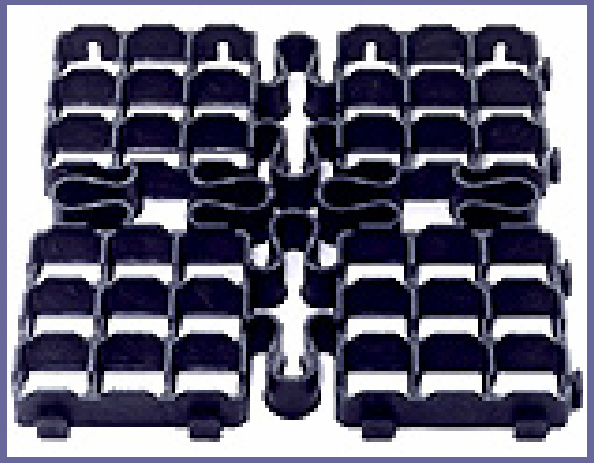
Bio-infiltration and Bio-reactors:
New WQ BMPs for Agricultural Applications in Southern RI?

Art Gold, Professor
University of RI, Kingston, RI 02881
with input from Mike Dietz, Ph.D. UCONN

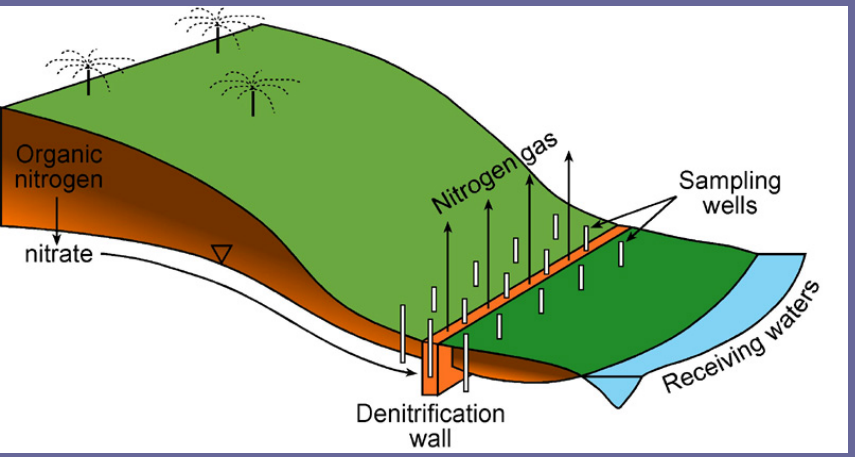
Southern New England Chapter of the Soil and Water Conserv. Soc.
Low Impact Development Workshop
February 15, 2007
Sturbridge,MA

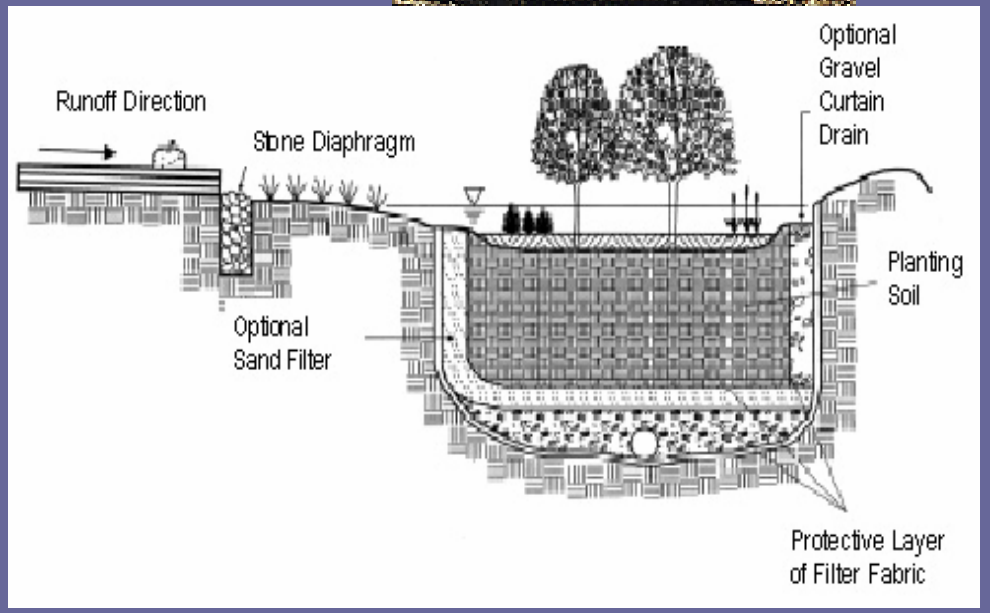
NRCS
UNIVERSITY OF Rhode Island
ELS
Applying knowledge to improve water quality
New England Regional Water Program
A Partnership of USDA CSREES & Land Grant Colleges and Universities

Quick Look At Bio-Infiltration/Bio-reactors Components



Netpave Grid for Equestrian Applications





Outline of Talk

- What are the potential agricultural applications?
- What challenges must be overcome?
- What are these new BMPs?
- Feedback from the Audience

Premise: Infiltration Treats Many agricultural pollutants

- Filters sediment
- Extended travel time in aerobic environments lowers pathogen risks
- Most soils in Southern New England have large P removal capacity
- Does not remove N effectively; transforms to Nitrate

Status of Bio-infiltration/bioreactor Systems

- Rain Gardens for suburban situations:
  - Widely applied today, designs being refined to address site constraints and maintenance
- Bio-reactors to treat polluted groundwater
  - Field Pilot studies since 1996, siting and longevity still under development
- Bio-infiltration basins to treat agricultural runoff
  - Column study completed at Rutgers;
  - Field Pilot studies are in planning stage through CIG in RI

Potential Agricultural Applications

- Treating polluted groundwater at the site
- Treating runoff from heavy use animal areas
- Treating compost leachate

Potential Application: Heavy Use Areas

- Heavy Use Animal Areas: Increasing common in Southern New England
  - Areas of High Stocking Rates
  - Feeding Areas
  - Horse Corrals
  - “Sacrifice Areas” that protect pasture regrowth

Heavy Use Areas: Site Conditions Argue for LID Systems

- Areas are small: < ¼ acre
- Little to no vegetated cover
- Often compact surface: Ranges from mud to dust
- Major Water Quality Concern: Polluted Overland Runoff
- Contaminated groundwater in sandy soils

BMPs: Heavy Use Areas

- Isolate From Upgradient Runoff Sources
- Collect Runoff and Treat with Lagoons
- Bio-infiltration Basins
- Tile drainage with bio-reactors (need high water table situation)
- Bio-reactors to treat polluted groundwater

Potential Application: Compost Leachate

- Treating Leachate from Small Farm Composting of Animal Manure
  - Major Concern: Groundwater N pollution from leachate
  - Leachate volume:16-92% of rainfall
  - Nitrate levels > 100 mg/L in subsoils below windrows during composting.

BMPs: Compost Leachate

- Put a roof over it (does not apply to windrows)
- Put it on a pad, capture leachate and treat (Waste Lagoon? or Bio-infiltration basin?)
- Treat polluted groundwater on site with bioreactors?

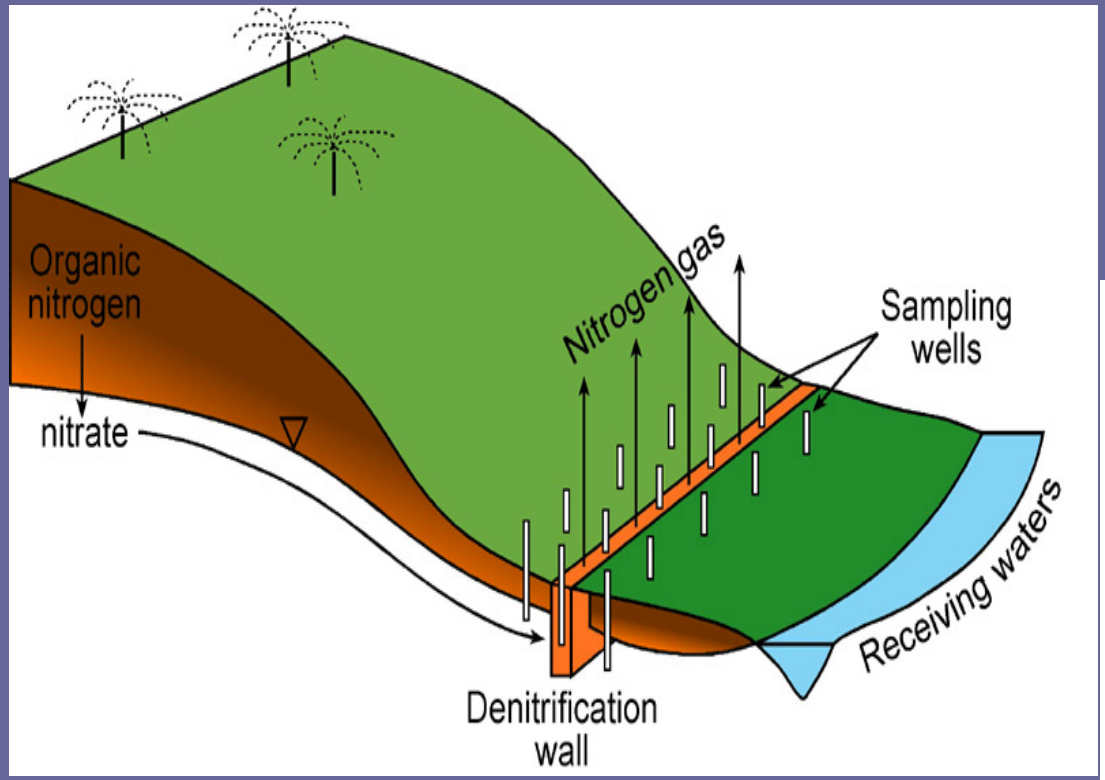
Challenges For Design and Performance:

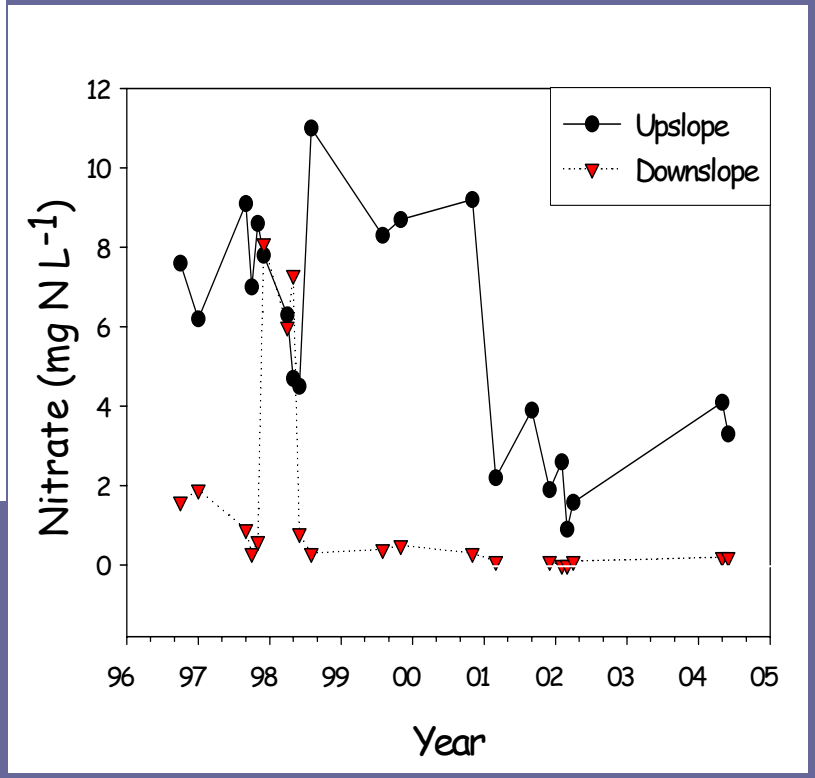
- Waste composition differs from Roof and Pavement Runoff
  - High Organic Loads: High potential for clogging
  - High Nutrient Loads: Nitrogen and Phosphorus
  - High Pathogen Loads

Subsurface Bio-Reactors: On Site Treatment of Polluted Groundwater

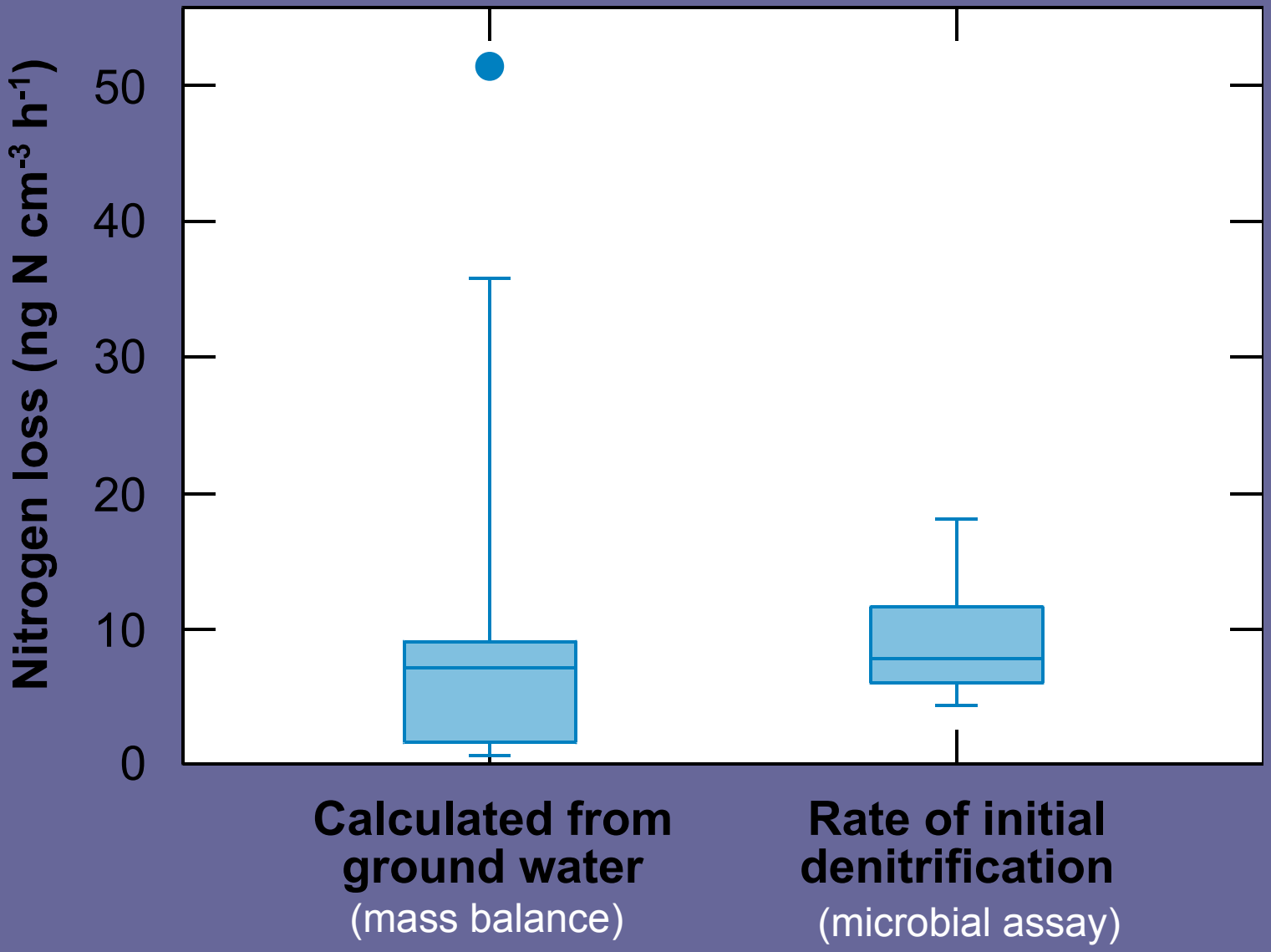
- Considerable history of testing
  - New Zealand
  - Waterloo Canada
  - New England
- Denitrification Walls
- Denitrification Barriers to treat subsurface drainage
- Applicable in sandy, aquifers with **shallow** water tables

Denitrification wall Bioreactor: 60- 96% decline in NO_3 concentration (Robertson and Cherry, 1995; Schipper, 1998)

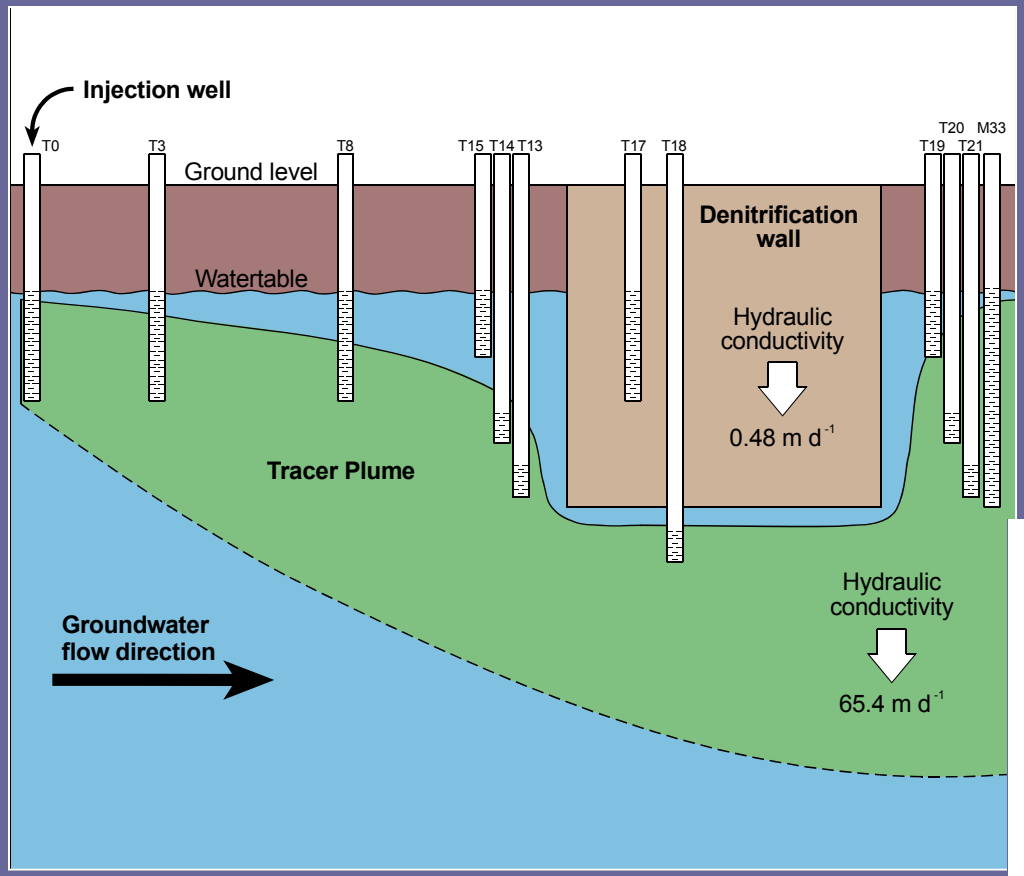




Role of denitrification in Initial Experimental NZ Site

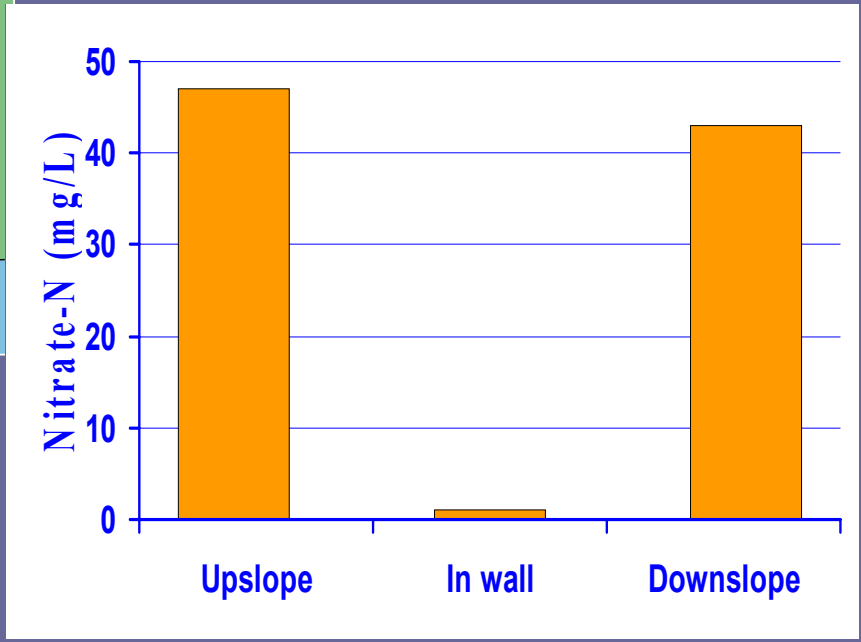


Hydrologic complexities (flowpaths):



Nitrate plumes can bypass wall ecosystem:

- Work best close to source and in shallow aquifers



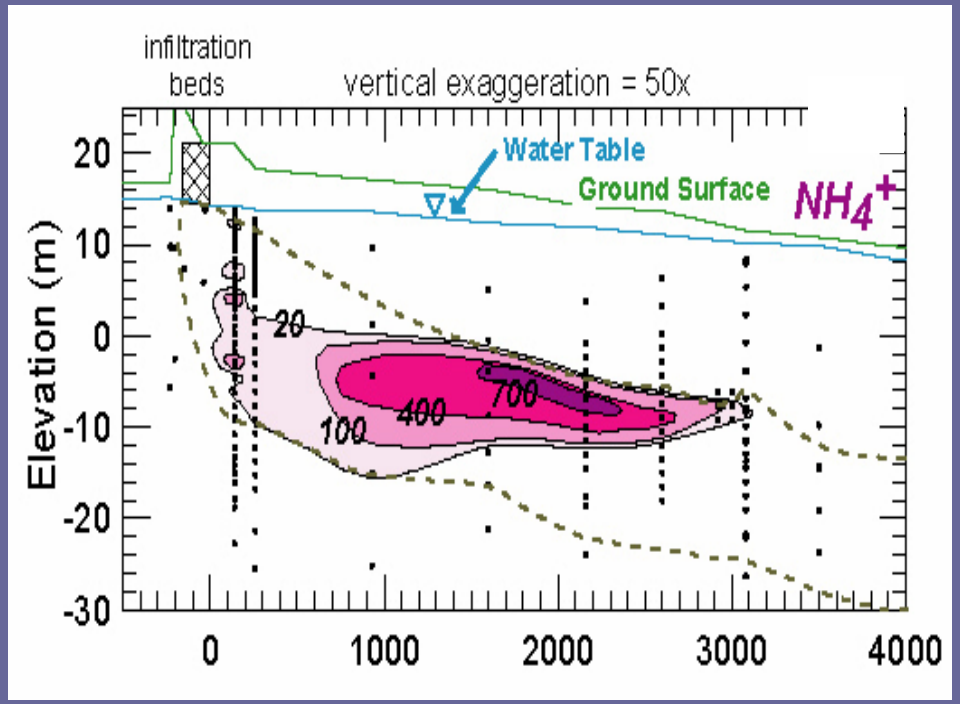
Source: Schipper and Barkle

Hydrology and Site Constraints Limit Capacity to Generalize Denitrification Wall Models

- Construction constrains wall depth to upper 1 – 1.5 m of groundwater
  - Many nitrate plumes move at deeper depths
- Plumes are often narrow
  - Piezometers in Waquoit Bay **10 meters apart**:

    25 fold differences in nitrate concentrations

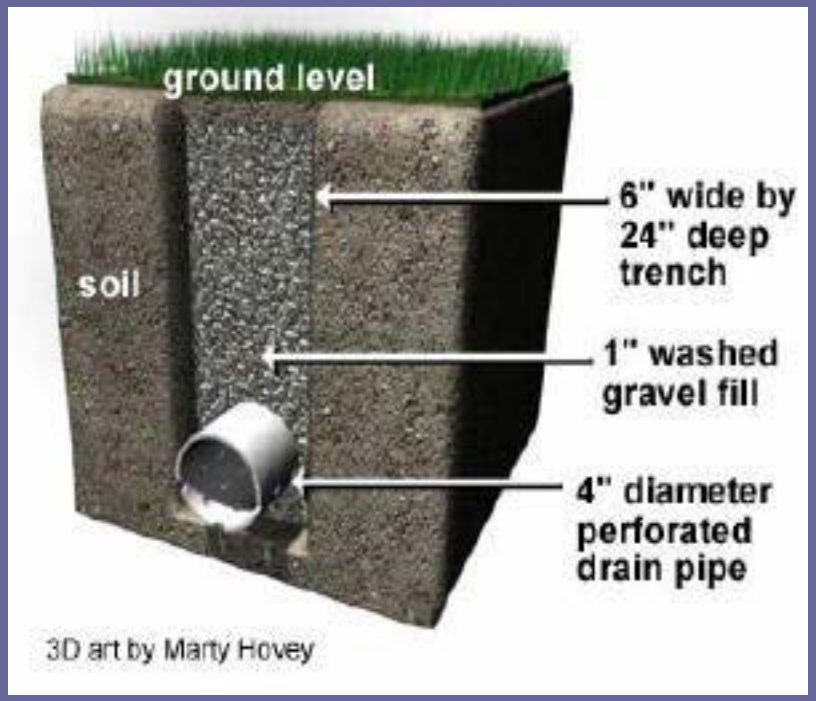
  (Source: Lomardi Assoc.)



Source: Bohlke et al. 2006

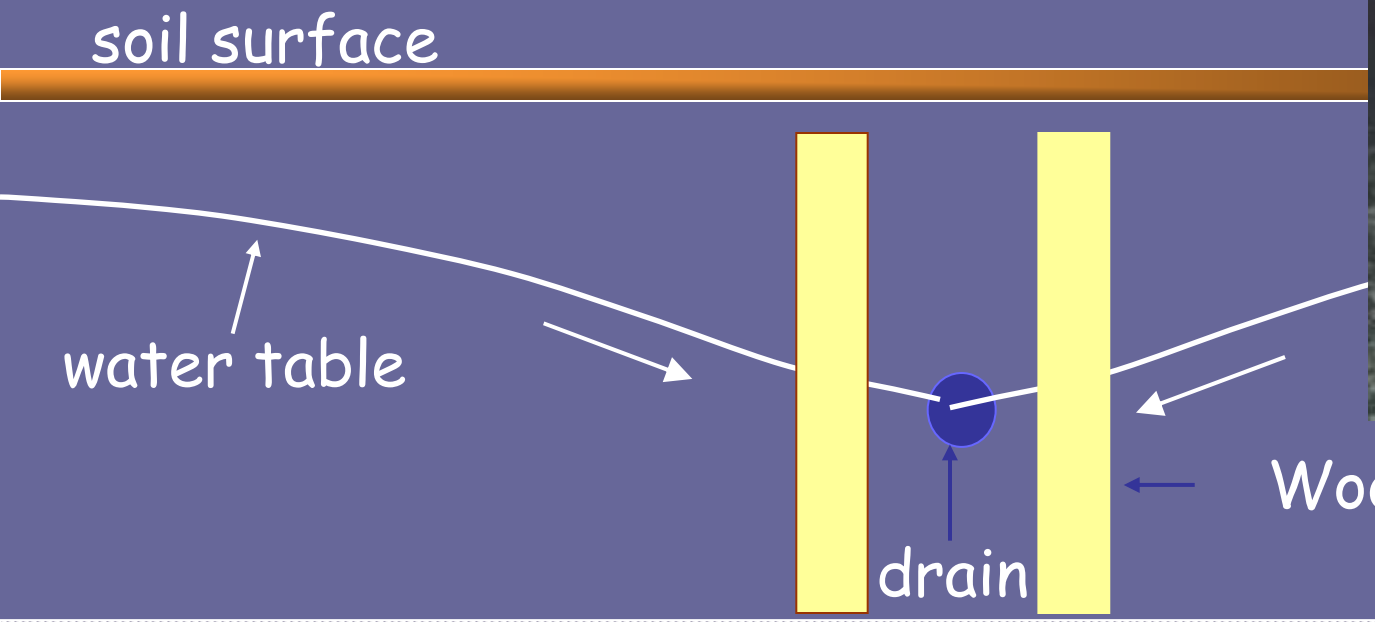
Tile drainage and Bioreactors For Heavy Use Areas: Shallow water table applications

- Lowers water table around the tile
- Reduces overland runoff
- Enhances infiltration
  - Reduces sediment, phosphorus and pathogen contamination
- Normally increases nitrate export from site
- Requires an outlet for discharge



Dan Jaynes
et al.

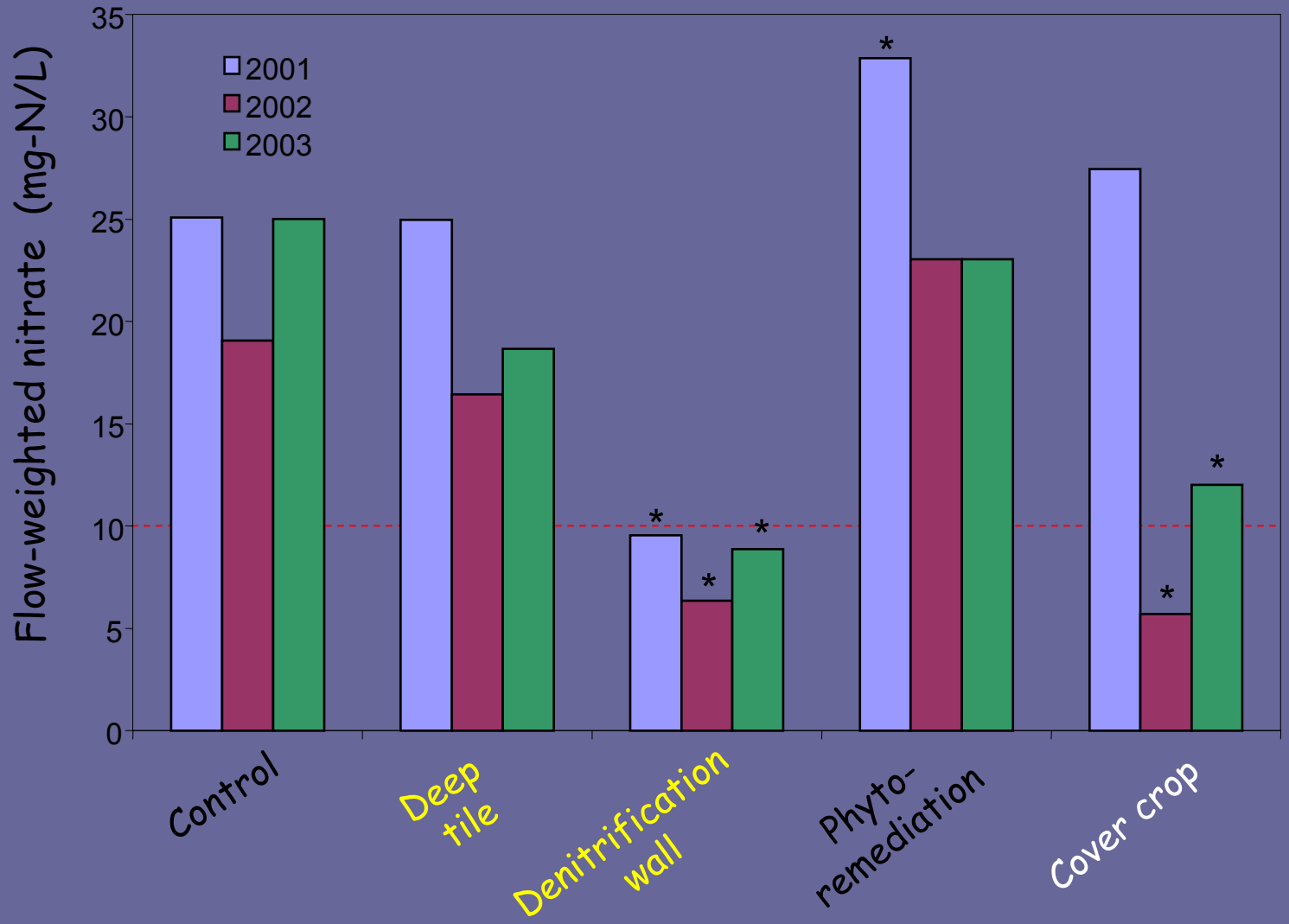
Bio-reactor: Buried C source both sides of a tile promote Groundwater denitrification



Wood Chips: C source

Dan Jaynes
et al.

Groundwater Nitrate removal



Wood Chips Remaining After Two Years

Depth (cm)	% Remaining
90	67 ± 17
155	89 ± 1.0

Dan Jaynes et al.

Bio-Infiltration Systems

- Design adapted from Rain-gardens
- Goal: Reduce offsite contamination from overland runoff polluted by animal waste

Approach:

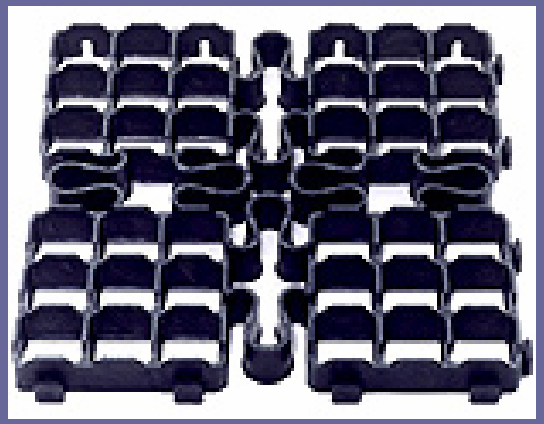
- Isolate contamination source from upstream runoff
- Intercept, infiltrate, filter and stimulate biogeochemical processing
- Discharge to surrounding soil or surface outlet

Design Challenges: Bio-Infiltration

- Clogging from organic waste and fines
  - Expose to surface air to promote aerobic decomposition at surface?
  - Maintenance: Surface exposed to permit raking
- Must minimize saturation within basin: *Problematic in tight soils and high water tables*
  - Requires subsurface drain leading to surface outlet
  - Or wide and shallow design

Heavy Animal Use Requires Stable Surfaces

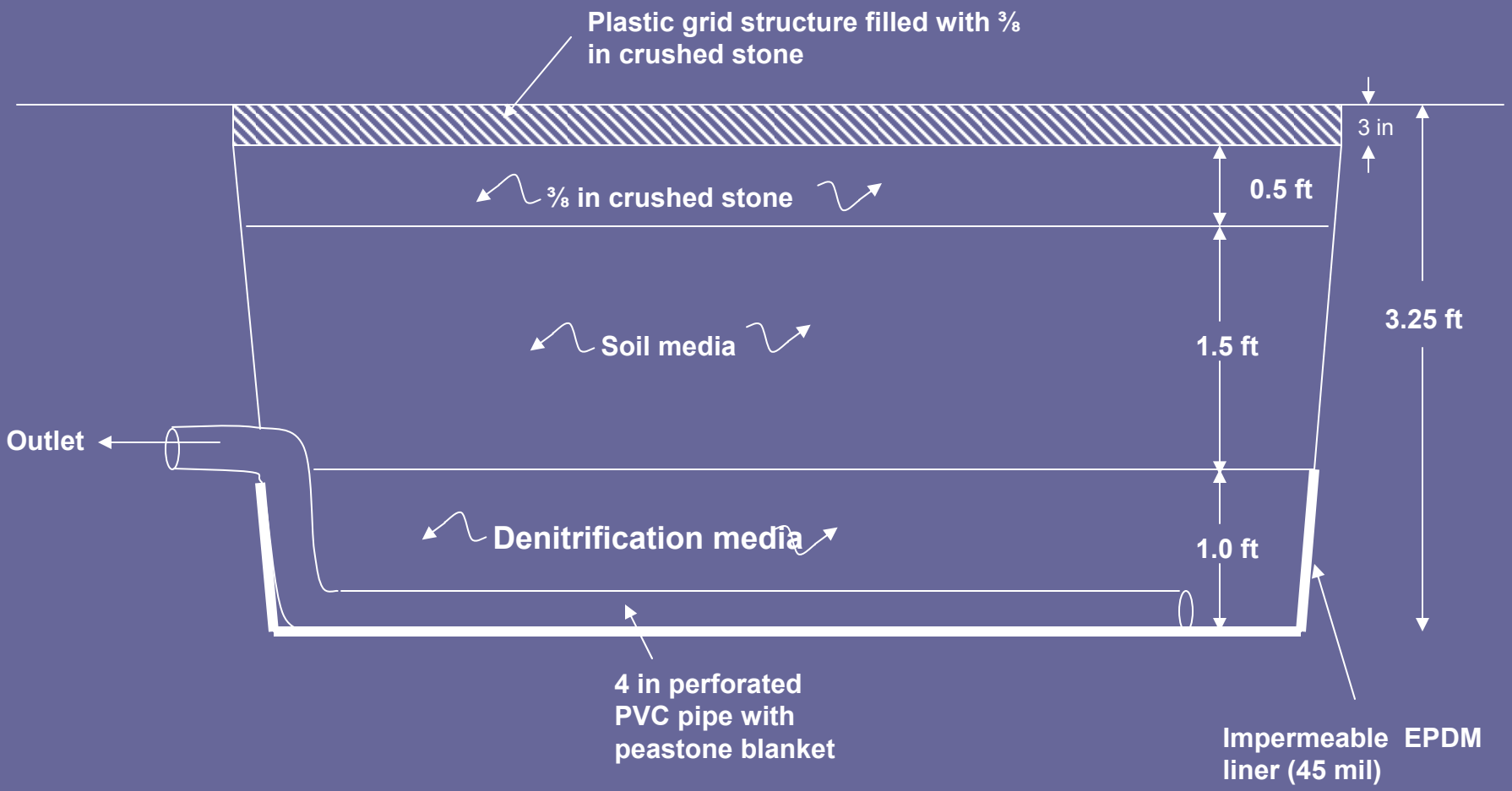
Netpave50:
Geogrid material
w/ gravel



Previous equestrian
applications: Paddocks; events areas

Bio-infiltration Design for Horse Paddock: (Proposed)

Side profile

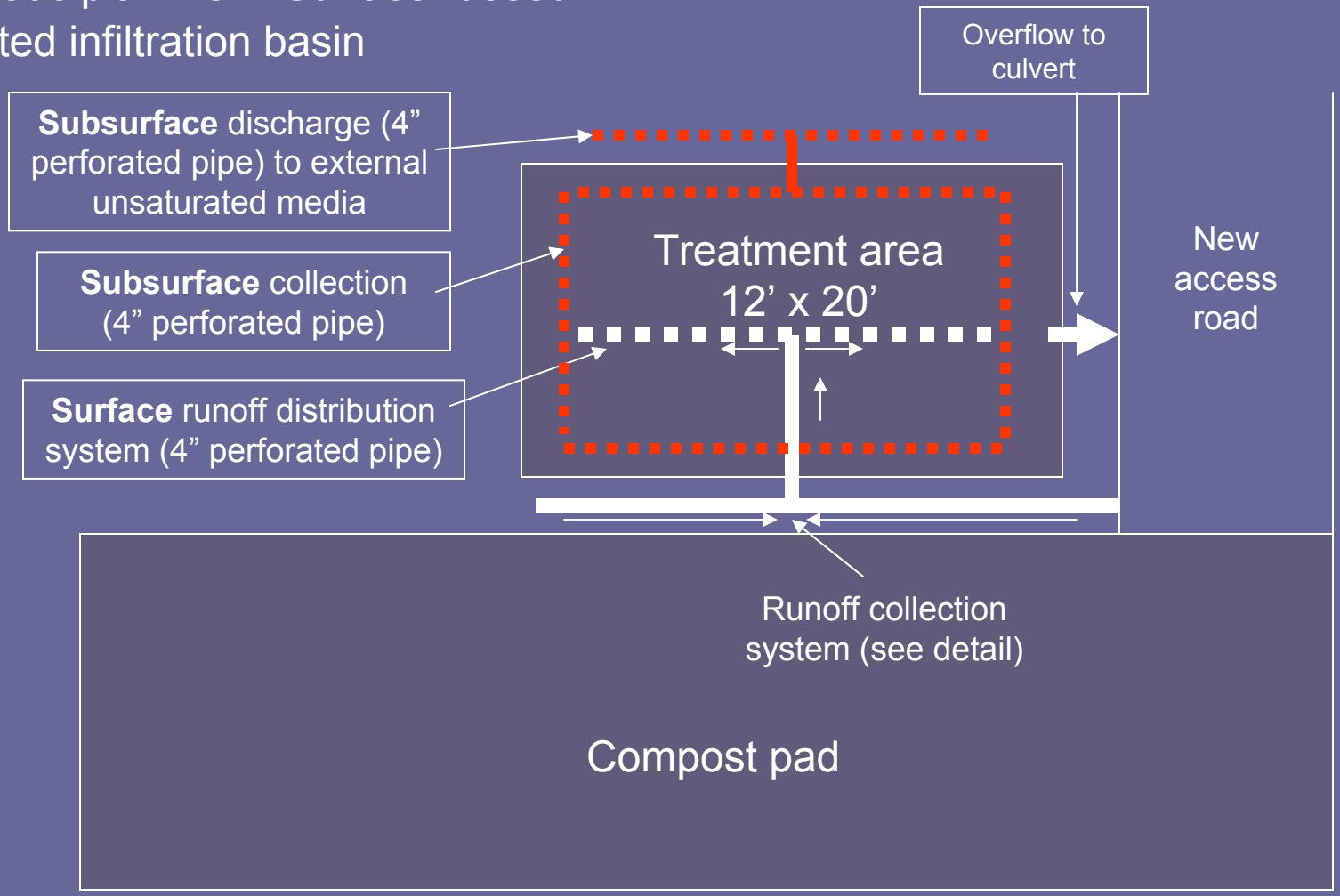


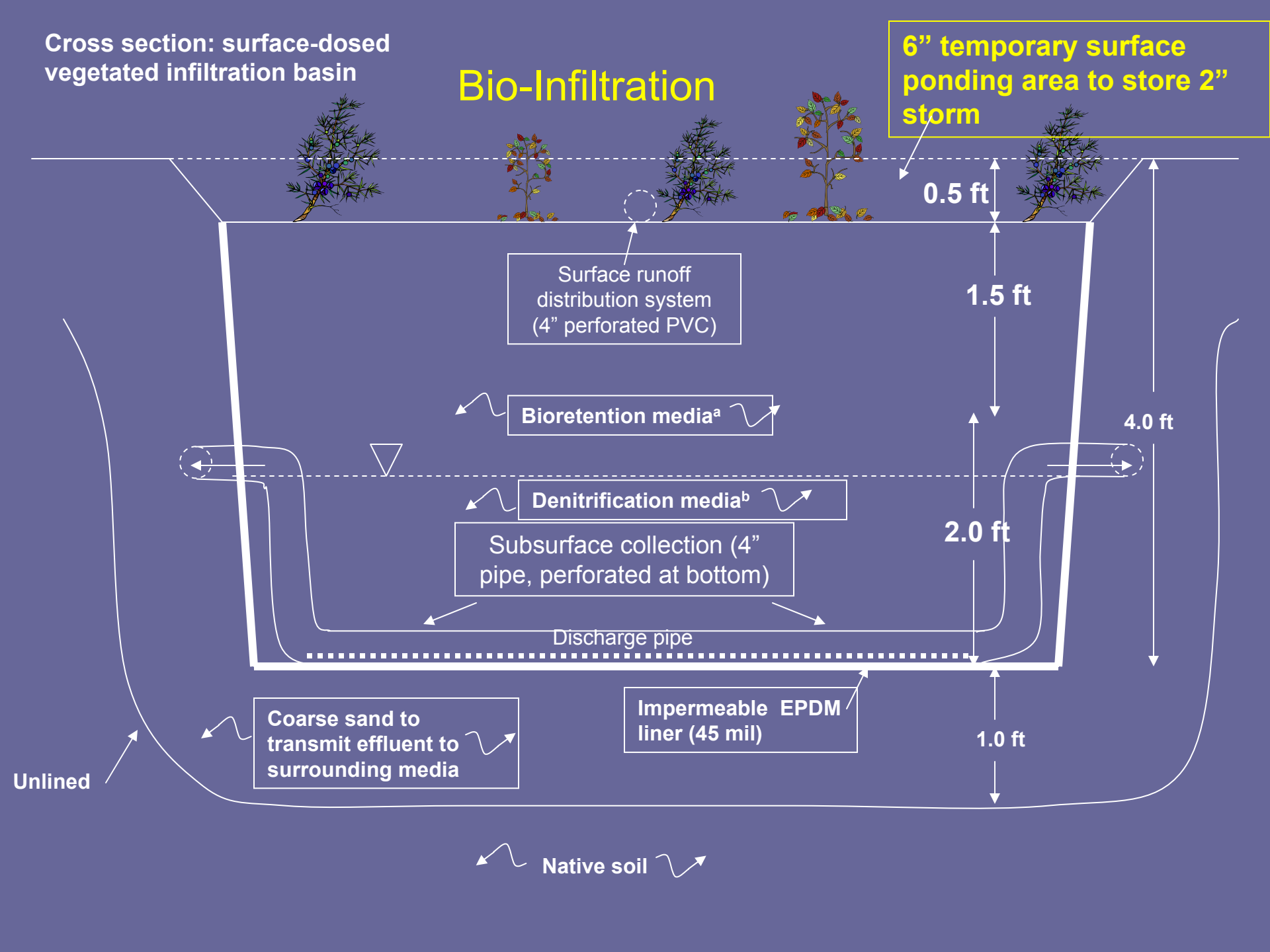
Media specifications

- [a]Bioretention media:
  - 60% coarse sand
  - 20% topsoil (low clay and silt content)
  - 20% compost
  - Unsaturated zone
- [b]Denitrification media:
  - Wood chip amendment
  - Permanently ponded area (artificial water table)

Bio-infiltration for Compost Leachate: Proposed

Schematic plan view: Surface- dosed vegetated infiltration basin




Cross section: surface-dosed vegetated infiltration basin
Bio-Infiltration
6” temporary surface ponding area to store 2” storm
0.5 ft
Surface runoff distribution system (4” perforated PVC)
1.5 ft
Bioretention media[a]
4.0 ft
Denitrification media[b]
Subsurface collection (4” pipe, perforated at bottom)
2.0 ft
Discharge pipe
Impermeable EPDM liner (45 mil)
Coarse sand to transmit effluent to surrounding media
1.0 ft
Unlined
Native soil

Status and Comments?

- Agricultural bio-infiltration demonstration site: Requirements
  - Reasonable soil depth (can't have bedrock near surface)
  - If water table is shallow – or soils are tight, must have discharge location
  - Cooperative Landowner
  - In shallow soils or where discharge is not available, liner can be eliminated (no denitrification)

Status and Comments

- Agricultural bio-reactor demonstration site: Requirements
  - Shallow groundwater (within 4-5 feet of surface)
  - Permeable media
  - Landowner willing to have drains or denitrification wall