Using SWAT to Evaluate Green Infrastructure in an Urbanized Watershed

Watershed Protection Department

City of Austin, Texas

Presented at

2015 International SWAT Conference

Pula Sardinia Italy

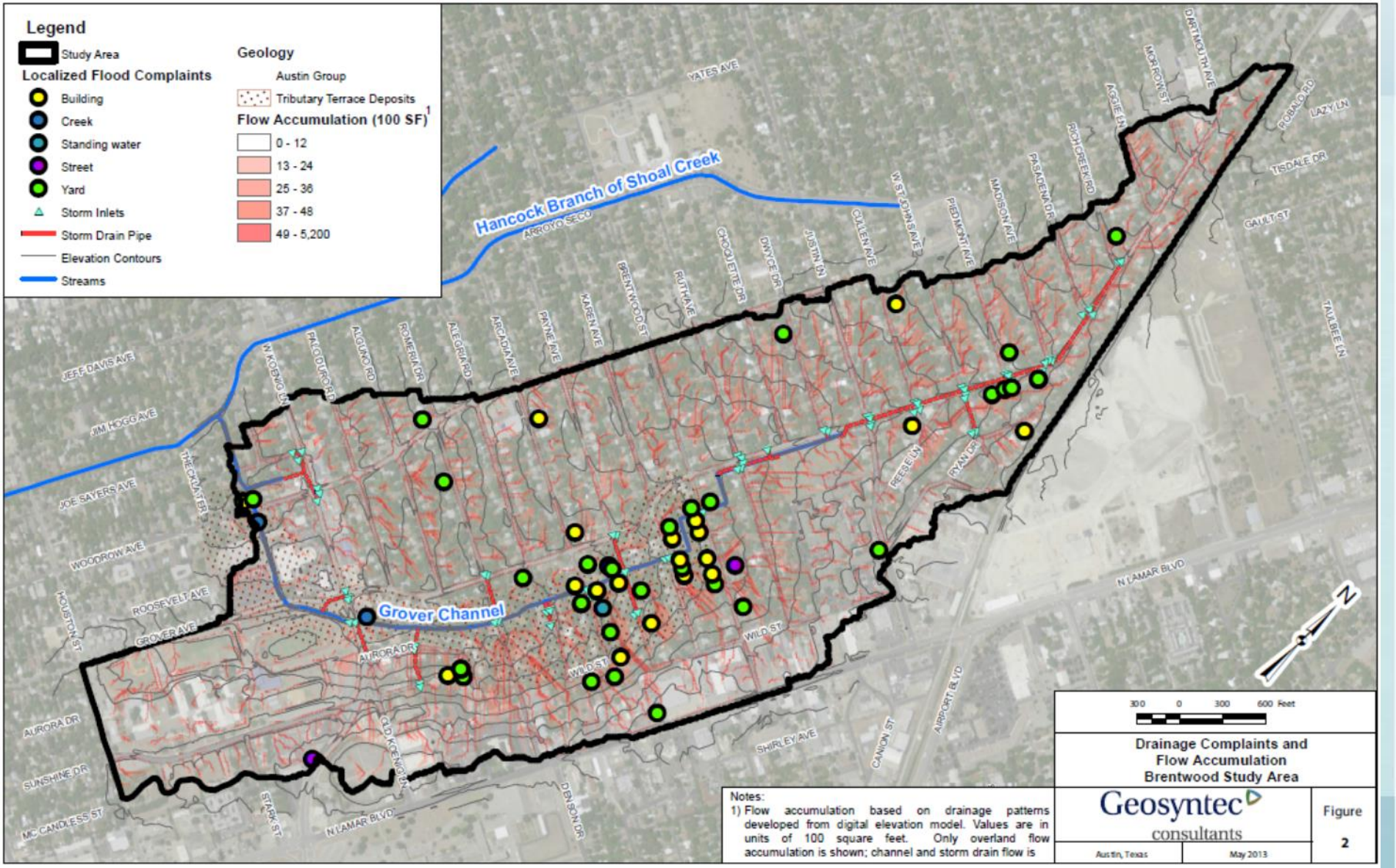
Geosyntec consultants

engineers | scientists | innovators

City of Austin WATERSHED PROTECTION

BW Study **Objectives: Identify opportunities for the application of green infrastructure in COA-sponsored retrofits, private development and voluntary homeowner projects**

- Brentwood Watershed: Model large-scale application of decentralized GSI to assess impacts on flooding and WQ.
  - Local Flood Problems
  - Expected construction cost of >$100 million
  - PCSWMM Study to generalize assessment of Green Infrastructure applicability
  - SWAT Evaluation of new LID routines for quicker, cost-effective evaluations


Legend
Study Area
Localized Flood Complaints
Building
Creek
Standing water
Street
Yard
Storm Inlets
Storm Drain Pipe
Elevation Contours
Streams
Geology
Austin Group
Tributary Terrace Deposits
Flow Accumulation (100 SF)[1]
0 - 12
13 - 24
25 - 36
37 - 48
49 - 5,200
Hancock Branch of Shoal Creek
Grover Channel
YATES AVE
ARROYO SECO
W STASSNEY LN
PIEDMONT AVE
MADISON AVE
PASADENA DR
ROCKCREEK RD
DARTMOUTH AVE
MORROW ST
AGGIE LN
ROBALO RD
LAZY LN
TISDALE DR
GAULT ST
TAULBEE LN
CULLEN AVE
JUSTIN LN
DWYCE DR
CHOQUETTE DR
RUTH AVE
BRENTWOOD ST
KAREN AVE
PAYNE AVE
ARCADIA AVE
ALEGRIA RD
ROMERIA DR
ALGUNO RD
PALO DURO RD
W GOLDEN LN
JEFF DAVIS AVE
JIM HOGG AVE
JOE SAYERS AVE
WOODROW AVE
ROOSEVELT AVE
GROVER AVE
AURORA DR
HOUSTON ST
SUNSHINE DR
MC CANDLESS ST
STARK ST
OLD KENOSHA DR
DENSON DR
N LAMAR BLVD
WILD ST
SHIRLEY AVE
CANION ST
AIRPORT BLVD
RYAN DR
REESE LN
THECKWATER
N
300 0 300 600 Feet
Drainage Complaints and
Flow Accumulation
Brentwood Study Area
Geosyntec consultants
Austin, Texas
May 2013
Figure
2
Notes:
1) Flow accumulation based on drainage patterns developed from digital elevation model. Values are in units of 100 square feet. Only overland flow accumulation is shown; channel and storm drain flow is

Payne Ave

April 2, 2013


HOME

Cost Estimates for Storm Drain Upgrades to Comply with DCM

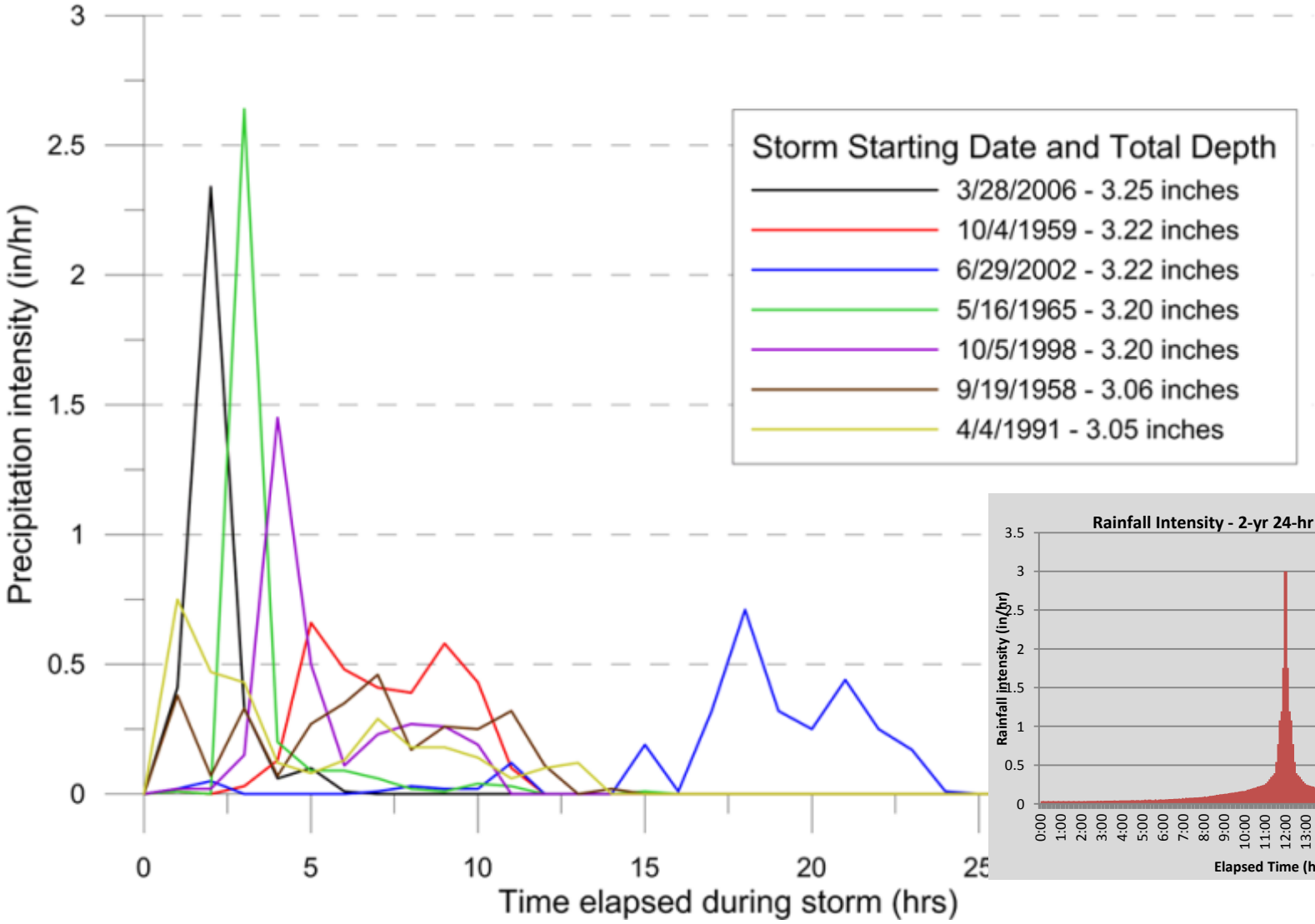
Project	Cost Estimate
Project No. 1 Local Street Storm Drain System Improvements	$26,796,345
Project No. 2 Woodrow Avenue and Grover Avenue Storm Drain Diversion Conduits	$87,074,896
Project No. 3 Grover Channel Improvements from Justin Lane to Koenig Lane	$20,078,060
Project No. 4 Grover Channel Improvements from Koenig Lane to Hancock Branch	$10,305,588
Project No. 5 Storm Water Detention on Grover Channel	$5,366,858
Project No. 6 Hancock Branch Channel Improvements	$42,958,018
Total Estimate	**$192,579,765**

Matched Significant Storm Event Dates in Complaint DB / Letters

Storm Date	Address	Comment	Event Depth, in	Event Duration, hours	Last 7 days rain	Peak Intensity, in/hr
9/4/2009	1106 Koenig	storm overtopping W. Koenig Ln	**3.36**	**2**	**0.24**	**3.24**
6/9/2004	1107 Payne	street flooding	**2.76**	**8**	**2.64**	**1.8**
Nov. 2004	1101 Allegria	house flooded	**3.36**	**1**	**5.52**	**3.36**
7/23/2007?	1006 Arcadia	overland flow through the back yard to the front yard/street	**1.8**	**5**	**1.68**	**0.72**
			1.44	**1**	**0.12**	**1.44**
11/15/2001	1102 Karen	Nov 15 storm caused bank collapse and erosion	**6**	**9**	**--**	**3.72**
			Events defined by 6 hour interevent time			

Reported issues correspond to a range of storm depths, durations, and antecedent conditions

What does a ‘typical’ 2-year storm event look like?



Drainage - Creek

Why Decentralized Green Infrastructure Evaluated?

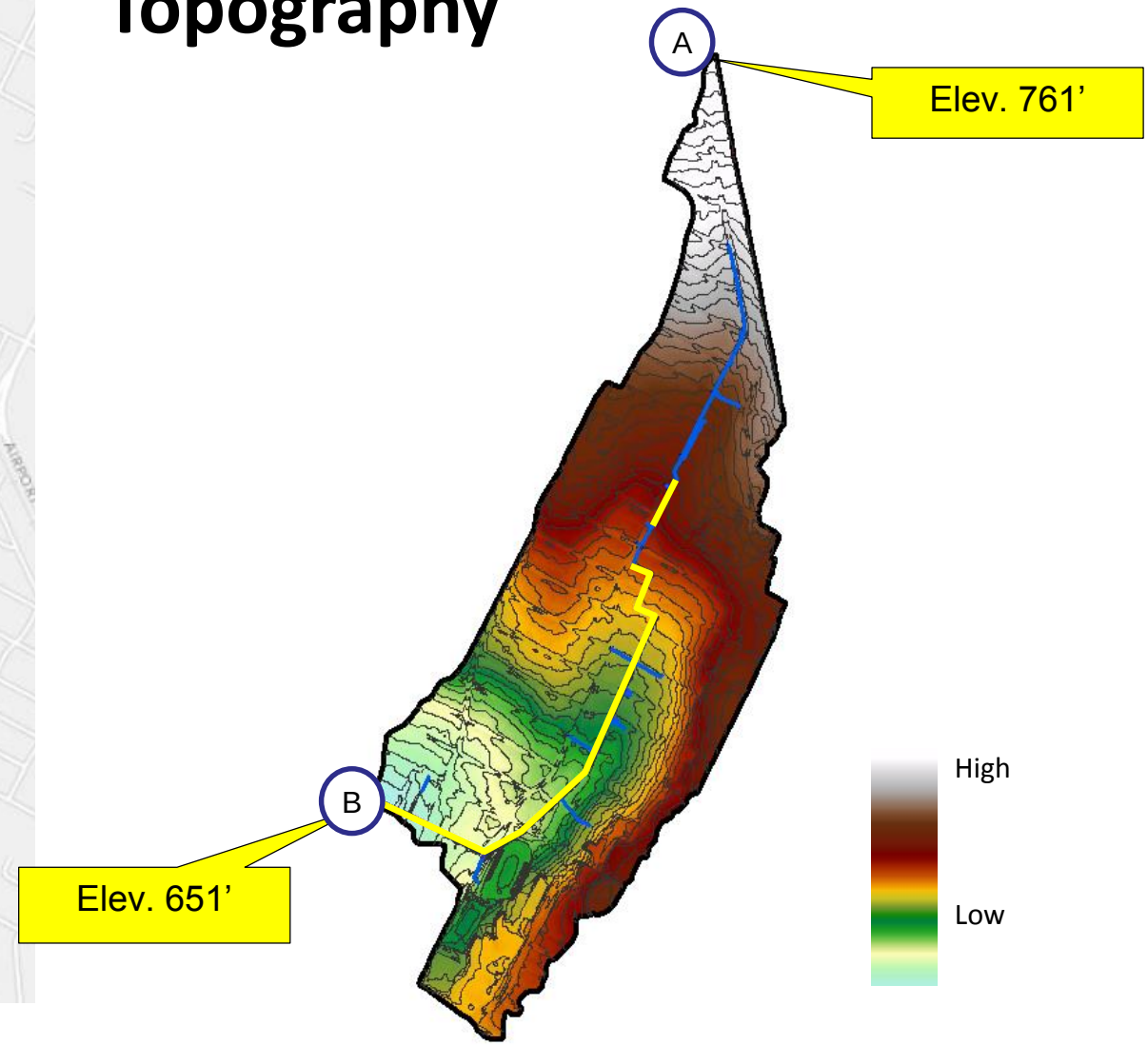
Primary cost drivers are:

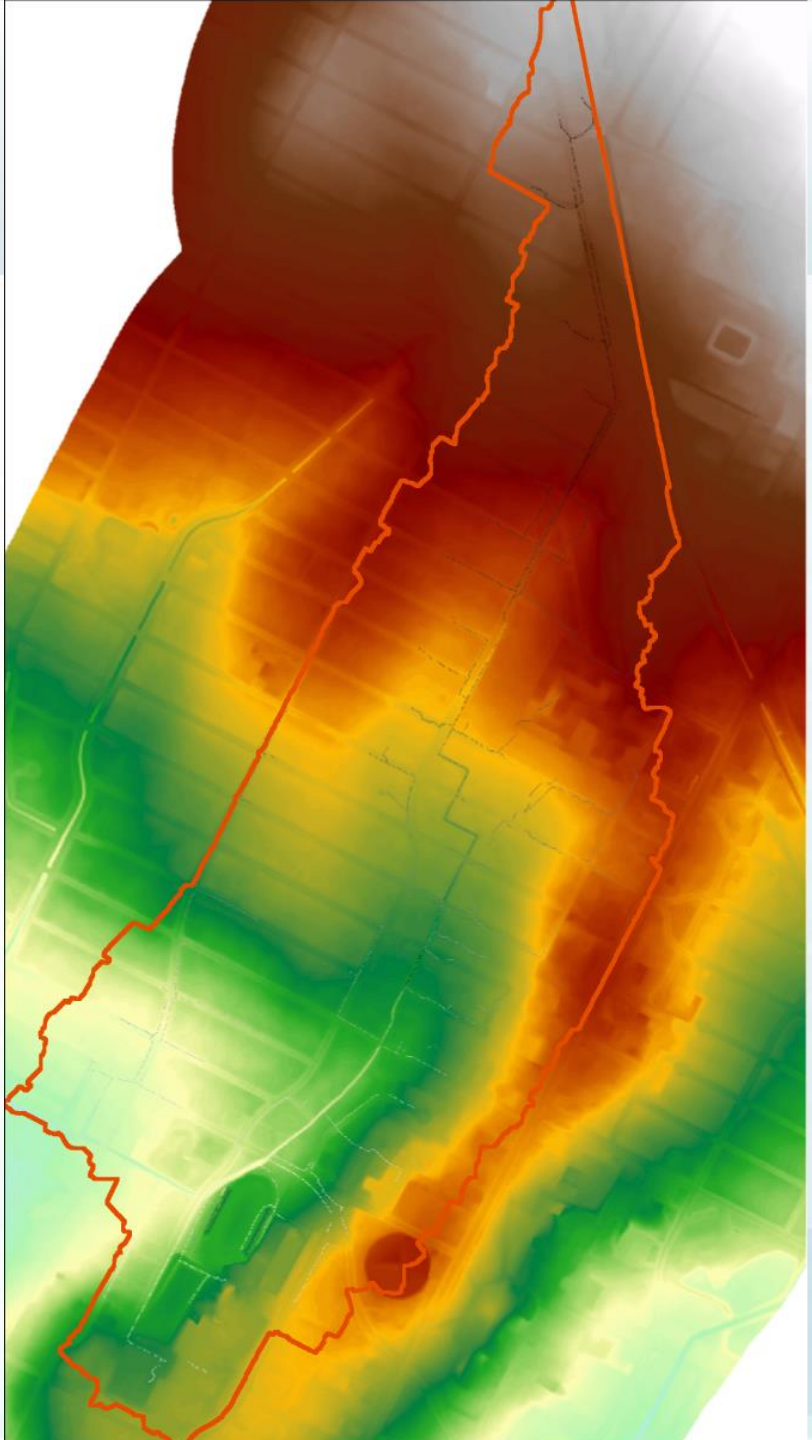
- Installation of larger pipes (and relocating adjacent underground utilities) to handle runoff;
- Downstream channel modifications to prevent increased creek flooding from increased peak discharges from stormdrain system

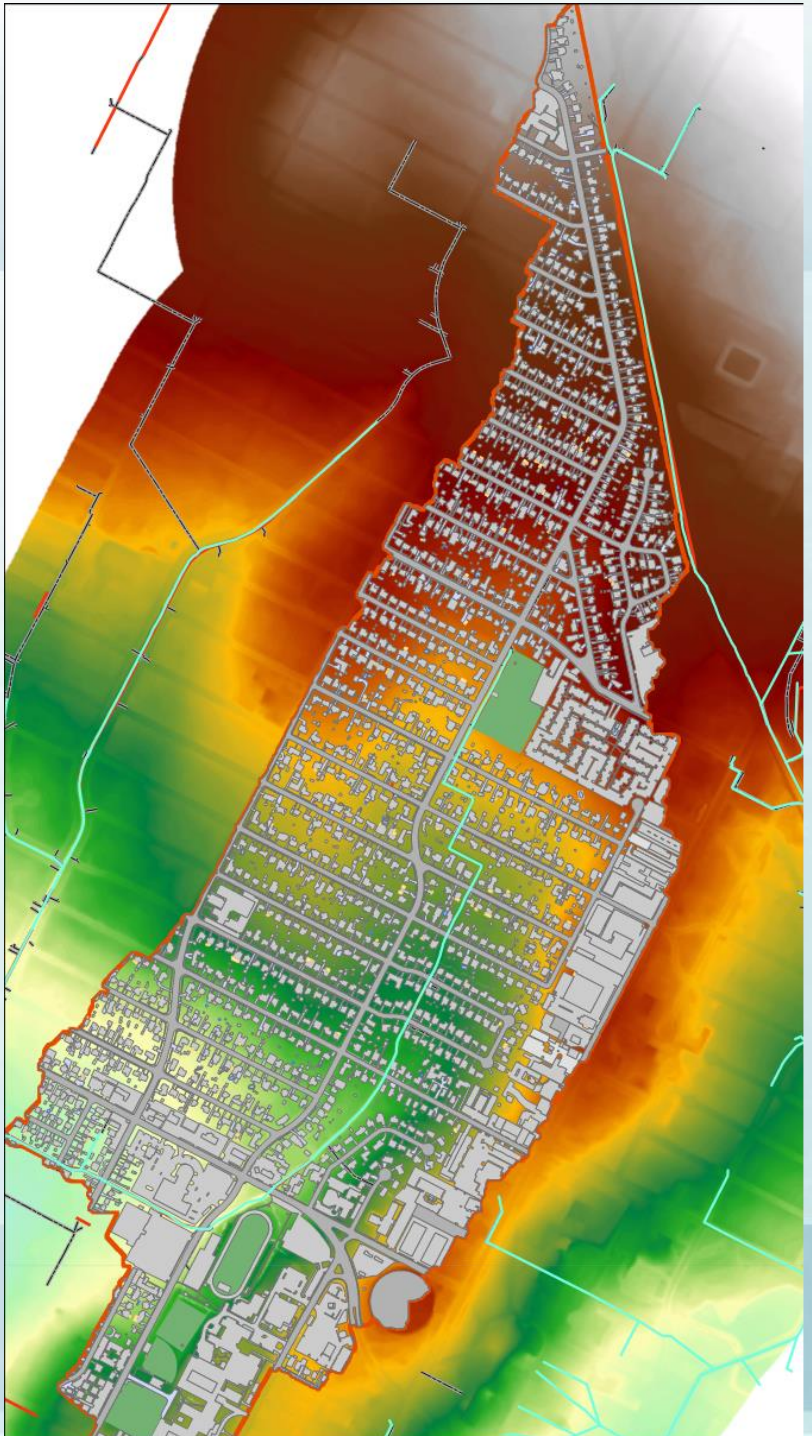
Therefore, if we change approach to volume (demand) reduction WPD may be able to use existing conveyance system and neutralize or reduce the impact on the downstream floodplain, as well as reduce pollutant loads and erosive flows.

Land Use

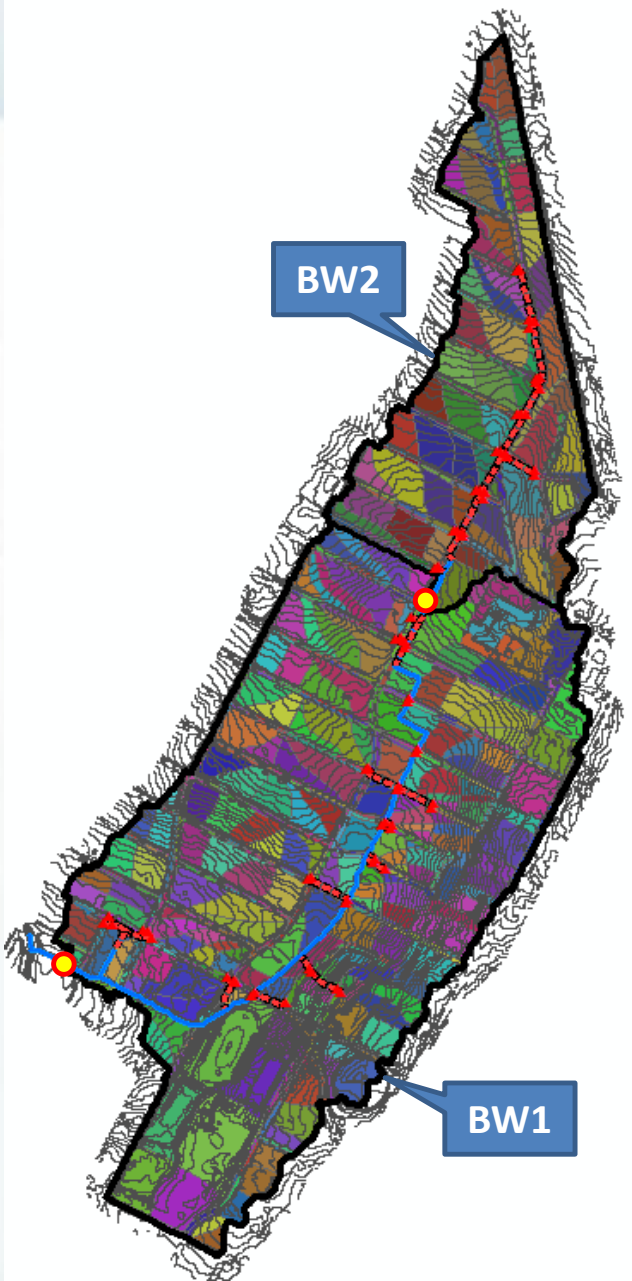
Topography







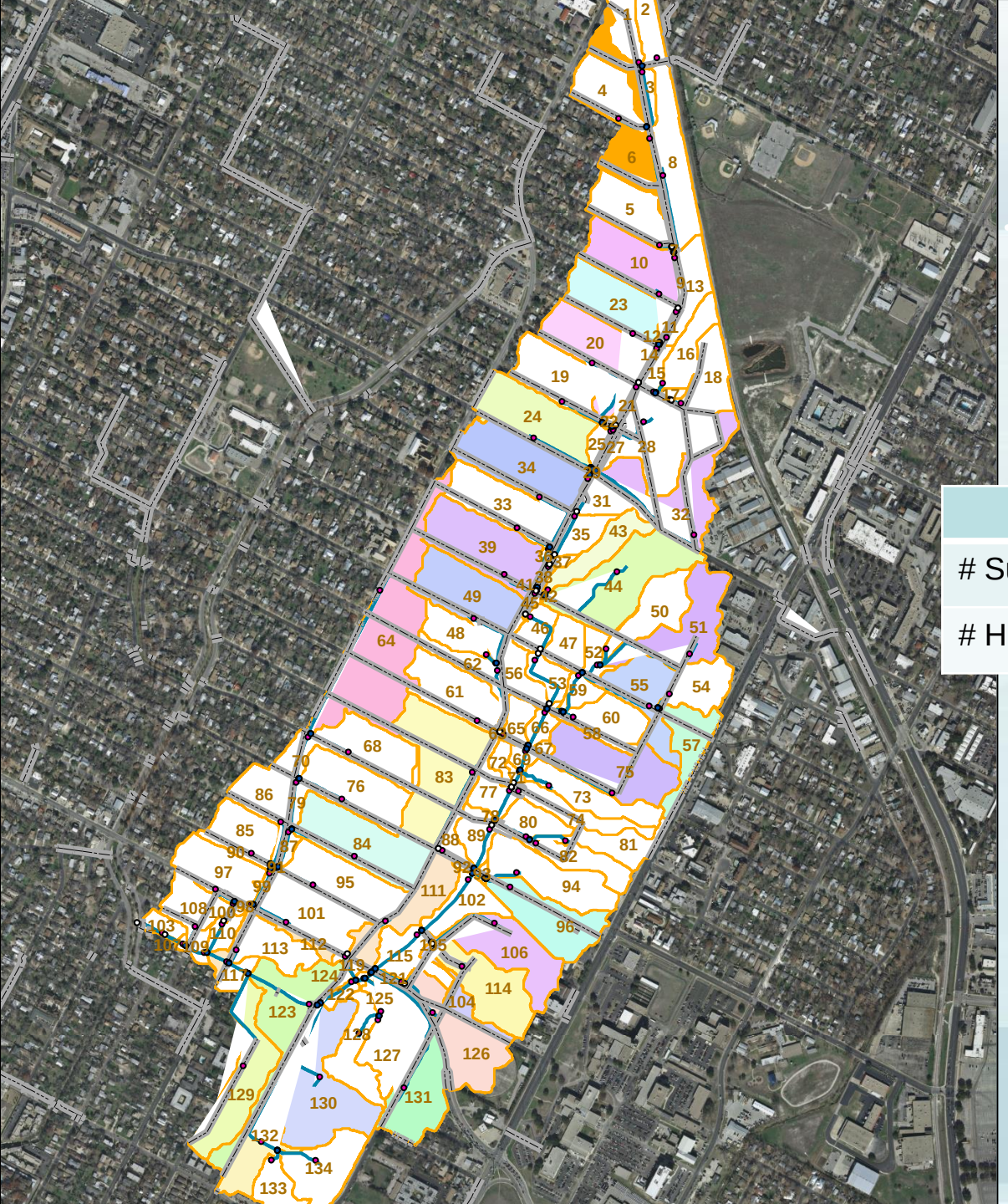
Catchment Delineations, Conveyance Pathways



Legend

- Monitoring Location
- Tributary Area to Monitoring Locations
- Contour Lines
- Open Channel
- Storm Drain Structure
- Subcatchment Delineations (various colors)

SWAT Model



	PCSWMM	SWAT
# Subcatchments	463	134
# HRUs		852

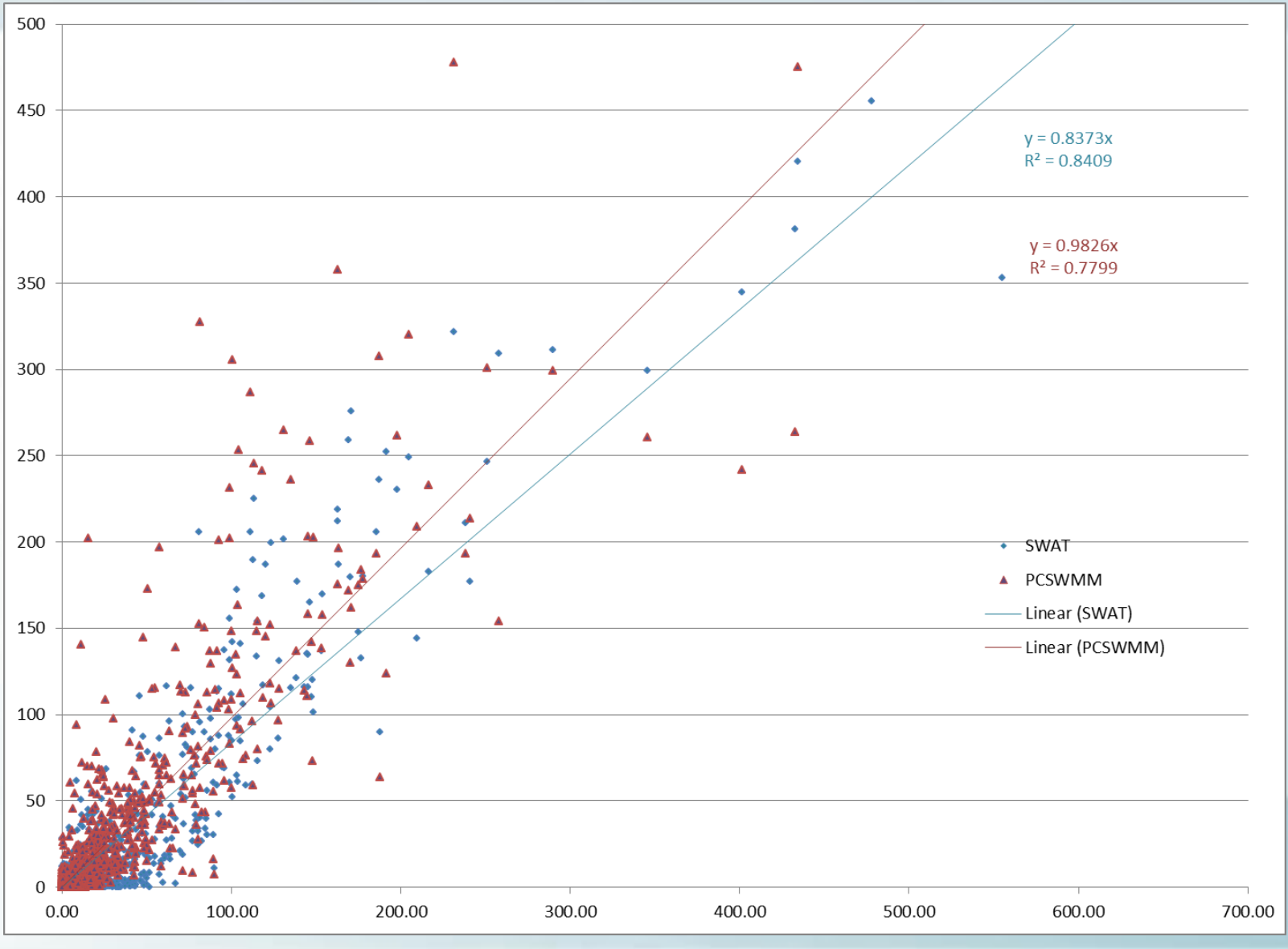
City of Austin
WATERSHED PROTECTION

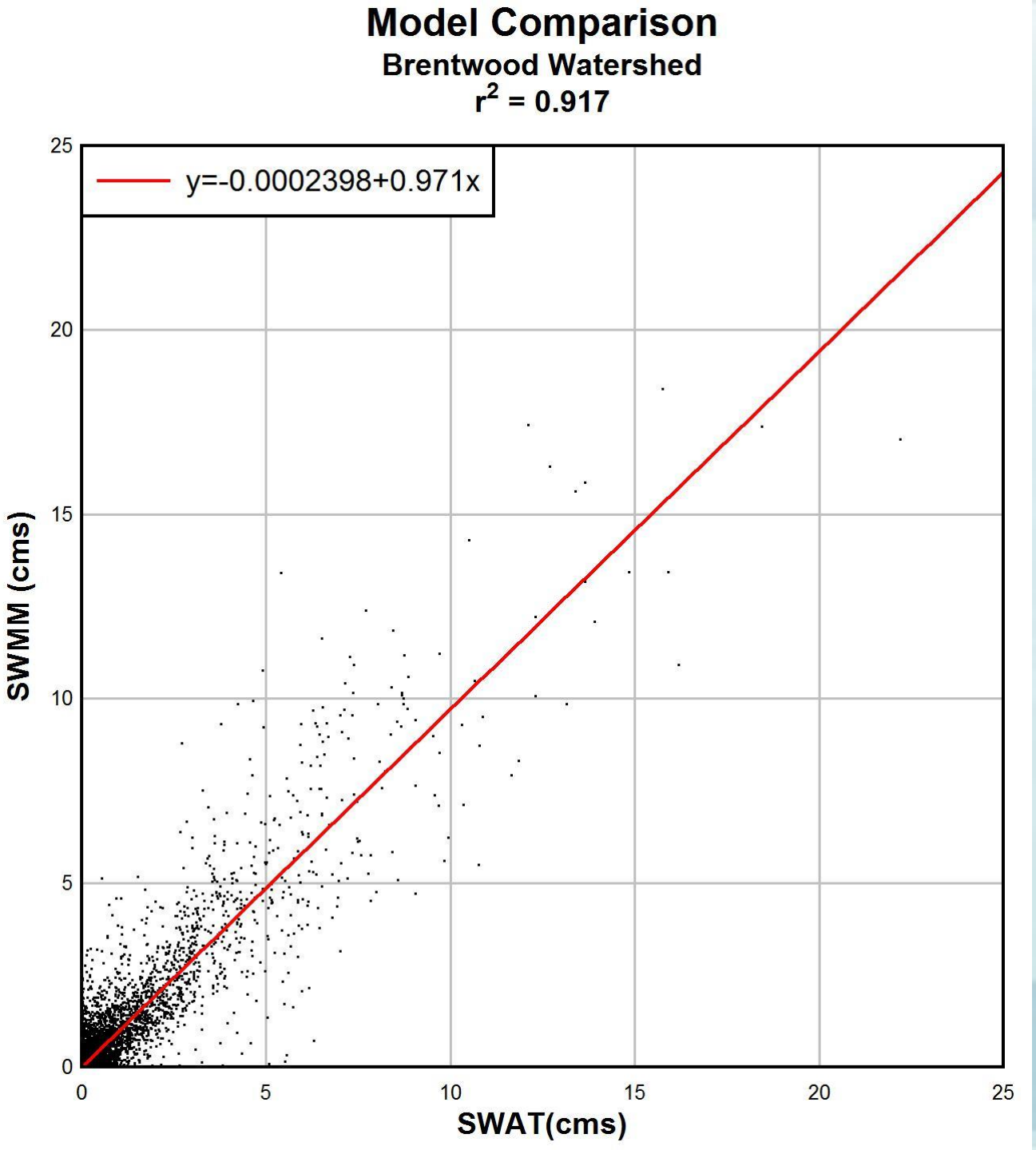
Model Representation of Existing Conditions

Calibration Statistic	Project Acceptable Target	PCSWMM	ArcSWAT
Overall NSE	>0.5	0.73	0.75
PBIAS	±25	3.37	3.21
RSR	<=0.7	0.52	0.5
Percent Total Runoff		103%	93%

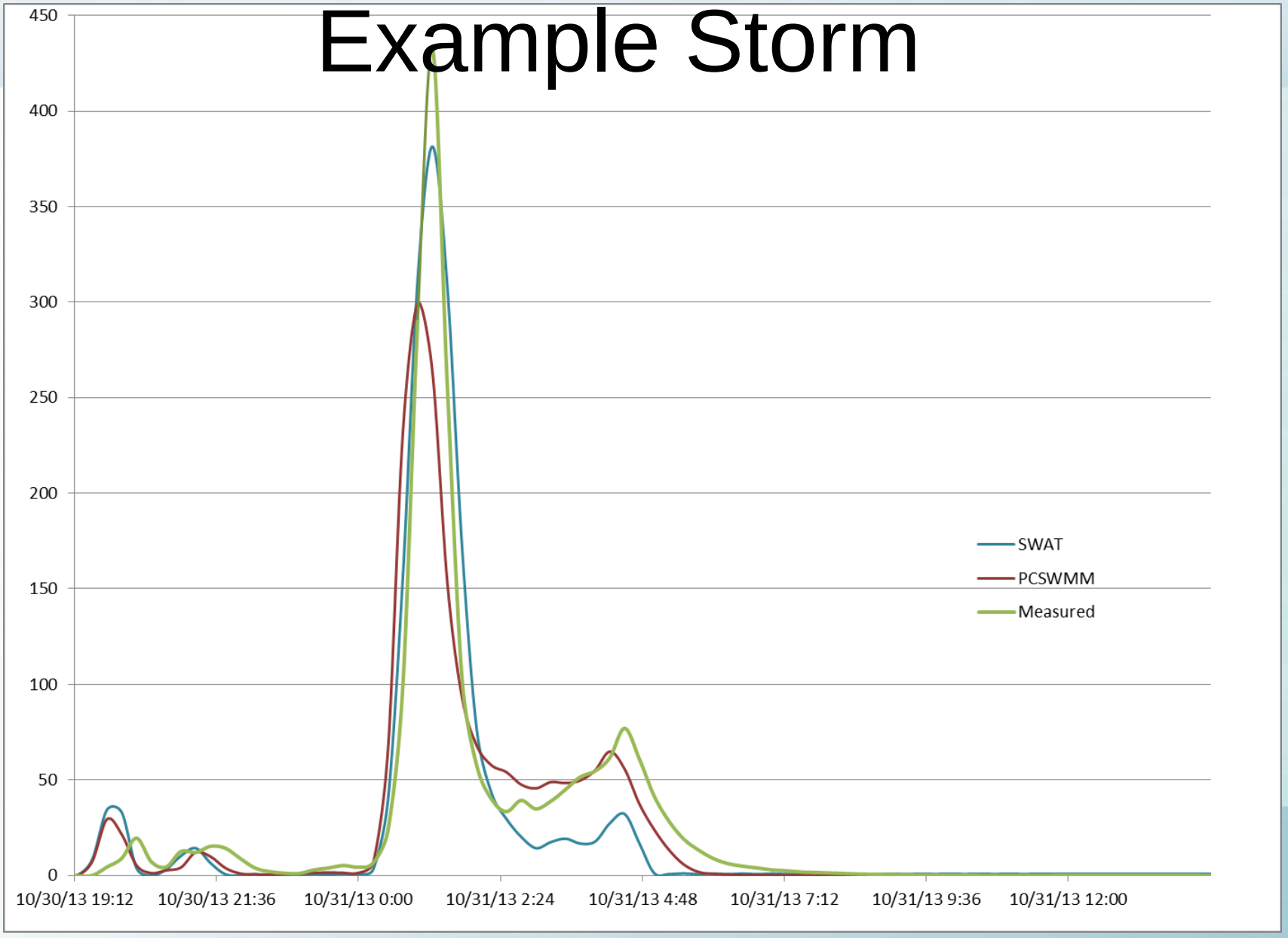
Watershed Protection
Development Review

Brentwood Calibration




Model Comparison
Brentwood Watershed
r2 = 0.917
y=-0.0002398+0.971x
SWMM (cms)
SWAT(cms)
0
5
10
15
20
25

Example Storm



Max Green Infrastructure

Feature	Summary	Approx. Footprint (ft^2)	Approx. Volume (ft^3)
Explicit Biofiltration	36 new biofiltration features located at existing storm drain inlets addressing over 150 acres	54,000	108,000
Explicit Biodetention	7 new biodetention features in strategic locations addressing approximately 18 acres	5,000	10,500
Lions Field Biodetention	Multi-stage storage and flow control addressing runoff from 8 acres	28,000	112,000
Channel Widening	New off-channel floodplain area	8,500	38,000
Green Streets	New green streets features addressing 111 total tributary acres, primarily in residential areas (approx. 100 individual features)	64,000	80,000
Green Parking Lots	New green parking lot features addressing 10 commercial/industrial lots	26,000	41,000
Residential Cisterns	New “shared use” cistern capacity (i.e., water conservation plus peak shaving) addressing 13 acres of roofs (approx. 370 homes)	16,000[1]	93,000
Non-Residential Cisterns and Blue Roofs	New detention-only cistern storage addressing 16 commercial/industrial/multi-family lots	15,000[1]	85,000
Residential Enhanced Disconnects	10 acres of decompaction and soil amendments receiving flow from 4.8 acres of impervious cover (approx. 120 lots)	450,000	73,000
Permeable Friction Course	Overlay of 18 acres of street	NA	NA
	Total	**666,500**	**640,500**

SWAT Model Implementation:

Cisterns modeled with
LID: Cisterns

Green Streets and Green Parking Lots modeled with
LID: rain gardens

Biodetention/biofiltration modeled with:
Sedimentation/filtration

Detention modeled with:
Detention ponds (limited design information available on detention controls)

Enhanced Disconnection modeled with: change in Fraction Connected IC

Permeable Friction Course modeled with: change in Manning's n

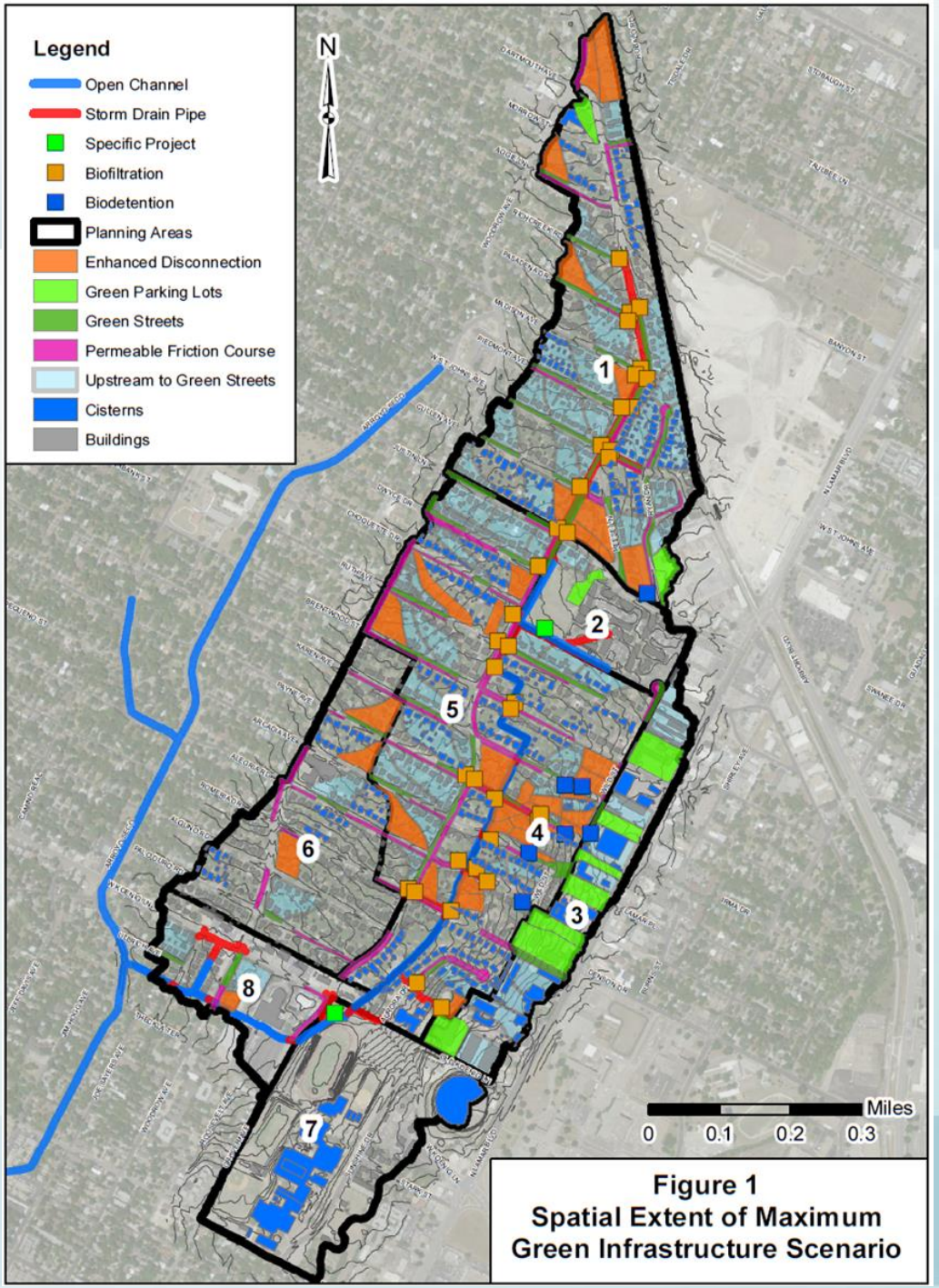
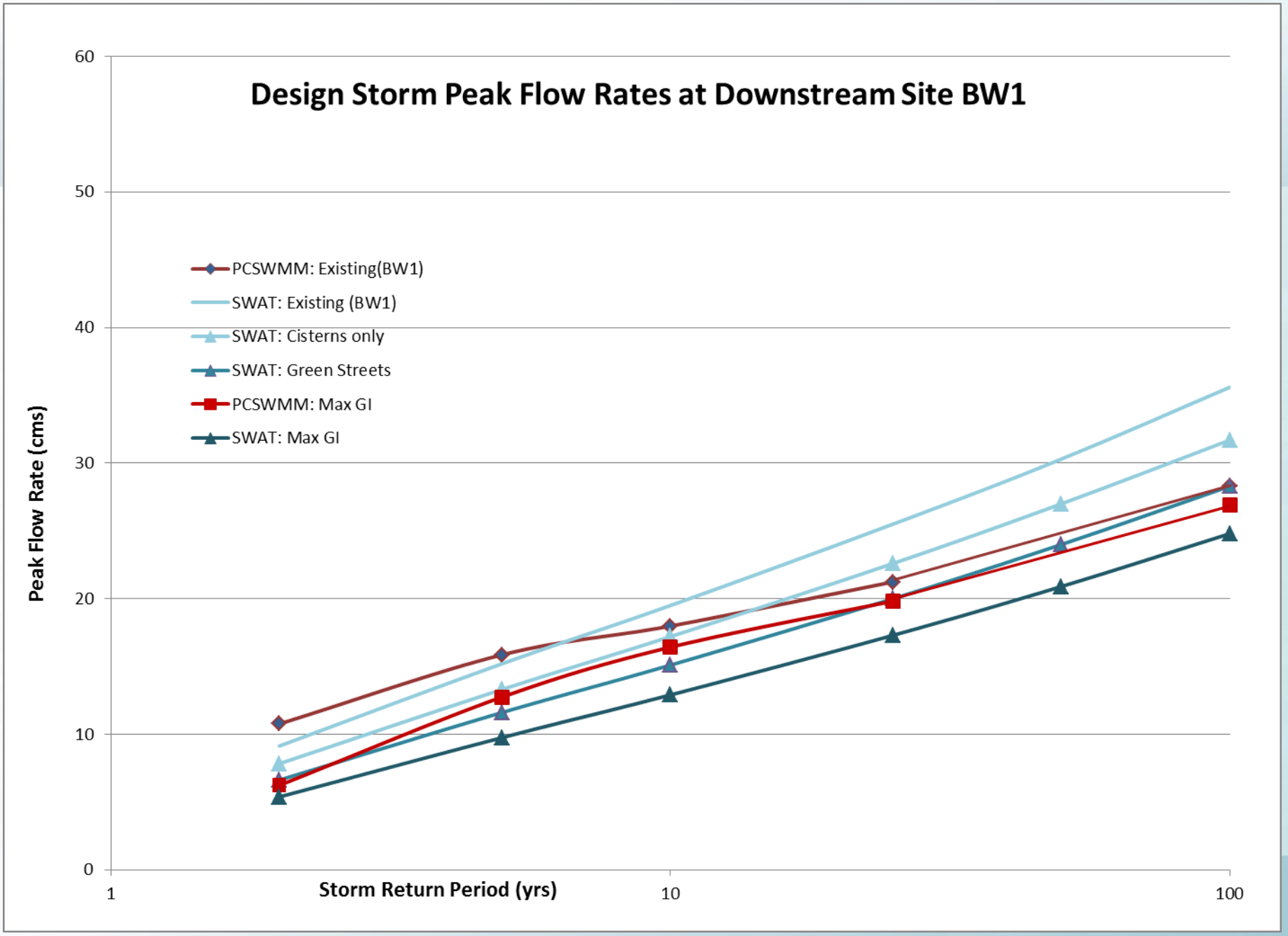


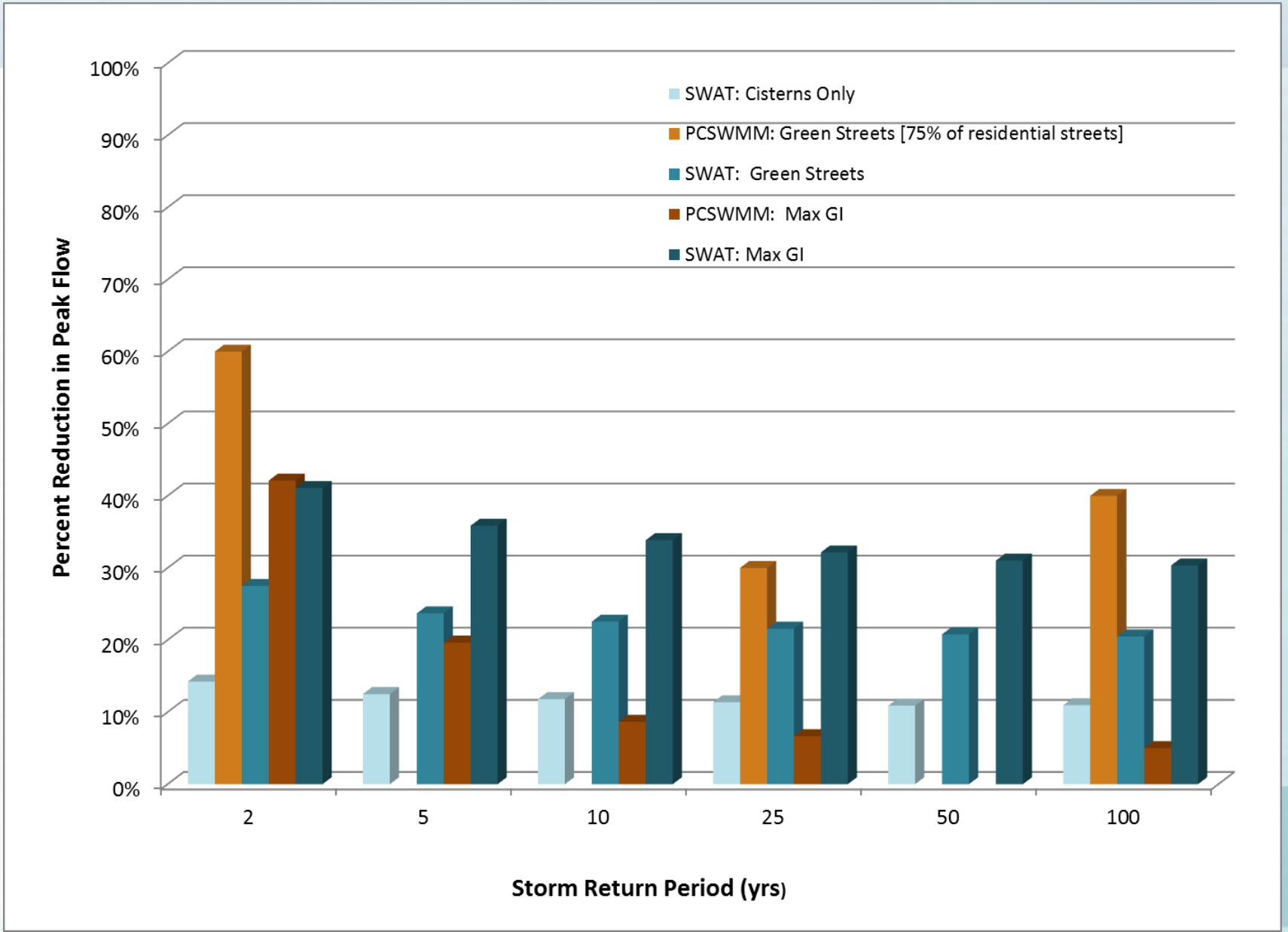
Figure 1
Spatial Extent of Maximum Green Infrastructure Scenario

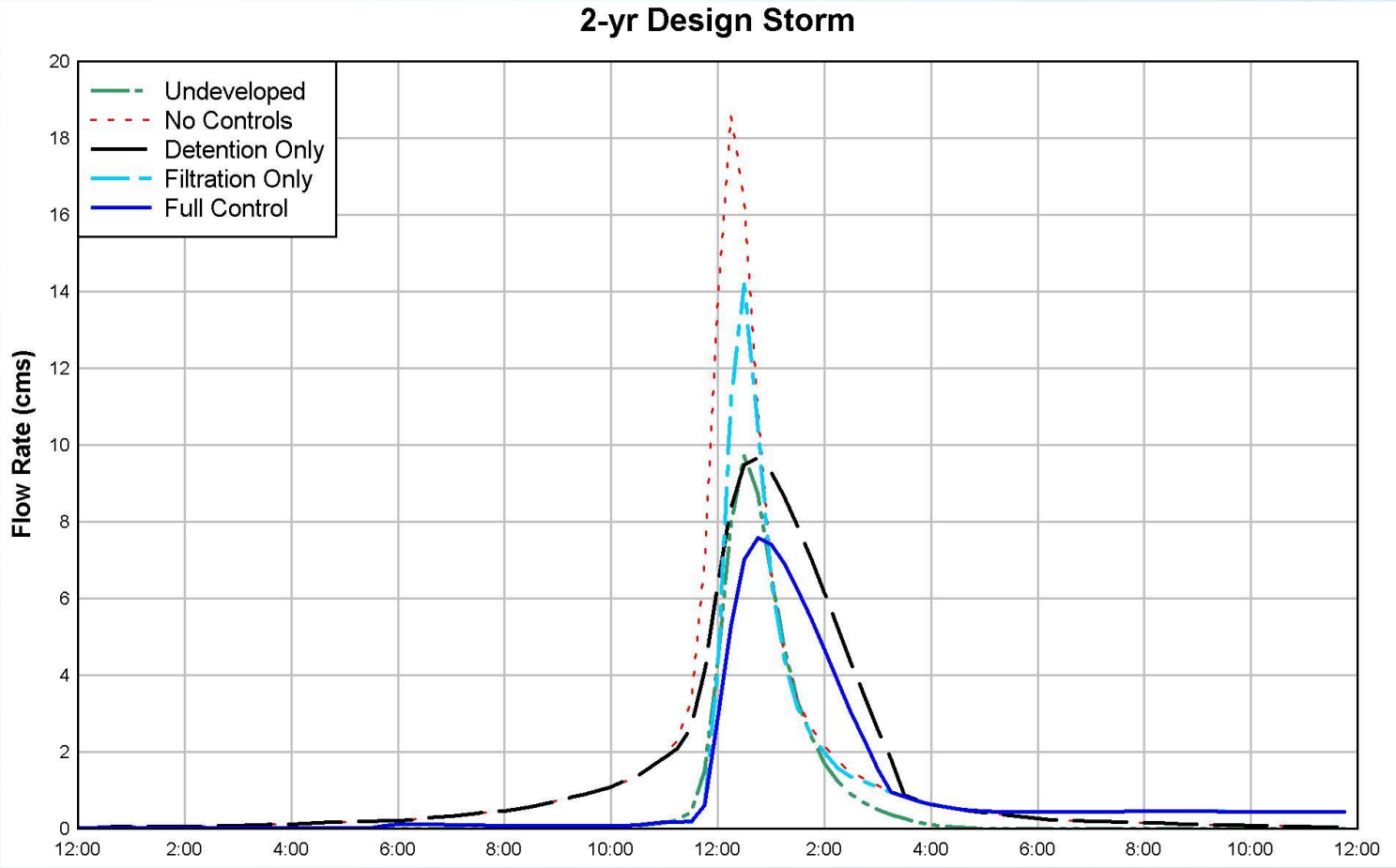

Design Storm Peak Flow Rates at Downstream Site BW1
Peak Flow Rate (cms)
60
50
40
30
20
10
0
PCSWMM: Existing(BW1)
SWAT: Existing (BW1)
SWAT: Cisterns only
SWAT: Green Streets
PCSWMM: Max GI
SWAT: Max GI
1
10
100
Storm Return Period (yrs)

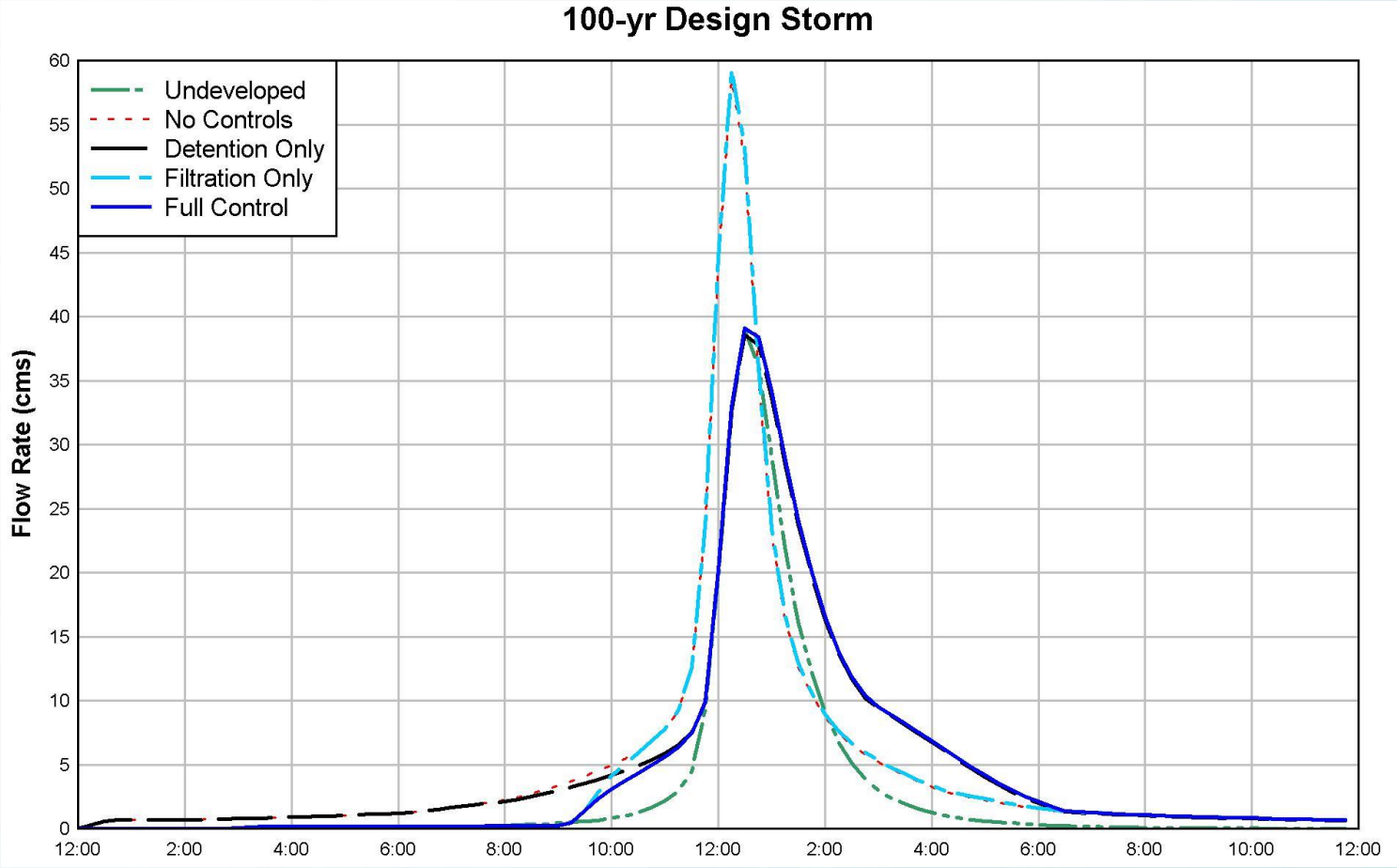
PCSWMM: Brentwood Evaluation Results for Green Streets

- Evaluation of Green Streets (small scale ROW biodetention) to 75% of residential streets (approx. 1 acre of surface area) showed:
  - 50% reduction in average annual flow volume
  - 30-60% reduction in peak flows for smaller storms
  - 40% reduction in peak flows for larger storms

Reductions in Peak Flow




2-yr Design Storm
Undeveloped
No Controls
Detention Only
Filtration Only
Full Control
Flow Rate (cms)
0
2
4
6
8
10
12
14
16
18
20
12:00
2:00
4:00
6:00
8:00
10:00
12:00
2:00
4:00
6:00
8:00
10:00
12:00


100-yr Design Storm
Undeveloped
No Controls
Detention Only
Filtration Only
Full Control
Flow Rate (cms)
60
55
50
45
40
35
30
25
20
15
10
5
0
12:00
2:00
4:00
6:00
8:00
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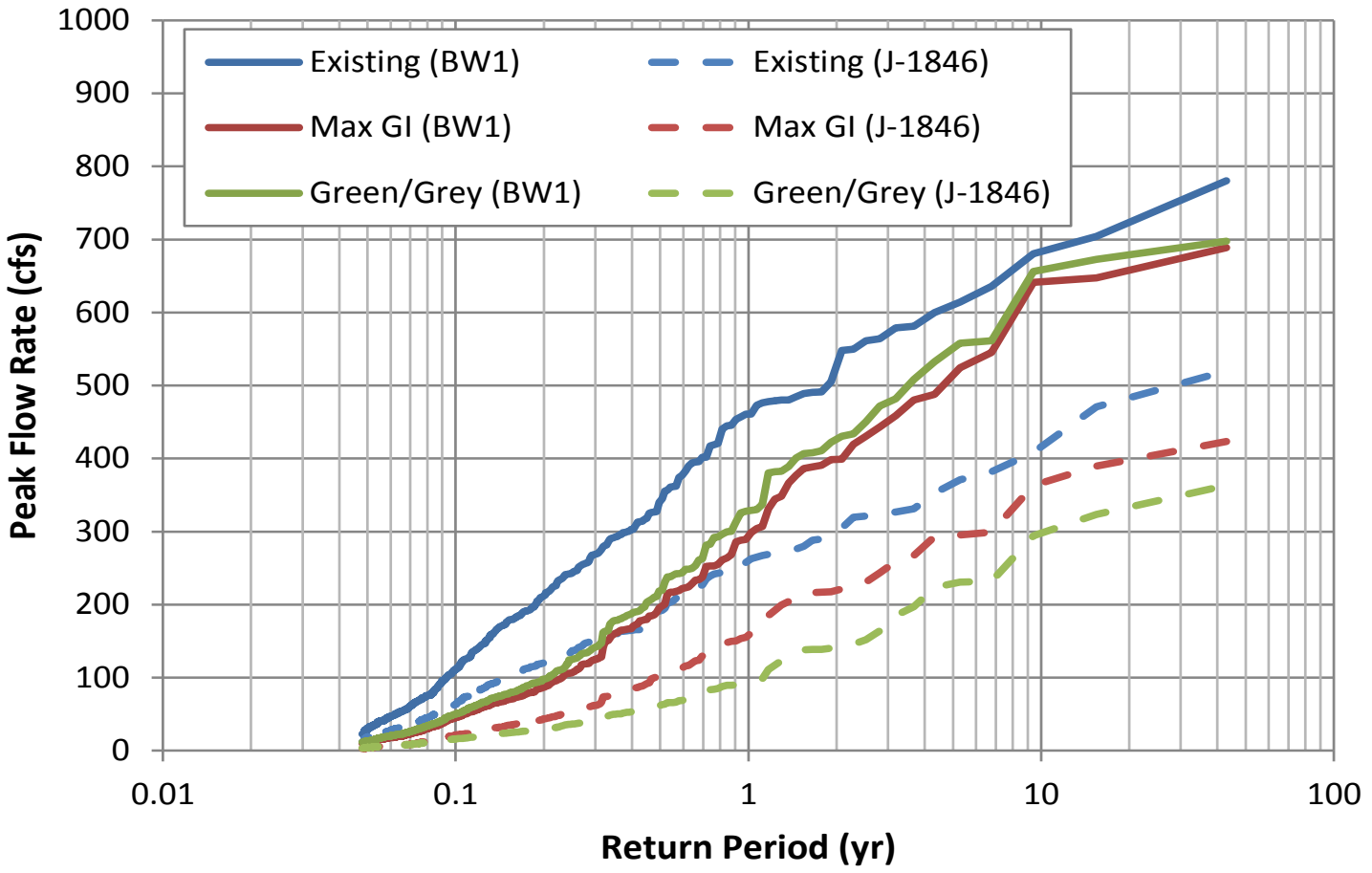
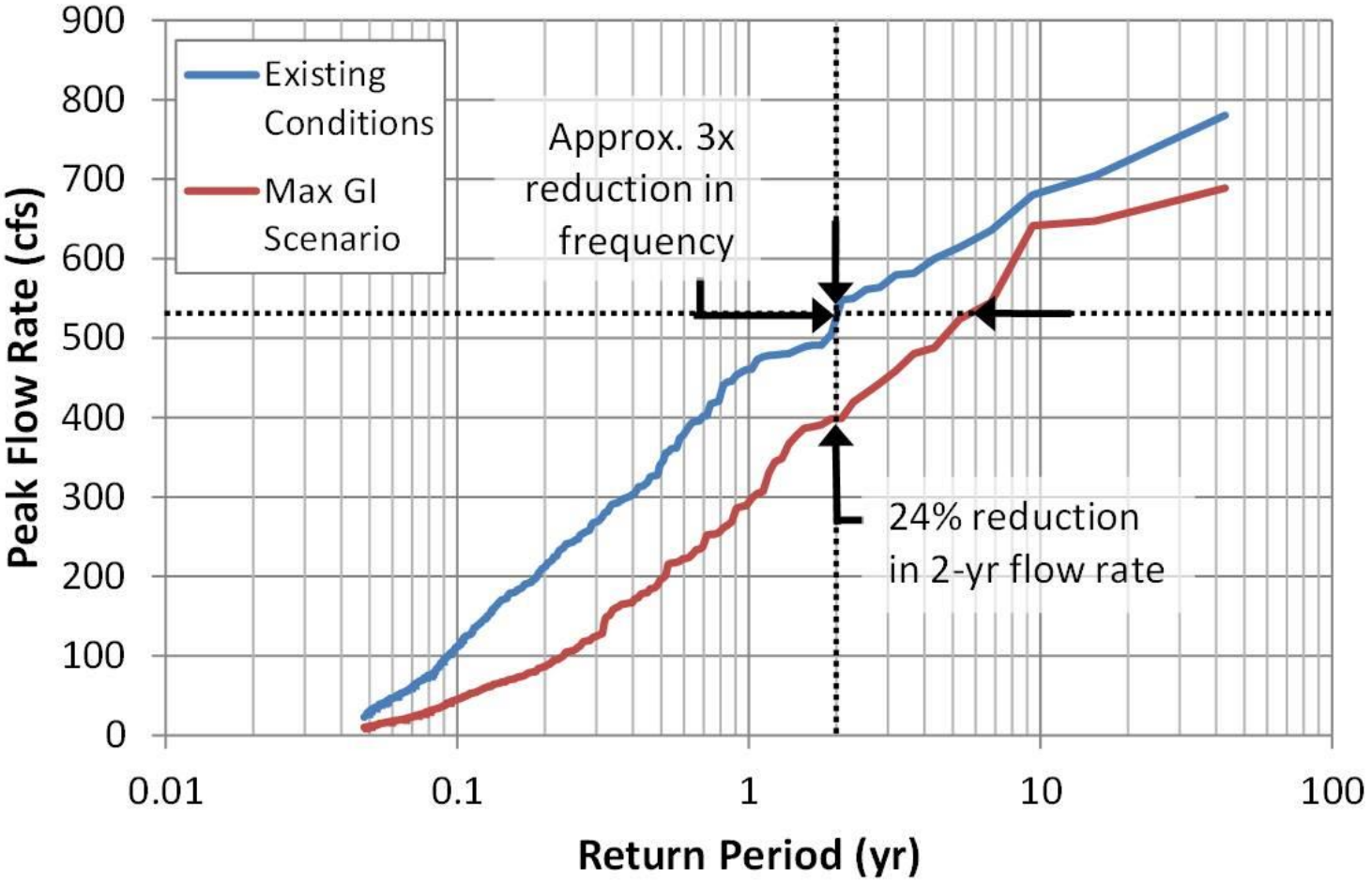
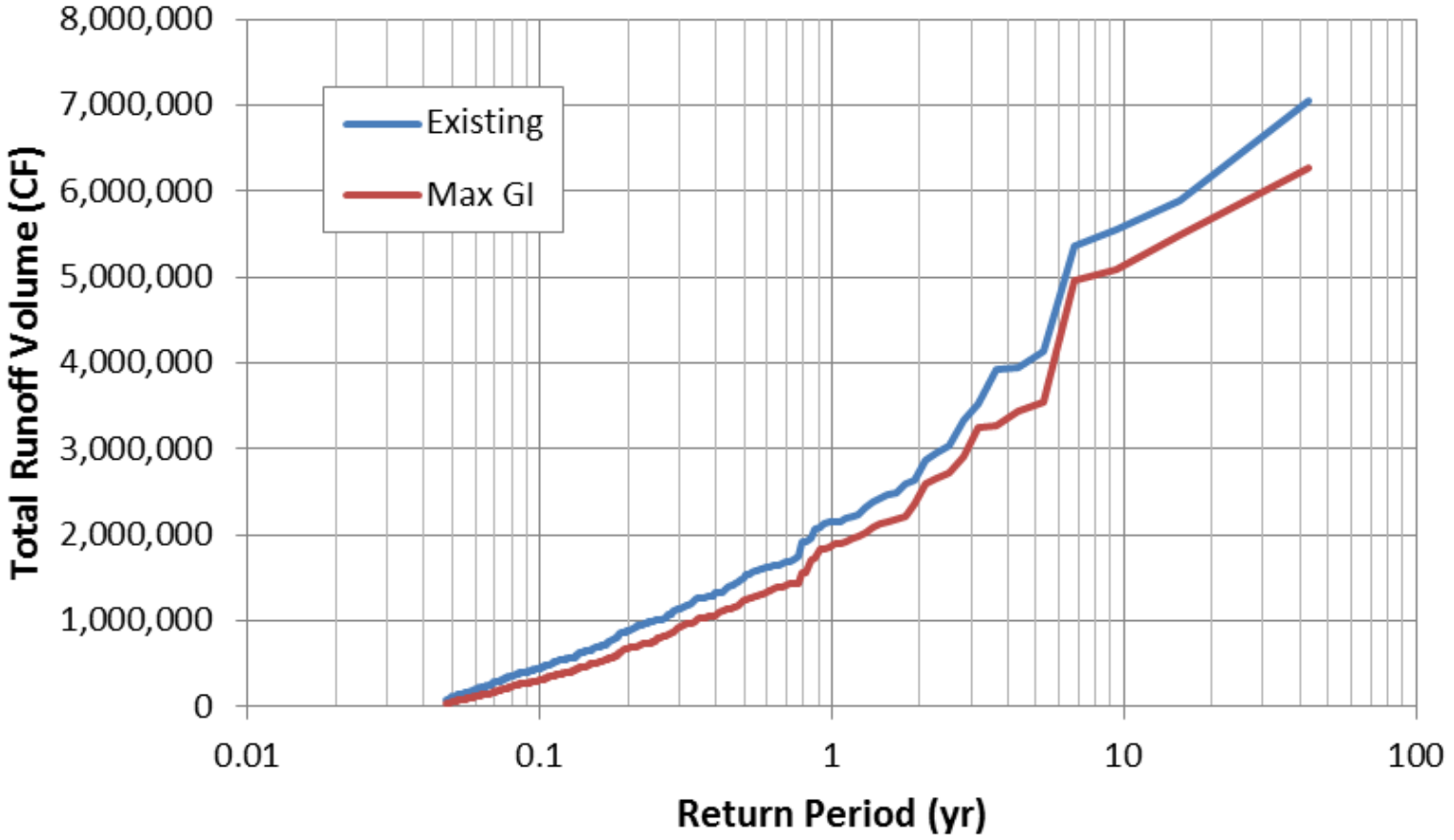


1D Continuous Simulation Peak Flow Rates at Watershed Outlet (BW1) and Interior Node (J-1846 in Channel North of Arcadia Ave)

Peak Flow vs. Return Period at Station BW1



Brentwood Flow Volume Reduction



Result: Identify opportunities for the application of green infrastructure in COA-sponsored retrofits, private development and voluntary homeowner projects

- Brentwood Study: Model large-scale application of decentralized GSI to assess impacts on flooding and WQ.
  - Significant Local Flood reduction for smaller (< 10 yr RI storms)\ Recent severe flooding
  - Expected construction cost of $15-$20 million
  - Level of Service assessment to be determined

Green Infrastructure: Implementation and long-term maintenance constraints

- Implementation constraints
  - Due to small volume, difficult to provide significant flood reduction benefit
  - Cost effectiveness for WQ is > $10/ lb. TSS for CIP; larger regional controls average < $3/lb. TSS.
- Maintenance constraints
  - Maintenance not complicated but requires more frequent inspection (2x/year min)
  - Small obstructions at inlet can cause bypass
  - Inability to track maintenance and upkeep of SF residential

Conclusions

- SWAT and PC SWMM model the urban landscape well.
- LID/GI Routines in SWAT physically simulate the changes in urban hydrology.
- LID/GI are part of the tool set to solve urban hydrological problems but are not magic.

Questions?

Questions?

Questions?