Selection of Modeling Tools for Sustainable Stormwater Management

Hosted by the Stormwater Management Committee
March 10, 2010

IAFSM
Illinois Association for Floodplain and Stormwater Management

Introduction –

Robert Murdock (Michael Baker Jr., Inc.)

Reasons for BMP Modeling Tools Selection Track

- Stricter, more far reaching stormwater requirements are likely to come soon
  - EPA initiate national rulemaking ([EPA–HQ–OW–2009–0817; FRL–9095–3])
  - National Research Council released the report *Urban Stormwater Management in the United States* (The National Academies Press, 2009)

NRCS Finding

"the rapid conversion of land to urban and suburban areas has profoundly altered how water flows during and following storm events, putting higher volumes of water and more pollutants into the nation's rivers, lakes, and estuaries. These changes have degraded water quality and habitat in virtually every urban stream system.''

Reasons for Modeling Tools – cont'd

EPA Stated Objectives for Rule Making:

- Expand the area subject to federal stormwater regulations.
- Establish specific requirements to control stormwater discharges from new development and redevelopment.

Green Infrastructure for Clean Water Act: IEPA to deliver report to IL General Assembly by June 30 2010:

"Findings and recommendations for adopting an urban storm water management regulatory program in Illinois which includes performance standards and encourages the use of green infrastructure"

.

Outline for Presentation

Co Presenters – Erin Pande (ERA), Greg Kacvinsky (Foth)

1. Overview of RECARGA, WinSLAMM, SUSTAIN, and EPA SWMM.
2. Provide 6 short scenarios on considerations for program selection.
3. Provide two in-depth examples

Introduction –

Erin Pande (Engineering Resource Associates, Inc.)

- Introduction to RECARGA
  - Simple tool for Hydrologic modeling of Bio/Infiltration systems
    - Quantifies Ponding
    - Infiltration
    - Overflow
    - Et
    - Recharge
  - Useful tool for impact analysis
    - Flexible – user inputs
  - RECARGA does not model water quality

Introduction –

Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- WinSLAMM
  - (**S**ource **L**oading **A**nd **M**anagement **M**odel)
  - Ideal for watershed-wide nonpoint source pollution controls
    - Structural BMPs (Ponds, Bioswales, Filters, etc.)
    - Non-Structural BMPs (Street sweeping, impervious area disconnection, etc.)

Introduction –

Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- WinSLAMM (KEY *INPUTS*)
  - Drainage area
  - Pervious/impervious surface percentages
    - Connected vs. disconnected
  - Land uses (i.e. "source areas")
  - Existing / proposed BMPs
    - Cost data for BMPs (if available)
  - Extended period rainfall file

Introduction –

Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- WinSLAMM (KEY ***OUTPUTS***)
  - Pollutant concentration(s) at outfall
  - Pollutant yield(s) (lbs)
  - Runoff volume
  - Before/after comparison on impacts to receiving water
    - Removal efficiencies for individual BMPs
    - Cost efficiencies of individual BMPs

Introduction –

Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- WinSLAMM
  - Computations based on decades of field data for pollutant buildup and BMP removal efficiencies
  - Mainly a planning tool, although it can be used for site-specific BMP selection and sizing
  - Used widely in Wisconsin

Introduction –

Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- SUSTAIN (EPA)
  - **S**ystem for **U**rban **S**tormwater **T**reatment and **A**nalysis **IN**tegration
  - Similar to WinSLAMM
  - Planning tool for BMP selection and placement on a watershed scale
  - Cost-effectiveness analysis
  - GIS interface

Introduction –

Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- SUSTAIN (EPA)
  - Version 1.0 available on EPA's website
    - Includes flow routing (uses EPA SWMM engine)
    - Sediment transport
    - BMP Optimization (load reduction vs. cost)
    - Scaled use from individual sites to community-wide watersheds

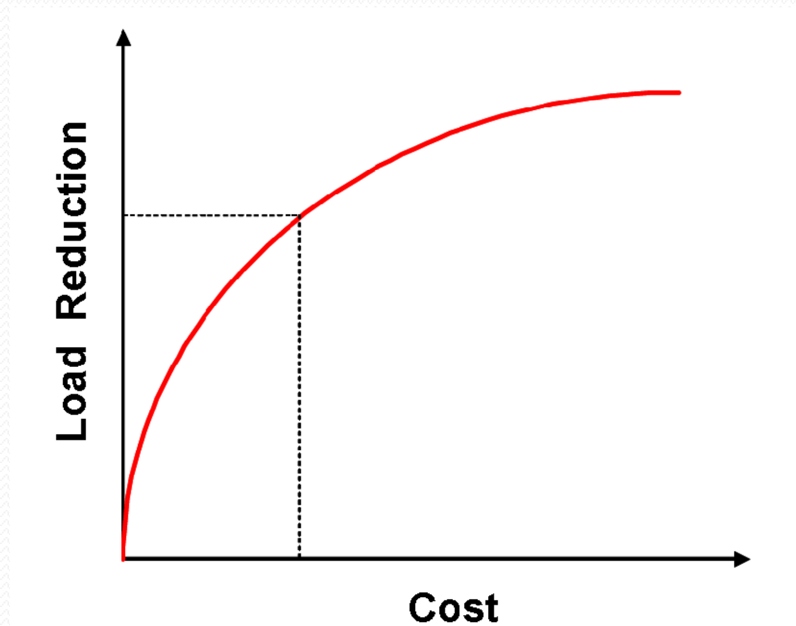
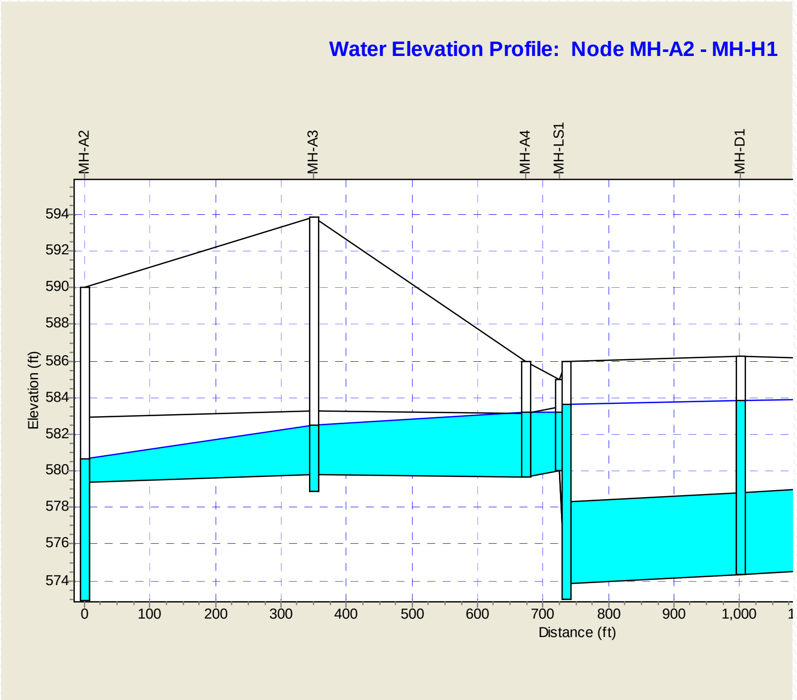


Image Source: US EPA

Introduction –

Robert Murdock (Michael Baker Jr., Inc.)

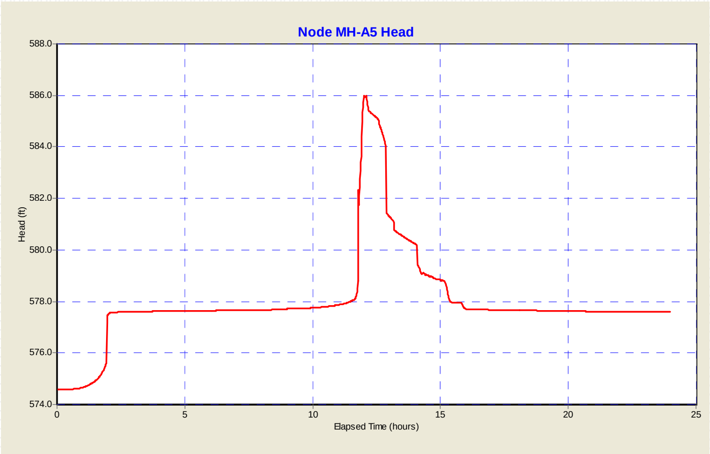
- EPA Storm Water Management Model (SWMM) Capabilities
  - Dynamic rainfall-runoff simulation model
  - Single event or long-term (continuous) simulation of runoff quantity *and* quality
  - Intended for urban areas
  - Full hydrology and hydraulics capabilities
  - Models water quality, infiltration, and snow melt.



Introduction –

Robert Murdock (Michael Baker Jr., Inc.)

- EPA Storm Water Management Model (SWMM) – Uses
  - Evaluate Best Management Practices (BMPs)
  - Design and size drainage system components (including detention)
  - Analyze combined and sanitary sewer overflows (CSOs and SSOs)
  - Generate non-point source pollutant loadings for wasteload allocation studies
  - Flood plain mapping of natural channel systems



Introduction –

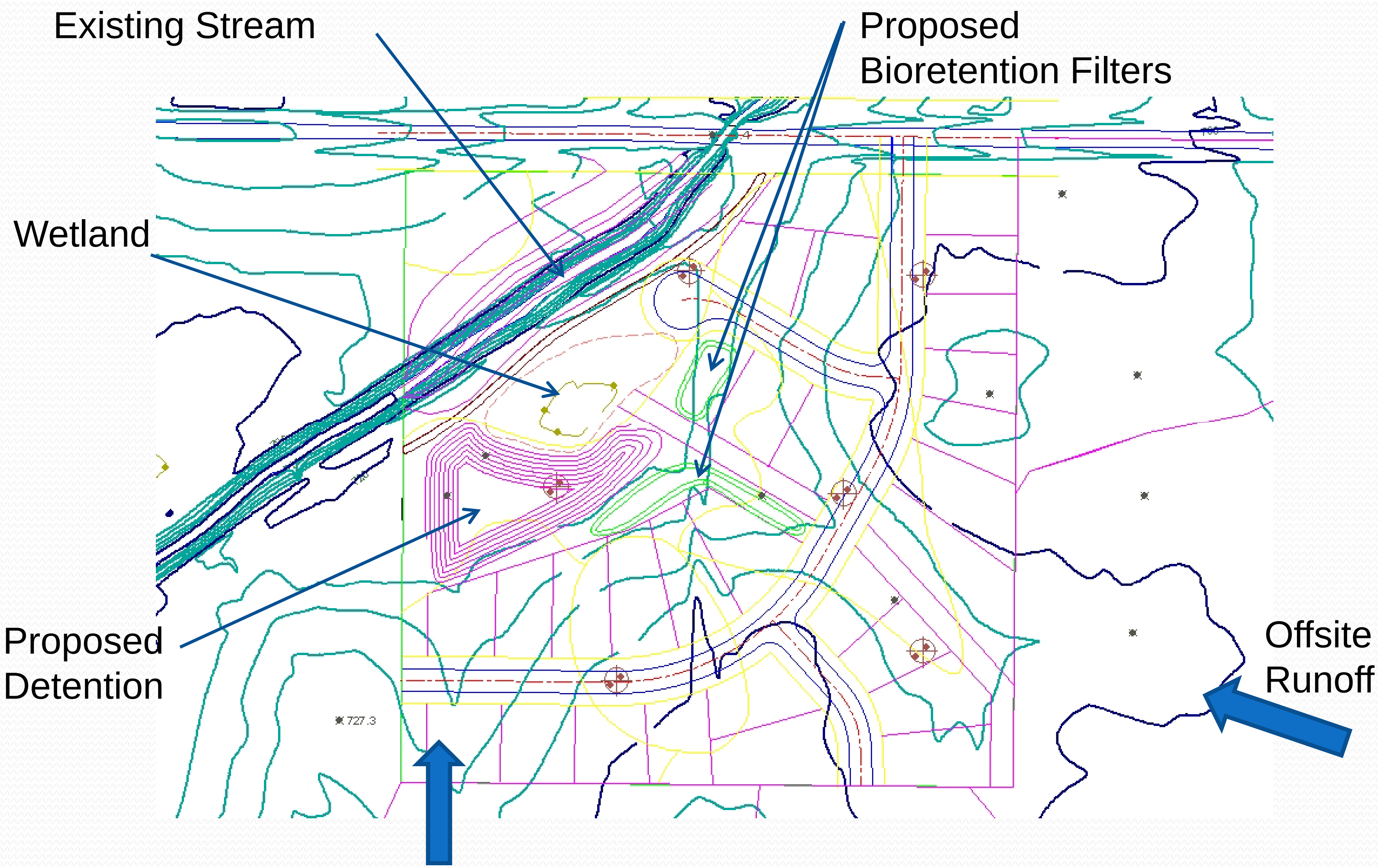
Robert Murdock (Michael Baker Jr., Inc.)

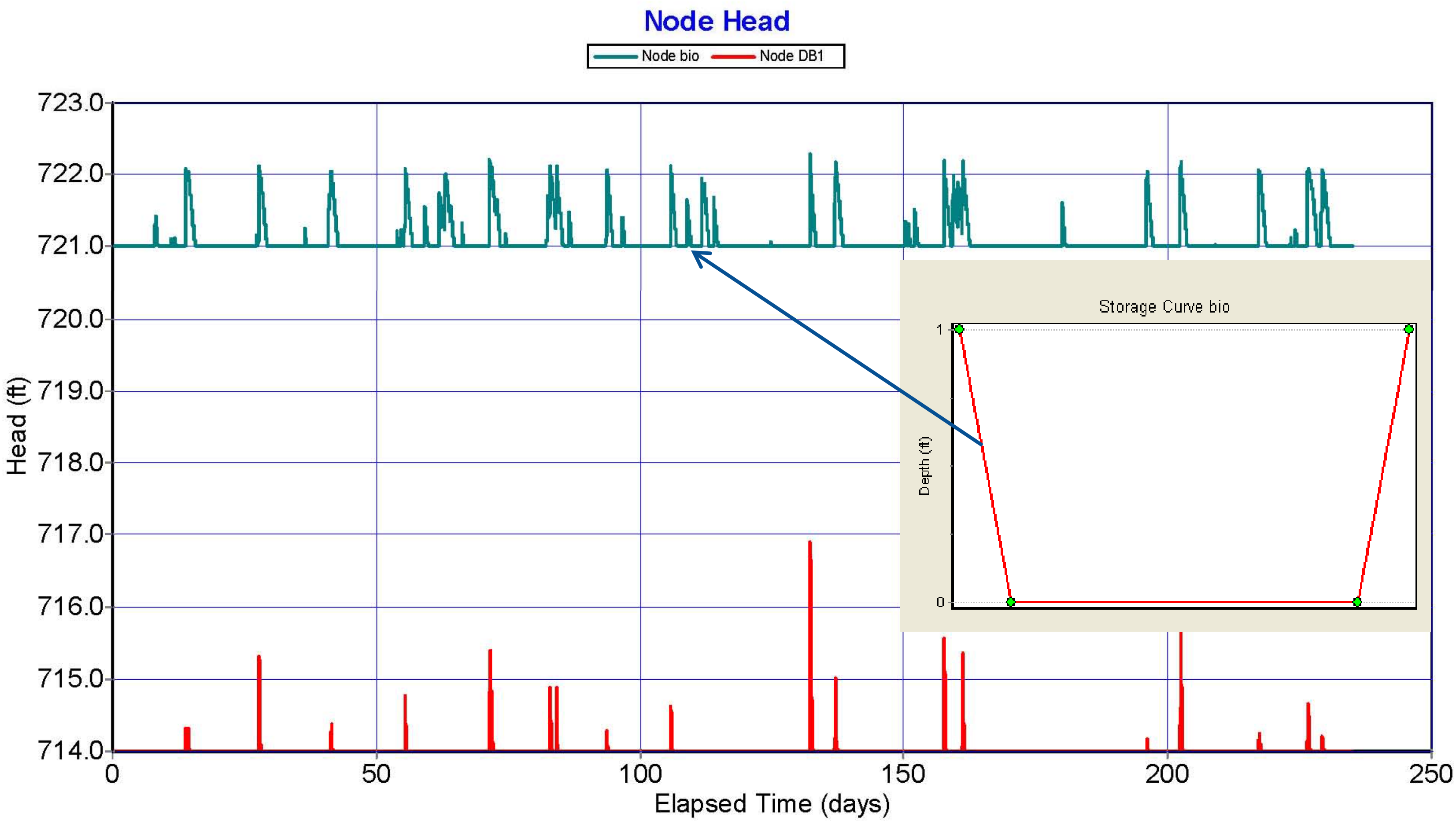
- Key differences between models
  - WinSLAMM, SUSTAIN
    - WinSLAMM is a ***proprietary model***
    - Primarily intended for watershed-wide planning
    - Decision support systems
  - RECARGA
    - Infiltration BMP sizing and design
    - Event-based and continuous simulation
    - Underdrain function
  - EPA SWMM
    - Full hydraulics and hydrology
    - Ideal for collection system design *and* BMP sizing/design
    - Event-based and continuous simulation
    - Primarily for urban watersheds.

Application Examples–

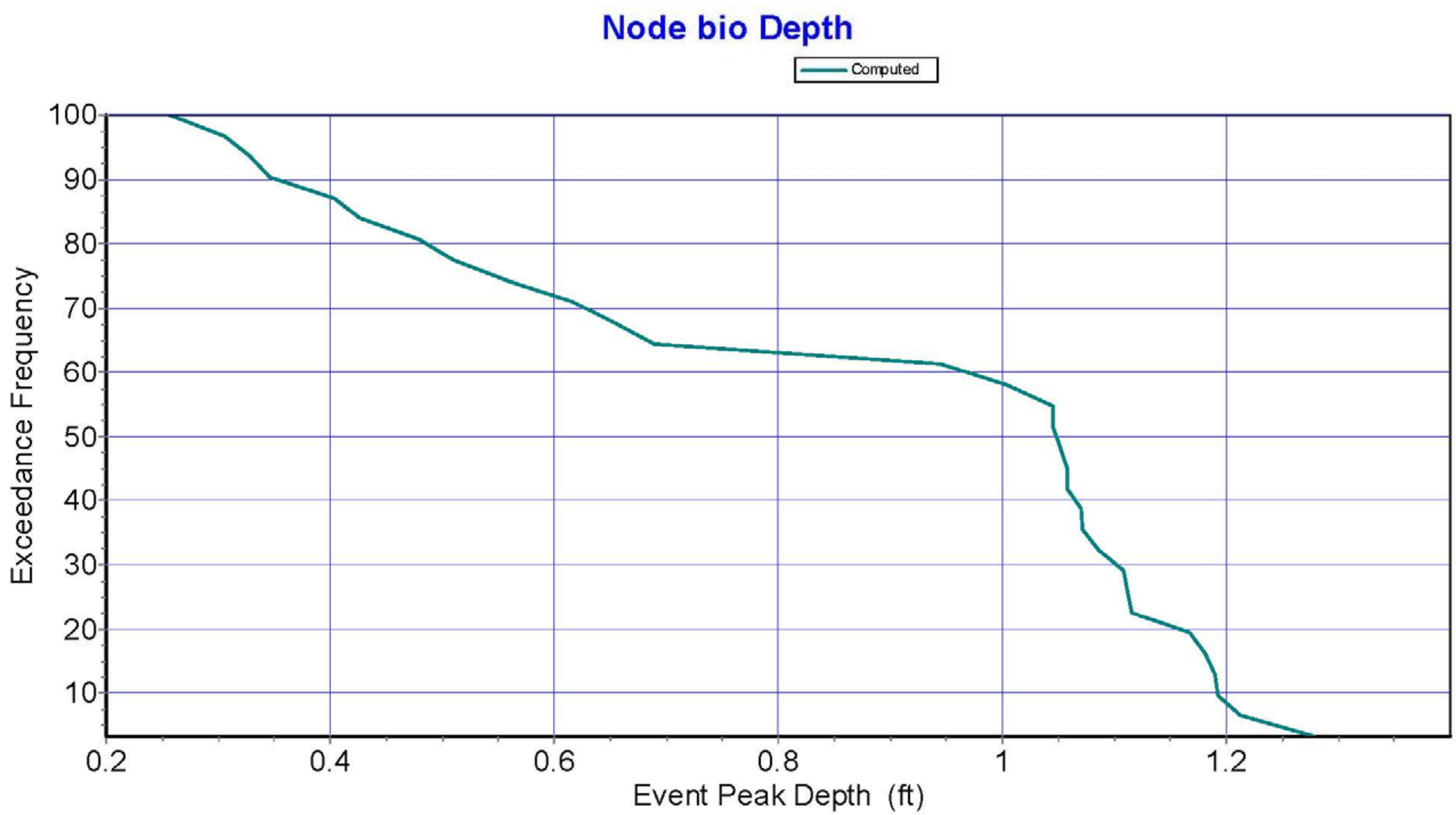
- Site #1: 28-lot single-family residential development: design for local stormwater management requirements
    - EPA SWMM
    - Why use this model ?

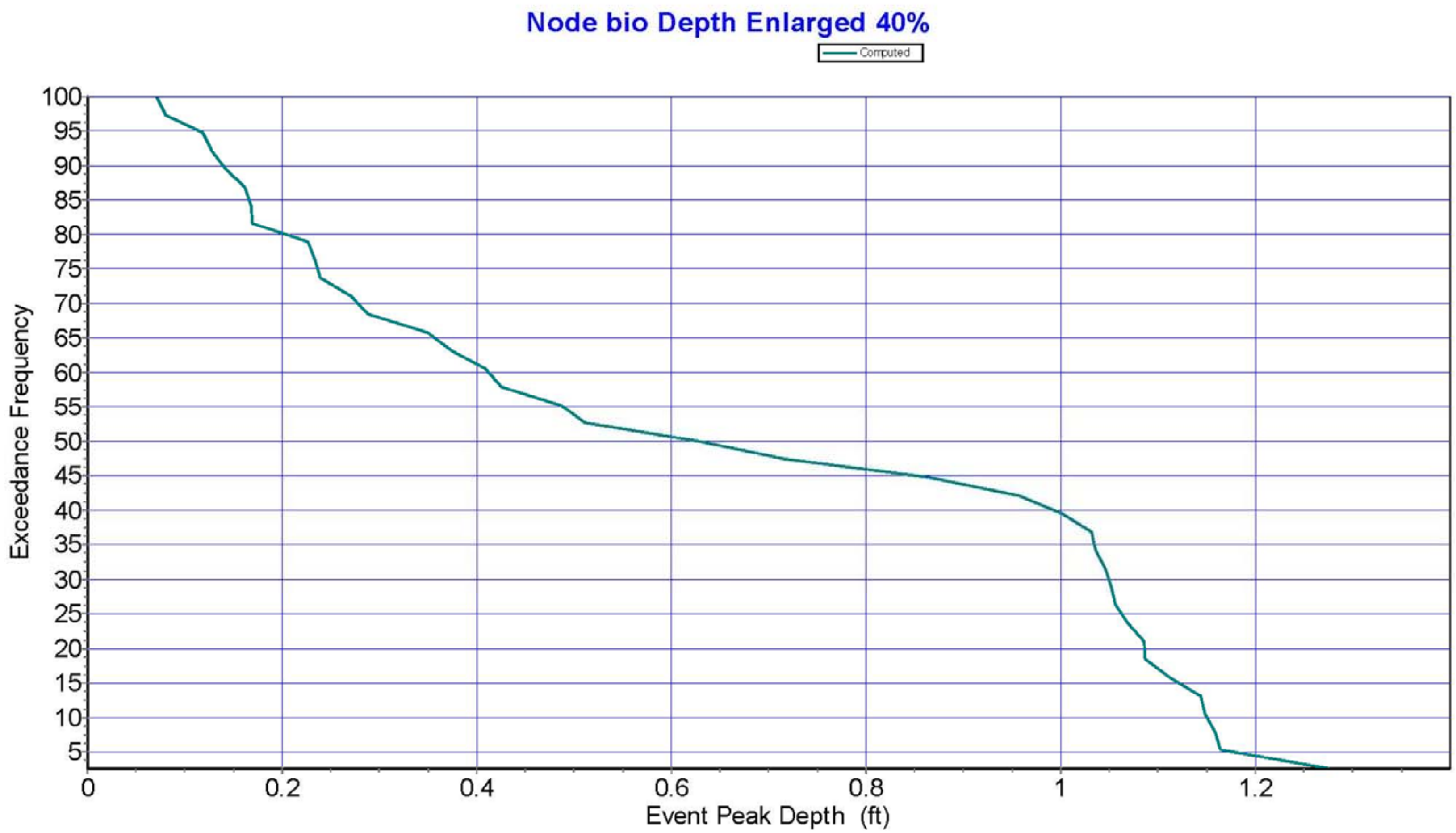
Factors: Detention, Wetland, Water Qual Vol Capture



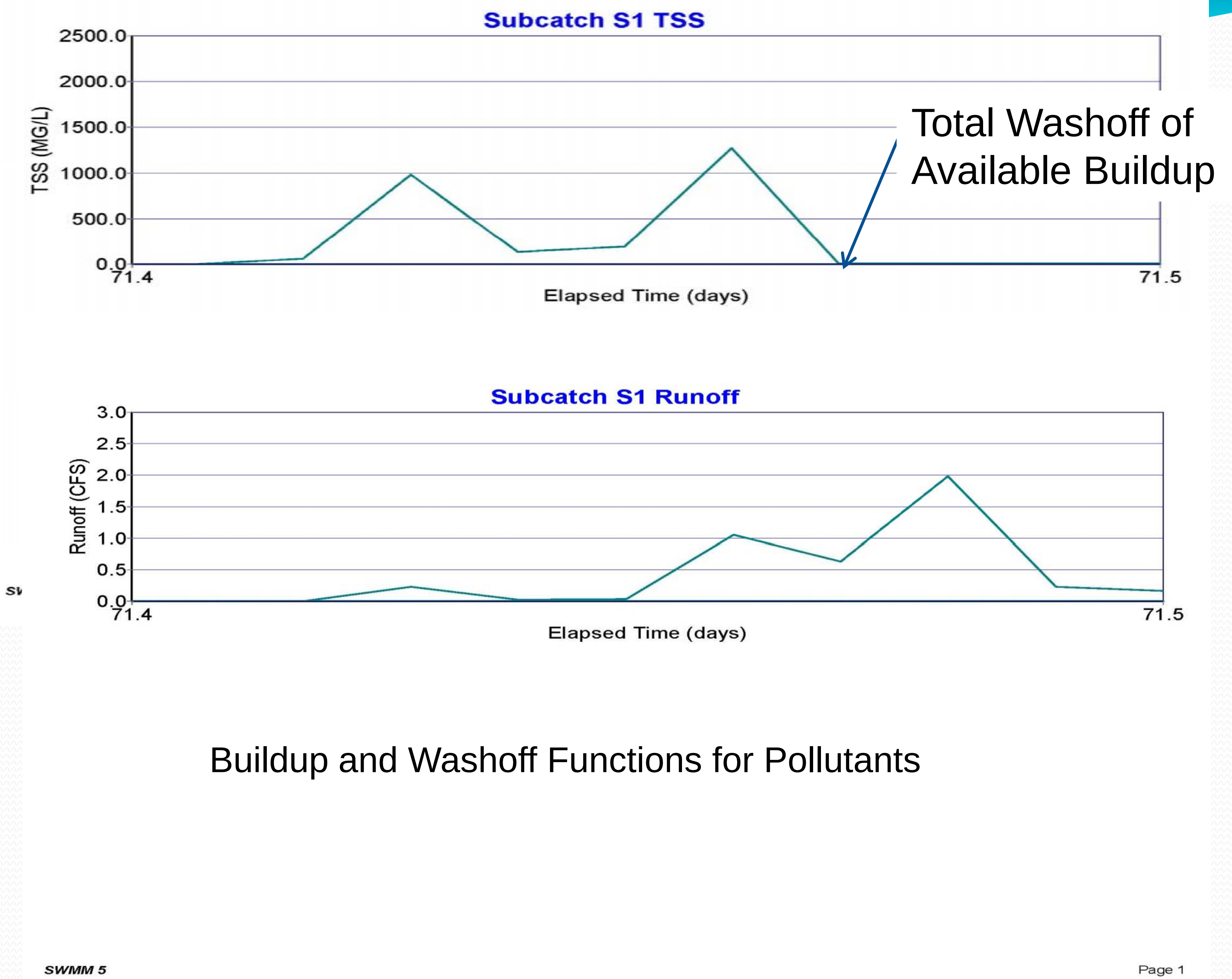


Node Head
Node bio
Node DB1
723.0
722.0
721.0
720.0
719.0
718.0
717.0
716.0
715.0
714.0
Head (ft)
0
50
100
150
200
250
Elapsed Time (days)
Storage Curve bio
1
0
Depth (ft)


Node bio Depth
Computed
100
90
80
70
60
50
40
30
20
10
Exceedance Frequency
0.2
0.4
0.6
0.8
1
1.2
Event Peak Depth (ft)



Node bio Depth Enlarged 40%
Computed
Exceedance Frequency
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0.2
0.4
0.6
0.8
1
1.2
Event Peak Depth (ft)



Buildup and Washoff Functions for Pollutants

Application Examples–

- Site #2: 10-acre commercial redevelopment

Application Examples–

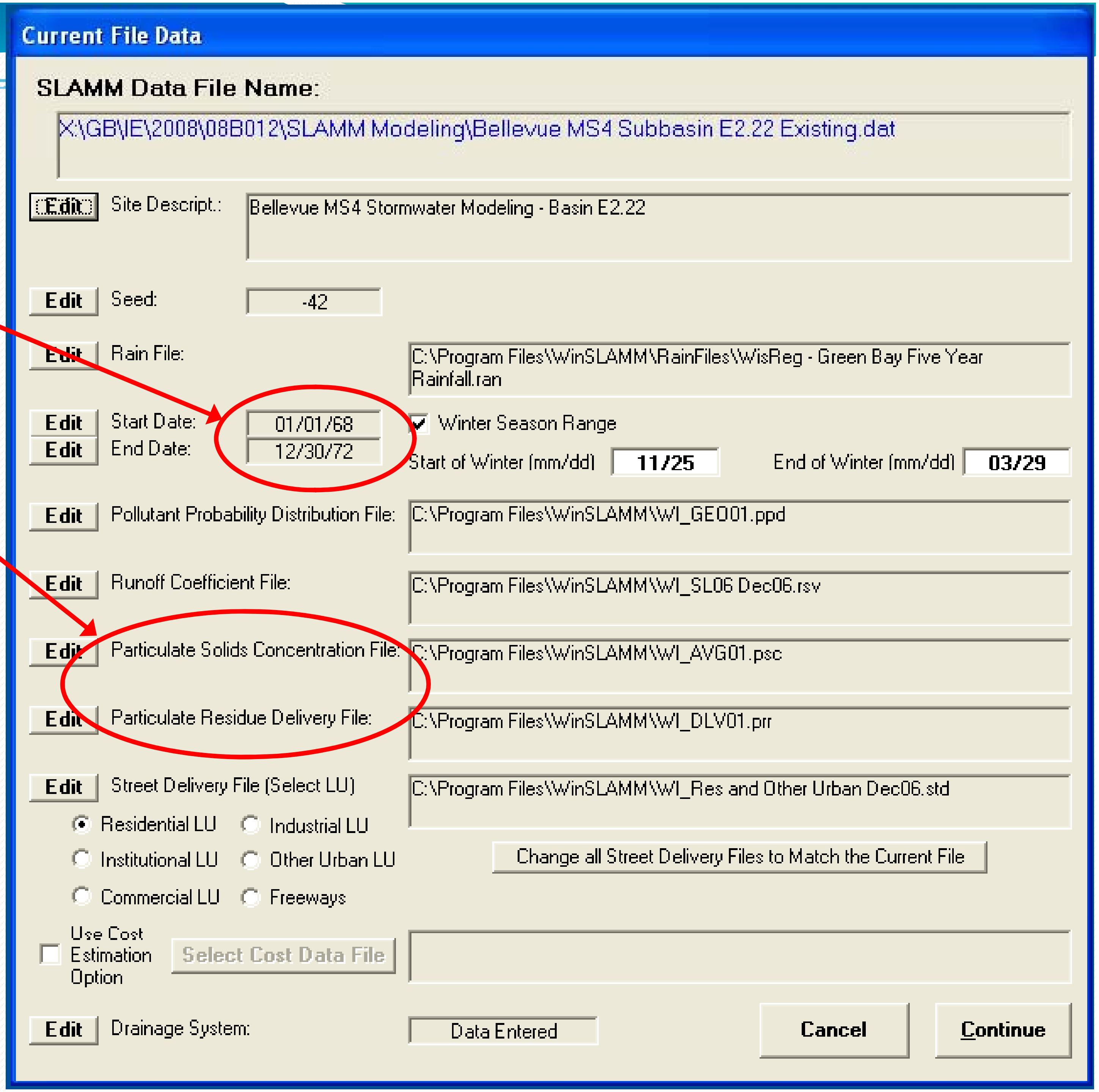
- Site #2: 10-acre commercial redevelopment: design bioretention to meet local stormwater quality requirements
- RECARGA: Why use this model / why not use others?
    - Easy to determine required area needed for BMP
    - Local MS4 Permit requires treatment of water quality storm
    - Detention basin is pre-existing

Application Examples–

- Site #3: Urbanized watershed: develop Watershed Master Plan to satisfy MS4 Notice of Intent
- WinSLAMM
- Why use this model / why not use others?
    - Local MS4 Permit requires % reduction in TSS over next 5 yrs
    - Need to evaluate City-wide BMPs (both structural and non-structural)
    - Evaluate cost-effectiveness of BMPs
    - No design-level effort necessary at this stage (planning only)

WinSLAMM Input

- 5-year rainfall data set
- Pollutant loadings based on field research



WinSLAMM Input

- Land uses and corresponding areas defined
- Each *<u>Source Area</u>* has its own pollutant buildup profile
- Each Source Area has other key characteristics:
  - Disconnected impervious areas
  - Existing BMPs

WinSLAMM Data File: [X:\GB\IE\2008\08B012\SLAMM Modeling\Bellevue E2.22.dat]

File Land Use Pollutants Tools Run Utilities Help

SLAMM Data File:

Bellevue E2.DAT

Current Land Use: Residential

Current Source Area

Current File Data...

Current File Status

Current File Data Entered

Land Use Areas

Residential Area:	18.50 Acres
Institutional Area:	19.90 Acres
Commercial Area:	0.00 Acres
Industrial Area:	0.00 Acres
Other Urban Area:	0.00 Acres
Freeway Area:	0.00 Acres
Total Area:	38.40 Acres

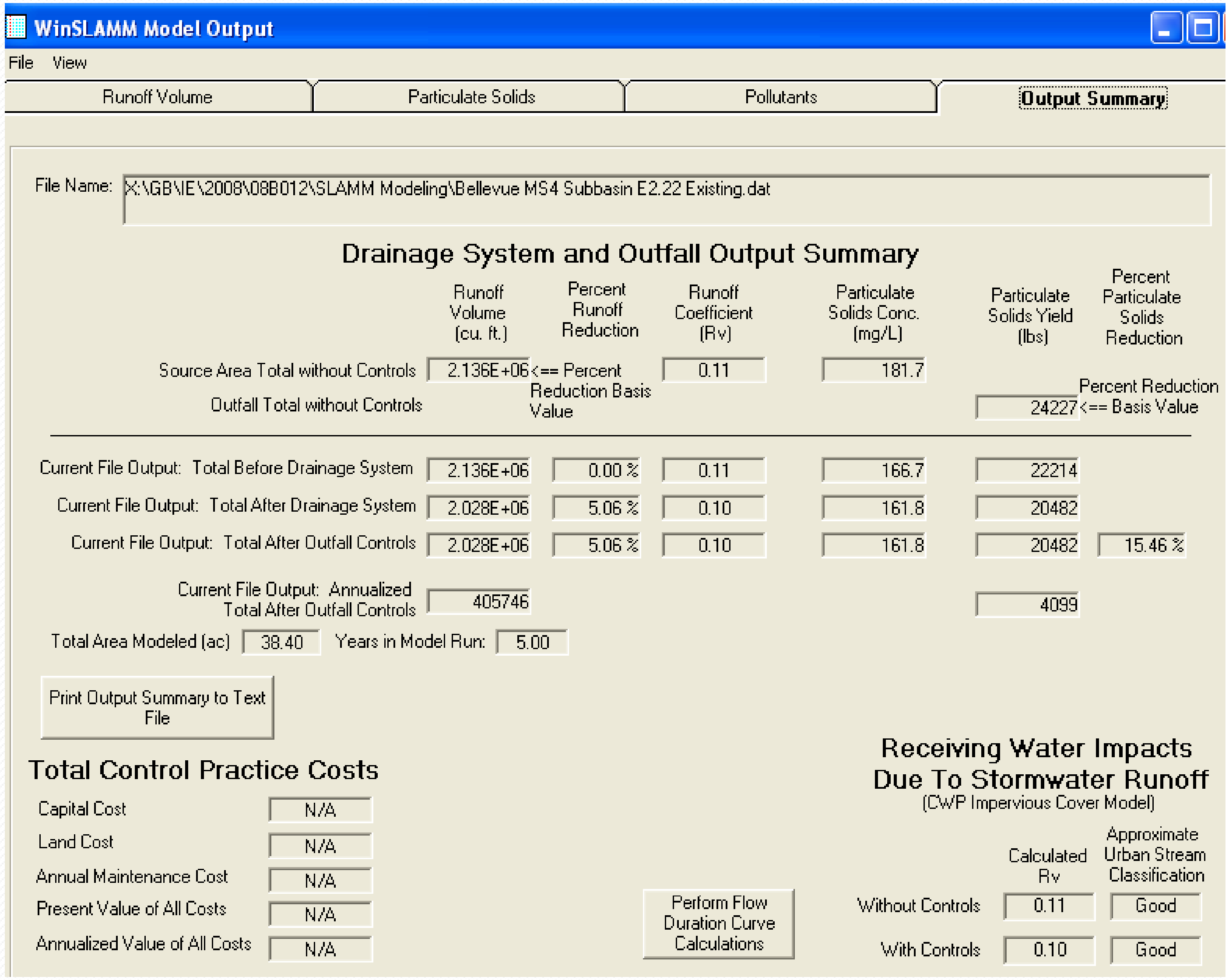
Exit Program

Press F1 for Help

Source Area No.	Source Area	Area (acres)	H	W	P	O	S	B	Source Area Parameters
1	Roofs 1	3.70							Entered
2	Roofs 2								
3	Roofs 3								
4	Roofs 4								
5	Roofs 5								
6	Paved Parking/Storage 1								
7	Paved Parking/Storage 2								
8	Paved Parking/Storage 3								
9	Unpaved Prkng/Storage 1								
10	Unpaved Prkng/Storage 2								
11	Playground 1								
12	Playground 2								
13	Driveways 1	1.60							Entered
14	Driveways 2								
15	Driveways 3								
16	Sidewalks/Walks 1								
17	Sidewalks/Walks 2								
18	Street Area 1	2.40					S		Entered
19	Street Area 2								
20	Street Area 3								
21	Large Landscaped Area 1								
22	Large Landscaped Area 2								
23	Undeveloped Area								
24	Small Landscaped Area 1	10.80							Entered
25	Small Landscaped Area 2								
26	Small Landscaped Area 3								
27	Isolated/Water Body Area								
28	Other Pervious Area								
29	Other Dir Cnctd Imp Area								
30	Other Part Cnctd Imp Area								

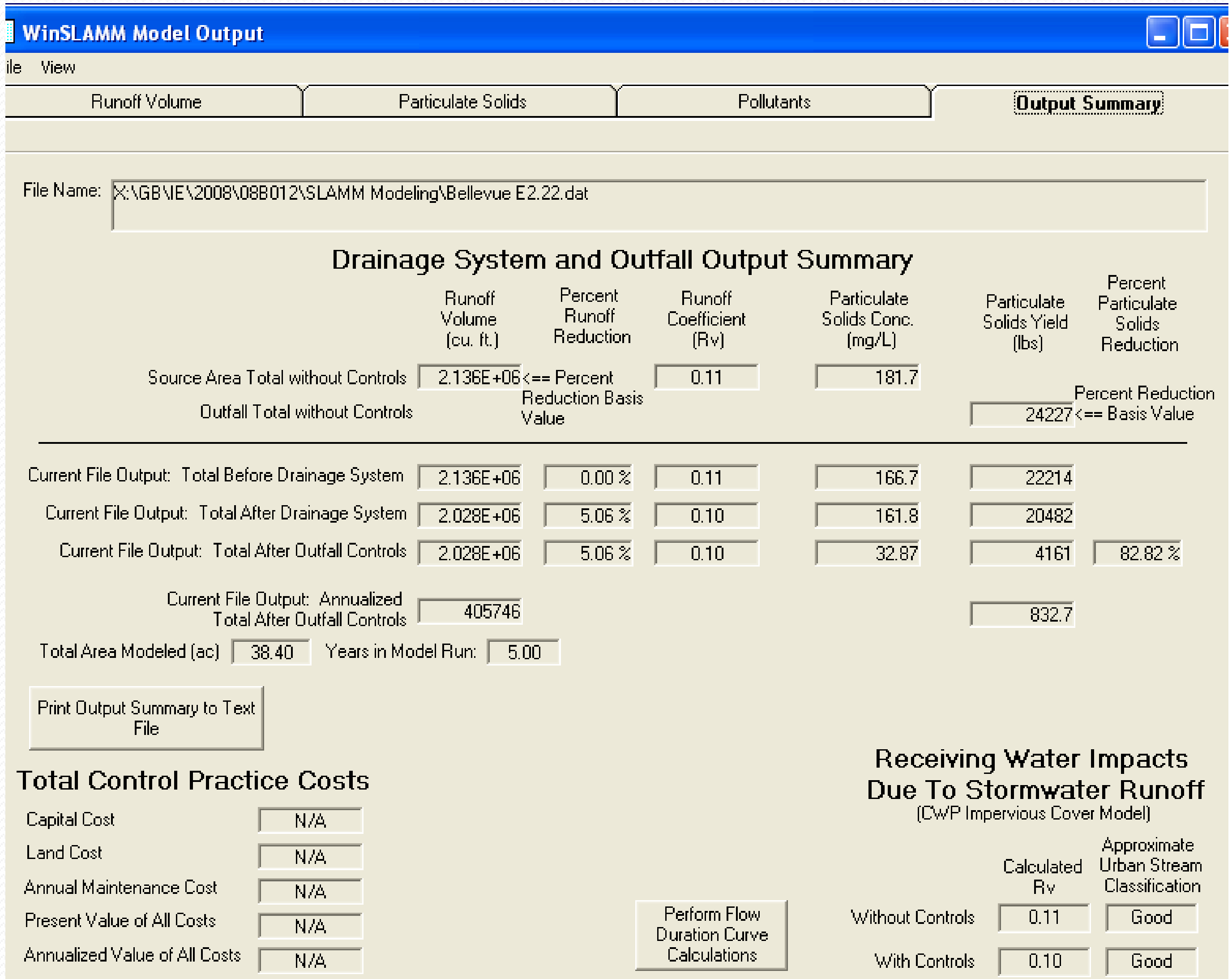
WinSLAMM Output (Existing Conditions)

- Total pollutant yields (lbs)
- Can break out data per pollutant type
- Sets benchmark for future pollutant reduction



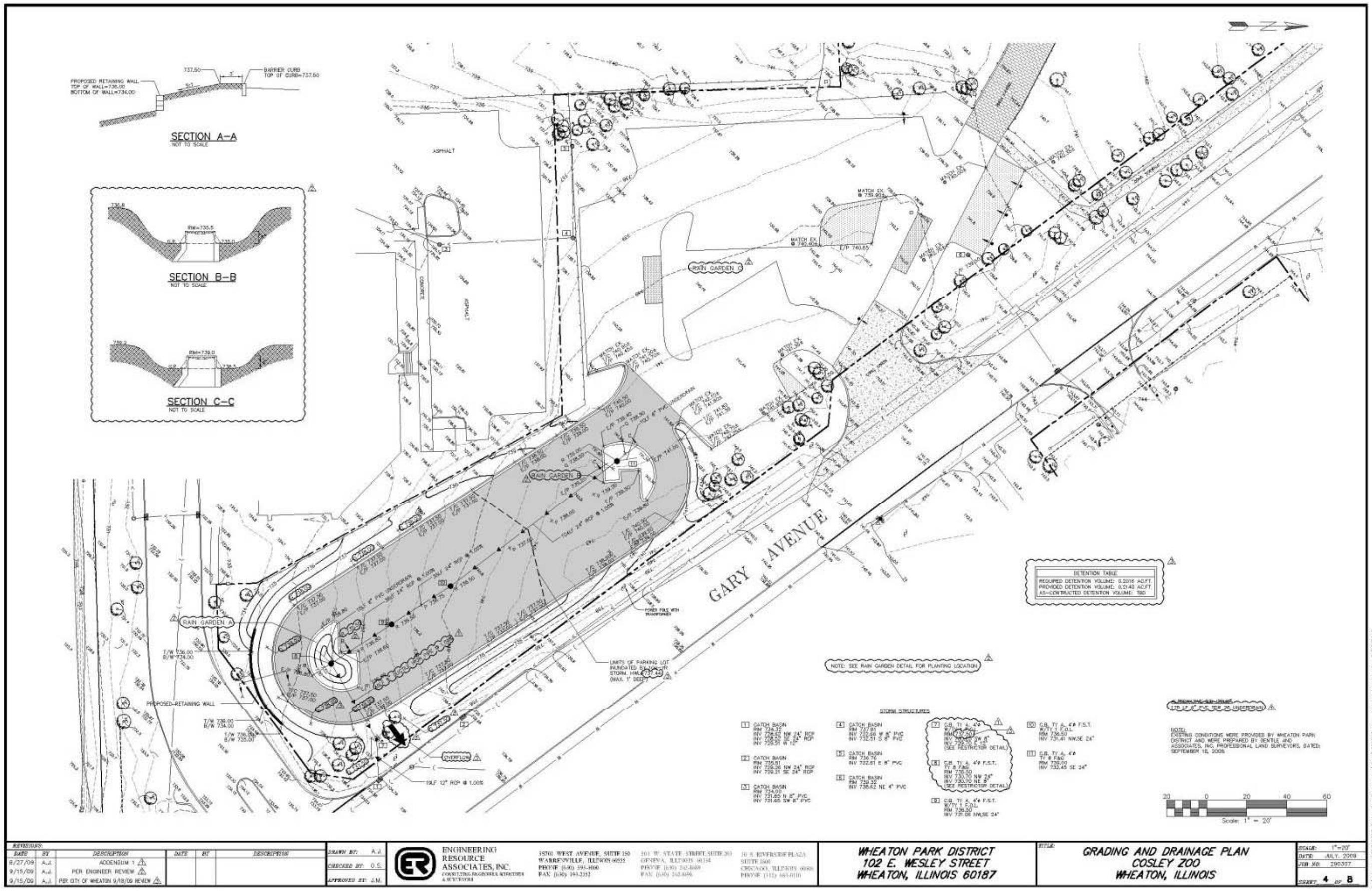
WinSLAMM Output (Future Conditions)

- 82% reduction in solids
- Controls reduce particulate concentration from 162 mg/L to 33 mg/L
- BMP cost data can be added for additional planning tool



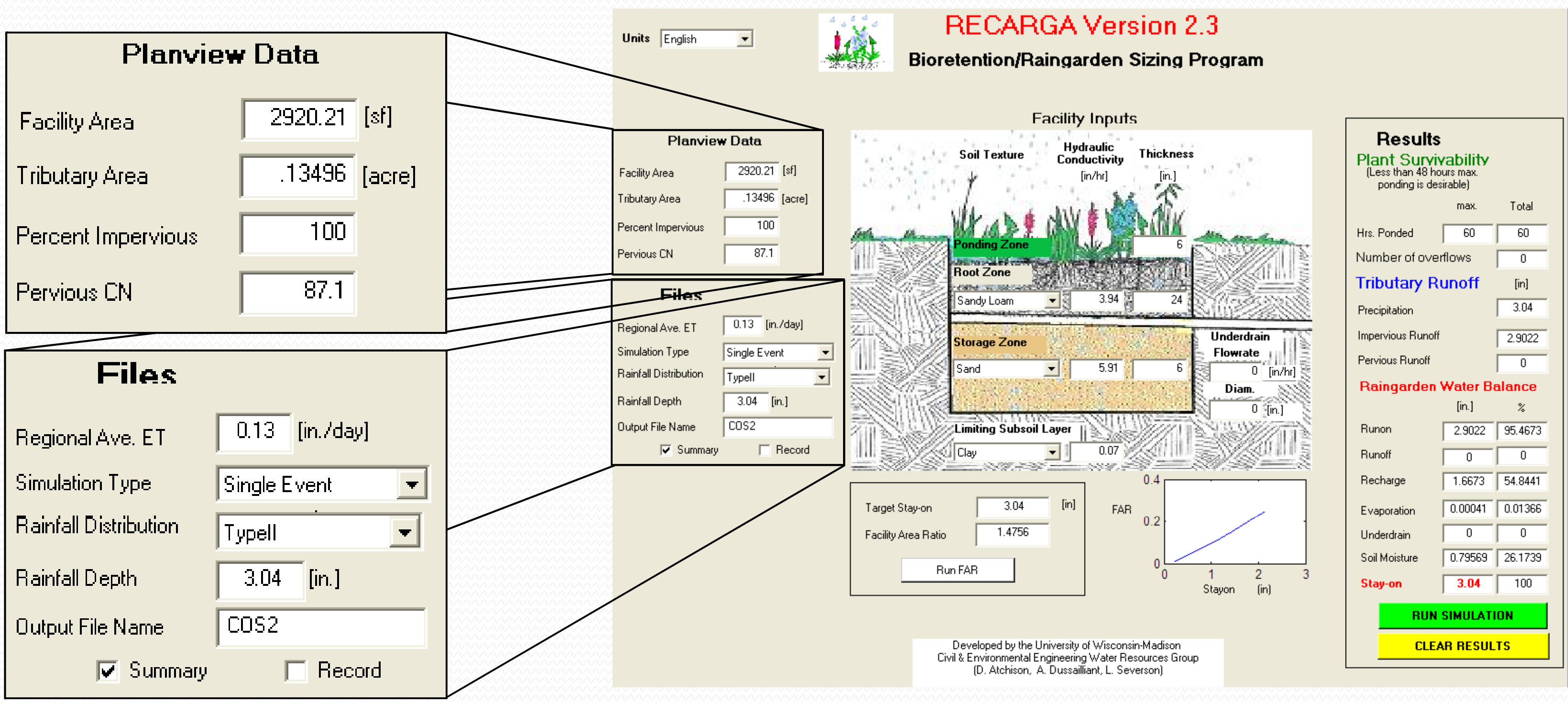
Application Examples–

- Site #4: Small Municipal Project



Application Examples–

- Site #4: Small Municipal Project
  - RECARGA – Cosley Zoo
  - Why use this model / why not use others?



Application Examples–

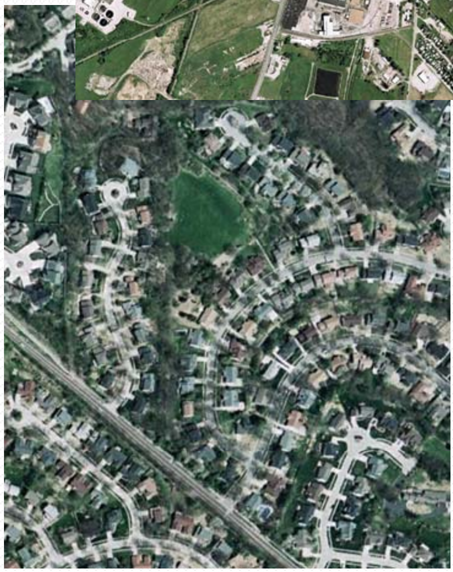
- Site #4: Small Municipal Project

Application Examples–

- Site #5: Municipality (10,000 pop.) with 3 separate watersheds: analyze impacts of City-wide stormwater quality BMPs on receiving streams (local TMDL issues)
- WinSLAMM
- Why use this model / why not use others?
    - WinSLAMM can model removal efficiencies for multiple pollutants, especially those typically found in TMDLs

Application Examples–

- Site #5: Municipality (10,000 pop.) with 3 separate watersheds (WinSLAMM):
  - Watershed 1: Heavy industrial area developed before detention regulations (TMDLs: Lead, Zinc)
  - Watershed 2: Developing area with significant ongoing construction (Potential for innovative design by coordinating with developers)
  - Watershed 3: Commercial / Residential mix (TMDL: Total Nitrogen)

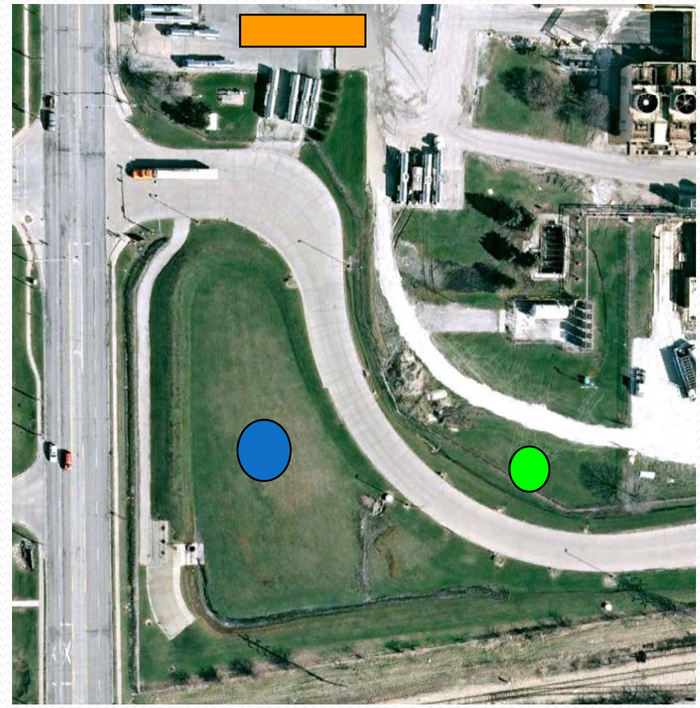


Application Examples–

- Site #5: Analyze Watershed-Specific Solutions (WinSLAMM)
    - Watershed 1: Reduce heavy metals: targeted wet detention, facility pavement sweeping, targeted mechanical separation (swirl concentrators)
    - Watershed 2: Opportunity for application of newer stormwater management techniques (i.e. bioretention)
    - Watershed 3: Reduce Total Nitrogen: street sweeping, impervious area disconnection, targeted rain gardens, detention pond retrofits

Application Examples–

- Site #5: Analyze Watershed-Specific Solutions (WinSLAMM)
  - Total cost of BMPs per watershed
  - Evaluate cost effectiveness of recommended BMPs
    - Prioritize BMPs based on cost-effectiveness
  - Locate and determine preliminary size for each BMP
  - Update land development ordinances
  - Submit materials for regulatory review



Pavement Sweeping

Dry Detention Pond

Bioretention

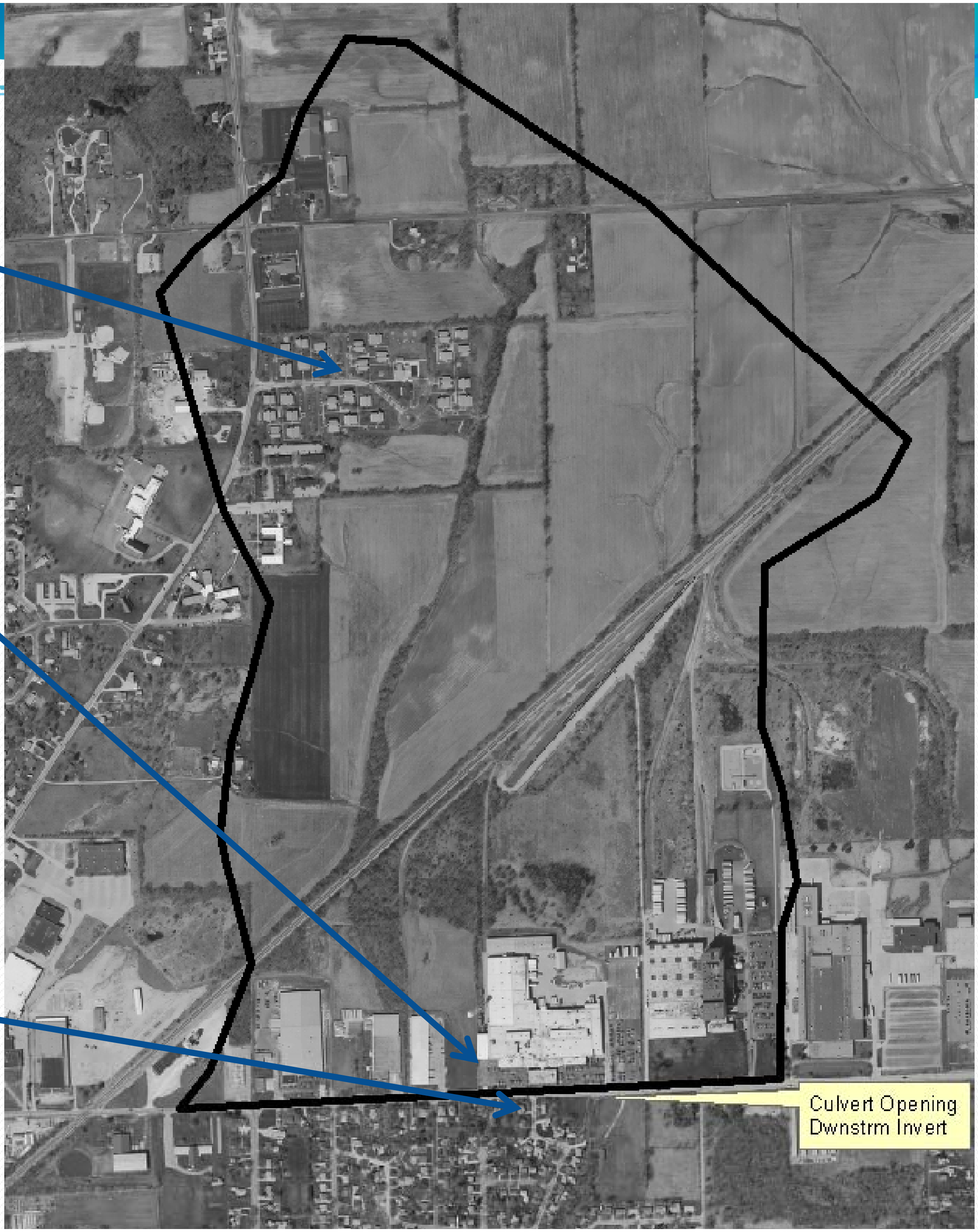
Application Examples–

- Site #6: 640 acre mixed use watershed
  - EPA SWMM – Show Dynamic flood modeling combined with Pollutant reduction measures

Local Flooding

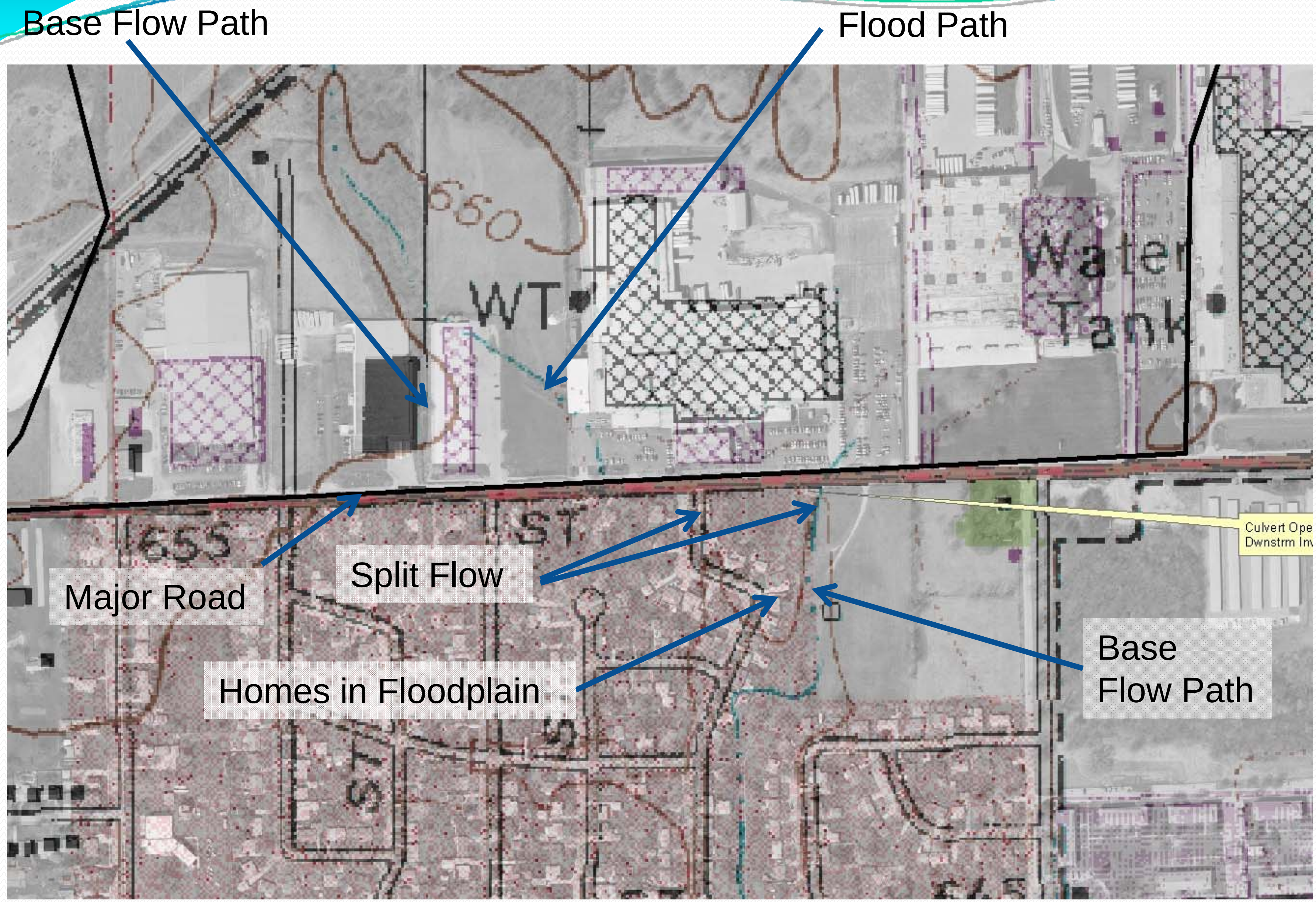
Frequent Flooding of Commercial Establishment

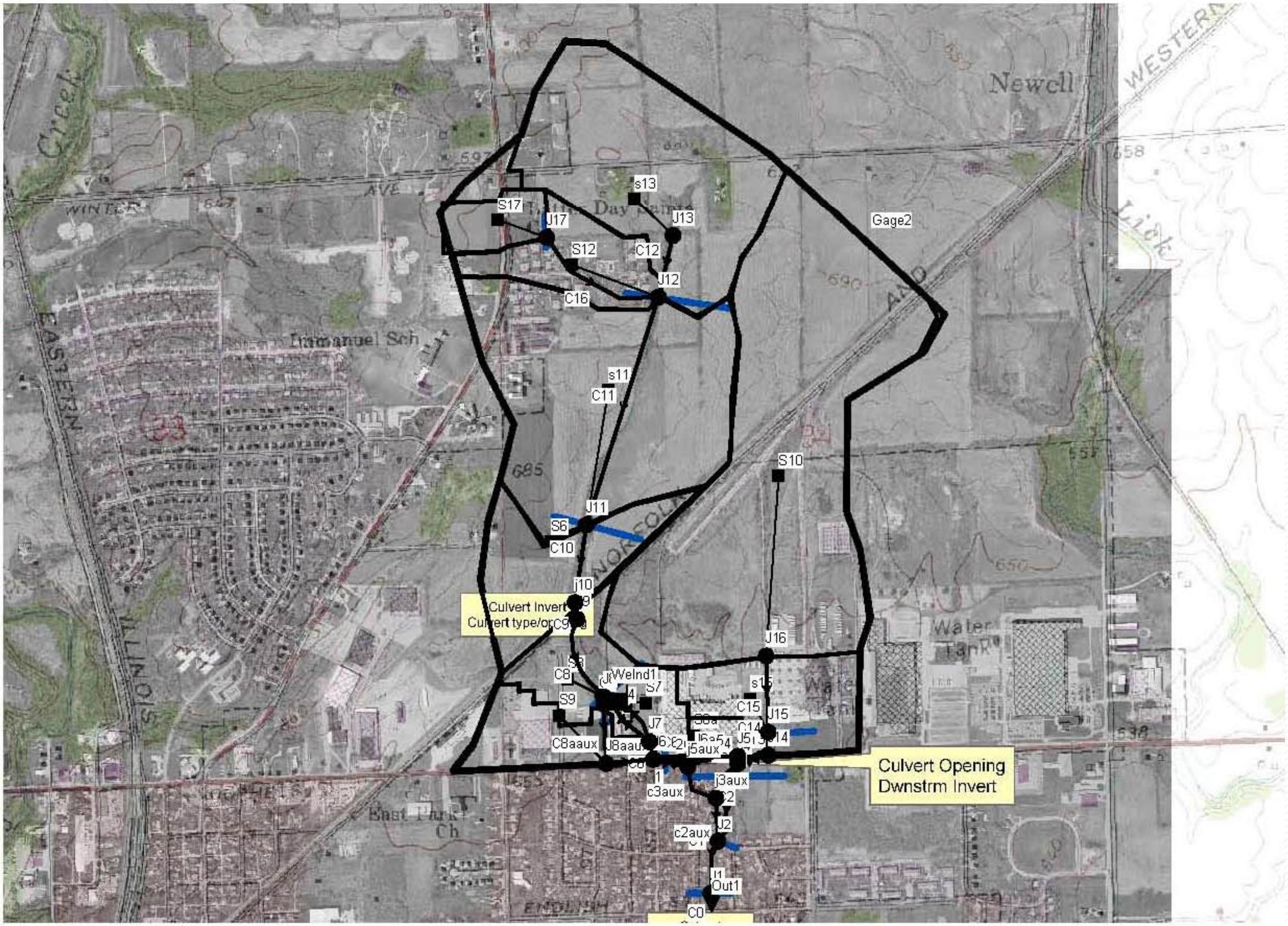
Frequent Roadway Overtopping



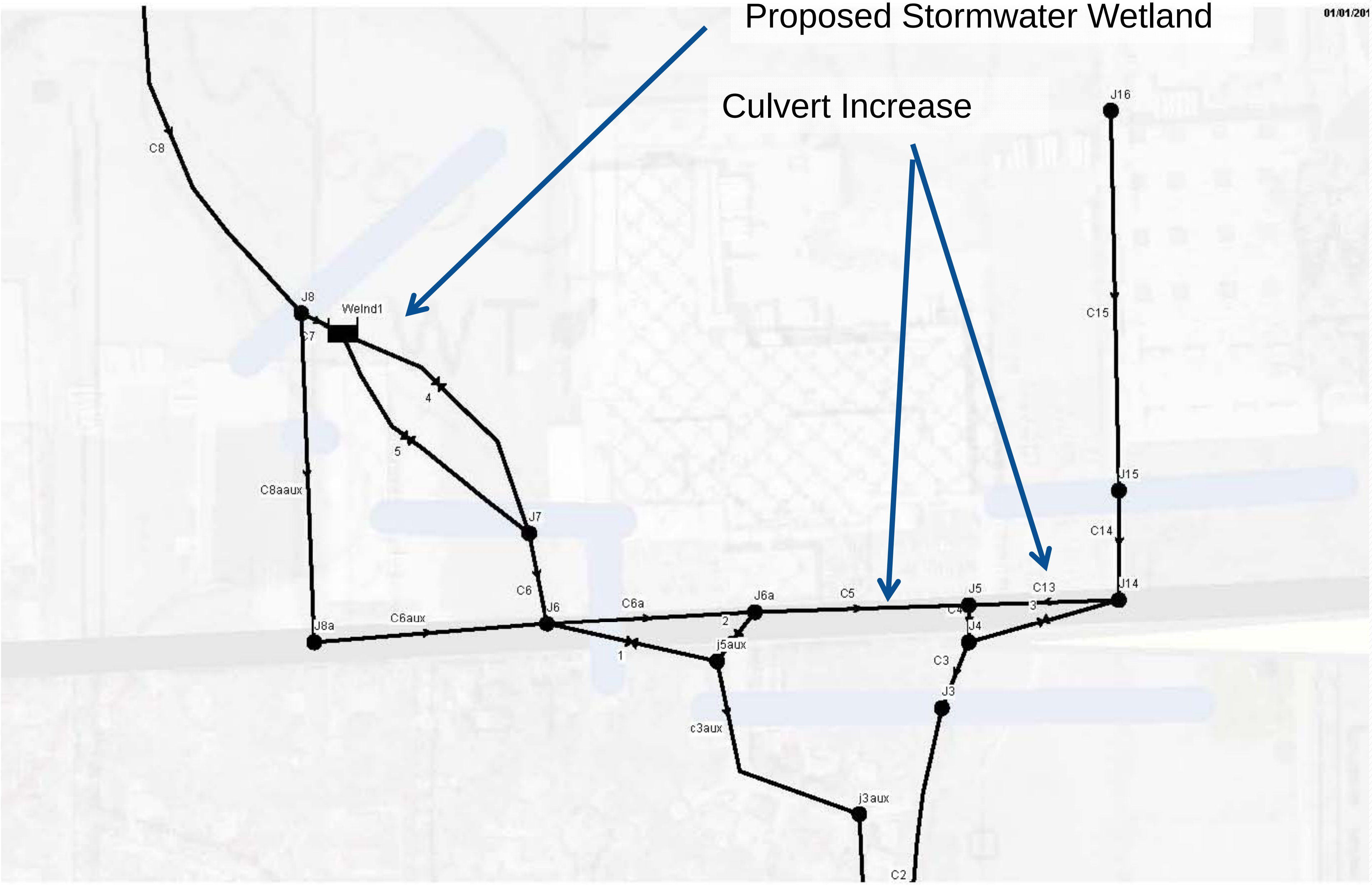

Culvert Ope
Dwnstrm Inv

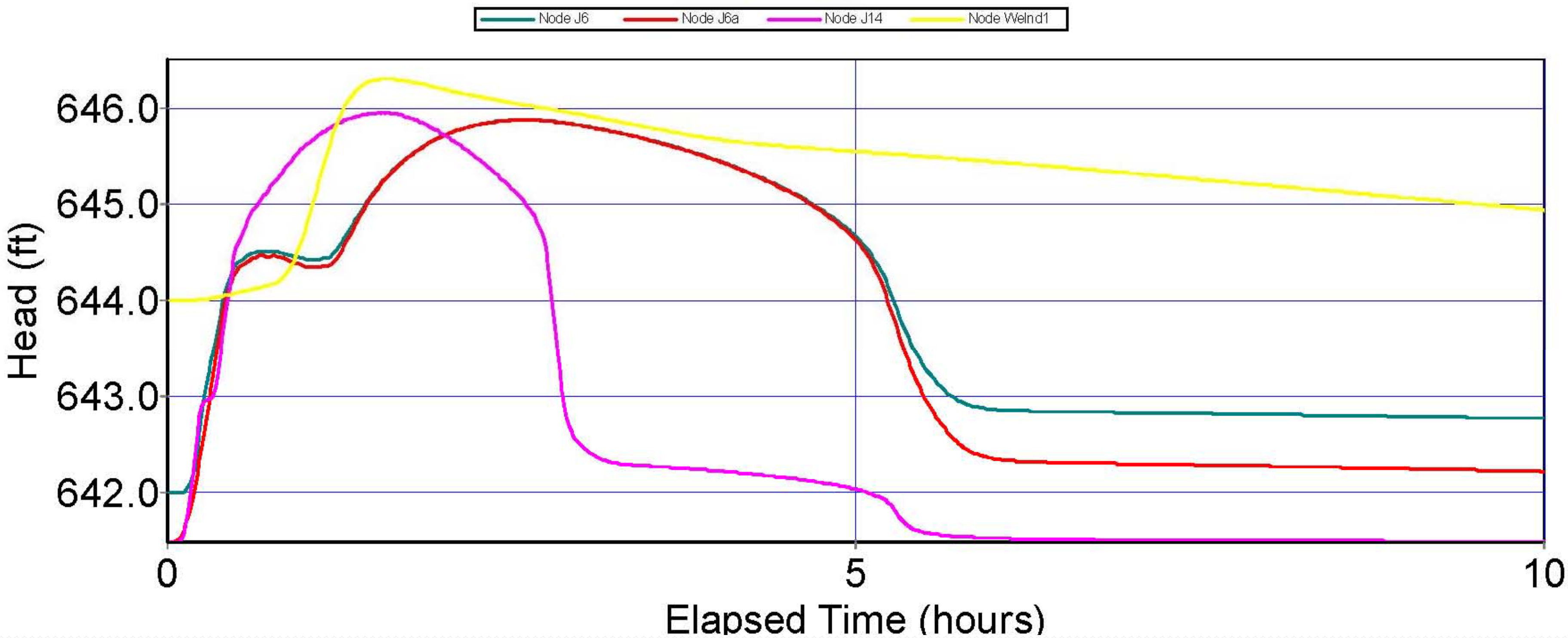
Significant Storage and Dynamic Flow Situations

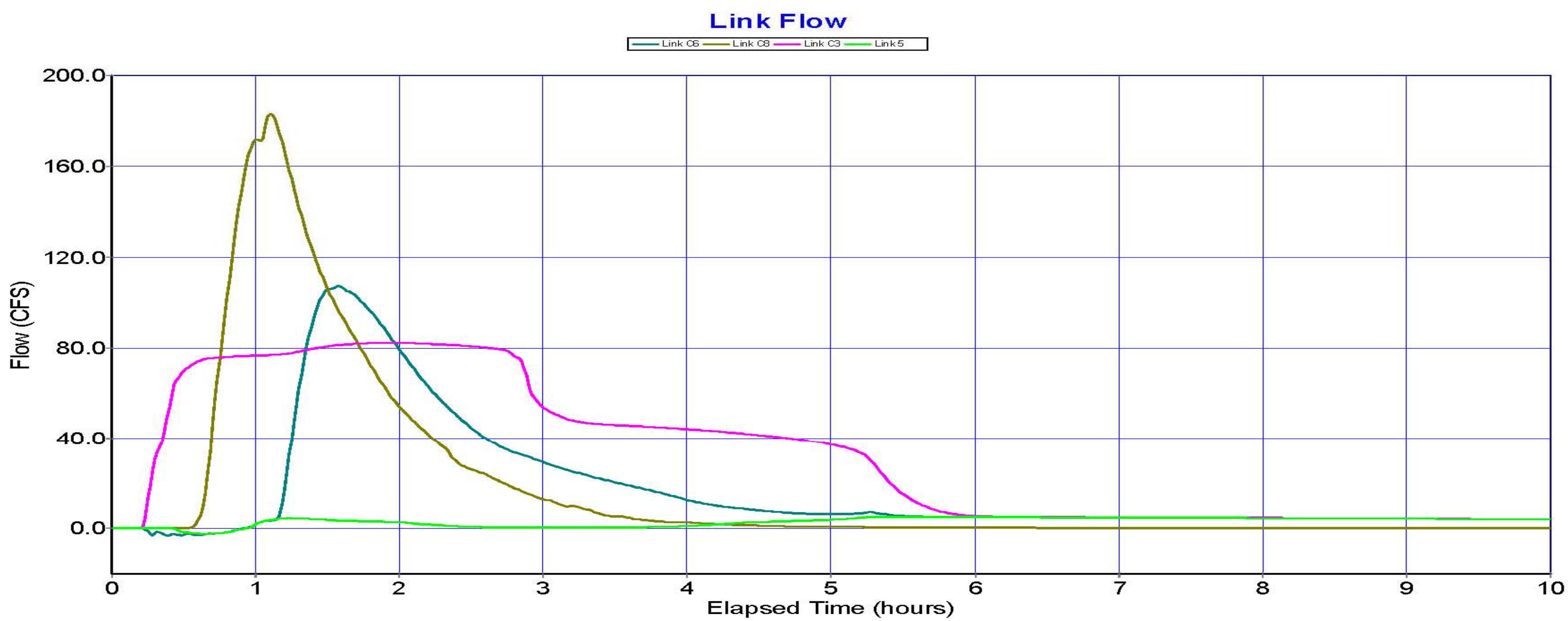




Newell
WESTERN
Creek
WINTER
AVE
EASTERN
ILLINOIS
Immanuel Sch
NORFOLK
AND
Water Tank
East Park Ch
ENGLISH
Gage2
s13
S17
J17
J13
S12
C12
J12
C16
s11
C11
S10
J11
S6
C10
j10
Culvert Invert
Culvert type/or
J16
S8
C8
Welnd1
S7
S9
s15
C15
J15
J7
C14
C8aaux
J8aaux
j5aux
J5
C6
J14
Culvert Opening
Dwnstrm Invert
c3aux
j3aux
C2
J2
c2aux
Out1
C0


Proposed Stormwater Wetland
Culvert Increase
01/01/201
J16
C8
C15
J8
Welnd1
C7
4
5
C8aaux
J7
J15
C14
C6
J6
C6a
J6a
C5
J5
C13
J14
J8a
C6aux
2
C4
3
J4
j5aux
1
C3
J3
c3aux
j3aux
C2


Node J6
Node J6a
Node J14
Node Welnd1
Head (ft)
646.0
645.0
644.0
643.0
642.0
0
5
10
Elapsed Time (hours)


Link Flow
Link C6
Link C8
Link C3
Link 5
Flow (CFS)
200.0
160.0
120.0
80.0
40.0
0.0
0
1
2
3
4
5
6
7
8
9
10
Elapsed Time (hours)

Modeling Examples–

Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- Site #1: 40-acre single-family residential development
  - Model: EPA SWMM
  - Model demonstration
    - Key data needs
    - Model structure and input data
    - Design alternative analysis using model
    - Output data and interpretation


35TH STREET
35TH STREET
1
2
3
4
5
6
16
20
21
22
23
24
25
26
27
28
29
30
CREEK
BRONSWOOD
50' FOREST PRESERVE PROPERTY

Modeling Examples–

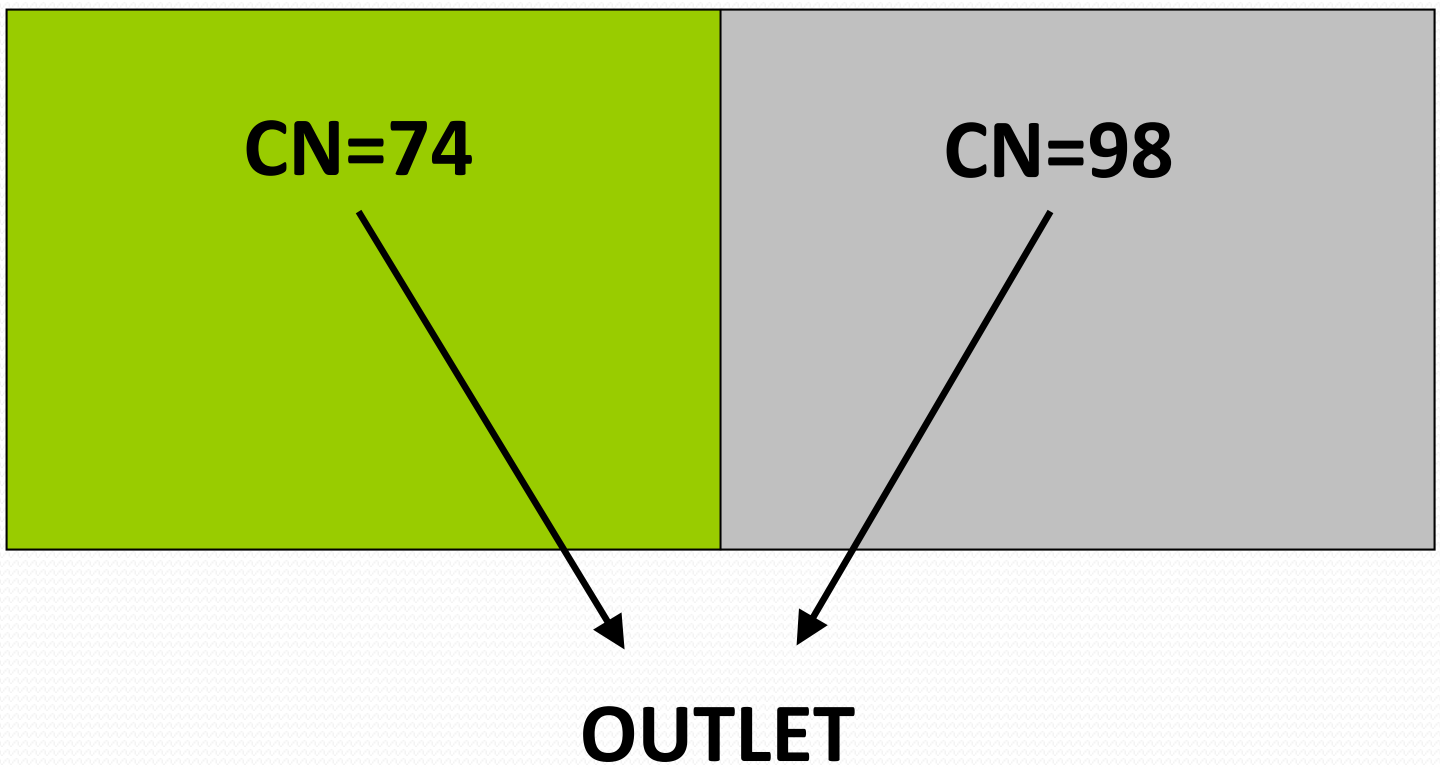
Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- Site #1: 40-acre single-family residential (EPA SWMM)
  - Data Needs:
    - Basic hydrologic variables
      - Drainage areas
      - % Impervious
      - ***% Disconnected Impervious***
    - Bioretention storage volume
    - Soil boring data (CRITICAL FOR BIORETENTION DESIGN)
      - K_{sat}

Modeling Examples–

Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

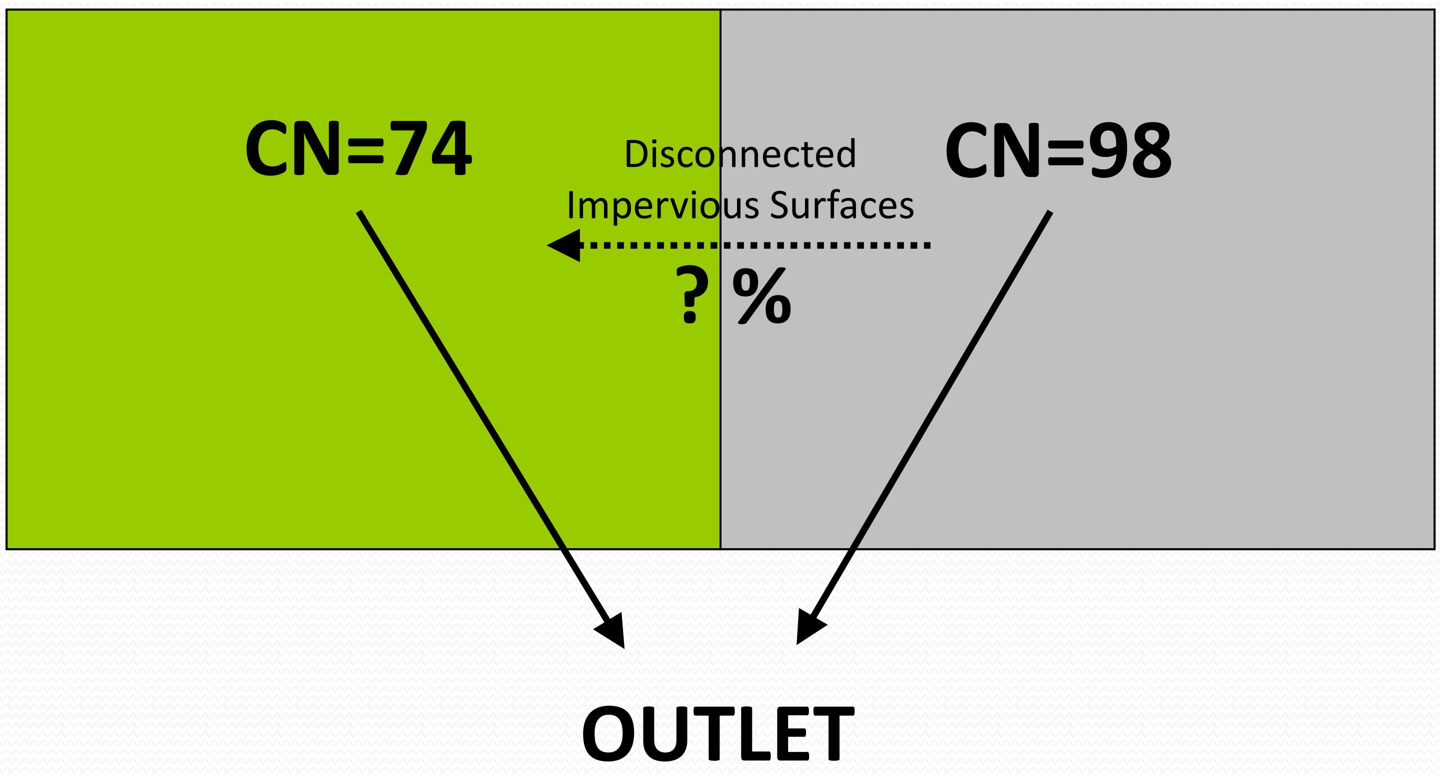
Runoff Calculations in EPA SWMM



Modeling Examples–

Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

Runoff Calculations in EPA SWMM



Modeling Examples–

Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- **EPA SWMM**
  - Hydrology relies on the *Distributed CN Approach*
  - *Composite CN Approach* is not necessarily appropriate for small storm hydrology

<table>
<tr><td colspan="7">Example of Runoff Underestimation for a 1.3-inch Precipitation Event</td></tr>
<tr><th>Approach</th><th>Area (acres)</th><th>Curve Number</th><th>Description</th><th>Runoff Depth (in.)</th><th colspan="2">Runoff Volume (ac-ft)</th></tr>
<tr><td>Composite CN</td><td>20</td><td>75</td><td>¼ acre lots, 38% impervious, SCS Soil Type B</td><td>0.1</td><td colspan="2">0.17</td></tr>
<tr><td rowspan="2">Distributed CN</td><td>6</td><td>98</td><td>Paved roads, rooftops</td><td>1.08</td><td>0.54</td><td rowspan="2">0.55</td></tr>
<tr><td>14</td><td>65</td><td>Green spaces with disconnected impervious area interspersed</td><td>0.01</td><td>0.01</td></tr>
</table>

Source: Stormwater Magazine, March-April 2010

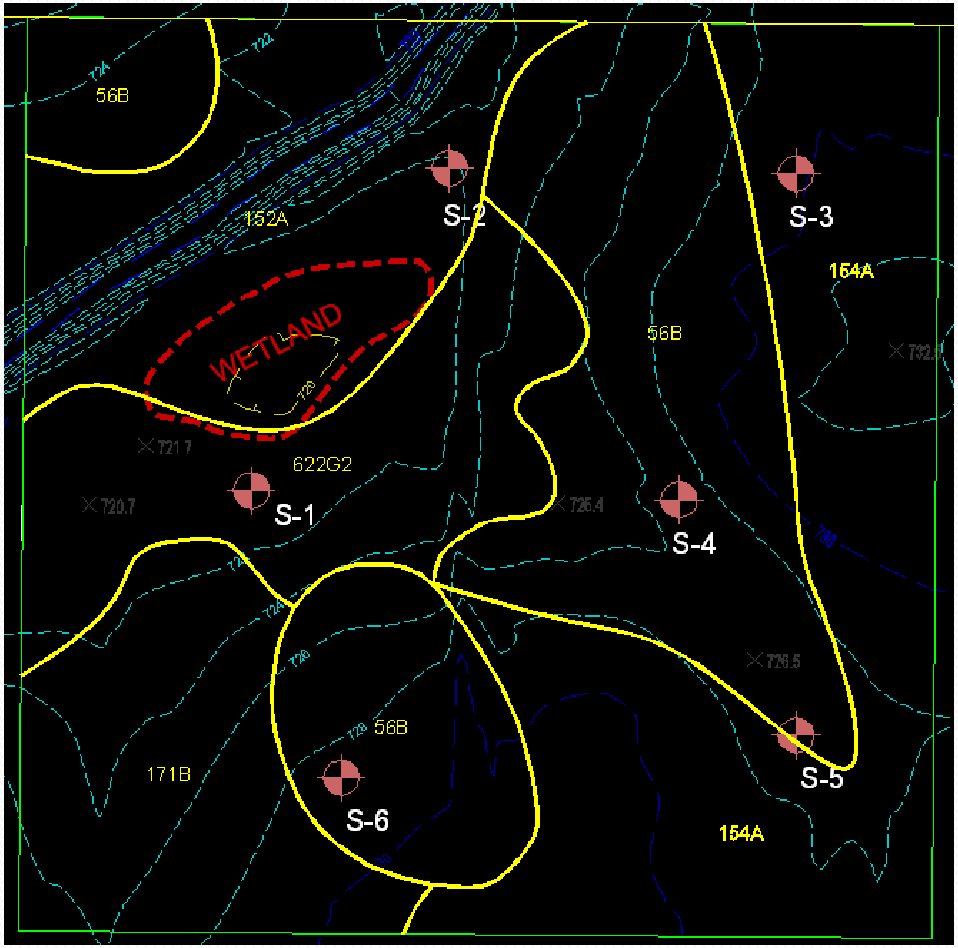
Modeling Examples–

Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

Bioretention Modeling

Ideal location for infiltration BMPs?

Depends on the soil characteristics

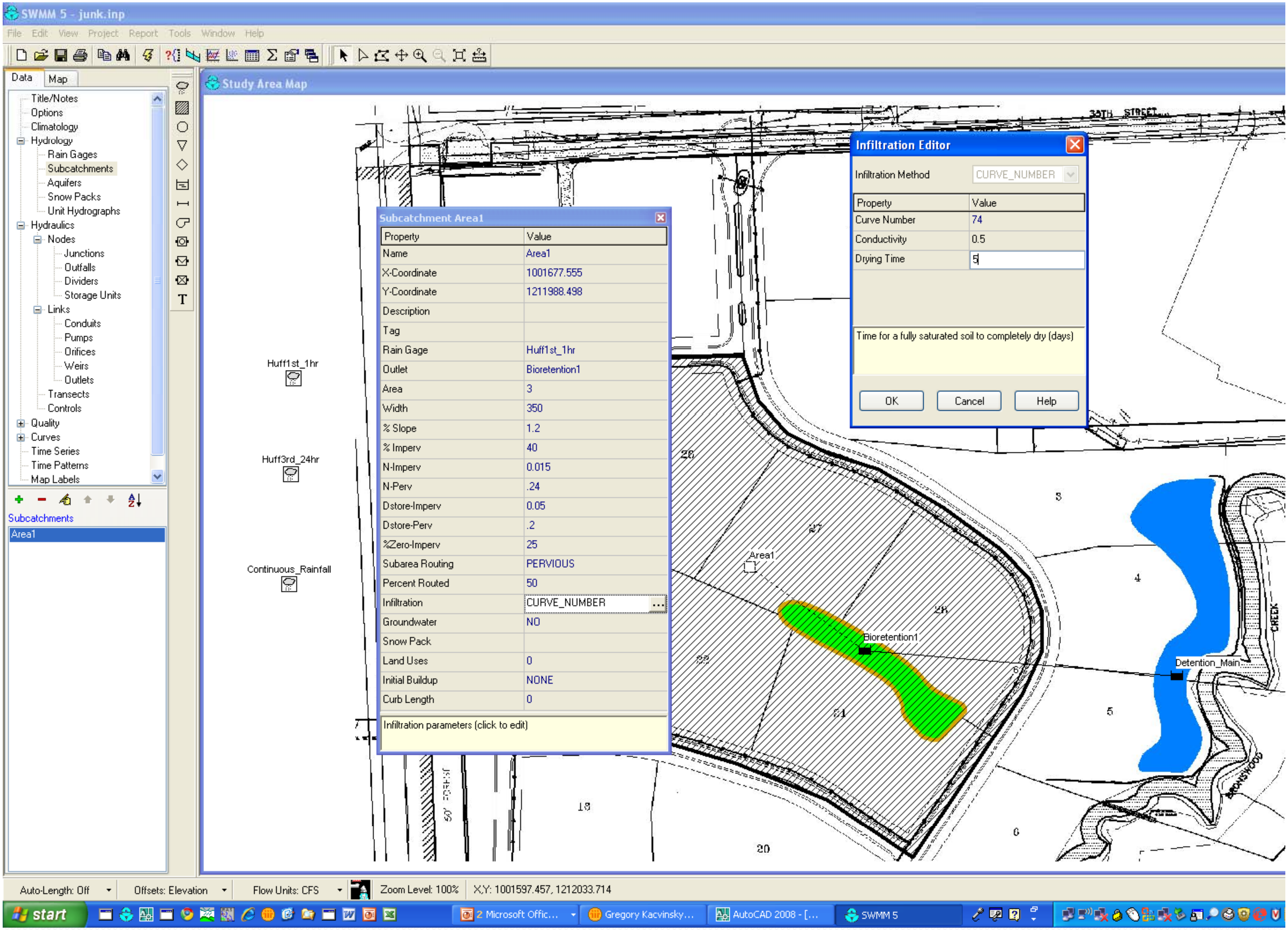


Modeling Examples–

Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- Geotechnical data
  - S-1: Silty loam, Ksat <0.50 in/hr
  - S-2: Clayey Silt, Ksat <0.10 in/hr
  - S-3: Clayey Silt, Ksat <0.20 in/hr
  - S-4: Silty Clay, Ksat <0.05 in/hr
  - S-5: Silty Clay, Ksat <0.1 in/hr
  - *Water table for all samples generally between 12 -20 feet below the surface*

VISUAL SOIL CLASSIFICATION	FT.	SAMPLE NO.	N	Q_p (tsf)	Q_u (tsf)	MC (%)	Dd (pcf)	REMARKS
7" Topsoil		1-AU	-	-	-	27	-	
Brown silty CLAY (CL)		2-SS	7	2.0	2.2	31	96	
	5	3-SS	5	1.0	1.4	17	95	
Brown silty CLAY with sand and small gravel (ML-CL) Till		4-SS	14	2.5	5.2	15	105	
	10	5-SS	15	2.3	4.2	13	120	
Gray silty CLAY with sand and small gravel (CL) Till		6-SS	18	4.5+	7.4	11	128	
	15	7-SS	18	4.0	5.9	12	128	Completion: 15 ft.
	20	8-SS	16	4.0	4.2	12	109	Drilling: 20 ft.
END OF BORING AT 21.5 FEET								

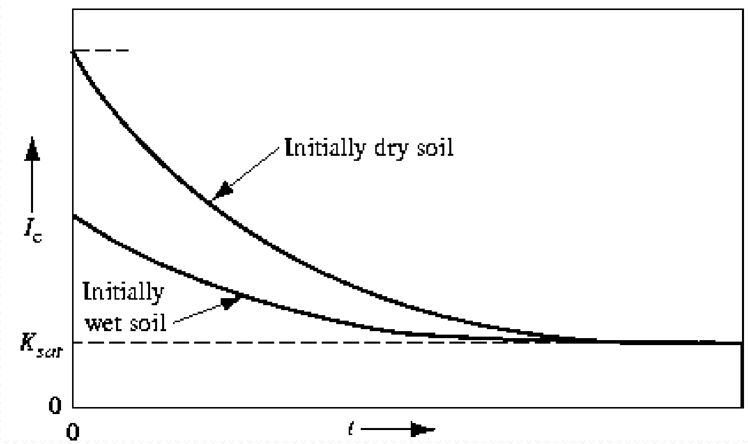

SWMM 5 - junk.inp
File Edit View Project Report Tools Window Help
Data
Map
Title/Notes
Options
Climatology
Hydrology
Rain Gages
Subcatchments
Aquifers
Snow Packs
Unit Hydrographs
Hydraulics
Nodes
Junctions
Outfalls
Dividers
Storage Units
Links
Conduits
Pumps
Orifices
Weirs
Outlets
Transects
Controls
Quality
Curves
Time Series
Time Patterns
Map Labels
Subcatchments
Area1
Study Area Map
Huff1st_1hr
Huff3rd_24hr
Continuous_Rainfall
Subcatchment Area1
Property | Value
Name | Area1
X-Coordinate | 1001677.555
Y-Coordinate | 1211988.498
Description
Tag
Rain Gage | Huff1st_1hr
Outlet | Bioretention1
Area | 3
Width | 350
% Slope | 1.2
% Imperv | 40
N-Imperv | 0.015
N-Perv | .24
Dstore-Imperv | 0.05
Dstore-Perv | .2
%Zero-Imperv | 25
Subarea Routing | PERVIOUS
Percent Routed | 50
Infiltration | CURVE_NUMBER
Groundwater | NO
Snow Pack
Land Uses | 0
Initial Buildup | NONE
Curb Length | 0
Infiltration parameters (click to edit)
Infiltration Editor
Infiltration Method | CURVE_NUMBER
Property | Value
Curve Number | 74
Conductivity | 0.5
Drying Time | 5
Time for a fully saturated soil to completely dry (days)
OK
Cancel
Help
Area1
Bioretention1
Detention_Main
Auto-Length: Off
Offsets: Elevation
Flow Units: CFS
Zoom Level: 100%
X,Y: 1001597.457, 1212033.714
start
2 Microsoft Offic...
Gregory Kacvinsky...
AutoCAD 2008 - [...
SWMM 5

Modeling Examples–

Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- Site #1: 40-acre single-family residential (EPA SWMM)
  - Model Structure / Input Data:
    - Distributed CN approach
      - Consider compacted soils (SCS Soil Type B → C ?)
    - Bioretention storage volume and infiltration rates
    - Rainfall data (Huff 1st and 3rd distributions, continuous data set)
    - Evaporation data
    - Hydraulic connections (bioretention overflow to detention pond

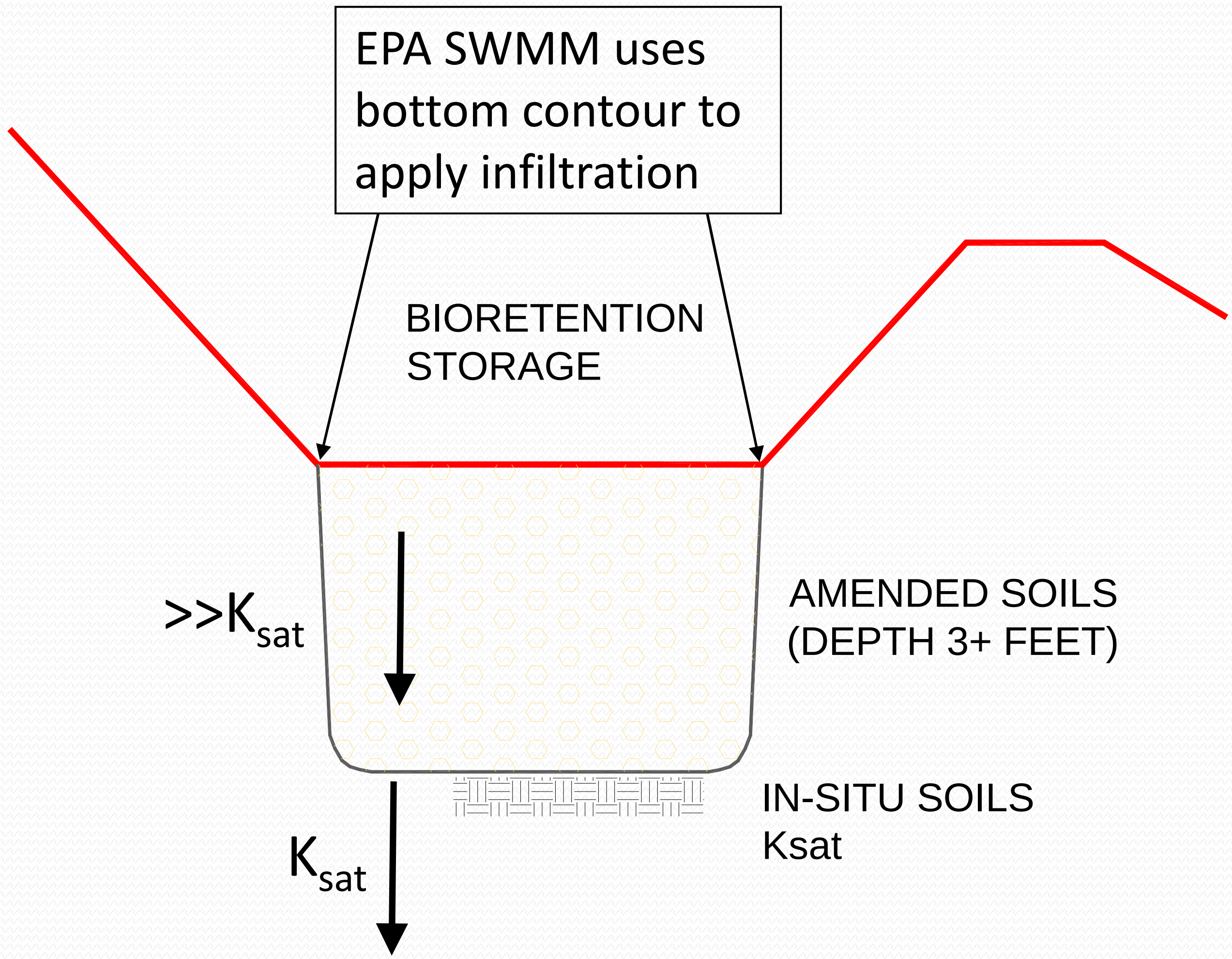
Modeling Examples–



- Bioretention modeling:
  - Establishing infiltration criteria
    - Green-Ampt method
      - **Conductivity (in/hr): Ksat (saturated soil conductivity)**
        - MOST IMPORTANT VARIABLE
        - Should be at least 0.3-0.4 in/hr for effective infiltration
      - Suction Head (in): capillary suction
        - Higher for fine-grained soils
      - Initial deficit (fraction): lower for saturated soils
        - Typically 0.2 – 0.5 (lower for wet soils)

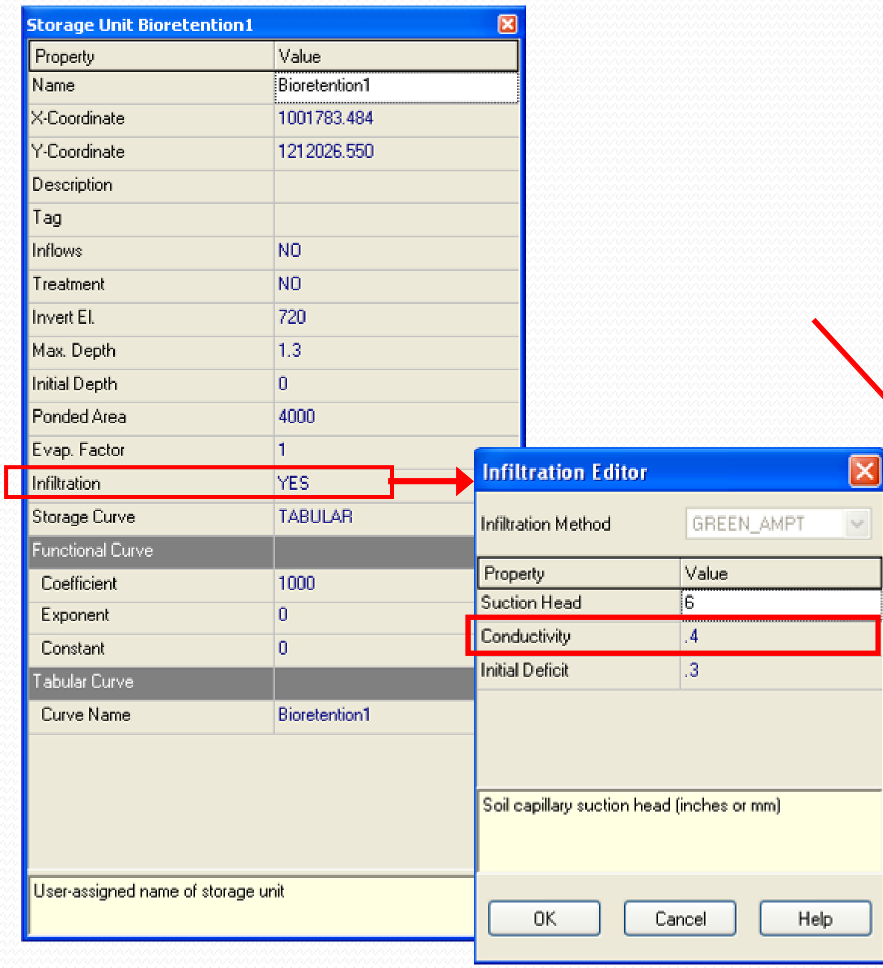
Modeling Examples–

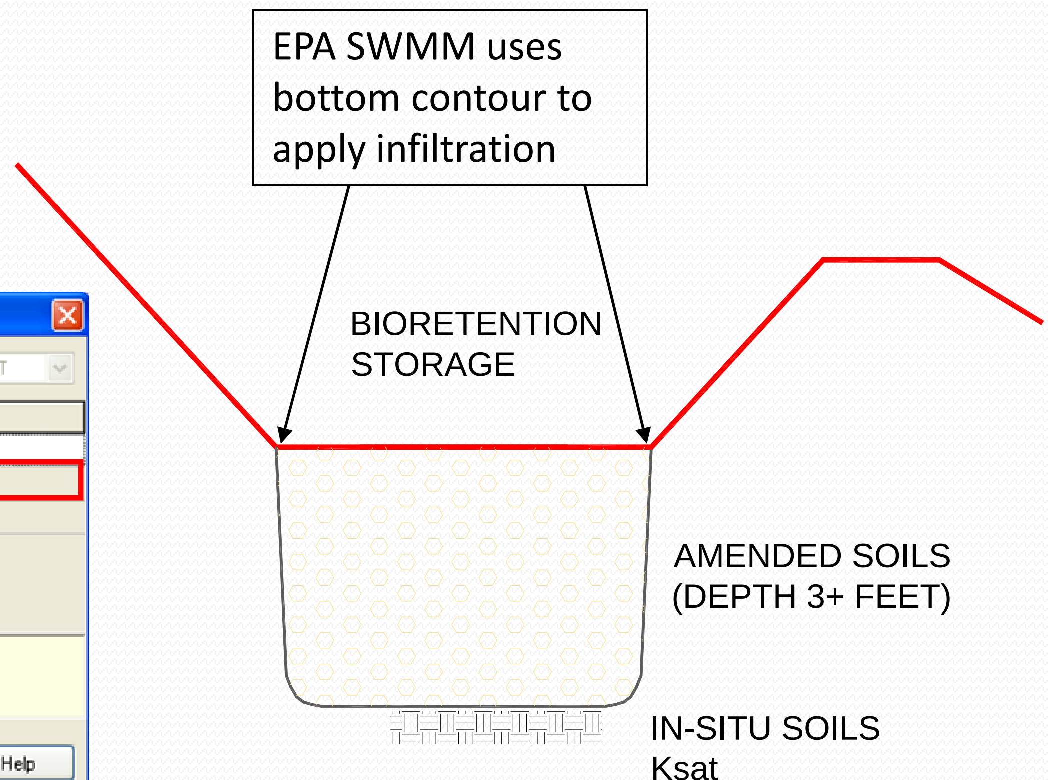
EPA SWMM uses K_{sat} for bioretention drawdown, although amended soils (and vegetation) may increase infiltration potential



Modeling Examples–

Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)





Modeling Examples–

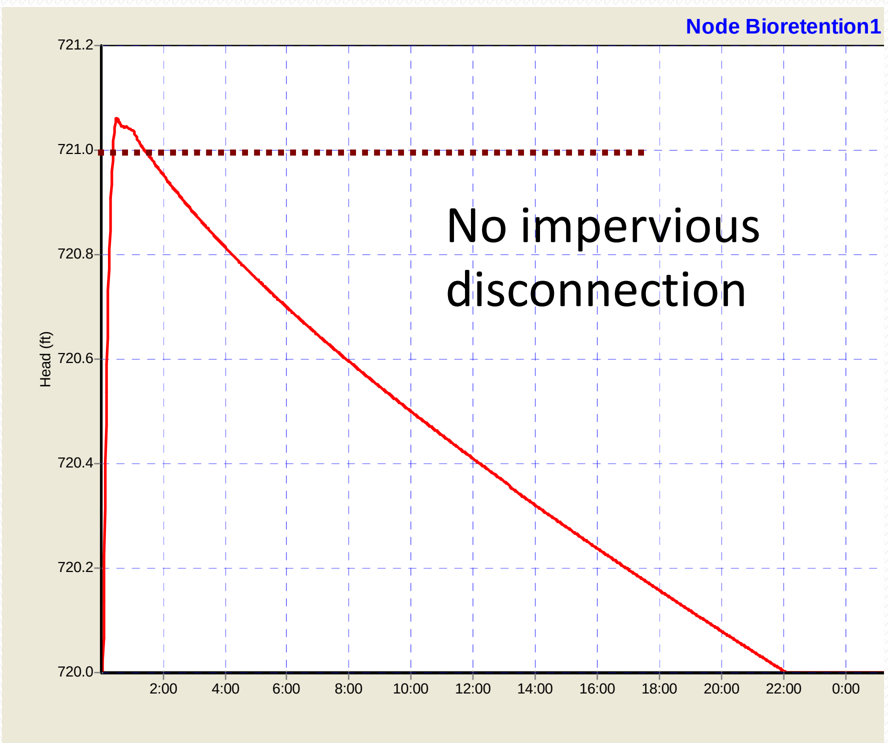
Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

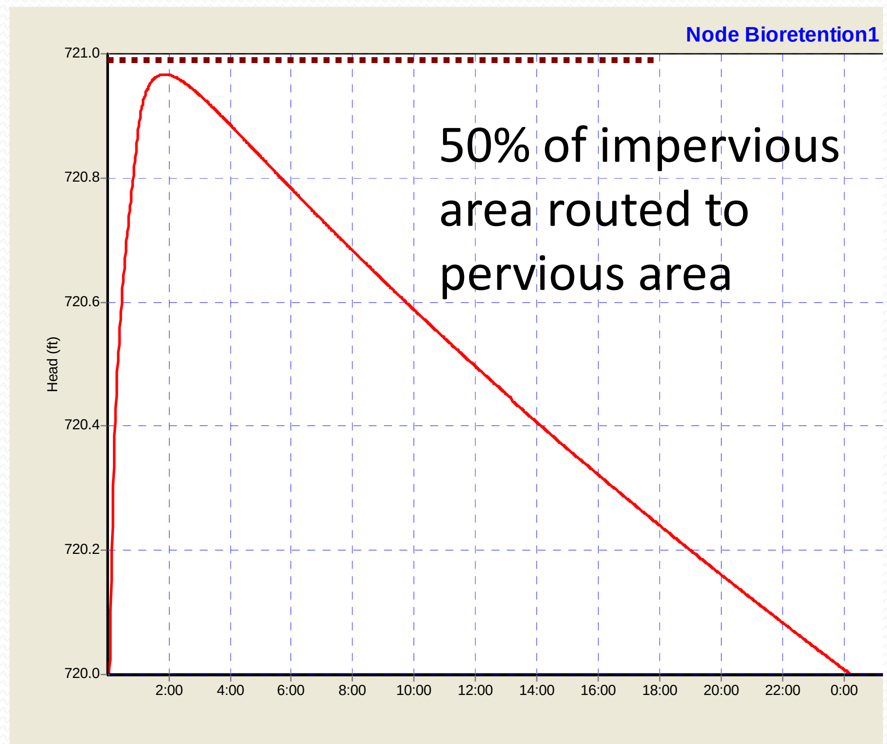
- Site #1: 40-acre single-family residential (EPA SWMM)
  - BMP performance measures:
    - Water quality event (i.e. 1-yr, 2-yr)
      - Example: 1-inch, 1-hour storm (zero runoff)
    - Continuous Simulation (1 year of rainfall data)
      - Maintain % of pre-development runoff (i.e. 90%)
  - Design Alternative Analysis:
    - Vary bioretention footprint size
    - Adjust % disconnected impervious area
    - Wet / dry detention pond (infiltration / evaporation)

Modeling Examples–

Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- Site #1: 40-acre single-family residential (EPA SWMM)
  - Output data interpretation:

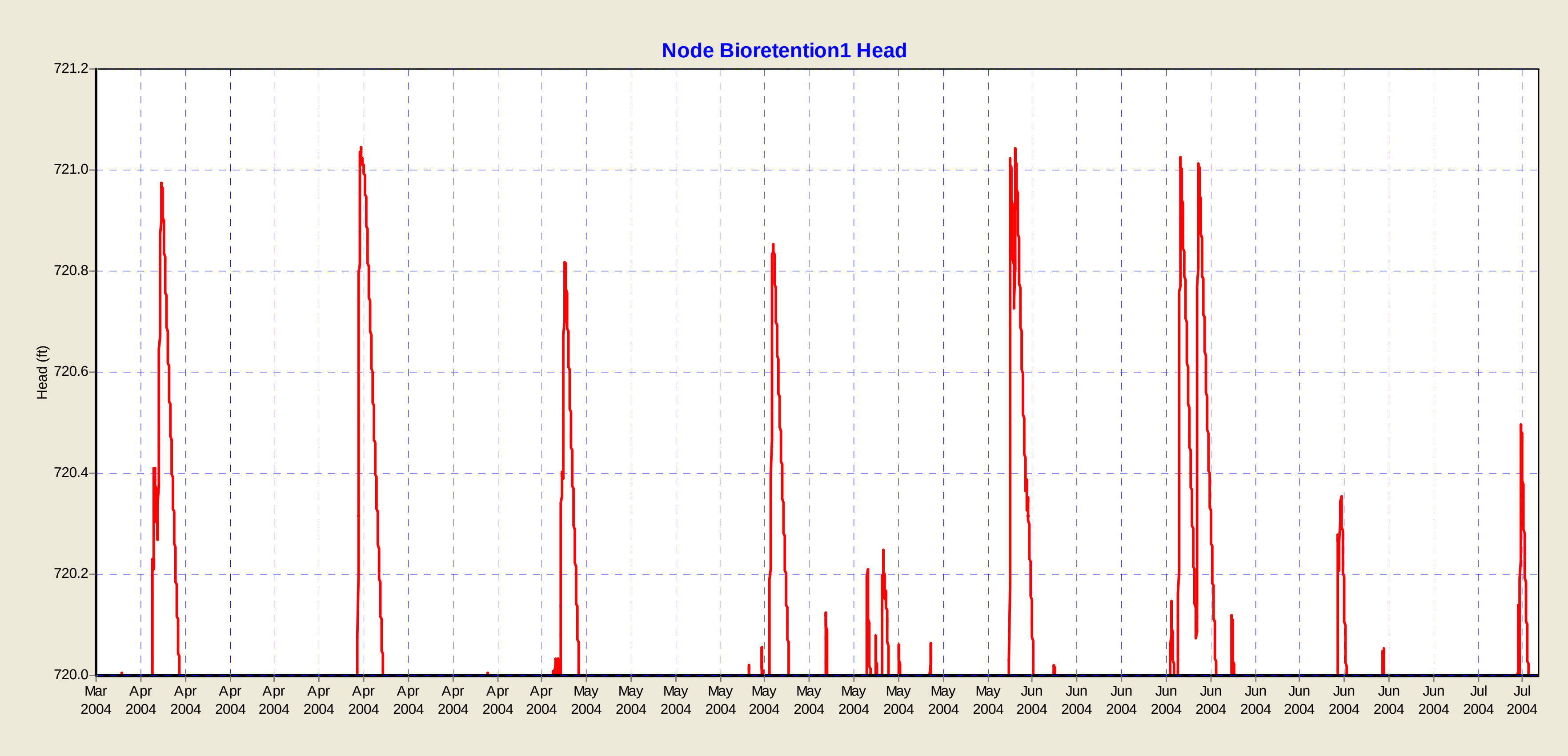




Modeling Examples–

Gregory Kacvinsky (Foth Infrastructure & Environment, LLC)

- Site #1: 40-acre single-family residential (EPA SWMM)



Modeling Examples–

Erin Pande (Engineering Resource Associates, Inc.)

- Site #2: 10-acre commercial re-development

Modeling Examples–

Erin Pande (Engineering Resource Associates, Inc.)

- Site #2: 10-acre commercial re-development
  - Key data needs
    - What are you designing the bio-infiltration for?
      - Specific storm event (e.g. in DuPage 2yr 24 hr, 3.04in)
      - Reduced percentage of runoff from impervious area (e.g. in Wisconsin post−development infiltration volume shall be at least 90% of the pre−development infiltration volume, based on an average annual rainfall)

Modeling Examples–

Erin Pande (Engineering Resource Associates, Inc.)

- Site #2: 10-acre commercial re-development
  - Model structure
    - Continuous Simulation–Model-generated runoff
    - Design-Storm–SCS Type I, IA, II, III
    - Green-Ampt infiltration model for initial infiltration into the soil surface
    - Van Genuchten relationship for drainage between soil layers

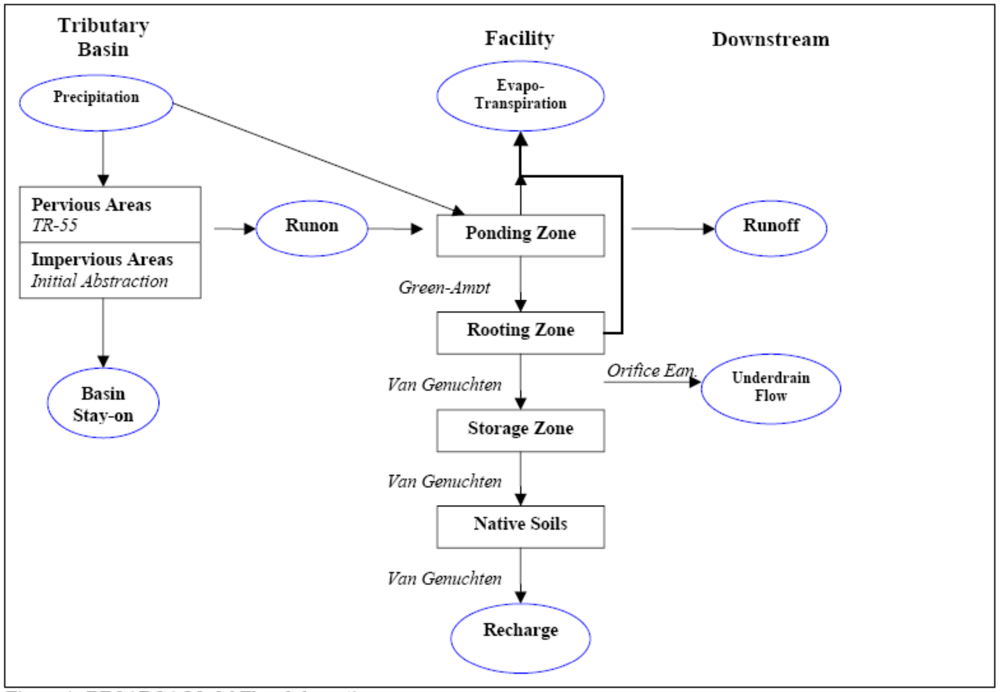


Figure 4. RECARGA Model Flow Schematic

Modeling Examples–

Erin Pande (Engineering Resource Associates, Inc.)

- Site #2: 10-acre commercial development
- Input Data
  - Tributary Area
  - Percent Impervious
  - Pervious CN (*not* composite CN)
  - Precipitation Input Files (if using user specified data)
  - Saturated Hydraulic Conductivity of underlying soils

Modeling Examples–

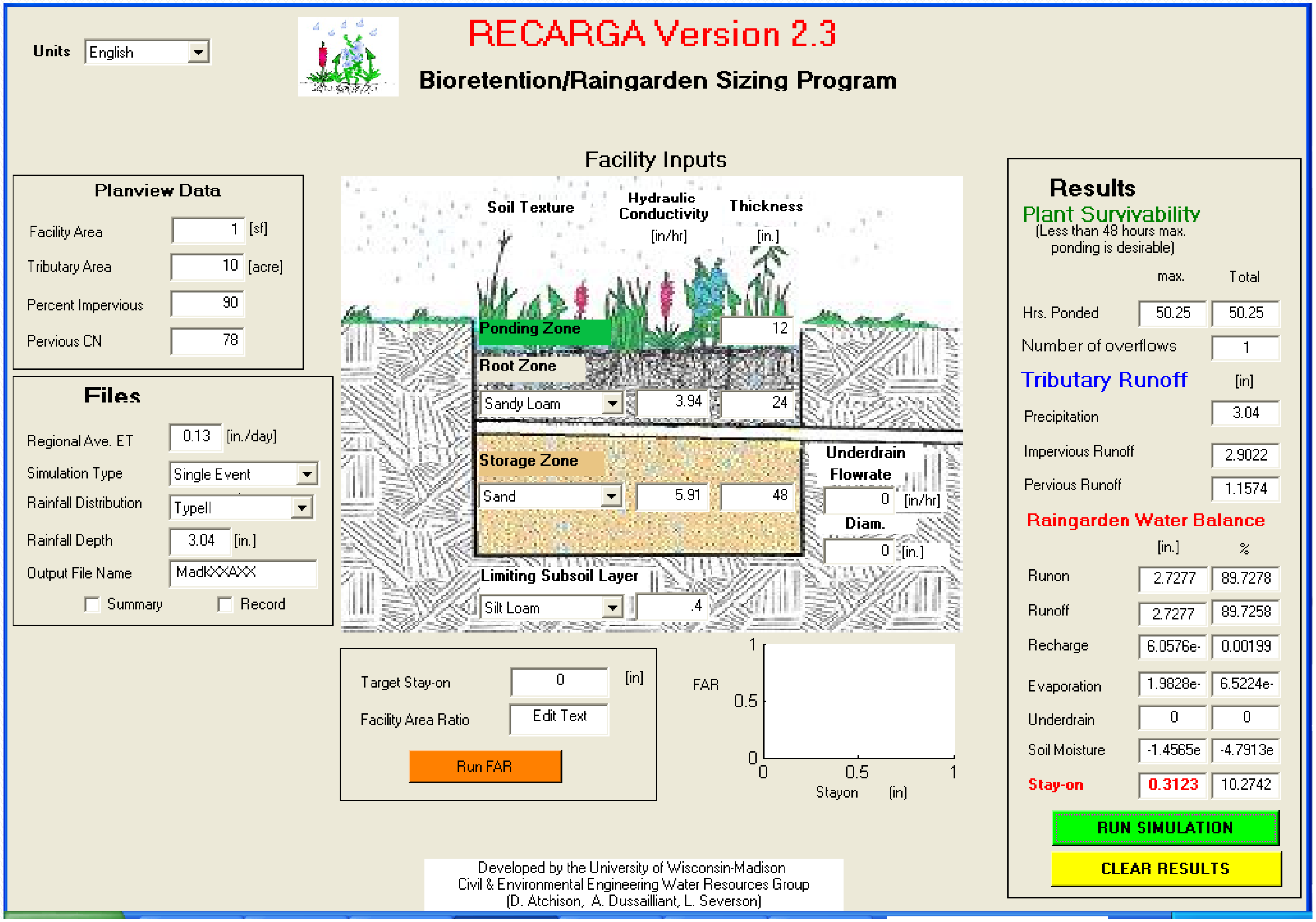
Erin Pande (Engineering Resource Associates, Inc.)

- Site #2: 10-acre commercial development
- Determine area needed for bio-infiltration facility
  - Assumes event based (2yr 24hr event)
  - Tributary area = 10 acres
  - Percent Impervious = 98%
  - Pervious CN = 78
  - Approximate depths and materials to be used in facility
  - K_{sat} of underlying soils = 0.4 in/hr

Modeling Examples–

Erin Pande (Engineering Resource Associates, Inc.)

- Existing
  - 2yr 24 hr storm (3.04 in) Design-Storm–SCS Type II
  - Must input 1 ft for facility or you will get an error
  - Tributary area = 10acres
  - Percent impervious 90%
  - Pervious CN = 78
  - **Existing Infiltration = 0.3123**



Modeling Examples–

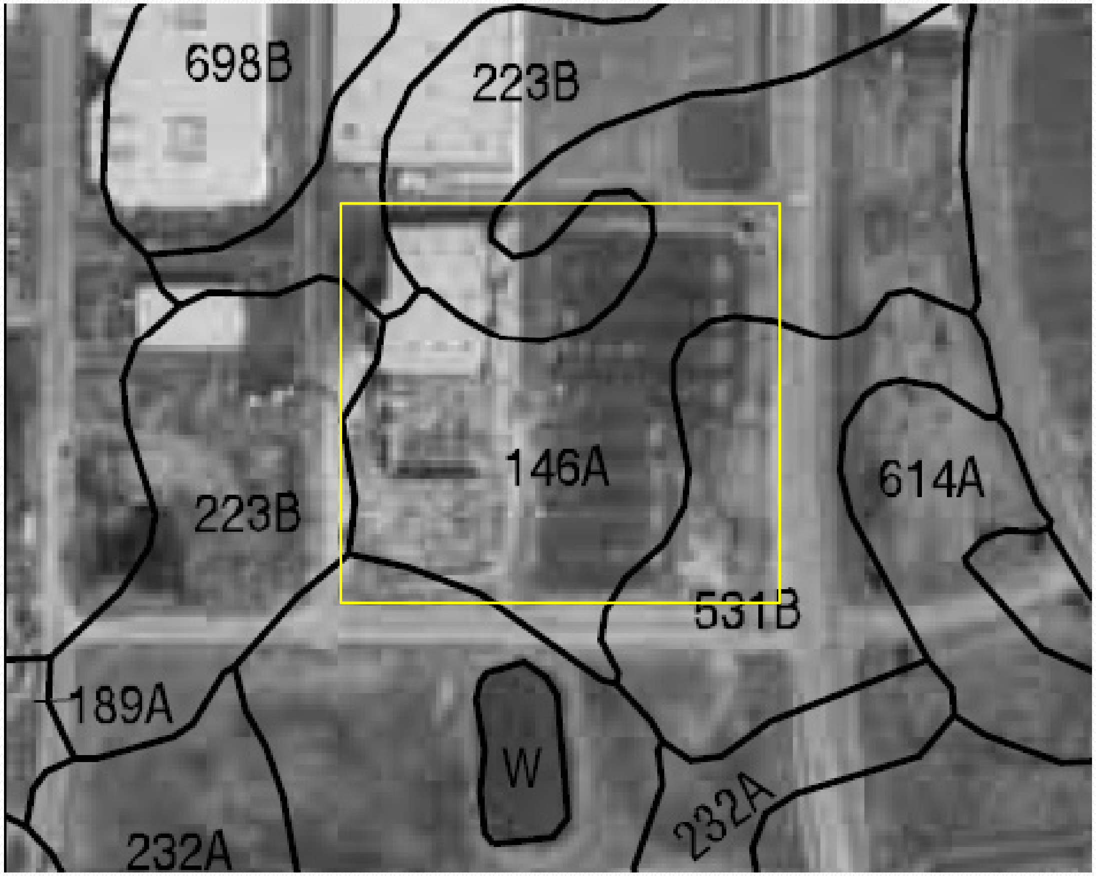
Erin Pande (Engineering Resource Associates, Inc.)

- Site #2: 10-acre commercial re-development

Modeling Examples–

Erin Pande (Engineering Resource Associates, Inc.)

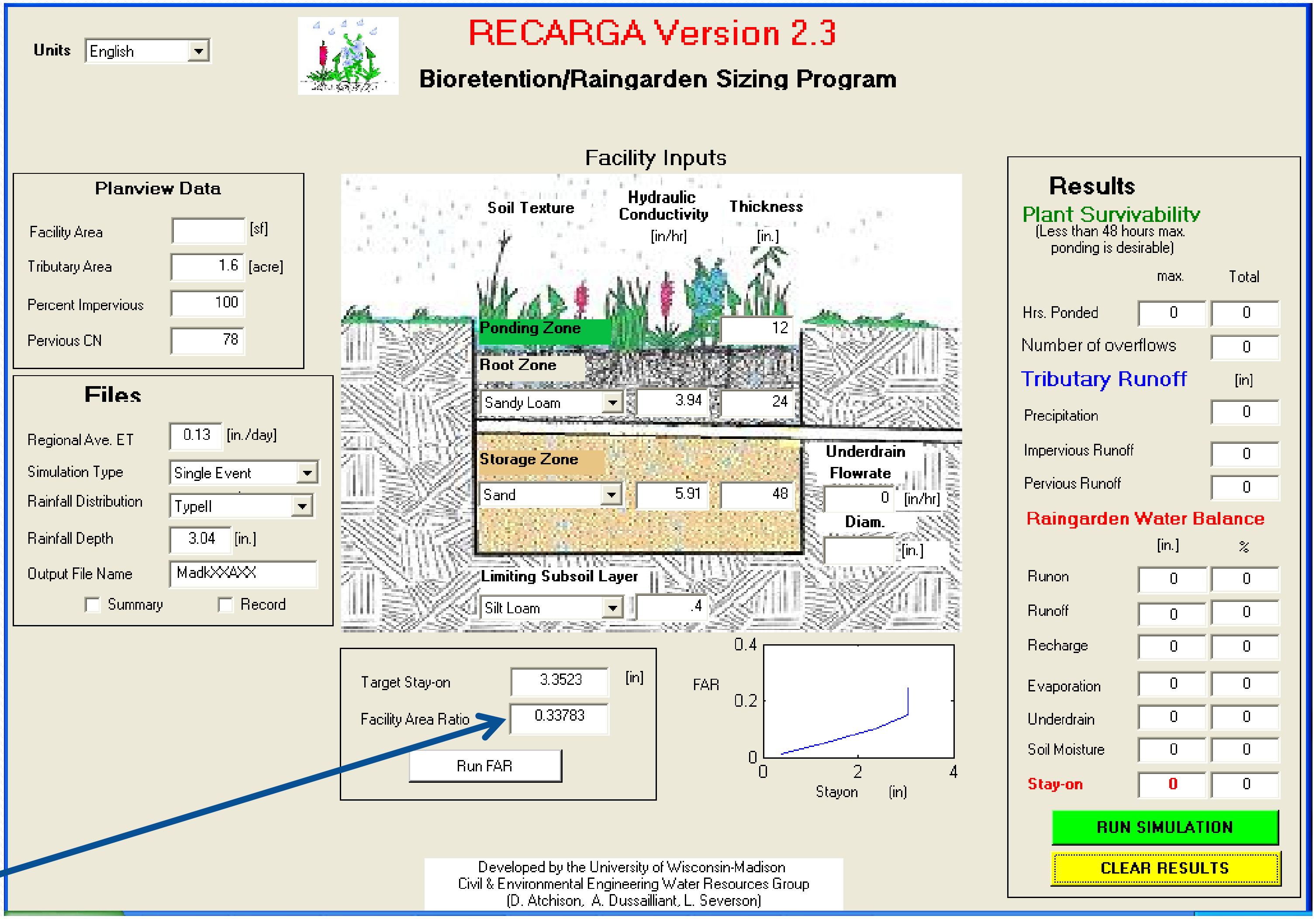
- Existing
  - Eliot Silt Loam
  - K_{sat} = 0.2-0.6



Modeling Examples–

Erin Pande (Engineering Resource Associates, Inc.)

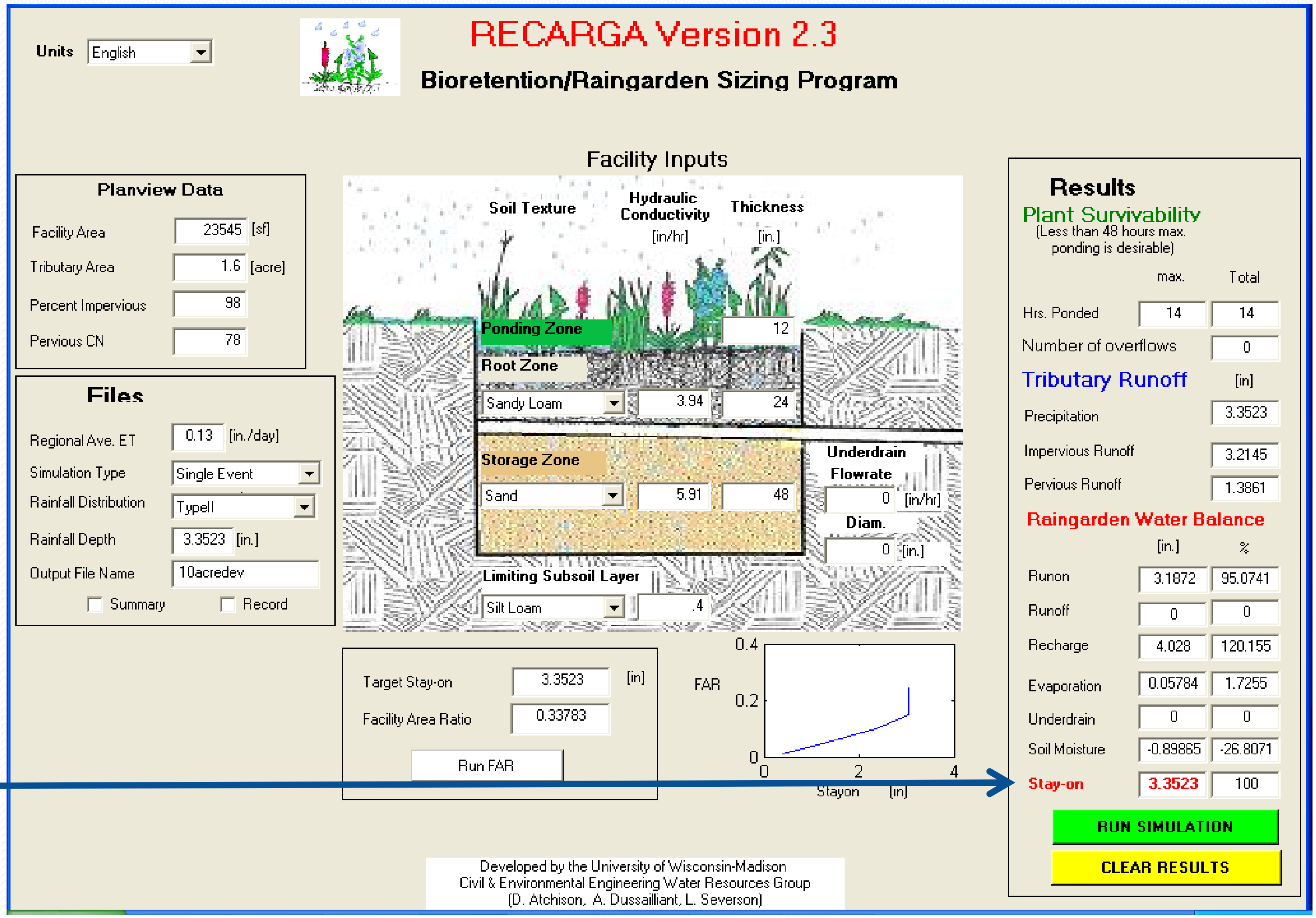
- Determine Facility Area Ratio for new developed area
  - 2yr 24 hr storm (3.04 in) Type II
  - Redevelopment area = 1.6 acres
  - Percent impervious 100%
  - K_{sat} = 0.4 in/hr
  - Target infiltration (3.04 in + 0.3123 in) = 3.3523 in
  - **FAR = 0.3123**



Modeling Examples–

Erin Pande (Engineering Resource Associates, Inc.)

- Proposed Facility
  - 3.35 in Type II
  - Redevelopment area = 1.6 acres
  - Percent impervious 100%
  - K_{sat} = 0.4 in/hr
  - **Infiltration = 3.35 in**



Modeling Examples–

Erin Pande (Engineering Resource Associates, Inc.)

- Site #2: 10-acre commercial re-development

Modeling Examples–

Erin Pande (Engineering Resource Associates, Inc.)

	[in.]	%
Runon	2.7277	89.7278
Runoff	2.7277	89.7258
Recharge	6.0576e-	0.00199
Evaporation	1.9828e-	6.5224e-
Underdrain	0	0
Soil Moisture	-1.4565e	-4.7913e
Stay-on	**0.3123**	10.2742

Existing = 740,700 gallons

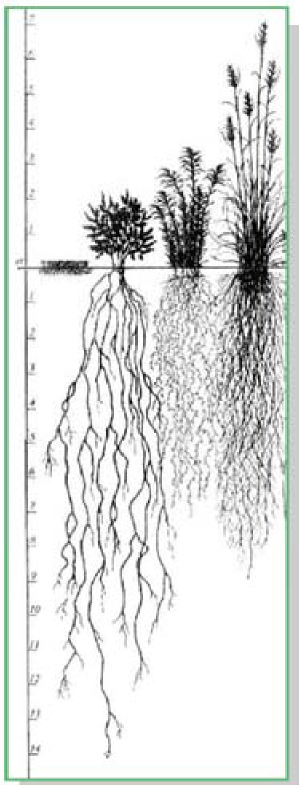
	[in.]	%
Runon	2.8691	94.3782
Runoff	1.5875	52.2213
Recharge	1.3096	43.079
Evaporation	0.00442	0.1457
Underdrain	0	0
Soil Moisture	-0.03246	-1.0678
Stay-on	**1.4525**	47.7787

Proposed = 430,100 gallons

- Comparison of results of existing 10 acre development vs. proposed 1.6 acre re-development with full 10 acres tributary to bio-infiltration practices

Modeling Examples–

Erin Pande (Engineering Resource Associates, Inc.)



Root length of conventional turf grass (left)as compared to native plant roots (right).

- Choose vegetation that will withstand depth and duration of proposed ponding

Time(hr)		Runon(in)		Ponding(in)		Infil(in)		Runoff(in)		Drain(in)
0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.318	0.353	0.421
1.000	0.000	0.000	0.000	0.000	0.000	0.037	0.000	0.311	0.353	0.450
2.000	0.000	0.000	0.000	0.000	0.000	0.219	0.000	0.306	0.352	0.435
3.000	0.000	0.000	0.000	0.000	0.000	0.125	0.000	0.301	0.351	0.443
4.000	0.000	0.000	0.000	0.000	0.000	0.182	0.000	0.296	0.350	0.434
5.000	0.726	0.000	0.726	0.000	0.000	0.148	0.000	0.322	0.350	0.434
6.000	0.931	0.000	0.931	0.000	0.000	0.145	0.000	0.350	0.352	0.434
7.000	1.051	0.000	1.051	0.000	0.000	0.125	0.000	0.371	0.360	0.446
8.000	1.214	0.000	1.214	0.000	0.000	0.225	0.000	0.384	0.374	0.443
9.000	1.453	0.000	1.453	0.000	0.000	0.244	0.000	0.390	0.396	0.450
10.000	1.846	0.048	1.798	0.000	0.000	0.400	0.000	0.400	0.420	0.450
11.000	2.666	2.315	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
12.000	10.822	12.000	0.400	0.736	0.000	0.400	0.000	0.400	0.420	0.450
13.000	15.551	12.000	0.400	15.151	0.000	0.400	0.000	0.400	0.420	0.450
14.000	7.777	12.000	0.400	7.377	0.000	0.400	0.000	0.400	0.420	0.450
15.000	2.437	12.000	0.400	2.037	0.000	0.400	0.000	0.400	0.420	0.450
16.000	1.752	12.000	0.400	1.352	0.000	0.400	0.000	0.400	0.420	0.450
17.000	1.402	12.000	0.400	1.002	0.000	0.400	0.000	0.400	0.420	0.450
18.000	1.183	12.000	0.400	0.783	0.000	0.400	0.000	0.400	0.420	0.450
19.000	1.031	12.000	0.400	0.631	0.000	0.400	0.000	0.400	0.420	0.450
20.000	0.918	12.000	0.400	0.518	0.000	0.400	0.000	0.400	0.420	0.450
21.000	0.831	12.000	0.400	0.431	0.000	0.400	0.000	0.400	0.420	0.450
22.000	0.761	12.000	0.400	0.361	0.000	0.400	0.000	0.400	0.420	0.450
23.000	0.703	12.000	0.400	0.303	0.000	0.400	0.000	0.400	0.420	0.450
24.000	0.655	12.000	0.400	0.255	0.000	0.400	0.000	0.400	0.420	0.450
25.000	0.239	11.820	0.400	0.020	0.000	0.400	0.000	0.400	0.420	0.450
26.000	0.000	11.420	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		11.020	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		10.620	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		10.220	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		9.820	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		9.420	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		9.020	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		8.620	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		8.220	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		7.820	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		7.420	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		7.020	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		6.620	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		6.220	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		5.820	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		5.420	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		5.020	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		4.620	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		4.220	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
		3.820	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
46.000	0.000	3.420	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
47.000	0.000	3.020	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
48.000	0.000	2.620	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450
49.000	0.000	2.220	0.400	0.000	0.000	0.400	0.000	0.400	0.420	0.450

Plant Survivability

(Less than 48 hours max. ponding is desirable)

	max.	Total
Hrs. Ponded	44.5	44.5
Number of overflows		1

Recap and Close – Q&A