B.4 Constructed Pile Experiment

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Constructed Pile Experiment

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Part of the
Waste Rock Hydrology
Research Program

University of British Columbia
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Cameco Corporation
NSERC

Outline of the Presentation

This talk discusses some of the results of the ongoing research program on unsaturated waste rock hydrogeology at the University of British Columbia. An intermediate-scale (8m x 8m x 5m) waste rock pile has been constructed and instrumented at the Cluff Lake mine in northern Saskatchewan. The constructed pile is monitored for moisture content, matric suction, temperature, matrix water chemistry, gas chemistry, gas pressure, rainfall, evaporation, discharge volume and discharge chemistry. The pile is built upon a grid of 16 contiguous 2m x 2m lysimeters. The experiment is designed to investigate the mechanisms that create rapid water flow through a pile and its exchange with slower-moving matrix water.

Instrumentation

Long-term performance of instrumentation for the measurement of matric suction, and the measurement of moisture content has been evaluated. The matric suction sensors installed in the pile have been found to be of limited applicability. Moisture content sensors installed in the pile have been successful. Limitations of the moisture content instrumentation and measurement algorithms have been identified.

Flow and Transport Mechanisms

A transient tracer test was started on the constructed pile in September 1999. Since the tracer application, seven artificial rainfall events and a number of large natural rainfall events have infiltrated into the pile. Three distinct flow mechanisms can be inferred from the measured tracer data. Some of the infiltrating water bypasses the slow-moving water resident within the soil matrix (matrix water) with limited interaction and discharges from the pile during a single rainfall event prior to the arrival of a wetting front. A fraction of the infiltrating water flows in large macropores and interacts with the matrix water, but was found to maintain a water chemistry distinct from the matrix water for at least a month. The residence time of this water ranges from hours to over a month. The remaining infiltrating water becomes part of the matrix water where the residence time is expected to be years. The majority of water discharge following the arrival of a wetting front at the base of the constructed pile is matrix water.

Presentation Outline

- Introduction to the Constructed Pile Experiment
- Instrumentation
  - Matric Suction
  - Moisture Content
- Tracer test results and flow mechanisms
- Representative Lysimeter Size

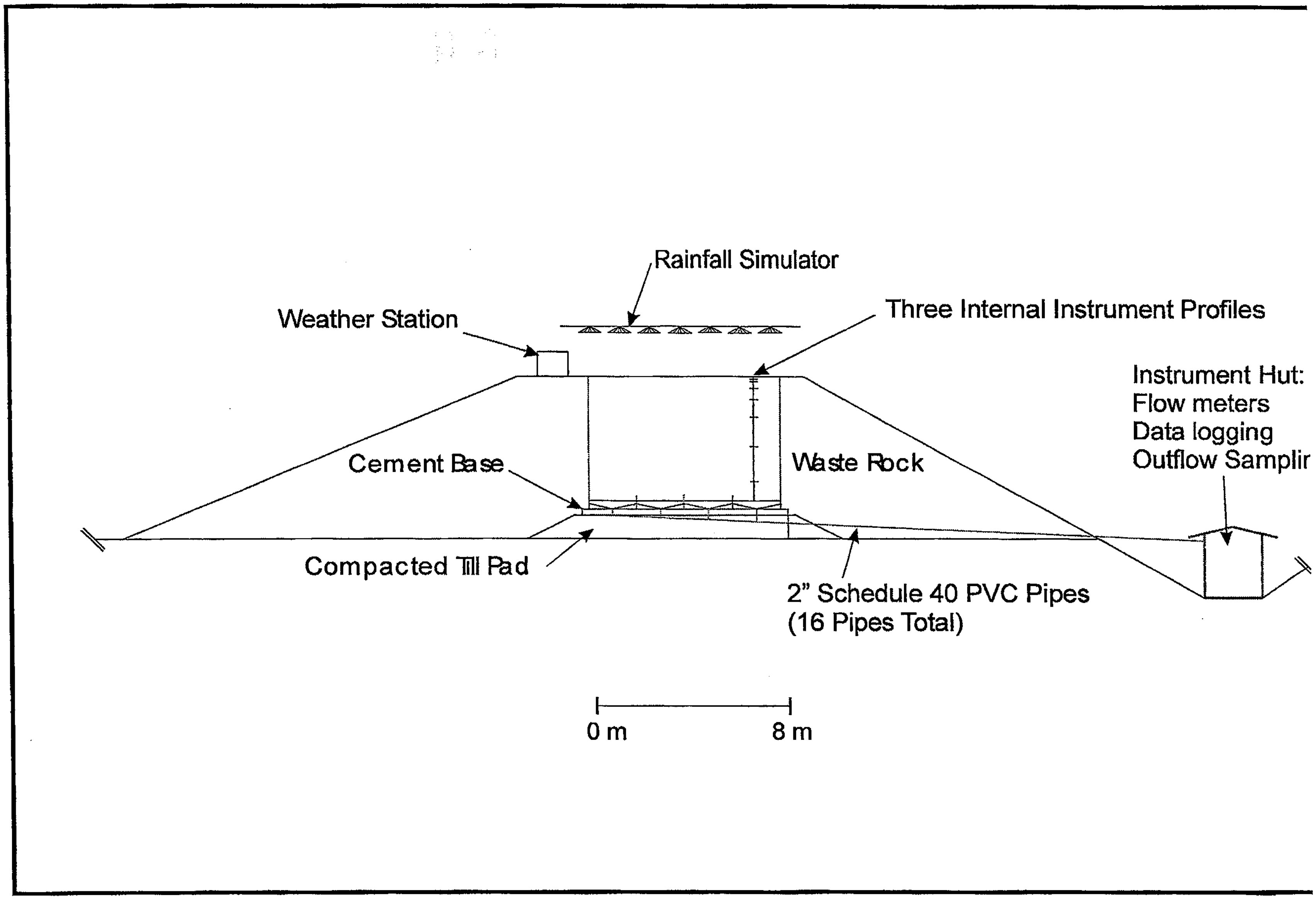
Research Outline

Primary Objective:

Investigate the mechanisms leading to environmental loadings of metals and acid from mine waste rock piles.

Critical Hydrogeological Issues:

- Physical mechanisms of flow.
- Initiation of rapid flow of water.
- Relationships between rapid flow, matrix flow and the time-dependant release of metals.
- The physical properties which are critical to the characterization of flow in waste rock.
- Degree of spatial variability of unsaturated flow and metal loadings.
- Scale of experiments / test piles that are appropriate.



Simplified Cross-Section of Constructed Pile

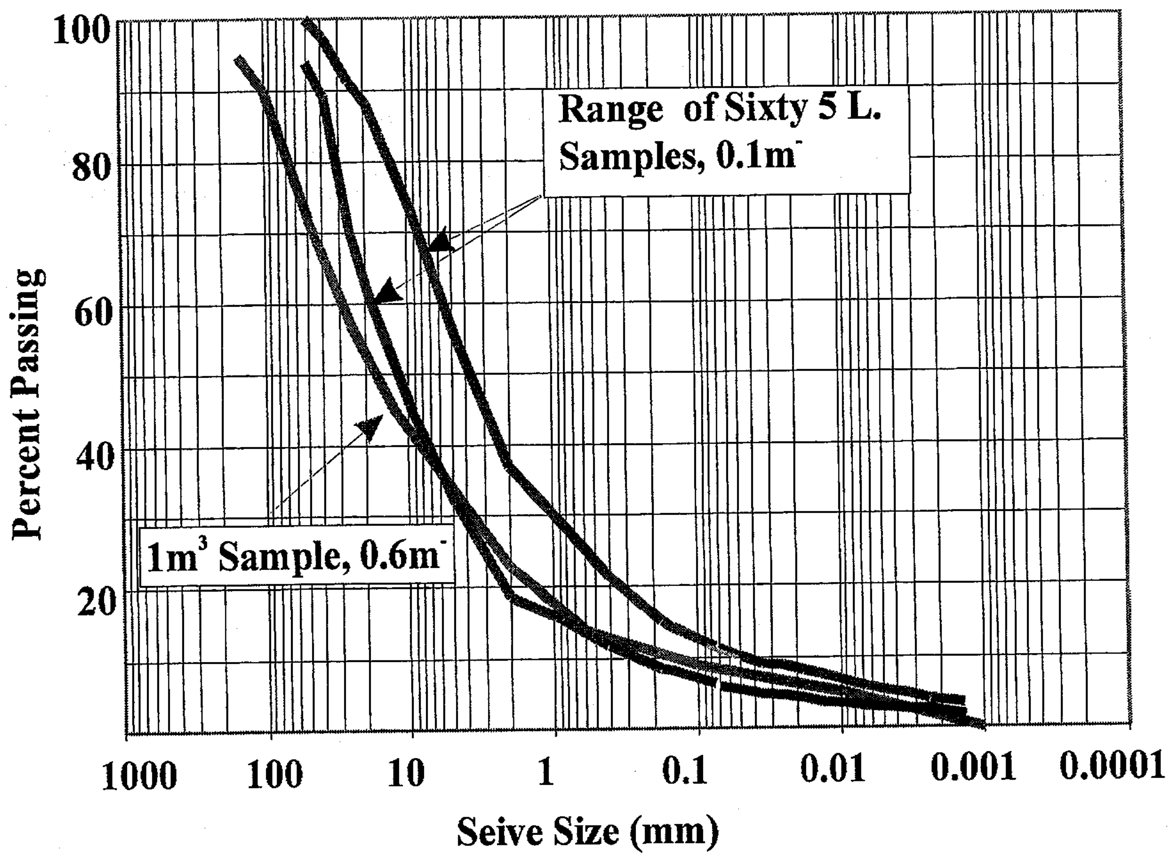
Waste Rock Characteristics

Source Material

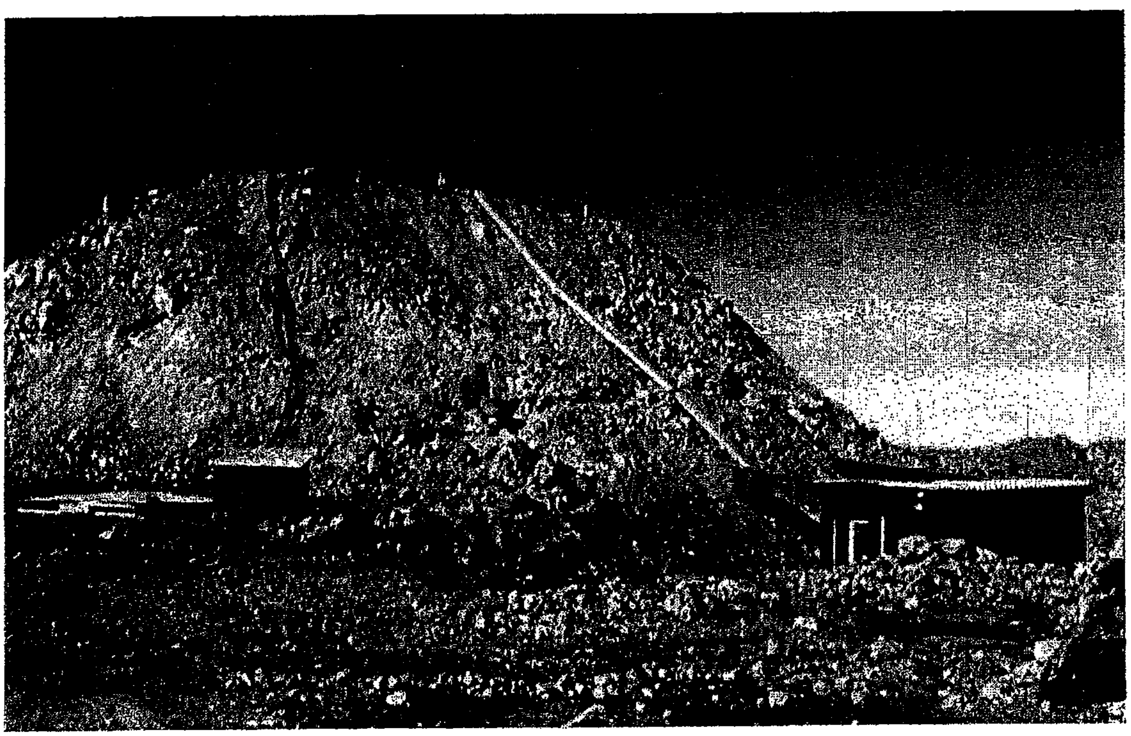
- Mined in fall: 1996
- Pile constructed: summer 1998
- Average total sulphur (0.2-0.5%)
- NP:AP Ratios from 13.2 to 0.1, Average 2.0

Grain Sizes:

- 20%-30% Sand
- 10% Silts and Clay
- Boulders to 1.5 m

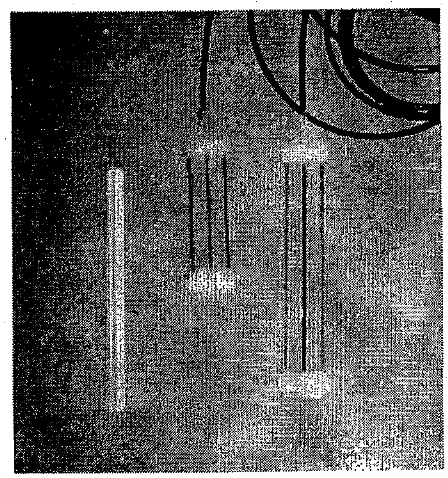


Pile Top Surface



Pile Side View and Instrumentation Hut

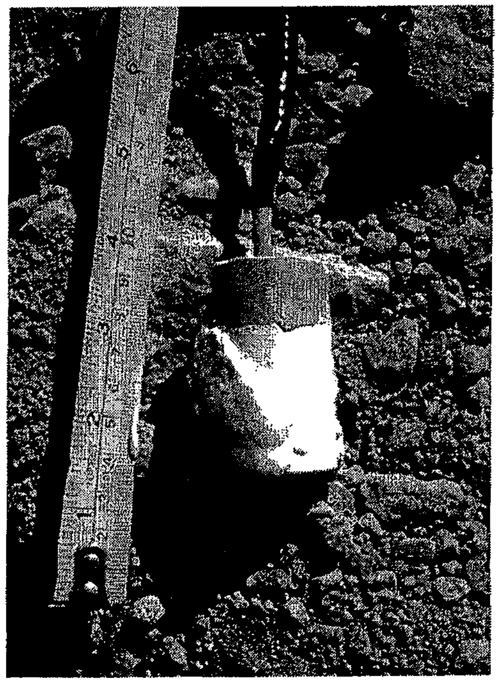
Measurement of Moisture Content
Time Domain Reflectometry
Velocity of an electromagnetic wave in soil.



Conclusions:

- Semi-quantitative results.
- High soil-water solution conductivity requires custom-built coated probes.
- Remote diode shorting method systematically biased in mine waste materials.
- Sophisticated soil-specific calibration required.
- Temperature correction not yet understood in theory or practice.

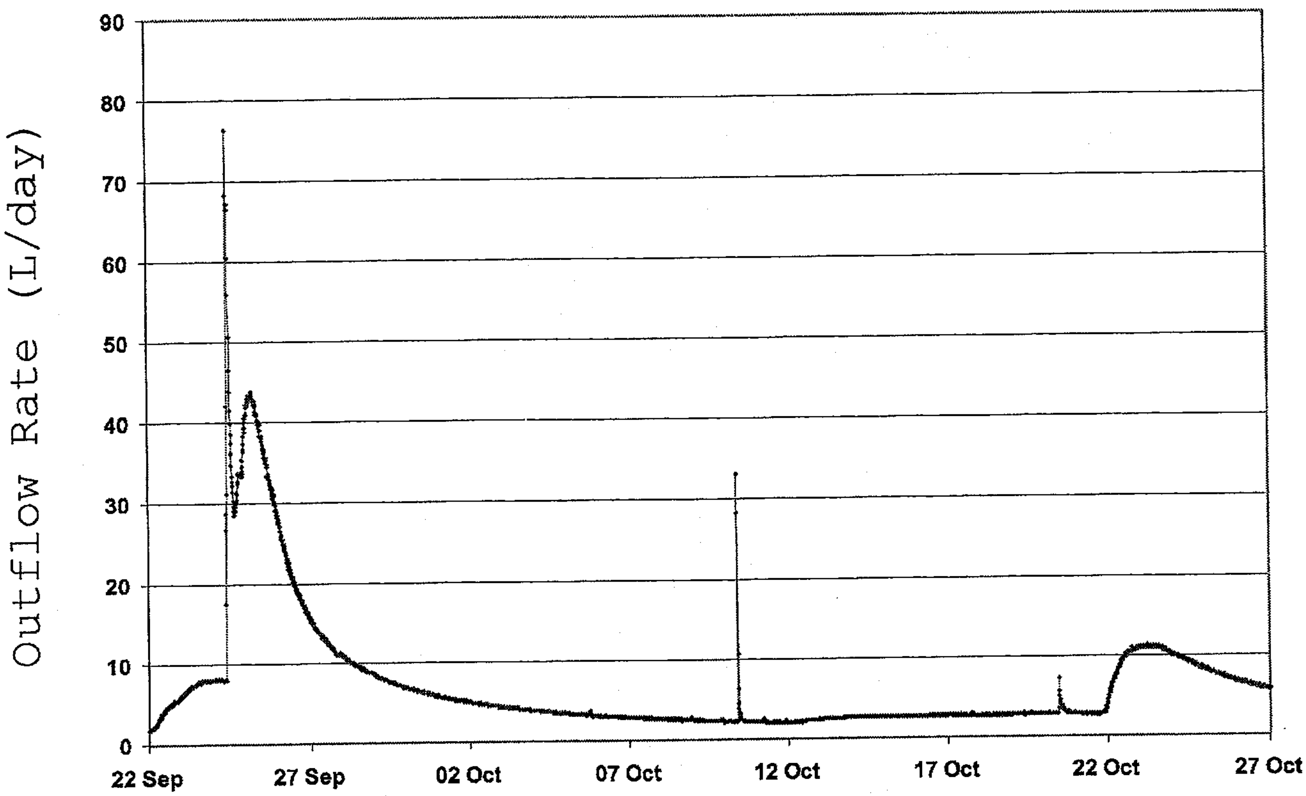
Measurement of Matric Suction
Thermal Dissipation Sensors
Dissipation of heat pulse in a ceramic body.

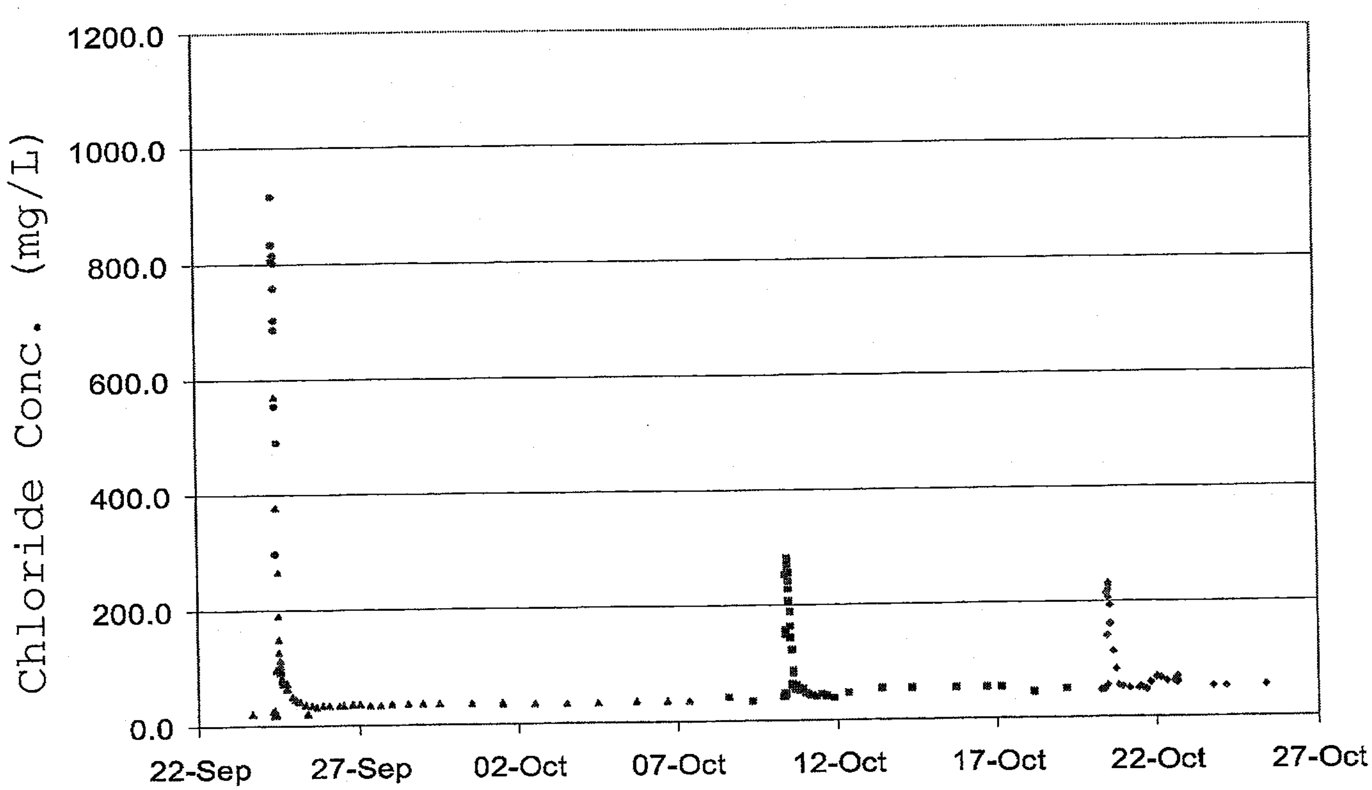


Conclusions:

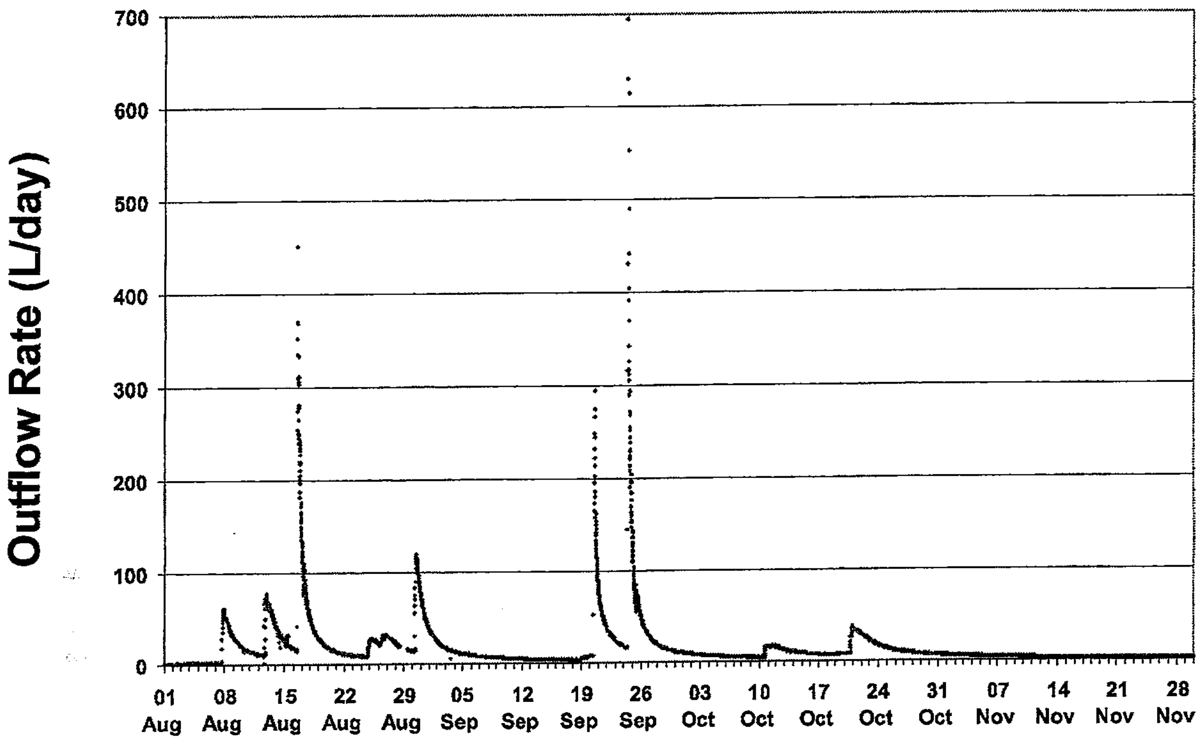
- All sensors installed at > 0.2 m depth have drifted off calibration curves. (15/18)
- Long term failure at low matric suctions. Only reliable if dried out to <-15 kPa regularly.
- Poor response time: Up to 1 to 5 days behind other sensors.

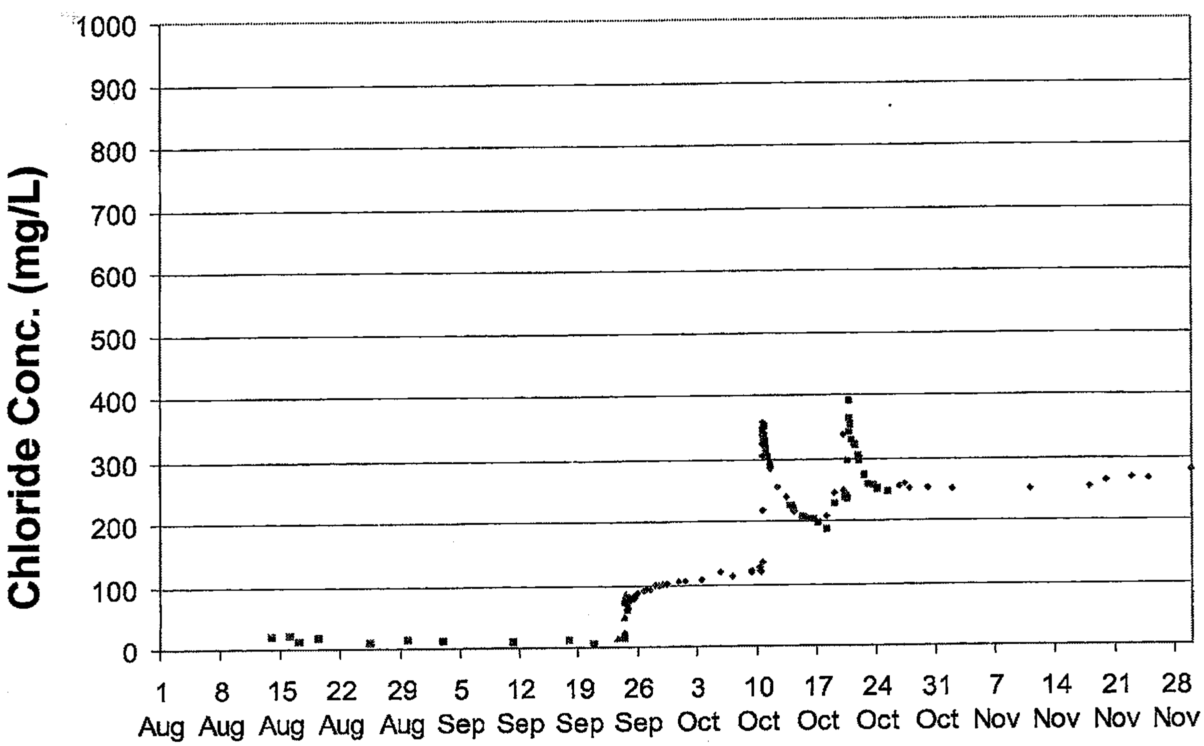
Cell 3: Outflow Rate & Tracer Concentration



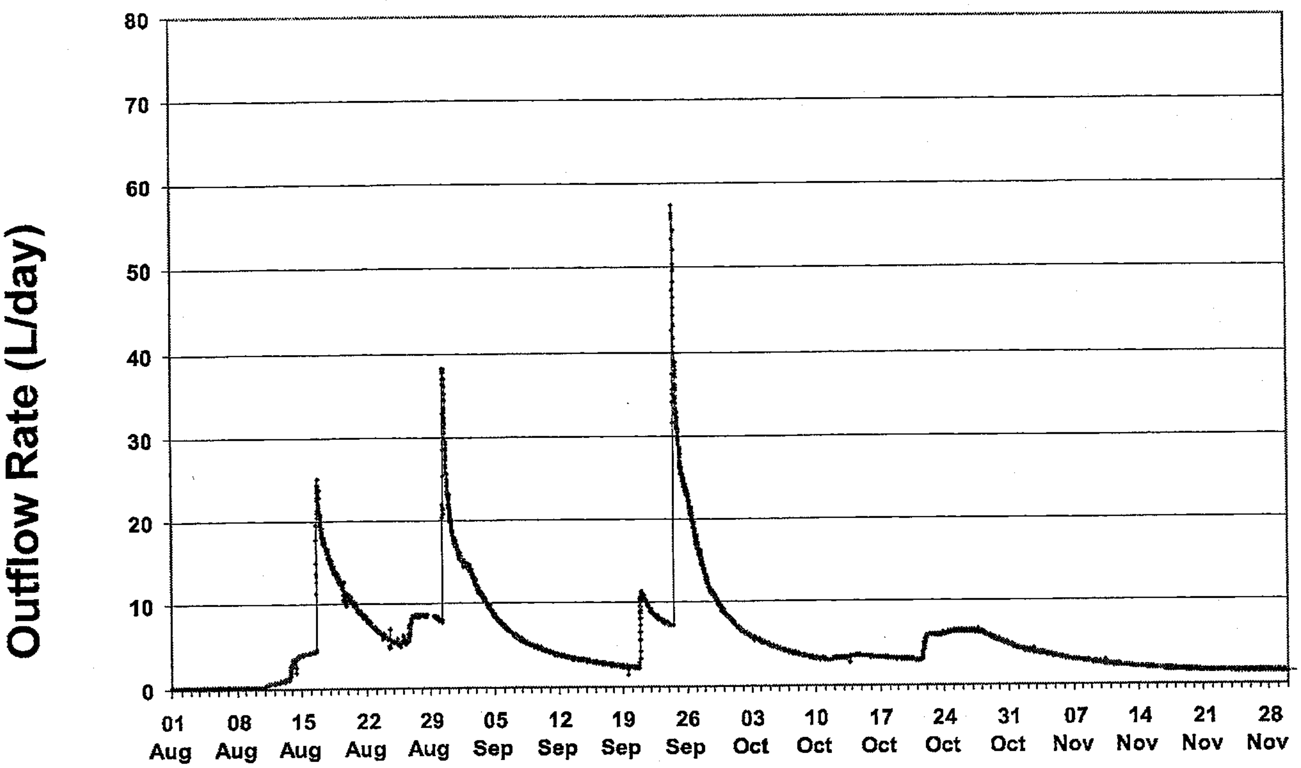


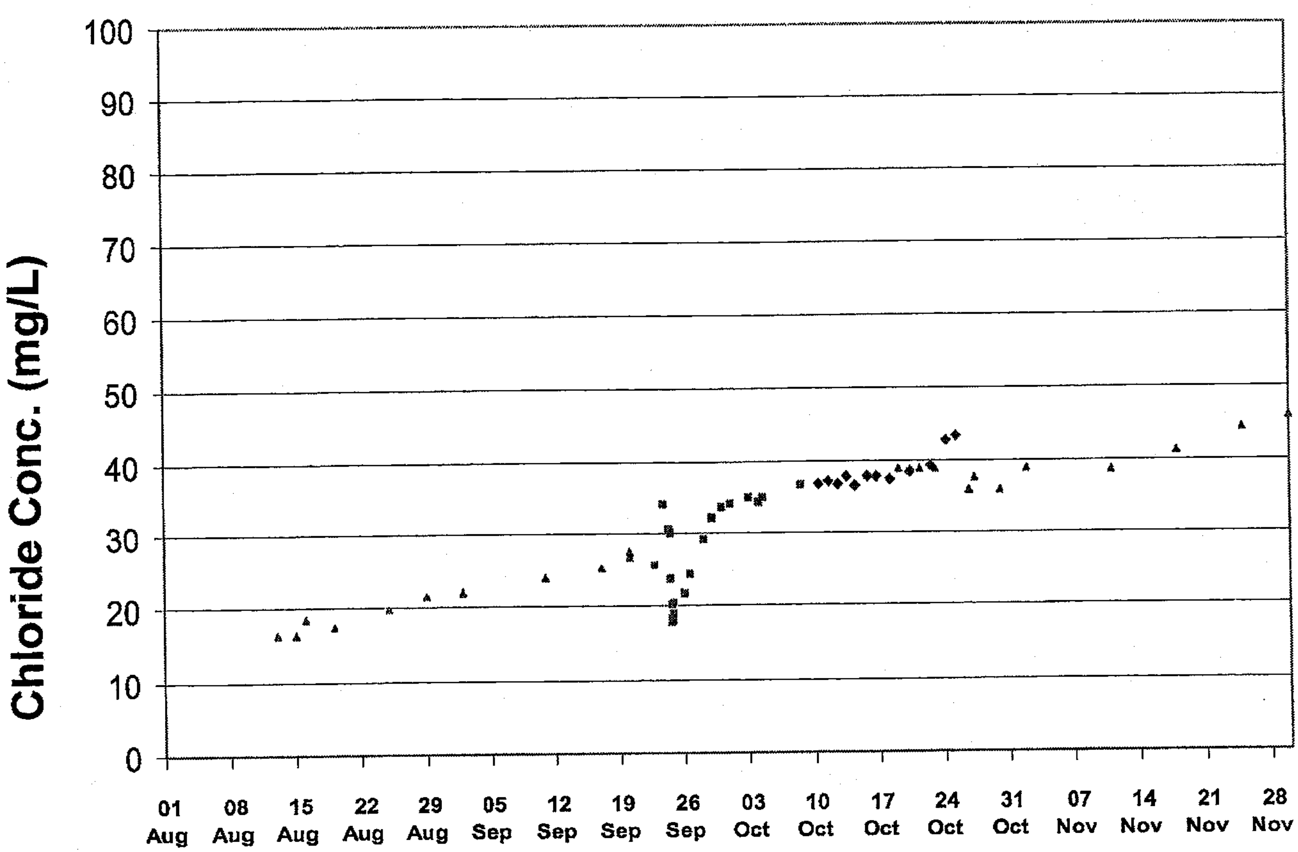
Cell 6: Outflow Rate & Tracer Concentration





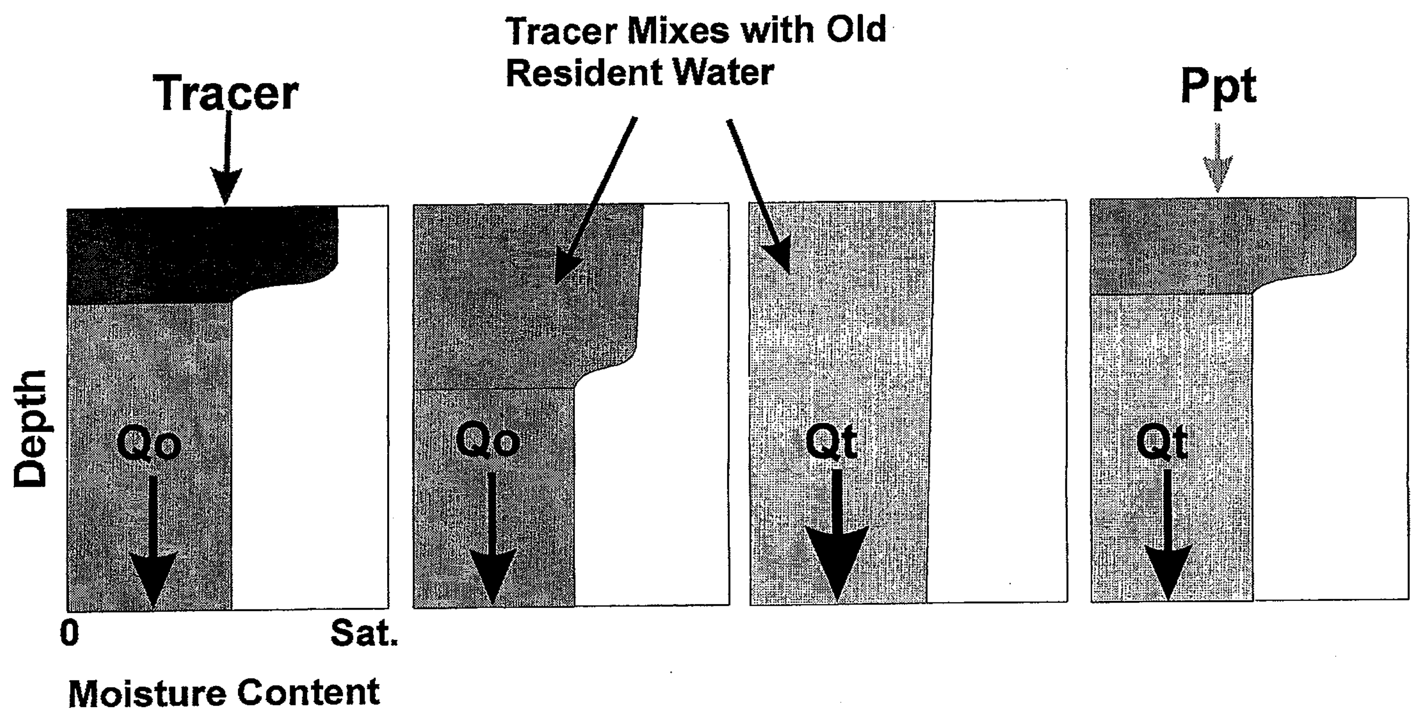
Cell 9: Outflow Rate & Tracer Concentration

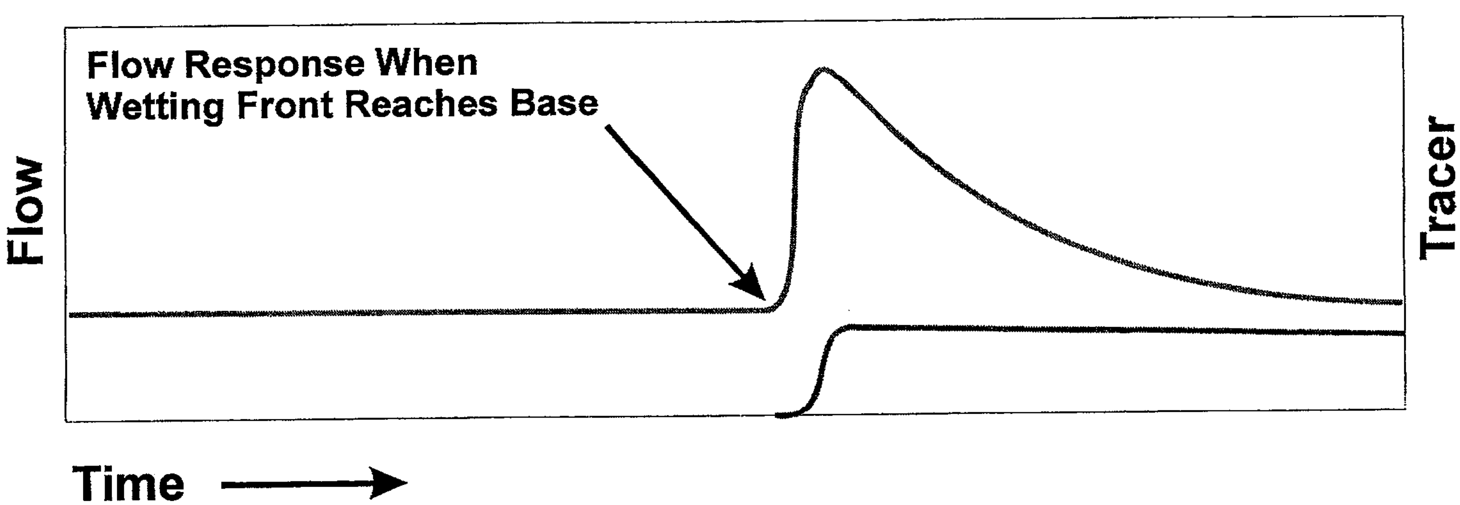




Flow Mechanism 1: Incorrect Interpretation of Wetting Front

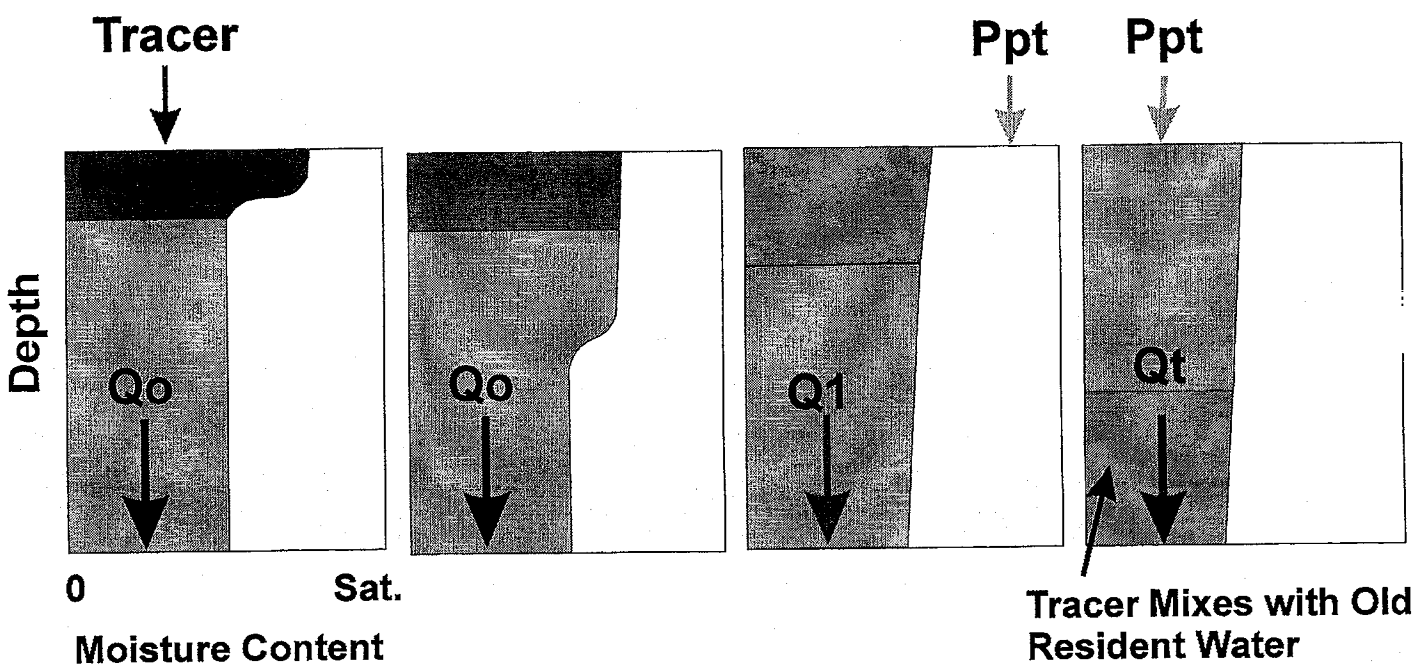
Wetting front in the matrix is the interface between old water and infiltrating new water.

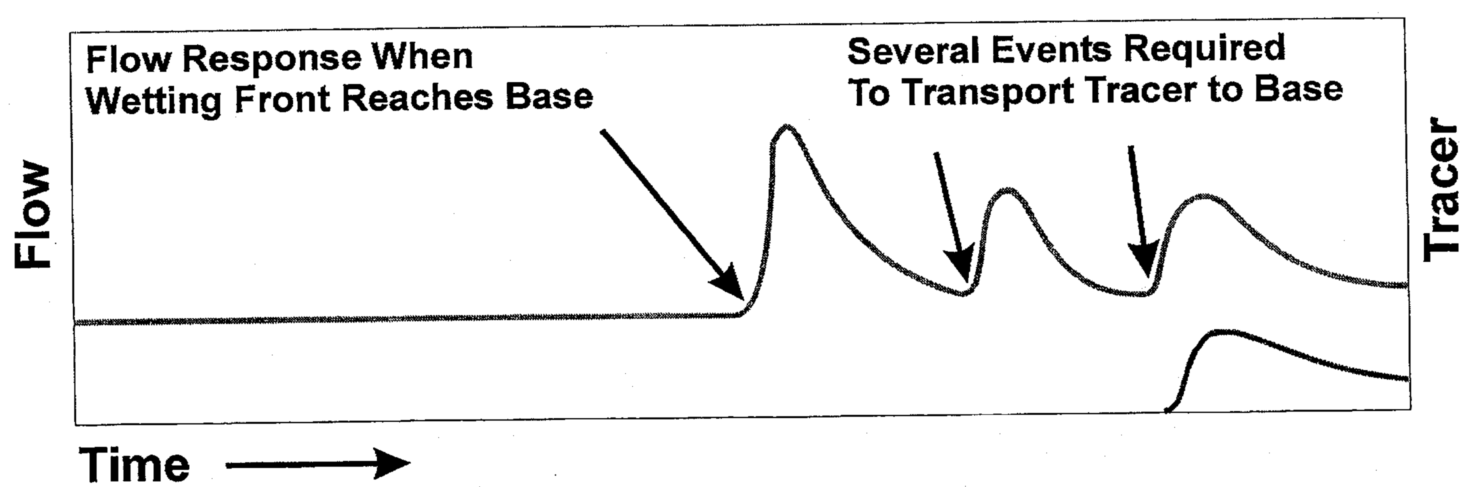




Flow Mechanism 2:
Improved Interpretation of Wetting Front

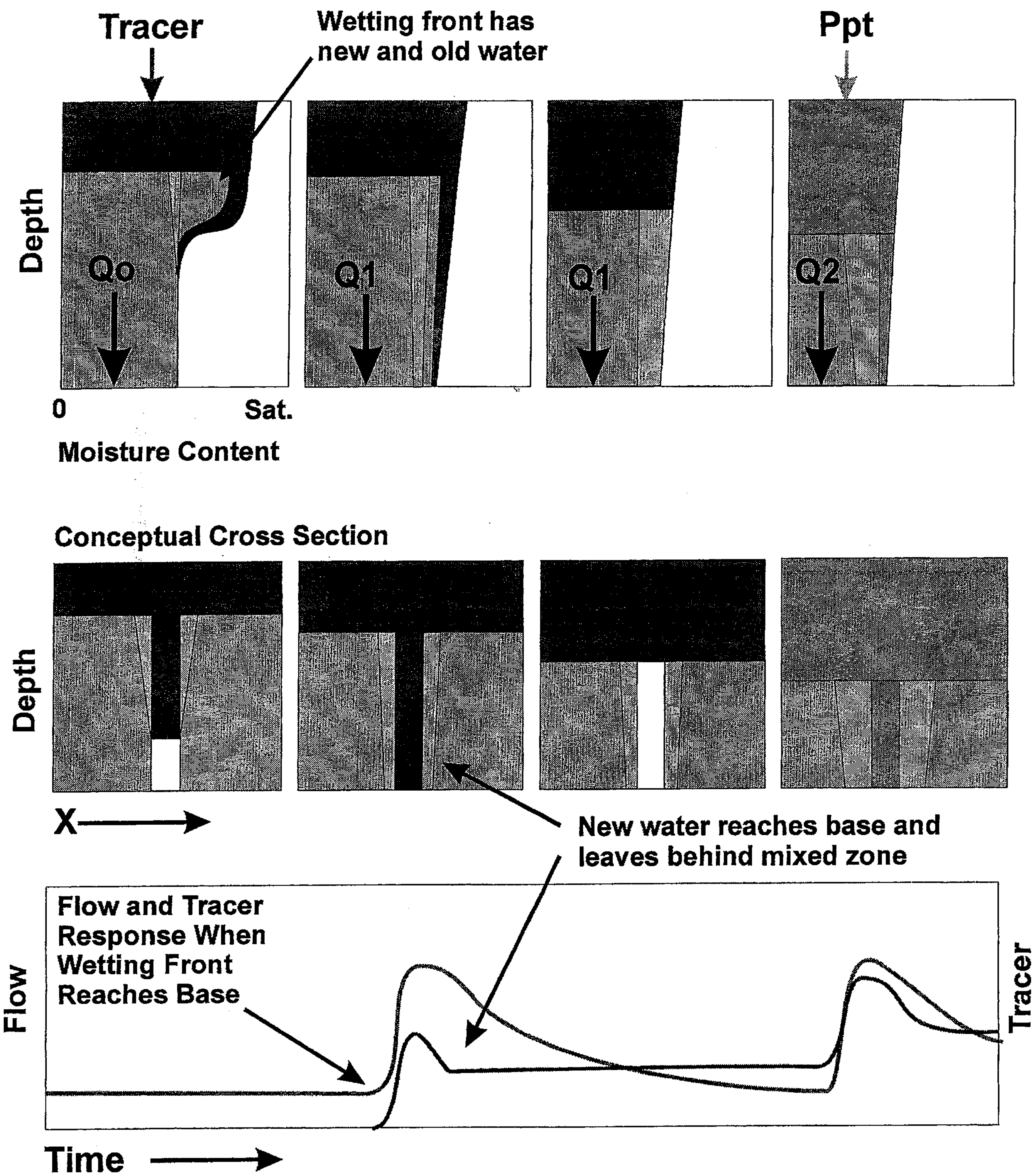
The wetting front propogates ahead of the tracer. Each rainfall event produces a wetting front, and advances the tracer, until the tracer reaches the base.





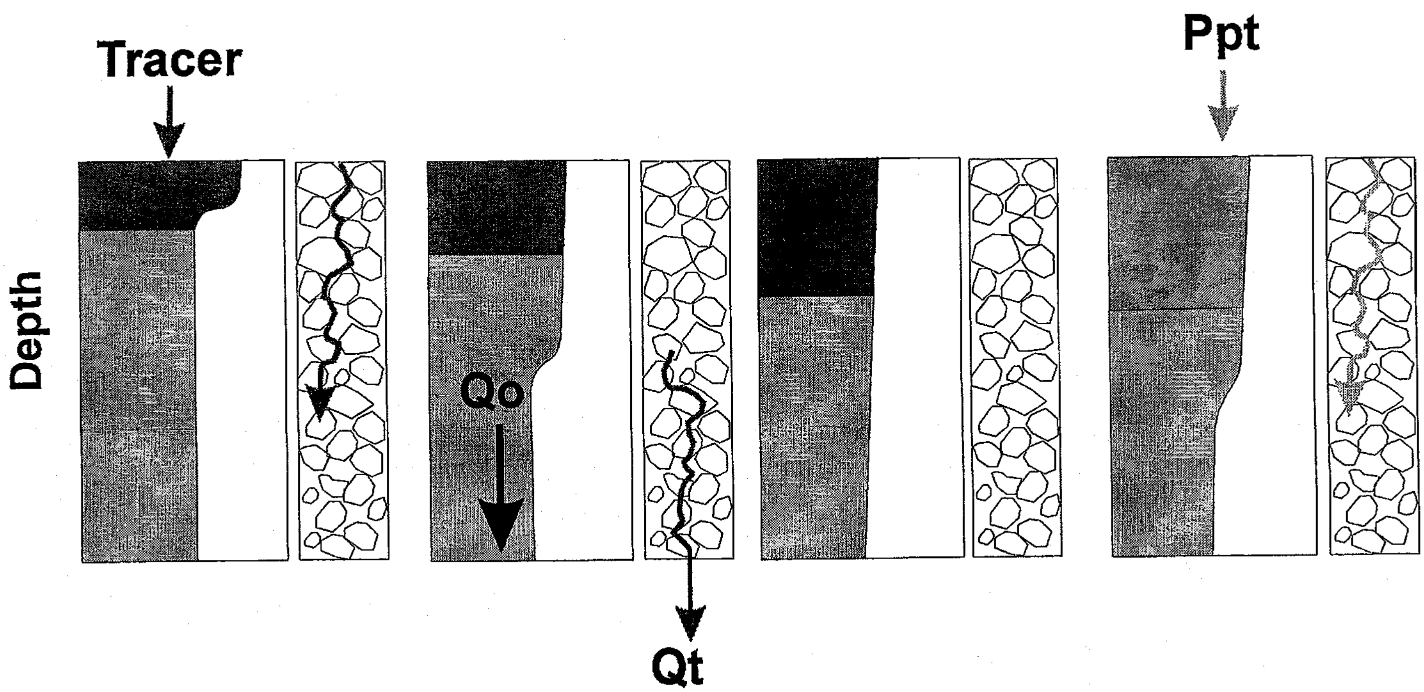
Flow Mechanism 3: Macropores

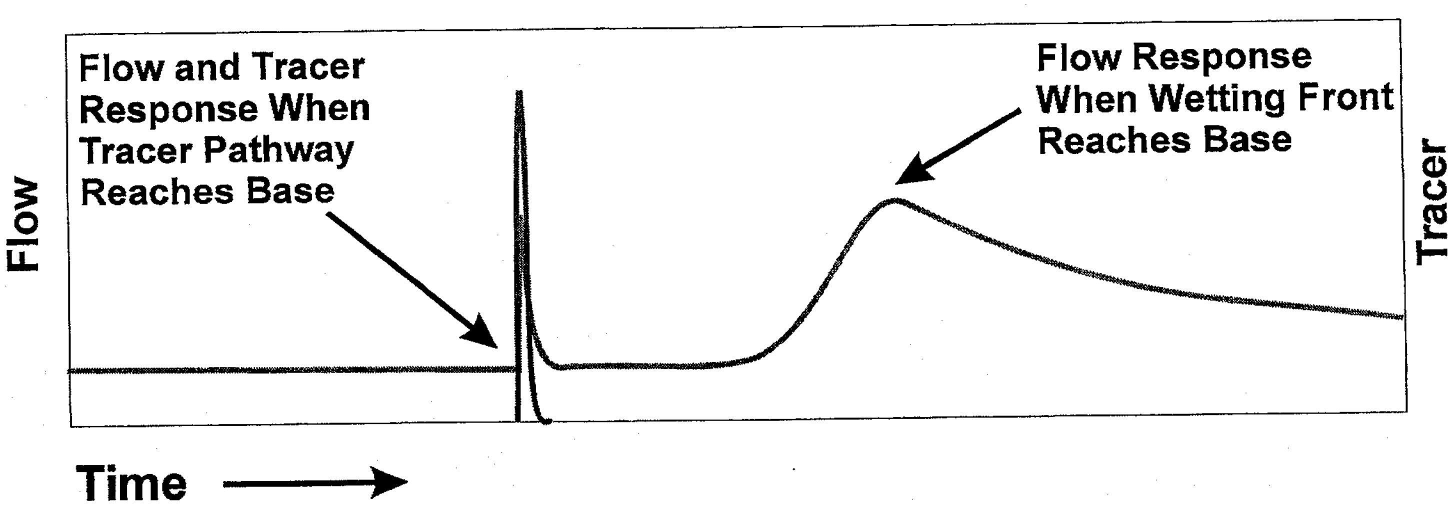
Some new water does move with the wetting front.



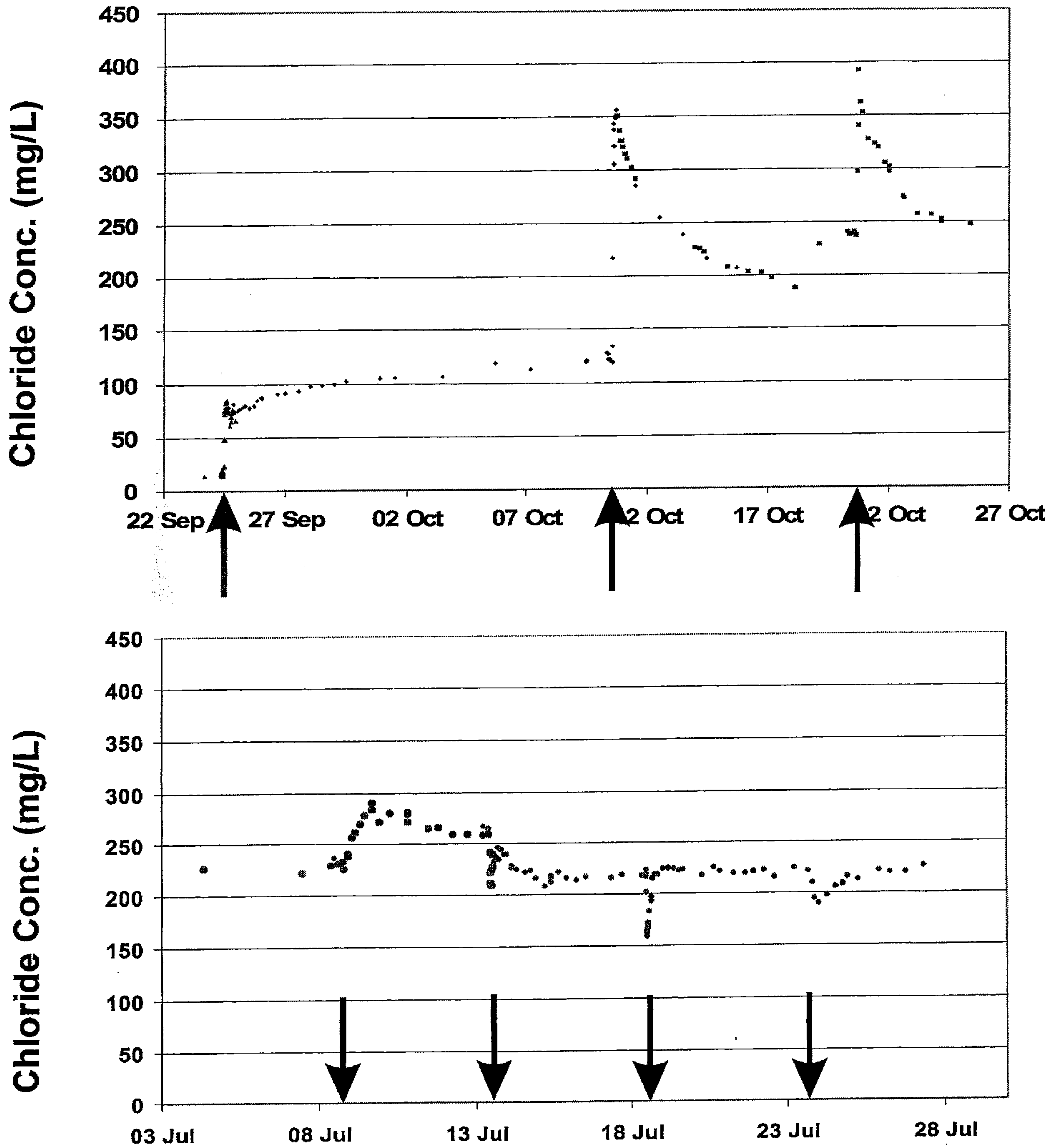
Flow Mechanism 4: Non-Capillary Flowpaths

Tracer is able to move in non-capillary flowpaths that largely bypass the matrix water.
Tracer reaches the base before the wetting front.

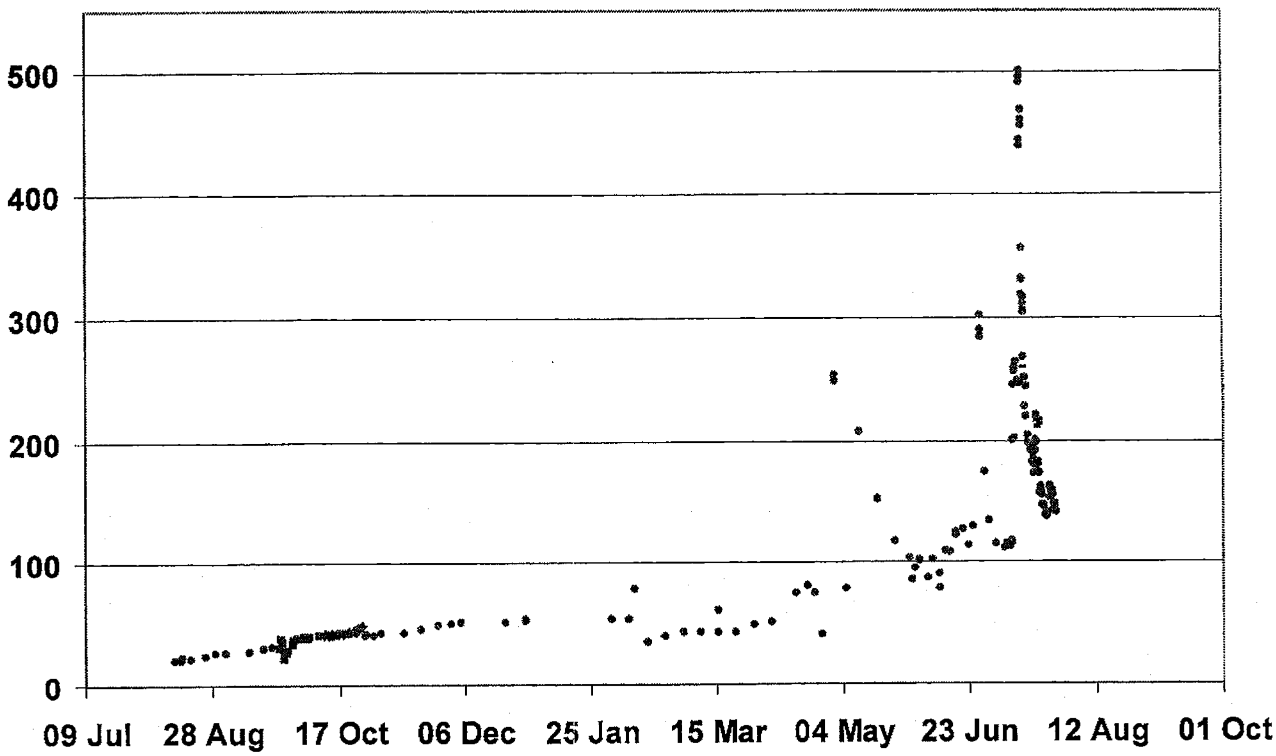




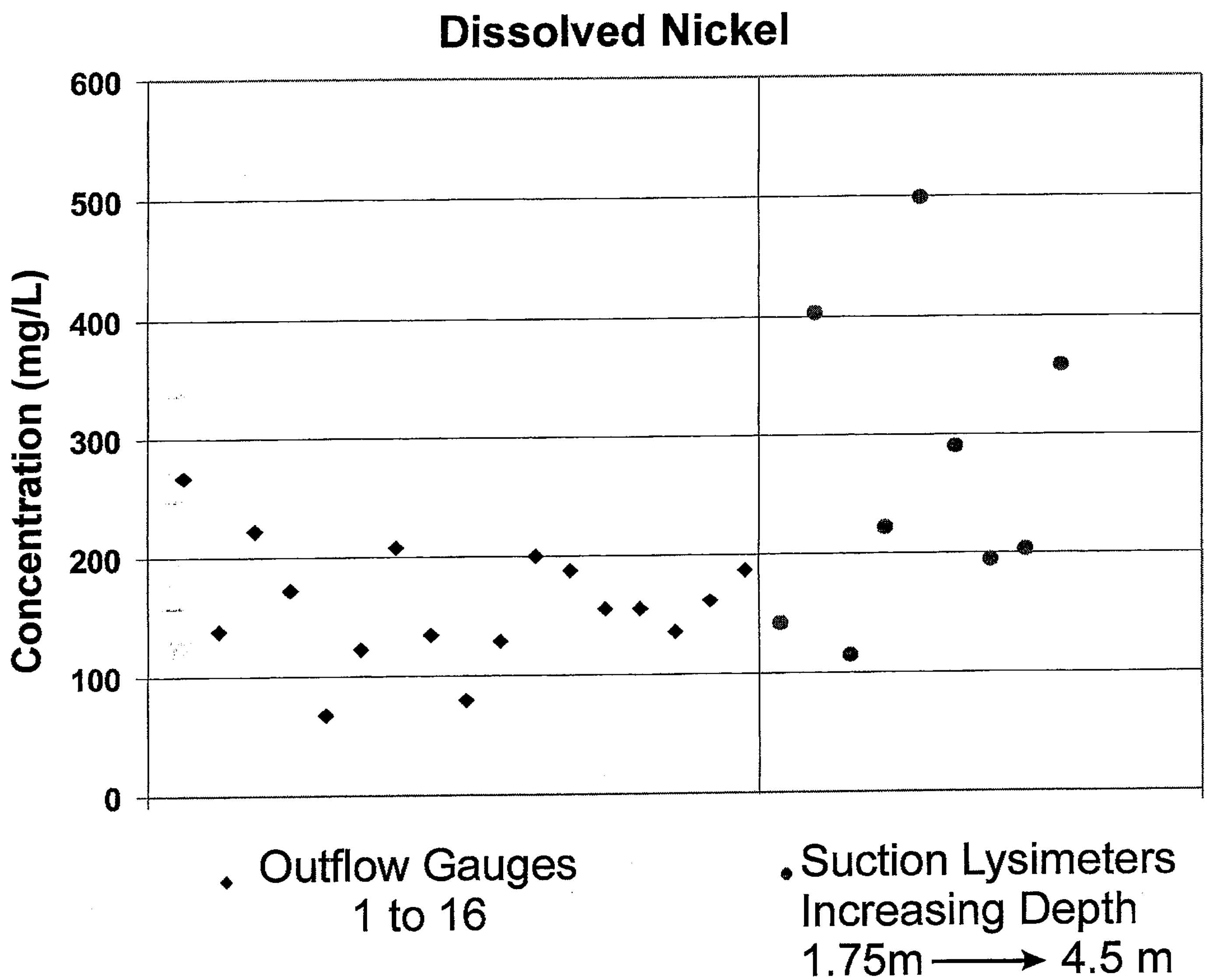
Outflow Gauge 6:
Tracer Concentration
Fall 1999 vs Spring 2000



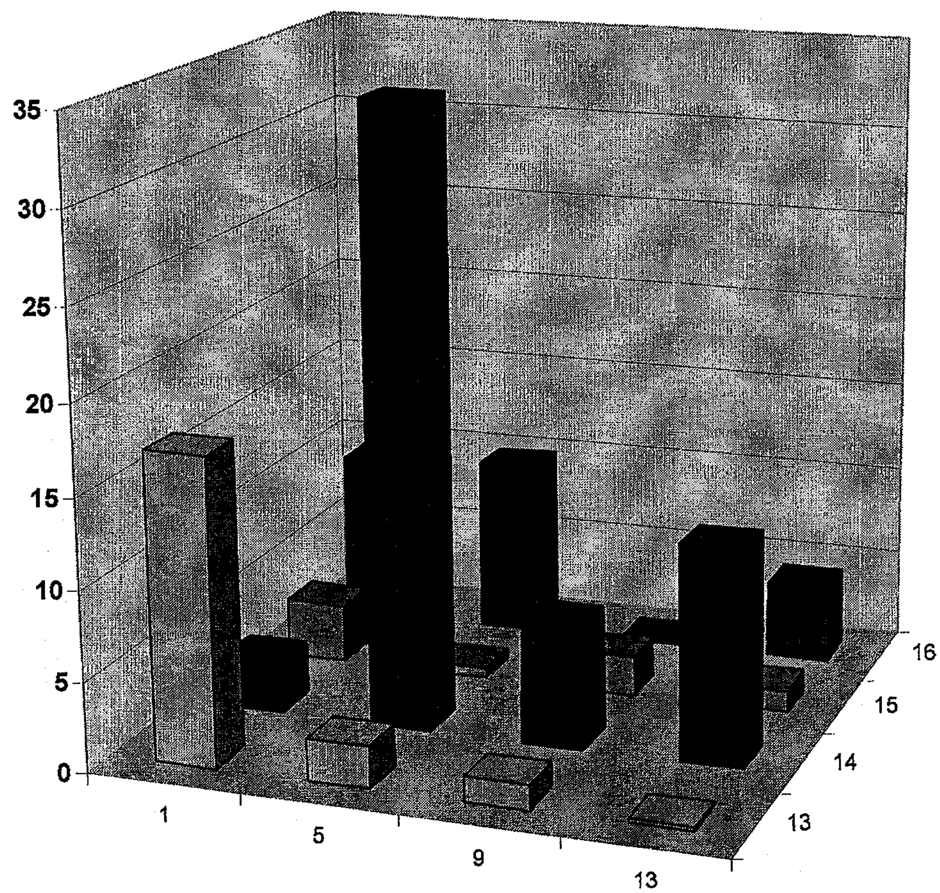
Outflow Gauge 9:
Fall 1999 to Summer 2000



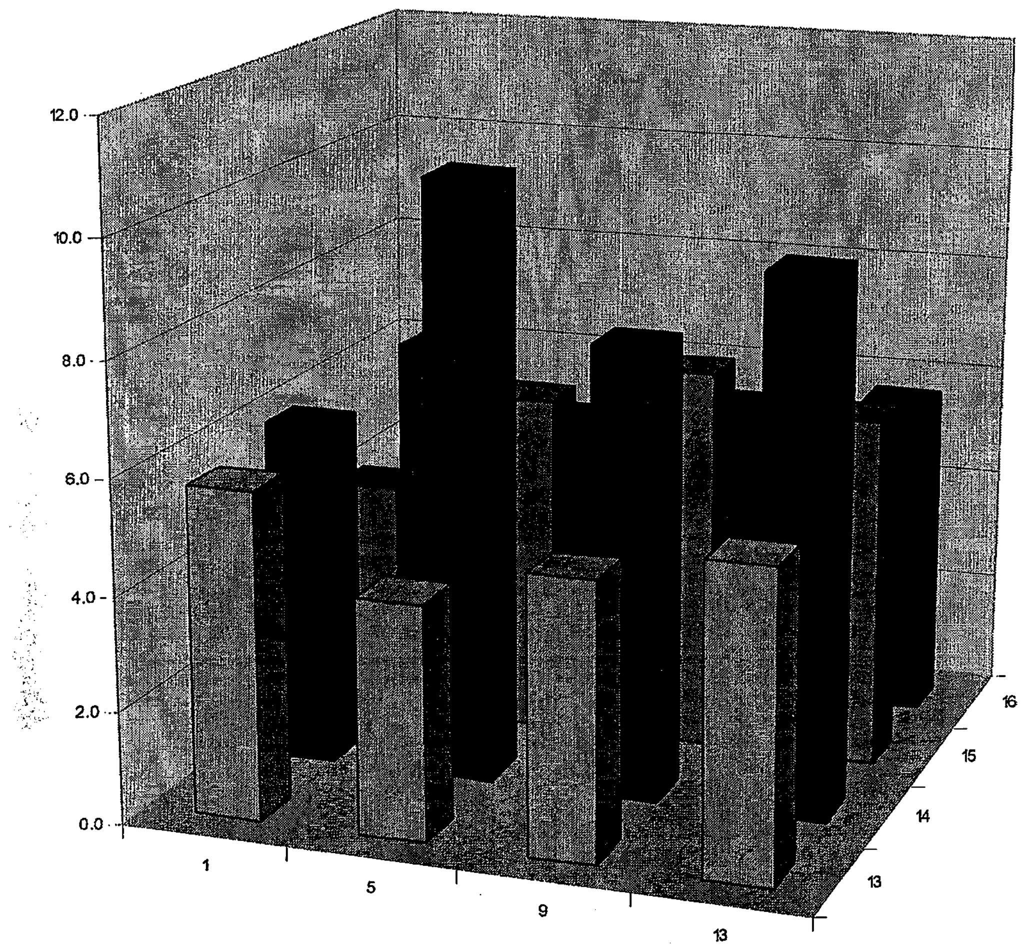
Outflow Chemistry and Internal Chemistry



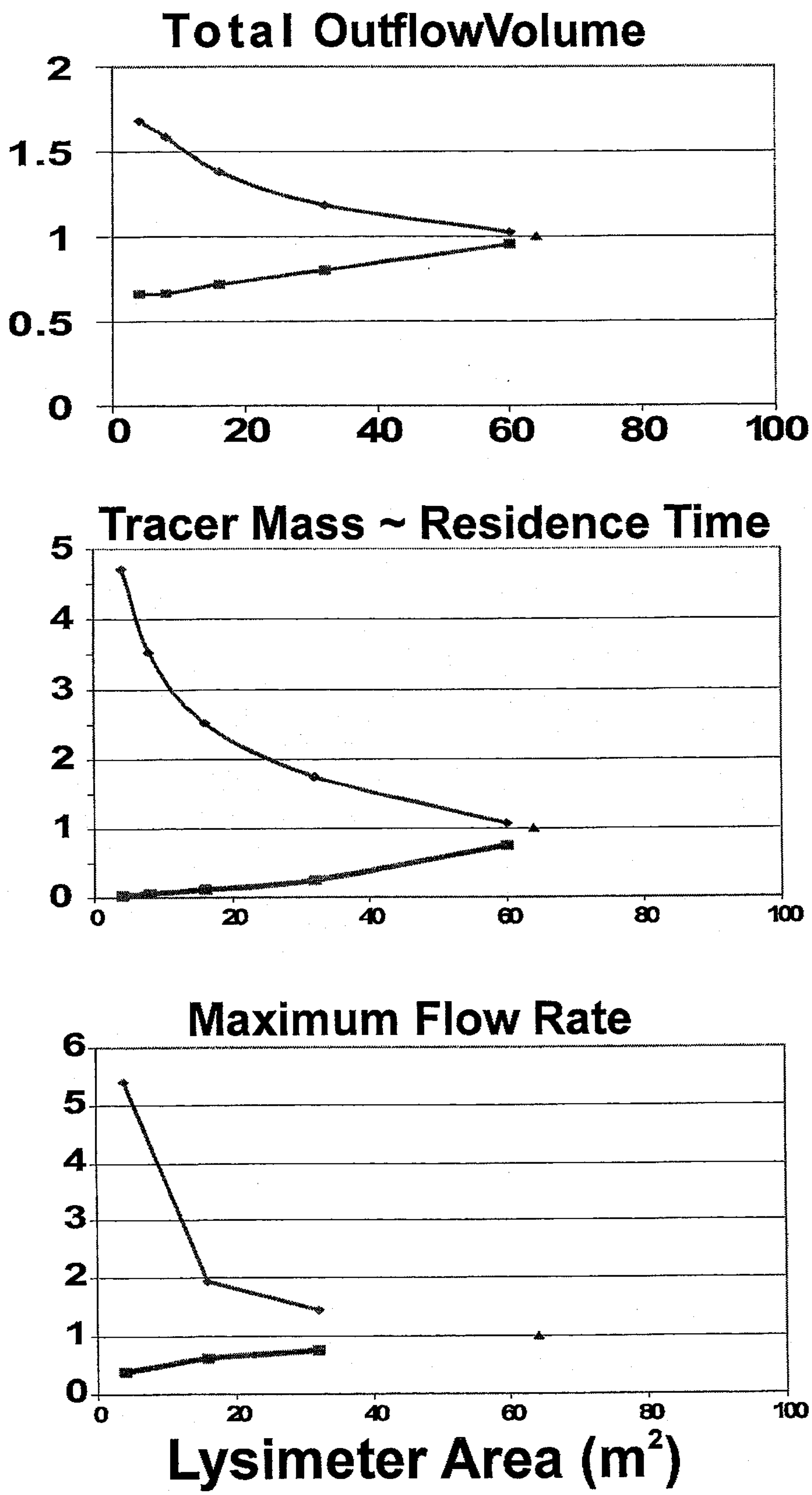
Invidual LysimeterTracer Mass Discharge as Percent of Total Tracer Applied to One Cell
Sept 24/99 - Feb 16/00



Invidual Lysimeter Discharge Volume as Percent of Total
Sept 24/99 - Feb 16/00



Effects of Lysimeter Size and Number



Conclusions to Date

1. We have demonstrated that several different flow mechanisms operate:

- Matric flow
- Macropores
- Bypass Flow

2. With no surface runoff or focussed infiltration occurring, the majority of outflow appears to be old water.

3. Chemical differences exist between resident and outflow water. The degree of mixing between newly infiltrated water and older resident water is spatially and temporally variable.

4. Flow and transport are spatially variable at scales < 8m x 8m.