Modelling LIDs using PCSWMM and EPA SWMM5

March 28, 2012

Presented by: Rob James (CHI)

Credit to: Lewis Rossman (US EPA)

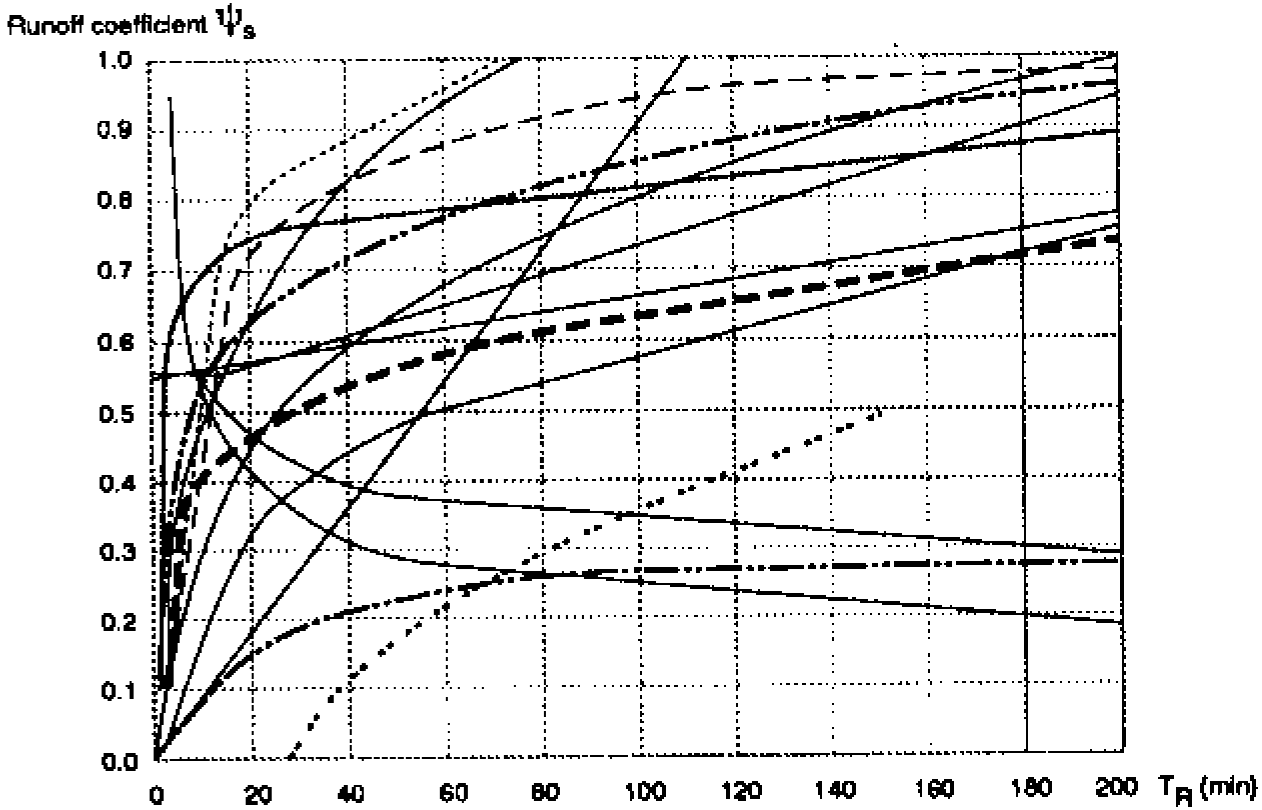
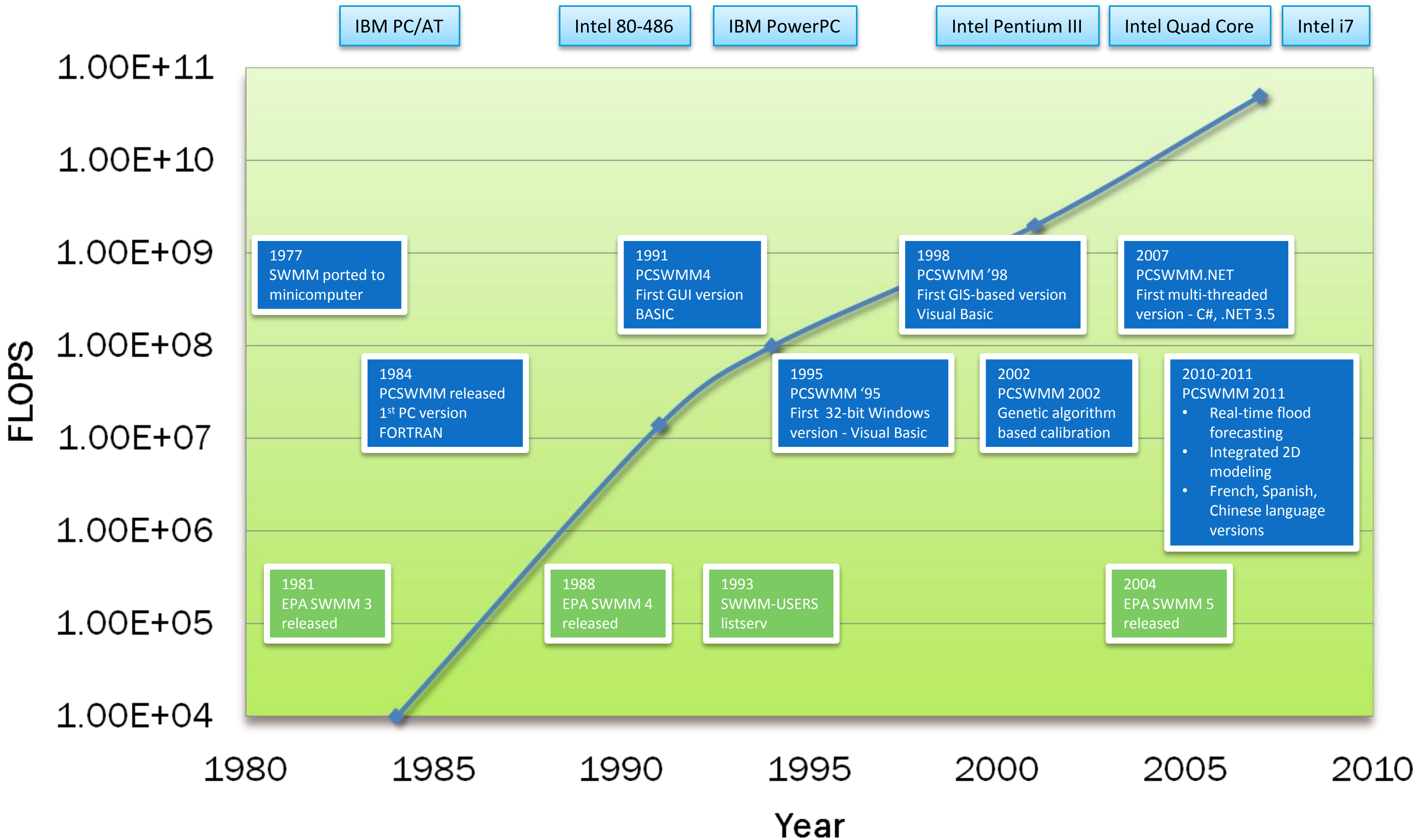


FIGURE 2.1
Runoff coefficient as function of the duration of rain, according to a study by Pecher.



IBM PC/AT
Intel 80-486
IBM PowerPC
Intel Pentium III
Intel Quad Core
Intel i7
1.00E+11
1.00E+10
1.00E+09
1.00E+08
1.00E+07
1.00E+06
1.00E+05
1.00E+04
FLOPS
1977 SWMM ported to minicomputer
1984 PCSWMM released 1st PC version FORTRAN
1981 EPA SWMM 3 released
1988 EPA SWMM 4 released
1991 PCSWMM4 First GUI version BASIC
1993 SWMM-USERS listserv
1995 PCSWMM ‘95 First 32-bit Windows version - Visual Basic
1998 PCSWMM ’98 First GIS-based version Visual Basic
2002 PCSWMM 2002 Genetic algorithm based calibration
2004 EPA SWMM 5 released
2007 PCSWMM.NET First multi-threaded version - C#, .NET 3.5
2010-2011 PCSWMM 2011
• Real-time flood forecasting
• Integrated 2D modeling
• French, Spanish, Chinese language versions
1980
1985
1990
1995
2000
2005
2010
Year

Processing power increase over the history of PCSWMM

100,000,000

TIMES

PCSWMM`s computational grid at CHI

1,000,000,000,000,000

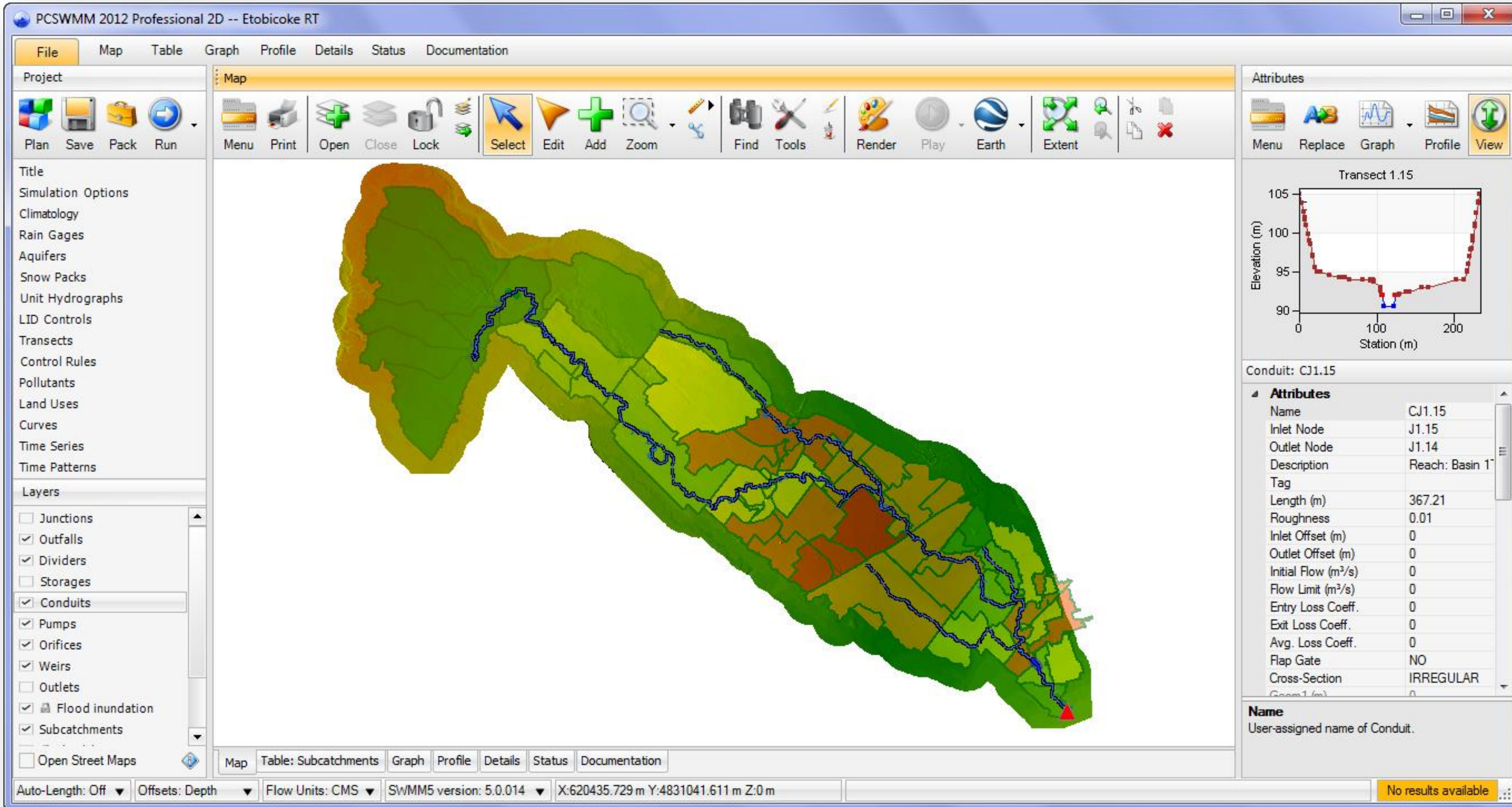
FLOPS

So how much is 1 trillion floating point operations?

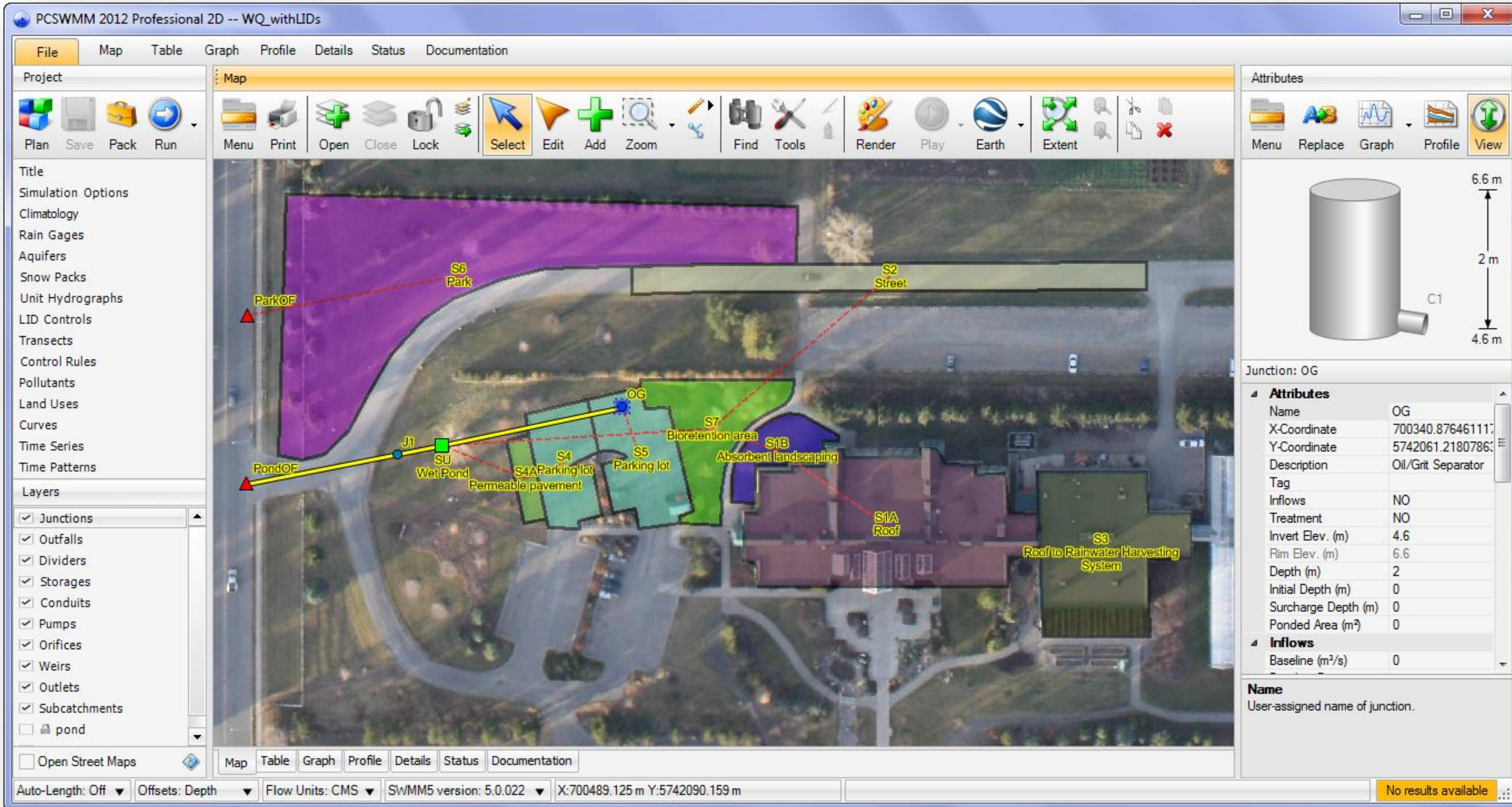
$$1 \times 60\text{s} \times 60\text{m} \times 2100\text{h} \times 40\text{y}$$

$$\frac{302{,}400{,}000}{1{,}000{,}000{,}000{,}000} = 0.03\%$$

PCSWMM: Spatial DSS for EPA SWMM5



PCSWMM: Spatial DSS for EPA SWMM5



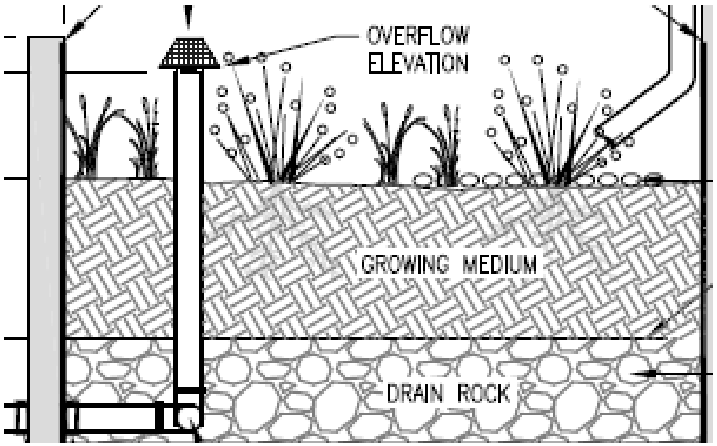
PCSWMM/SWMM5 LID toolbox

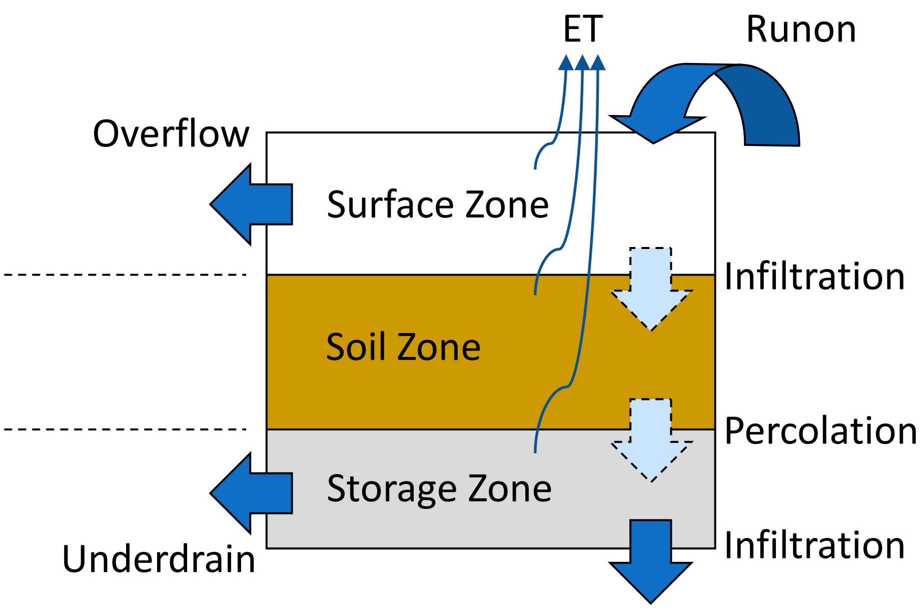
- Physically-based processes
- Flexible components
- SWMM Version 5.0.022
- Simplifies the modeling of:
  - Lot level implementations
  - Watershed scale or city master planning
  - Single event
  - Continuous
  - Performance degradation

Examples of SWMM5 LID controls

EPA SWMM5 LID toolkit: follows the methodology of PCSWMM for PP

Conceptual Model of an LID Process



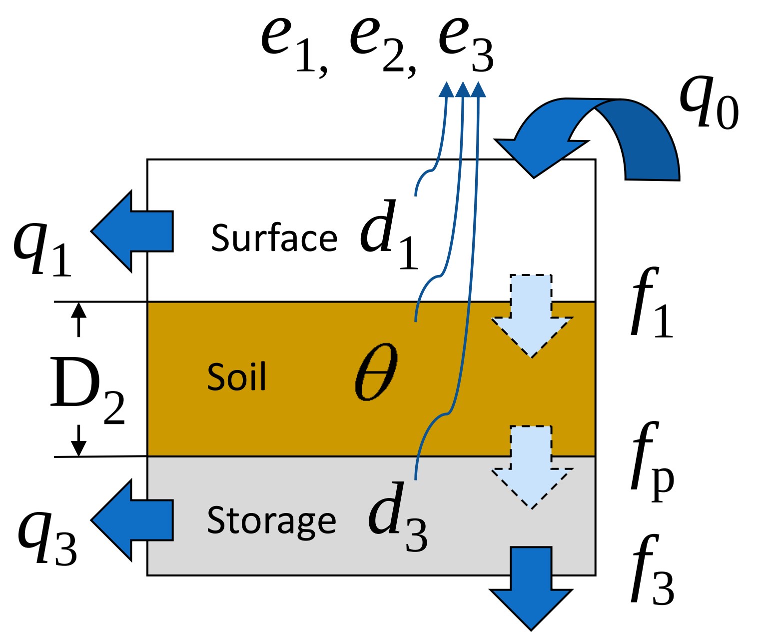


Flow Balance Equations

$$\frac{\partial d_1}{\partial t} = q_0 - e_1 - f_1 - q_1$$

$$D_2 \frac{\partial \theta}{\partial t} = f_1 - e_2 - f_p$$

$$\phi \frac{\partial d_3}{\partial t} = f_p - e_3 - f_3 - q_3$$

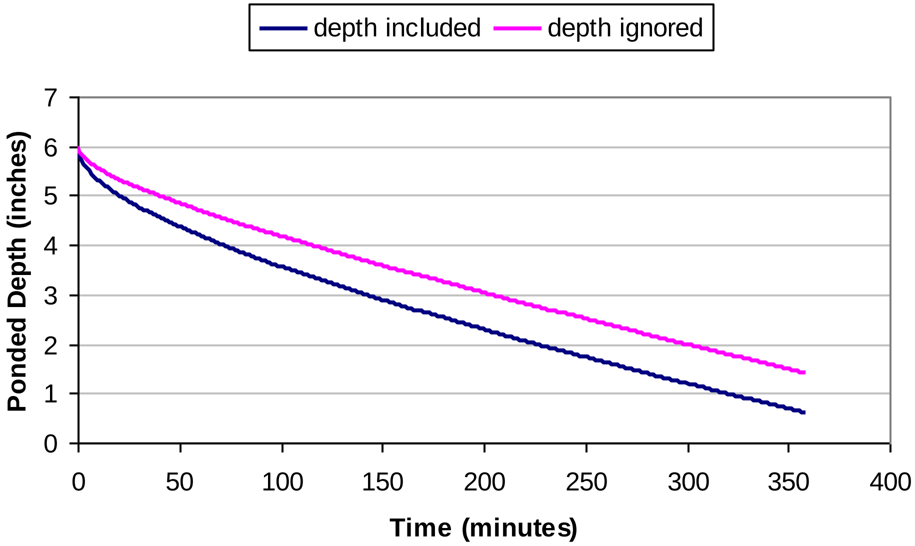


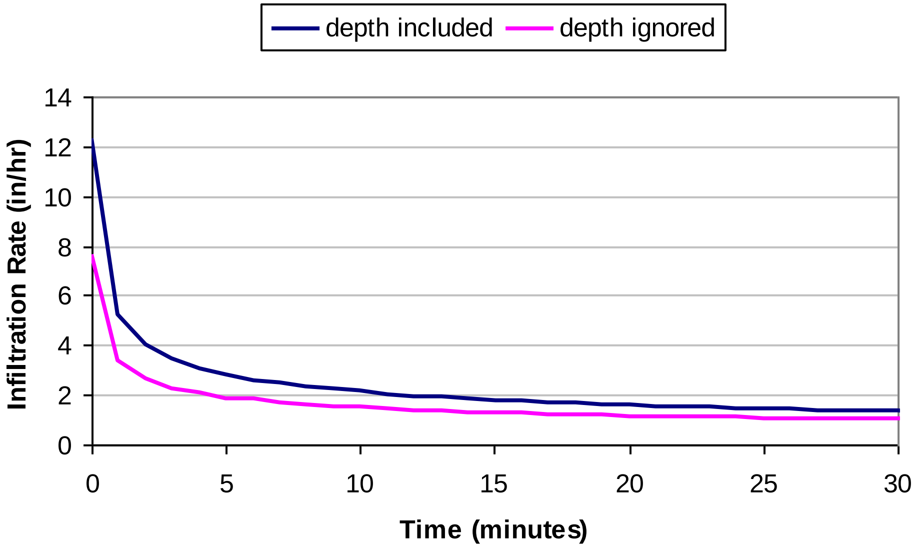
Infiltration Flux

Classical Green-Ampt Eqn:
(depth d is normally ignored)

$$f = K_{sat}\left(1 + \frac{(\phi - \theta)(d + \psi)}{F}\right)$$

Effect of ponded depth (d) on infiltration rate (K_{sat} = 0.5 in/hr)





Percolation Flux

Rate of percolation (f_p) through the unsaturated soil zone as a function of moisture content (θ) is described by Darcy's Law:

$$f_p = K(\theta)\left(1 + \frac{\psi(\theta)}{D}\right)$$

$$K = K_{sat}\exp(-(\phi - \theta)HCO)$$

$$\psi = 135\exp(-(\theta - \theta_{FC})PCO)$$

K = hydraulic conductivity, ψ = capillary tension, ϕ = porosity, θ_{FC} = field capacity, and HCO and PCO are coefficients.

Outflow Fluxes

- Flux rates are functions of zone's water depth (d)
- Surface zone
  - Overland flow using Manning's formula

    $Q = (1.49/n)AR^{2/3}S^{1/2}$ where A and R depend on d

  - Overflow using the weir equation

    $Q = C_W L(d)^{1.5}$

- Storage zone underdrain flow

    $Q = C_D(d)^{\eta}$

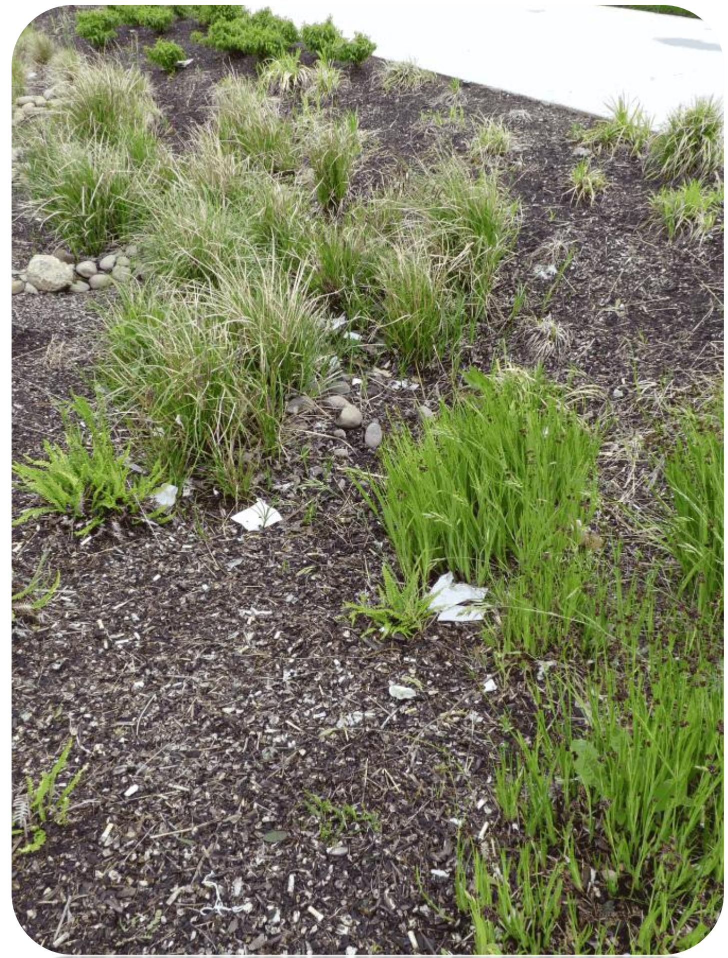
    n = Manning's roughness, A = flow area, R = hyd. radius, S = surface slope, L = length of weir crest, and C_w, C_D, and η are coefficients.

Representing Different LID Alternatives

LID Alternative	Zones	Processes (besides ET)
Rain Barrel	Surface, Storage	Surface Overflow Storage Underdrain Flow
Porous Pavement	Surface, Storage	Surface Overland Flow Storage Infiltration*
Infiltration Trench	Surface, Storage	Surface Overflow Storage Infiltration
Vegetative Swale	Surface	Surface Overland Flow Surface Infiltration
Bioretention Cell	Surface, Soil, Storage	Surface Overflow Soil Infiltration Soil Percolation Storage Infiltration*

*May also include storage underdrain flow

Bio-retention cell – ‘Street Planter’



LID example: Valleyfield, PQ

- New residential development to include 22 boulevard planters
- Reduce minor system inflow
- Reduce pollutant loading

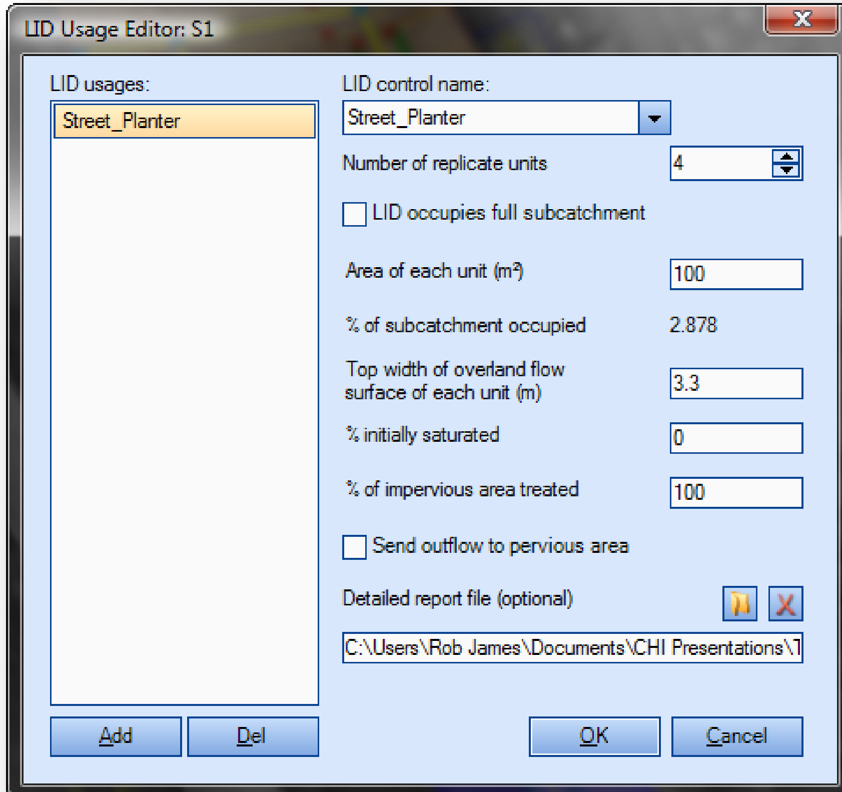
Boulevard Planters

Alternate designs

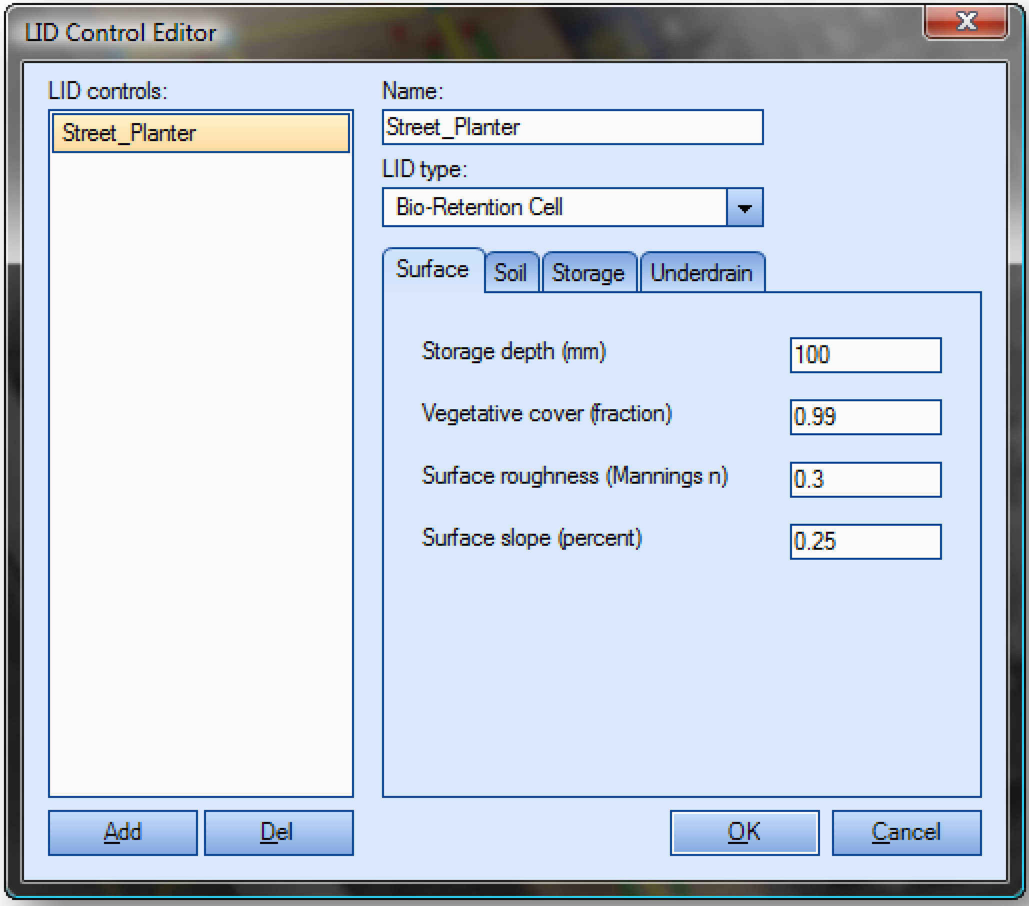
Valleyfield, Quebec – LID retrofit example

Bio-retention cell to be installed in typical residential neighbourhood

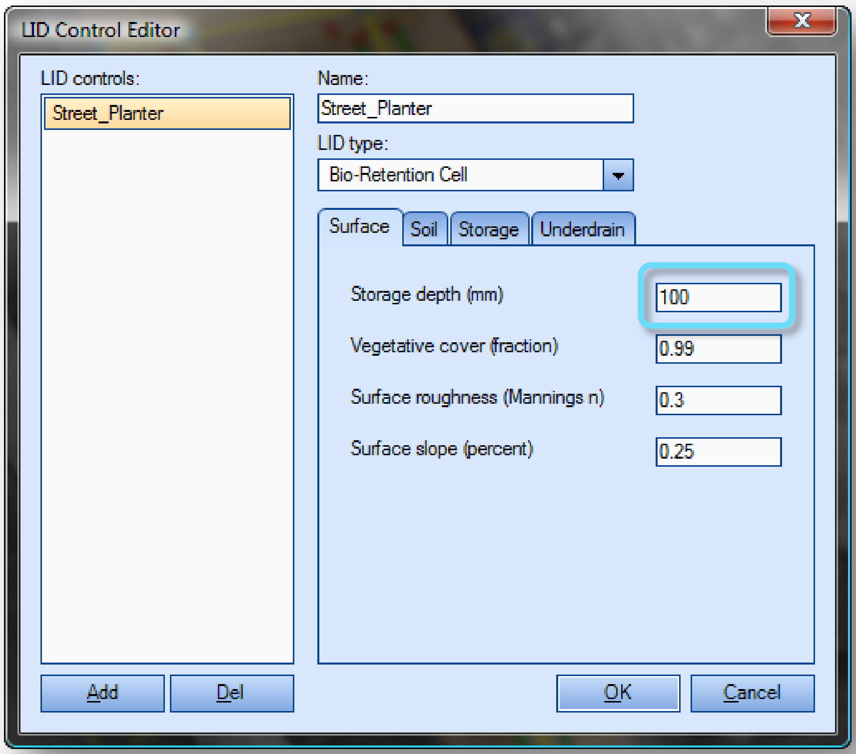
PCSWMM LID representation



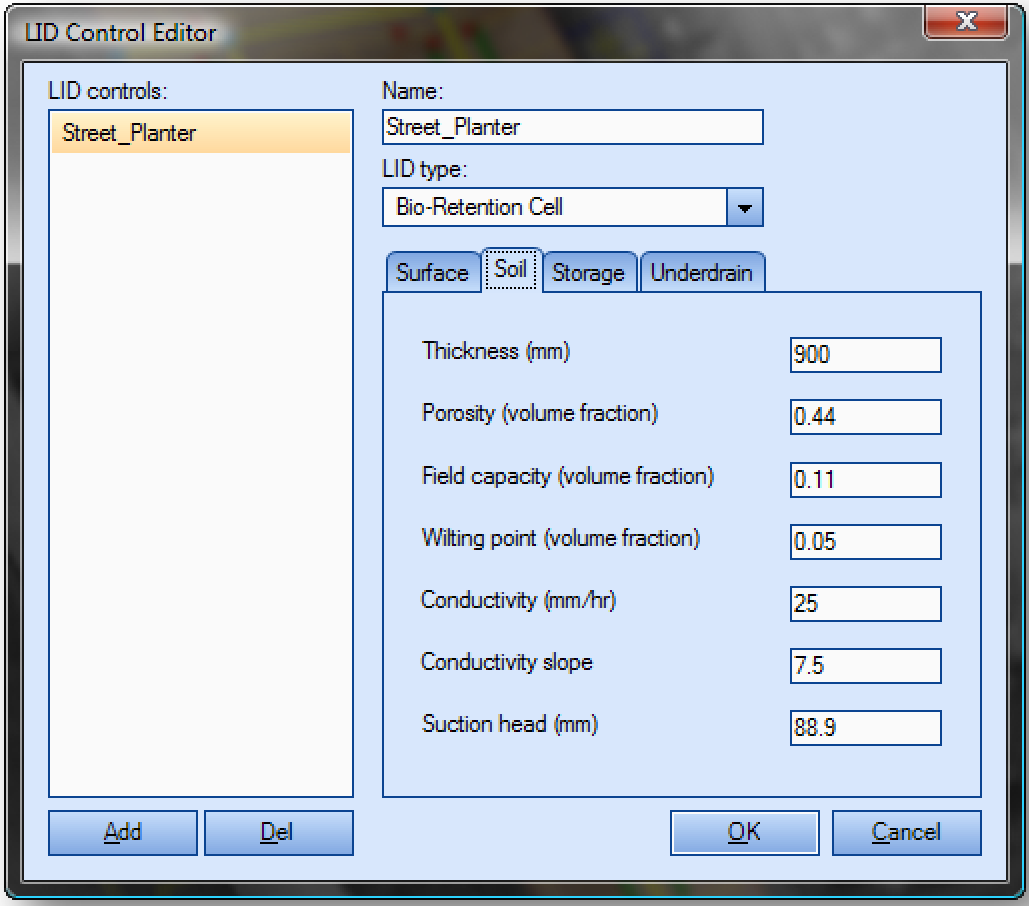
PCSWMM LID representation: surface



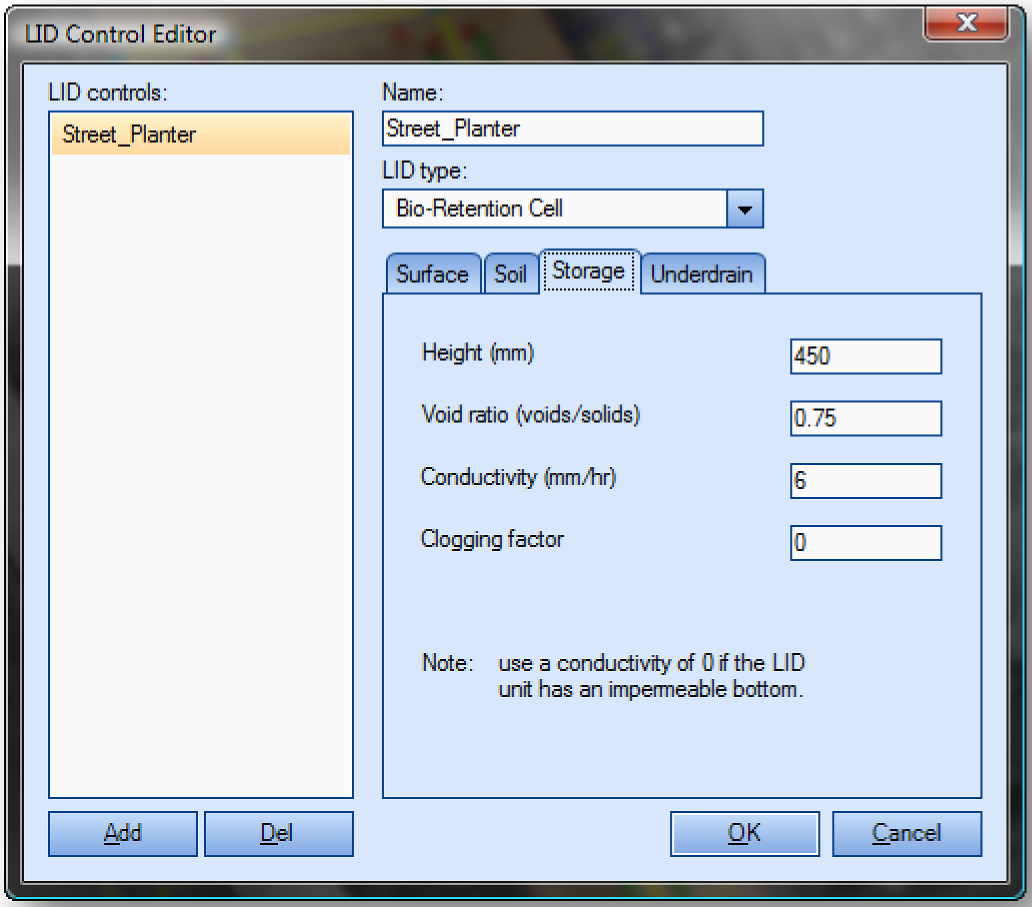
PCSWMM LID representation: surface storage



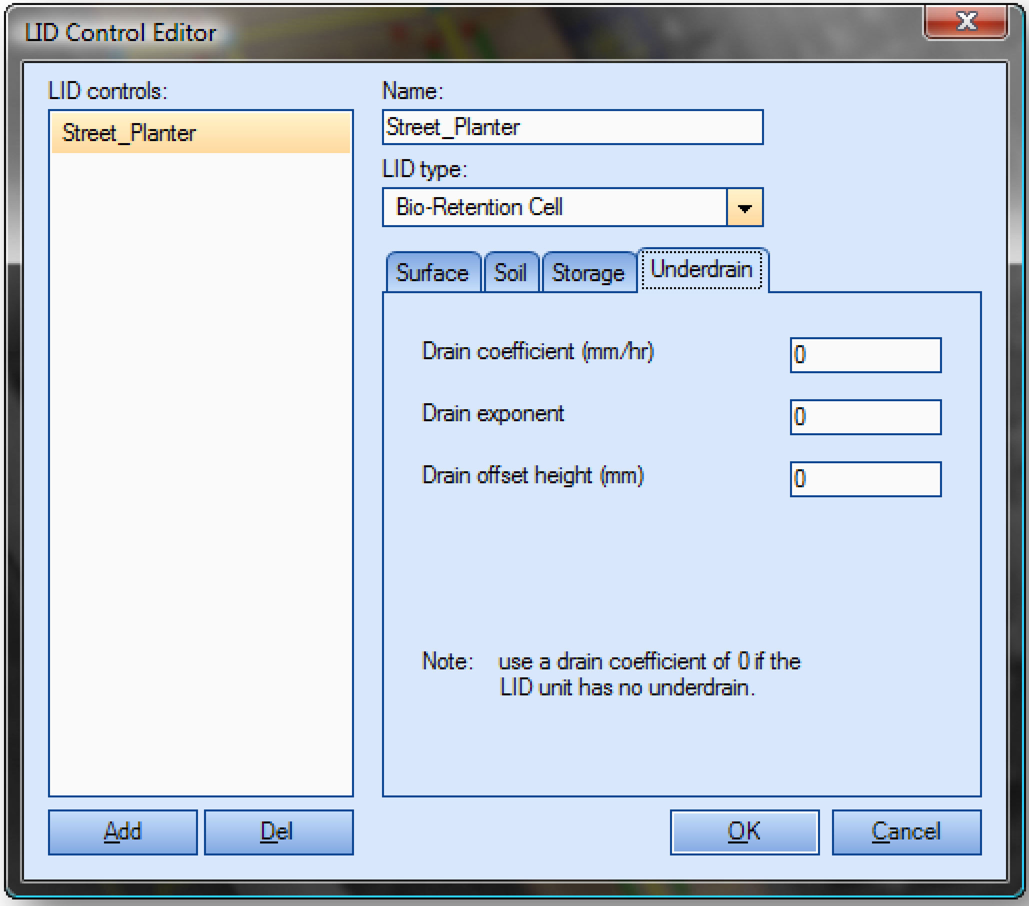
PCSWMM LID representation: soil



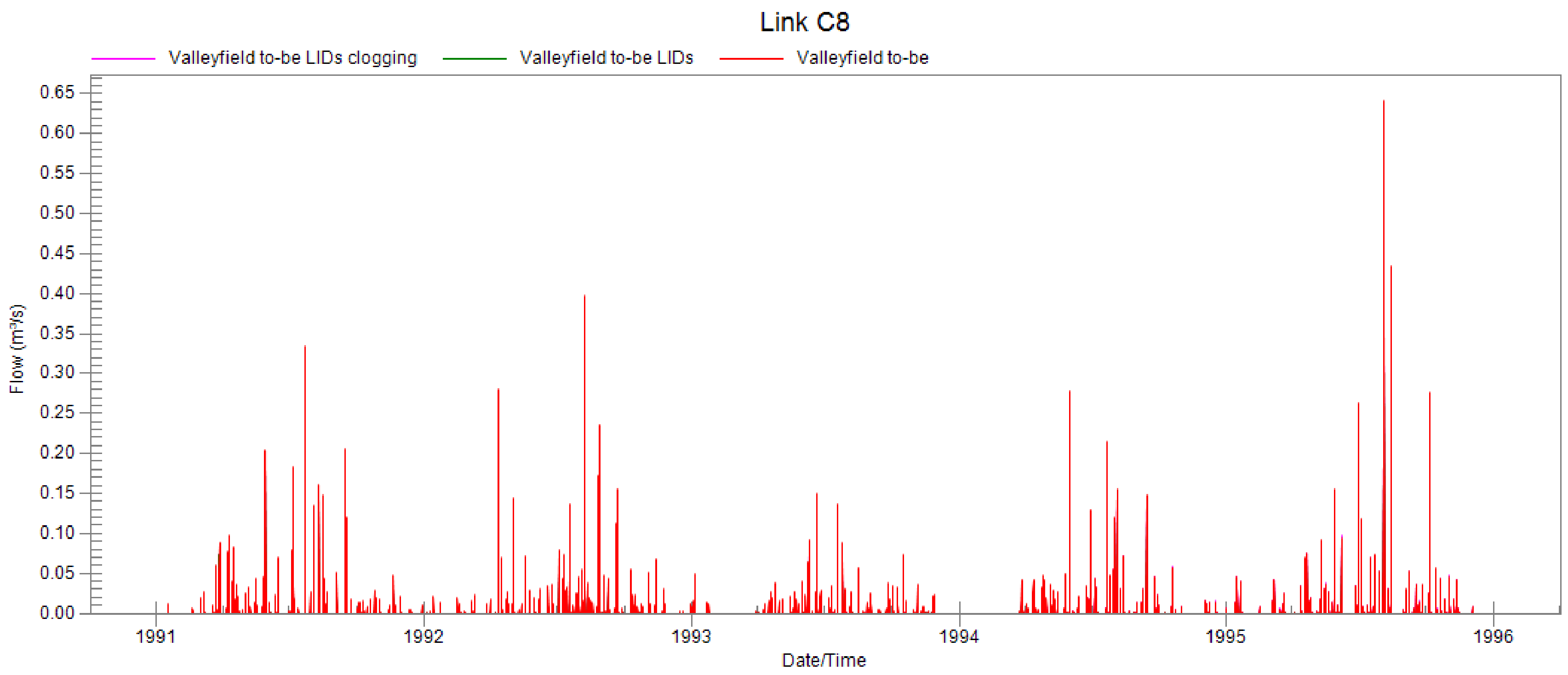
PCSWMM LID representation: storage



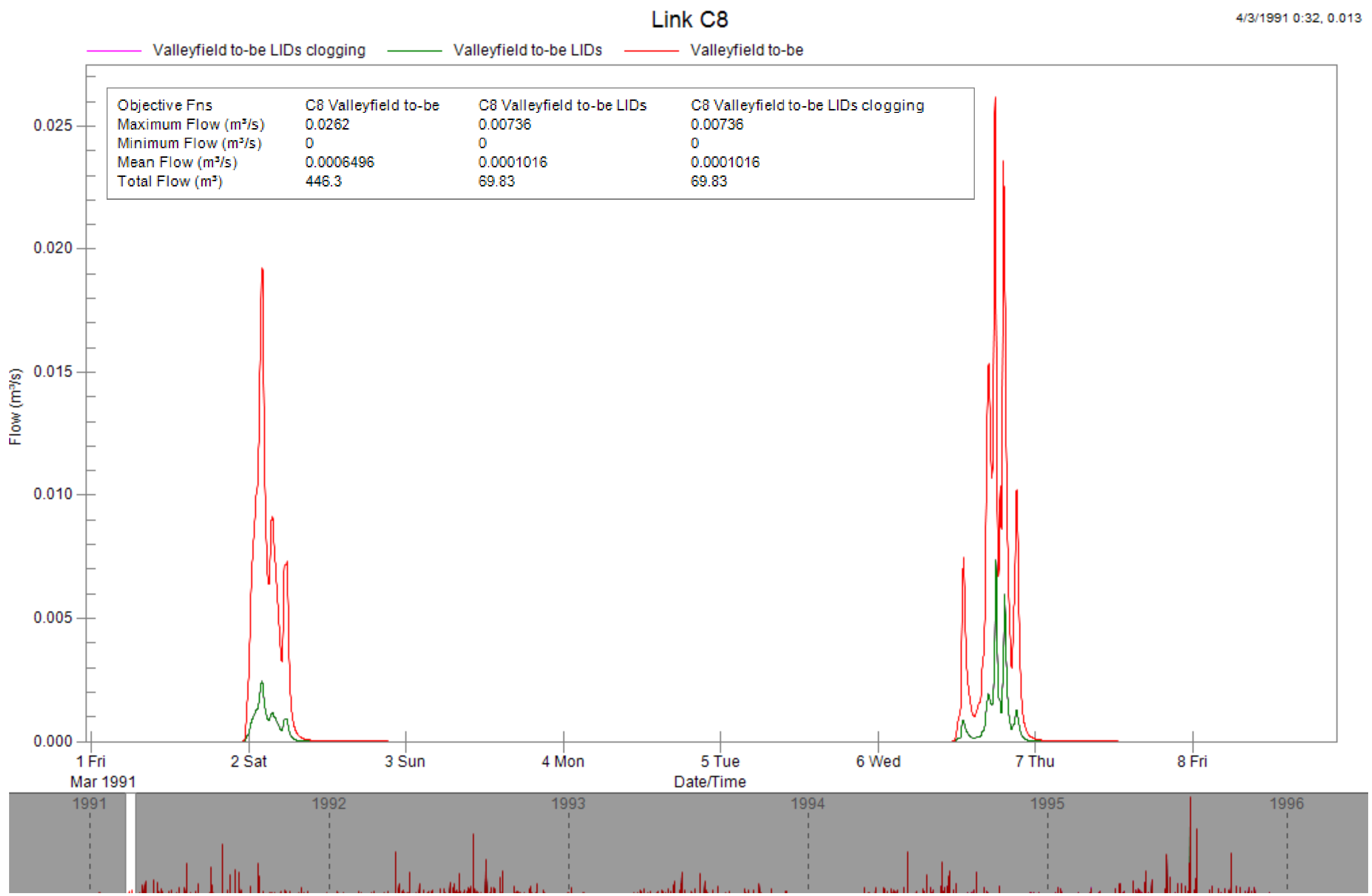
PCSWMM LID representation: tile drain



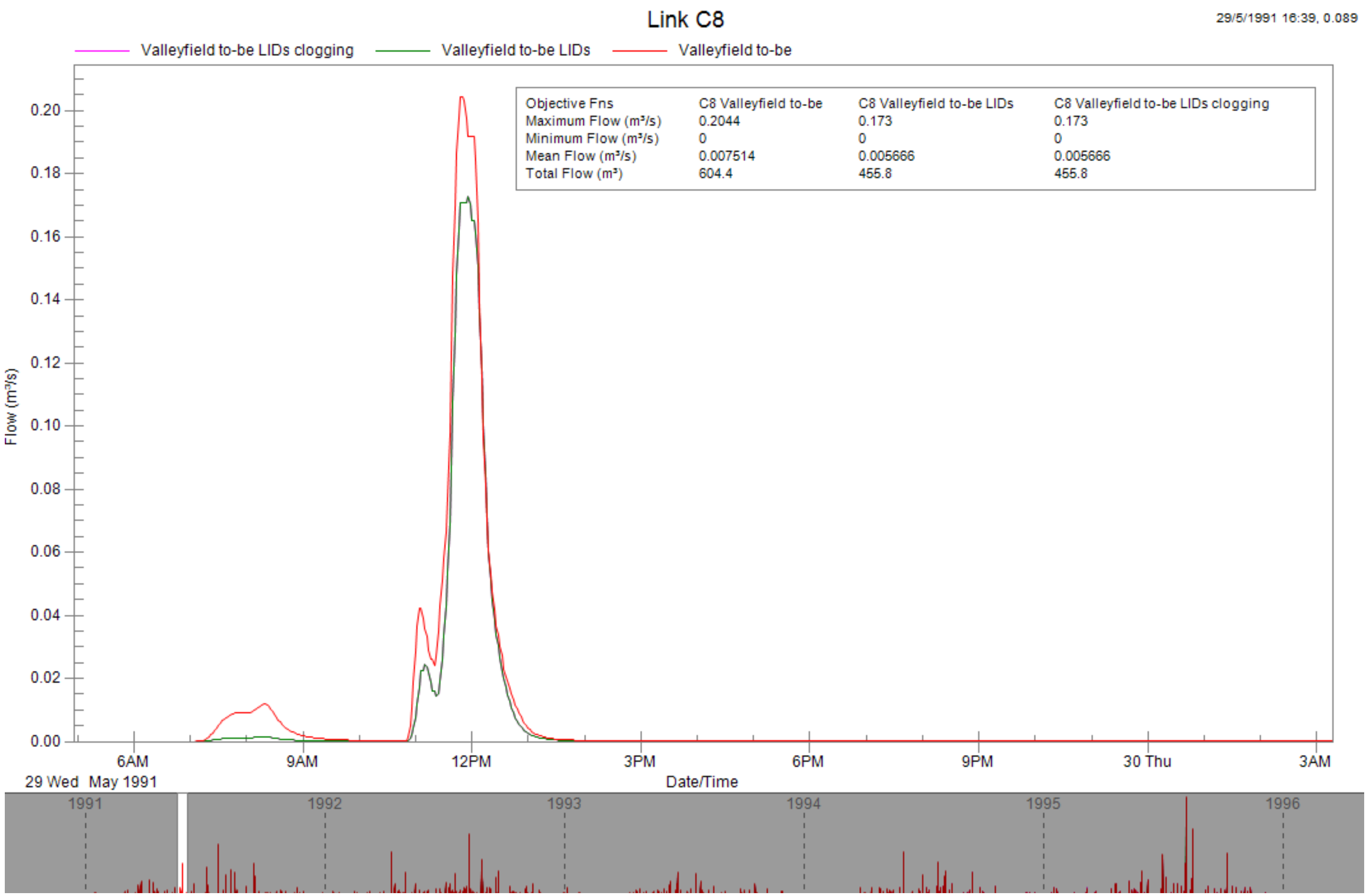
Continuous LID analysis



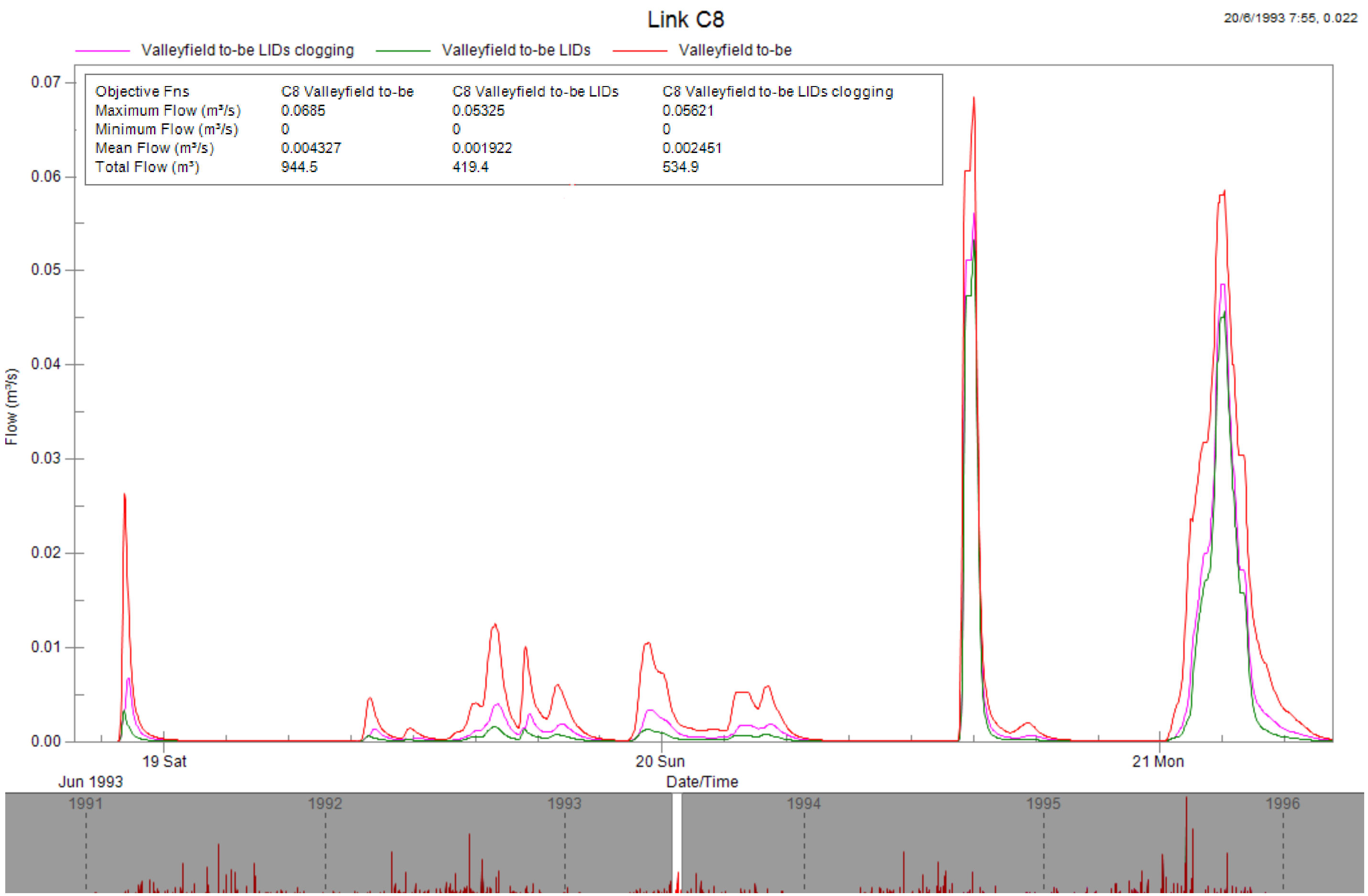
Continuous LID analysis: small events



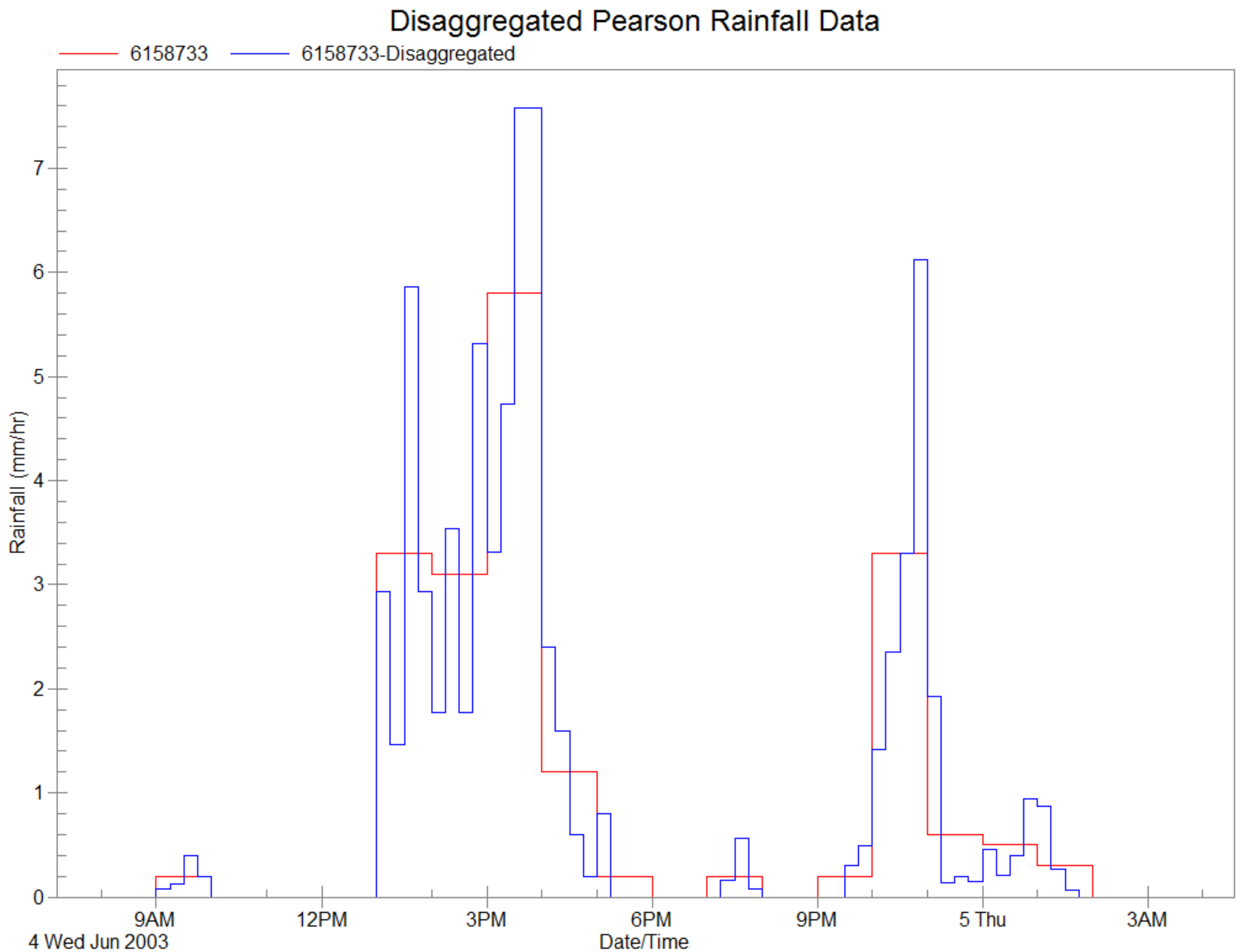
Continuous LID analysis: large events



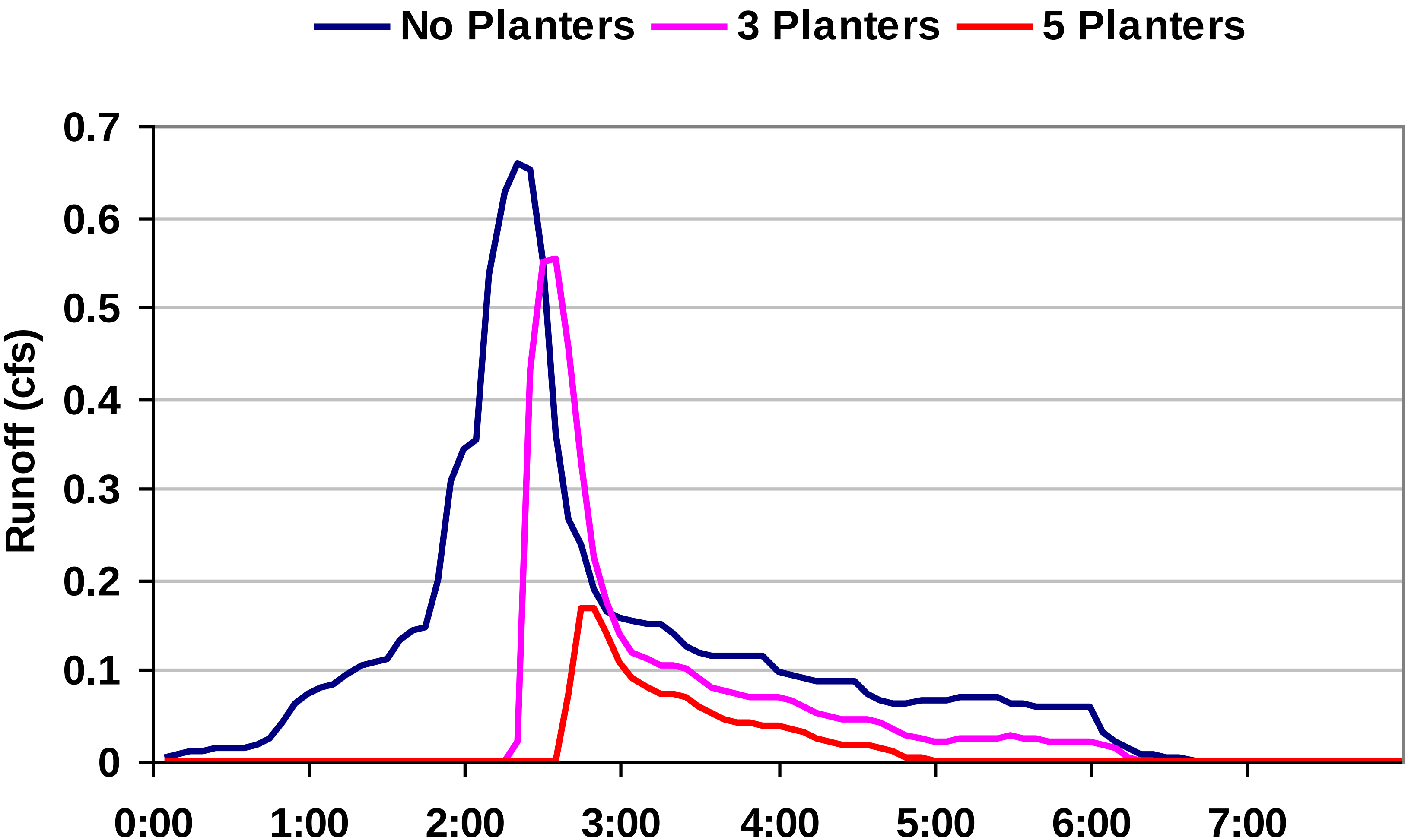
Continuous LID analysis: clogging potential



Enabling continuous LID analysis: Rainfall Processing with PCSWMM

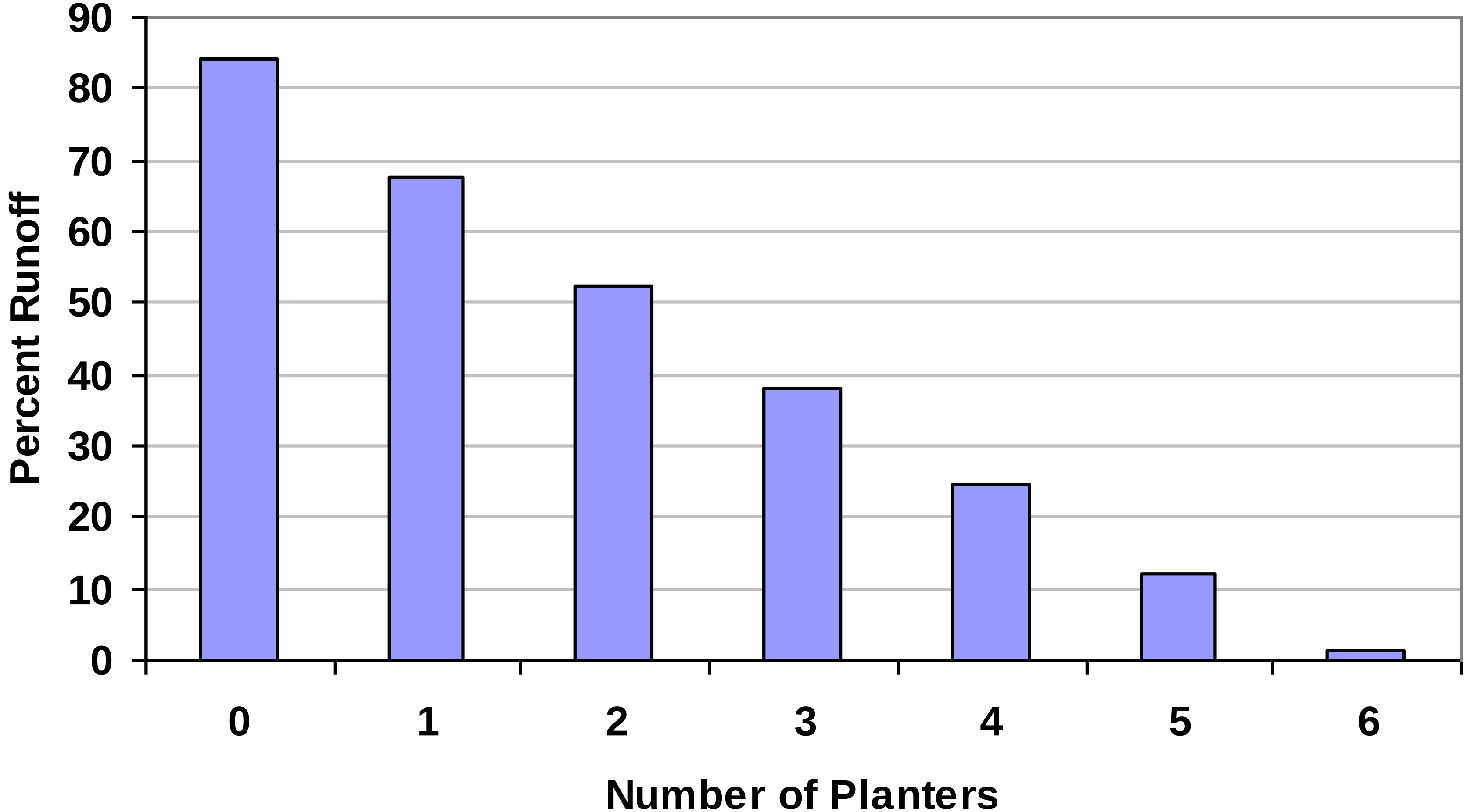


Runoff for 1-inch, 6-hr Event



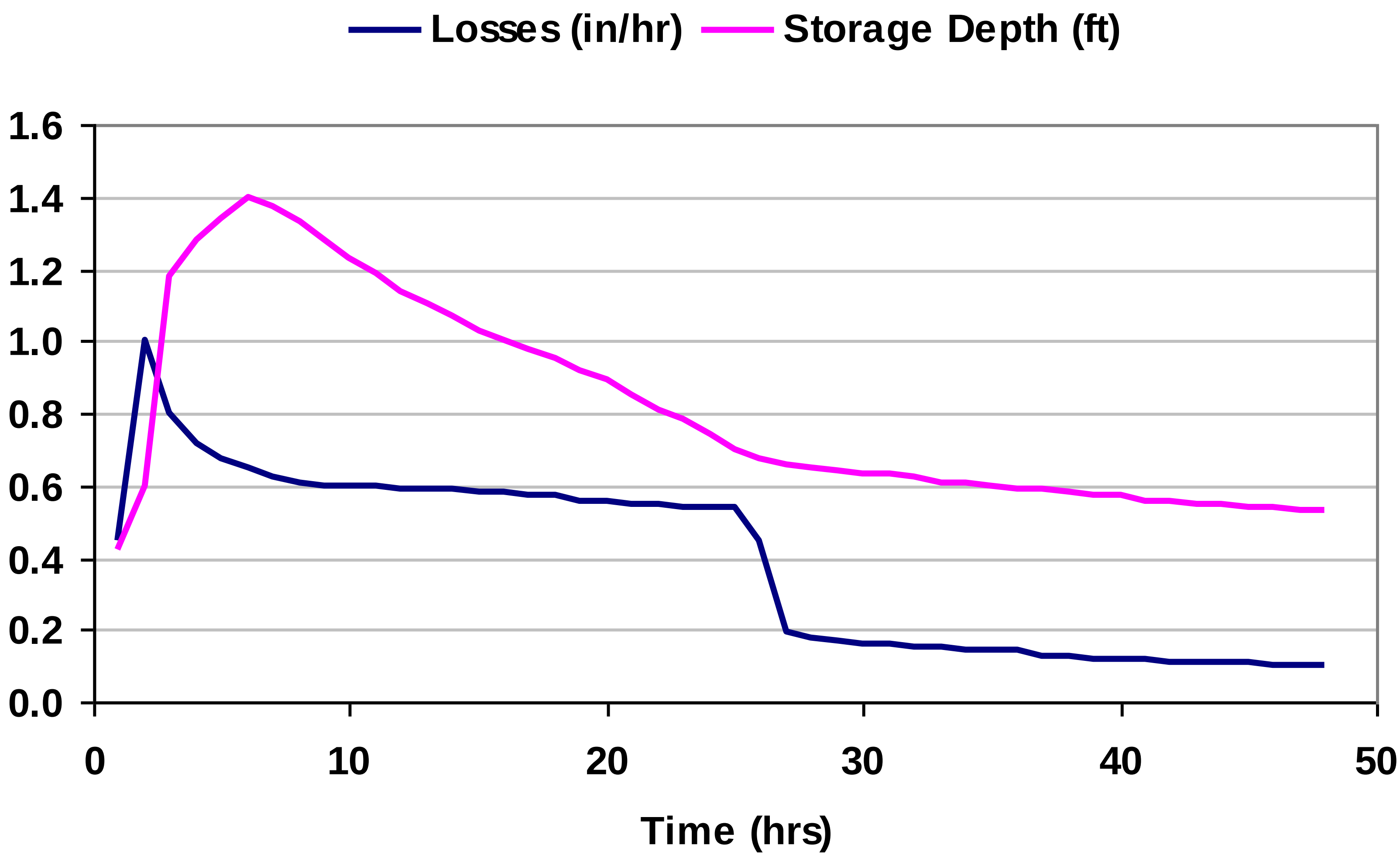
Rossman (2009)

Effect of Number of Planters



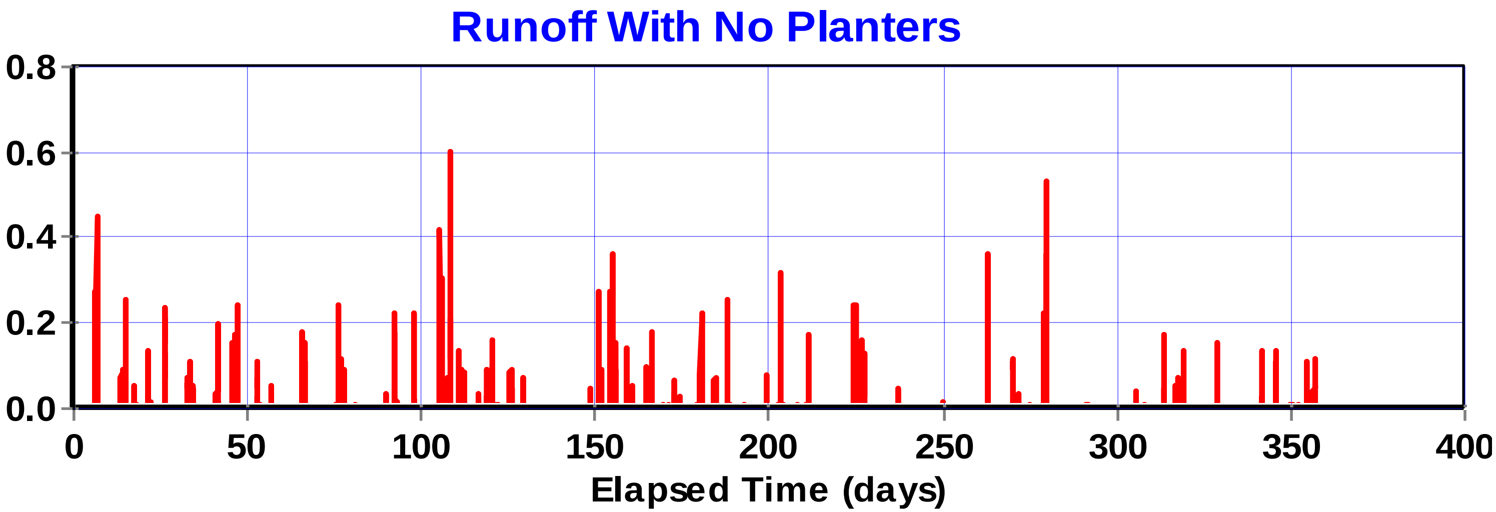
Rossman (2009)

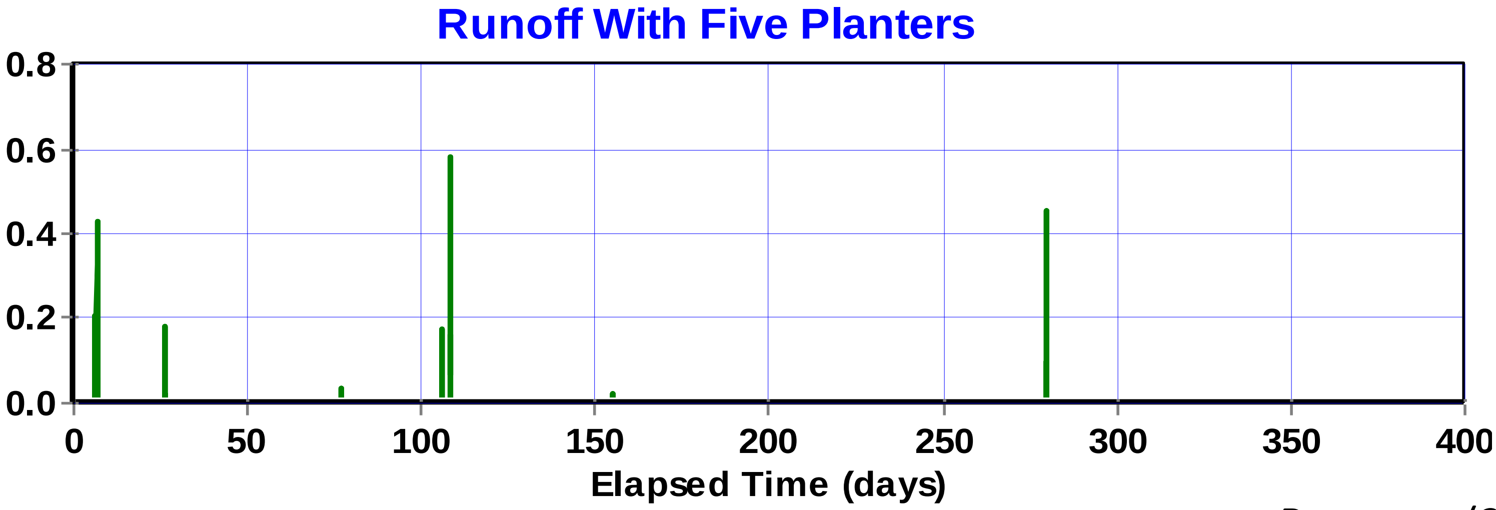
Loss of Stored Water Over Time



Rossman (2009)

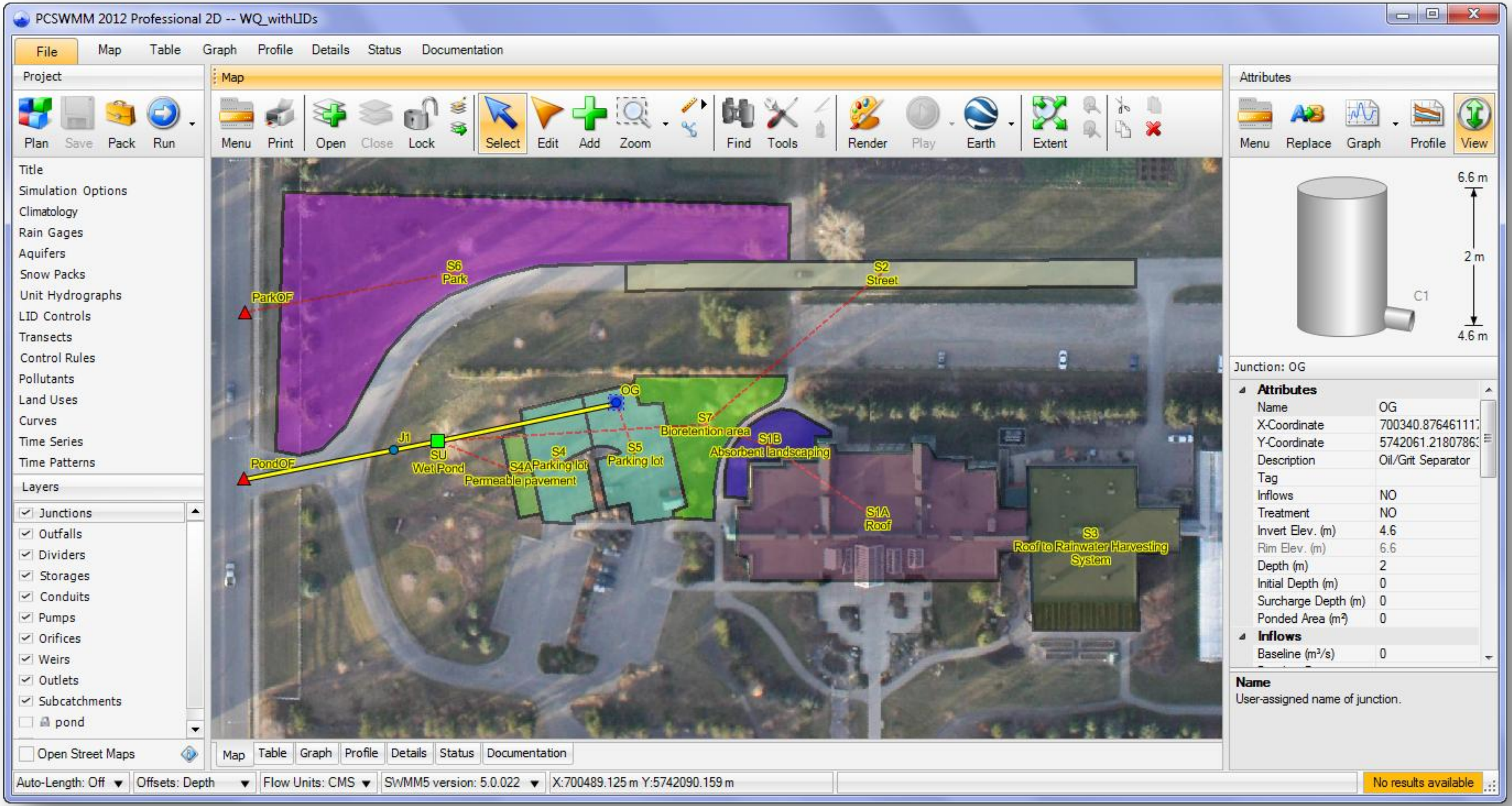
Long Term Performance





Rossman (2009)

Olds College Demonstration Project

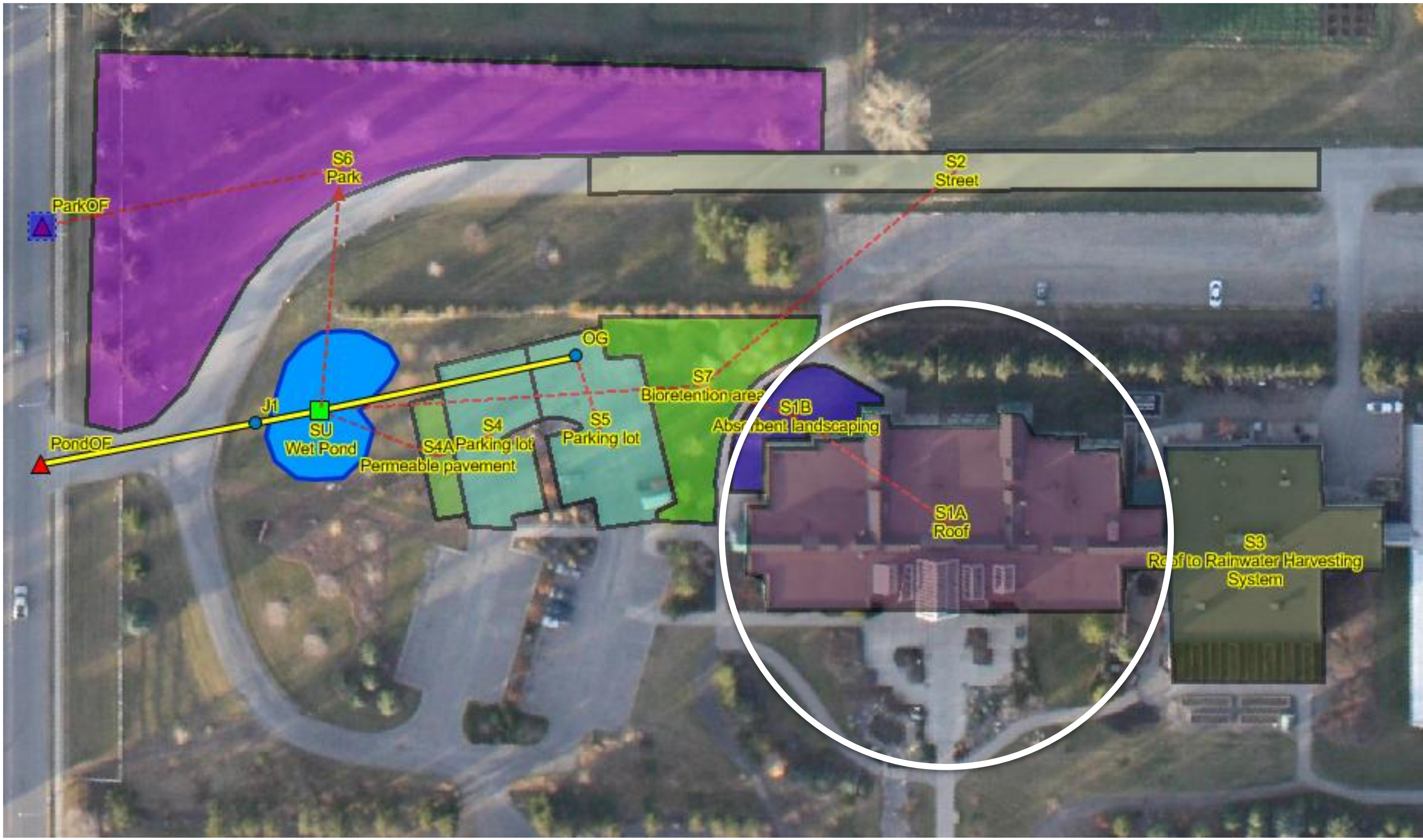


Olds College: lot-level analysis

Olds College: subcatchments

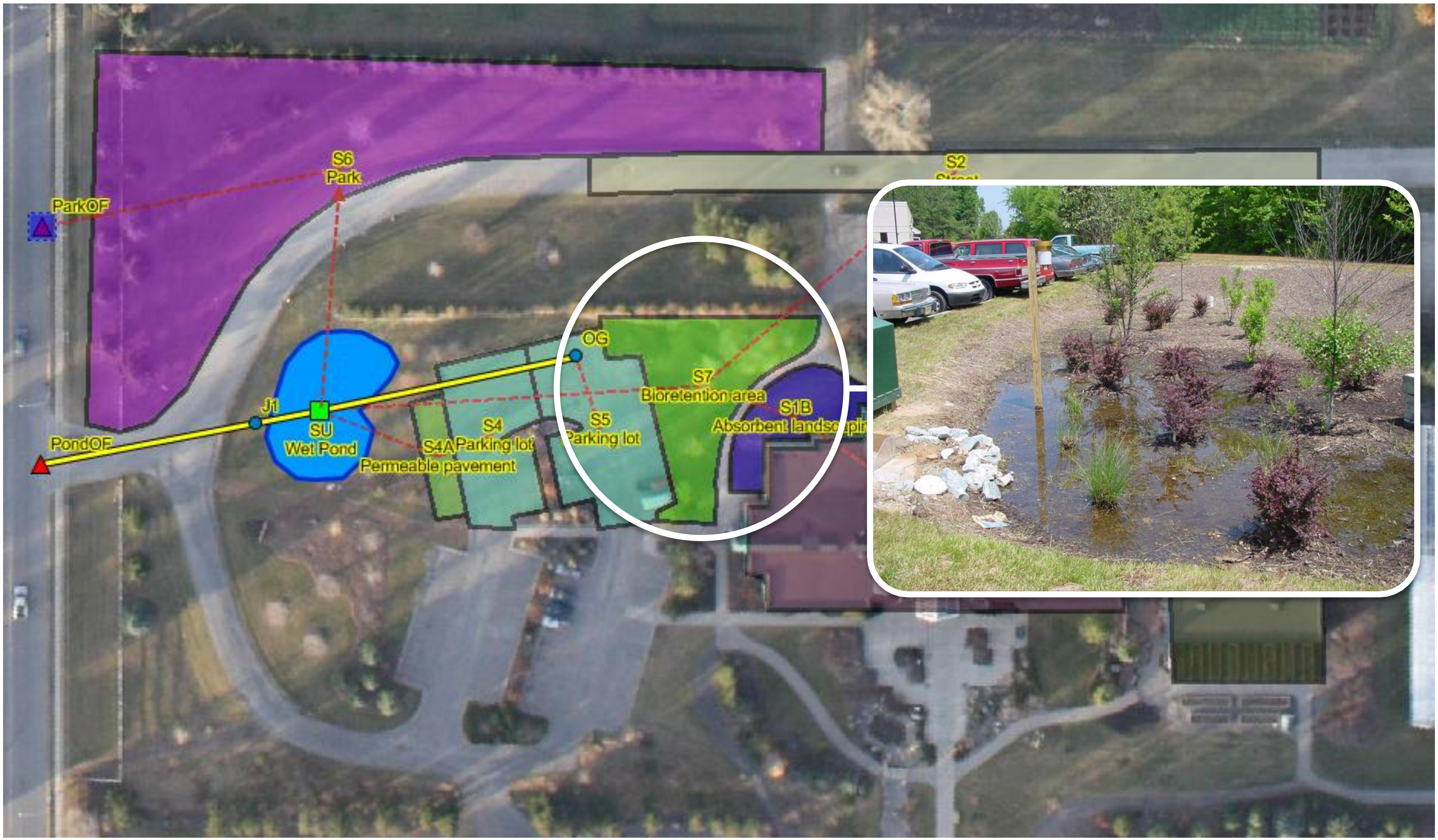
Olds College : roof to cistern

Olds College: roof to landscaping

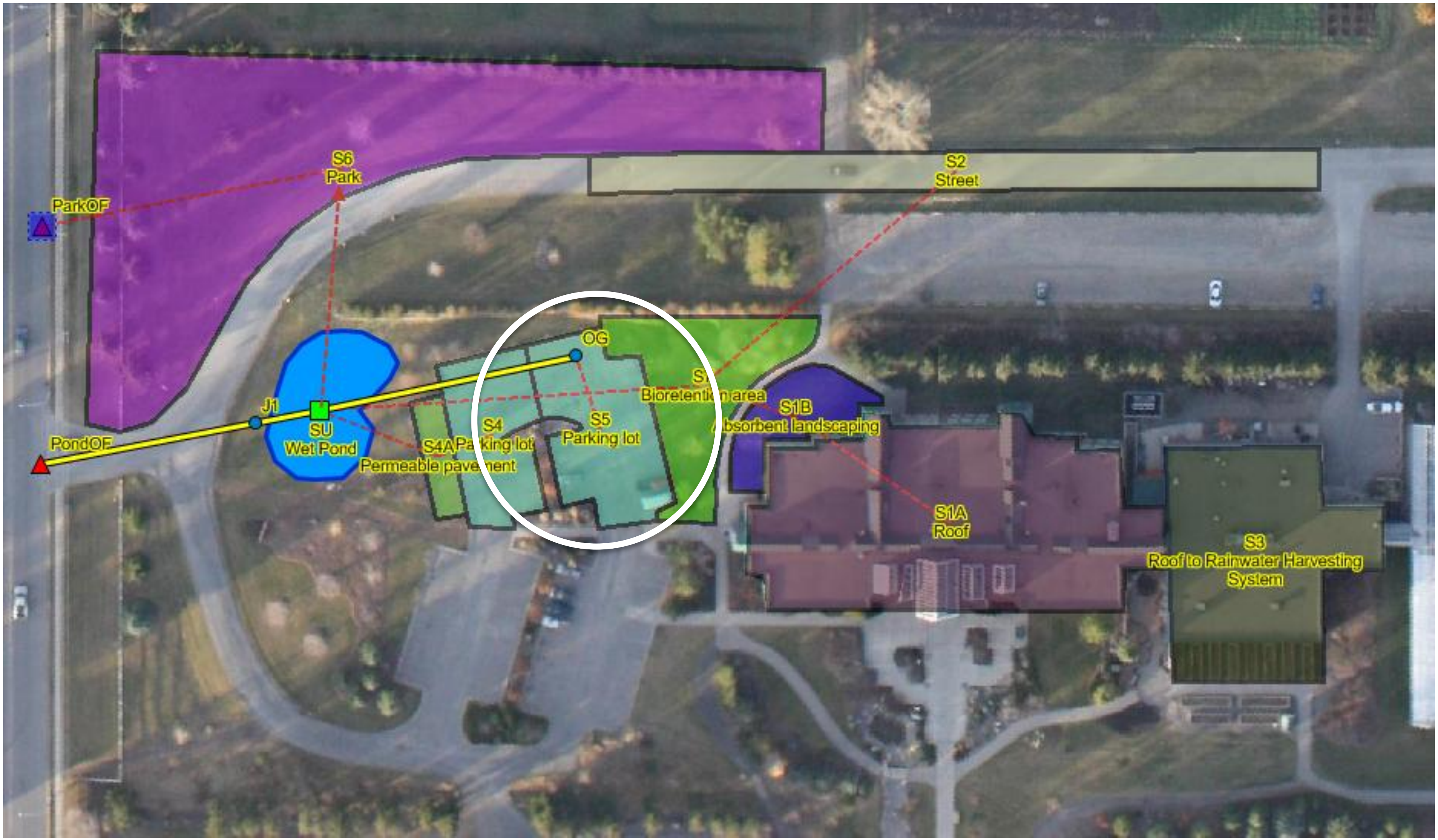


Olds College : absorbent landscaping

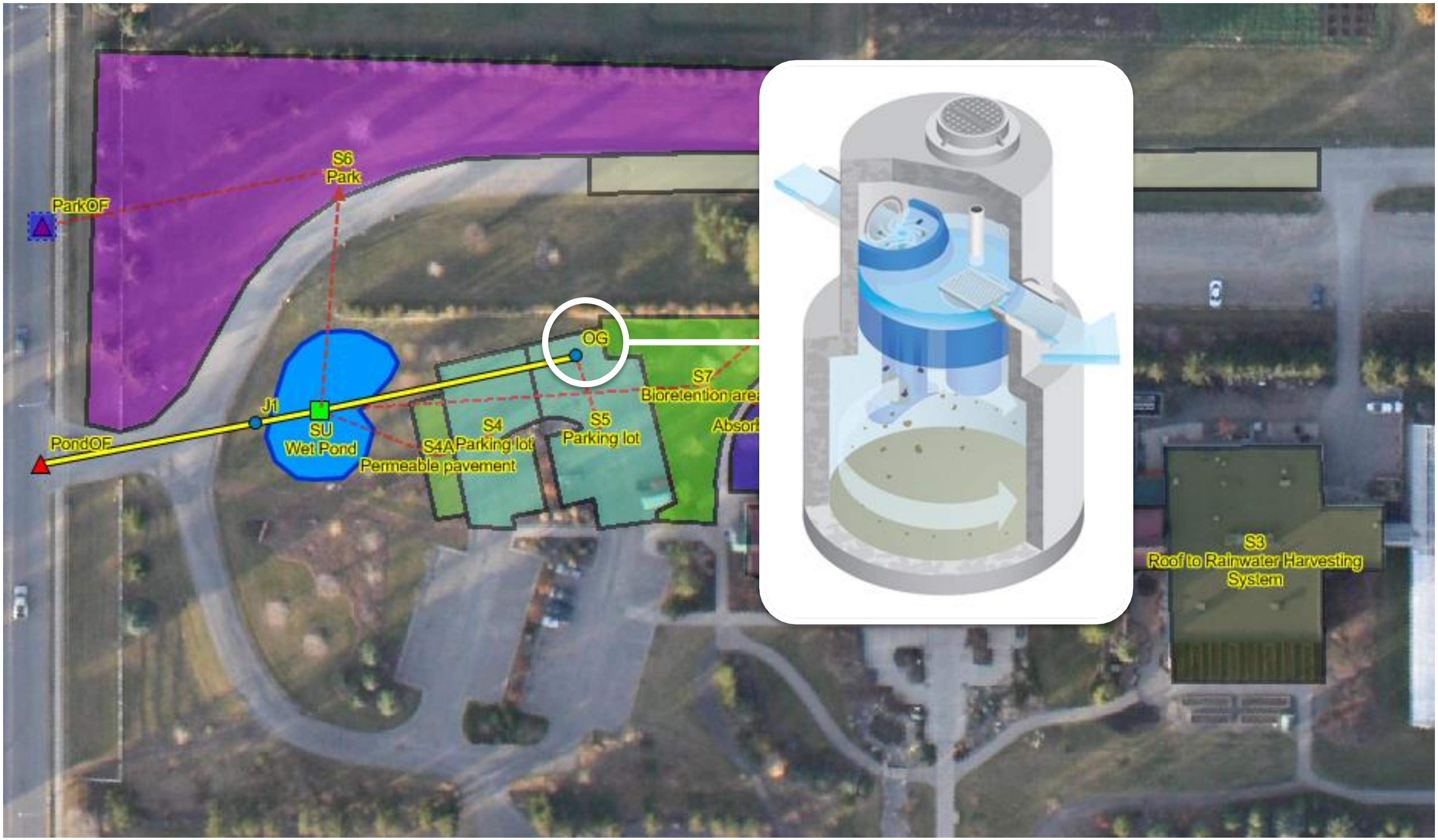
Olds College: bio-retention area



Olds College : parking lot 2

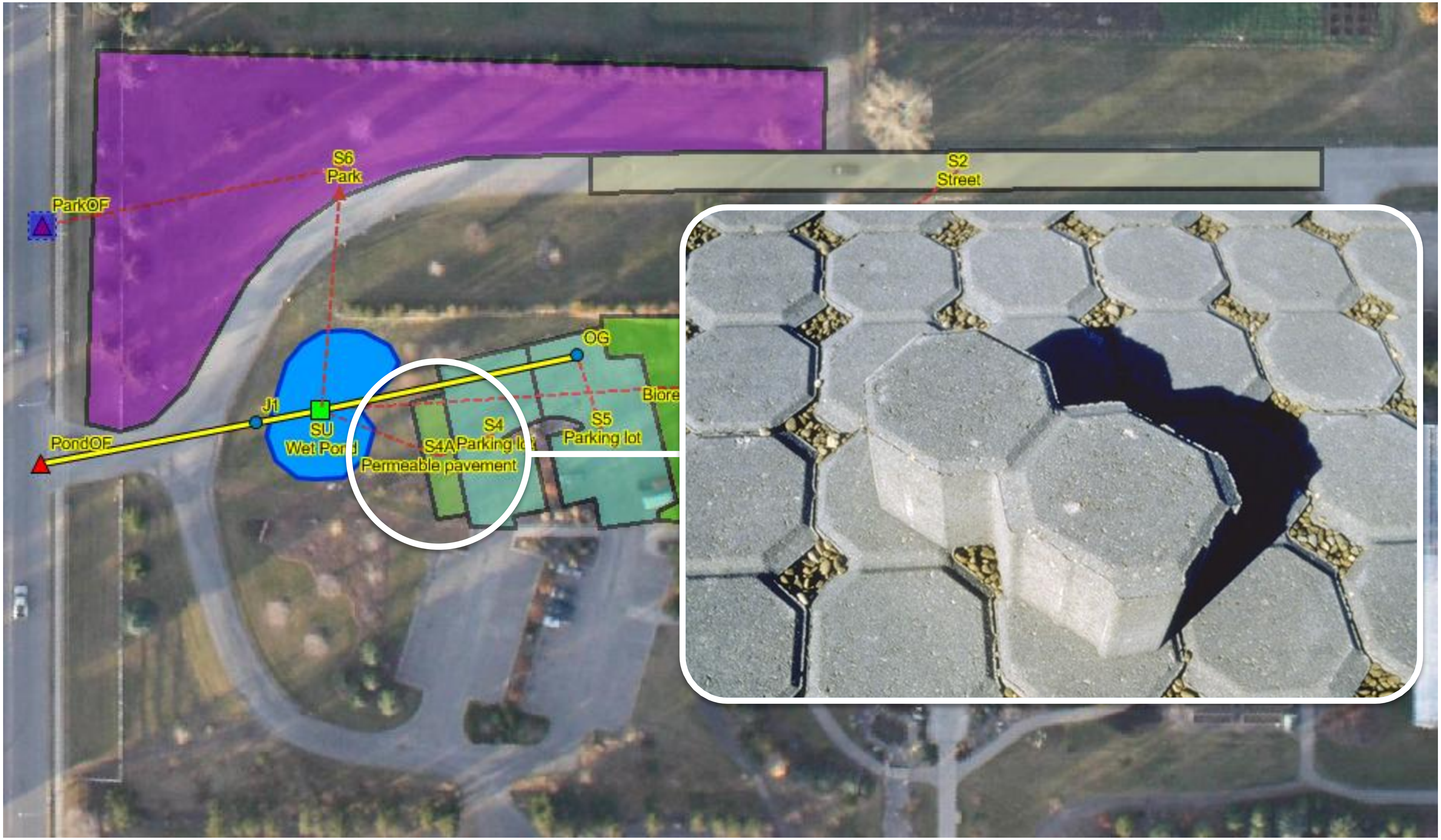


Olds College: oil & grit separator

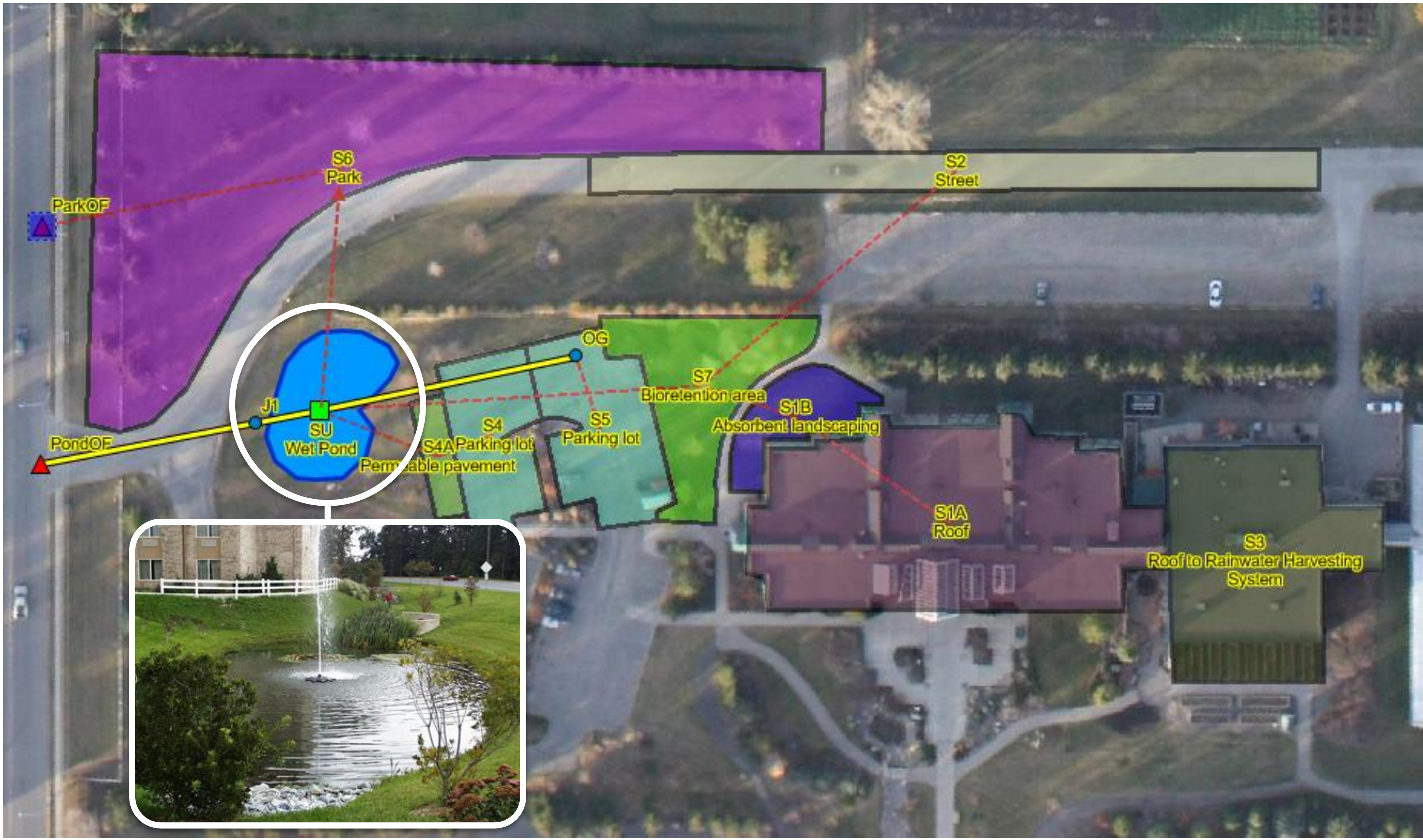


Olds College: parking lot 2

Olds College: permeable pavement

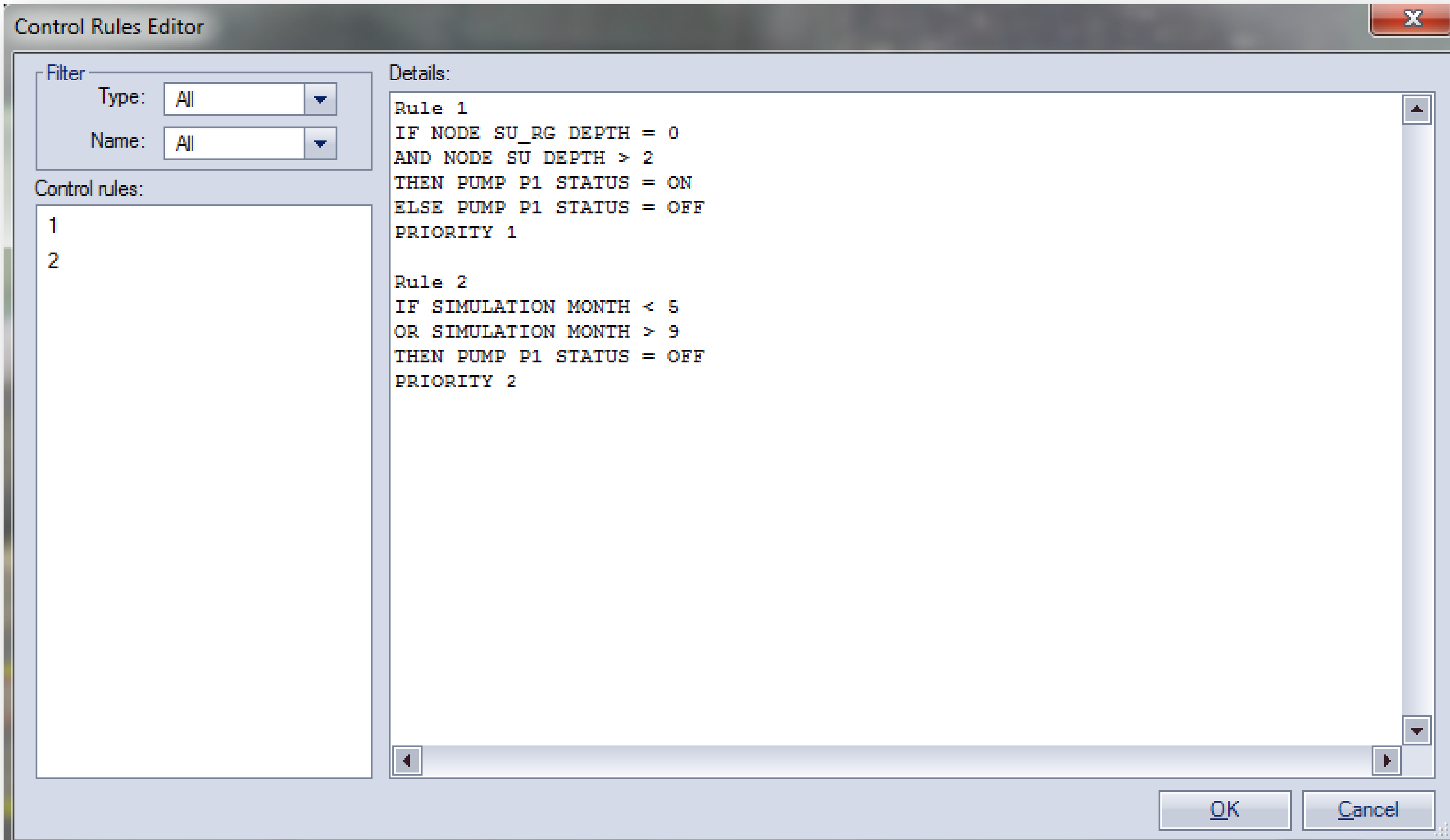


Olds College: wet pond



Olds College: Irrigation

Continuous simulation of re-use



Irrigation

Weekly Watering Schedule #1 (Depth of Irrigation) (mm)

	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Jan							
Feb							
Mar							
Apr							
May						10	
Jun			10			15	
Jul		10		10		15	
Aug		10		10		15	
Sep			10			15	
Oct							
Nov							
Dec							

If the rainfall in the preceding two days is more than 10 mm, irrigation is delayed.

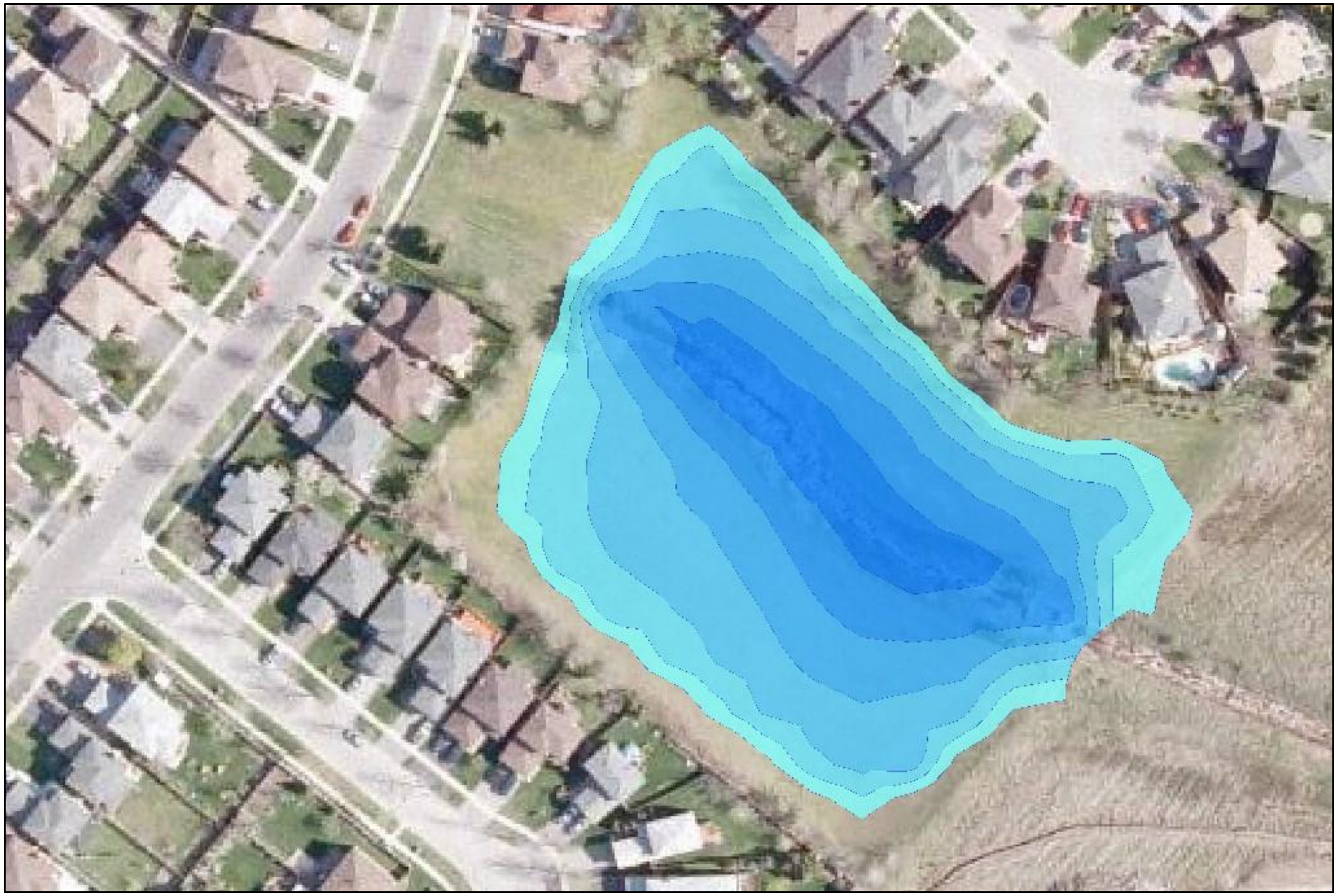
Irrigation

Weekly Watering Schedule #1 (Depth of Irrigation) (mm)

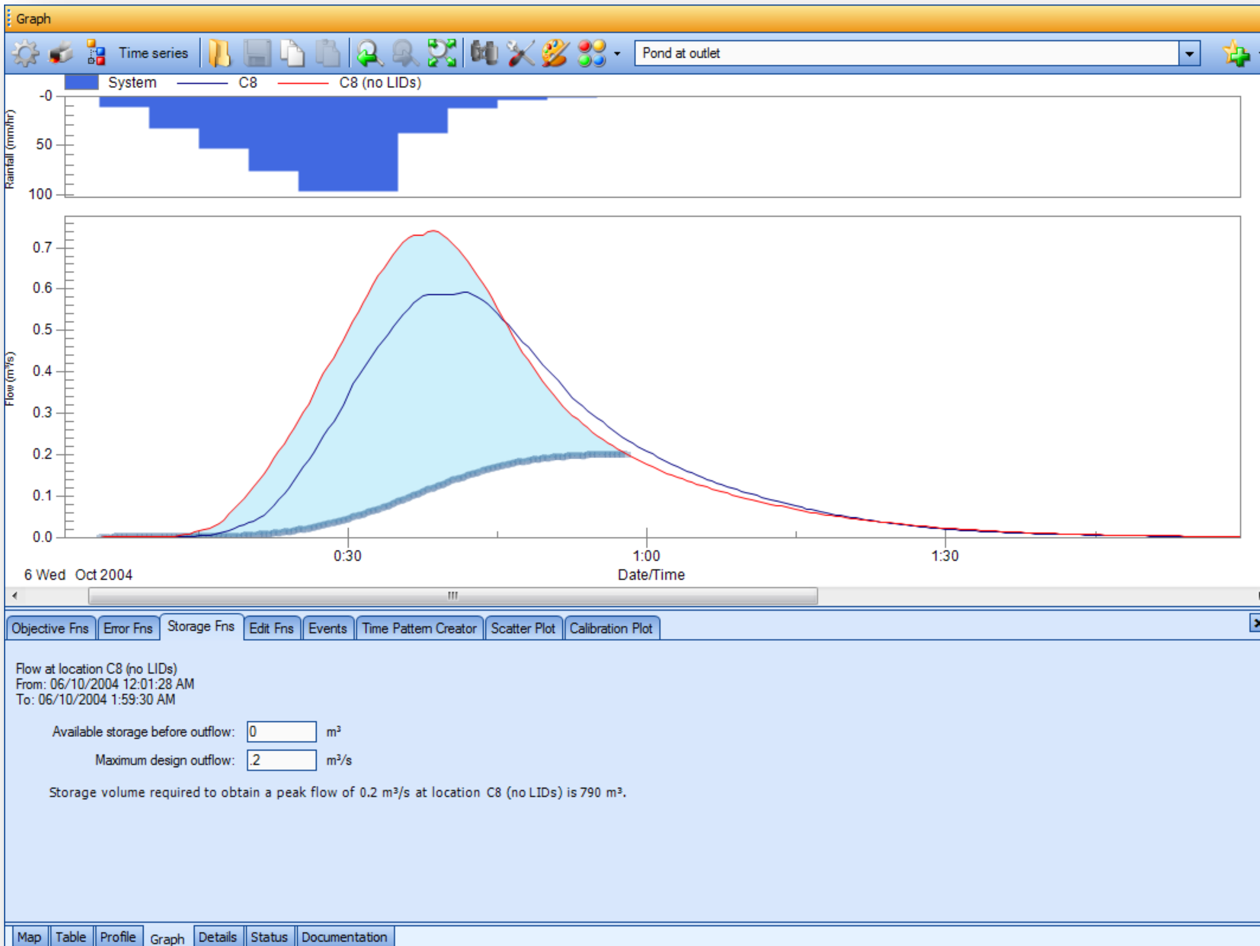
	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Jan							
Feb							
Mar							
Apr							
May						10	
Jun			10			15	
Jul		10		10		15	
Aug		10		10		15	
Sep			10			15	
Oct							
Nov							
Dec							

- Rule 1
  IF SIMULATION MONTH = 5
  AND SIMULATION DAY = 6
  AND NODE SU_RG DEPTH = 0
  AND NODE SU DEPTH > 2
  THEN PUMP P1 SETTING = 1
- Rule 2
  IF SIMULATION MONTH = 6
  AND SIMULATION DAY = 3
  AND NODE SU_RG DEPTH = 0
  AND NODE SU DEPTH > 2
  THEN PUMP P1 SETTING = 1
- Rule 3
  IF SIMULATION MONTH = 6
  AND SIMULATION DAY = 6
  AND NODE SU_RG DEPTH = 0
  AND NODE SU DEPTH > 2
  THEN PUMP P1 SETTING = 1.5
  ELSE PUMP P1 STATUS = OFF

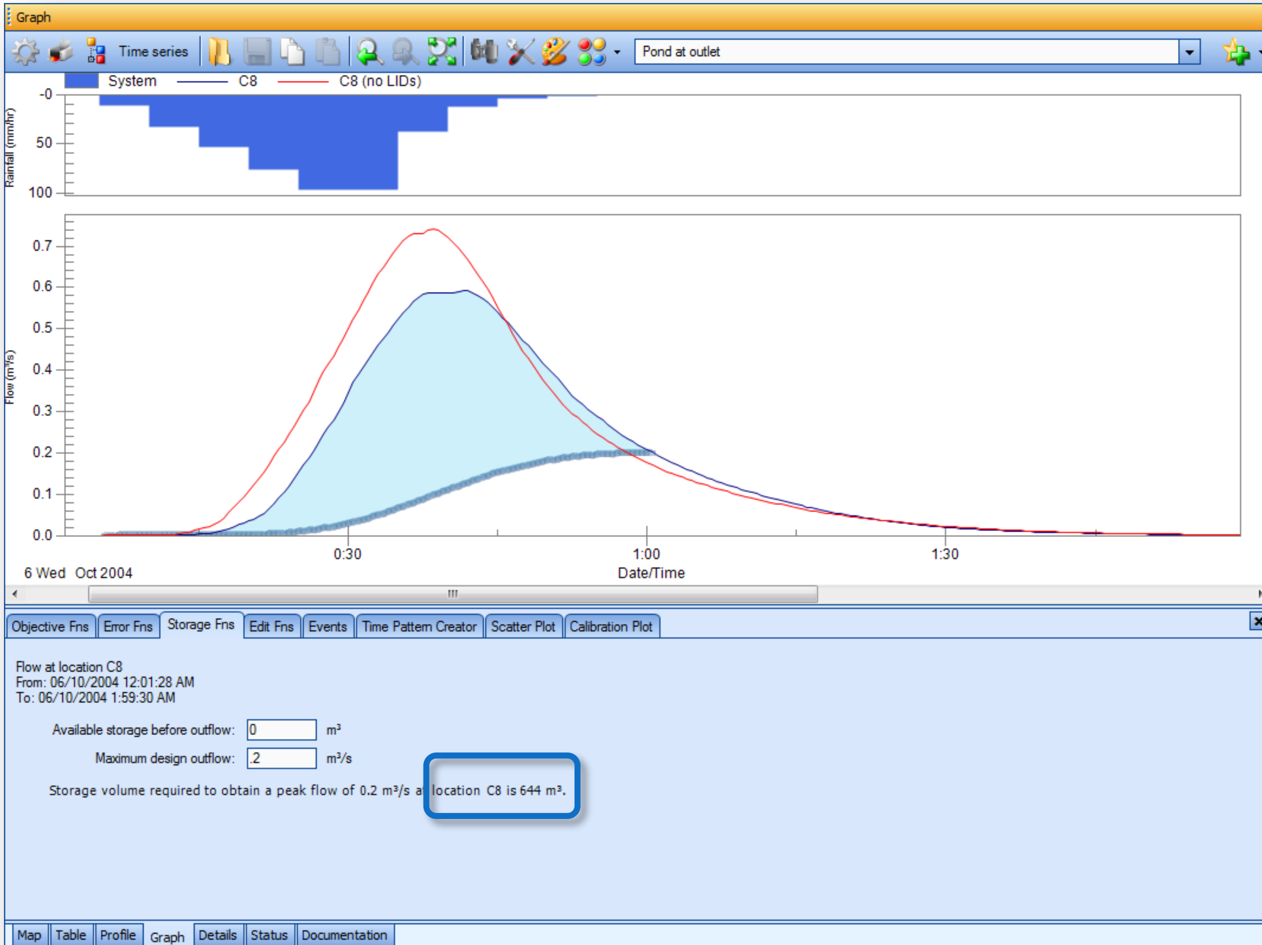
Single event LID analysis: detention pond sizing



Design storm analysis: pond sizing no LIDs



Design storm analysis: pond sizing with LIDs



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