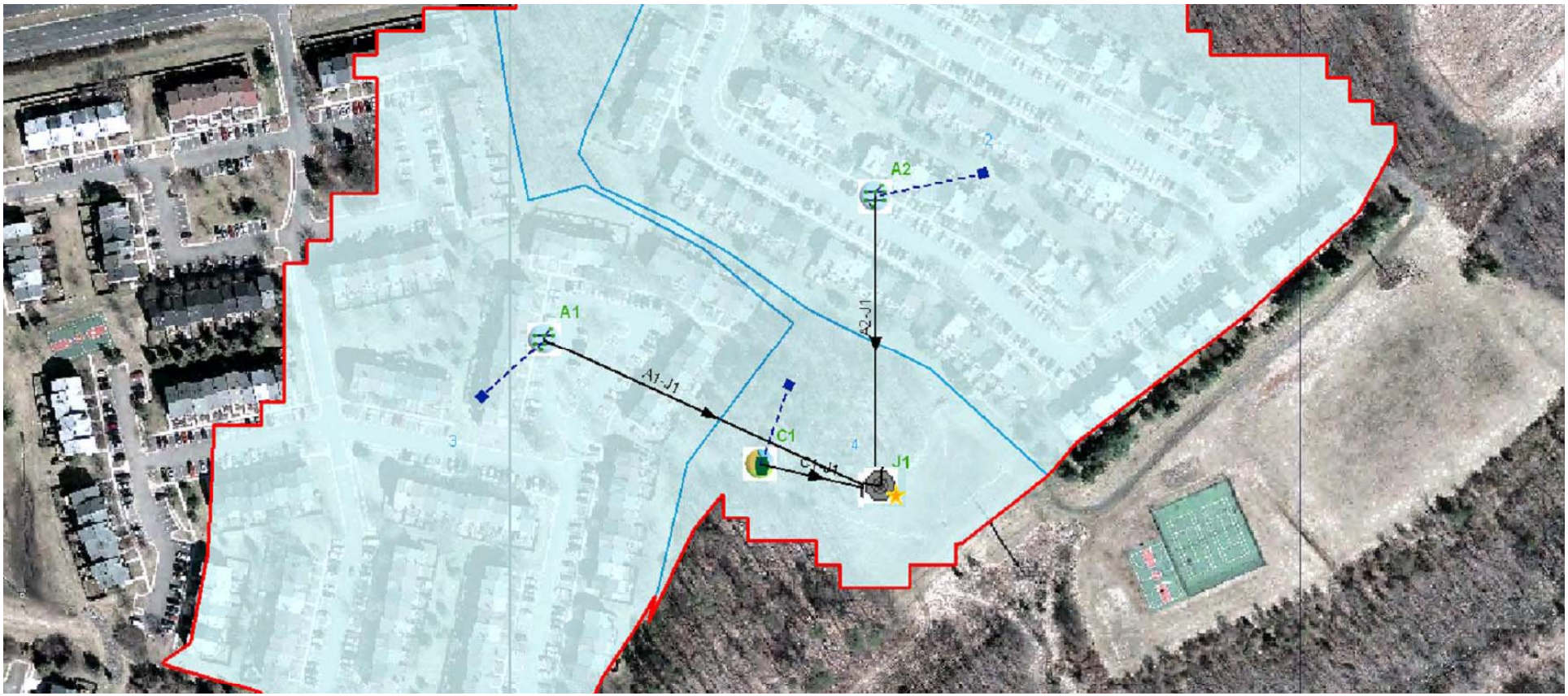
Modeling Nitrogen in Urban Watersheds



Nutrient Sensitive Waters Science Advisory Board

February 4, 2011 Presentation at the Triangle J Council of Governments, Durham, North Carolina

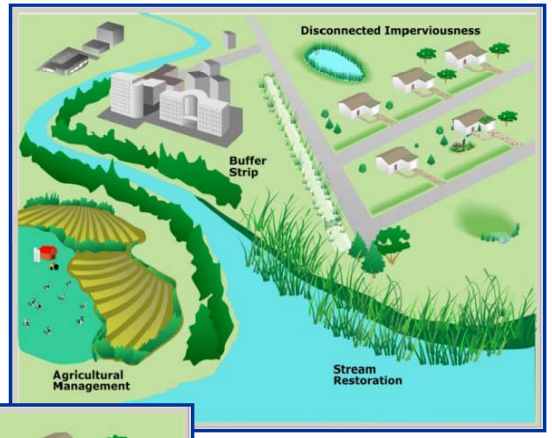
Trevor Clements, Water Resources Director
Dr. Jon Butcher, PH

TETRA TECH

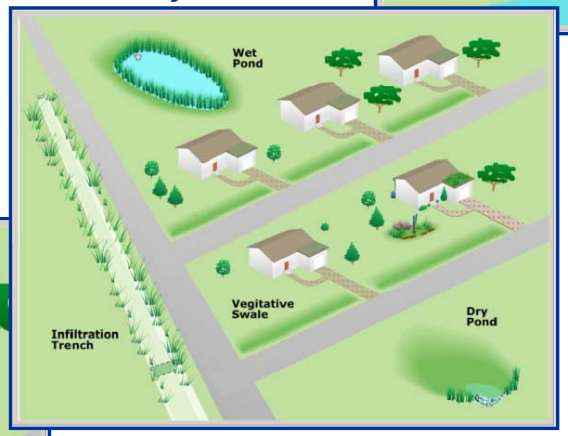
Presentation Overview

- Model Context (Trevor)
- Site Modeling Options (Jon)

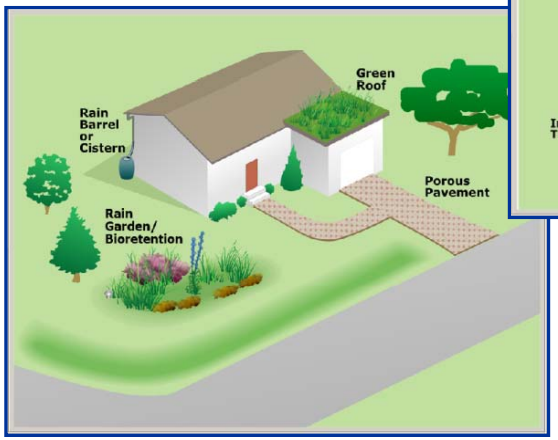
Watershed Scale



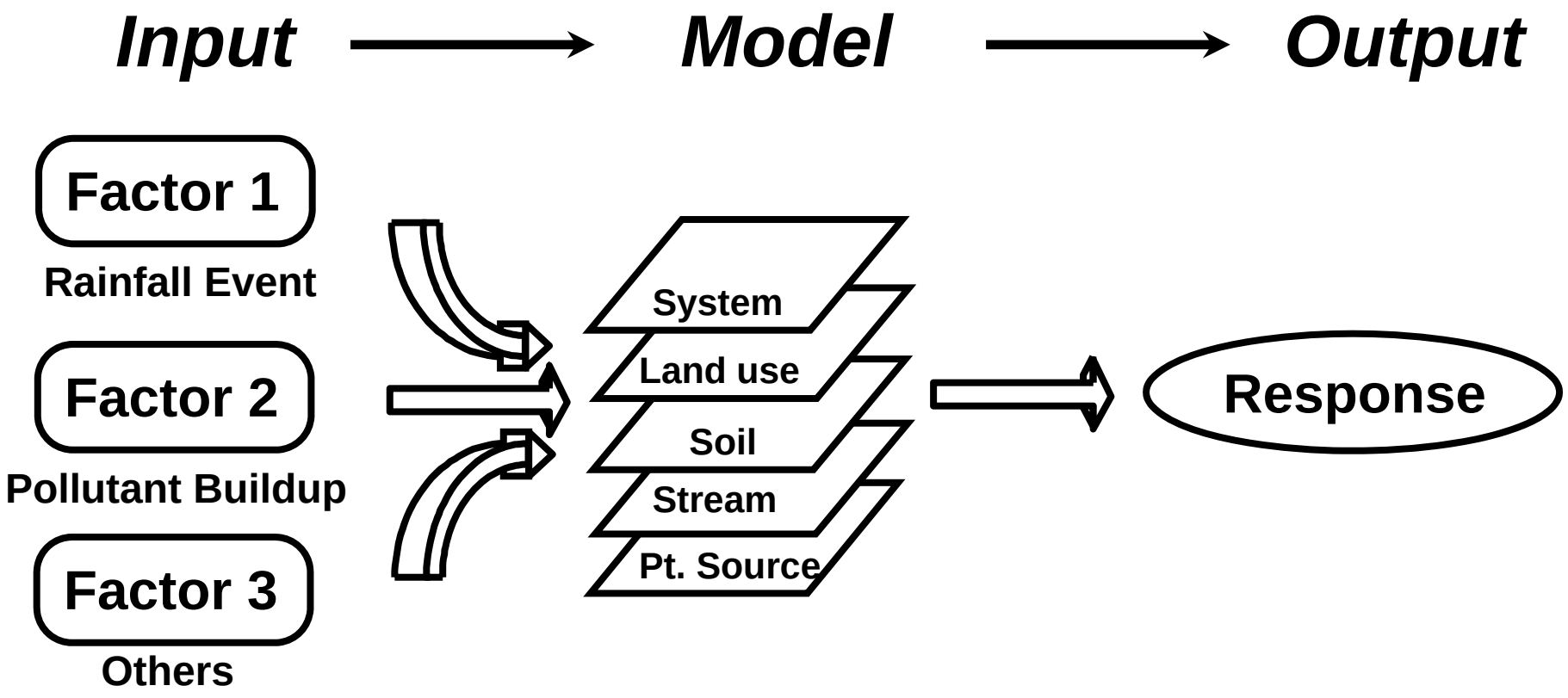
Community Scale



Lot Scale

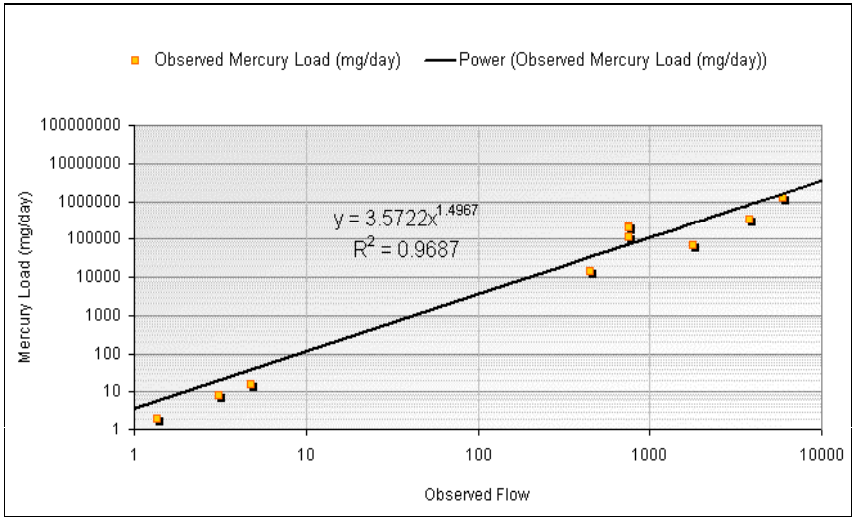


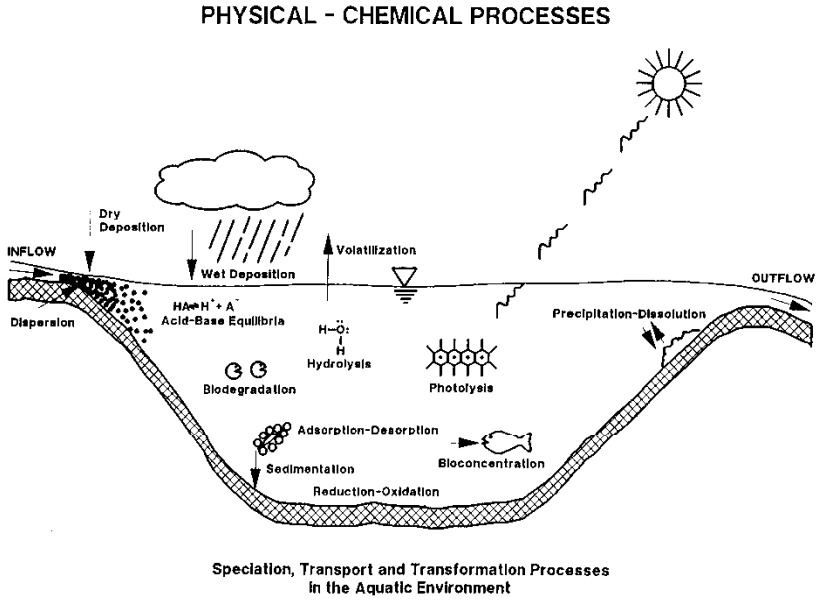
What constitutes a model?



Model Basis

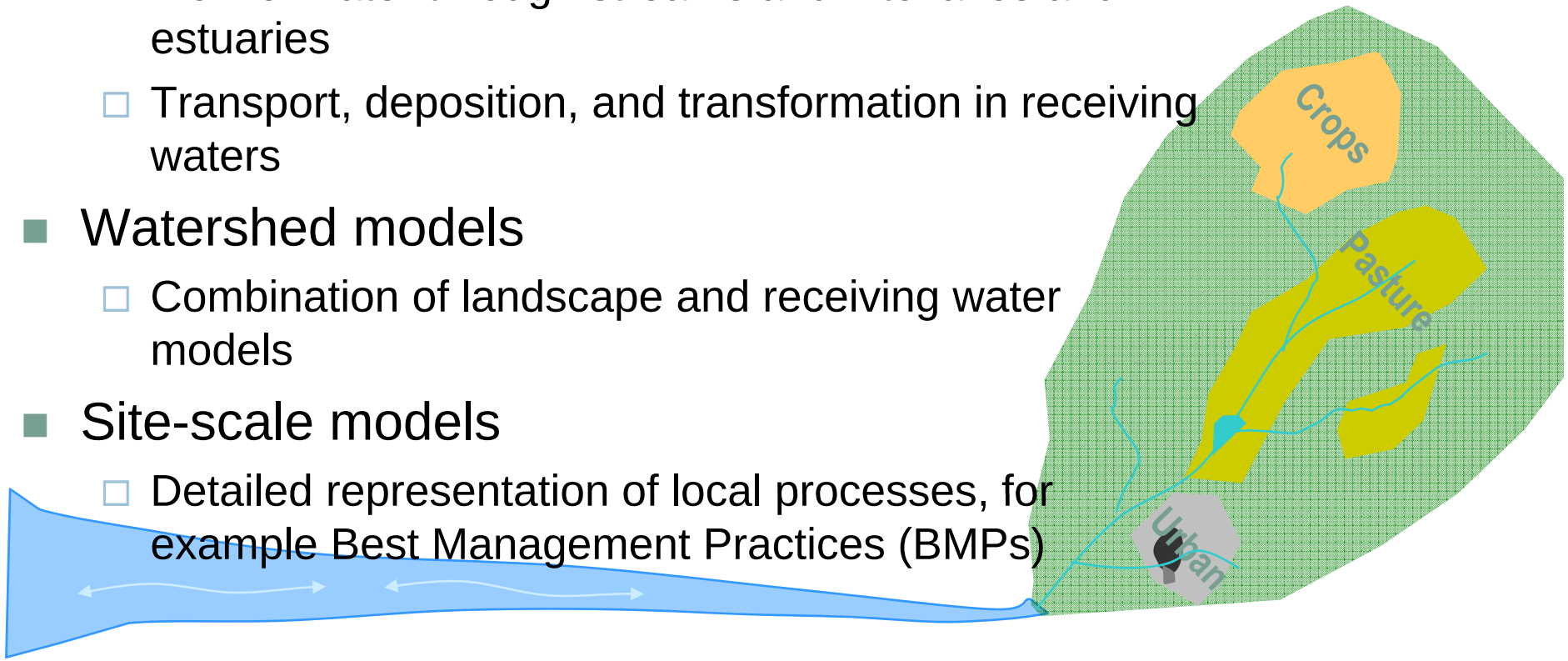
- Empirical formulations
  - mathematical relationship based on observed data rather than theoretical relationships
- Deterministic models
  - mathematical models designed to produce system responses or outputs to temporal and spatial inputs (process-based)





Model Categories

- Landscape models
  - Runoff of water and materials on and through the land surface
- Receiving water models
  - Flow of water through streams and into lakes and estuaries
  - Transport, deposition, and transformation in receiving waters
- Watershed models
  - Combination of landscape and receiving water models
- Site-scale models
  - Detailed representation of local processes, for example Best Management Practices (BMPs)



Spatial Focus

- Site accounting versus delivered loads
  - Delivered loads (to reservoirs, estuaries) are what matter
  - But, regulation focuses on site loads
- Stream and reservoir models enable process-based evaluation of delivered or exerted loads
  - A pound of nitrogen in the headwaters has less impact than a pound of nitrogen discharged at lake side

Spatial Focus

- Watershed models allow evaluation of urban loads in context with other load sources
  - Provide basis for trading evaluations
- Such models should evaluate urban and rural runoff, as well as instream transformations
  - HSPF, SWAT, and WARMF are examples
  - Each has its own strengths and weaknesses

Process and Temporal Resolution

- Site accounting models
  - Establish N baseline
  - Reduction credits for management measures
- Levels of resolution:
  - Steady-state, empirical
  - Dynamic, semi-empirical
  - Full process basis

Empirical Tools

- Jordan Lake tool is a simple empirical model
  - Assigns EMCs to land uses and BMPs
  - Evaluates average annual load – does not provide simulation of loading time series or year-to-year variability
- Other examples include:
  - Site Evaluation Tool (SET)
  - PLoad

Empirical Tools

- Pros
  - Simple, easy to use
  - Provide a consistent framework
- Cons
  - Don’t enable analysis of changes in assumptions
    - No process-based representation of changes in management and upland practices
    - No ability to tweak BMP design
    - Can’t evaluate responses to climate change
  - Don’t enable detailed source tracking

More Complex Tools

- Add dynamic representation
- Attempt some level of process-based representation of sources
- Require considerably more effort to implement
  - When is this worthwhile?

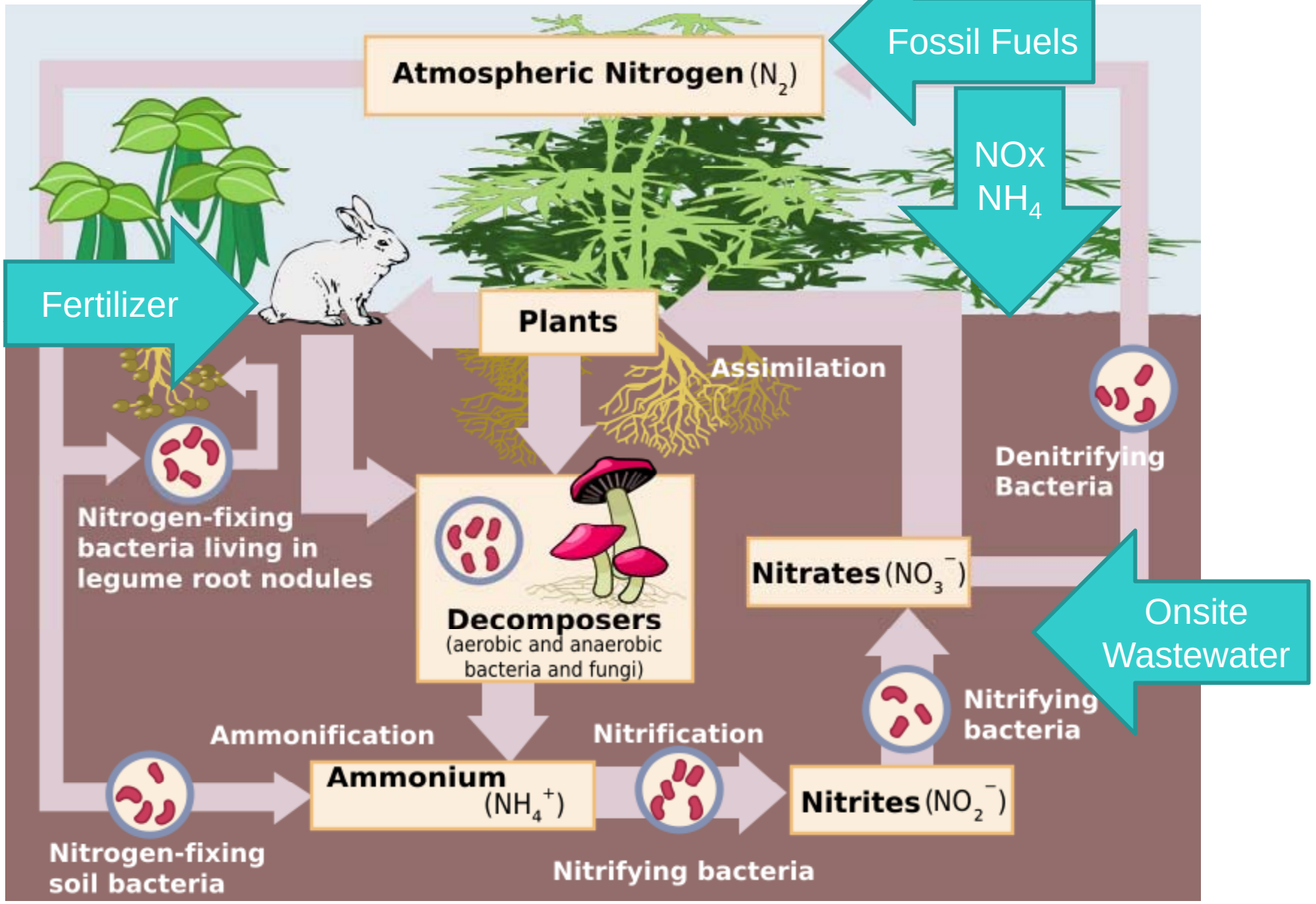
Dynamic, Semi-Empirical Tools

- Wide range available, from simpler to more complex, e.g.
- SLAMM: Simple continuous simulation with pollutant probability distributions
- SWMM: Sophisticated stormwater simulation with buildup-washoff representation of pollutants and simple instream transformations (without explicit atmospheric deposition)
- HSPF: Sophisticated stormwater simulation with buildup-washoff, atmospheric deposition, and detailed instream processes.

Dynamic, Semi-Empirical Tools

- All these tools are still semi-empirical, because they do not fully represent processes that control N loads
- Similar considerations apply to representation of BMPs:
  - N mitigation generally depends on the natural processes of denitrification and plant uptake
  - SLAMM: treatment efficiencies
  - SWMM: Flexible equation-based representation of treatment (external resolution of the processes)
  - HSPF: Add-ons, such as BMP-DSS provide some process-based representation of pollutant removal as a function of hydrology

Full Process-Based Simulation



Full Process-Based Simulation

- Requires simulation of plant growth and soil stores
- Surface-groundwater interactions
- Models that do all this are largely experimental or academic
  - SWAT provides the plant growth simulation, but is weaker on urban hydrology
  - Newer grid-based models (e.g., GSSHA) attempt to do full surface-groundwater linkage, but still in development

SUSTAIN

U.S. EPA ORD - Edison

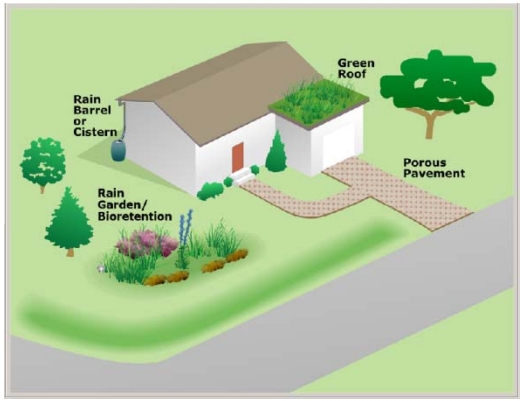
System for Urban Stormwater Treatment and Analysis INtegration

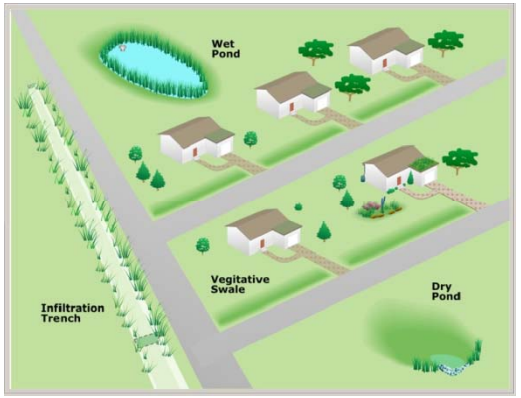
- A GIS-based framework designed to support decision-making
  - Evaluate and select BMPs to achieve loading targets set by a **TMDL**
  - Identify protective management practices and evaluate pollutant loadings for **Source Water Protection**
  - Develop cost-effective management options for a municipal **MS4** program
  - Determine a cost-effective mix of green infrastructure measures to help meet optimal flow reduction goals in a **CSO** control study
- Released in November ’09

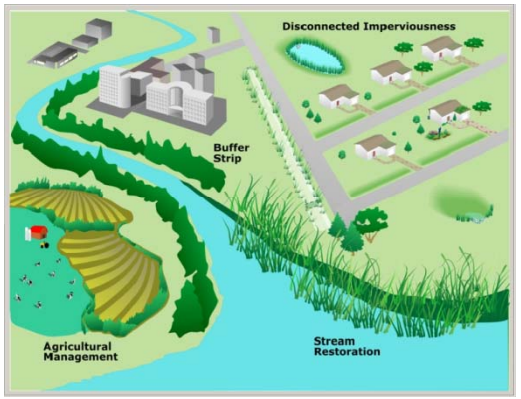
http://www.epa.gov/ednnrmrl/models/sustain/index.html

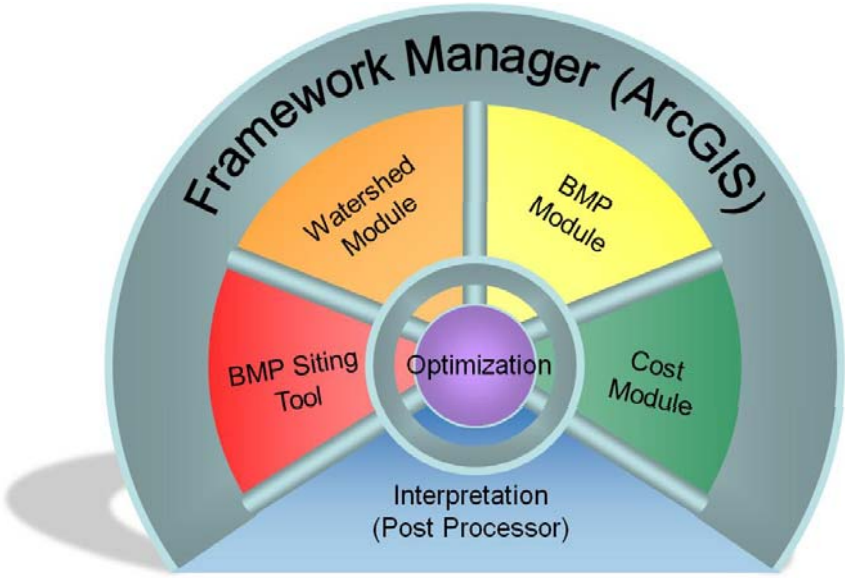
SUSTAIN Advantages

- Multi-scale application
- Detailed BMP simulation
- Cost consideration
- Optimization





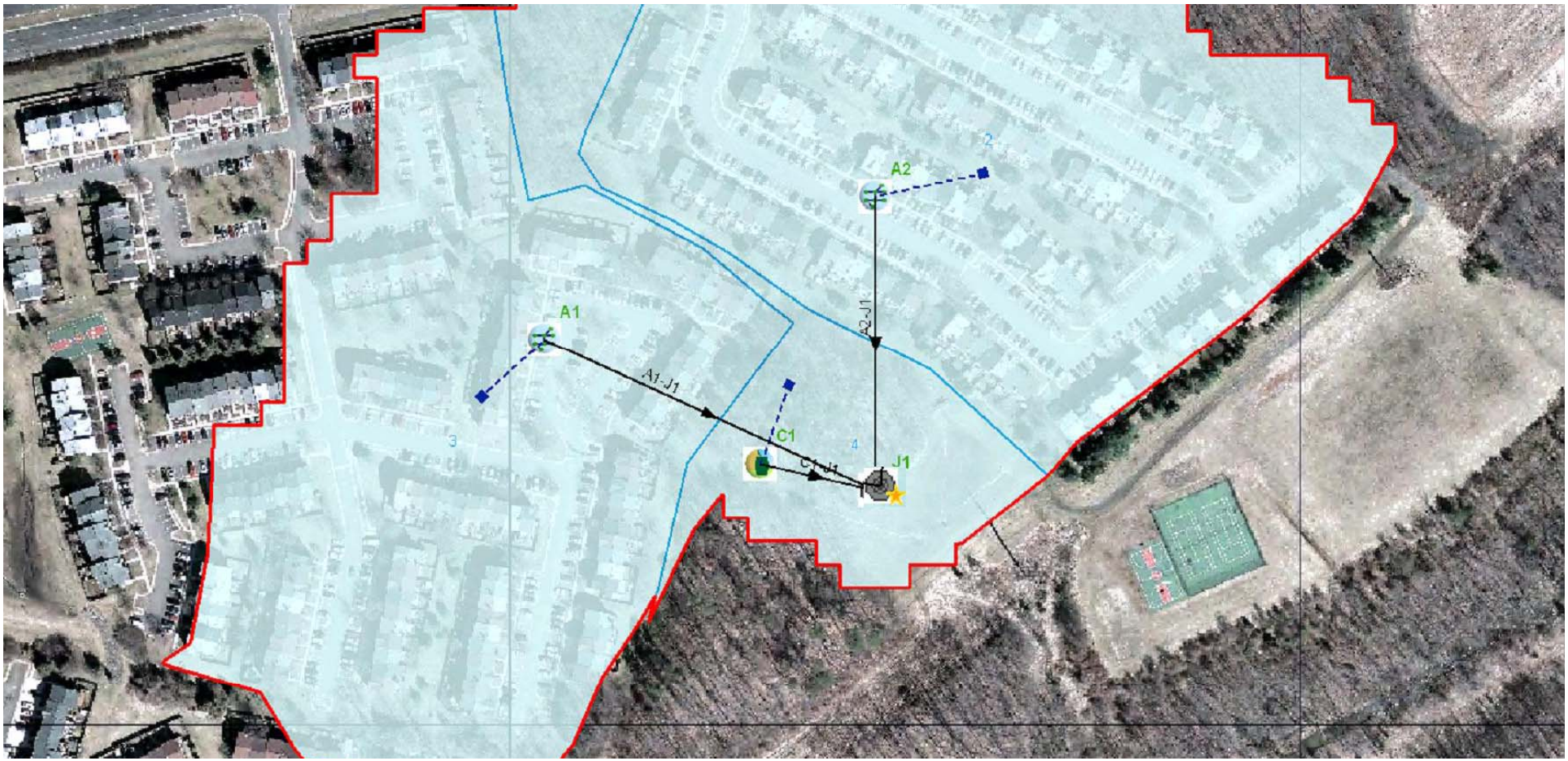




Summary - model selection factors to consider…

- Utility: ability to answer key management questions and convey results
- Relevance:
  - Representation of key processes
  - Assumptions and limitations
- Credibility: peer-reviewed, public domain
- Usability:
  - Match to data availability
  - Cost and level of expertise required
- Resources Available: time and funding

Thank you!



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