Low-Impact Development Modeling Programs

In

Prince George's County, Maryland

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PRINCE GEORGE'S COUNTY MARYLAND

PRINCE GEORGE'S COUNTY Department of Environmental Resources

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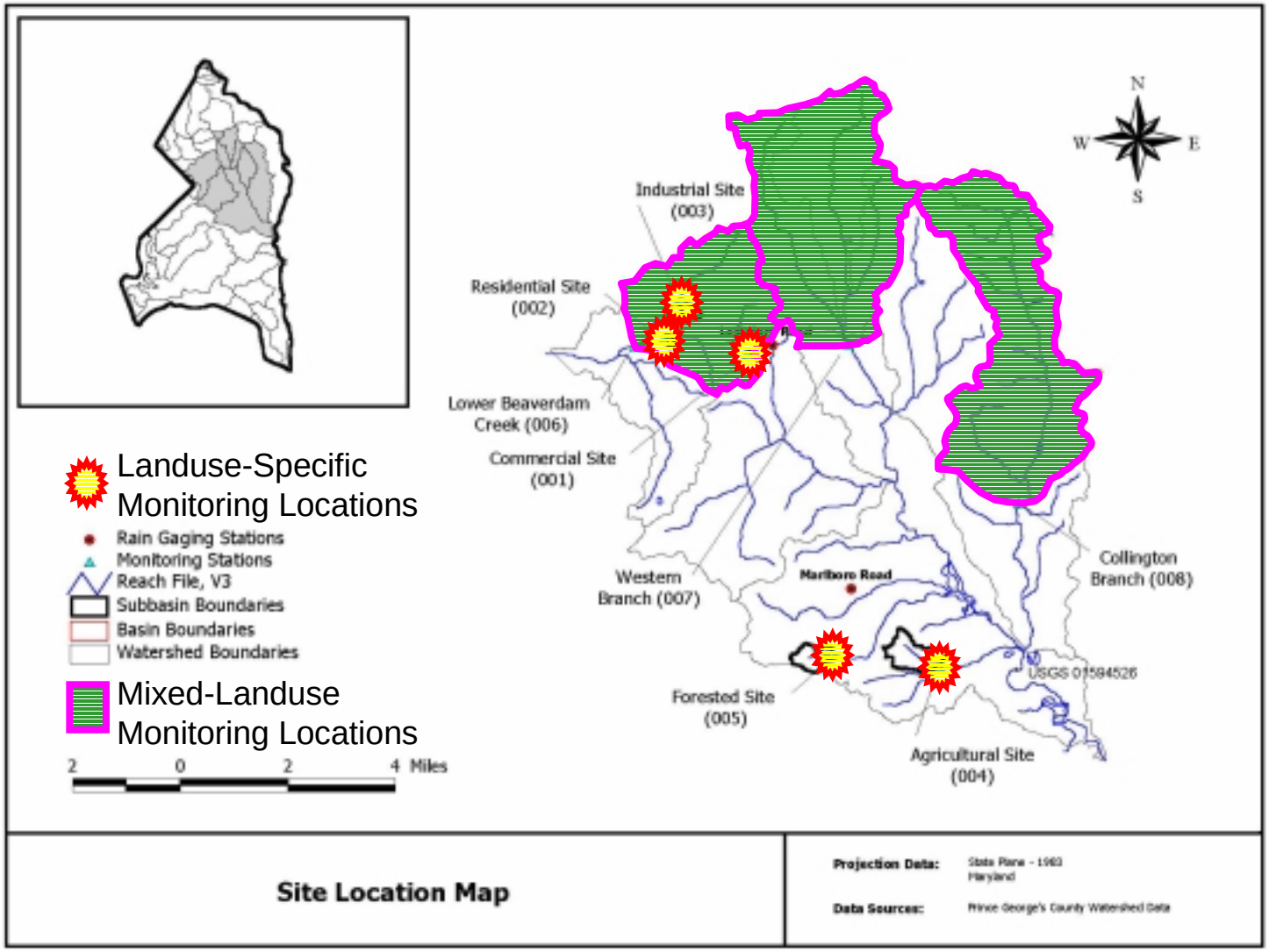
Presentation Outline

- Project Background
- BMP Simulation Modeling
  - Existing functions
  - Enhancements
- Ongoing System Enhancements
  - GIS system integration
  - Optimization
  - LID case study application for CSO overflows
- Next Steps

Project Background

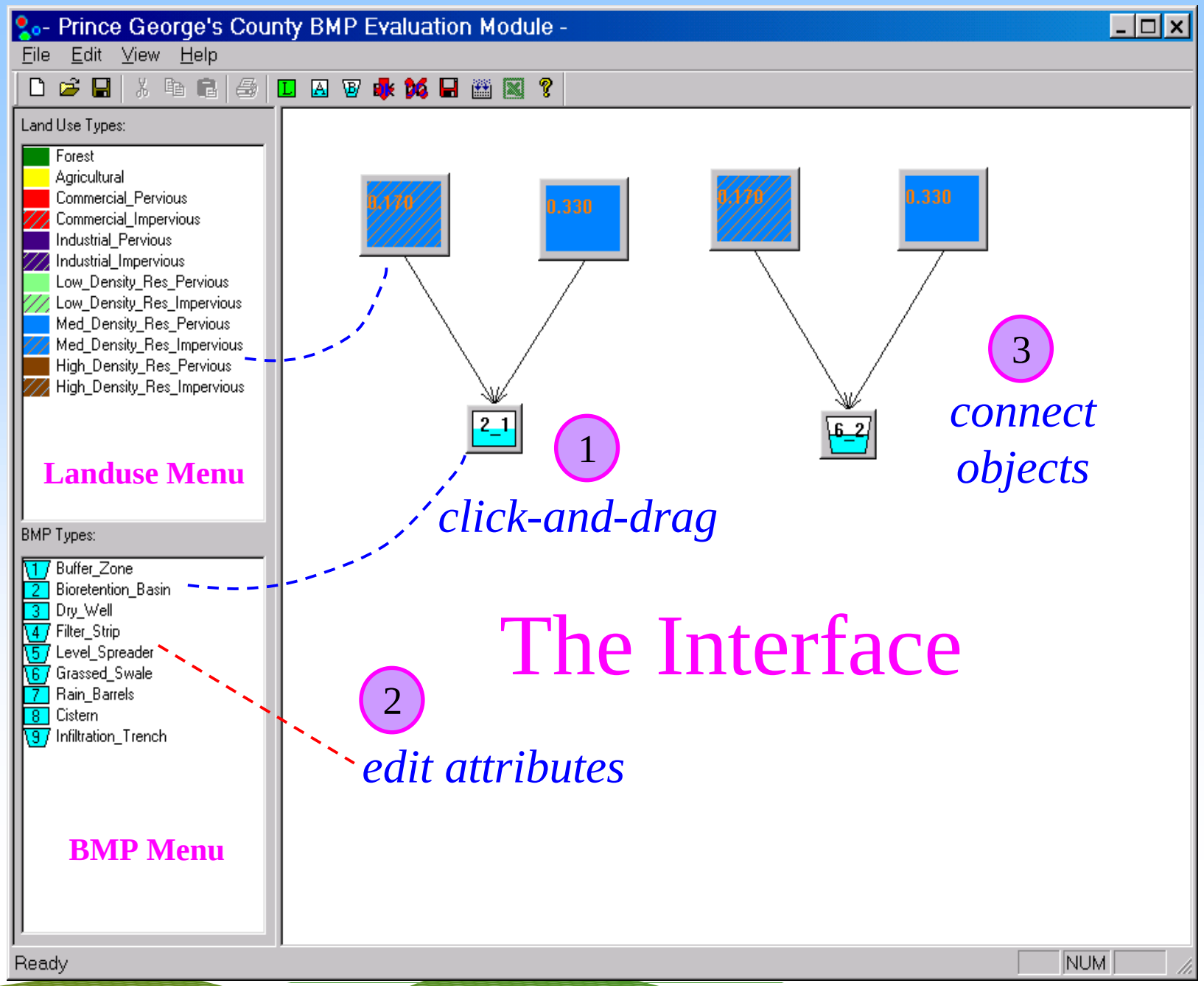
- County-wide storm water monitoring
  - 1993 to present
- Development of Prince George's County HSPF model parameter database
  - 1998-1999
- BMP Module development
  - 1999 to present

HSPF Landuse Representation

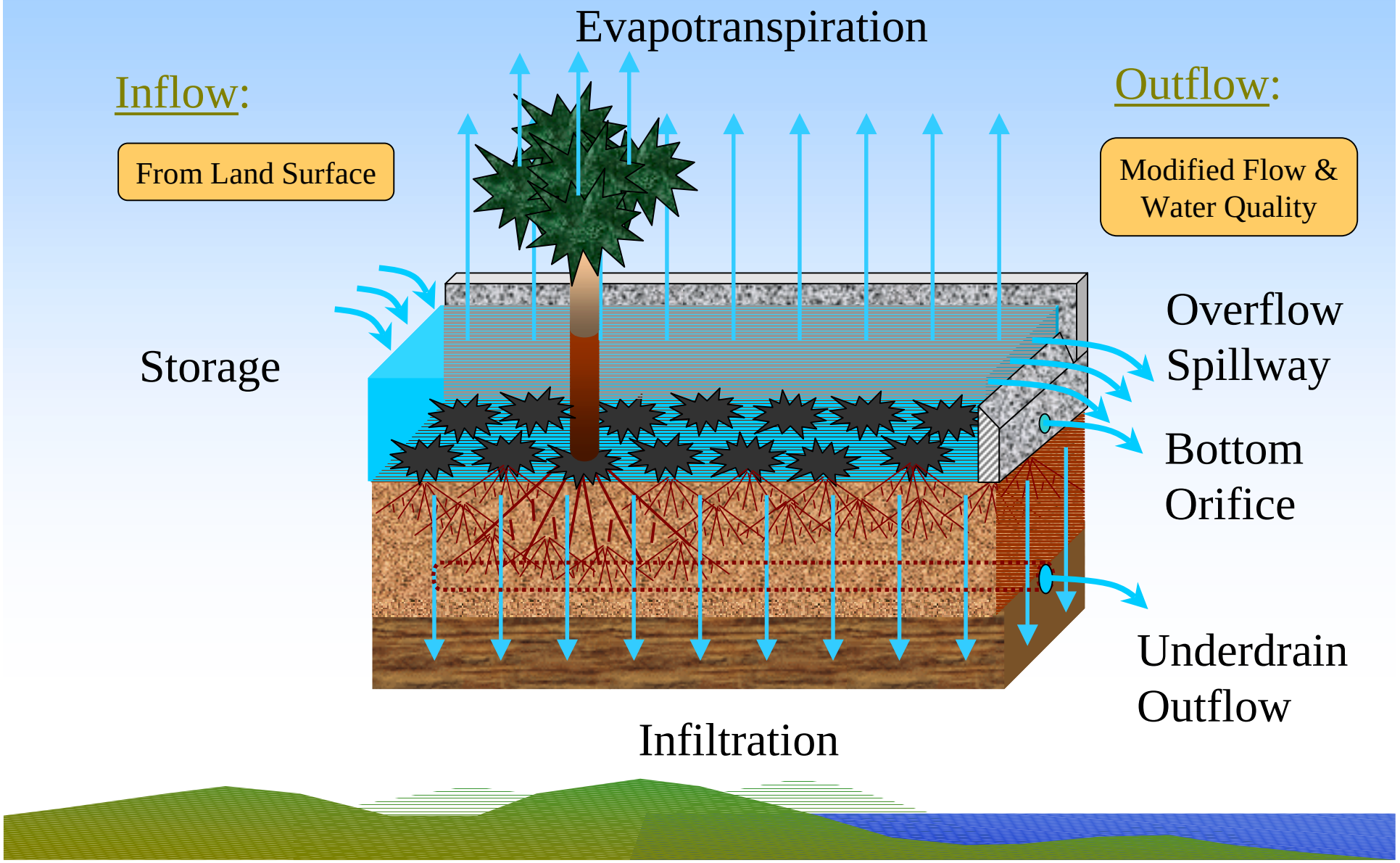


BMP Physical Processes

- Possible storage processes include:
  - Evapotranspiration
  - Infiltration
  - Orifice outflow
  - Weir-controlled overflow spillway
  - Underdrain outflow
  - Bottom slope influence
  - Bottom roughness influence
  - General loss or decay of pollutant
  - (Due to settling, plant-uptake, volatilization, etc)
  - Pollutant filtration through soil medium
  - (Represented with underdrain outflow)
- Depending on the design and type of the BMP, any combination of processes may occur during simulation

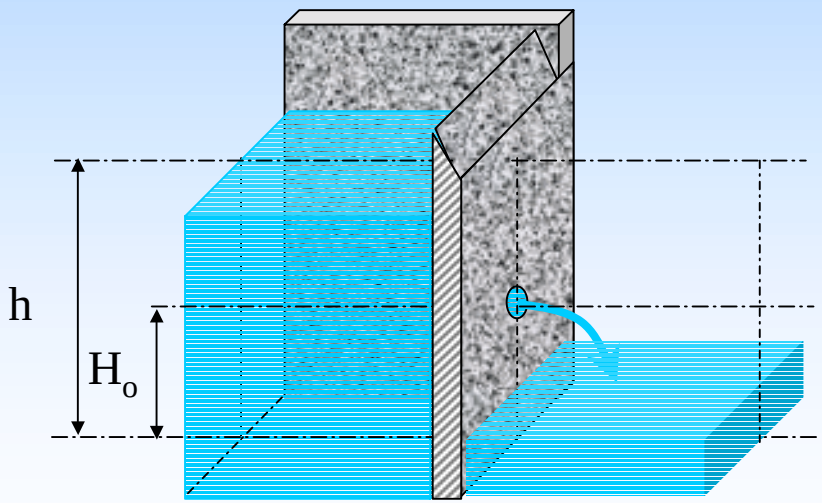

Prince George's County BMP Evaluation Module -
File Edit View Help
Land Use Types:
Forest
Agricultural
Commercial_Pervious
Commercial_Impervious
Industrial_Pervious
Industrial_Impervious
Low_Density_Res_Pervious
Low_Density_Res_Impervious
Med_Density_Res_Pervious
Med_Density_Res_Impervious
High_Density_Res_Pervious
High_Density_Res_Impervious
Landuse Menu
BMP Types:
Buffer_Zone
Bioretention_Basin
Dry_Well
Filter_Strip
Level_Spreader
Grassed_Swale
Rain_Barrels
Cistern
Infiltration_Trench
BMP Menu
0.170
0.330
0.170
0.330
2_1
6_2
1
click-and-drag
2
edit attributes
3
connect objects
The Interface
Ready
NUM

BMP Class A: Storage/Detention



Process:

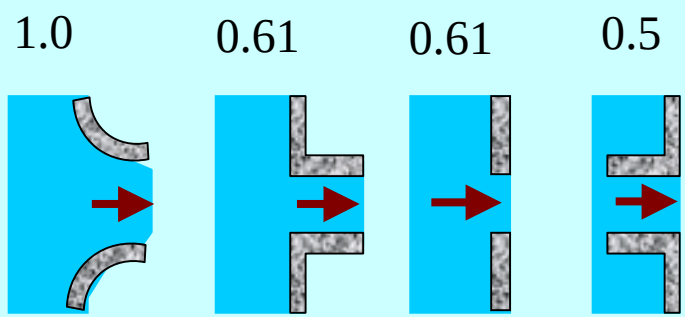
- Function of stored water level, orifice size, and exit design
- Variable time step calculation



Standard Orifice Equation

$$Q = C_{exit} A_{orifice} \sqrt{2g(h - H_o)}$$

Values of Exit Coefficient (C_{exit}):

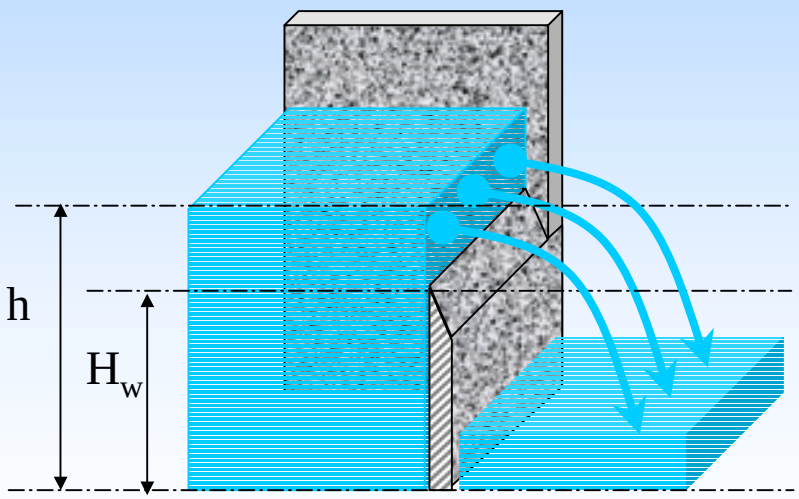


Output:

Orifice Flow
(Retarded Flow)

Process:

- Function of stored water level, weir dimensions
- Variable time step calculation

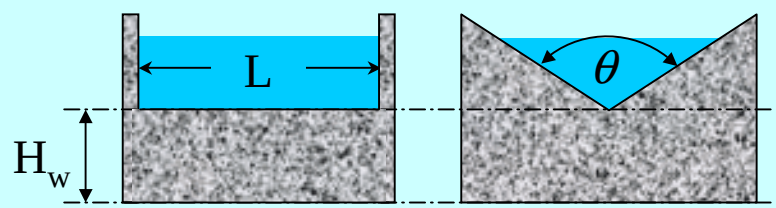


Rectangular Sharp Crested

$$Q = C_w L (h - H_w)^{3/2}$$

Triangular (V-notch)

$$Q = C_w'' \sqrt{2g} (h - H_w)^{5/2} \tan\left(\frac{\theta}{2}\right)$$

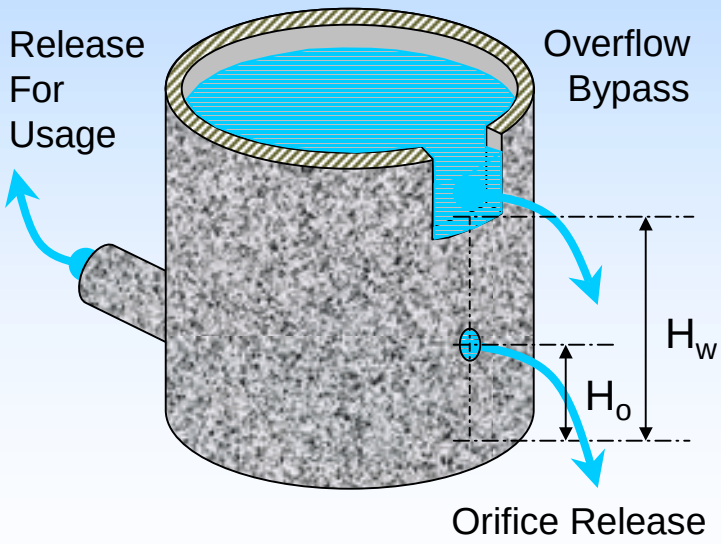


Output:

Weir Overflow

Process: Cistern/Rain Barrel Functionality

- Function of stored volume, release rates, and water level
- Variable time step calculation



<u>Release For Usage</u>

When cistern water is pumped for domestic use, the modeler can define an hourly per-capita usage rate and the number of people

<u>Orifice Release</u>

The modeler defines the number of dry days following a storm event, after which water from a rain-barrel is released.

<u>Output</u>:

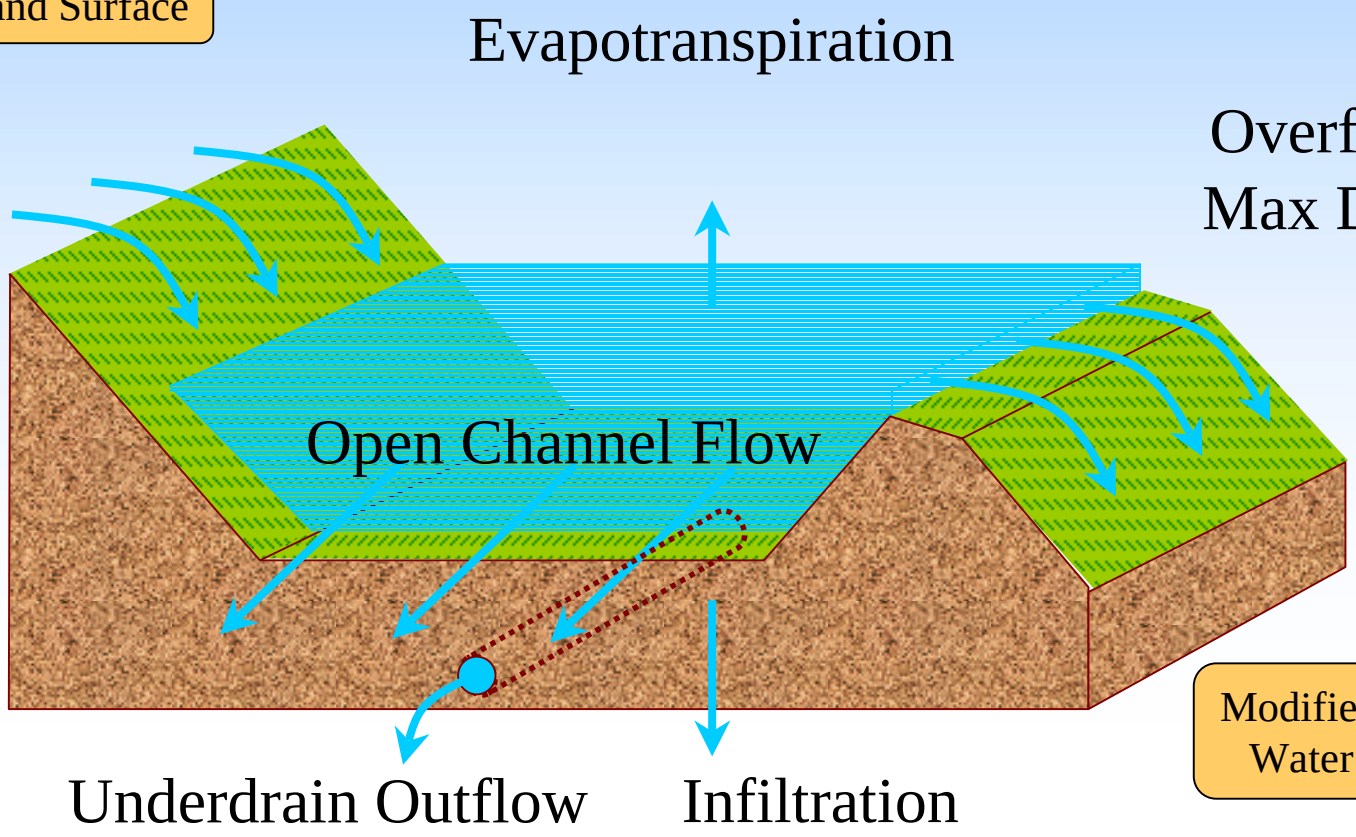
Weir Overflow
Orifice Release

BMP Class B: Open Channel

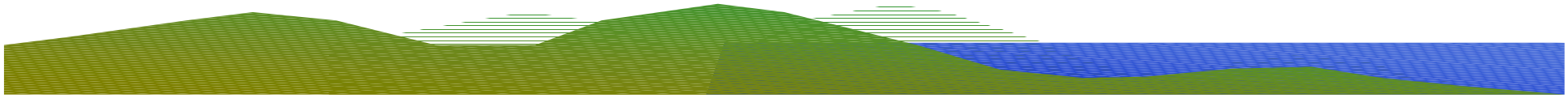
Inflow:

From Land Surface

Outflow:

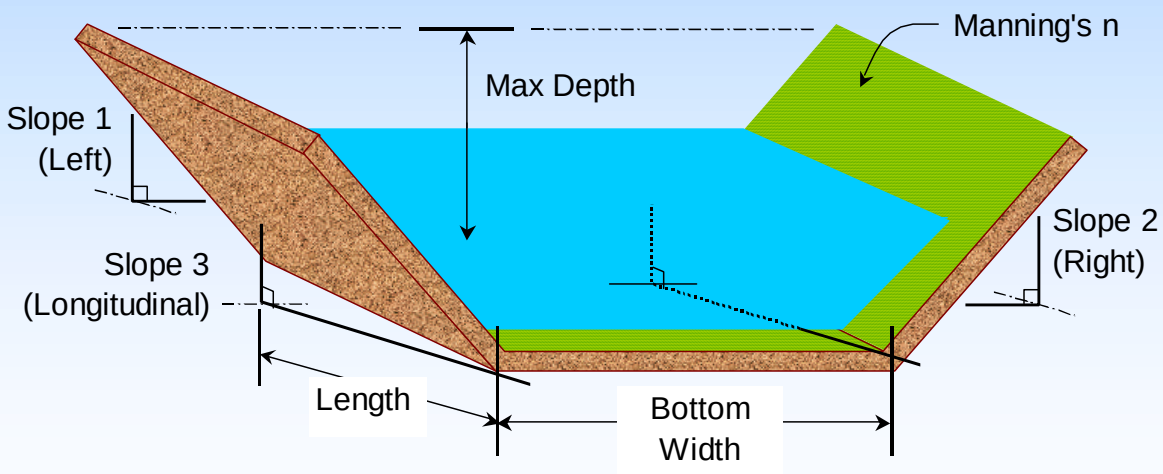


Modified Flow & Water Quality



Process: Mannings Equation for Open Channel Flow

- Calculated using timestep of input data
- Function of channel geometry and roughness



Manning's Velocity

$$V = \frac{1.49}{n} R^{2/3} S^{1/2}$$

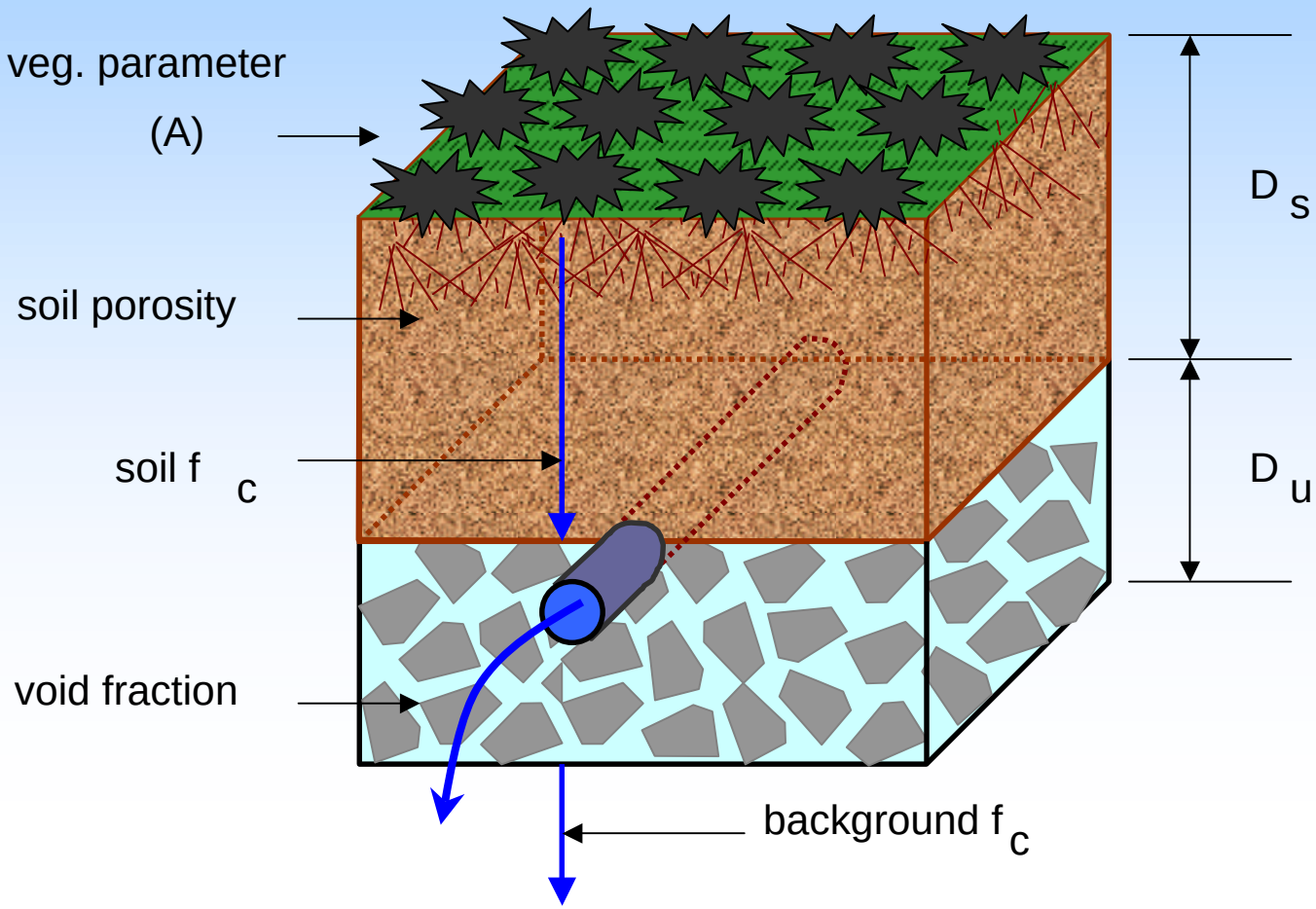
Continuity

$$Q = VA$$

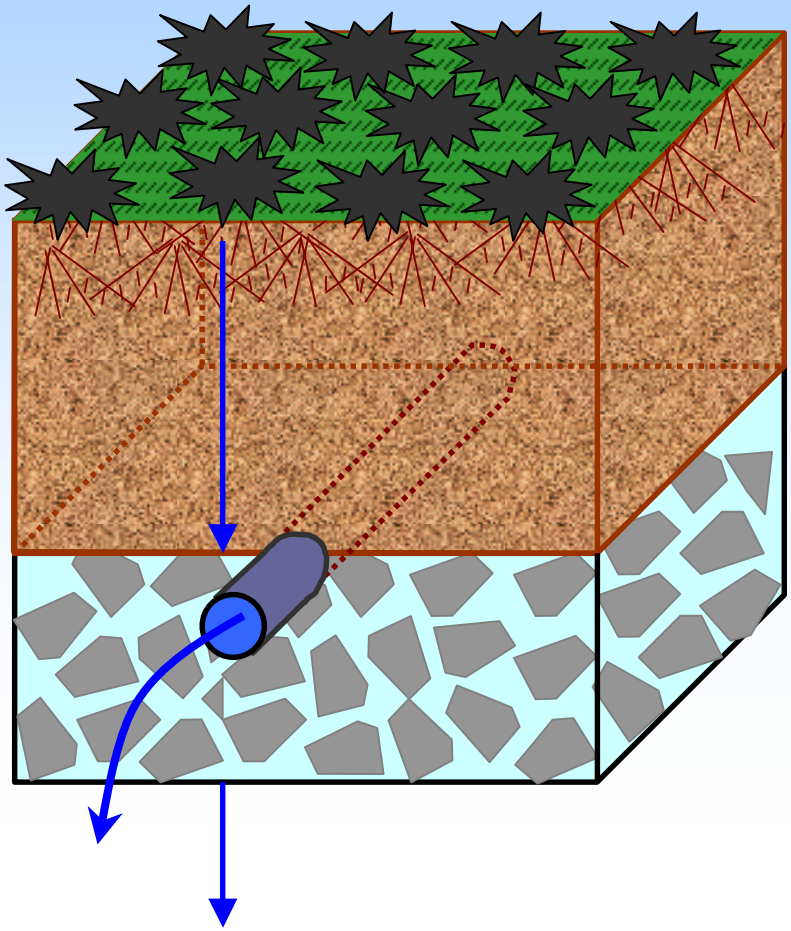
Output: Open Channel Flow (Retarded Flow)

Holtan Infiltration Model Adapted for Underdrain Outflow

$$f = GI\,AS_a^{1.4} + f_c$$

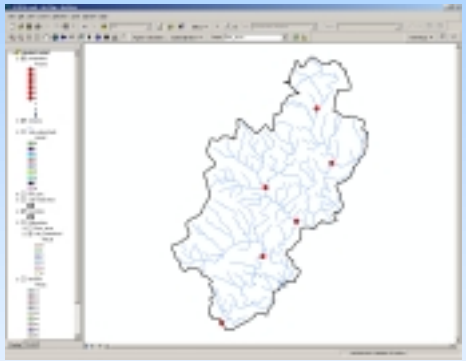


Substrate Model Enhancements

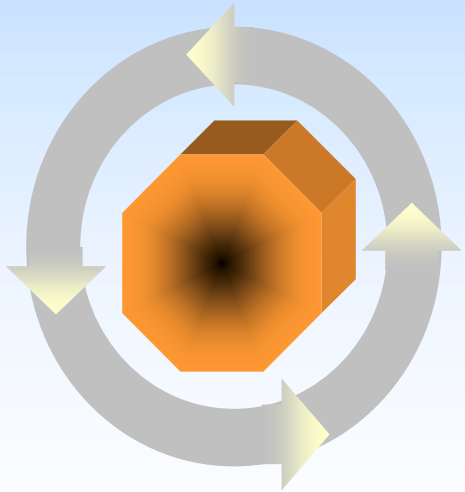


- Water Budget
  - Add Green-Ampt method
  - Evapotranspiration
- Phosphorus Modeling
  - Dissolved/particulate
  - Adsorption/desorption
  - Plant uptake
- Multiple Layer Effects
  - Mulch layer
  - Root zone layer
  - Underdrain retention layer

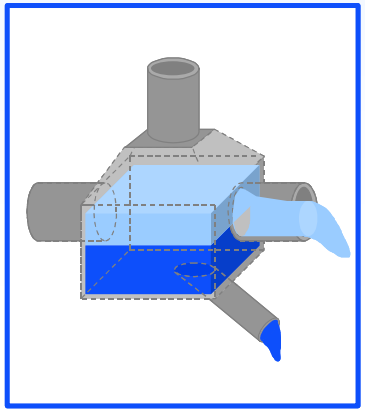
BMP Module Enhancements



- GIS linkage

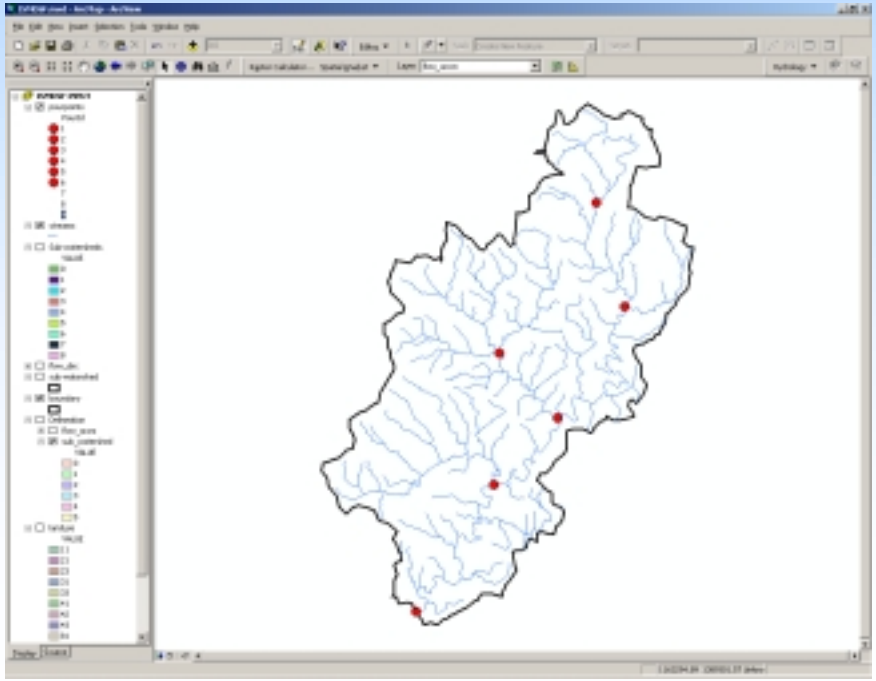


- Optimization



- LID – CSO linkage

BMP Module – GIS Linkage

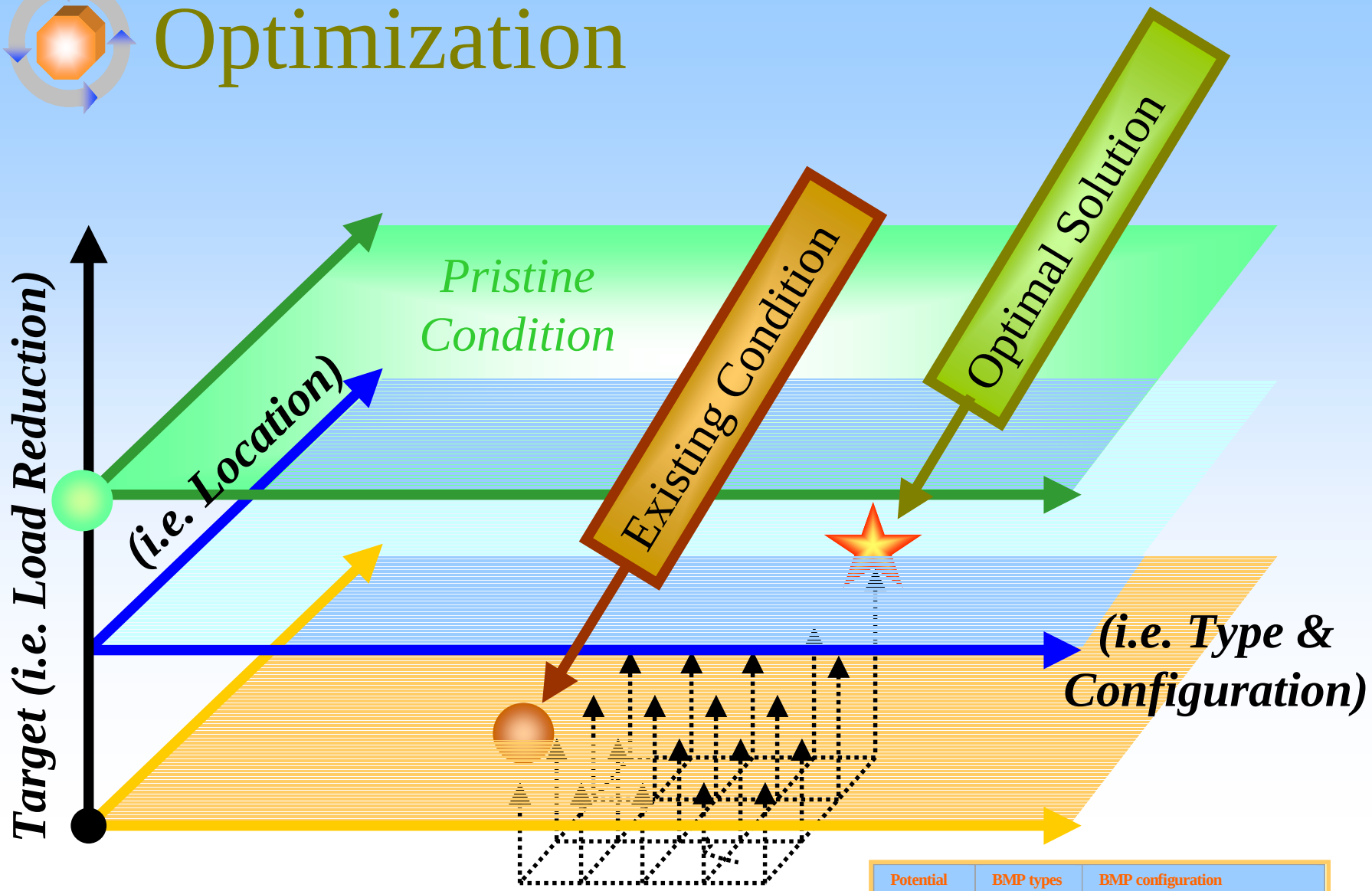


- Landuse Functions
  - Reclassify or group landuse
  - Time series association
- BMP Functions
  - Add/remove BMP
  - Modify BMP design
- GIS/System Functions
  - Delineate watershed or BMP drainage area
  - Generate network
  - Run optimizer model

Optimization

- Problem Formulation
  - Objectives & constraints
  - Evaluation factors & assessment points
  - Potential BMP types and locations
- Solution Techniques
  - Scatter search
  - Genetic algorithm

Optimization



Potential Location	BMP types	BMP configuration		
1 (0-1)	A, B, C…	Depth	Surface area	…
2 (0-1)	A, B, C…	Depth	Surface area	…

Feasible Alternatives

Defining BMP Optimization

Find *optimum* BMP placement and selection strategies based on pre-selected potential sites and applicable BMP types.

- What is optimum?

  Problem Formulation: Minimize cost and/or maximize pollutant load reduction from runoff using various BMP/LID alternatives.

- How does one measure optimum?

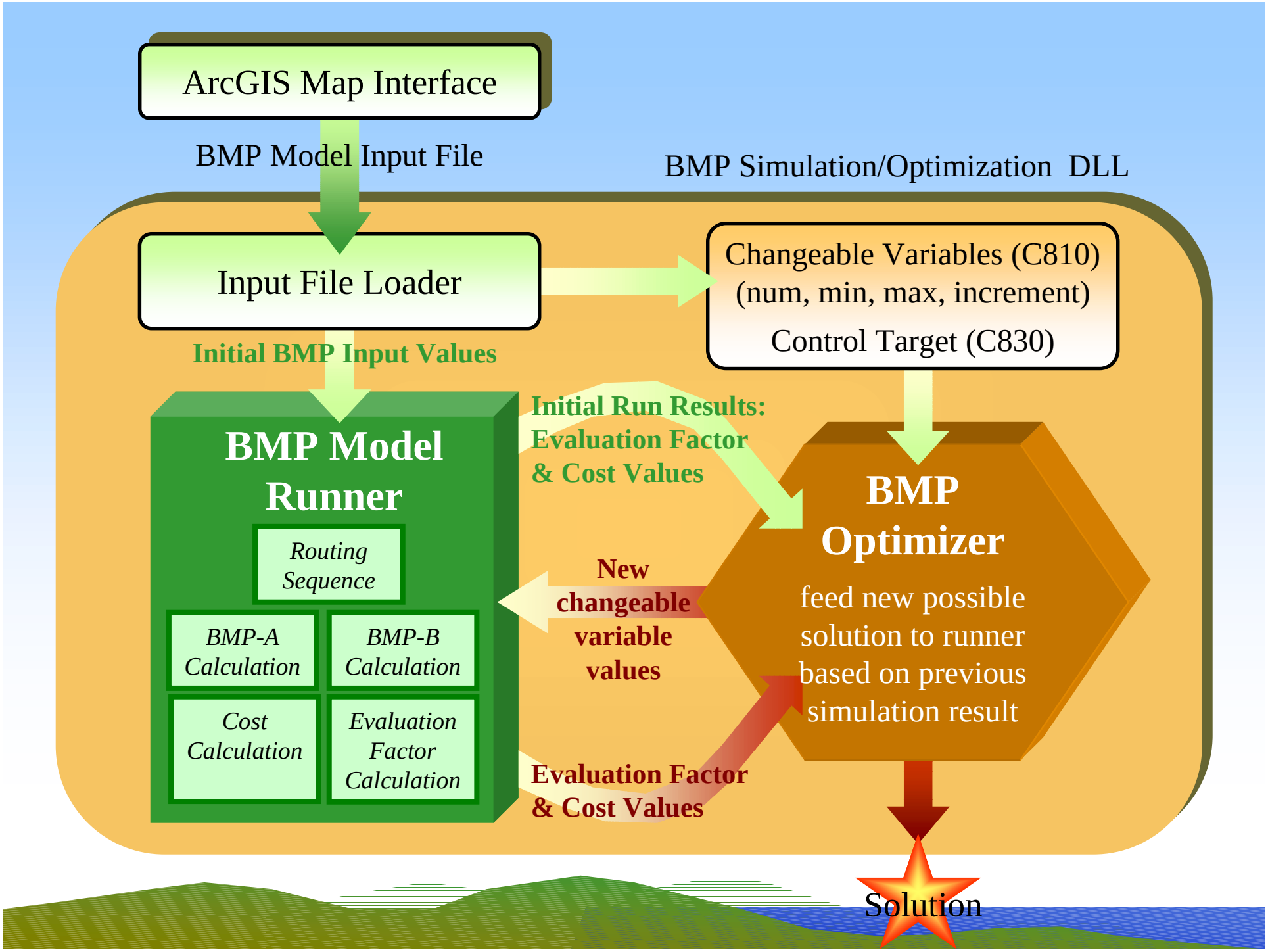
  Evaluation Criteria: (using continuous simulation)

  - Minimum long-term flows and pollutant loads
  - Best-fit multi-storm curve with pre-developed condition

Optimization Procedure

Two common methods, Genetic Algorithms and Scatter Search, are both meta-heuristic approaches that select alternatives from within a set range of attributes present within the population.

- Genetic Algorithm – *Stochastic Method*
  - Uses probabilistic rather than deterministic search rules.
  - Uses randomization to select which "traits" of "parent" alternatives are combined to generate "offspring."
  - Strongest "offspring" traits used in the "next generation"
- Scatter Search – *Strategic Method*
  - Uses both deterministic and probabilistic search rules
  - Not randomized – treats all alternatives equal at the start
  - Narrows search based on system response and history

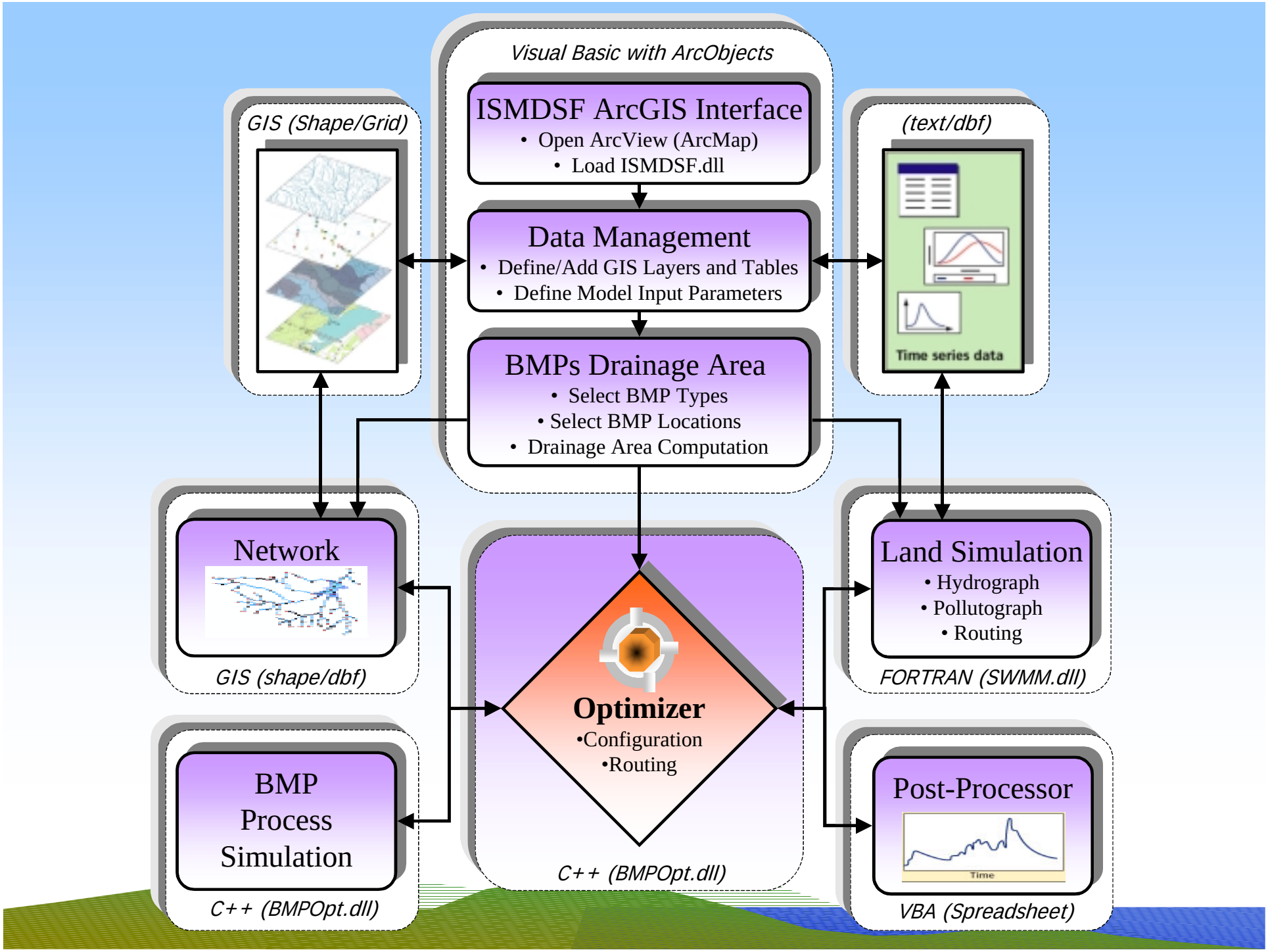

ArcGIS Map Interface
BMP Model Input File
BMP Simulation/Optimization DLL
Input File Loader
Changeable Variables (C810)
(num, min, max, increment)
Control Target (C830)
Initial BMP Input Values
BMP Model Runner
Routing Sequence
BMP-A Calculation
BMP-B Calculation
Cost Calculation
Evaluation Factor Calculation
Initial Run Results: Evaluation Factor & Cost Values
New changeable variable values
Evaluation Factor & Cost Values
BMP Optimizer
feed new possible solution to runner based on previous simulation result
Solution

Case Study Application

- Incorporate data from existing D.C. WASA CSS Model for two blocks city blocks in Anacostia Watershed.
- Develop potential LID configuration scenarios
- Test BMP selection and placement optimization
- Summarize effect of potential LID configurations on runoff volume and CSO inflow reduction
- CSO storm water inflow reduction is associated with reduction of CSO overflow frequency

Next Steps

- Ongoing Work
  - System application and testing in Washington D.C. (Anacostia CSO Case Study)
- Future Development Efforts
  - Support USEPA-ORD ISMDSF project
  - Wetland modeling
  - Other BMP simulation techniques and enhancements


Visual Basic with ArcObjects
ISMDSF ArcGIS Interface
• Open ArcView (ArcMap)
• Load ISMDSF.dll
Data Management
• Define/Add GIS Layers and Tables
• Define Model Input Parameters
BMPs Drainage Area
• Select BMP Types
• Select BMP Locations
• Drainage Area Computation
GIS (Shape/Grid)
(text/dbf)
Time series data
Network
GIS (shape/dbf)
Land Simulation
• Hydrograph
• Pollutograph
• Routing
FORTRAN (SWMM.dll)
Optimizer
•Configuration
•Routing
C++ (BMPOpt.dll)
BMP
Process
Simulation
C++ (BMPOpt.dll)
Post-Processor
Time
VBA (Spreadsheet)

Thank You.

Questions?

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