A Modeling Framework for Linking Urban Stormwater Load Allocation, Implementation Plan, and BMP Design

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Outline

- Background
- Modeling for non-point source management
- Modeling framework for City of Calgary
- Preliminary results

Background: City of Calgary

- Regulatory environment
  - City is required to develop total loading objective assessment to support City's permit application/renewal (not necessary impaired)
  - Province provide a guideline and City develop the water quality criteria
  - City submit the loadings to the Province for approval
- Close relationship between regulator and the City
  - Province fully informed with the technical approach from model selection to model calibration and application

Non-point Source management: TMDL Modeling

- TMDL projects funded by EPA and states
- Following the boundaries of natural watershed – HSPF, SWAT models
- Allocation to sub-watershed, HRU, or MS4 levels
- Disconnected with urban development planning

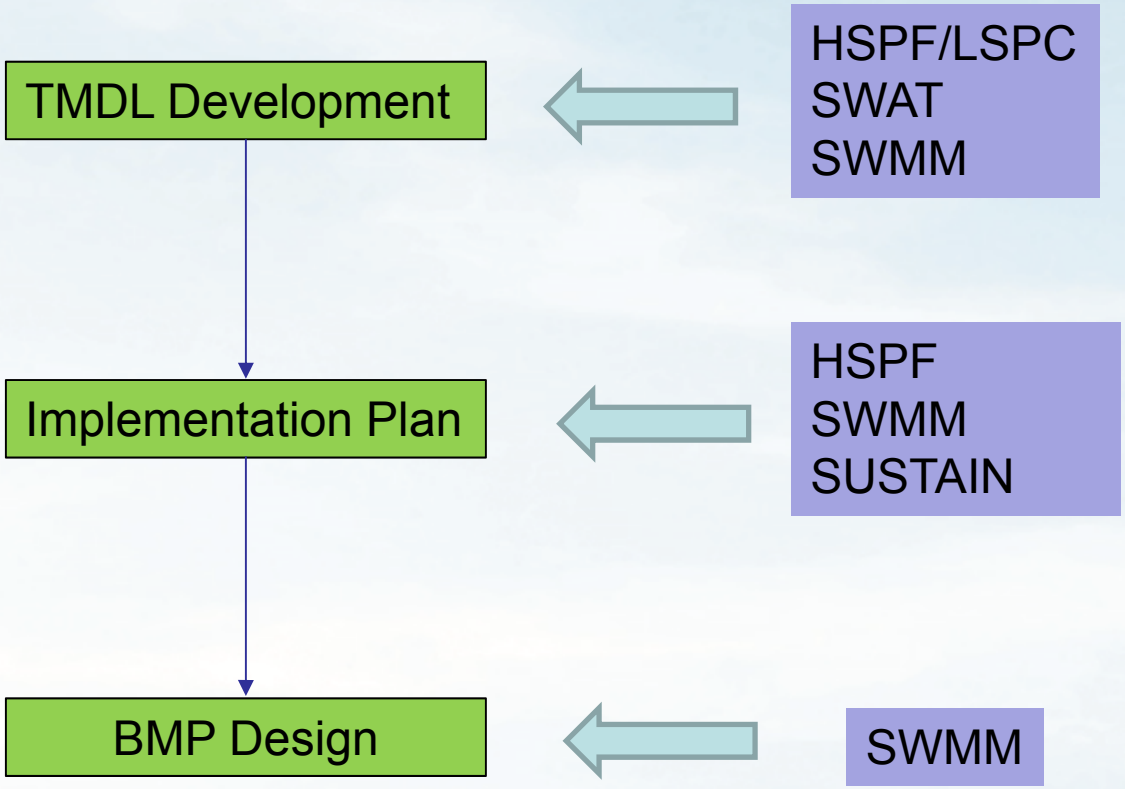
Non-point Source management : Modeling for Supporting Implementation Plan Development

- Need to know contributions from different HRUs
  - From models for TMDL development
- Need to be able to evaluate performances of BMPs
- Cost-effective implementation plan needs optimization to identify the lowest cost to achieve the control targets

Non-point Source management : Modeling for Supporting BMP Design

- Much smaller scale than modeling for TMDL development
- SWMM is widely used
- Event based design rainfall, or continuous simulation

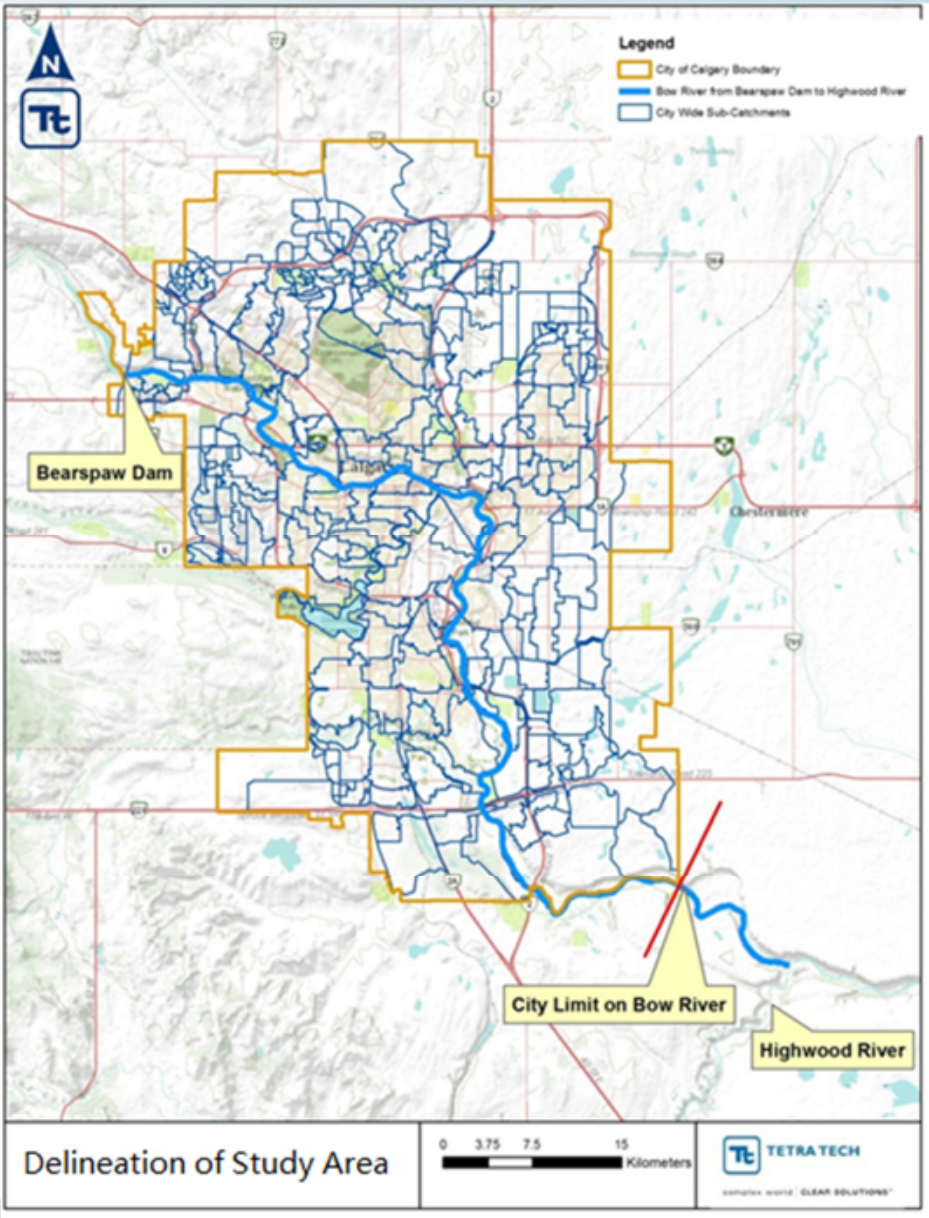
Communications of the Three Stages



Potential Problems

- Different models may be used for different stages
  - Difficult to communicate among models
  - Wasting time & resources
  - High technical requirement for understanding multiple models
- Options for model selection
  - Select most suitable model for each specific stage
  - Or select models considering the three stages together

City of Calgary



- Background
  - 836 km^2
  - Bow River runs through
  - 80% pervious area
  - Strong spatial variability of rainfall
  - Approximately 300 stormwater ponds

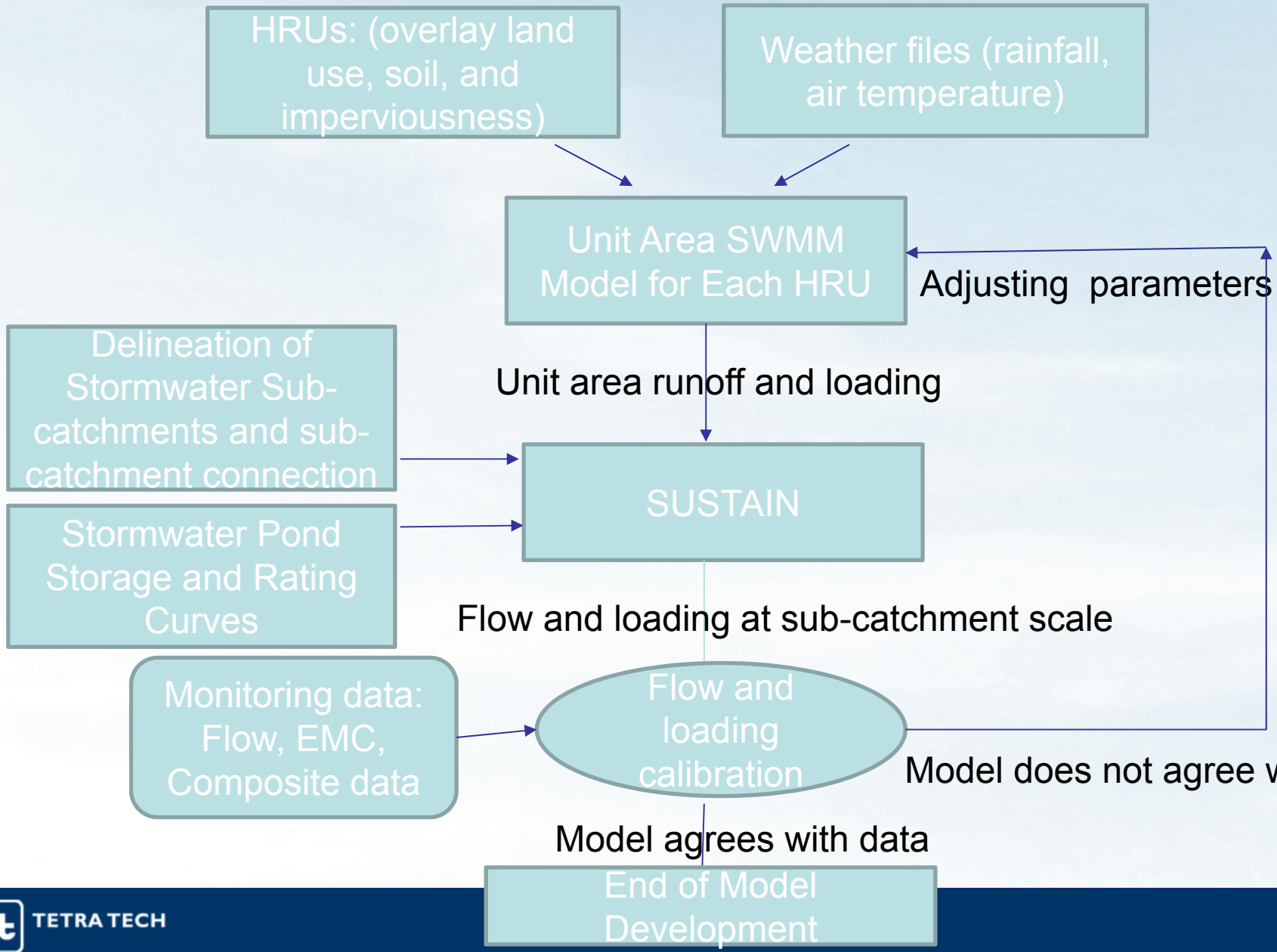
Model Selection – City of Calgary

- Considerations
  - Goal is to develop loading targets for specific land surface to meet total loading objectives allocated for stormwater
  - City has already developed multiple SWMM models for drainage planning and BMP design
  - City technical staff are familiar with SWMM
  - City has developed future urban development plan
  - Need to know runoff and pollutant loadings from unit area of HRUs
  - Need to consider all the stormwater ponds

Model Selection (continue)

- Model comparison: HSPF vs. SWMM
  - HSPF based on HRU, no pipe simulation function, one representative channel per sub-catchment
  - SWMM not based on HRU, land use component for quality disconnected with pervious/impervious land, good pipe simulation function
- Select SWMM
  - HRU is the key component
  - SWMM is configured at unit HRU level, not at sub-catchment level
  - SUSTAIN summarize unit HRU runoff and loading, and route through BMPs

SWMM-SUSTAIN Model Framework



Advantages of the Framework

- Able to calculate runoff and loadings from unit area of HRUs using SWMM
- Able to handle multiple stormwater ponds within one sub-catchment
- Calibration results by using unit HRUs can be used for parameterization of SWMM models for BMP design
- The time series results of runoff and loadings of unit area of HRUs can be used to quickly estimate total runoff and loadings from any drainage area without re-running a model
- Ready for incorporating cost functions for optimization

Representations of Pollutant Yield, Fate, and Transport Processes

- Generic framework
  - bacteria, metals, toxicants, nutrients, sediment
- Land surface: build-up and wash-off in SWMM
- BMP processes: fate and transport in SUSTAIN
  - Sediment associated pollutants: adsorption, settling
  - Dissolved pollutants: first order decay
  - Bacteria: first order die-off

An Example of Non-point Source Processes

Fecal Coliform

Build-up on land (SWMM)

Build-up on land if not picked up

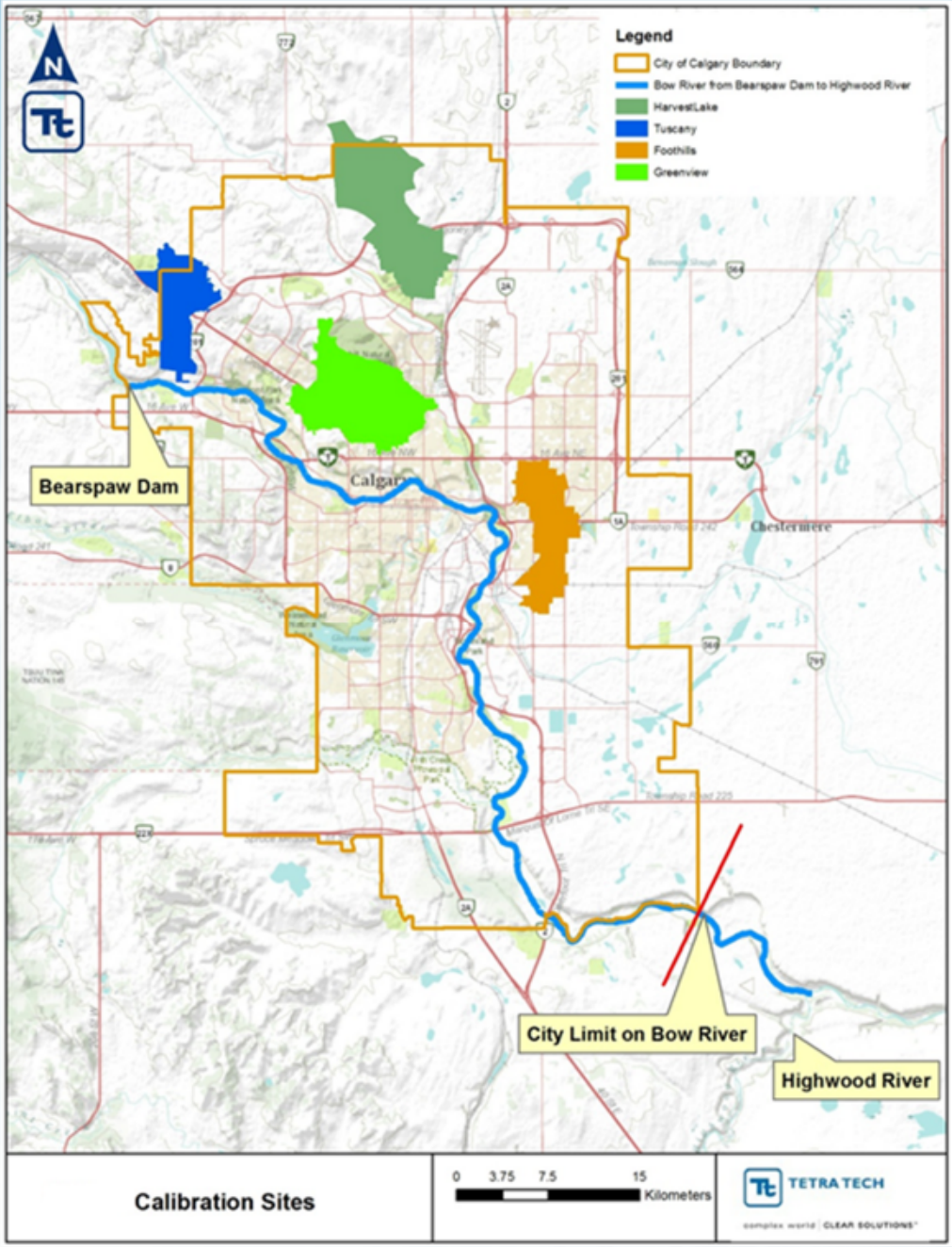
Wash-off (SWMM)

Fate and Transport in wet pond (SUSTAIN)

Discharge to river

An Example of SWMM-SUSTAIN

- Selected Harvest Lake
- Six stormwater ponds
- Total area 28.75 KM^2
- 20 HRUs (10 pervious, 10 impervious)



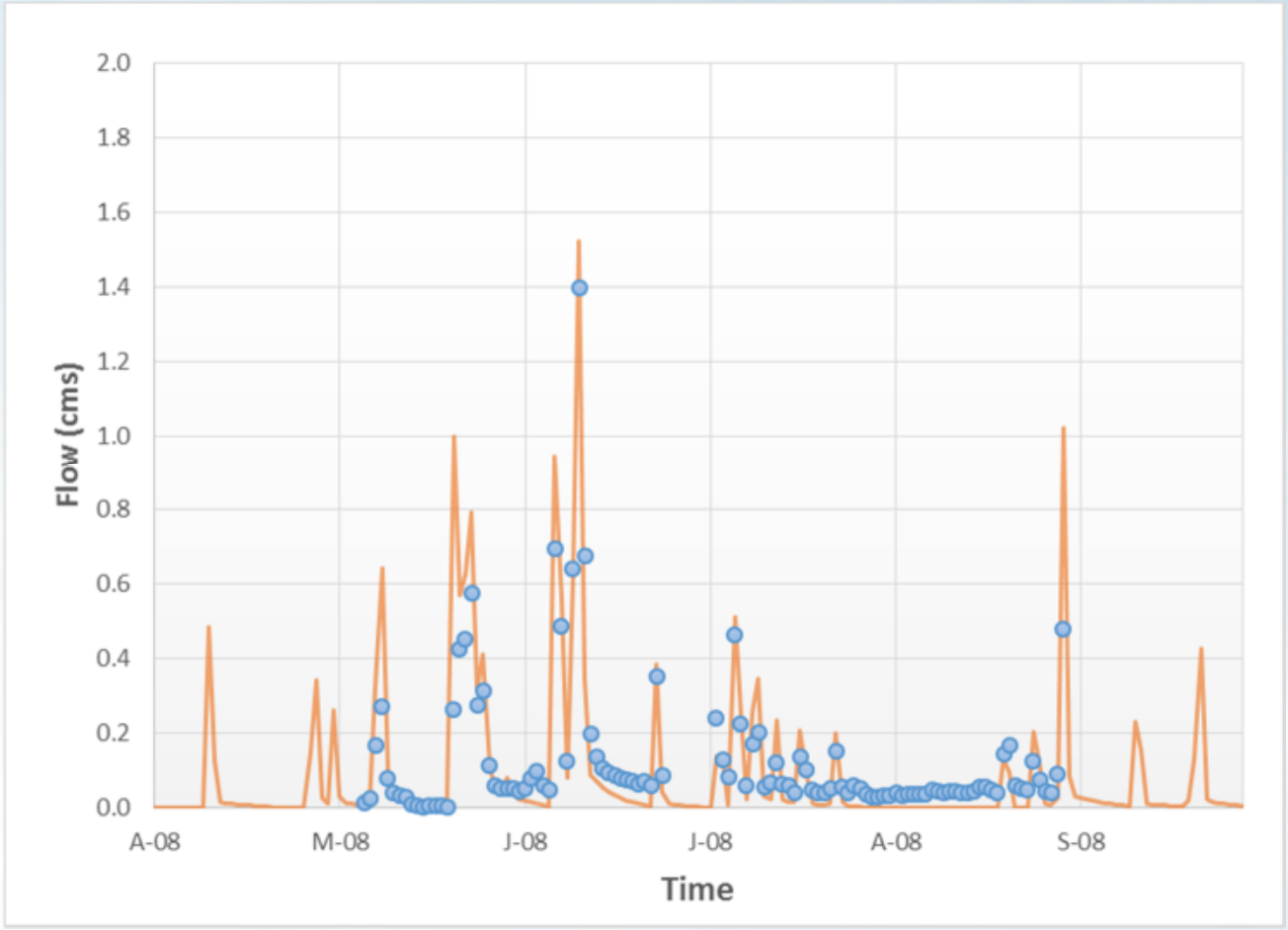
SWMM Model Configuration

- 20 hypothetical sub-catchments for 20 HRUs
  - 1 hectare for each HRU
  - Land uses for quality matches with HRUs
- 0% imperviousness for pervious HRUs
- 100% imperviousness for impervious HRUs
- Stormwater ponds are not included
- Model results output to time series

SUSTAIN Model Configuration

- Read in SWMM results: time series of flow from 20 HRUs
- Specify stormwater pond drainage areas and areas of HRUs
- Specify F-Tables (depth-area-volume-out flow) for stormwater pond routing
- Specify connections of ponds
- Optimization not activated
- SUSTAIN summarizes runoff and simulate the routing through stormwater ponds

Model Results

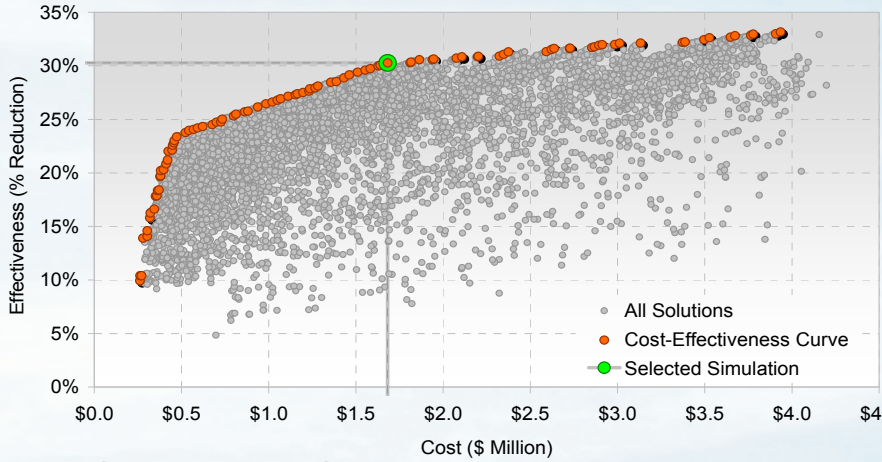


SUSTAIN output

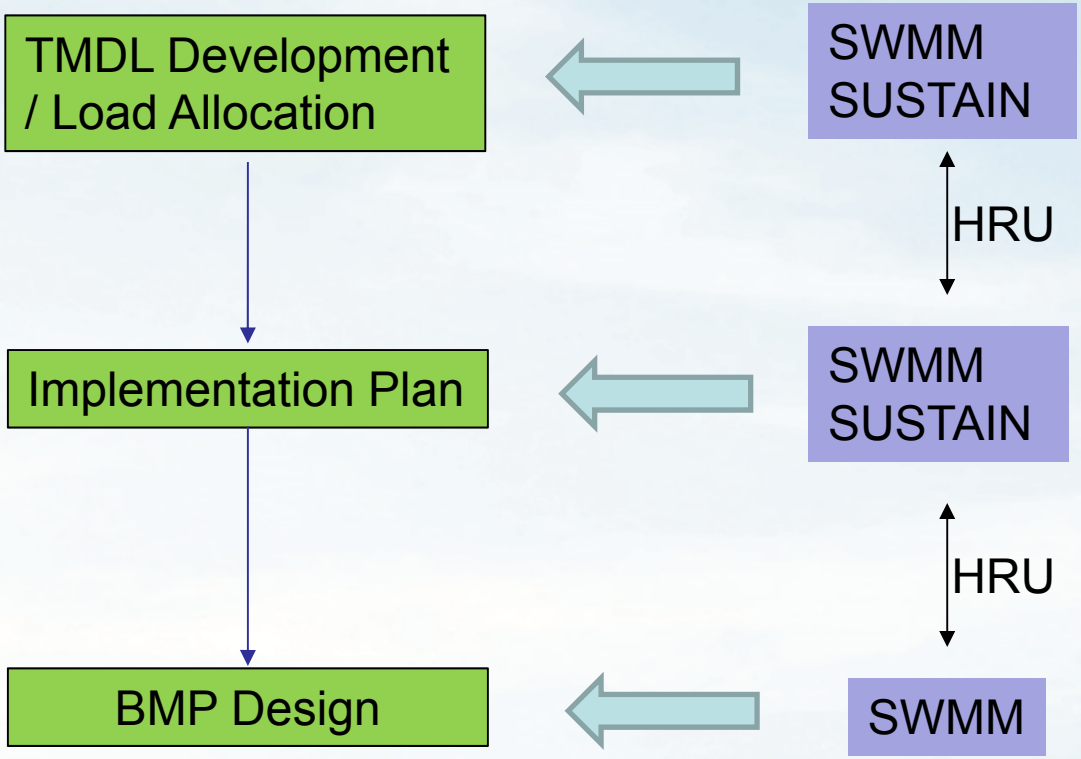
Observed flow at outfall

Support for Implementation Plan Development

- The modeling framework is ready for supporting implementation plan development
- Scenario based simulation
  - Adjust current BMP sizes in SUSTAIN
  - Adding new BMPs in SUSTAIN
  - No need to re-run SWMM
- Optimization based simulation
  - Need cost functions
  - No need to re-run SWMM
  - Provide one cost-effective solution for specified control target
  - Or provide Pareto Front Curve for a set of solutions



Communications of the Three Stages



Summary and Conclusions

- Modeling needs for load allocation, implementation plan, and BMP design were discussed
- A linked SWMM-SUSTAIN model framework is recommended
- The framework is generic and can be applied for various pollutants
- Results of the framework can support load allocation, and implementation plan development and can provide parameters for BMP design
- BMP design can be incorporated back to SWMM-SUSTAIN to evaluate the effectiveness of BMPs

Questions??

Thank you!