Watershed Simulation of Nutrient Processes

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Nitrogen and Phosphorous

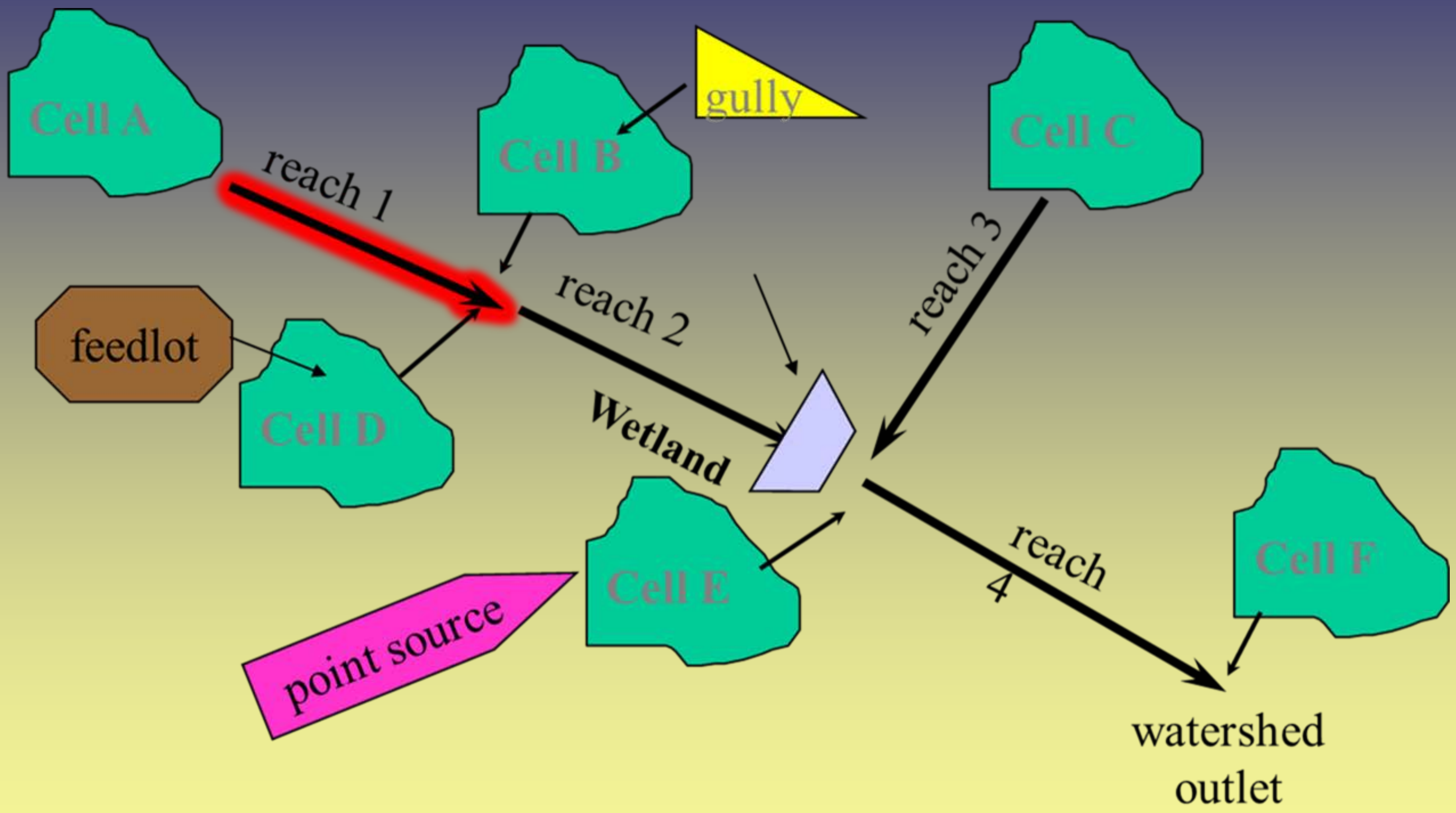
- **Nutrient (N & P) losses to surface waters continue to be a great concern on both national and regional scales.**
- **Many models have been developed to evaluate the nonpoint source pollution at field and watershed scales.**
- **Results from various studies on model performance and application indicated mixed success of nutrient simulations.**

AnnAGNPS – A Watershed Model

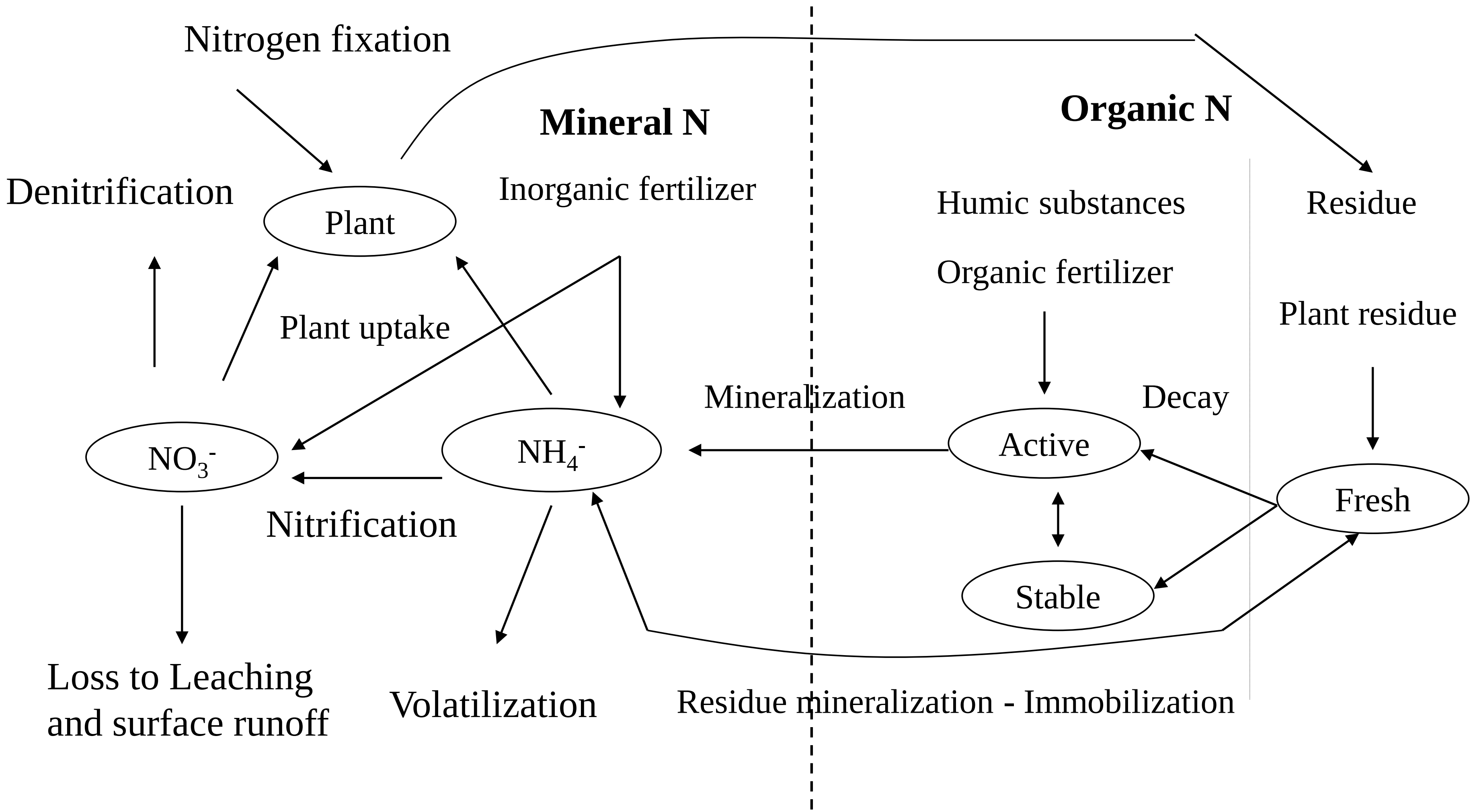
- AnnAGNPS simulates runoff, sediment, nutrients and pesticides leaving the land surface and being transported through the watershed channel system to the watershed outlet on a daily time step basis.
- The model routes the physical and chemical constituents from each AnnAGNPS cell into the stream network and finally to the watershed outlet and has the capability to identify the sources of pollutants at their origin and track them as they move through the watershed system.
- The model has been developed to evaluate the effect of BMPs/conservation practices on water quality for conservation practice implementation/integrated watershed management planning.

- **watershed**

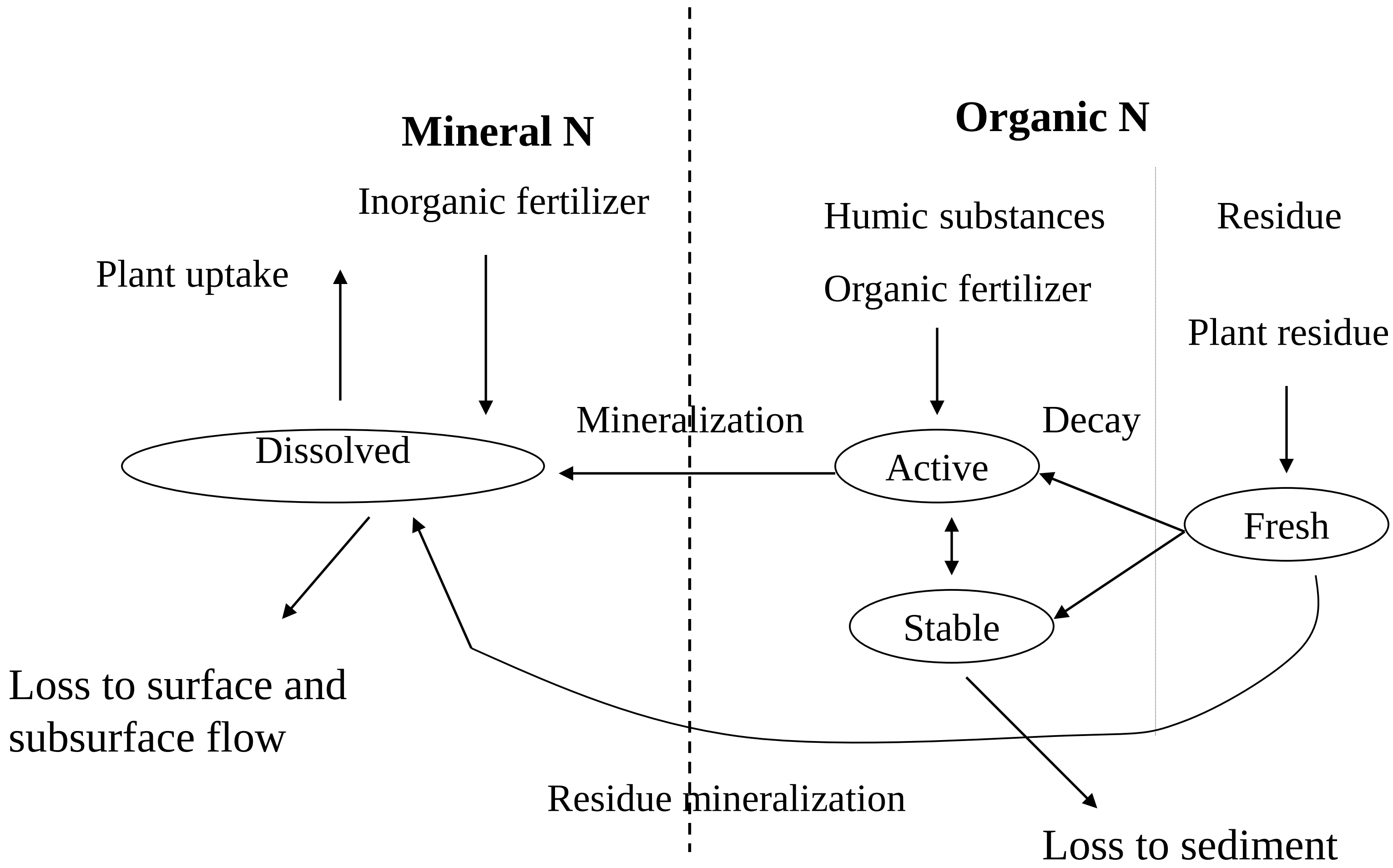
- **field**



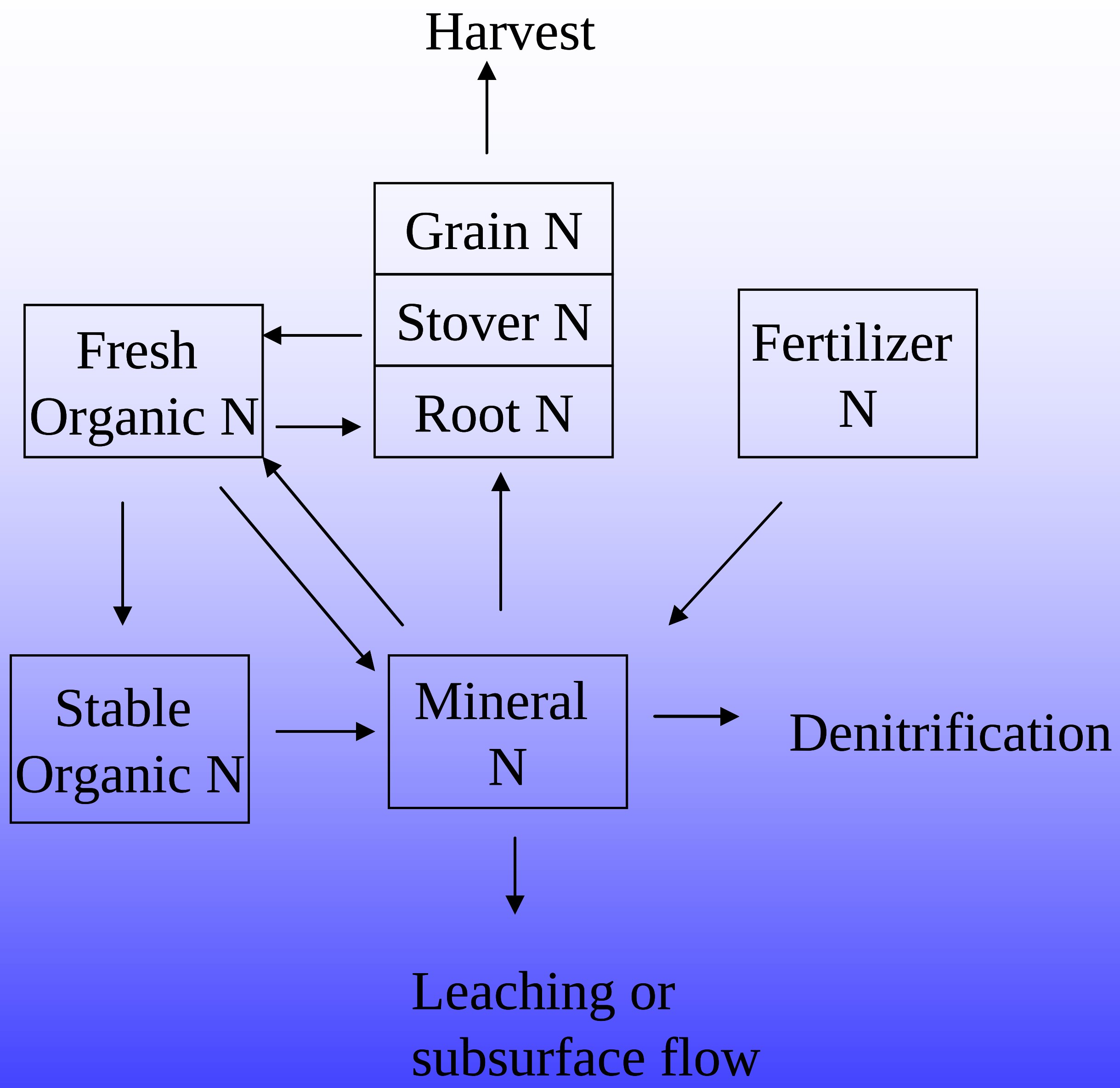
Watershed Simulation Processes



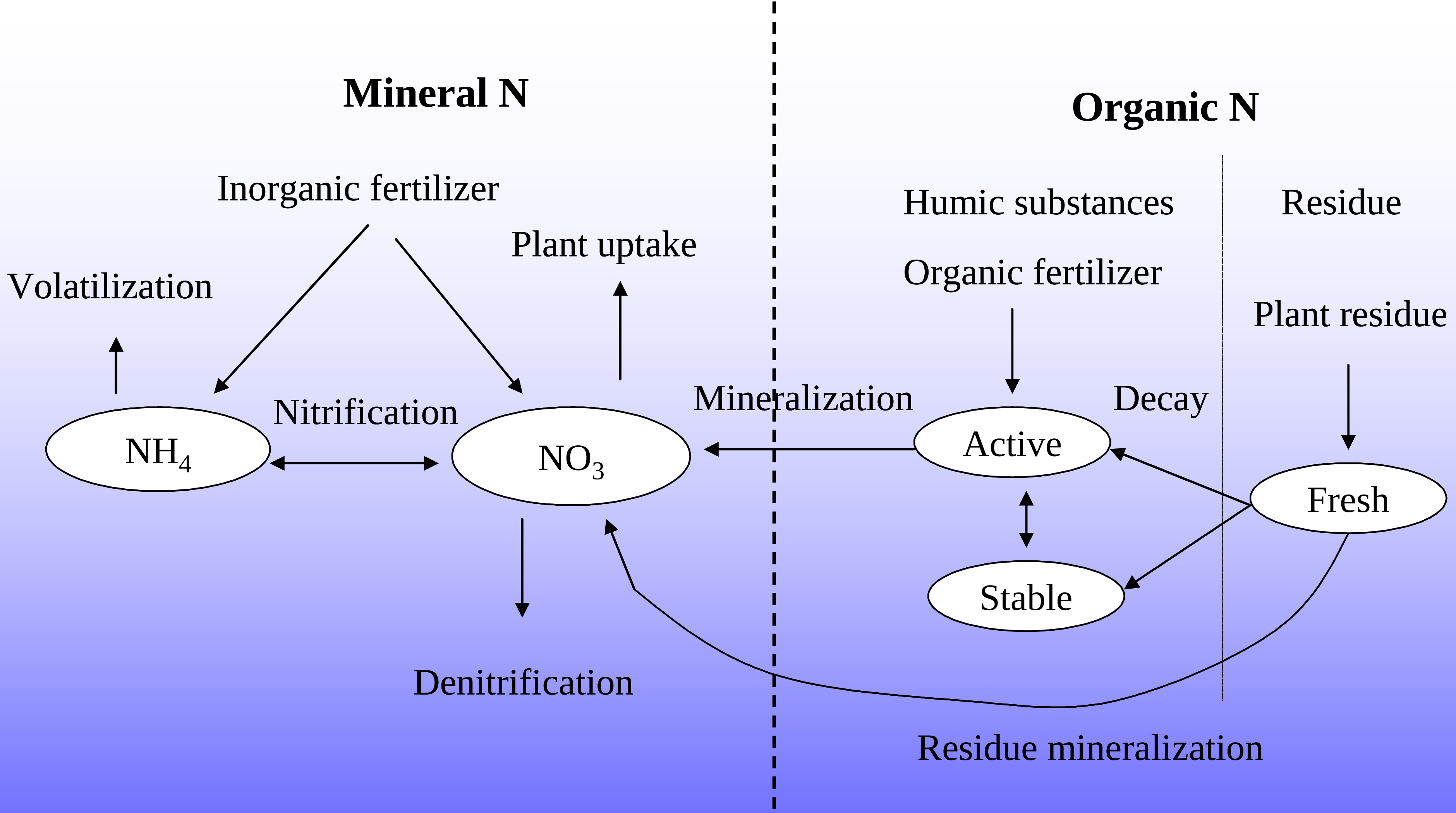
A simplification of nitrogen processes (Havlin et al., 1999)



Soil N pools and processes that move N in and out of pools in AnnAGNPS



Soil N pools and flows in APEX



Soil N pools and processes that move N in and out of pools in SWAT

N Simulation Processes

- **Nitrogen mass balance is based on the computational unit (sub-area or cell) and maintained for composite soil layers.**
- **N is partitioned into organic N and inorganic N.**
- **A separate mass balance is maintained for organic and inorganic N.**

Organic N Simulation Processes

$$orgN_{t+1} = orgN(1)t + \frac{(resN + fer\_orgN - hmnN - sedN)*1000000}{Conv}$$

Where:

- **$orgN_t$ = organic N content for each soil layer at beginning of day (ppm),**
- **resN = organic N addition from residue decomposition on current day (kg),**
- **Fer_orgN = organic N from fertilizer application such as manure or other sources on current day (kg),**
- **hmnN = organic N mineralized on current day (kg), and**
- **sedN = organic N loss by attaching to sediment (kg).**
- **Conv = conversion factor.**

Inorganic N Simulation Processes

- **Addition from fertilizer application is calculated first.**
- **Followed by the losses to runoff and plant uptake.**
- **At the end of the day, mass balance is updated for inorganic nitrogen that incorporates mineralization of organic N.**
- **In other words, mineralization of organic N is not used to calculate losses to runoff and plant uptake.**
- **The simulation is in a sequence of calculation.**

Fertilizer Application

- After inorganic N fertilizer is applied, the fertilizer could stay on soil surface or be mixed with the soil profile depending on soil disturbance (tillage).
- If the fertilizer stays on soil surface, it is either lost to surface runoff or carried into soil profile by infiltration after rainfall.
- The amount of dissolved inorganic N carried away with runoff or carried into soil profile with infiltration is determined by the amount of runoff generated and the amount of infiltration during the rainfall.
- If no surface runoff is generated, it is assumed that all inorganic N is carried into soil profile.

Inorganic N loss to Surface Runoff

- If the fertilizer stays on soil surface, it is either lost to surface runoff or carried into soil profile by infiltration after rainfall.
- The amount of dissolved inorganic N carried away with runoff or carried into soil profile with infiltration is determined by the amount of runoff generated and the amount of infiltration during the rainfall.
- In the case that no inorganic N stays on soil surface, runoff interacts with soil and carries soluble inorganic N in the soil profile away from fields when rainfall occurs. The effective soil depth of runoff interaction is a user input (1 mm to 10 mm) depending on soil properties.
- Total mass of inorganic N lost to surface runoff includes soil incorporated and surface applied N lost.

Table 1. The nitrogen transformation processes simulated in each model

Models	Nitrogen Transformation					
	Residue decomposition & mineralization	Humus Mineralization	Nitrification & ammonia volatilization	Dinitrification	Fixation	Rainfall
AnnAGNPS	Yes	Yes, the same as APEX/EPIC	No	Yes	No	No
APEX/ EPIC	Yes	Yes	Yes	Yes	Yes	Yes
SWAT	Yes, the same as APEX/EPIC	Yes, the same as APEX/EPIC	Yes	Yes, the same as APEX/EPIC	Yes, the same as APEX/ EPIC	Yes

Stream Processes

- Once the model determines the loadings of water, sediment, nutrients and pesticides to the stream, the loadings are routed through the stream network.
- The model keeps track of mass flow in the channel.
- The model also models the transformation of chemicals in the stream and streambed Routing.

Stream Processes

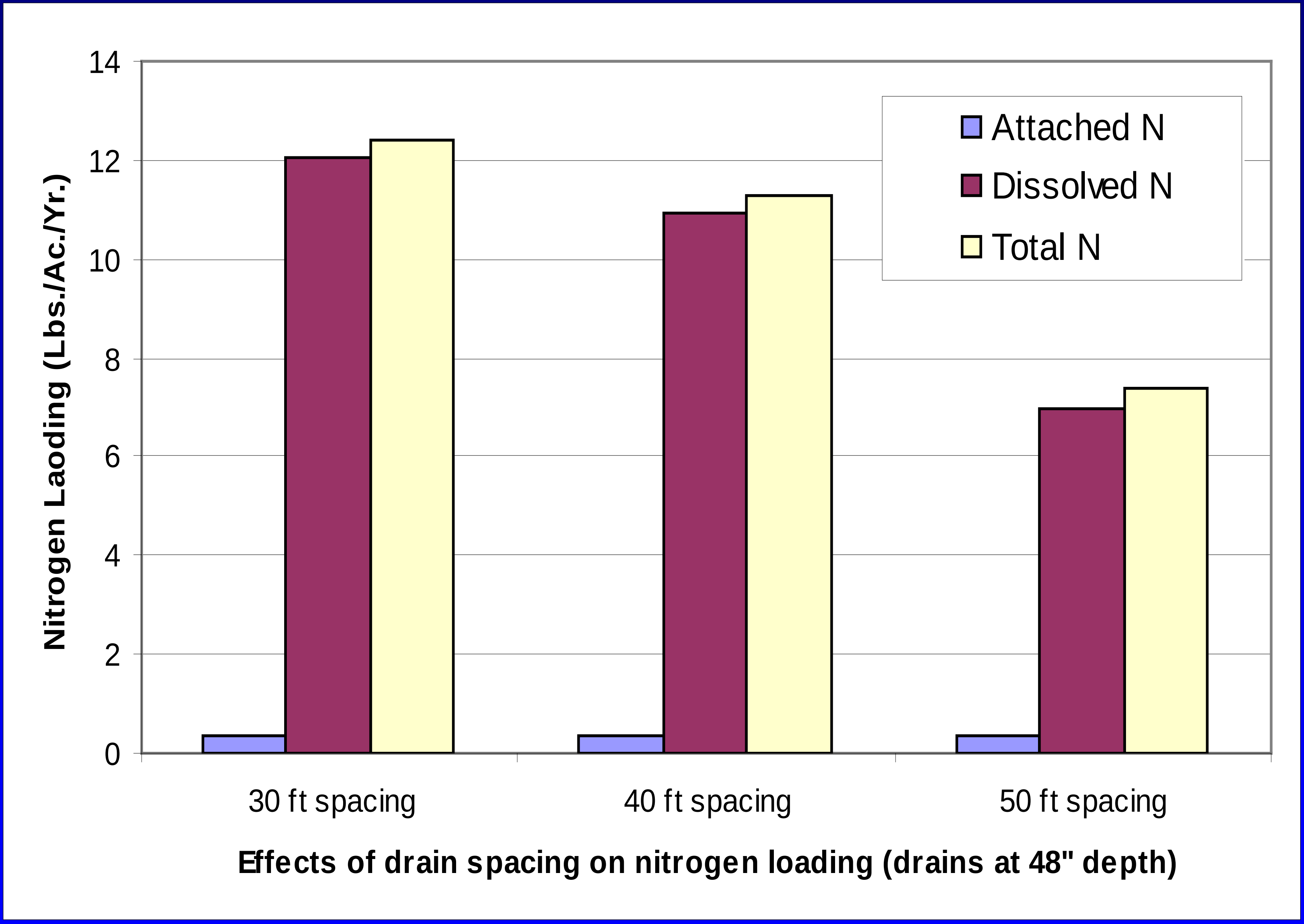
- **Dissolved transport.**
- **Particle transport**
- **Deposition**
- **Resuspension**
- **Biodegradation and transformation**
- **Dilution and diffusion**

AnnAGNPS Application for Assessing Drainage Management Practices

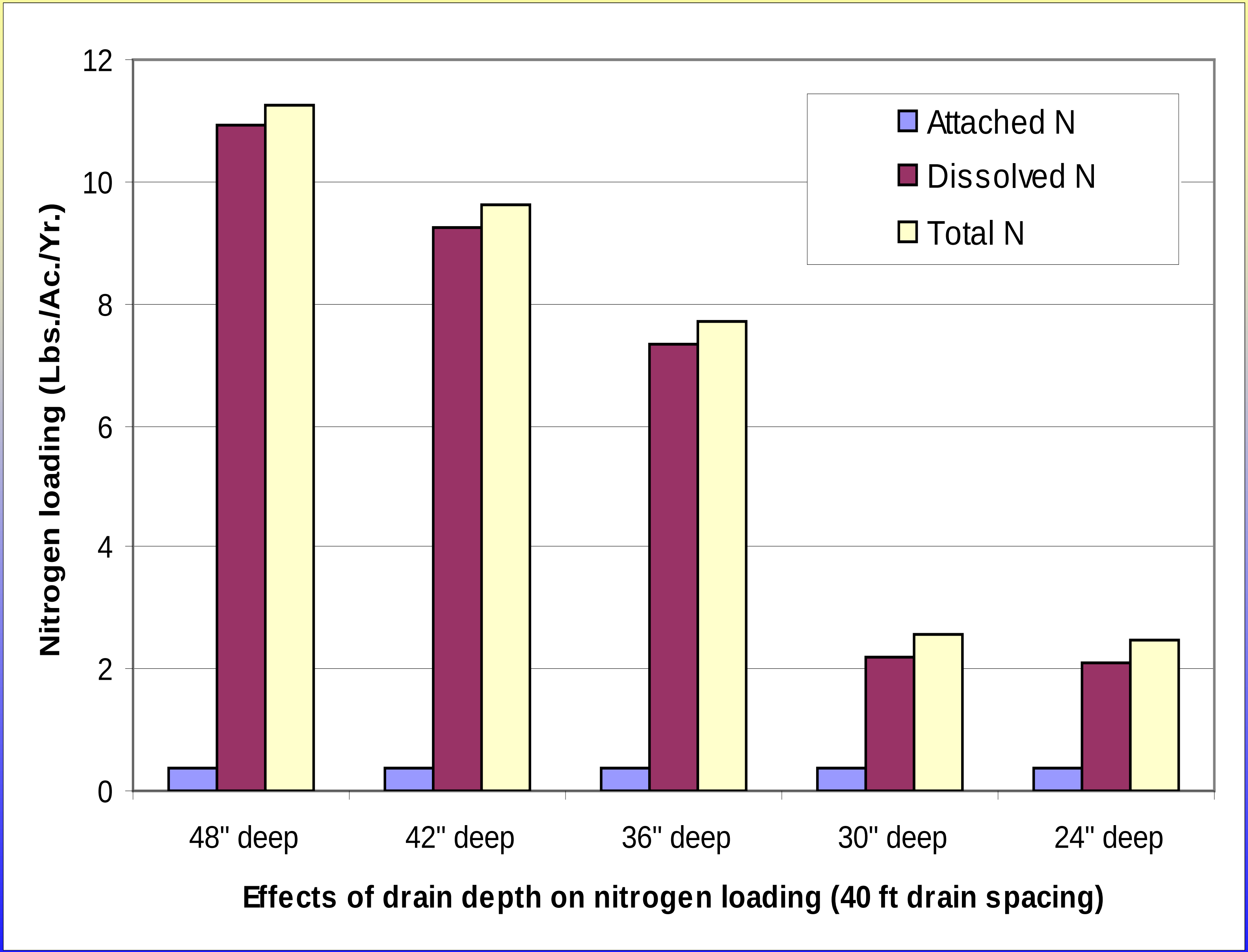
To apply the model to examine the long-term effects of drainage system management on reducing N losses

- **Effects of drain spacing**
- **Effects of drain depth**
- **Effects of turning drains off during dormant season**

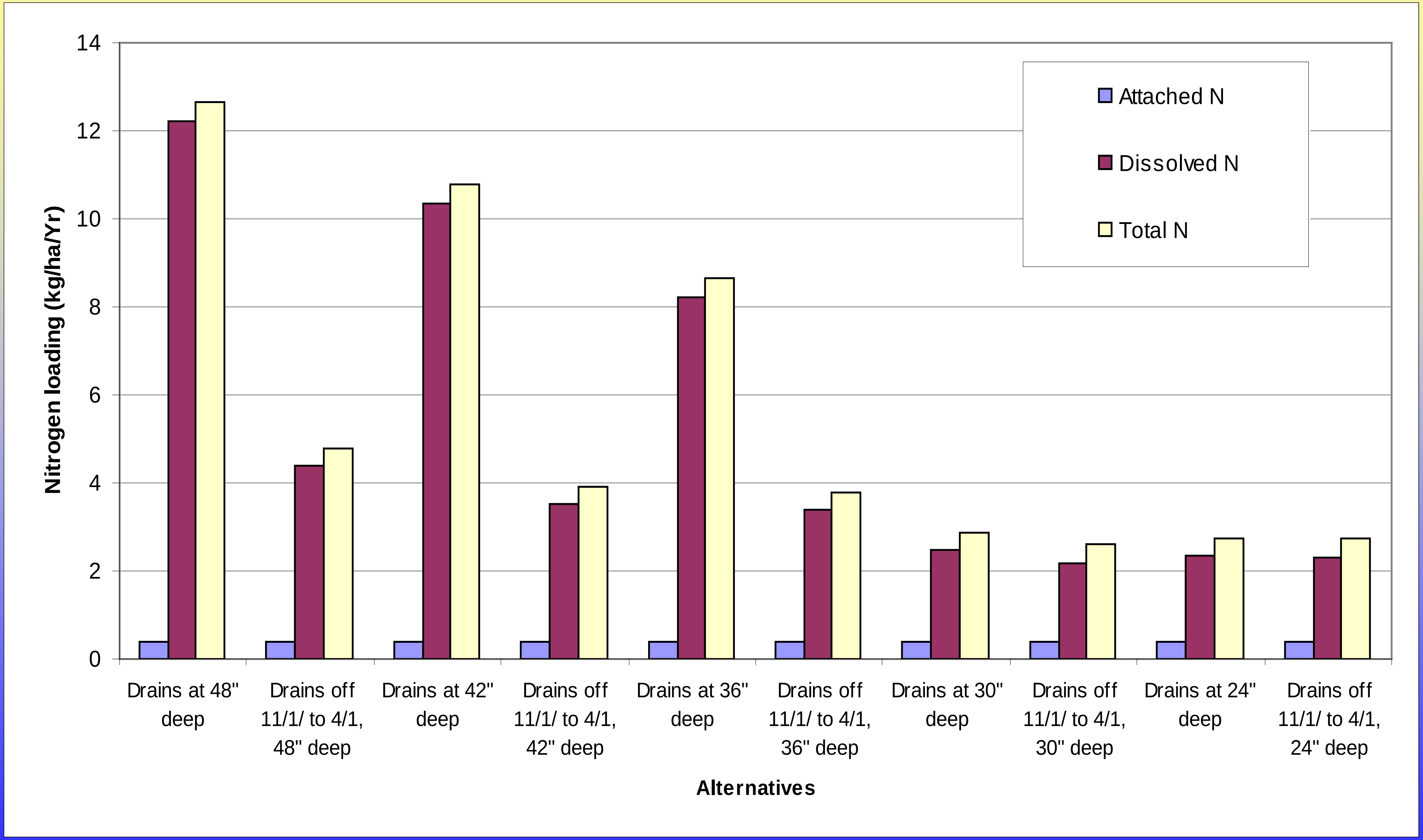
Upper Auglaize Watershed, OH



Upper Auglaize Watershed, OH



Effects of turning drains off during dormant season (Nov. 1 to Apr. 1) on N loading



Supporting Decision Making

- Wider drain spacing and shallow depth to drain can reduce N loadings.
- N loading could be significantly reduced by controlling subsurface drains from November 1 to April 1 of each year.
- Those results can be used for the development of guidelines for drain installation or drainage improvement through controlled structures.

Challenges

- Enabling more accurate simulation of currently supported processes.
- Continued incorporating advancements in scientific knowledge.
- Continued interactions with stakeholders to identify gaps and useful endpoints.
- Air, land and water interactions, such as nitrogen deposition.

Nitrogen Deposition

- Wet deposition, predominantly rain and snow, carries nitrate and ammonium.
- Dry deposition involves complex interactions between airborne nitrogen compounds and plant, water, soil, rock, or building surfaces.
- Key issues are the extent to which human activities are affecting the form and amount of nitrogen in the air, the deposition of nitrogen compounds from the air, and nitrogen cycling in the environment (impact on water quality and ecosystem).

Ongoing Work

- To link/couple models that facilitate exploration of complex nutrient questions, e.g. nitrogen cascade, through to ecological and human health endpoints.
- Currently exploring the sustainability of air, land and water quality as regards nitrogen under economically-driven agricultural land use change and climate change as well as the Clear Air Act.