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Equitable Responsibility for Transformative Design: A Watershed-scale Model for Stormwater Management and Risk Mitigation

TRIECA

March 20th, 2019

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Lake Simcoe Region conservation authority

PARADIGM ENVIRONMENTAL

Newmarket

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York Region

AURORA

Town of East Gwillimbury

Ontario

Sustainable Technologies EVALUATION PROGRAM

Toronto and Region Conservation for The Living City

CVC Credit Valley Conservation

Overview

- **Introduction:** Ben
  - Why study needed, objectives and background

- **Methods:** Dustin
  - Modeling approach, life-cycle cost, preliminary results

- **Municipal perspective:** Rachel
  - Why municipalities should care, operational benefits, wrap up

Initial research question

What is the root cause of the growing SWM infrastructure deficit, its attendant challenges and limited, ad hoc use of Green Infrastructure (GI)?

Research findings

- Municipal boundary, public land based stormwater planning & management
- Capital project, end-of-pipe focused – SWM ponds
- Primarily ad hoc approach to Green Infrastructure / Low Impact Development
- After-the-fact mitigation a significant driver of stormwater planning
- Full cost accounting rare
- **Lack of integrated, system level economic & optimization analysis.**

What's needed?

A PARADIGM SHIFT IN SWM

1. Watershed-based – the natural hydrologic unit
    - Equitable responsibility: individual to shared municipal approach.
2. Integrated optimization and economic analyses.
    - Apply scale, aggregation and integration to realize economies.

Study objectives

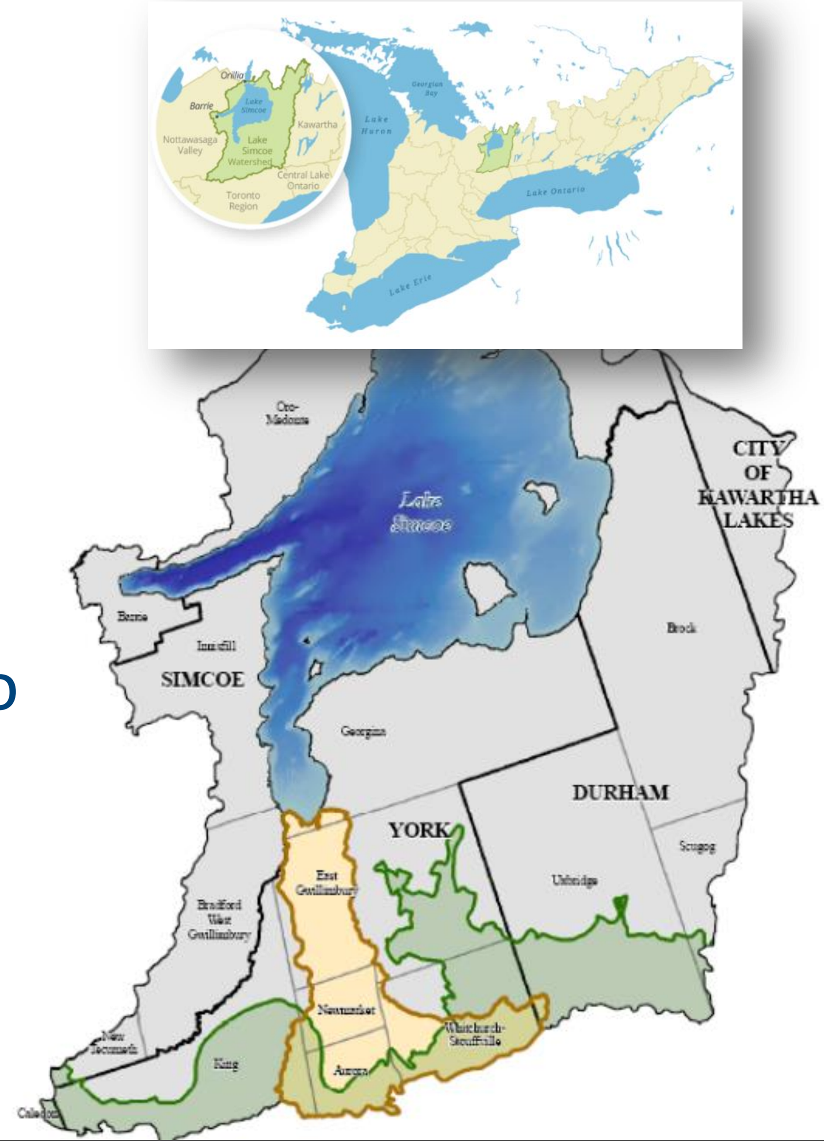
- Use processed-based decision modelling to evaluate the potential of an integrated, systems-based approach to SWM infrastructure.

- Determine the operational implications (e.g., policy, programming, finance, etc.) of an integrated or systems-based approach to municipal SWM.

- Develop the tools (methodology and enhanced open-domain model) and guidance for future SWM applications.

Study Area – East Holland River

- Peri-urban
- Growth and intensification
- Five municipalities
- Municipal Boundary ≠ Watershed Boundary
- Goldilocks - not too big, not too small!



Project stages

Stage 1
(2018)

- Secure funds, projects team and advisory committee
- Model data compilation and initiate build
- Initiate life cycle costing

Stage 2
(2019)

- Complete model build and life cycle costing
- Optimization modeling & scenarios → preferred management strategies

Stage 3
(2020)

- Reporting, outreach and engagement
- Policy implications and implementation plan

Modelling System Overview

Dustin Bambic, PH

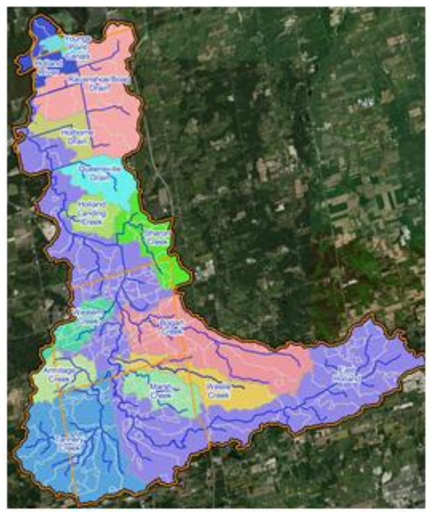
Modelling System for East Holland Subwatershed Study

LSPC
Current State

Input
- Climate / Rain
- Land Use / Soils
- Slope / Imperviousness
- Impoundments
- Point sources / takes
- And much more

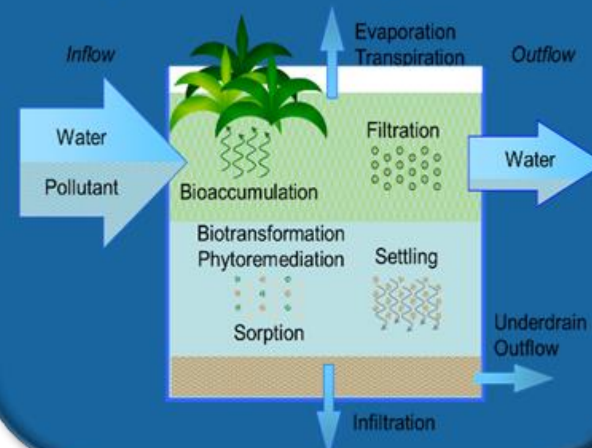
Output
- Continuous simulation time series of flow & contaminants for each land use, subwatershed and waterbody

East Holland



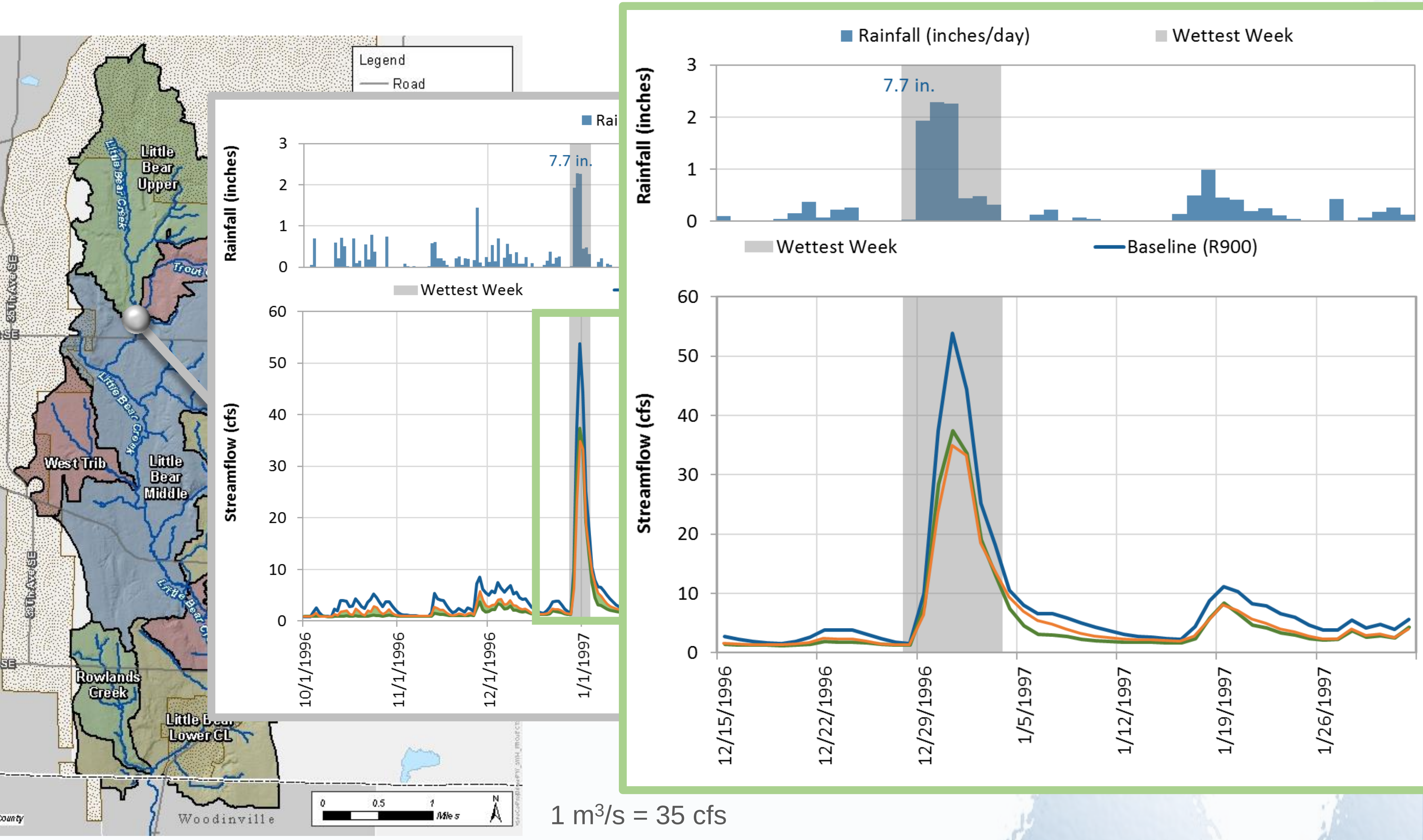
SUSTAIN
Future State

- Time series after implementation of optimized action plan



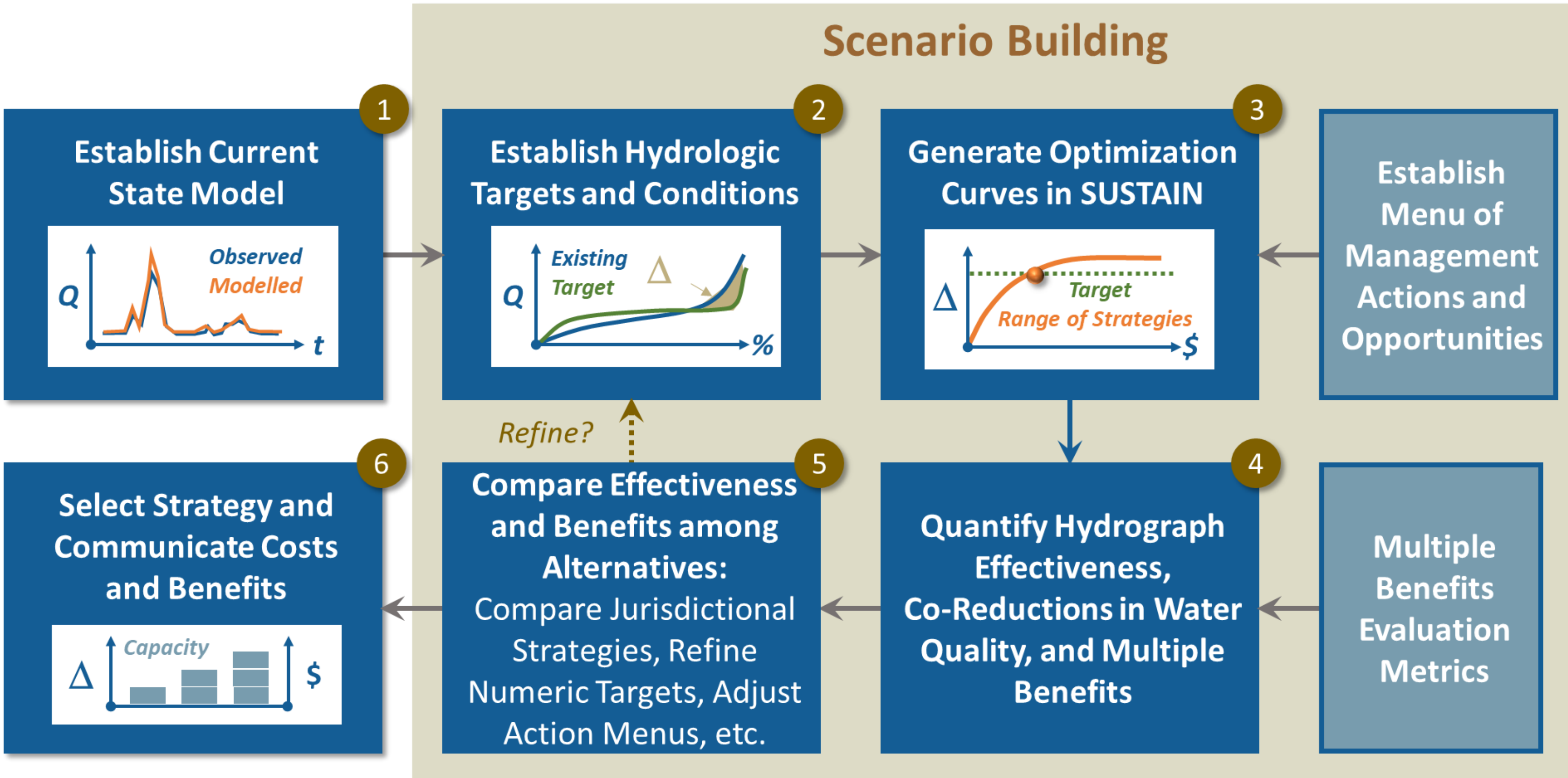
- **Process-based**
- **USEPA-developed**
- **Peer-reviewed**
- **Open source**
- **Unlimited scale**
- **Applied internationally**

Example Modelling System Output: Hydrograph Remediation

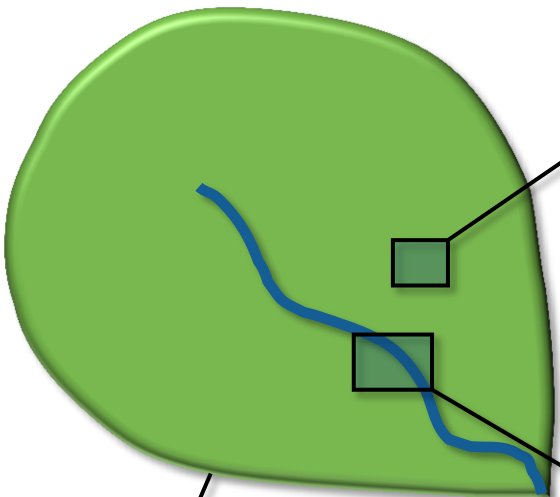


1 m³/s = 35 cfs

Modelling Process



Current State Model:
Key Model Building Blocks



Hydrologic Response Units:

- Response of land to climate
- Primary hydrological and chemical parameters

Model Stream Segments:

- Define channel geometry for routing
- Instream and bank erosion processes

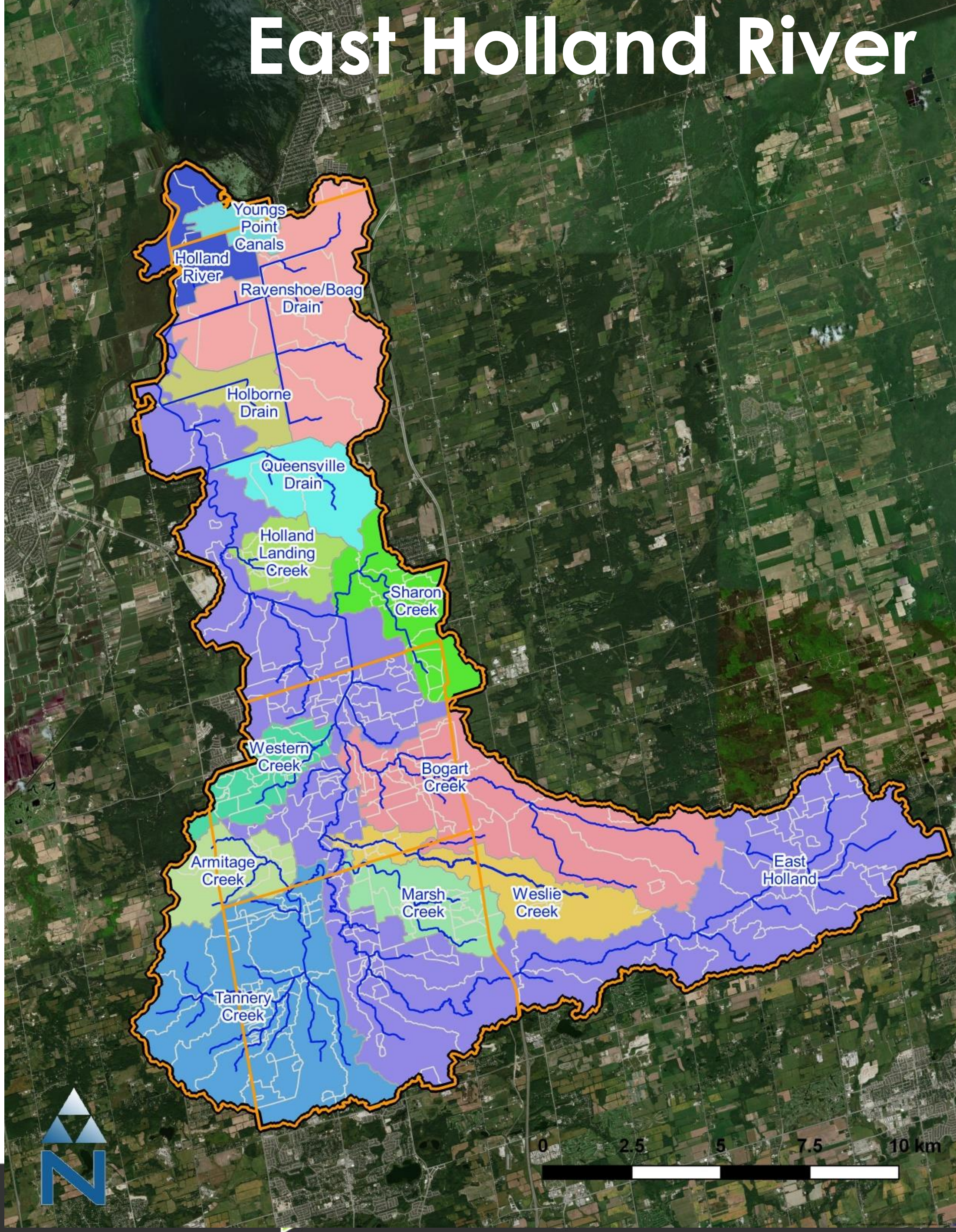
Subcatchments:

- Planning Units
- Define Watershed Routing

Current State: Subcatchments

- 315 model subcatchments
- 14 distinct receiving waters
- About 16% area is controlled by ponds

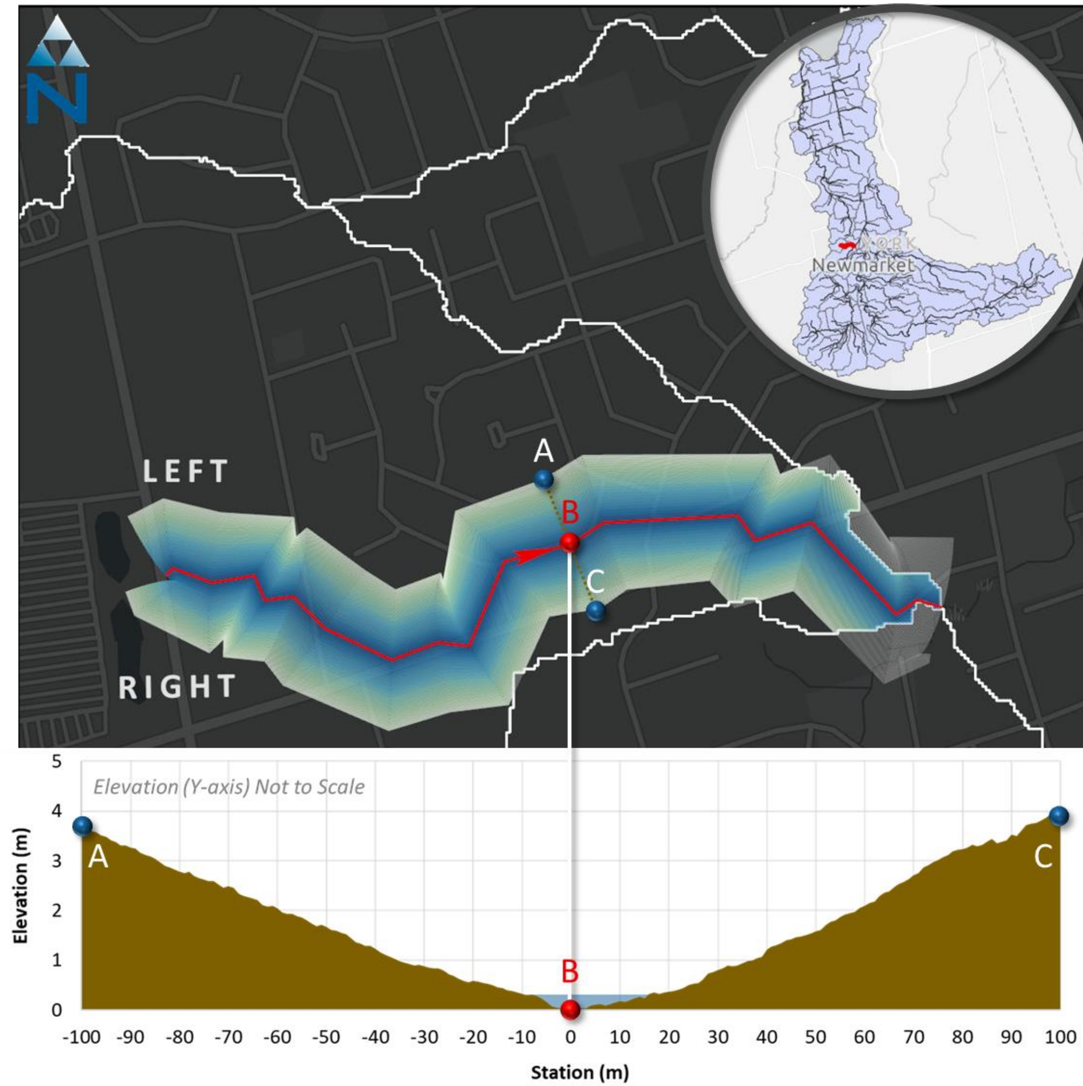
Subcatchment Type	Count	Area (sq. km.)
Ponded	188	37.8
Unponded	127	201.1
Total	**315**	**238.9**



Current State: Model Stream Segments

- Advanced GIS processing to leverage DEM to calculate elevations along stream centerlines

- Detailed cross sections will improve modelled velocities (sediment) and waters surface elevations (flooding)

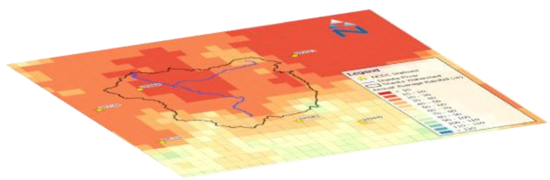


Current State: Hydrologic Response Units

Subcatchment Scale

Routing Network

Meteorological



×

Hydrologic Response Units

Land Cover

×

Imperviousness

×

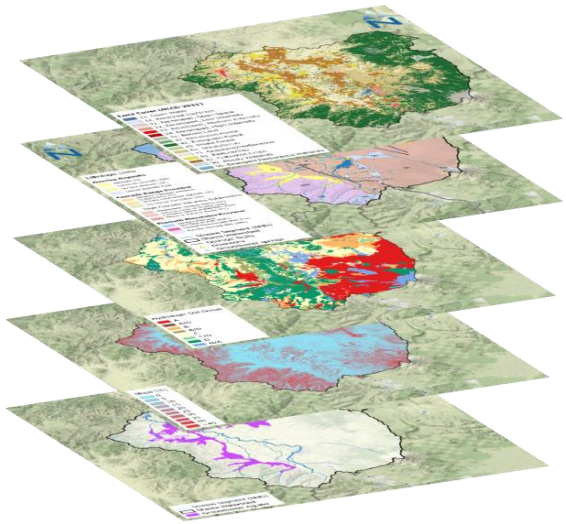
Soils Group

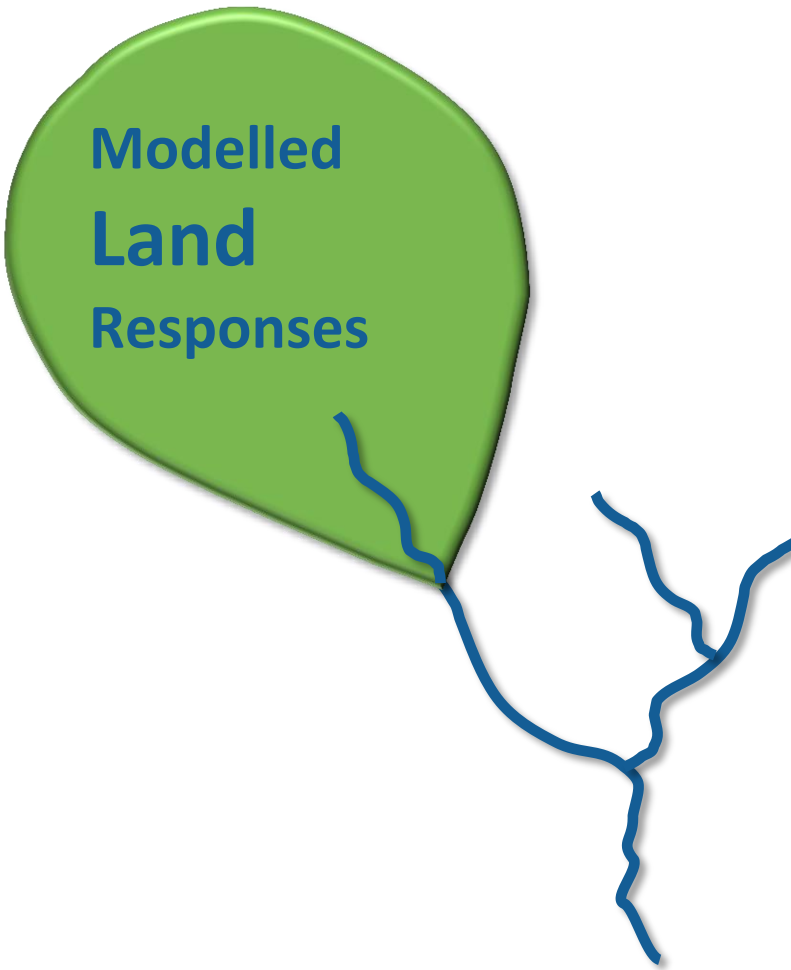
×

Slope

×

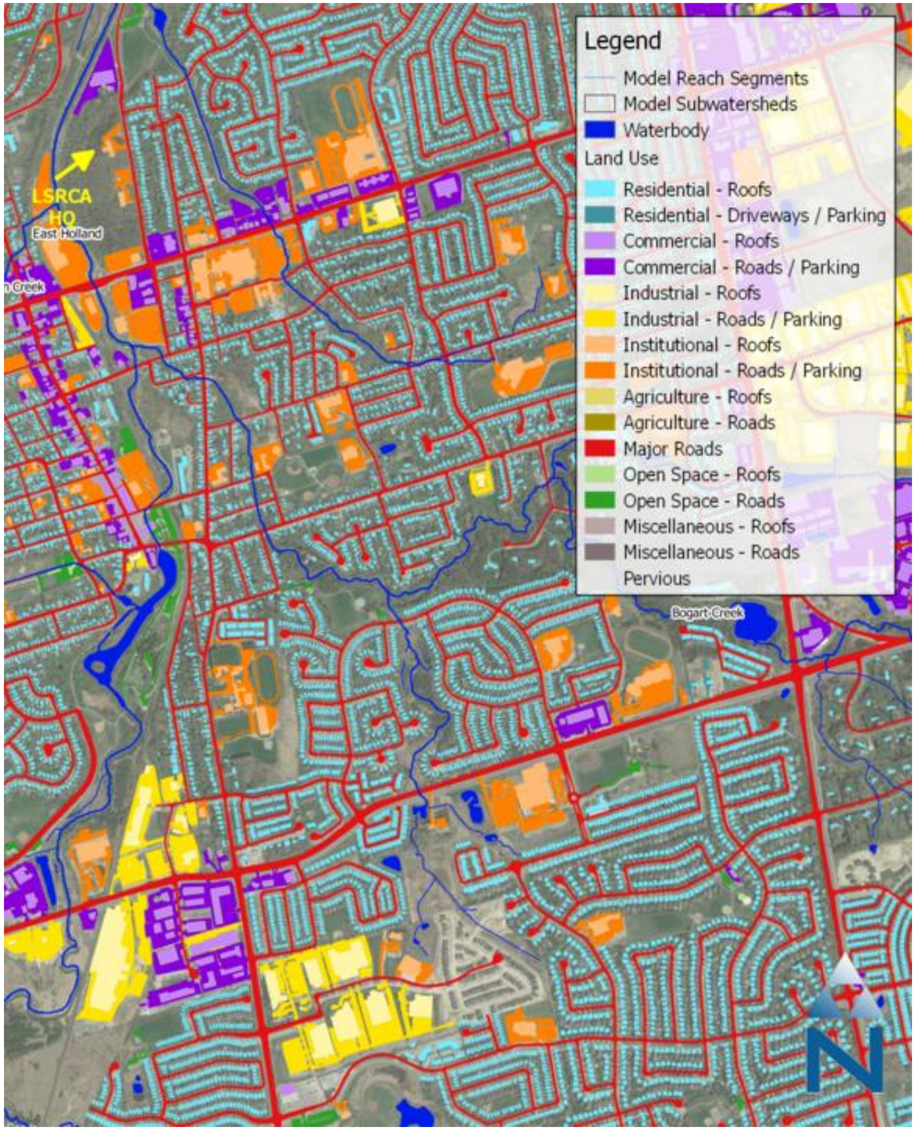
Sedimentary Deposits

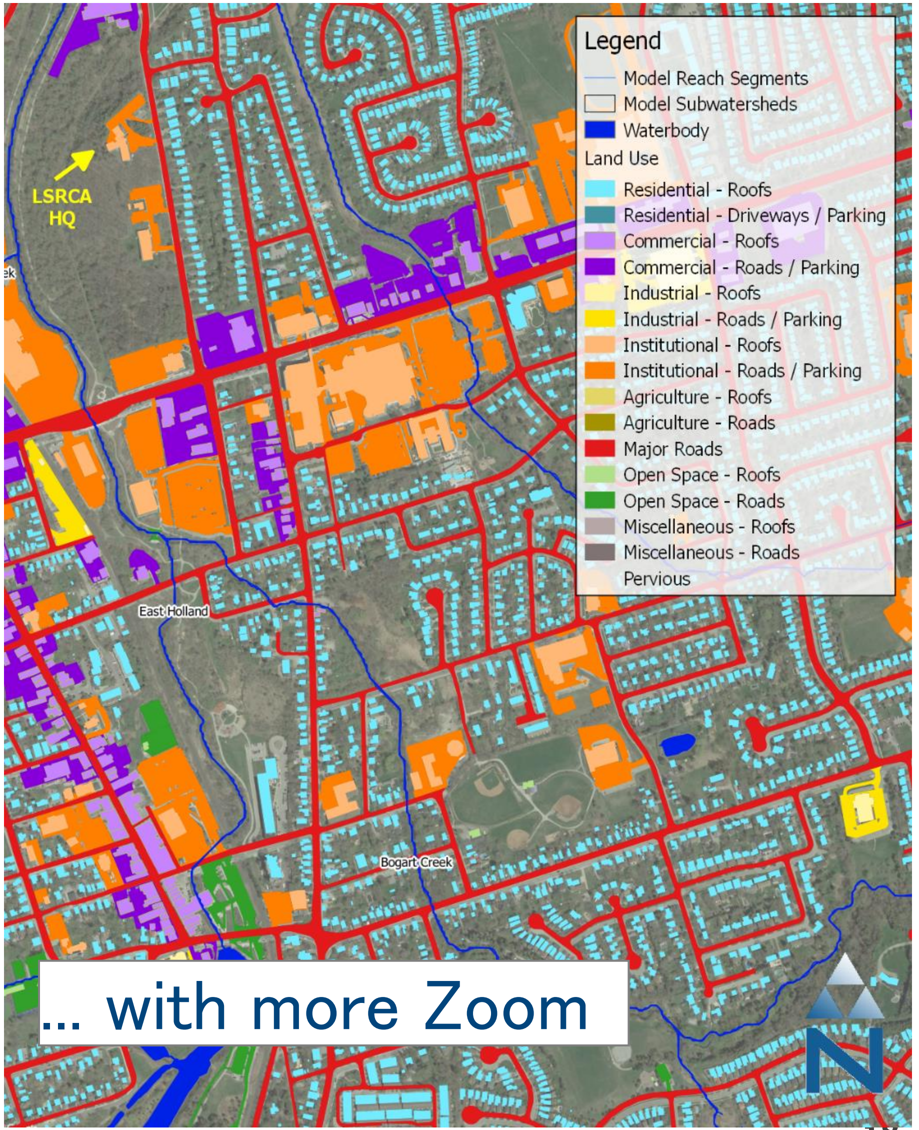




95 unique combinations of land cover, soils, slope, and geology.

Current State: Impervious Areas

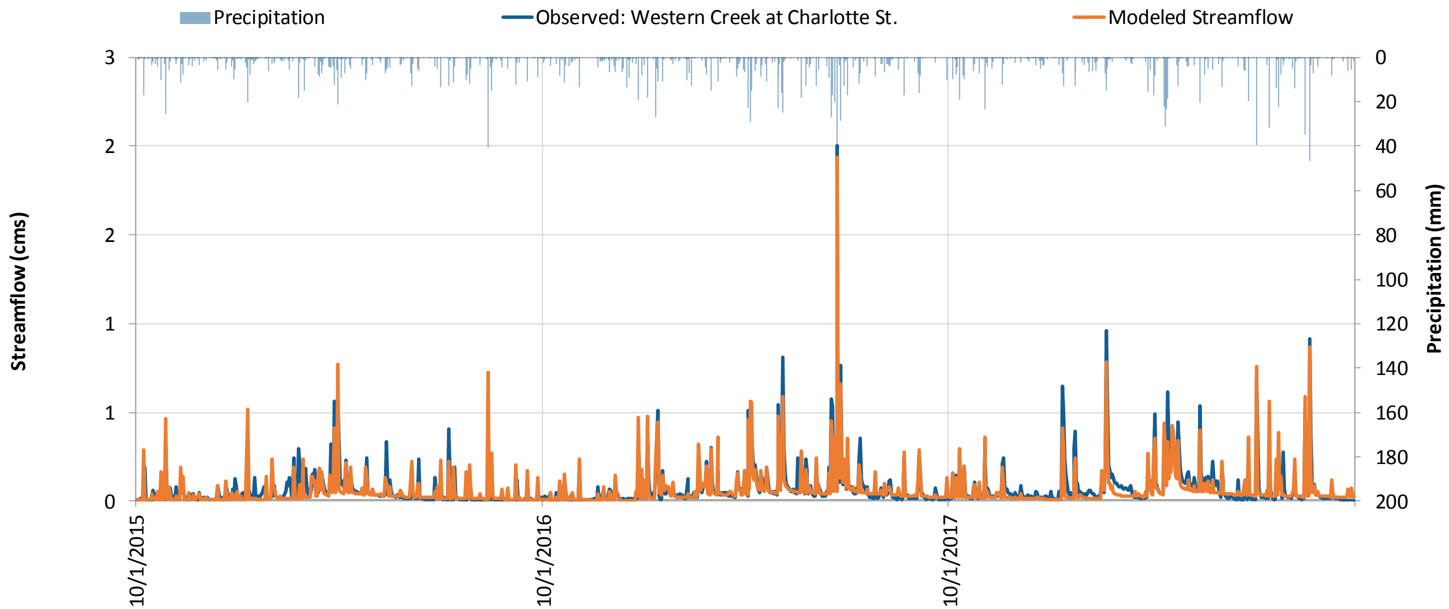


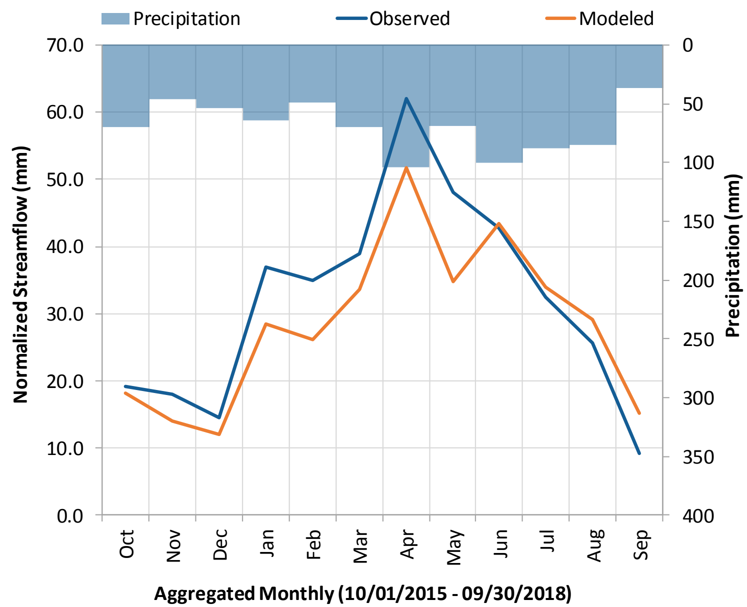


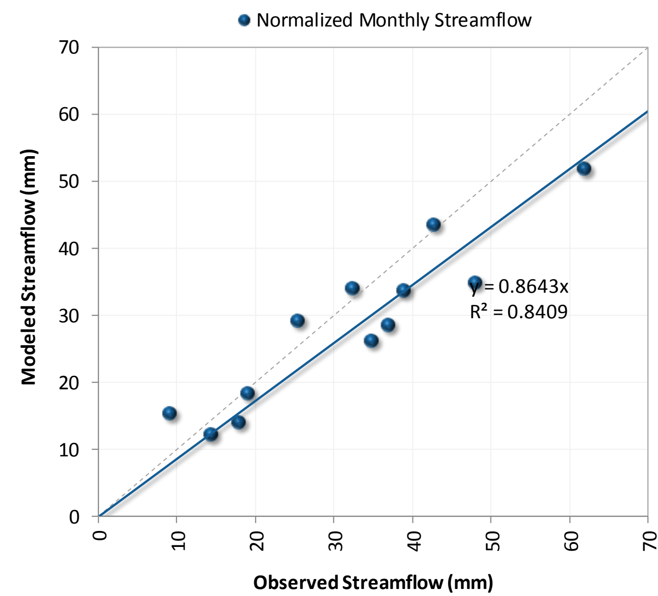
... with more Zoom

Current State: Configuration over Calibration

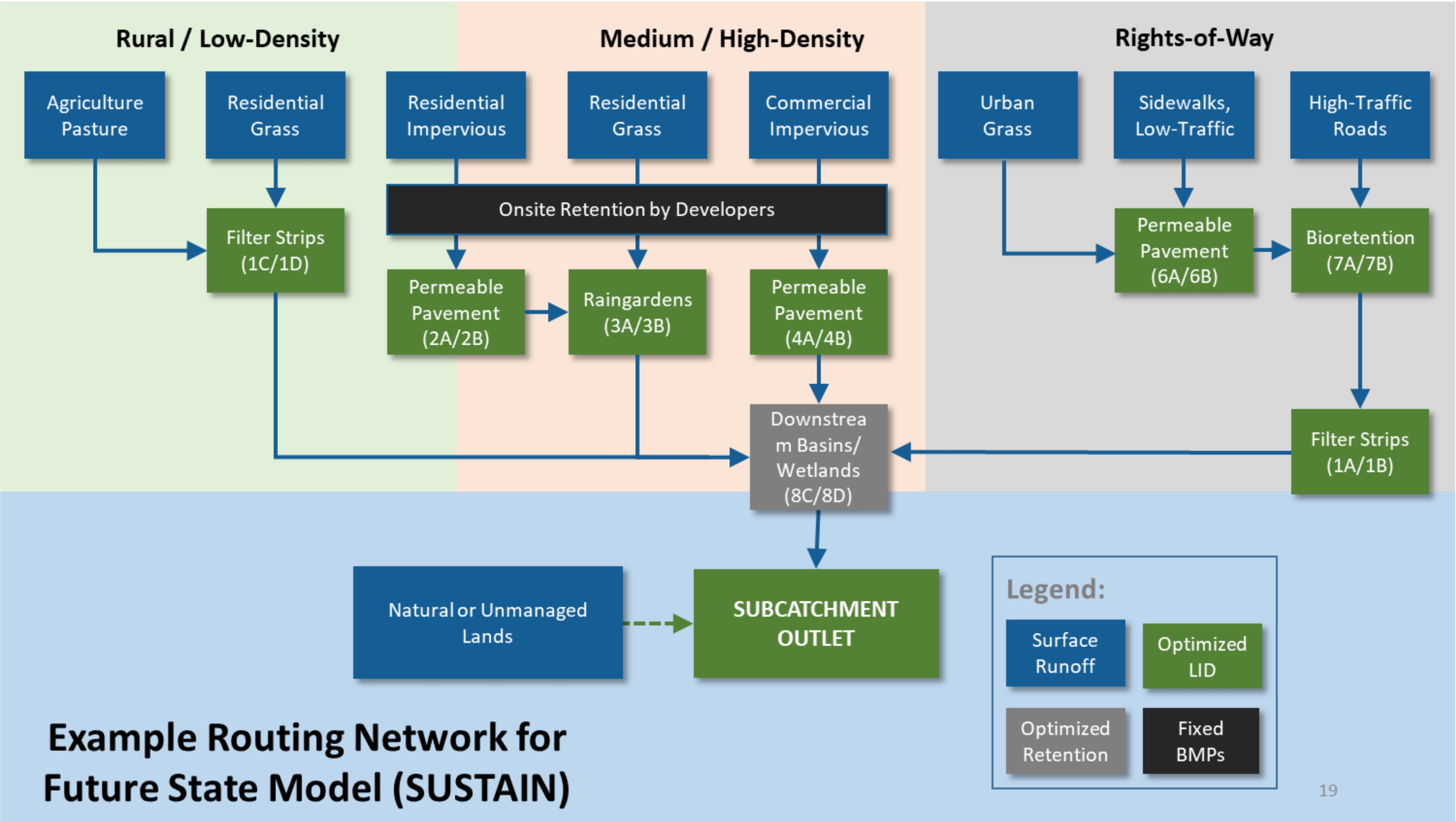
- Pre-calibration outputs!
- Hot off the presses
- Detailed configuration reduces the ‘burden’ on calibration







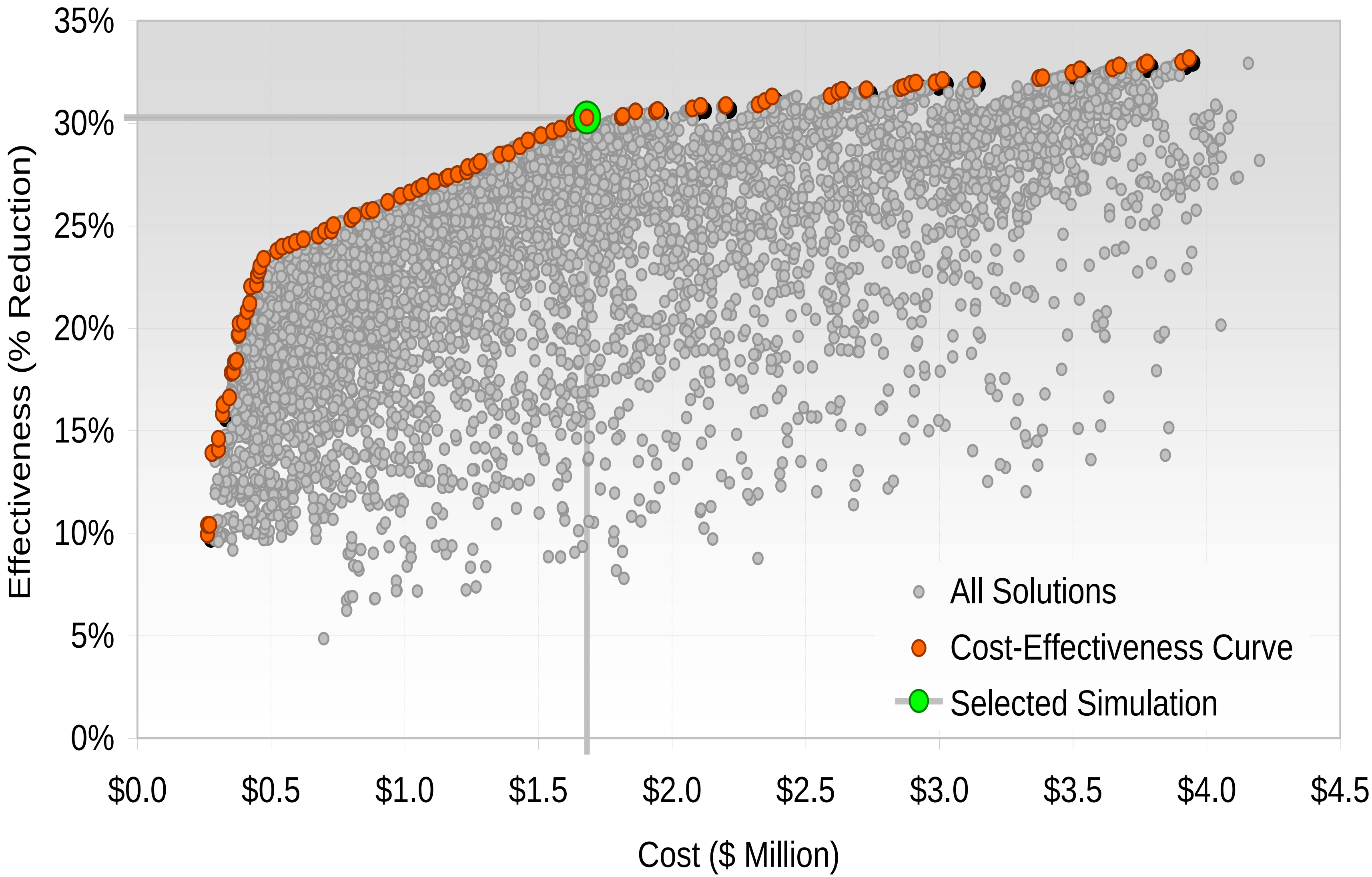
Future State: Establish Management Action Menu



- Each menu item has: defined opportunity areas, typical design details and unit cost functions!

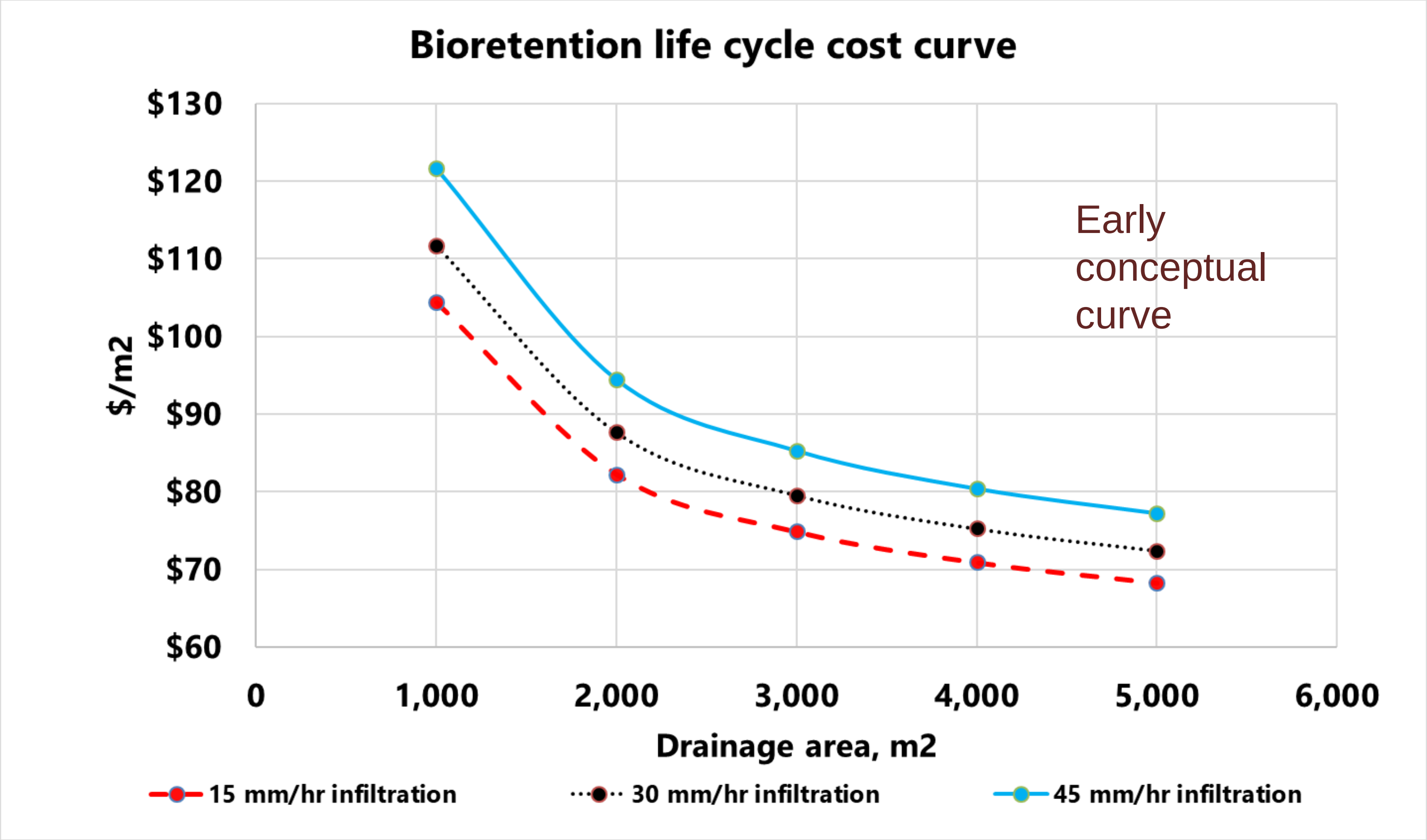
Future State: Cost Optimization

Millions of possible strategies analysed

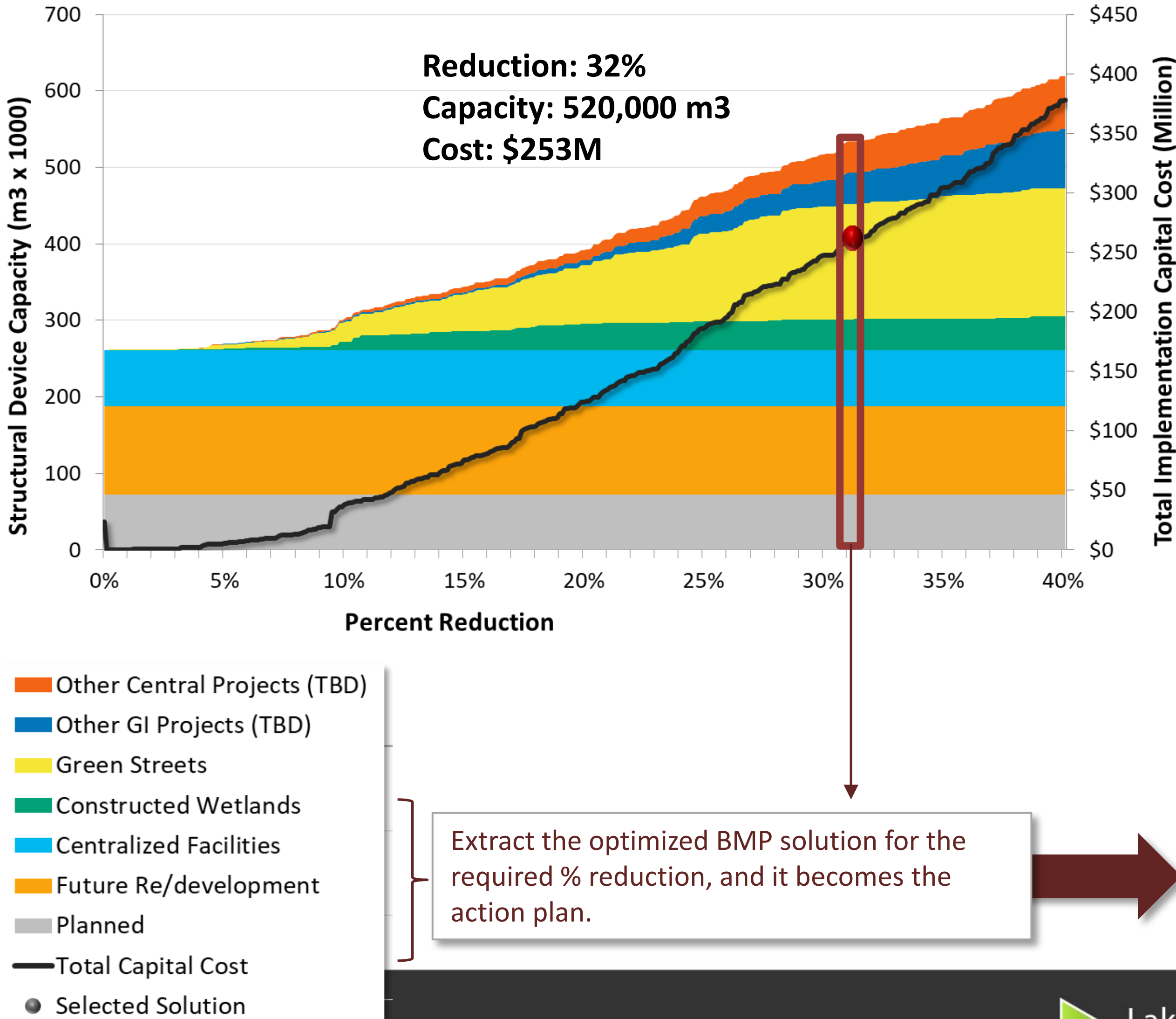


Cost Function Analysis

- Leveraging and updating STEP LID Costing Tool to generate a variety of cost functions



Optimize Across a *Range* of Action Levels



Extract the optimized BMP solution for the required % reduction, and it becomes the action plan.

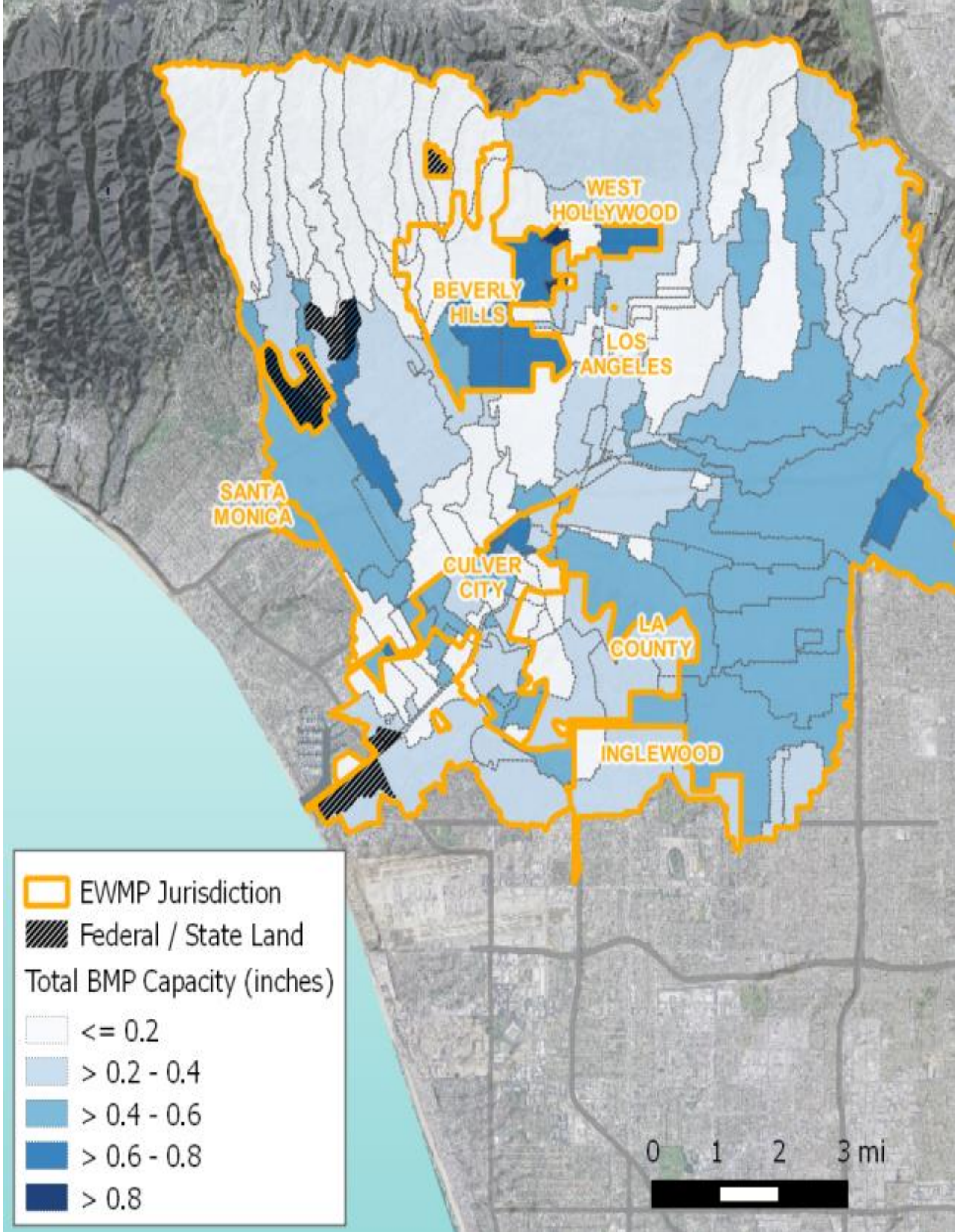
Sub-watershed ID	Subwatershed Management Level	
	% Load Reduction	Total Capacity (1000 m3)
1002	20%	6.0
1003	19%	8.0
1004	54%	17.3
1005	18%	17.9
1006	18%	3.5
1007	18%	16.8
1008	64%	10.0
1009	19%	11.5
1010	19%	6.1
1011	18%	27.6
1012	21%	10.4
1013	19%	0.2
1014	19%	7.0
1015	18%	98.0
1016	18%	25.3
1017	48%	18.8
1018	18%	39.6
1019	18%	83.8
1020	18%	91.7
1021	18%	15.6
Total	32%	520.0

Range of Action Levels Across Watershed

Detailed Strategy for each Subcatchment

And costs!

Example from LA Region



Sub-watershed ID	Watershed Management Metrics			Management Actions to Achieve Reduction (1000 m^3 capacity)							
				Existing/Planned			Optimized				
	% Load Reduction	Annual Volume Managed (1000 m3)	Impervious Area Treated (acres)	Existing Projects	Future Redevelop	Centralized Facilities	Wetlands	Green Streets	Other GI Projects	Other Central Projects (TBD)	Total BMP
1002	20%	63.64	110.25	0.36	0.19	1.93	0.16	2.53	0.11	0.75	
1003	19%	145.24	107.87	0.65	2.12	0.45	3.04	1.02	0.46	0.29	
1004	54%	199.30	163.61	0.50	16.82	--	--	--	--	--	
1005	18%	281.20	190.90	2.84	7.53	--	0.22	7.11	0.07	0.08	
1006	18%	116.53	68.98	1.39	0.30	0.26	0.80	0.00	0.54	0.16	
1007	18%	380.34	170.74	8.99	2.37	1.19	0.06	3.67	0.56	0.00	
1008	64%	105.77	110.74	1.46	5.00	--	1.57	2.00	--	--	
1009	19%	173.71	134.79	3.16	3.49	--	0.27	4.61	--	--	
1010	19%	118.09	47.71	0.00	0.16	--	--	5.85	--	0.10	
1011	18%	110.62	204.99	8.88	13.95	1.55	3.10	0.11	0.05	--	
1012	21%	192.01	120.81	0.51	3.49	--	0.09	6.23	0.00	0.09	
1013	19%	2.52	0.33	--	0.18	0.01	--	--	--	0.00	
1014	19%	129.91	16.19	--	0.57	--	--	2.60	0.10	3.69	
1015	18%	388.40	272.91	9.15	13.35	33.13	0.51	0.75	0.82	0.30	
1016	18%	202.38	168.65	1.23	5.52	16.66	1.77	0.08	--	--	
1017	48%	308.40	236.31	2.69	3.22	--	2.16	8.48	1.85	0.44	
1018	18%	583.75	457.05	5.61	16.51	--	3.41	14.11	--	0.00	
1019	18%	528.17	576.89	17.87	8.46	1.26	13.40	2.35	0.50	0.00	
1020	18%	306.75	242.20	6.74	10.04	15.99	2.00	6.73	0.09	0.09	
1021	18%	156.45	87.13	0.05	2.51	1.23	--	5.32	0.74	5.79	
Total	**32%**	**4,493.2**	**3,489.1**	**72.1**	**115.8**	**73.6**	**32.6**	**73.6**	**5.9**	**11.8**	

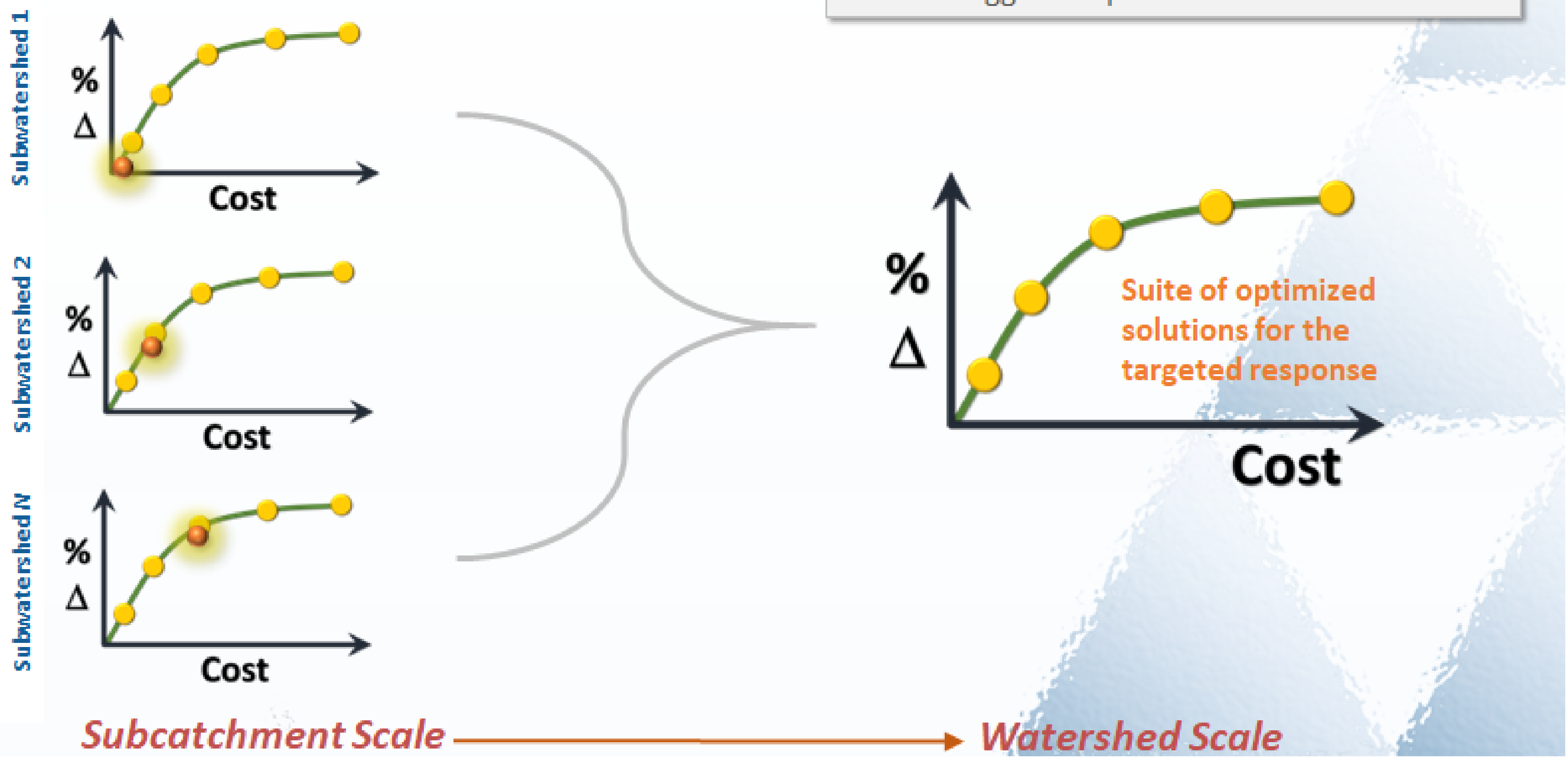
Watershed-wide vs Municipal

Tier 1 Optimization

Find optimal combinations of BMPs to achieve range of responses, with each increment being at lowest cost

Tier 2 Optimization

Search across Tier 1 solutions to find the optimal combinations (BMPs and locations) to achieve biggest response at lowest cost



Municipal Perspective

Rachel Prudhomme, P.Eng.

WHY SHOULD MUNICIPALITIES CARE?

Newmarket

- Flooding is our biggest climate change risk
- Need to address growth and ↑ in impervious surfaces
- Traditional SWM no longer works
- No control over flows from upstream municipalities
- Need a concerted approach to SWM across municipalities (e.g. watershed-wide)
- Makes sense to pool our resources across boundaries

OPERATIONAL BENEFITS

Newmarket

- In urban municipalities, typically more than 70% of land in a municipality is privately owned
- Need proven market-based instruments & costing
- Need to show proven cost efficiency to land owners
- This project is based on reliable data and will provide tools to recommend strategies that will bring the greatest bang for every buck spent (public AND private)

WRAP-UP

Newmarket

- On a path to identify the integrated management actions that provide the greatest cost-benefit for flood control and water quality improvement

- Robust and flexible tool to support a variety of applications including offset programs and stormwater master plans / capital programs

- Will provide <u>first-of-its-kind</u> outputs regarding the economic benefits of jurisdiction vs watershed-wide approaches for stormwater management

ACKNOWLEDGMENTS

Newmarket

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