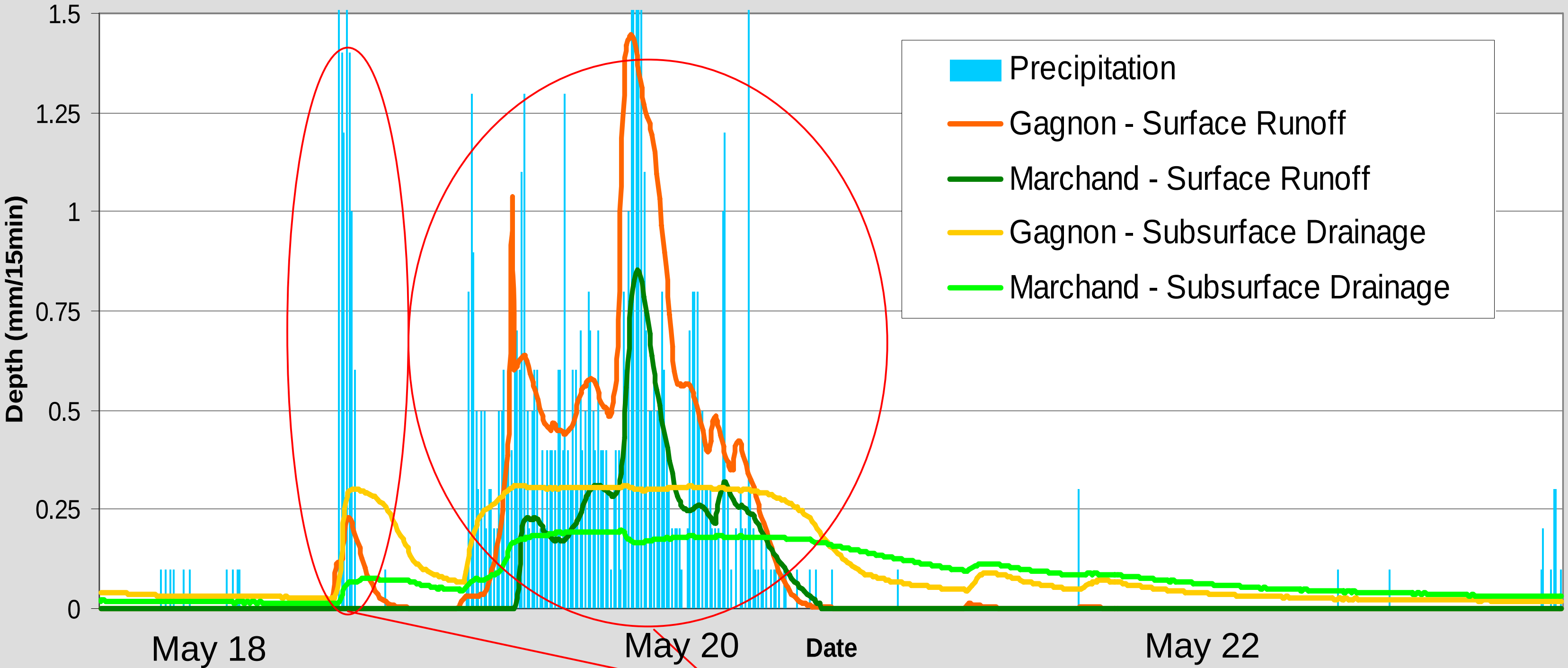
- Average subsurface drainage = 461mm and 405mm at sites A and B
- Average surface drainage = 139mm and 57mm at sites A and B





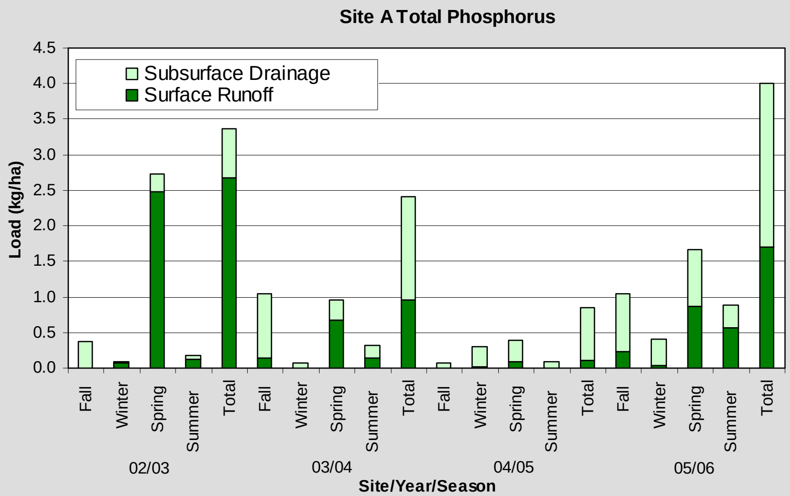
- Site A is much more hydrologically responsive – expected for surface runoff, but for subsurface drainage as well?

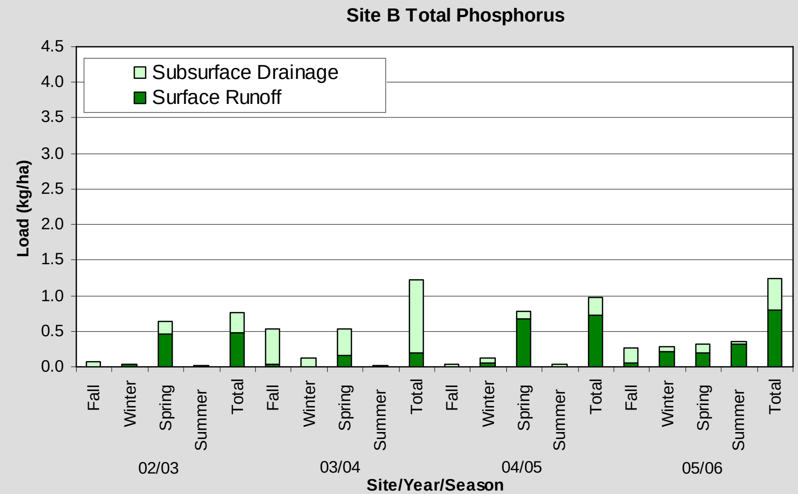
EVENT ANALYSIS – May 18-23, 2006



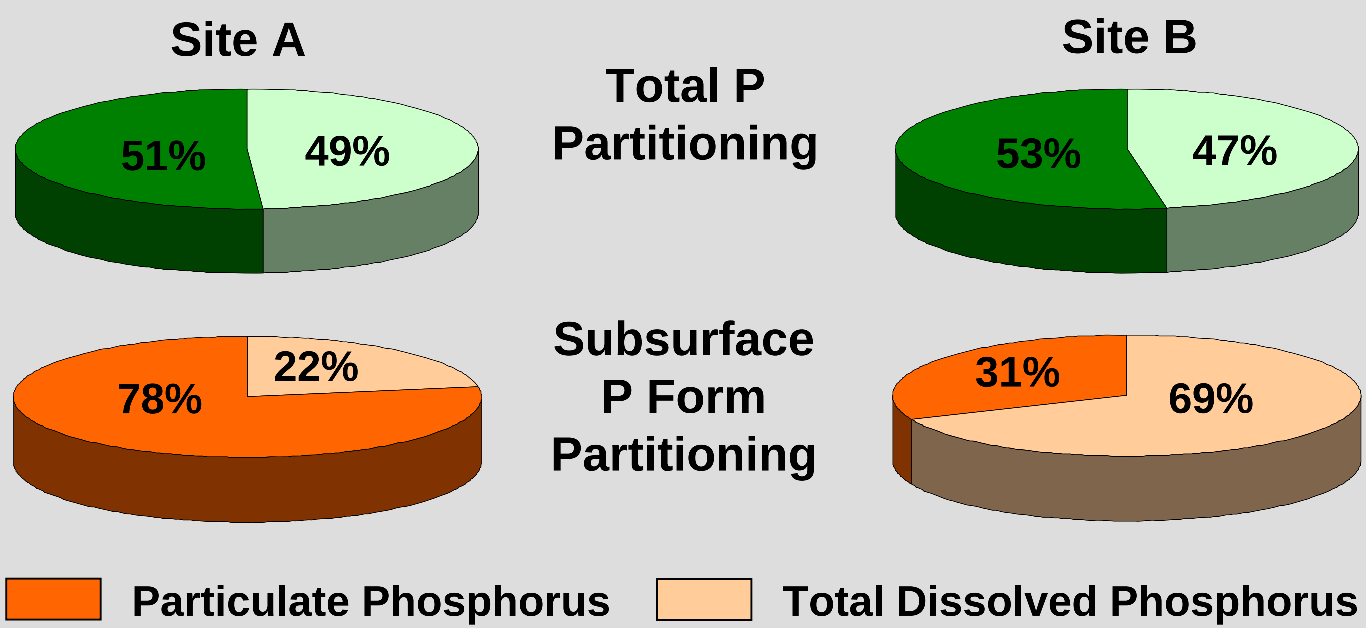
- Large rain event: fairly intense at times, long duration (3 days)
- Very short, intense rain event
- Rapid surface runoff and subsurface drainage response at Gagnon
- Rapid surface runoff and subsurface drainage response at Gagnon
- Less surface runoff and a slower subsurface drainage response at Marchand
- No surface runoff and a slow subsurface drainage response at Marchand
- Rapid subsurface response at Gagnon is a result of macropore/crack flow

PHOSPHORUS RESULTS



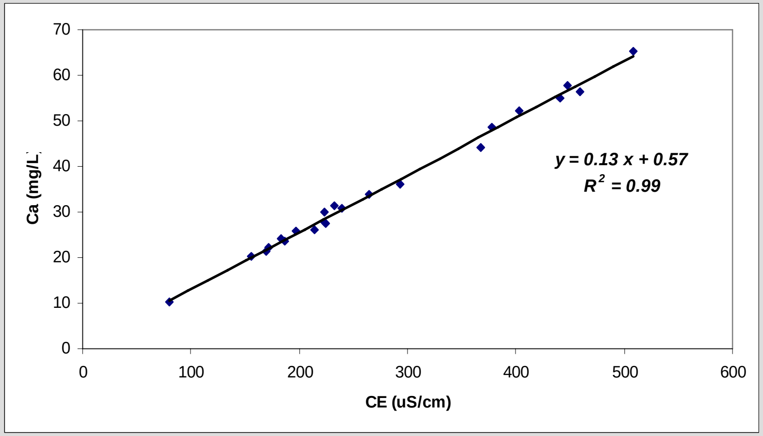


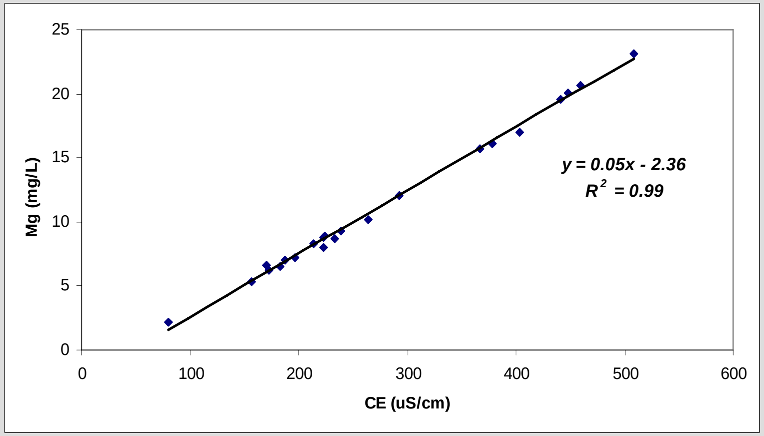
- Average annual Total P loads = 2.7 kg/ha at site A and 1.0 kg/ha at site B

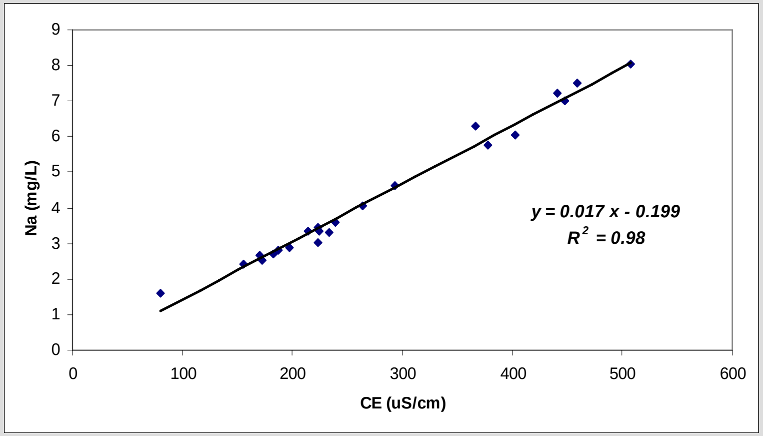


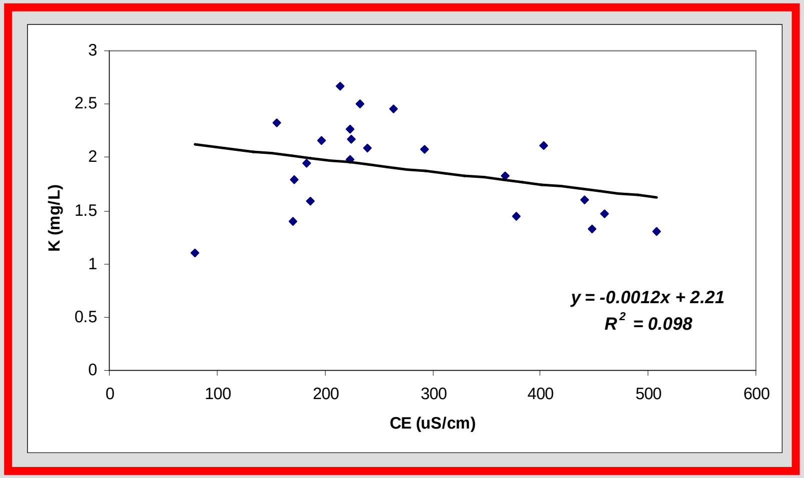
ESTIMATION OF PREFERENTIAL FLOW

Site A (Gagnon)



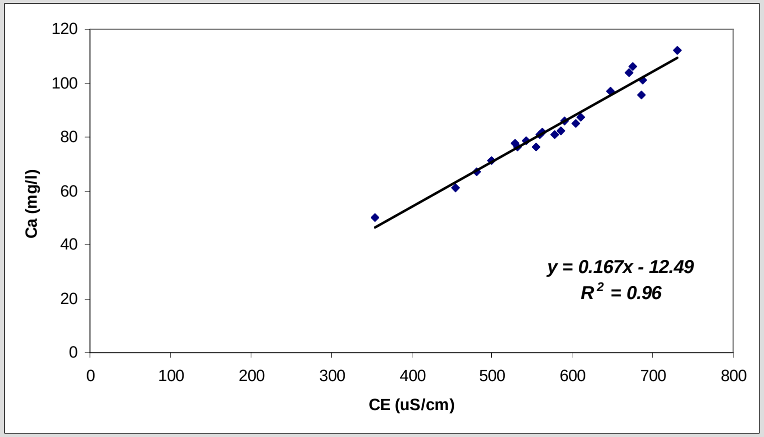


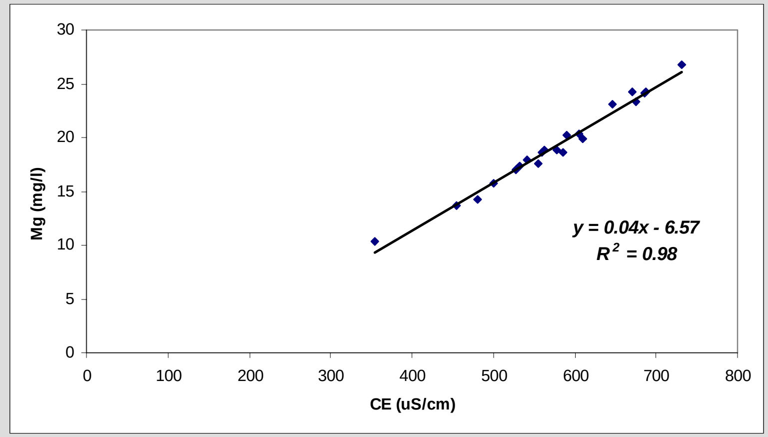


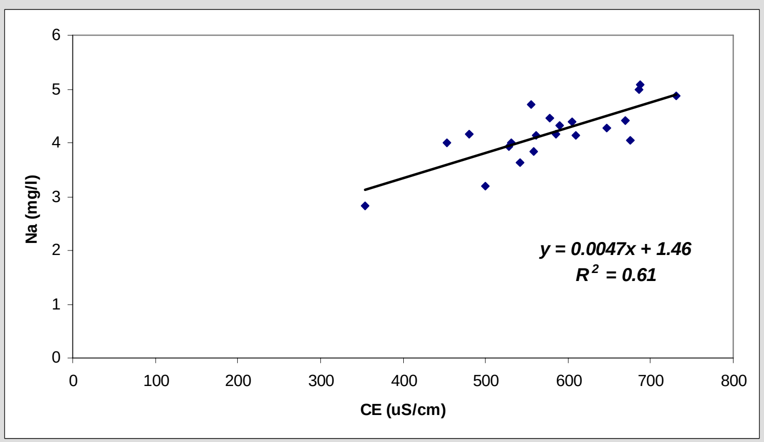


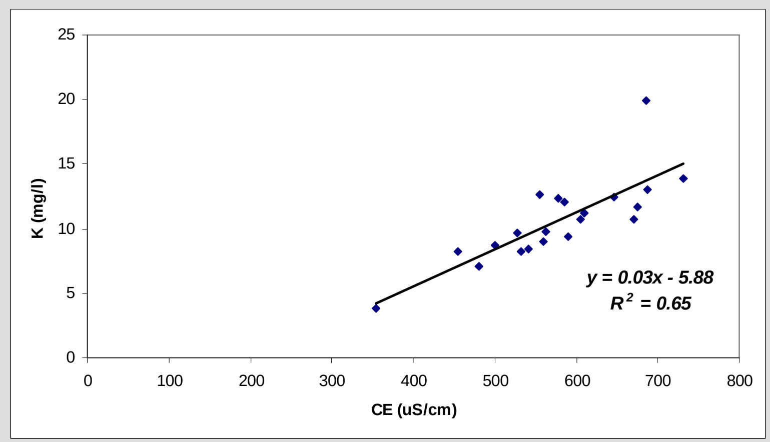
ESTIMATION OF PREFERENTIAL FLOW

Site B (Marchand)









ESTIMATION OF PREFERENTIAL FLOW

- Conservation of mass equations

(Stone et Wilson, 2006)

$$\begin{cases} Q_d = Q_m + Q_p \\ Q_d C_d = Q_m C_m + Q_p C_p \end{cases}$$

1- Preferential flow water reflects the chemistry of water from soil surface;

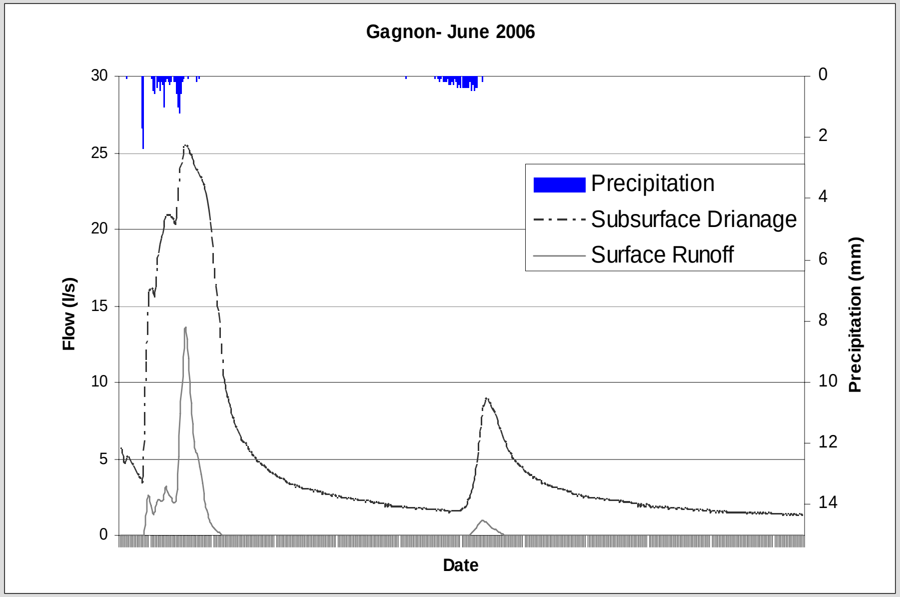
2- Matrix flow water reflects the chemistry of water that has more contact time with soil and base flow (Steenhuis et al., 1994).

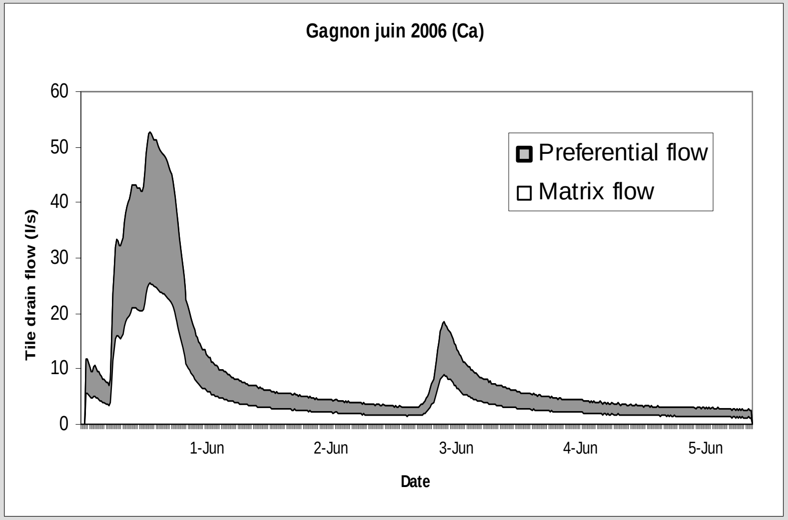
$$Q_p = \frac{Q_d (C_d - C_m)}{(C_p - C_m)}$$

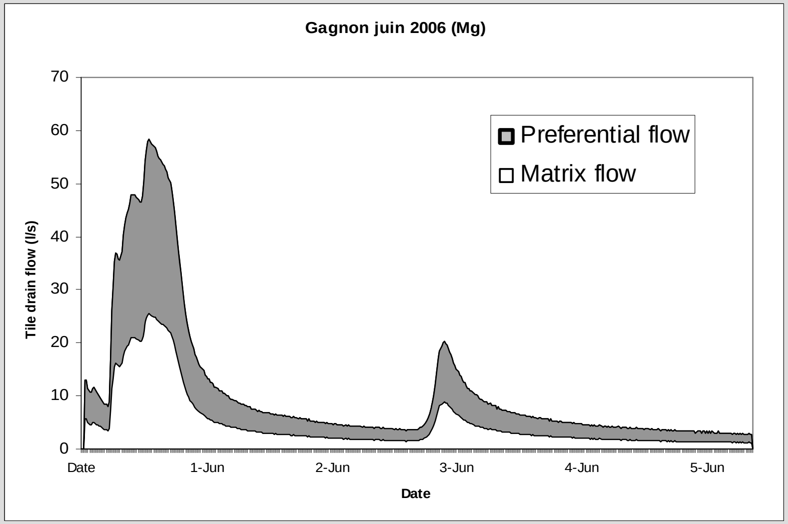
$$Q_m = \frac{Q_d (C_d - C_p)}{(C_m - C_p)}$$

ESTIMATION OF PREFERENTIAL FLOW

- Conservation of mass equations







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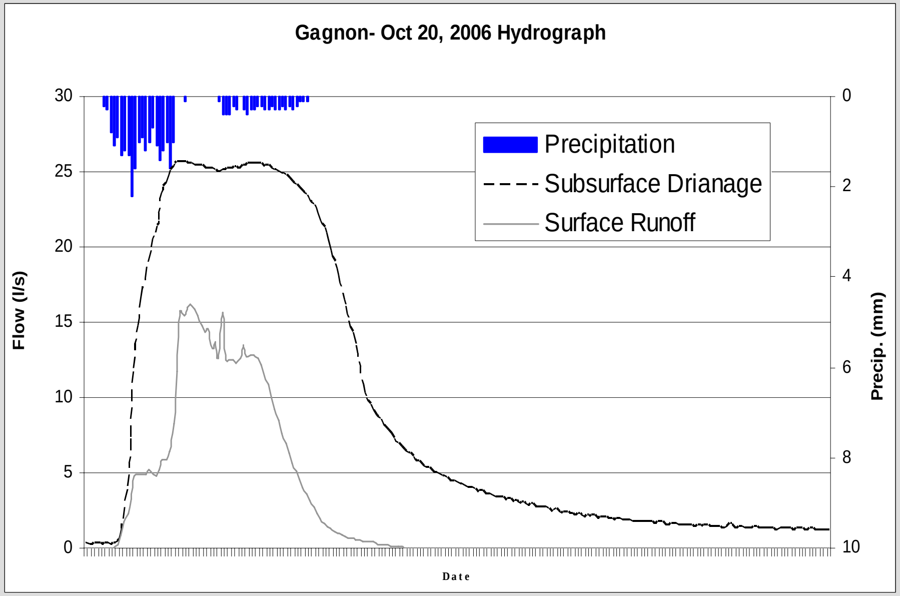

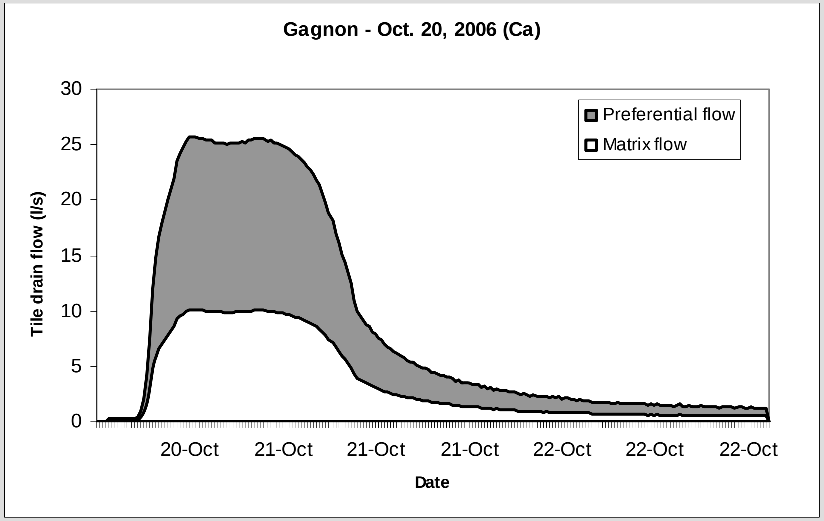

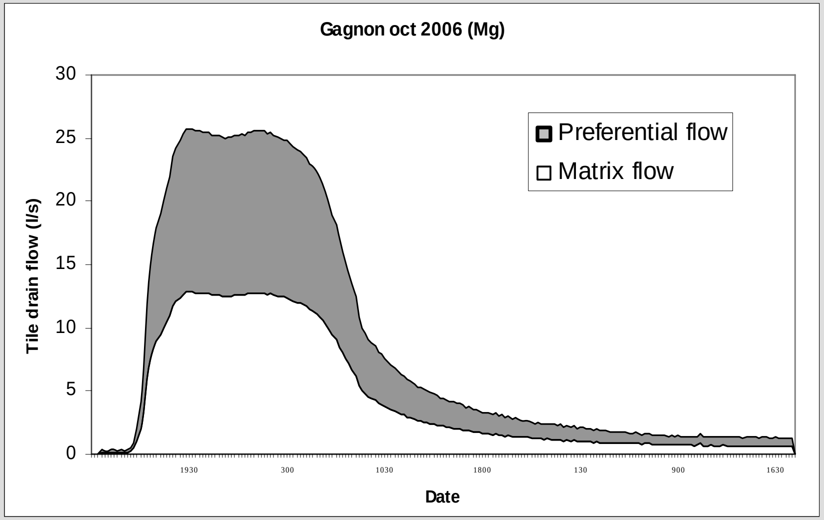

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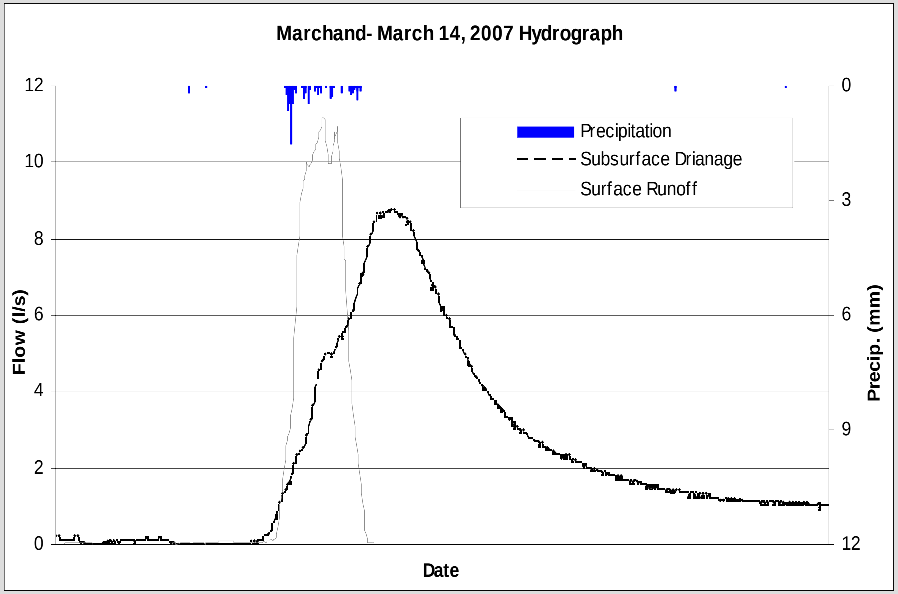

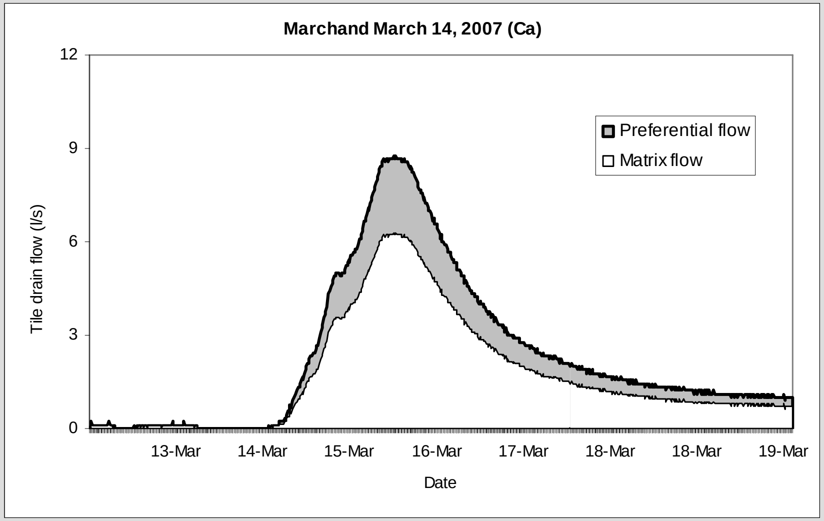

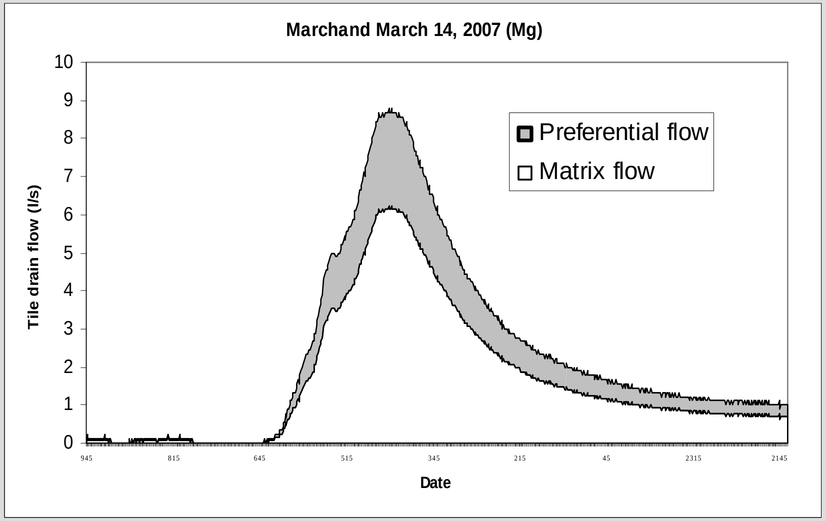

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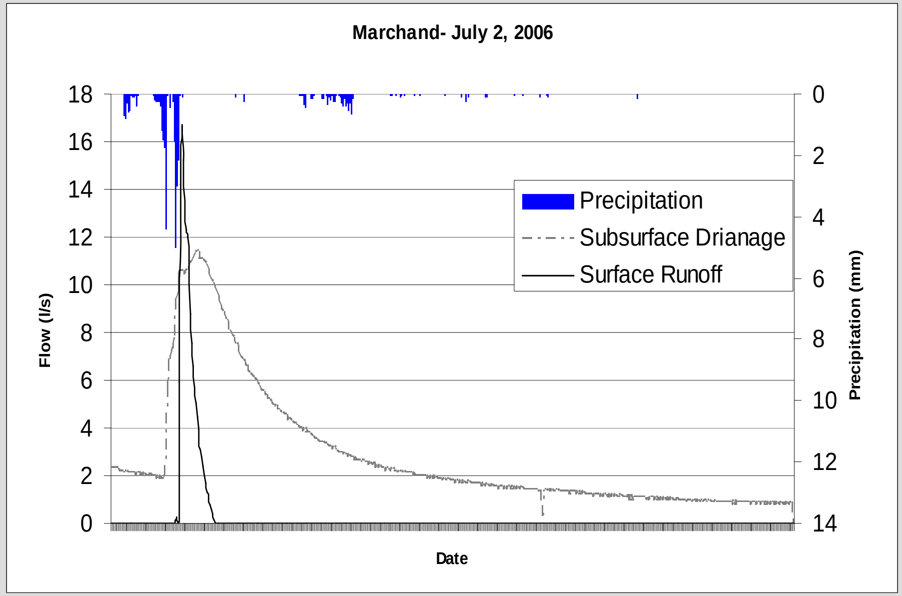

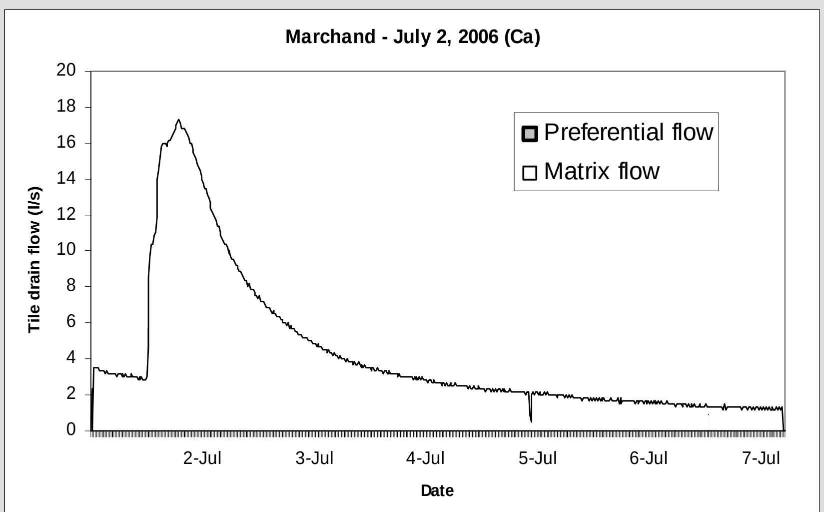

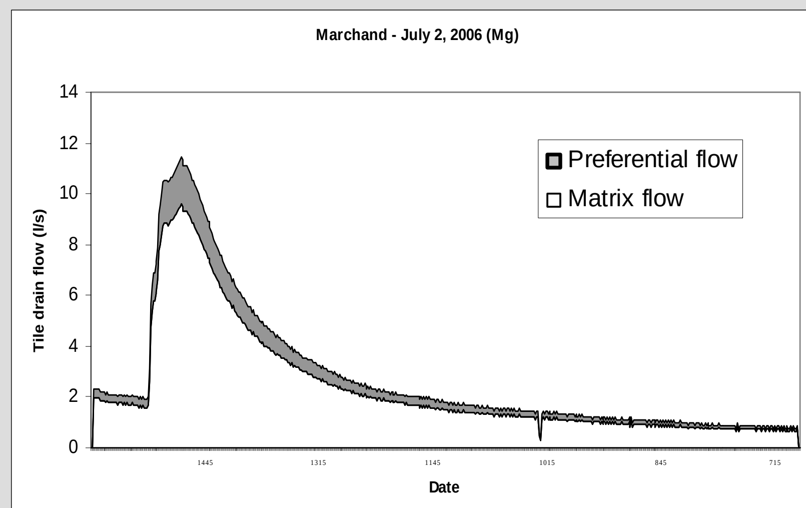

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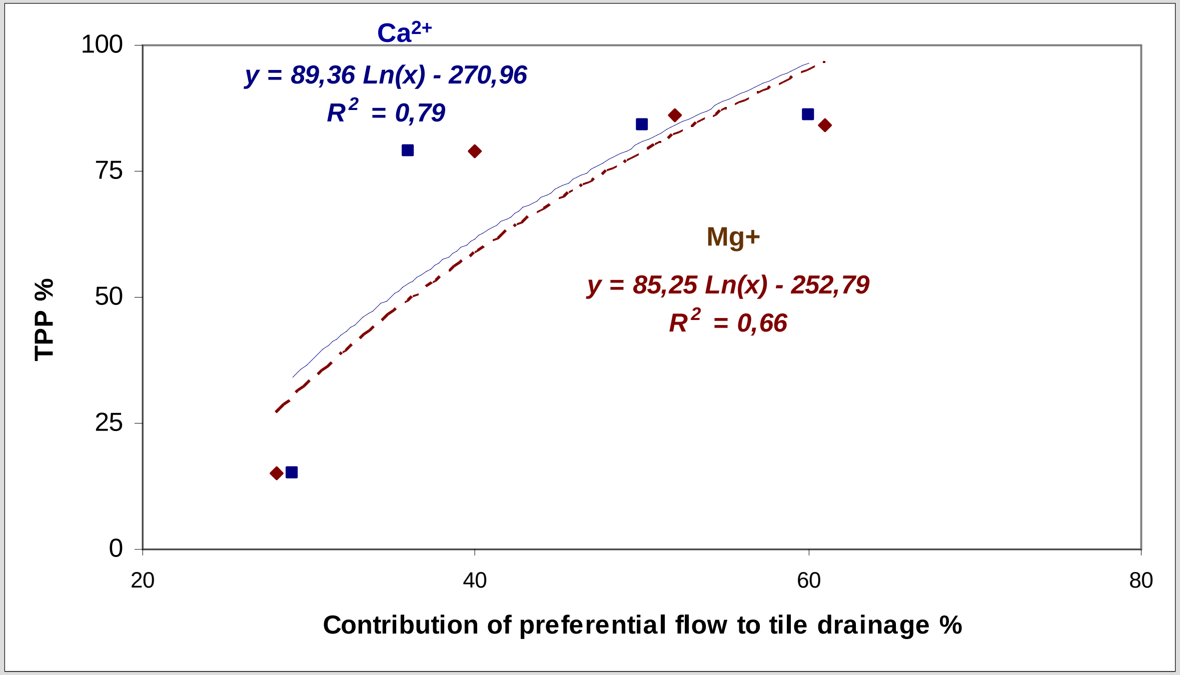

CONCLUSION

- ✓ The clay loam site (site A) was more hydrologically responsive in terms of surface runoff and subsurface drainage than the sandy loam site;

- ✓ Preferential flow through a fine soil is dominant (70%);

- ✓ Matrix flow through a coarse soil is dominant (80%);

CONCLUSION

- The peak of preferential flow coincided with the peak of tile drain;
- High intensity storms contribute larger proportions of preferential flow to tile drains than lower intensity storms (Kumar et al., 1997);
- Highest P loading occurred from one of the lowest P-test and P-Sat soils (Site A - 145 kg ha-1, 7%) and the lowest P loading occurred from the highest P-test and P-Sat soil (Site B - 289 kg ha-1, 17%)
- Preferential flow is an important transport mechanism for PP;
- Forms of P loads depend of type of flow and soil profile;
- The elements (Ca^{2+}, Mg^{2+}) satisfactorily predict the extent of preferential flow.

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