北京師範大學
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Assessment of agricultural best management practices using mathematical models: a review

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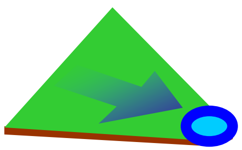
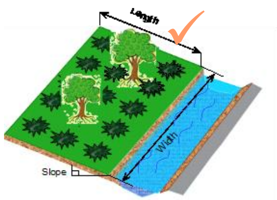
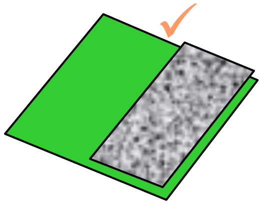
Background: What is BMPs



- **Point BMP**: Practices that capture upstream drainage at a specific location and use a combination of detention, infiltration, evaporation, settling, and transformation to manage flow and remove pollutants.

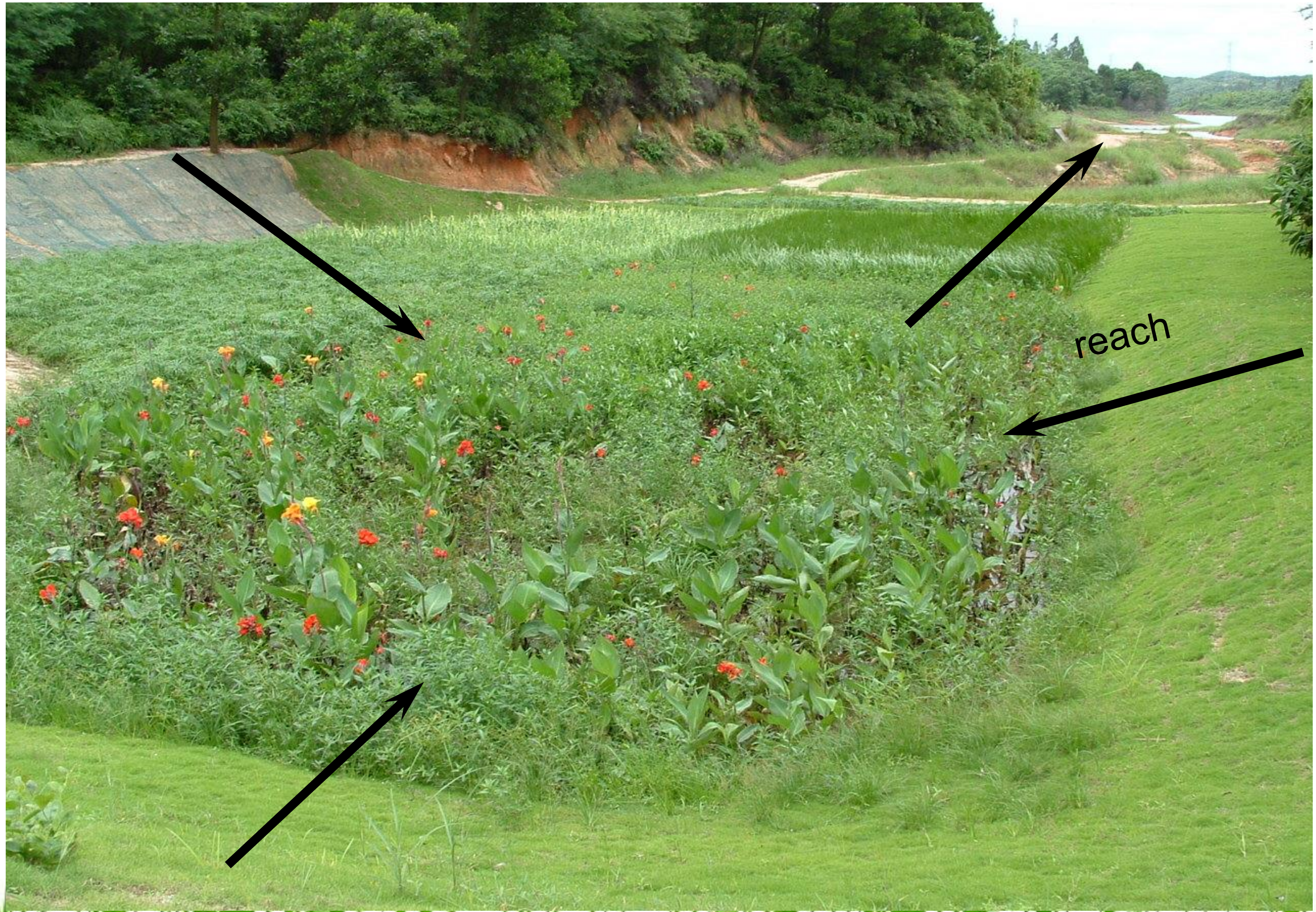


- **Linear BMP**: Areas adjacent to the stream channels that provide filtration of runoff, nutrient updates, and ancillary benefits of shading, habitat, and aesthetic value.



- **Area-based Practices**: Land-based practices that affect larger area management, land cover and pollutant Inputs (e.g., fertilizer, pet waste)

Biotention at Xikeng Reservoir, Shenzhen, China



Background: What is a model?

- A theoretical construct system to represent those geological-, hydrological-, and ecological processes in watersehds.

- Incorporating prior observations drawn from field ar

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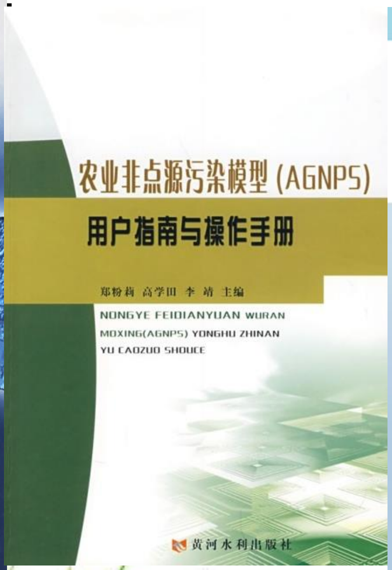
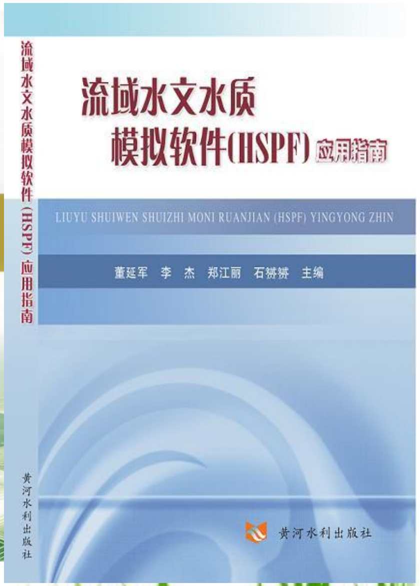
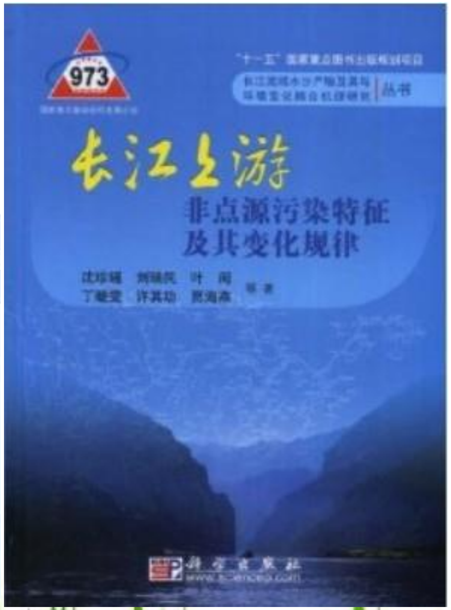
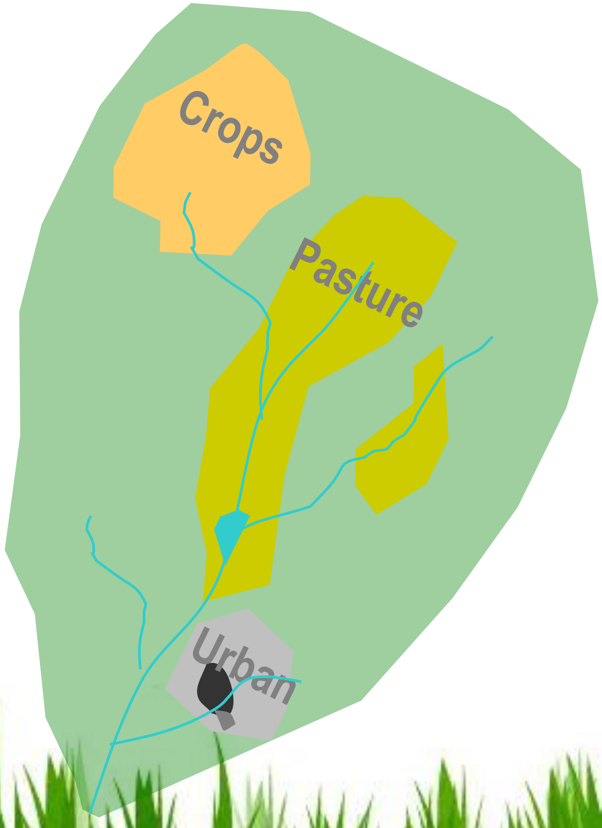






Background: Model Categories

- Landscape models
  - Runoff of water and materials on and through the land surface
- **Watershed models**
  - **Combination of landscape and receiving water models**
- **Site-scale models (BMP models)**
  - **Detailed representation of local processes**
- **Decision Support System (DSS)**
  - **Incorporation of GIS，watershed model and BMP model**



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Explicit vs. Lumped Treatment

Model Processes

● Explicit Representation
◖ Partial/Lumped
n/a Not Available

	Model Processes	GWLF	EGWLF	USLE	MUSLE	RUSLE	RUSLE2	KINEROS	SWAT	GBMM	CONCEPTS	SWMM5	HSPF/LSPC
	Timestep	daily monthly	daily	annual avg	daily	annual avg	daily monthly	event	daily	daily	subdaily	subdaily	subdaily
Land-Based	Atmospheric Deposition	◖	◖	◖	◖	◖	◖	n/a	●	●	n/a	◖	●
	Rainfall Detachment	●	●	●	◖	◖	◖	●	◖	◖	n/a	◖	●
	Scour/Gully Erosion	◖	◖	n/a	●	◖	◖	●	◖	◖	n/a	◖	●
	Data/Parameter Guidance	●	◖	●	◖	●	●	◖	●	●	n/a	◖	◖
	Particle Size Distribution	n/a	n/a	n/a	n/a	n/a	n/a	●	n/a	n/a	n/a	n/a	n/a
	Vegetation/Cover Impact	●	●	●	●	●	●	●	●	●	n/a	◖	●
	Agricultural Management	●	●	●	●	●	●	◖	●	n/a	n/a	◖	●
	Urban Management	n/a	n/a	n/a	n/a	n/a	n/a	◖	◖	n/a	n/a	●	●
Instream	Settling & Resuspension	n/a	●	n/a	n/a	n/a	n/a	●	●	●	●	◖	●
	Particle Size Distribution	n/a	●	n/a	n/a	n/a	n/a	●	n/a	n/a	●	n/a	●
	Stream Bank Erosion	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	●	n/a	n/a
	Sorption/Desorption	n/a	●	n/a	n/a	n/a	n/a	●	◖	◖	●	●	●

A summary of reported literature

Table 2 Comparison of the assessment ability of watershed models based on reported literatures

Agricultural BMPs	SWAT	AGNPS	AnnAGNPS	HSPF
Contour farming	√	√		√
Strip cropping	√	√		√
Rotation	√		√	√
Nutrient management	√	√		√
Integrated pesticide management	√			
Conservation tillage	√	√	√	
Crop residue	√			√
Pasture management	√			
Forage harvest management	√			
Poultry management	√			
Grazing management	√			
Extensive landuse management	√			
Cover crops	√		√	√
Barnyard management	√			
Turgrass sod	√			
Critical area planting	√			
Conversion of landuse	√	√	√	√
Recharge structures	√			
Terraces	√		√	√
Grade stabilization structure	√			
Grassed waterways	√			
Lined waterways	√			
Stream channel stabilization	√			
Porous gully plugs	√			
Pond	√		√	
diversion		√		
live stock access	√	√	√	√
multiple pond system		√		
Tile drains	√			
Filter strips	√	√	√	√
Filter borders	√			

Summary of Watersheds models

- **Appendix**

Table 1 Summary of watershed models with respect to BMP assessment

Models	Temporal resolution	Spatial representation	Overland flow routing	Overland sediment routing	Channel processes	**Developer**
SWAT	Continuous; daily or sub-daily time steps.	Sub-basins or further hydrologic response units defined by soil and land use/land cover.	CN method for infiltration and peak flow rate by modified Rational formula.	MUSLE characterized by runoff volume, peak flow rate, and USLE factors.	Channel degradation and sediment deposition with CH_EROD, CH_COV, CH_N2 and channel geometry to represent BMPs.	USDA
AGNPS	Storm-event; one storm duration as a time step.	Cells of equal size with channels included.	CN method for infiltration, and flow peak using a similar method with SWAT.	USLE for soil erosion and sediment routing through cells with *n*, USLE factors to be concerned with.	Included in overland cells.	USDA
AnnAGNPS	Continuous; daily or sub-daily steps.	Cells with homogeneous soil and land use.	CN method for infiltration and SCS TR-55 method for peak flow.	RUSLE to generate soil erosion daily or user-defined runoff event.	Channel degradation and sediment deposition with Modified Einstein equation and Bagnold equation.	USDA
HSPF	Continuous; variable constant steps (from 1 minute up to 1 day)	Pervious and impervious land areas, stream.	Philip's equation for infiltration.	Rainfall splash and wash off of detached sediment calculated by an experimental non-liner equation	Non-cohesive and cohesive sediment transport.	USGS; USEPA

How SWAT represent various BMPs

- **WDM: Watershed Data Management Files (Time Series Store, TSS Files)**

Table 3 Key parameters adjusted to represent various BMPs in SWAT model

Agricultural BMPs	CH_D2	CH_W2	CH_EROD	CH_COV	CH_N2	CH_N1	CH_S2	CH_K1	FILTERW	SLSUBBSN	*n*	CN2	USLE_C	USLE_P
Contouring farming												√		√
Filter strips									√					
Filter borders									√					
Grade stabilization structures			√				√							
Grassed waterways	√	√		√	√									
Lined waterways	√	√	√		√									
Parallel terraces										√		√		√
Residue management											√	√	√	
Stream channel stabilization	√	√	√		√									
Strip cropping											√	√	√	√
Porous gully plugs						√								
Recharge structures								√						

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Two typical BMP models

Table 2 Summary of BMP models and their characteristics

Model	Modules	Processes/ Mechanisms	Water Quality Constituents	Developer
REMM	Hydrology Sediment Nutrient Vegetative growth.	Infiltration Evaportransporation Surface and subsurface flow routing Nutrients cycling (C, N, P) Sediment transport.	Sediment Nutrients (C, N, P)	USDA
VFSMOD	Hydrology Sediment transport Pesticide removal.	Infiltration Overland flow routing Sediment transport Pesticide trapping.	Sediment Pesticide	NCSU Biological & Agricultural Engineering

BMP models: Point BMPs

BMPs	Present Approach	Optional Future Approaches
Bioretention	•Holtan-Lopez equation •Constant evapotranspiration (ET) rate •Stage-outflow storage routing using weir and/or orifice equations •Completely mixed pollutant routing •1st order decay •Under drain percent reduction (user defined)	•Green-Ampt infiltration •Calculate potential ET and actual ET •Continuously stirred tank reactor (CSTR) in series pollutant routing •Plug flow pollutant routing •Kadlec and Knight's (1996) 1st order kinetic method •Sedimentation •Physically based substrate filtration and sorption
Detention pond	•Holtan-Lopez equation •Constant ET rate •Stage-outflow storage routing using weir and/or orifice equations •Completely mixed pollutant routing •1st order decay	•Green-Ampt infiltration •Calculate potential ET and actual ET •CSTR in series pollutant routing •Plug flow pollutant routing •Kadlec and Knight's 1st order kinetic method •Sedimentation

BMP models: Point BMPs

BMPs	Present Approach	Optional Future Approaches
Wetland	•Holtan-Lopez equation •Constant ET rate •Stage-outflow storage routing using weir and/or orifice equations •Completely mixed pollutant routing •1st order decay	•Green-Ampt infiltration •Calculate potential ET and actual ET •Pollutant routing CSTR in series or plug flow •Kadlec and Knight's (1996) 1st order kinetic method •Sedimentation
Infiltration trench	•Holtan-Lopez equation •Constant ET rate •Stage-outflow storage routing using weir and/or orifice equations •Completely mixed pollutant routing •1st order decay	•Green-Ampt infiltration •Calculate potential ET and actual ET •Pollutant routing CSTR in series or plug flow •Kadlec and Knight's (1996) 1st order kinetic method •Sedimentation •Physically based substrate filtration and sorption

BMP models: Linear BMPs

BMPs	Present Approach	Optional Future Approaches
Linear BMPs: *Areas adjacent to the stream channels that provide filtration of runoff, nutrient uptates, and ancillary benefits of shading, habitat, and aesthetic value*		
Buffer Strip/Riparian Buffer	•Pollutant trap efficiency as a function of strip width (flow length)	•Nonlinear reservoir overland flow routing •Kinematic wave overland flow routing •Process-based sediment interception simulation method •Process-based nutrient/pollutant removal simulation method

BMP models: Area-based BMPs

BMPs	Present Approach	Optional Future Approaches
***Area BMPs**: Land-based practices that affect impervious area management, land cover, and pollutant inputs (e.g., fertilizer, pet waste)*		
Street Sweeping	•Street sweeping pollutant removal effectiveness (SWMM)	•Additional controls on type and frequency of sweeping
Impervious area reduction	•Pervious/impervious areas (SWMM)	•Impervious area to pervious area land routing
Land management	•Pollutant build-up/wash-off rates (SWMM) •Infiltration rate (SWMM)	•Update to Universal Soil Loss Equation (USLE), adjustment of parameters •Process-based simulation of soil profile and associated pollutant removal mechanism •Database approach for estimating pollutant reduction

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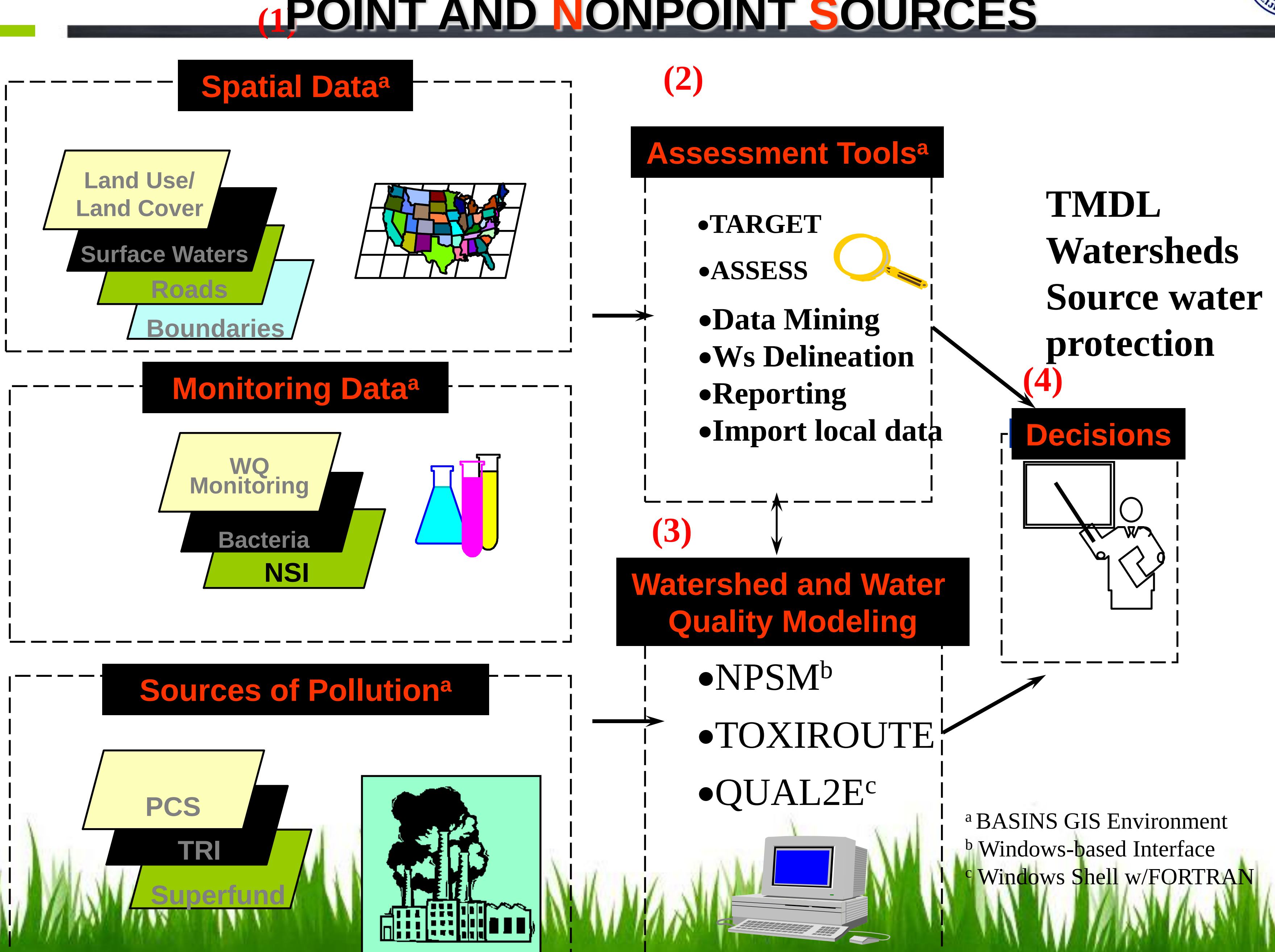
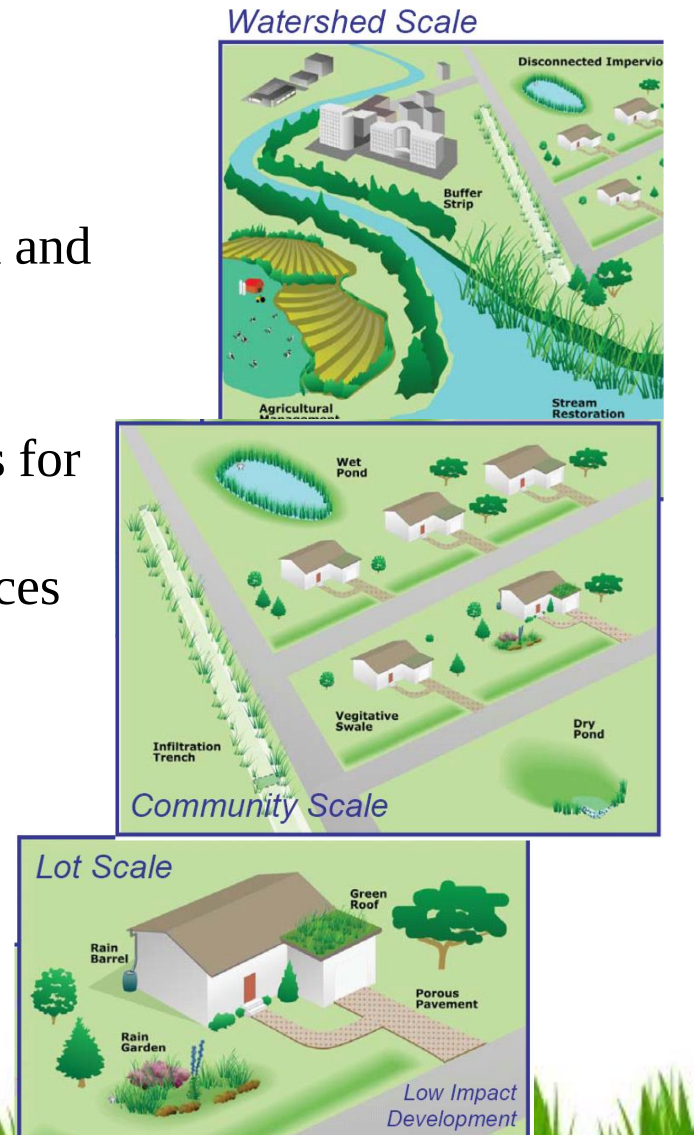
BETTER ASSESSMENT SCIENCE INTEGRATING POINT AND NONPOINT SOURCES

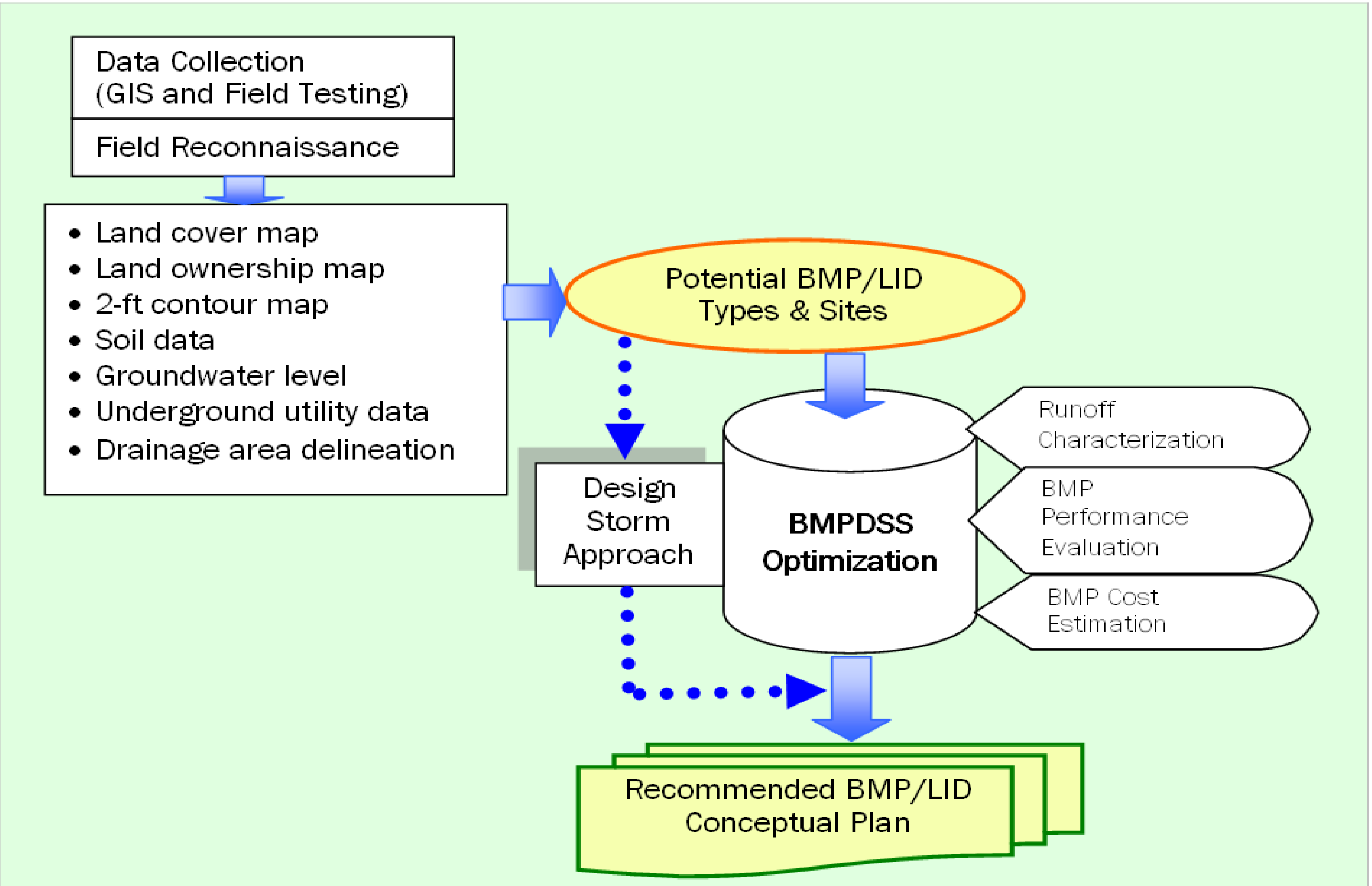


BETTER ASSESSMENT SCIENCE INTEGRATING POINT AND NONPOINT SOURCES

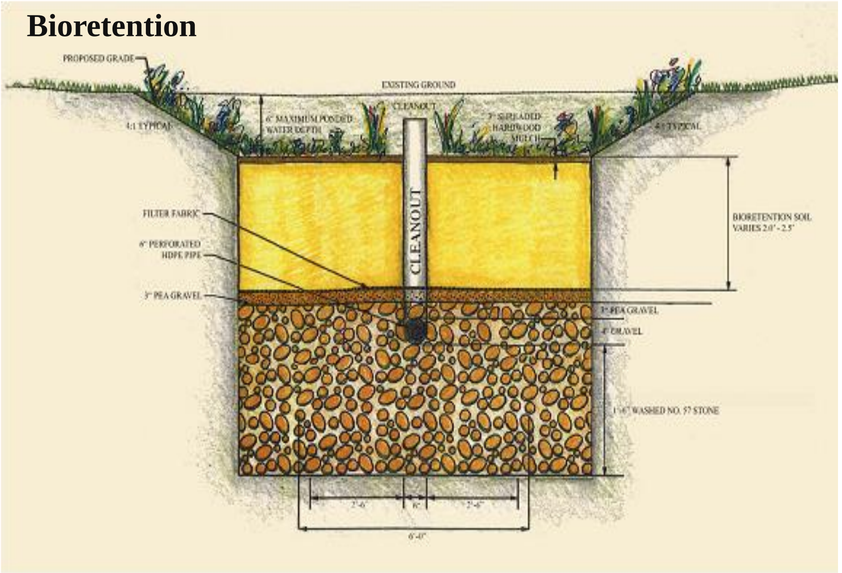
- BMP design
  - Properly size and configure practices
  - Evaluate effectiveness of BMP after design and construction
- Site development
  - Evaluate effectiveness of multiple practices for hydrology and water quality
  - Optimize selection and placement of practices
- Watershed management
  - Analyze watershed-wide implementation
    - Program evaluation
    - CSO reduction
    - TMDL compliance

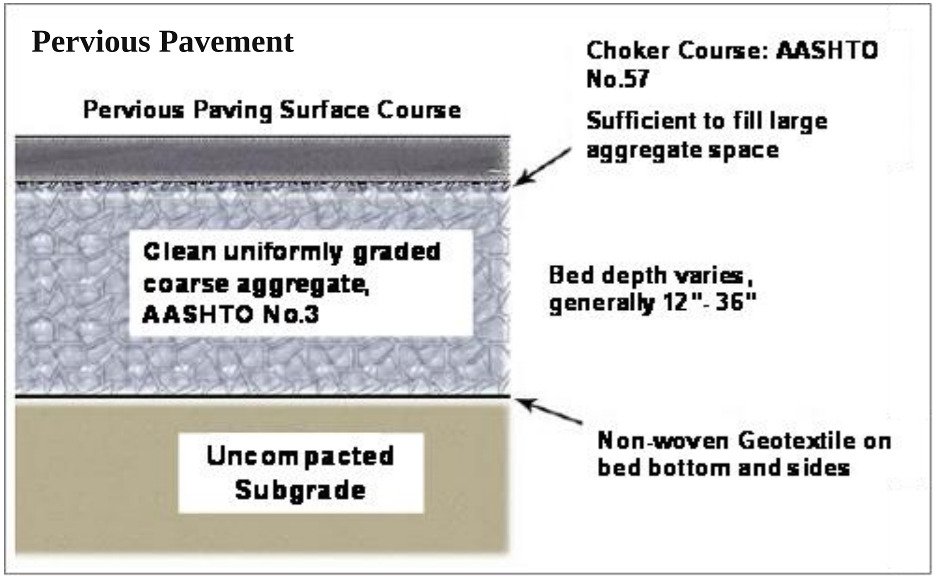


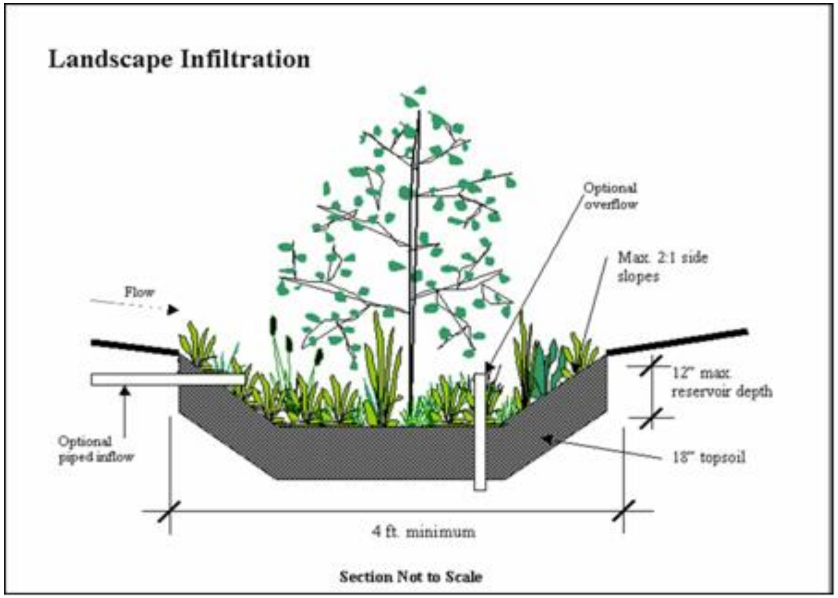
BMP-Decision Support System (BMP-DSS)

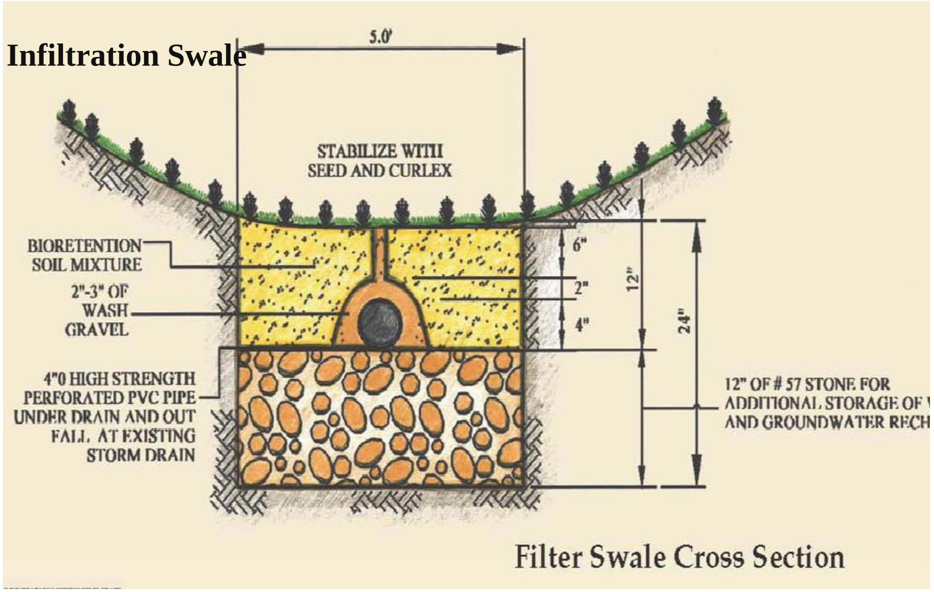


Selected BMP Types

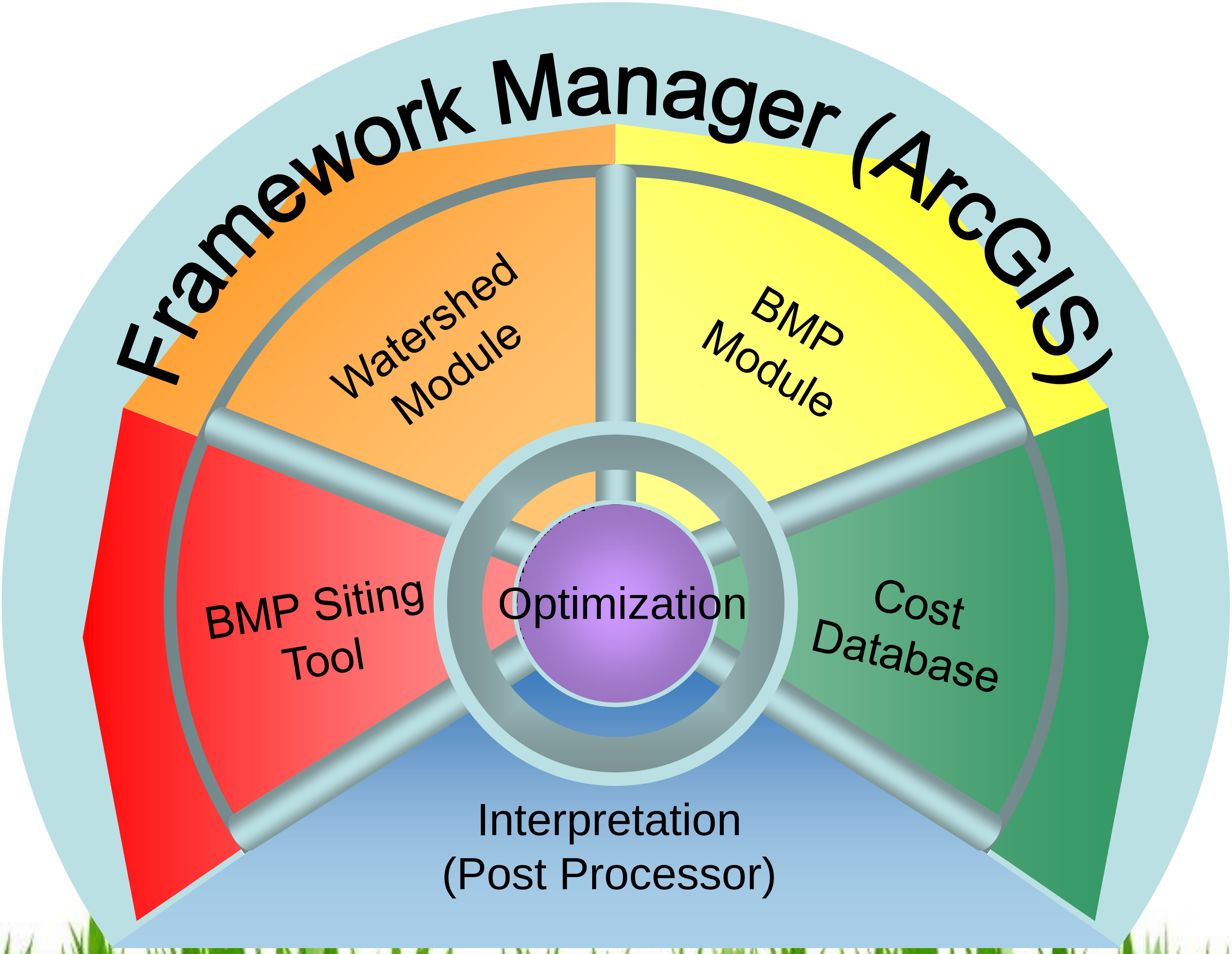




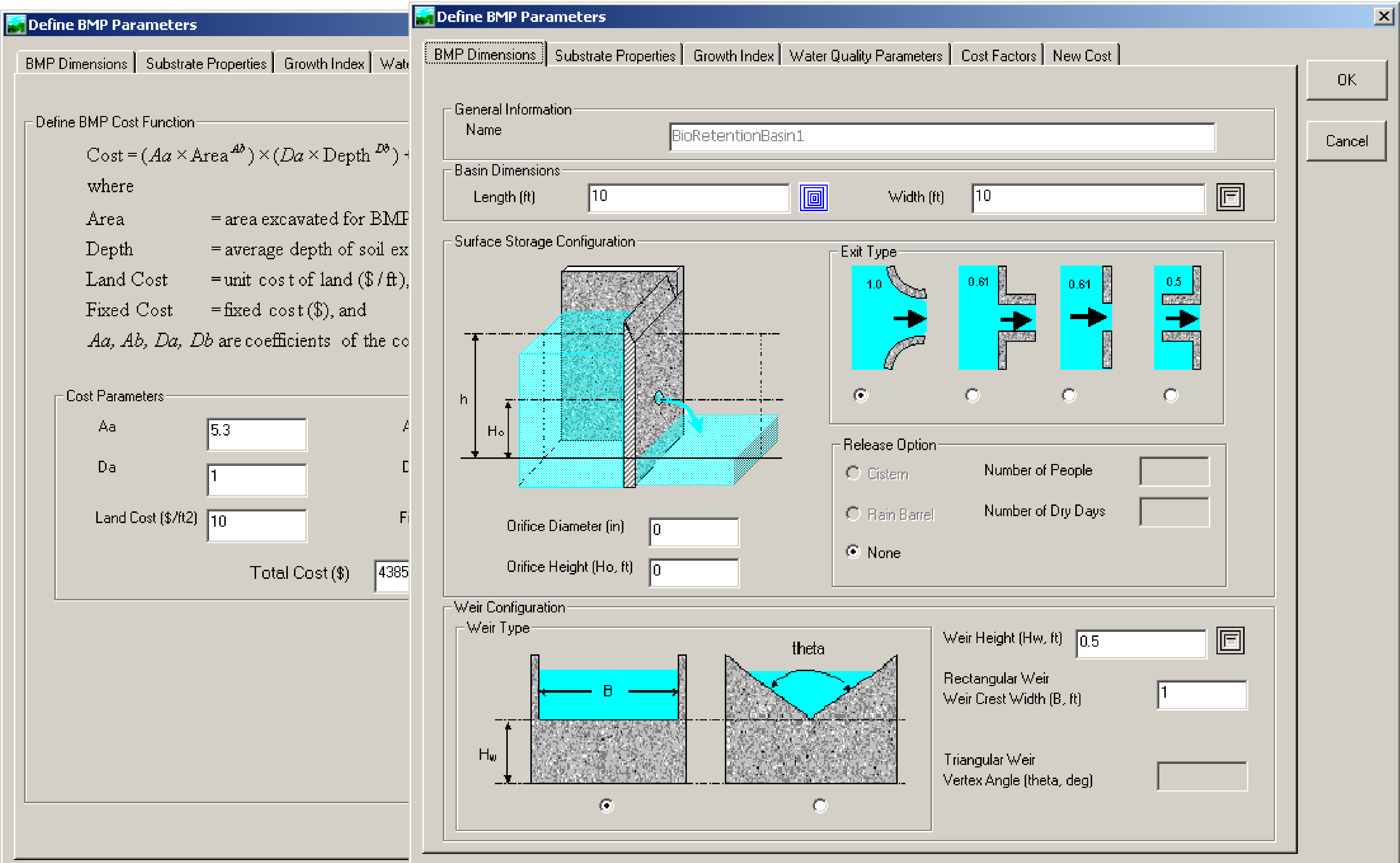




SUSTAIN Components



Define BMP Details by SUSTAIN



Optimal Design Solutions

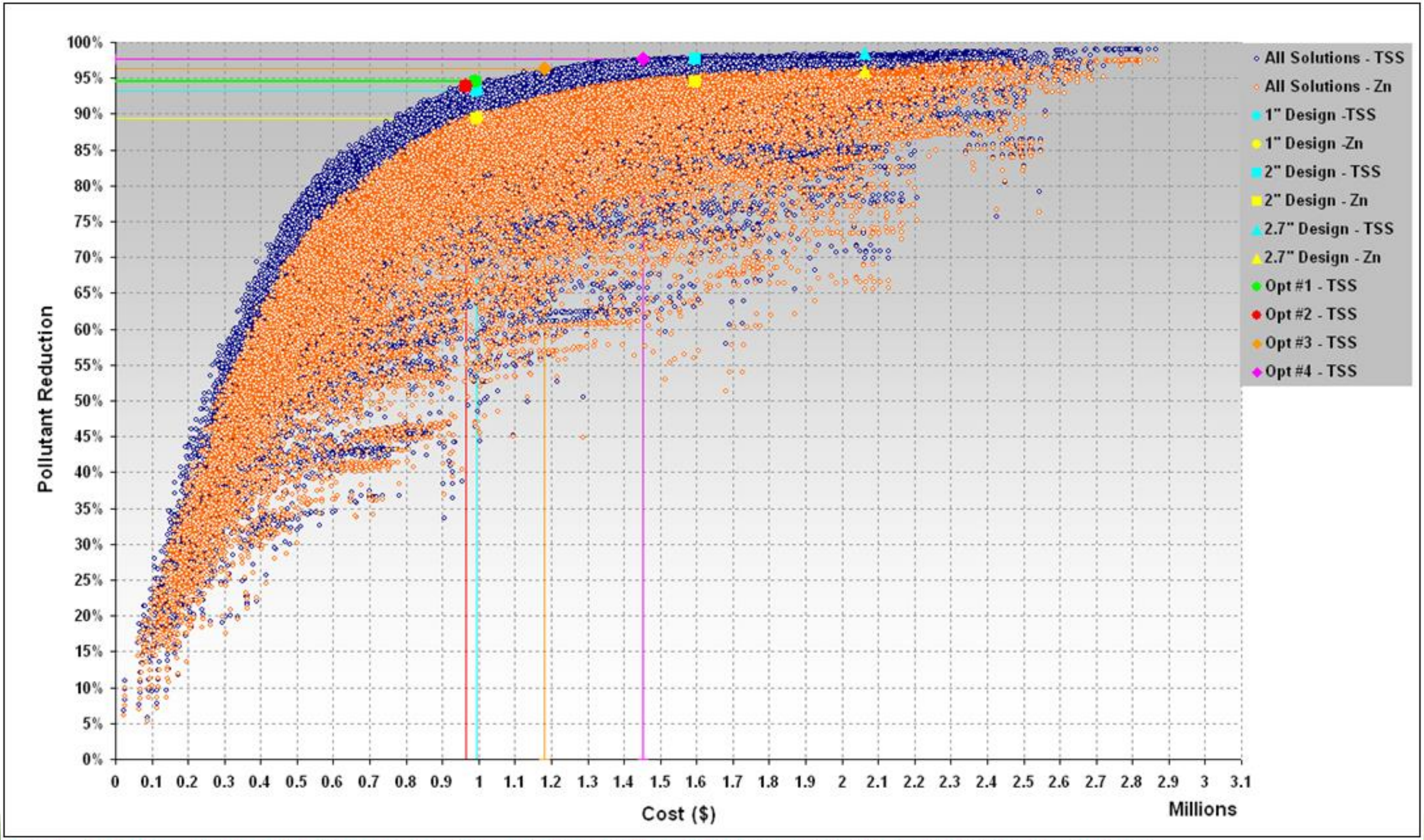


Figure 17. Comparison of BMP optimal and design solutions, and pollutant reduction vs. cost trade-off curve.

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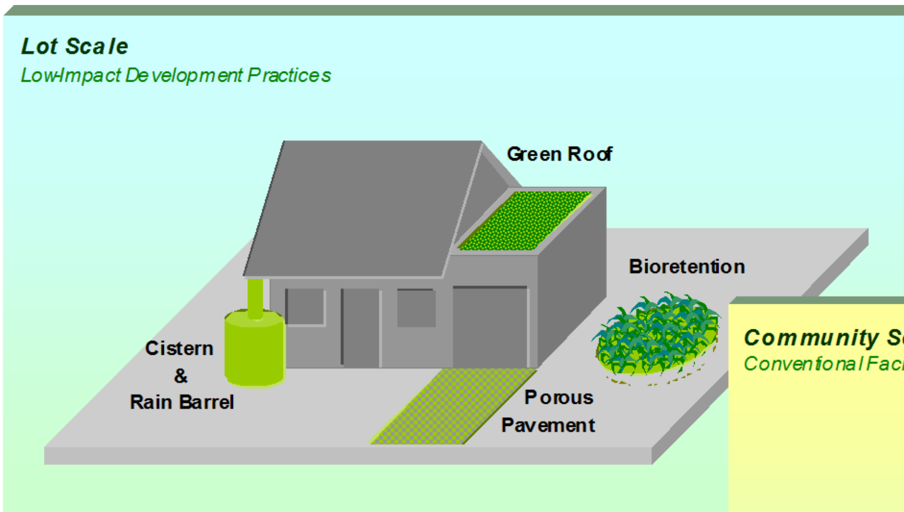
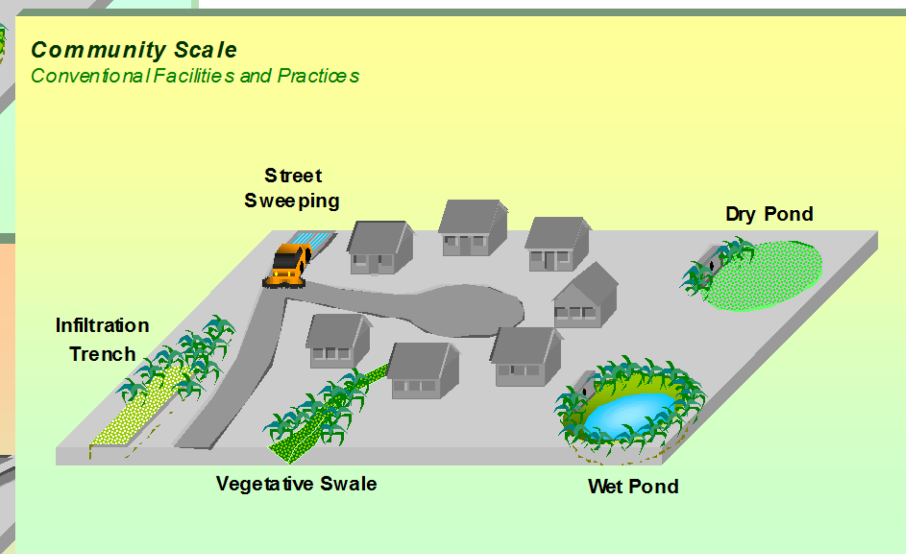
Future Enhancement - I

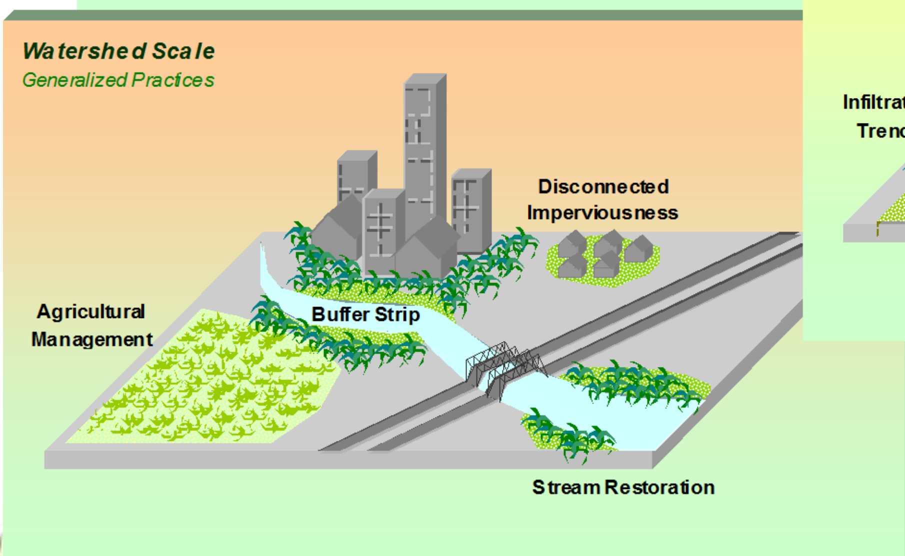
- ***Structured to allow users to select BMP types at various spatial scales***



Lot

Sub-watershed





Watershed

Future Enhancement - II

More Capabilities

- **Add BMP simulation techniques for emerging technologies/recent research;**
- **Add optimization alternatives;**
- **Provide the ability for users to add their own bmp formulations as a discrete module (requires developing a generic interface and data exchange tool);**

Future Enhancement - III

More Ground-Truth and Testing

- **Additional applications in diverse urban settings (could be co-sponsored by other groups);**

- **Evaluate performance using recent BMP specific monitoring studies.**

Thank you！

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