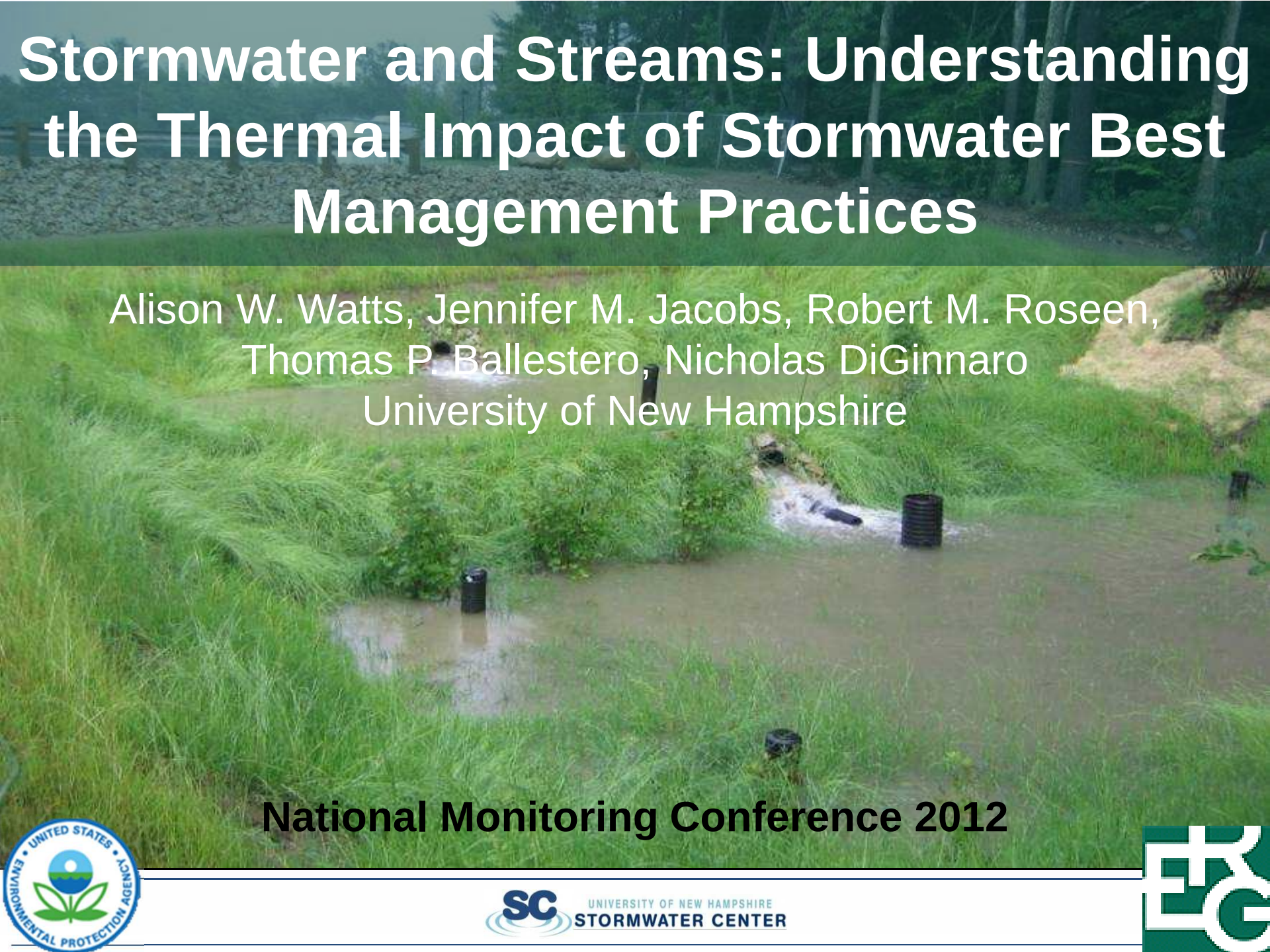
Stormwater and Streams: Understanding the Thermal Impact of Stormwater Best Management Practices

Alison W. Watts, Jennifer M. Jacobs, Robert M. Roseen, Thomas P. Ballestero, Nicholas DiGinnaro
University of New Hampshire



National Monitoring Conference 2012

UNIVERSITY OF NEW HAMPSHIRE STORMWATER CENTER

Stormwater Best Management Practices (BMPs)

- Primarily designed to retain flow and remove sediments
- Encouraged as a form of Low Impact Development
- Can be designed to restore site hydrology

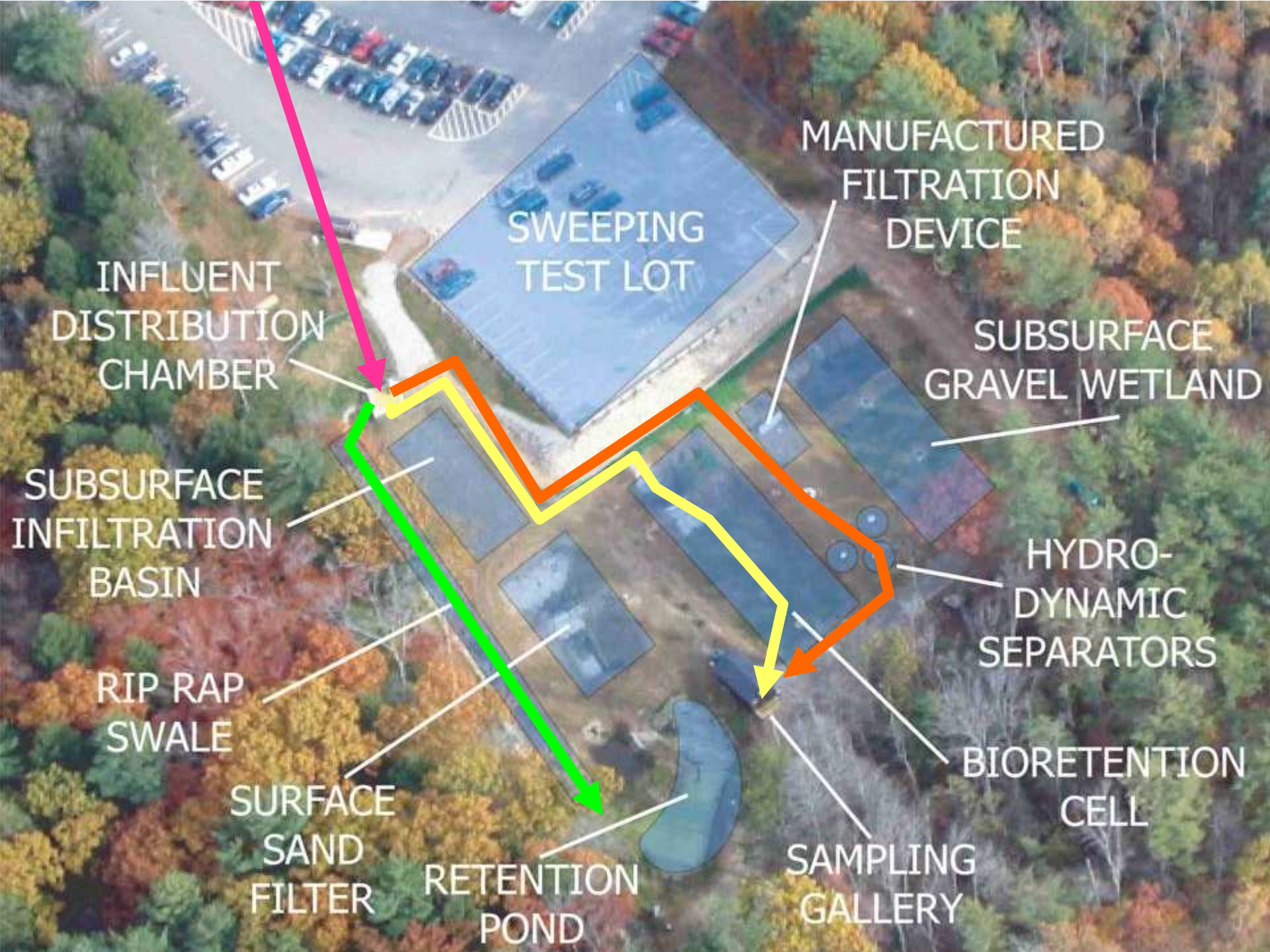
Existing Performance Data

Pollutants: Sediments, Compounds (nutrients, metals, hydrocarbons etc)

Physical characteristics: Flow regime, temperature

UNHSC Pollutant Removal Efficiencies								
Treatment Unit Description	Reference	TSS Total Suspended Solids (% Removal)	TPH-D Total Petroleum Hydrocarbons in the Diesel Range (% Removal)	NO3-N (DIN) Dissolved Inorganic Nitrogen (% Removal)	TZn Total Zinc (% Removal)	TP Total Phosphorus (% Removal)	Average Annual Peak Flow Reduction (% Removal)	Average Annual Lag Time (Minutes)
Conventional Treatment Devices								
Retention Pond	UNH	68	82	33	68	NT	86	455
Stone (rip-rap) Swale	UNH	50	33	NT	64	–	6	7
Vegetated Swale	UNH	58	82	NT	88	NT	52	38
Berm Swale	UNH	50	81	NT	50	8	24	58
Deep Sump Catch Basin	UNH	9	14	NT	NT	NT	NT	NT
Manufactured Treatment Devices (MTDs)								
ADS Infiltration Unit	UNH	99	99	NT	99	81	87	228
StormTech	UNH	80	93	NT	56	49	76	274
Aquafilter	UNH	62	26	NT	52	59	NT	NT
Hydrodynamic Separators	UNH	27	1	NT	24	42	NT	NT
Low Impact Development (LID)								
Surface Sand Filter	UNH	51	98	NT	77	33	69	187
Bioretention								
Bio I - 48" depth	UNH	97	99	44	99	–	75	266
Bio II - 30" depth	UNH	87	99	NT	68	34	79	309
Gravel Wetland	UNH	99	99	98	99	56	87	251
Porous Asphalt	UNH	99	99	NT	75	60	82	1,275

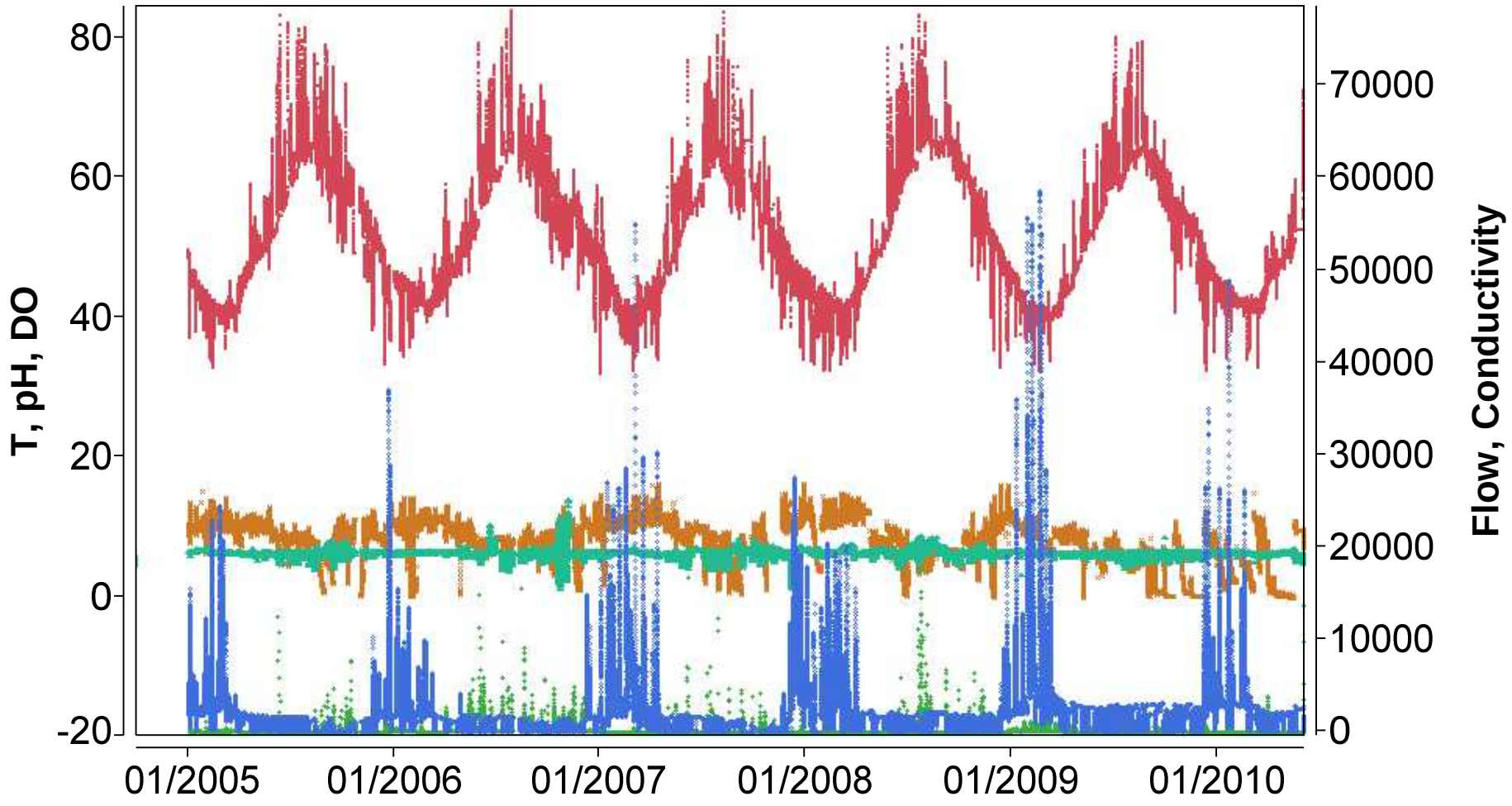
UNH STORMWATER CENTER, Durham


MANUFACTURED
FILTRATION
DEVICE
SWEEPING
TEST LOT
INFLUENT
DISTRIBUTION
CHAMBER
SUBSURFACE
GRAVEL WETLAND
SUBSURFACE
INFILTRATION
BASIN
HYDRO-
DYNAMIC
SEPARATORS
RIP RAP
SWALE
BIORETENTION
CELL
SURFACE
SAND
FILTER
RETENTION
POND
SAMPLING
GALLERY

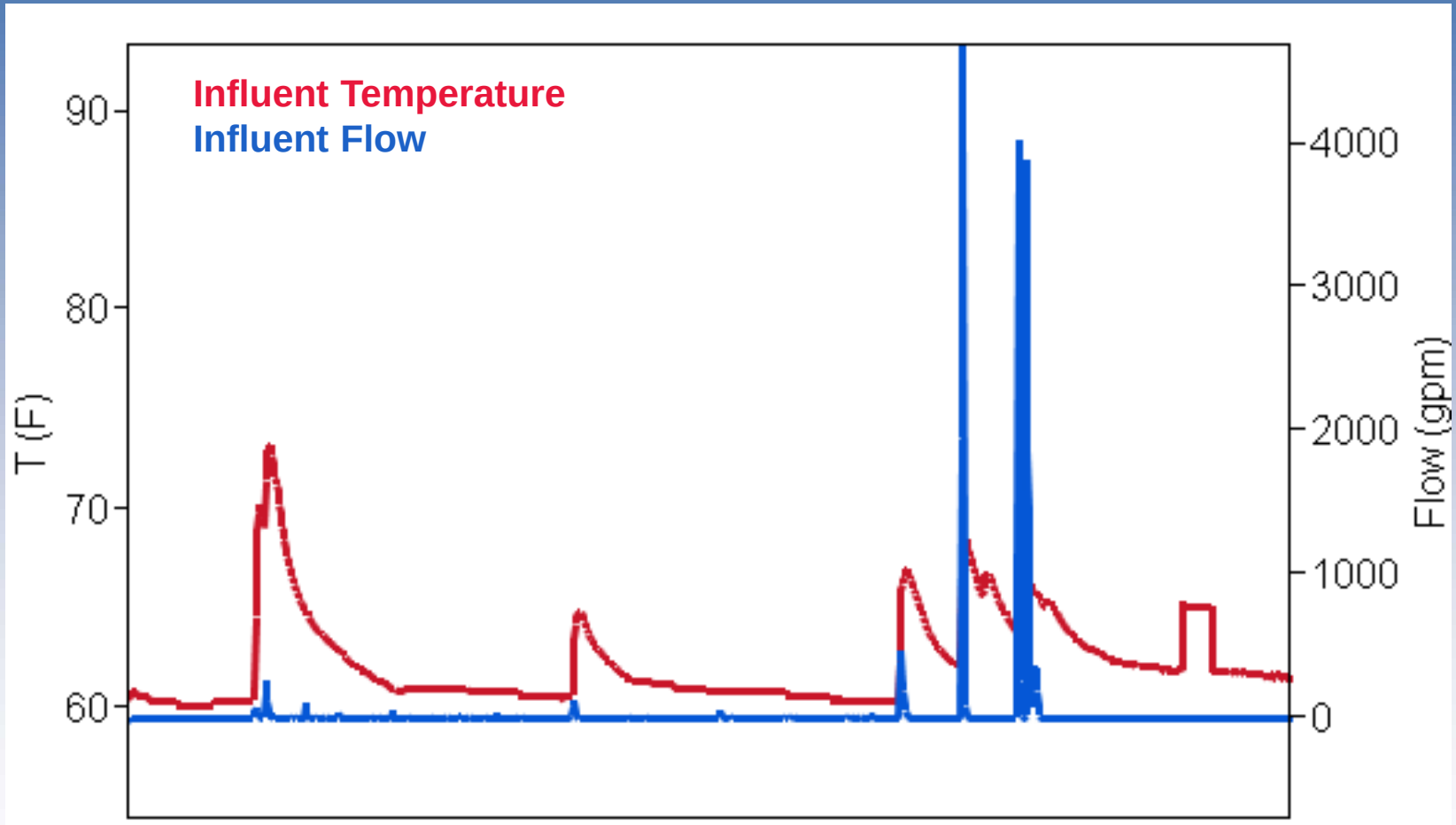
Real Time

Automated Samplers

Flow and Temperature
(5-year untreated parking lot runoff)



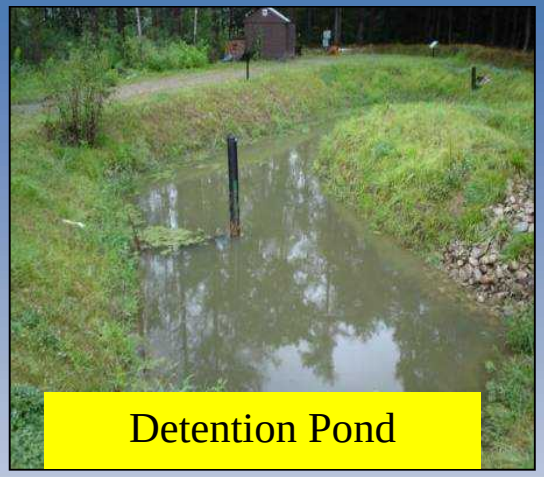
Runoff from hot pavement is hot!



July 17-23, 2009

Systems

Retention Pond



Detention Pond

Veg Swale

Gravel Wetland

Bioretention Unit

Subsurface Infiltration

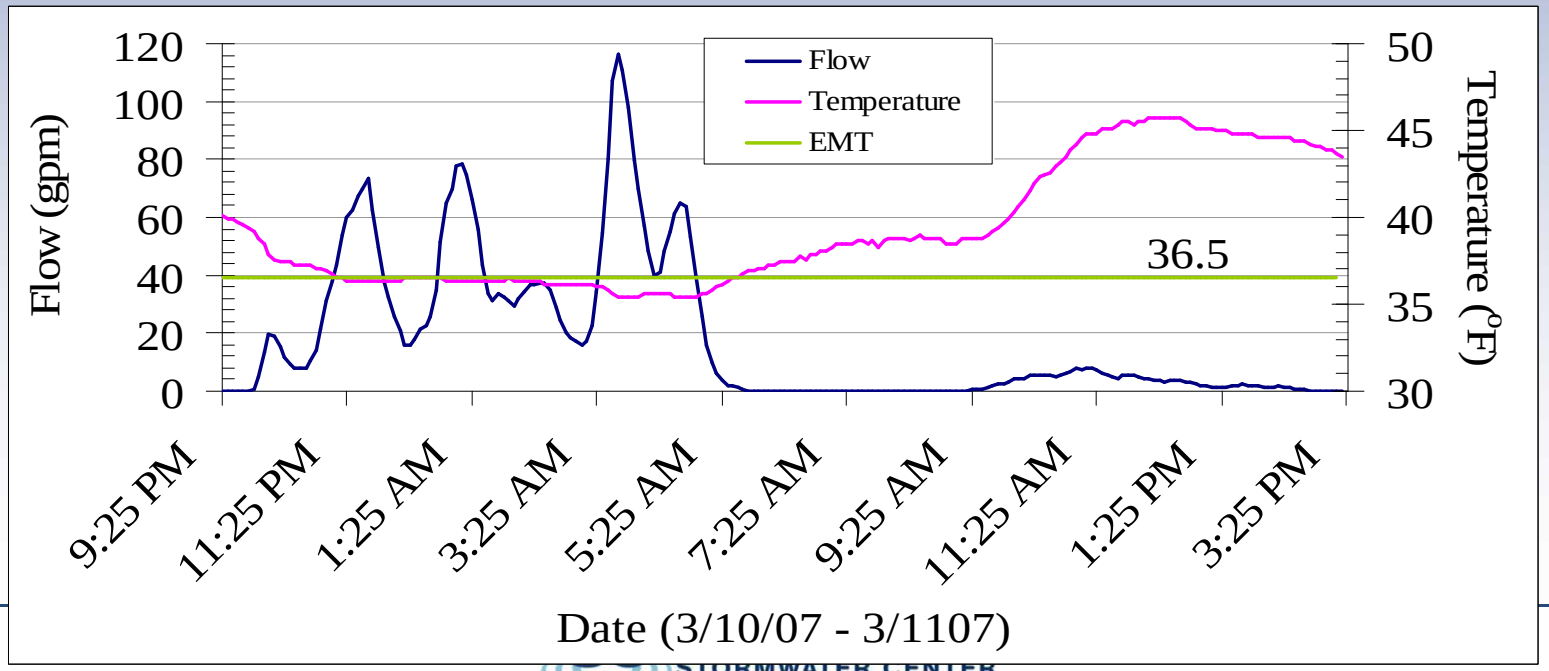
Isolator Row

Hydrodynamic Separator

Performance Metric

Flow or Volume weighted temperature calculated for each storm and each system (120 Influent EMTs)

$$\text{Event Mean Temperature, EMT} = \frac{\sum \text{Vol} * \text{Temp}}{\sum \text{Vol}}$$



Qualitative Analyses

25 storms per year, 5 years

Annual and Seasonal

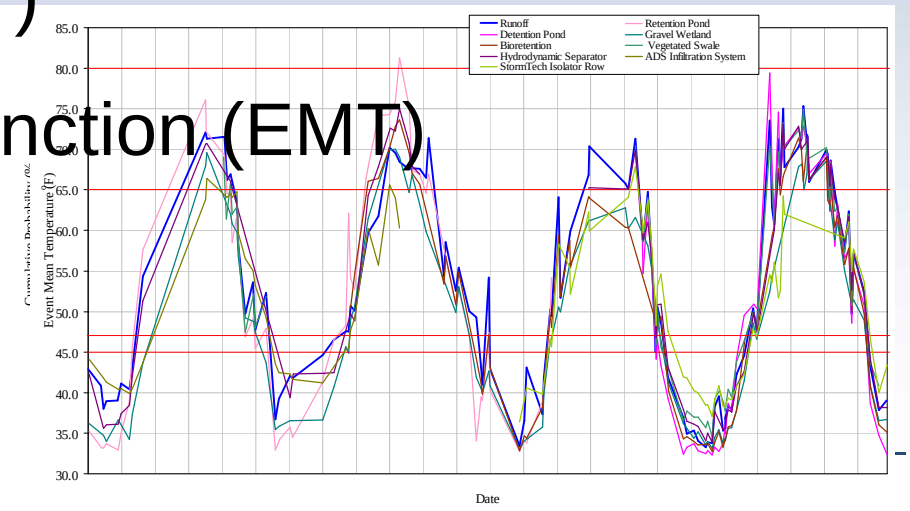
- Summer → April through September
- Winter → November through March

Time Series (EMT)

Quartile Assessment (EMT)

Cumulative Distribution Function (EMT)

Histogram (Temperature)



Environmental Indicators

Temperature Indices

- Lower Optimum Limit (LOL) = 45°F
- Upper Optimum Limit (UOL) = 65°F
- Lethal Limit (LL) = 80°F

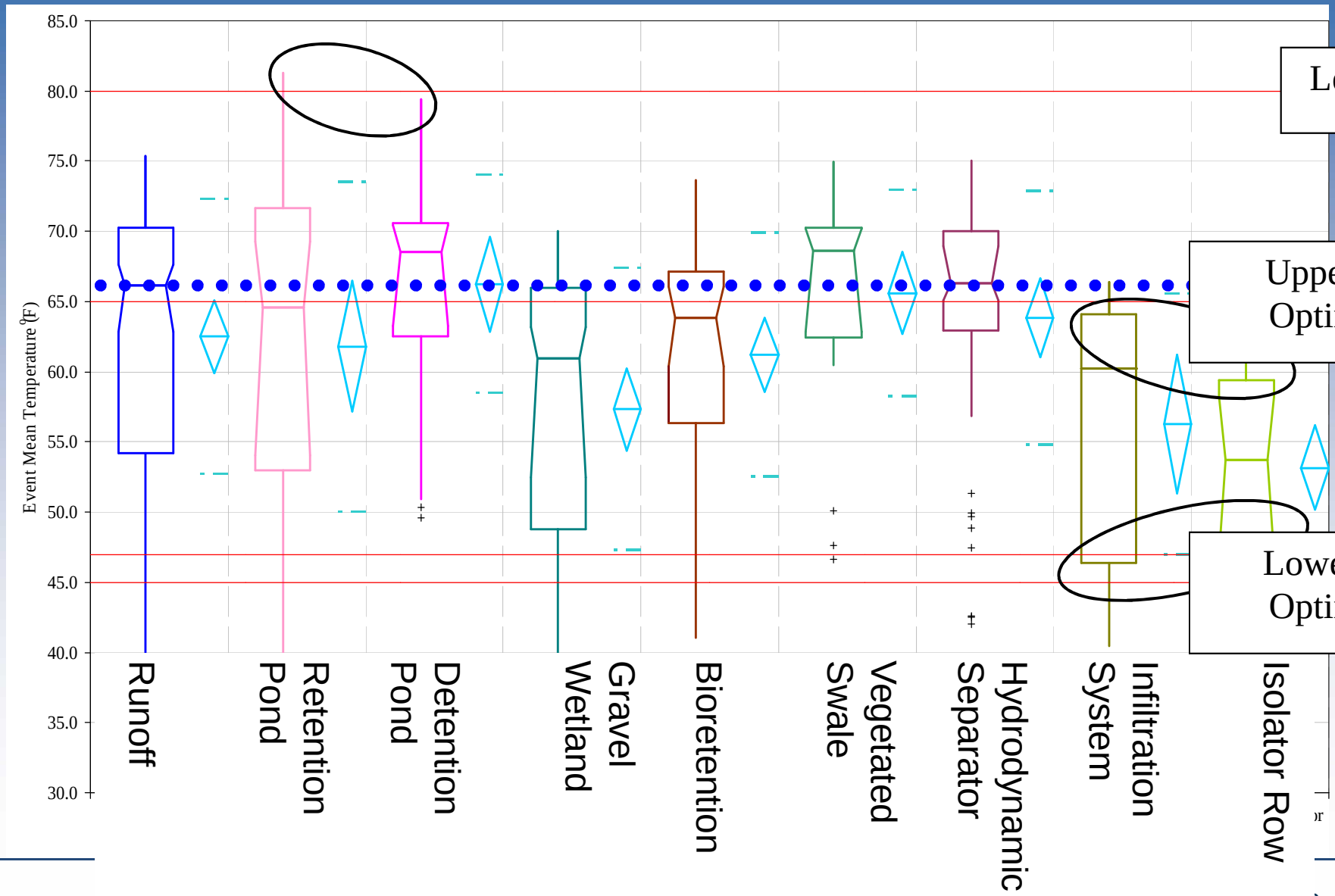
Mean July Temperatures

- Warmest month

Groundwater Temperature

- As a base flow condition
- New Hampshire = 47°F

Summer Quartile Assessment



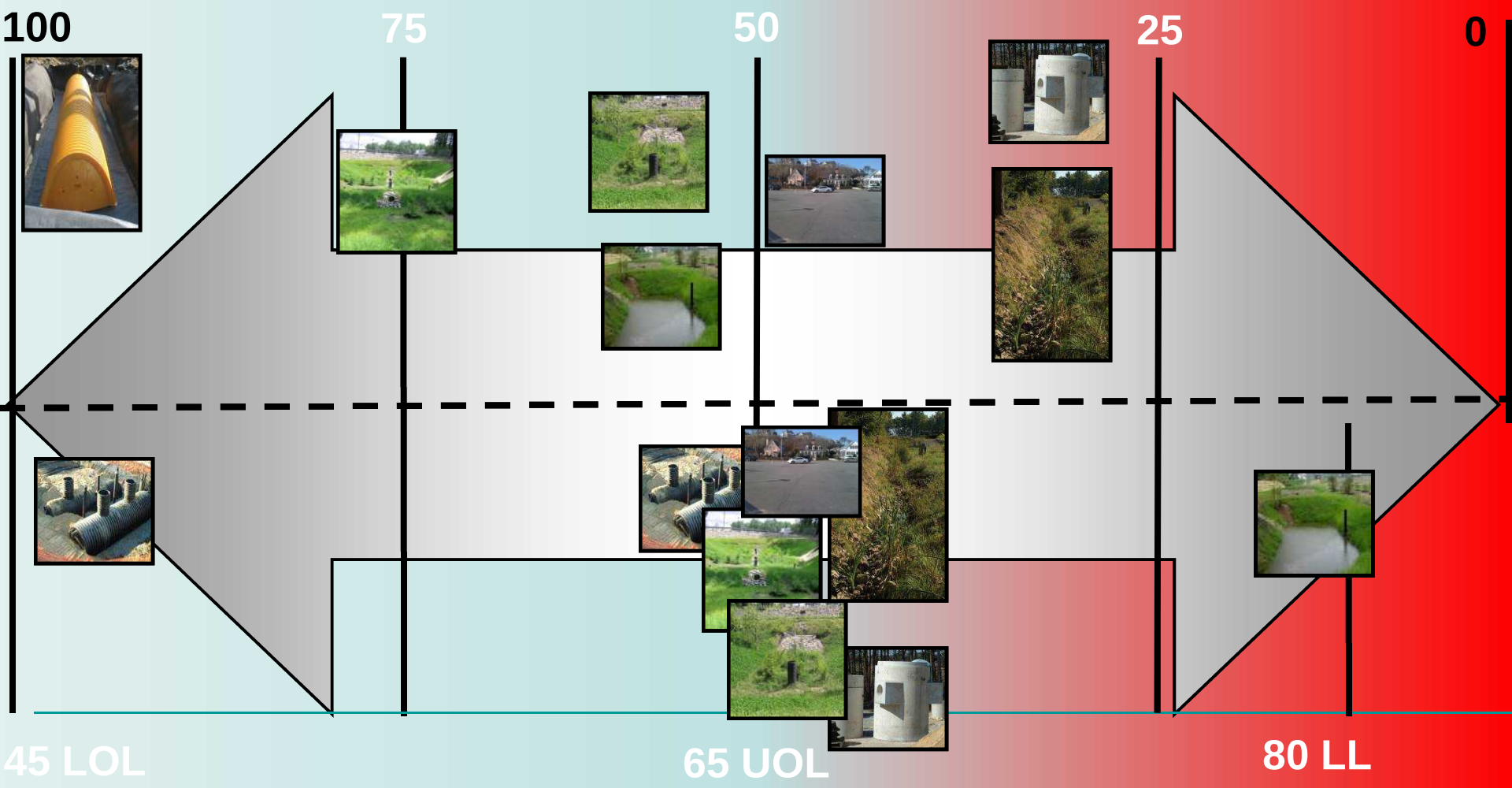
Results

Annual Assessments		Runoff	Retention Pond	Detention Pond	Gravel Wetland	Bioretention	Vegetated Swale	HDS	ADS	STIR
EMT (°F)	Median	52.4	48.1	52.8	47.3	51.8	57.3	56.6	49.2	47.6
	Mean	53.5	50.9	52.3	48.7	51.9	54.8	54.1	51.5	49.0
	Standard Deviation	12.7	14.6	15.1	12.0	13.1	12.6	13.6	9.7	9.2
	Maximum	75.4	81.3	79.4	70.0	73.7	75.0	75.0	66.4	67.8
% Non-Exceedance UOL (65°F)		72.5%	79.0%	71.5%	87.0%	78.0%	72.5%	65.0%	95.0%	98.5%

Summer Assessments		Runoff	Retention Pond	Detention Pond	Gravel Wetland	Bioretention	Vegetated Swale	HDS	ADS	STIR
EMT (°F)	Median	66.2	64.6	68.6	60.9	63.9	68.6	66.3	60.3	53.7
	Mean	62.5	61.8	66.3	57.3	61.2	65.6	63.8	56.3	53.2
	Standard Deviation	9.8	11.8	7.8	10.1	8.7	7.3	9.1	9.3	7.9
Mean July Temperatures (°F)		67.1	77.9	72.2	66.0	67.7	70.3	69.0	63.4	58.5
% Non-Exceedance UOL (65°F)		42.0%	56.0%	37.0%	73.0%	58.5%	35.0%	34.0%	91.0%	96.0%

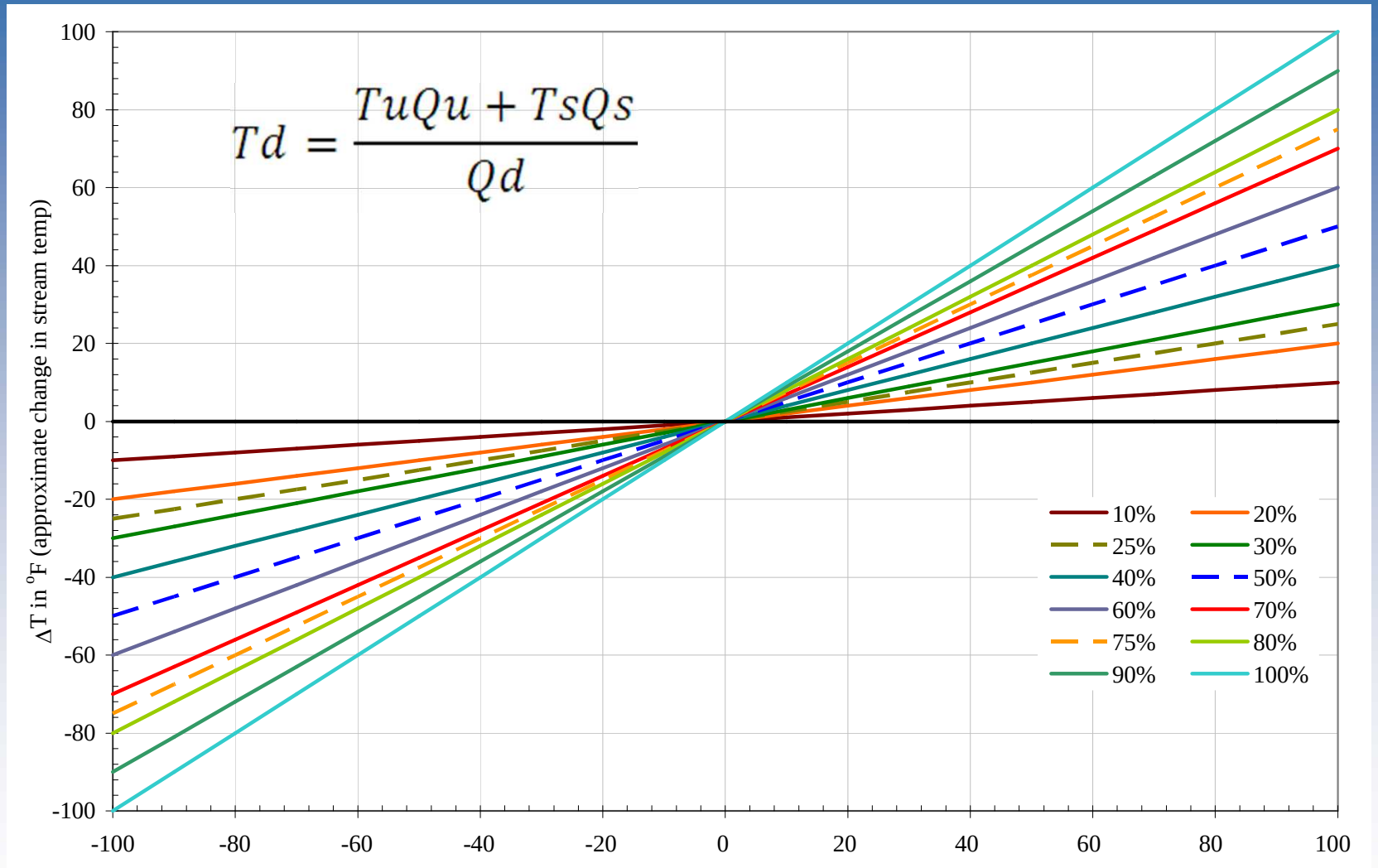
Thermal Performance

% Non-Exceedance Upper Optimum Limit 65*F



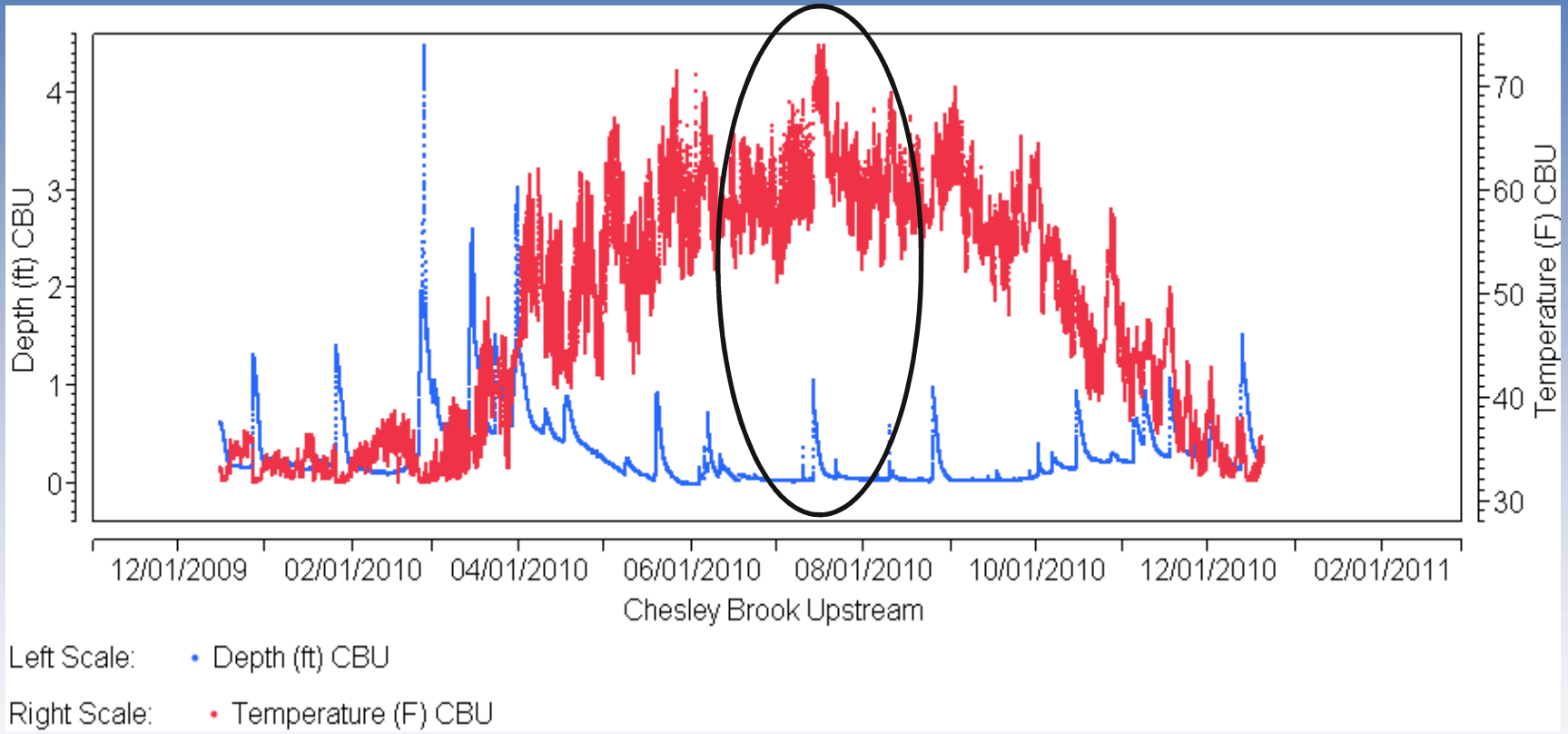
Mean July Temperature*F

Mixing Stream and Stormwater



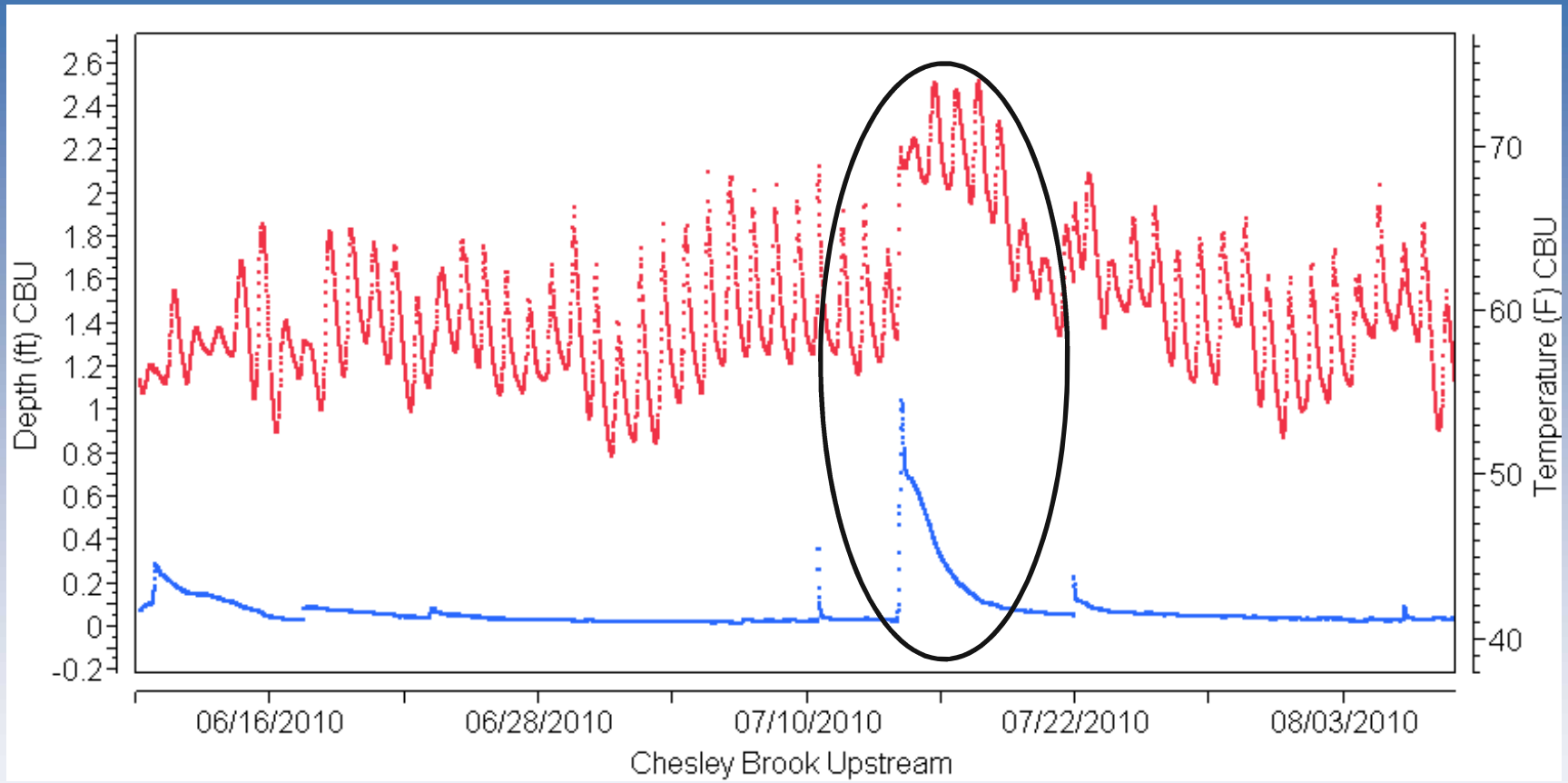
T =temperature Q = Flow
U = upstream, D = downstream, S =stormwater

Example – Chesley Brook



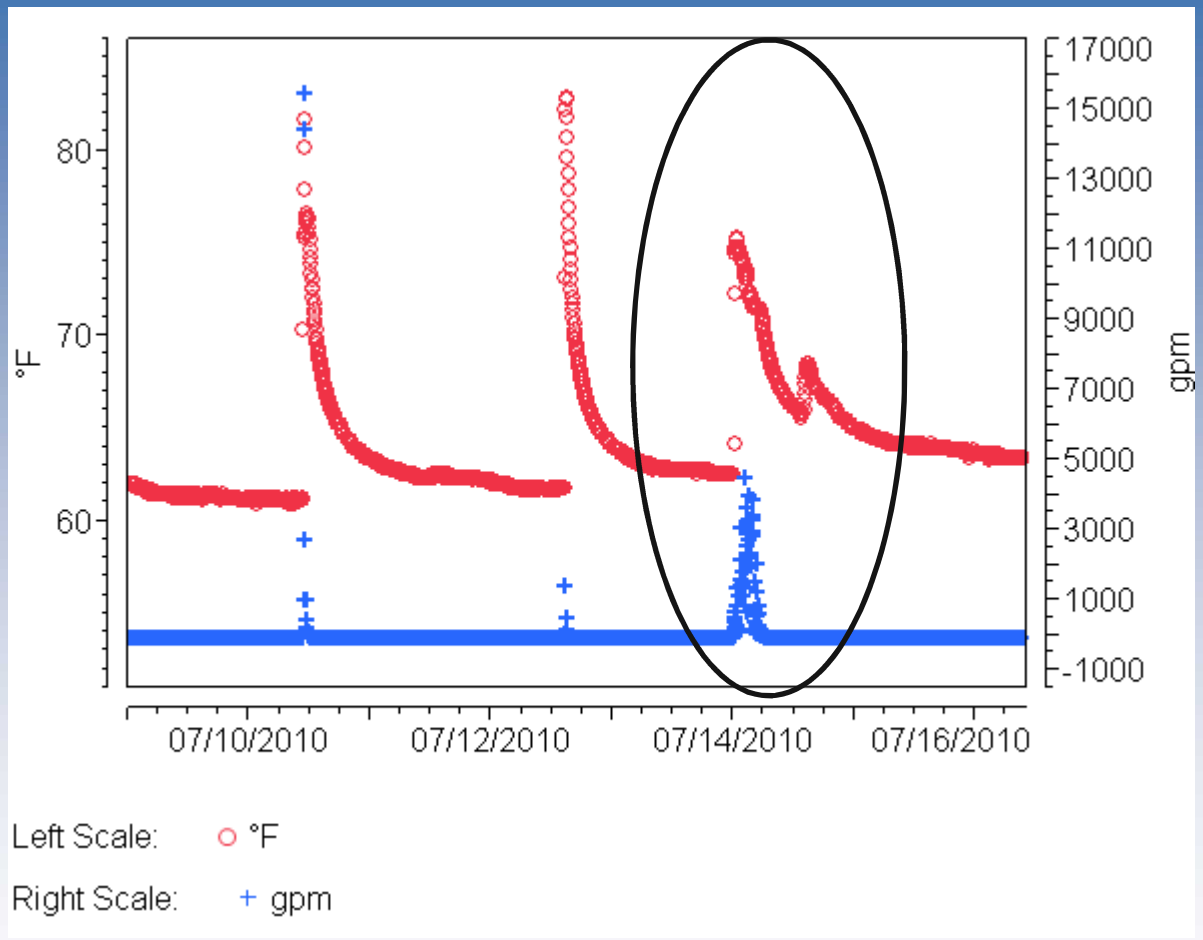
July 14, 2010 2.5 inches rain

Chesley Brook July 14, 2010



Storm = 68.5F, prior to storm = 58F

UNH Stormwater runoff July 14, 2010



EMT – 73F

Impact to Stream

If runoff from a 1-acre parking lot drained into this stream what would happen?

$$Td = \frac{TuQu + TsQs}{Qd}$$

Chesley Brook T=58ºF,
Untreated Stormwater T=73ºF
Stream Q = 1000gpm, Stormwater flow=740gpm
Stream T (downstream) = 64ºF **(ΔT=6ºF)**

Detention Pond EMT = 71ºF **(ΔT=5.5ºF)**

Isolator Row EMT = 63ºF **(ΔT=3ºF)**

Conclusions

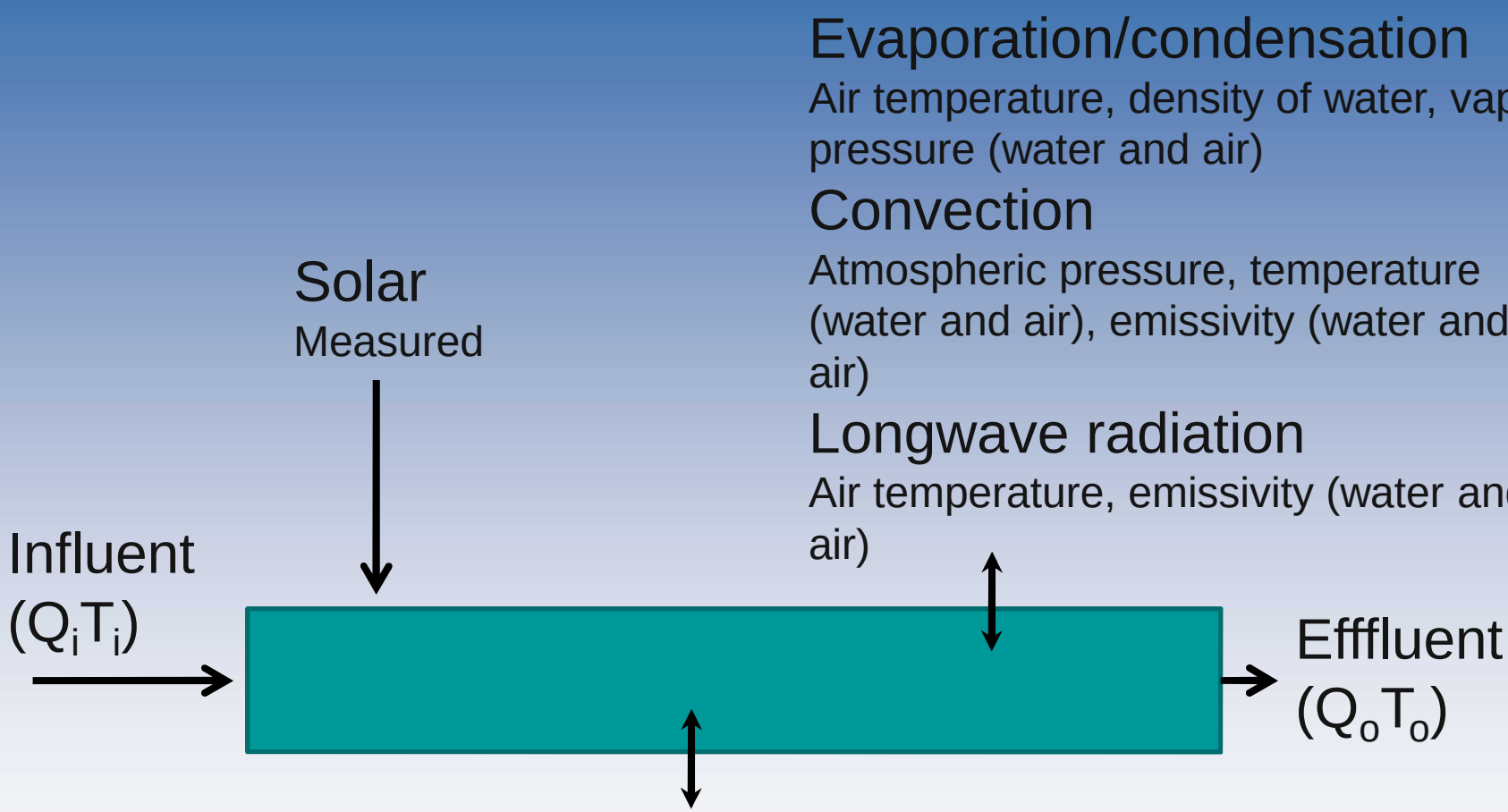
Large subsurface systems buffer stormwater temperature.

The longer subsurface flow paths, the greater the buffering.

Stormwater management designs that include ponding increase temperature.

Permanent pools of water act as heat sinks during the warmer summer months. Shading could reduce effect.

Designing BMPs to Mitigate Temp



Construction Factors

Heat inputs are a function of energy/area/time

Solar radiation	Surface area, shade
Longwave radiation	Surface area, exterior T(depth)
Evaporation	Surface area, shade?
Convection	Surface area
Conduction	Subsurface area, depth, lining
Hyporheic exchange	Lining material

Thank You

alison.watts@unh.edu

Project partners
UNH Stormwater Center, CICEET, USEPA Region1, NSF ADVANCE

Thermal Inputs to a BMP