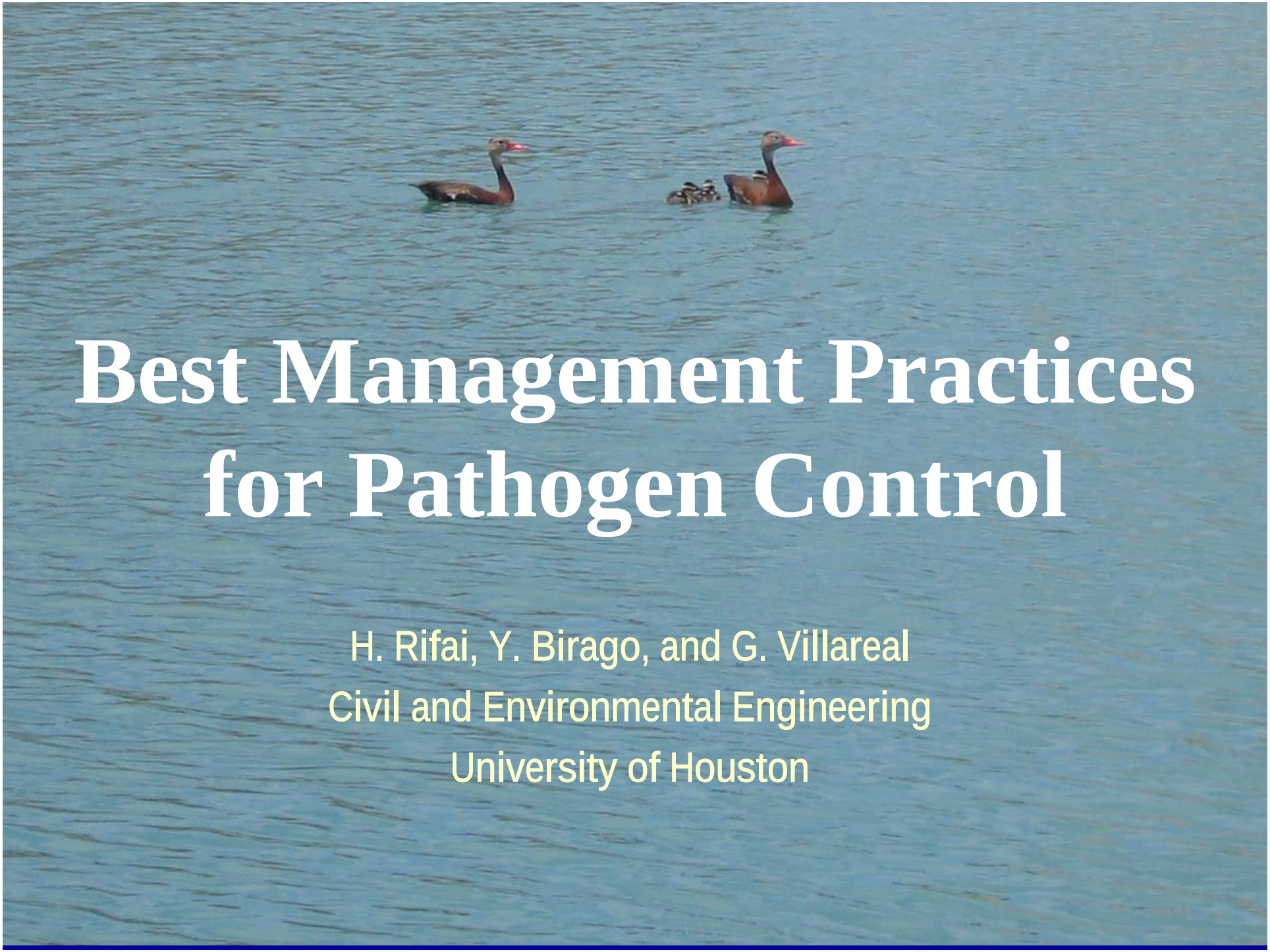
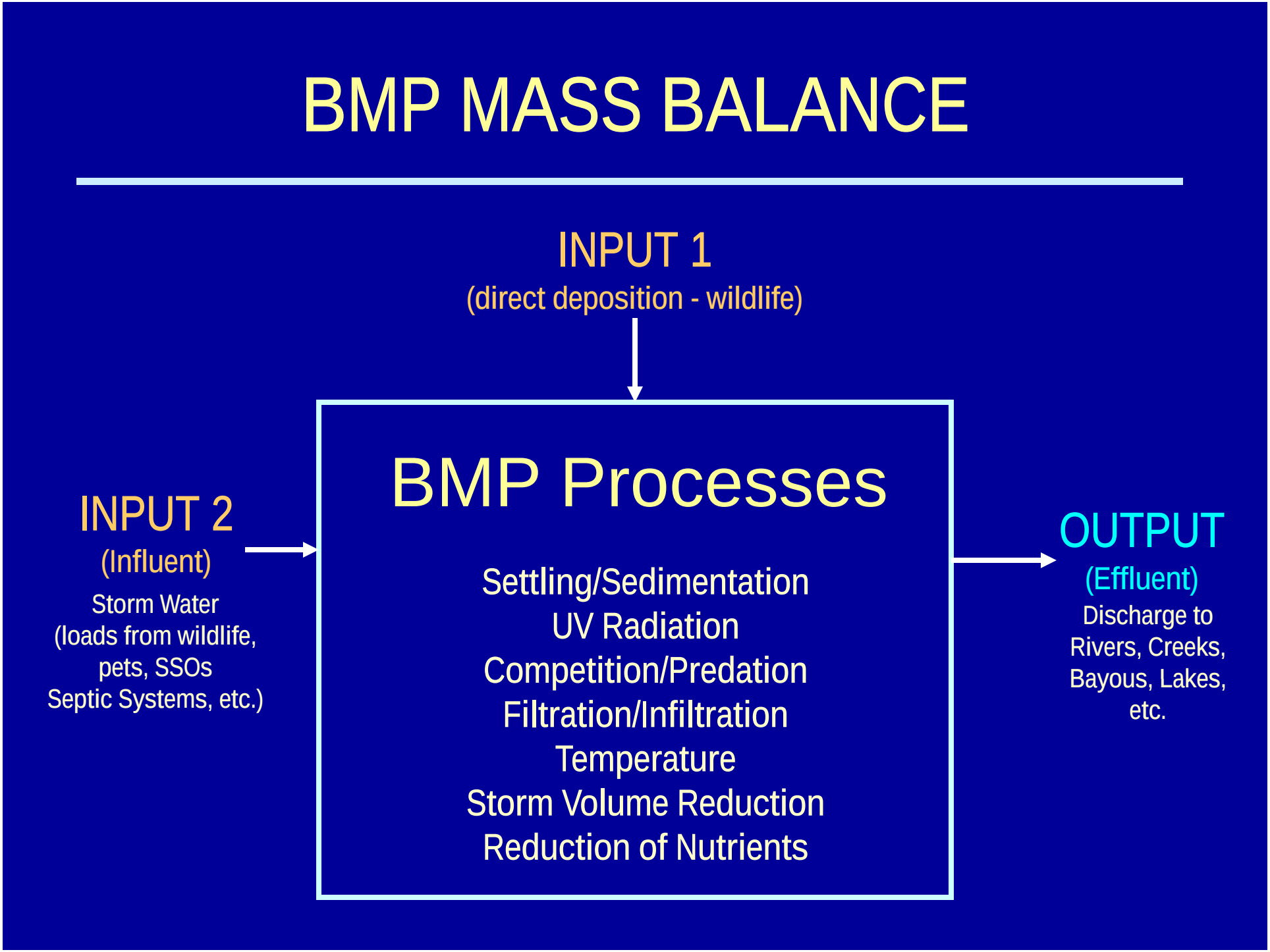


Best Management Practices for Pathogen Control

H. Rifai, Y. Birago, and G. Villareal
Civil and Environmental Engineering
University of Houston

BMP MASS BALANCE

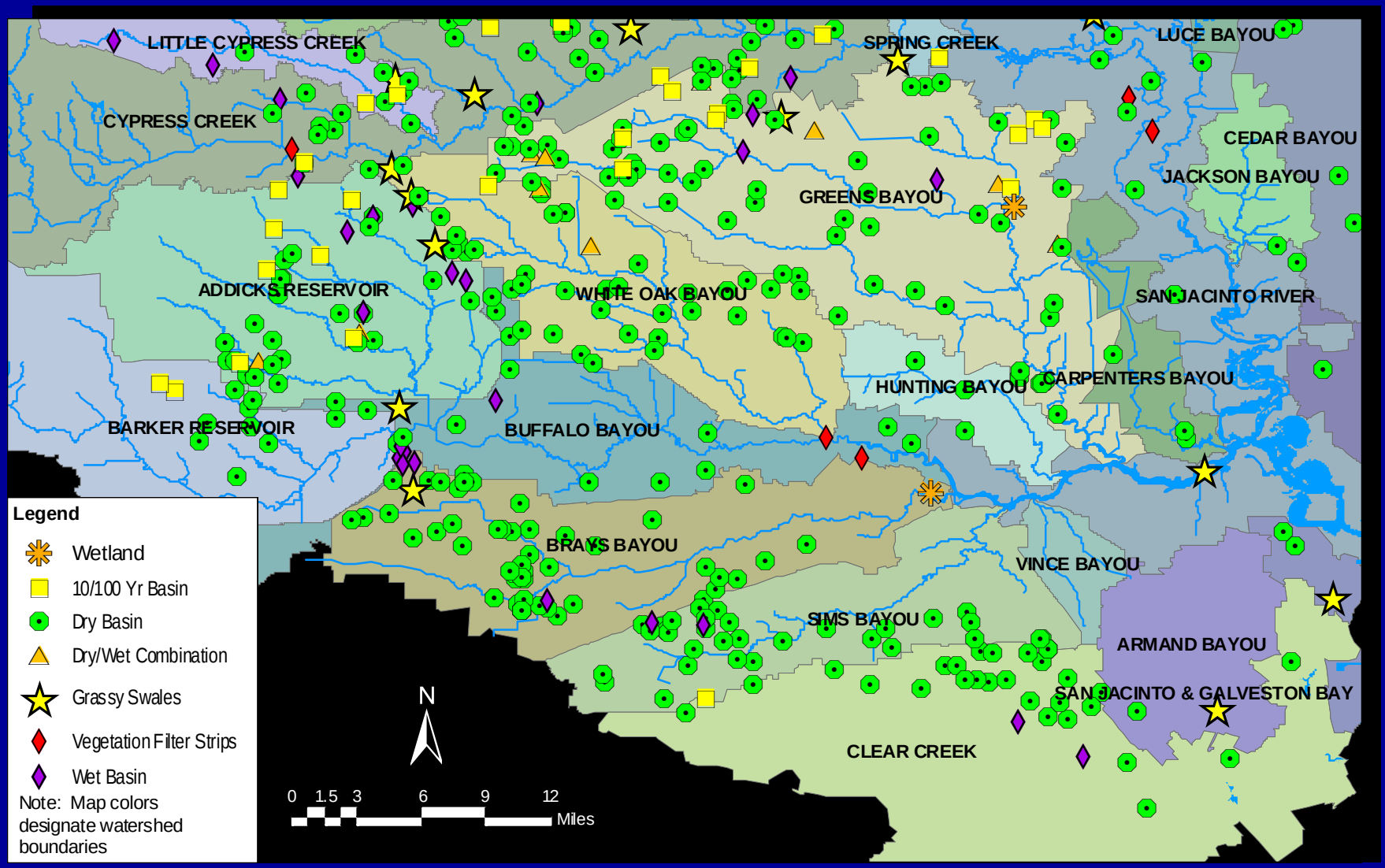


Bacteria Removal Efficiencies of BMPs from Literature

BMP Tested	Percent Removal	No of BMPs Tested	Total Samples
Dry Basin	90	1	N/R
Grassy Swale	-338	1	5
Vegetative Filter Strips	32	18	N/R
Wet Basin	47	11	222
Wetland	88	82	981

N/R – Not Reported

BMPs in Harris County and City of Houston



Permitted BMPs

AGENCY	BEST MANAGEMENT PRACTICE (BMP)	COUNT
Harris County	Dry Basin	286
	Wet Basin	45
	Flood Control/Water Quality Basin	19
	Wetland	1
	Grass Swale	12
	Vegetative Filter Strips	5
	Other	186
City of Houston	Dry Basin	166
	Wet Basin	9
	Flood Control/Water Quality Basin	1
	Grass Swale	5
	Vegetative Filter Strips	2
	Other	47
	Road sweeping & minimization plans for street maintenance yards	75% of yards
	Prevent Illicit discharges and Improper disposal	N/R
	Industrial and high risk runoff	N/R
	Wet screening of area served by the MS4	50% of total area
	Manhole cleaning, storm sewer cleaning/flushing, repairs and investigations	N/R

N/R – Not Reported

Permitted BMPs

AGENCY	BEST MANAGEMENT PRACTICES (BMPs)	COUNT
Harris County Flood Control District (HCFCD)	Wet basins	N/R
	Detention basins	N/R
	Vegetation/Stabilization of Drainageways	>50 miles of drainageways
	Wet Pond Extended Retrofit Sampling	If Deemed Necessary
	Inlet Basket to Surge Basin	1
	Maintenance of detention basins and drainage channels	N/R
	Monitoring of BMPs for Water Quality	N/R
	Trash Skimmer (Boat)	1
	Netting overlay (at White Oak Bayou Basin Outfall)	1
	Natural trash trap	1
	Planted Gabion Wall	1
Texas Department of Transportation (TxDOT)	Detention ponds	N/R
	Pump stations	N/R
	Grassy swales	N/R
	Vegetative filter strips	N/R
	Public Education Programs (Don't Mess W/ Texas, Adopt-A-Highway, etc.)	N/R
Joint Task Force	Public Education Program	N/R

N/R – Not Reported

BMPs Studied

- Dry Ponds
- Wet Ponds

2006-07

- Water Quality Basins
- Swales

2007-08

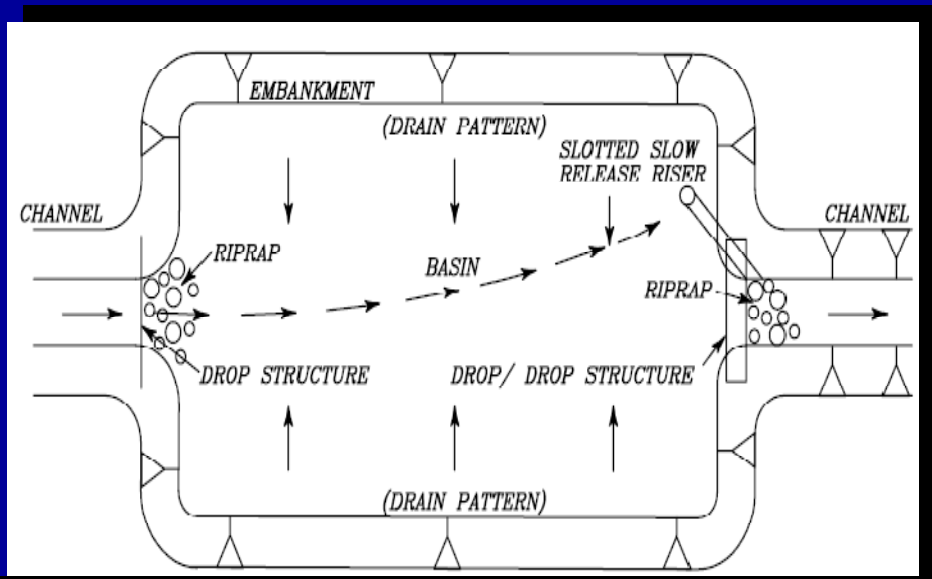


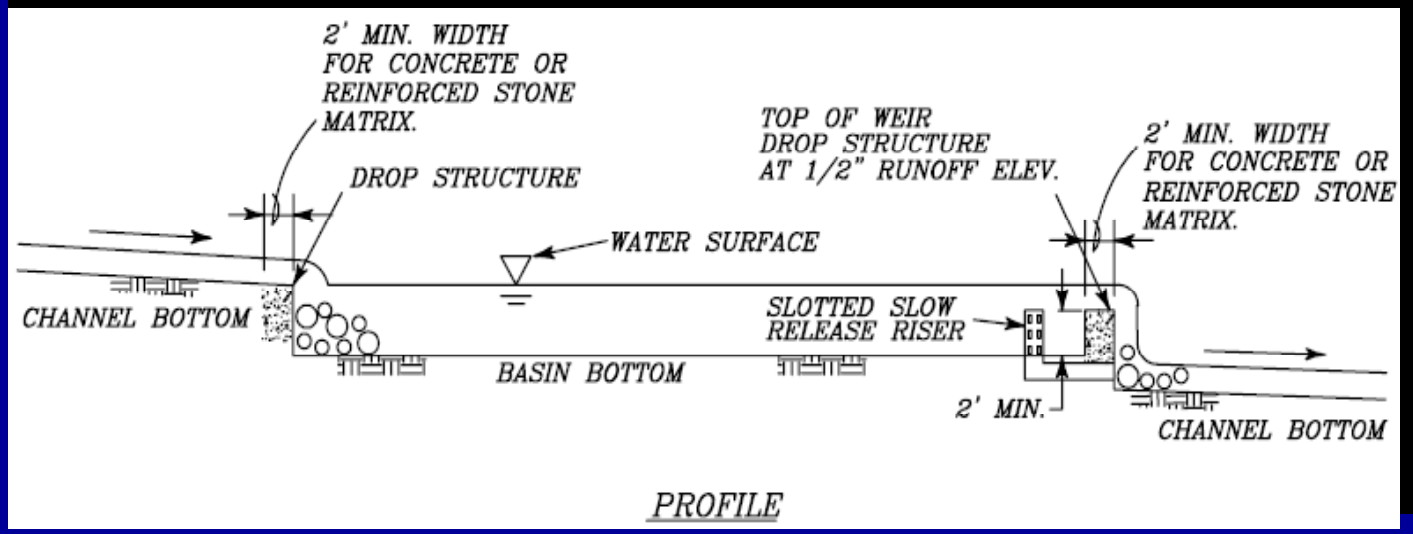
Dry and Wet Basins

- Structural BMPs
- Encourage sedimentation
- Increase exposure to other natural processes
- High reduction potential in literature BMP studies
- In the Houston Metropolitan Area:
  - Dry Basins 476 / 10,638 acres
  - Wet Basins 70 / 3,695 acres

Dry Basins

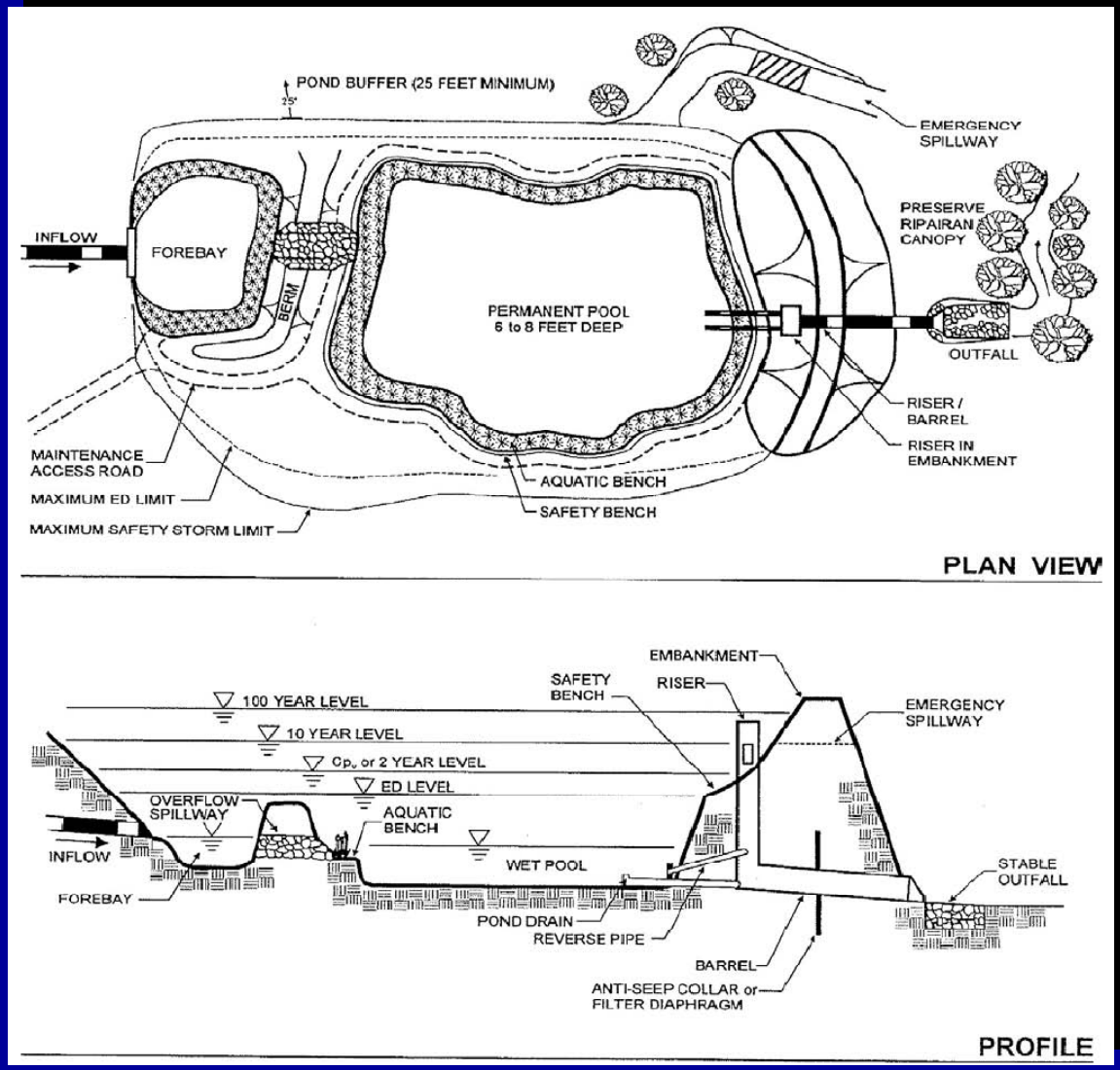
Average literature value for bacteria reduction:
90% (with filter)





Wet Basins

Average literature value for bacteria reduction: 47% (Range: 3% to 98%)



Sampling/Analysis for Wet and Dry Basins

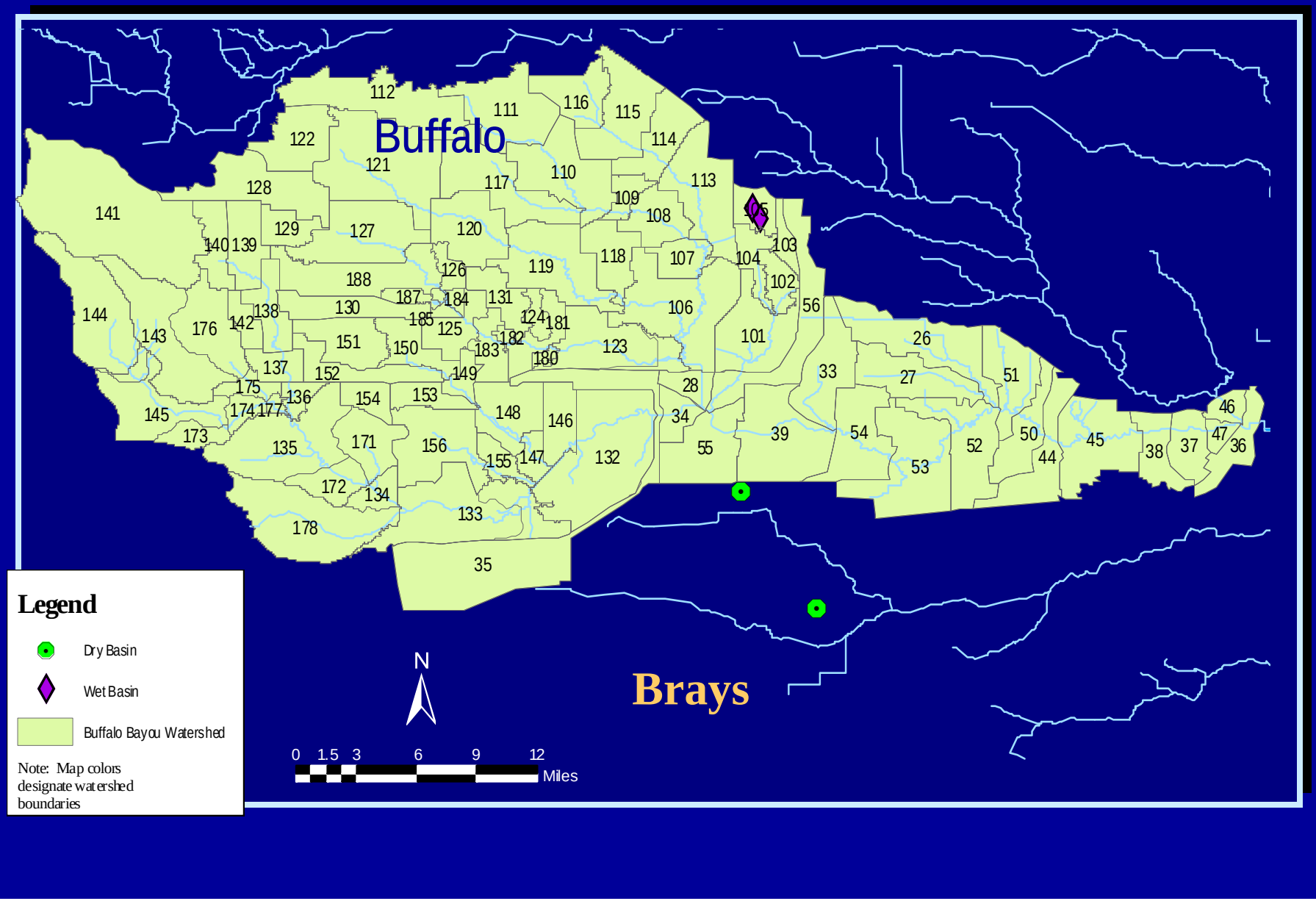
- Two Dry and Two Wet Basins were selected based on JTF requirements, implementation and maintenance
- Water samples were collected during five runoff events
- Efficiencies calculated for each event at each basin
- Their effectiveness studied using the Buffalo Bayou HSPF model
- Stream reductions were calculated for different scenarios using HSPF

BMP Efficiency and Effectiveness

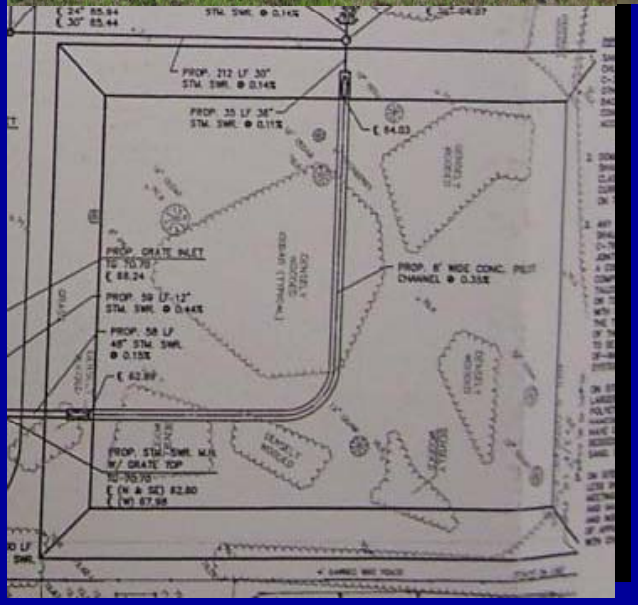
- Efficiency
  - Comparison of outlet to inlet concentrations of pathogen indicator
  - Function of individual BMP design/maintenance
  - Function of storm events
  - Pool concentrations studied but not factored into efficiency calculations

- Effectiveness
  - Impact on in-stream flows and concentrations
  - Function of location within watershed
  - Function of individual BMP design
  - Influenced by other BMPs in watershed

Locations of Wet/Dry Basins

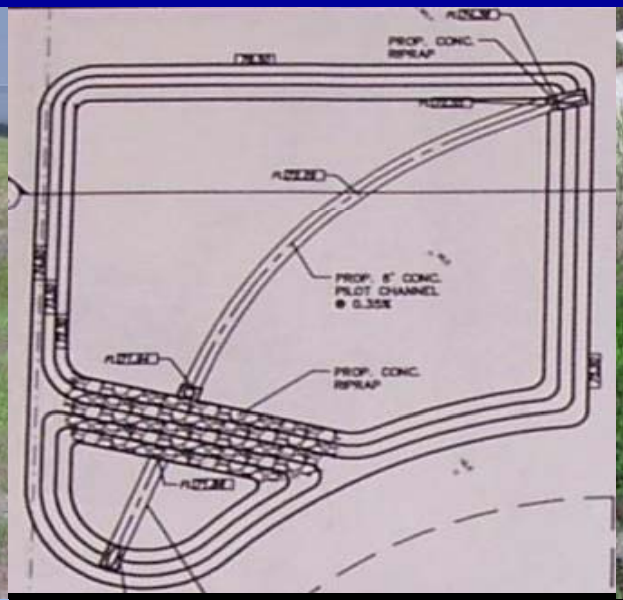


Dry Basin Site One



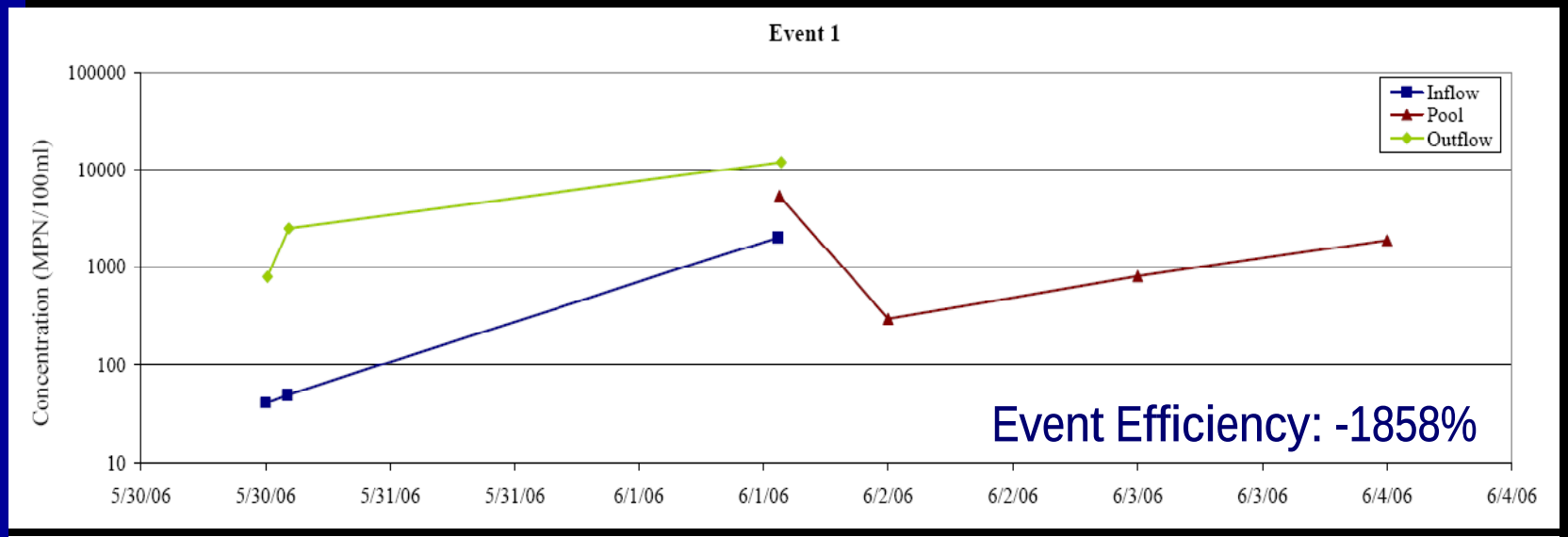
- Conventional Detention Basin
- Selected because of design, variation from DB2, proximity, access, and stabilization

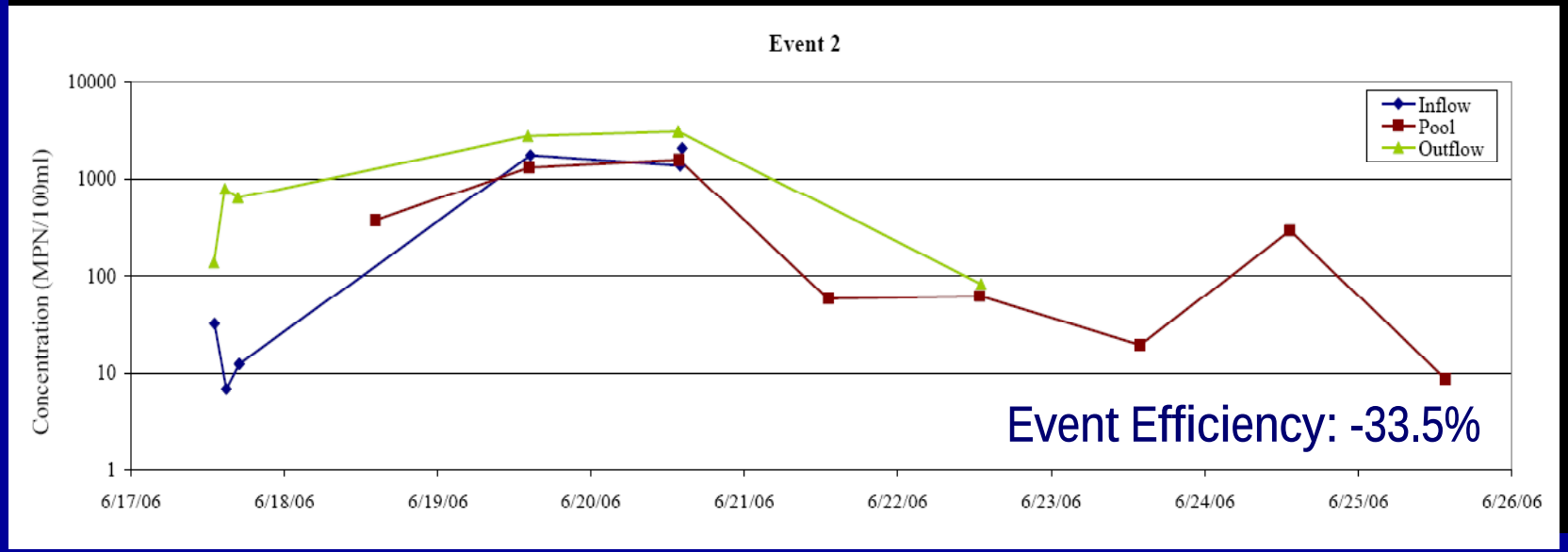
Dry Basin Site Two



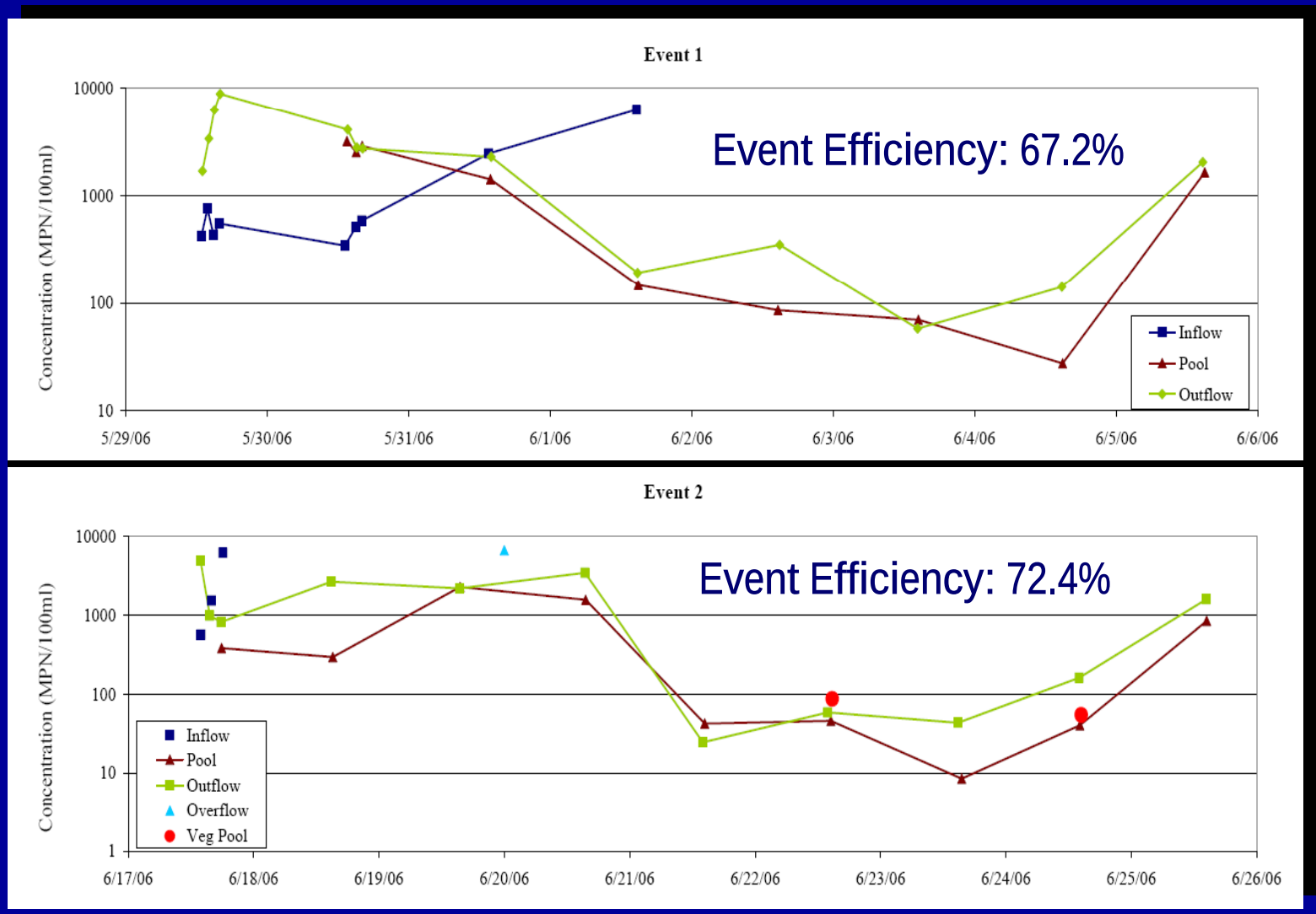
- Extended Detention Basin
- Selected because of design, maintenance and stabilization

DB1 Efficiency



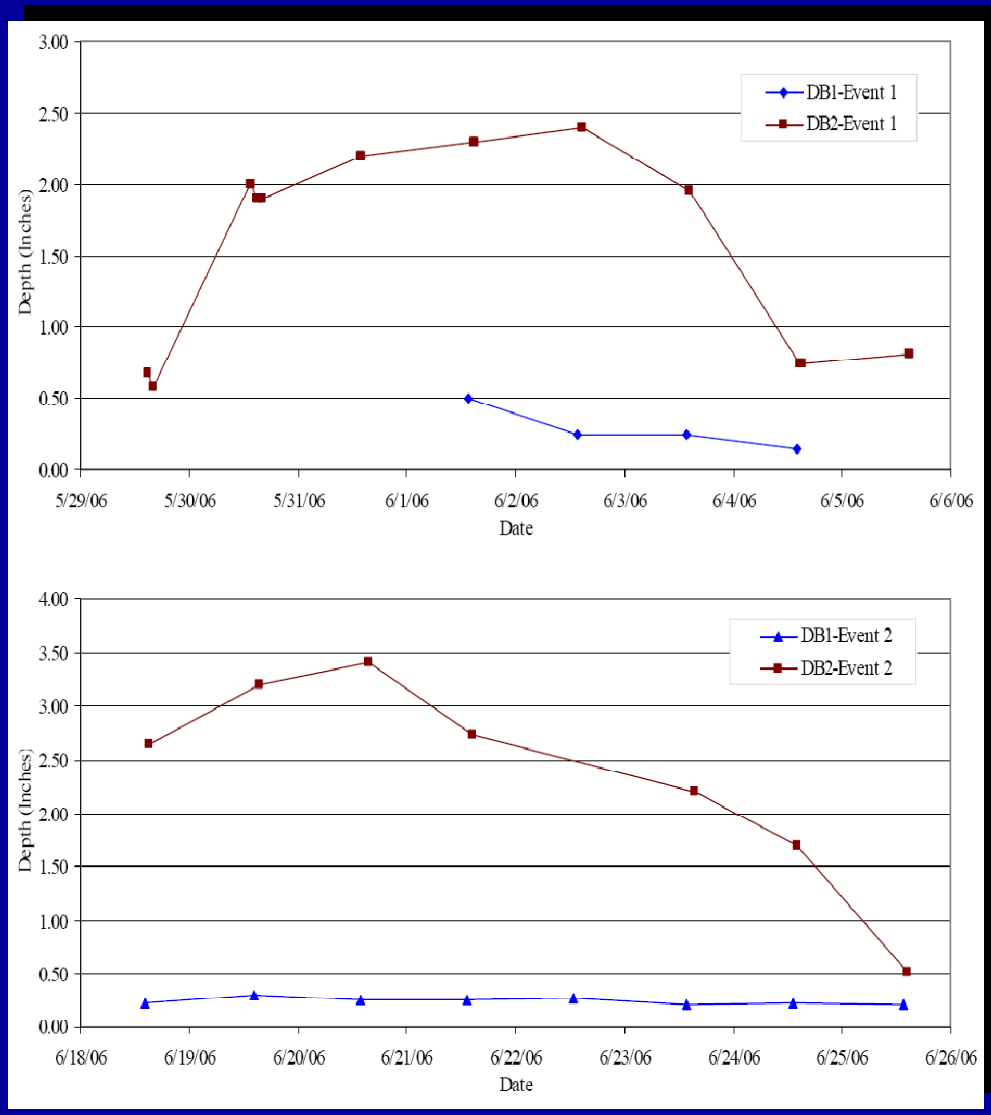


DB2 Efficiency

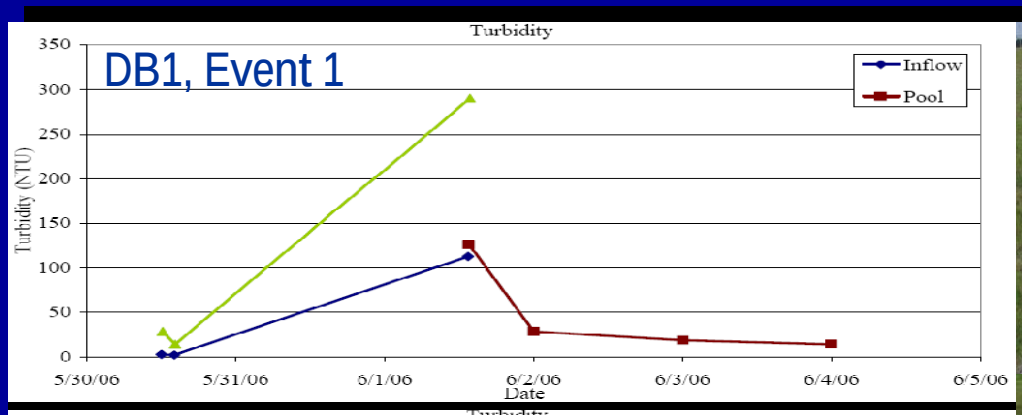


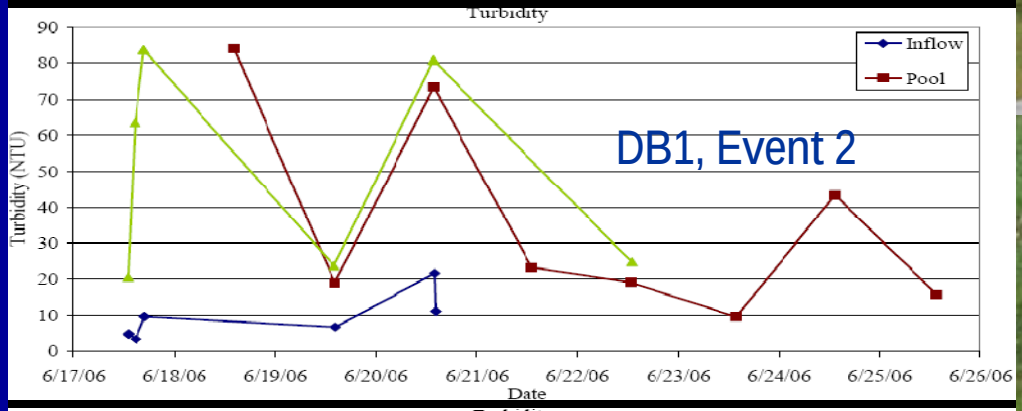
Issues with Dry Basins
&
Why Poor Performance at DB1?

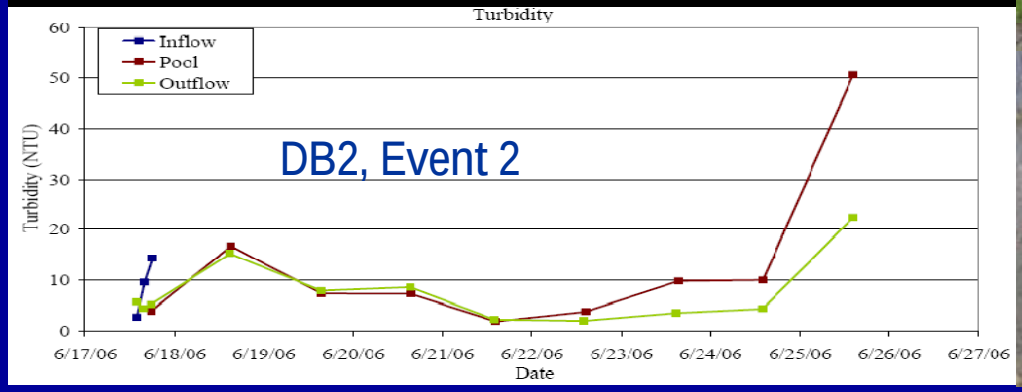
Pool Formation at DB1 and DB2



Resuspension





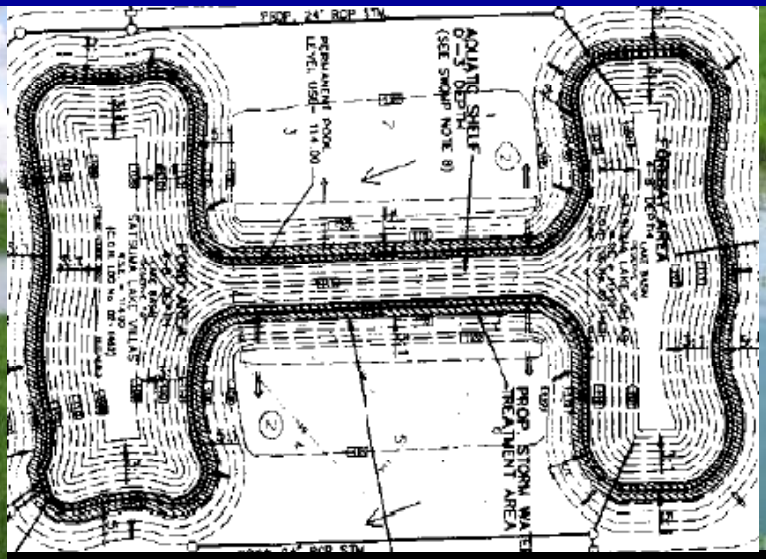


To Increase Efficiency

- Improve maintenance procedures
- Increase and ensure complete stabilization by vegetation
- Increase discharge period
- Reduce initial discharge

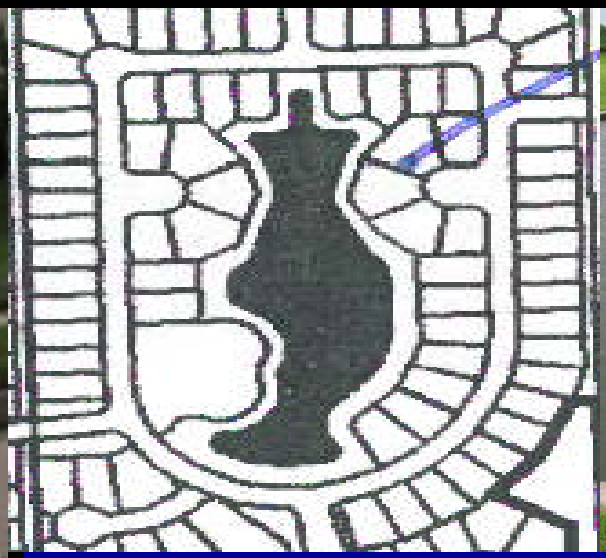
		Elimination of Discharge for:				
Detention Basin No.	Event	None	Day One	Day Two	Day Three	Day Four
1	1	-1858%	-806%	-426%	N/A	N/A
1	2	-34%	64%	66%	74%	82%
2	1	67%	70%	79%	83%	86%
2	2	72%	74%	78%	90%	94%

Wet Basin Site One



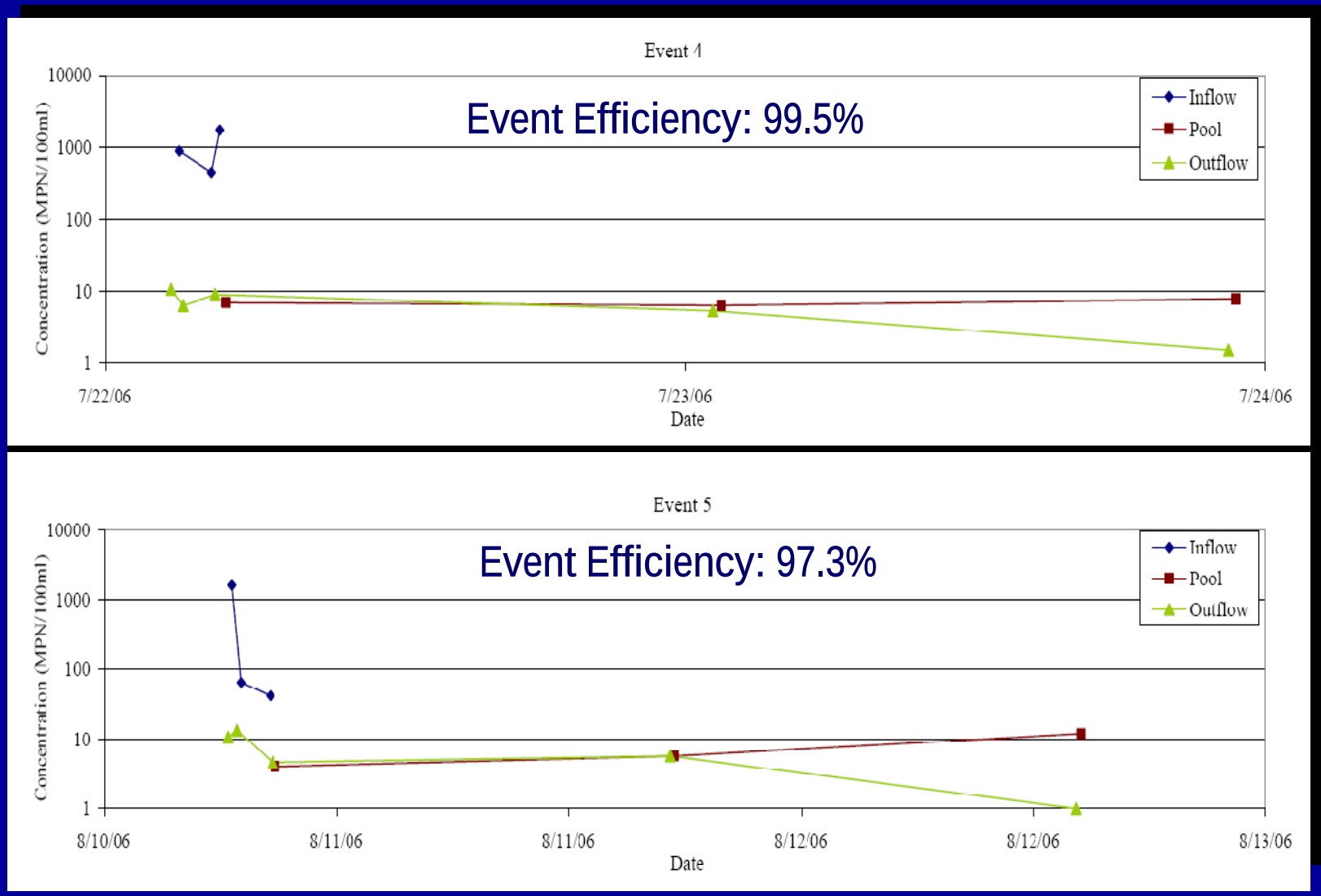
- Well maintained and stabilized retention pond
- Distinct/separate sediment forebay
- Two fountains: One at forebay and one in permanent pool
- Residential drainage area

Wet Basin Site Two

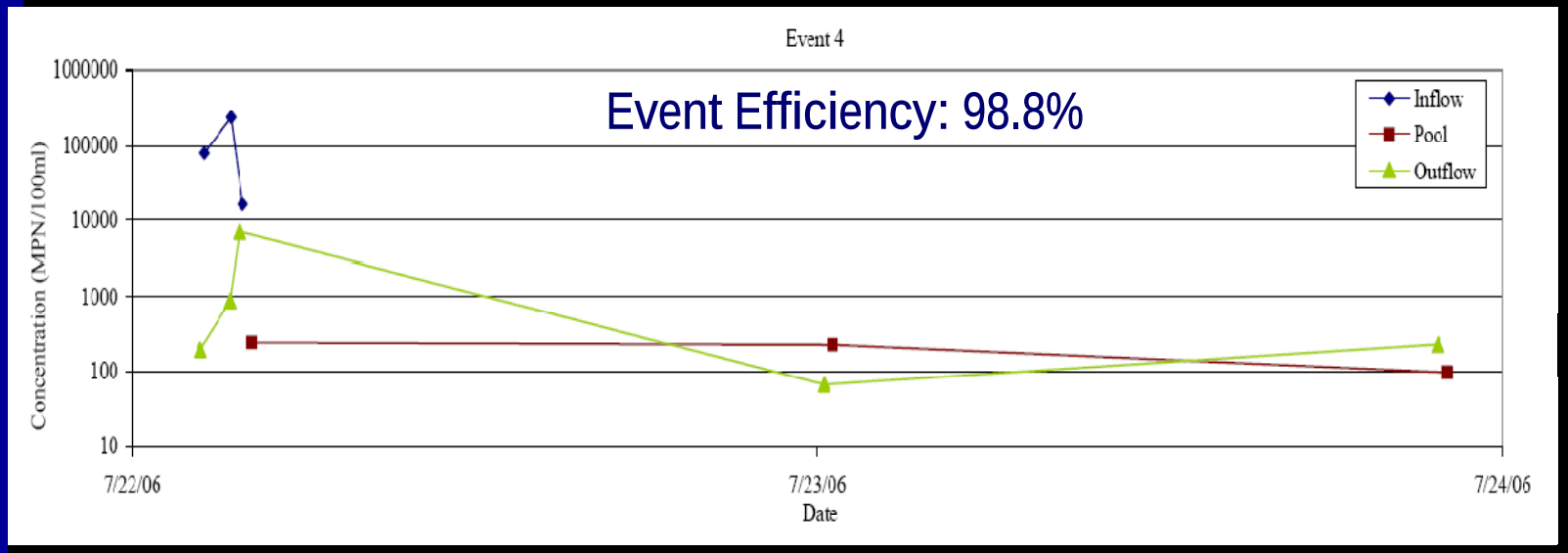


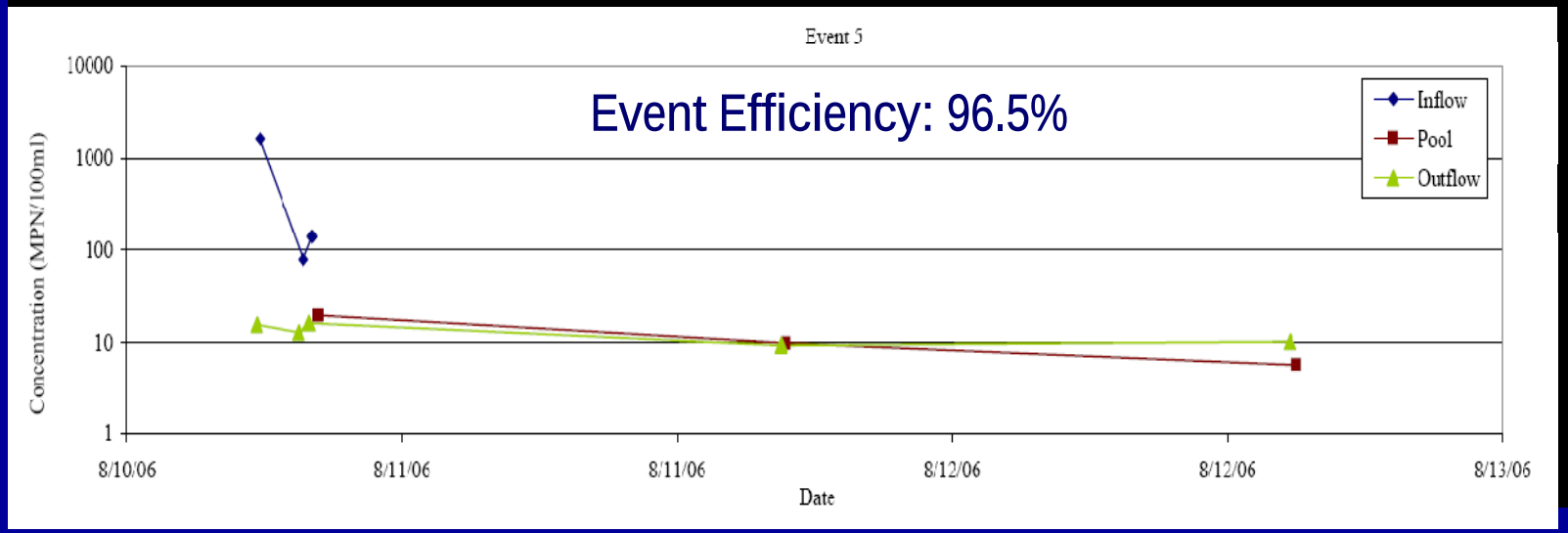
- Large, well maintained and stabilized retention pond
- No sediment forebay
- During reconnaissance and runoff event 1, no fountain
- Residential drainage area

WB1 Efficiency



WB2 Efficiency

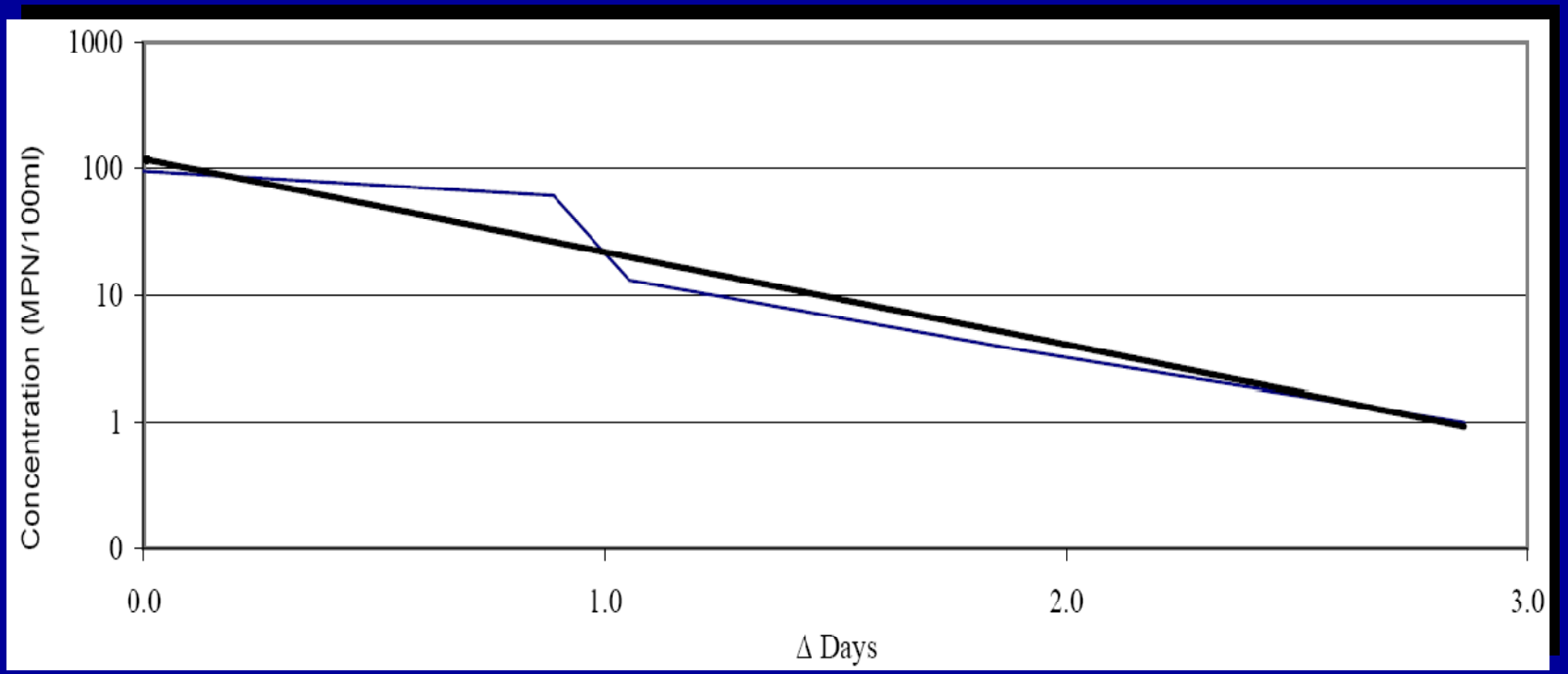




Event 3 (not shown) Efficiency: 99.9%

Die-Off Study

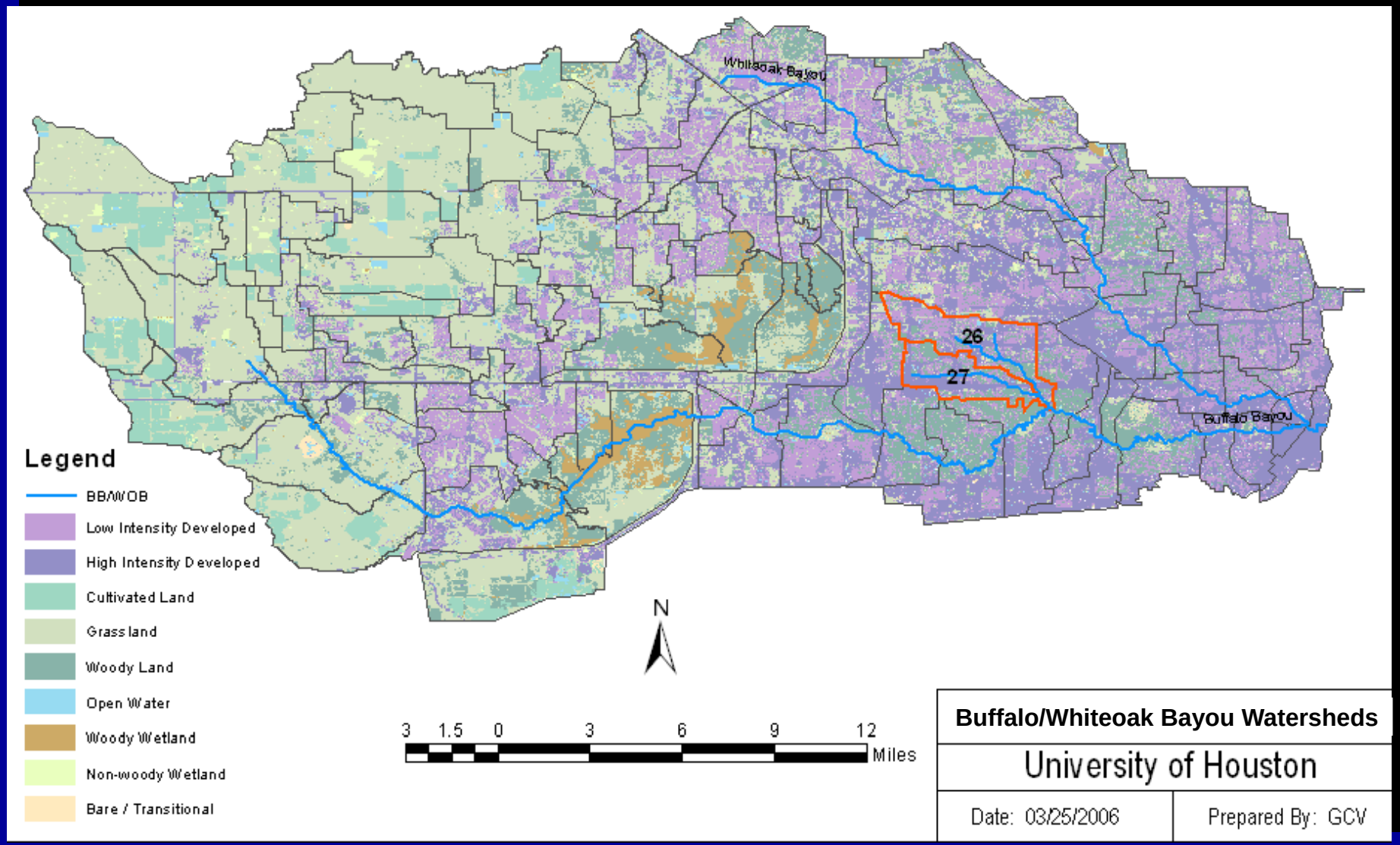
- Understand fecal pathogen survival/regrowth in basins.
- Mortality rate of 1.69 $log_{10}CFU \times 100ml^{-1} \times day^{-1}$ measured (r^2 of 0.93)



Buffalo Bayou HSPF Modeling to Evaluate Effectiveness

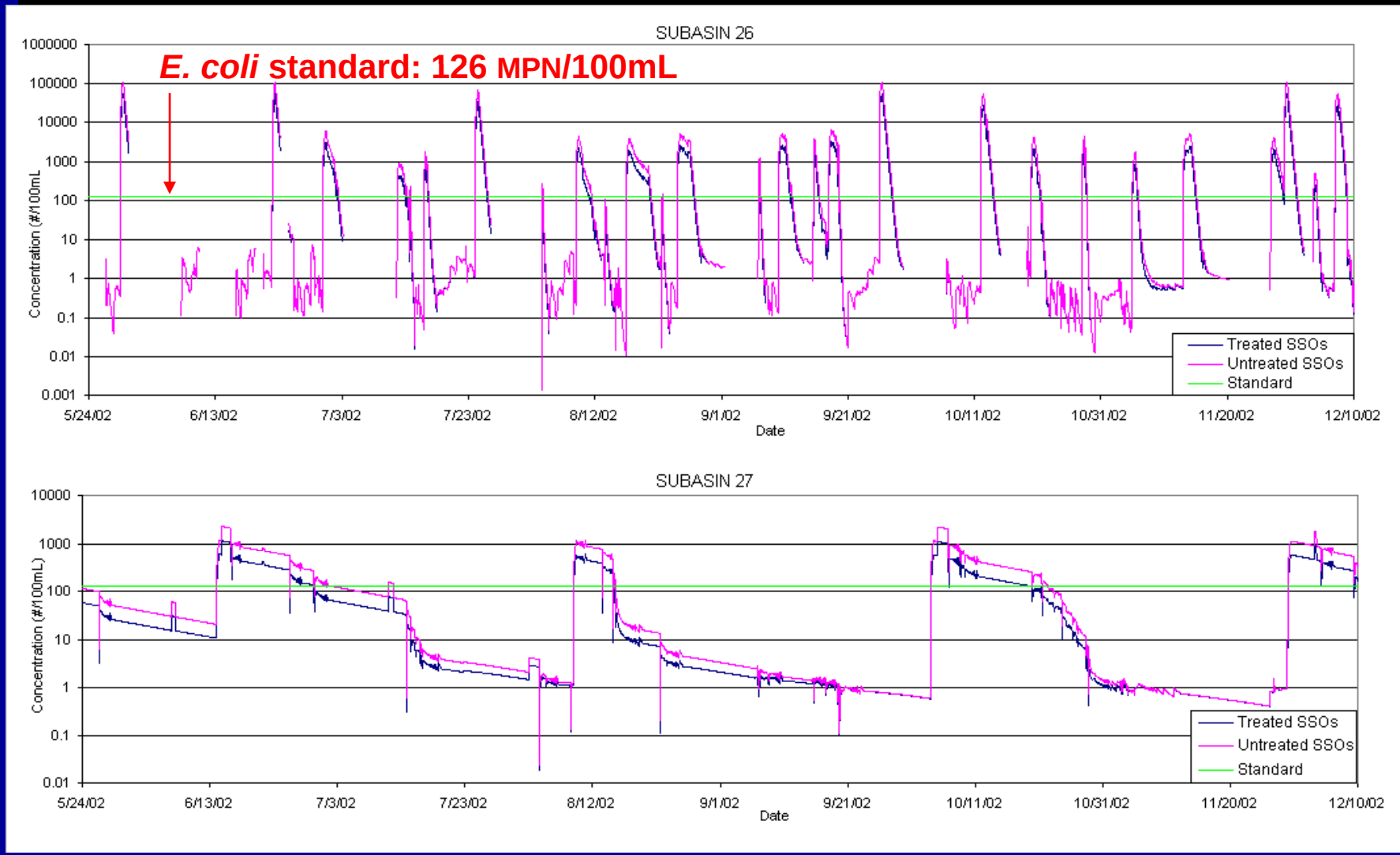
- HSPF Water quality model simulates the transport of contaminants from watershed to stream
- Hydrologic and water quality processes defined for pervious and impervious land and for in-stream processes
- Buffalo Bayou TMDL model modified to include BMPs
- BMP module added to incorporate reductions
- To simulate hydrologic changes caused by water quality basins, reach/reservoir segments added
- Observed flow rates and efficiencies used as model input

BMP Impacts on SSO Discharges



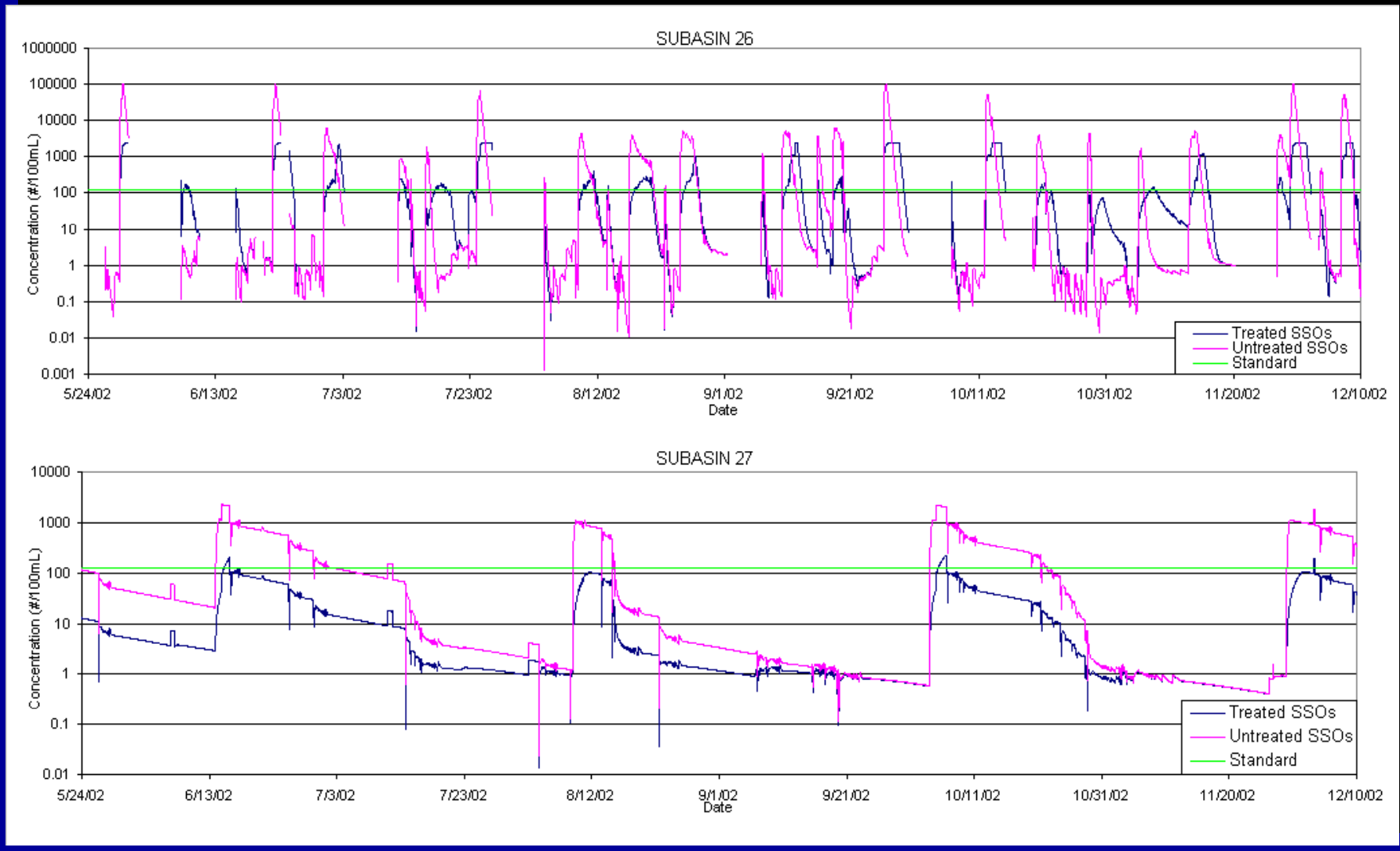
Vegetative Filter Strip Effectiveness

Stream *E. coli* concentrations With No Detention and 50% Removal



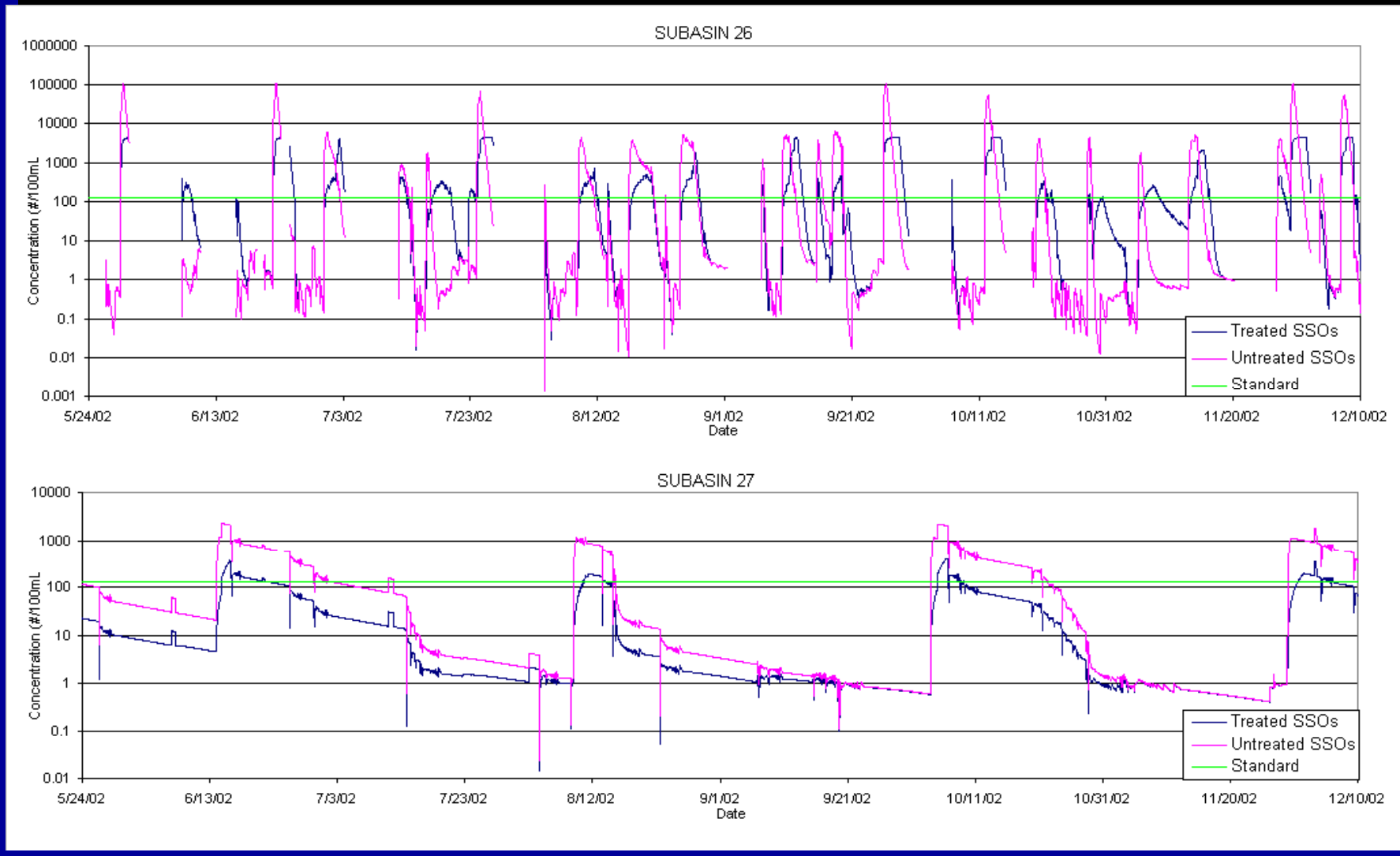
Dry Basin Effectiveness

Stream *E. coli* concentrations With 2 Day Detention and 90% Removal



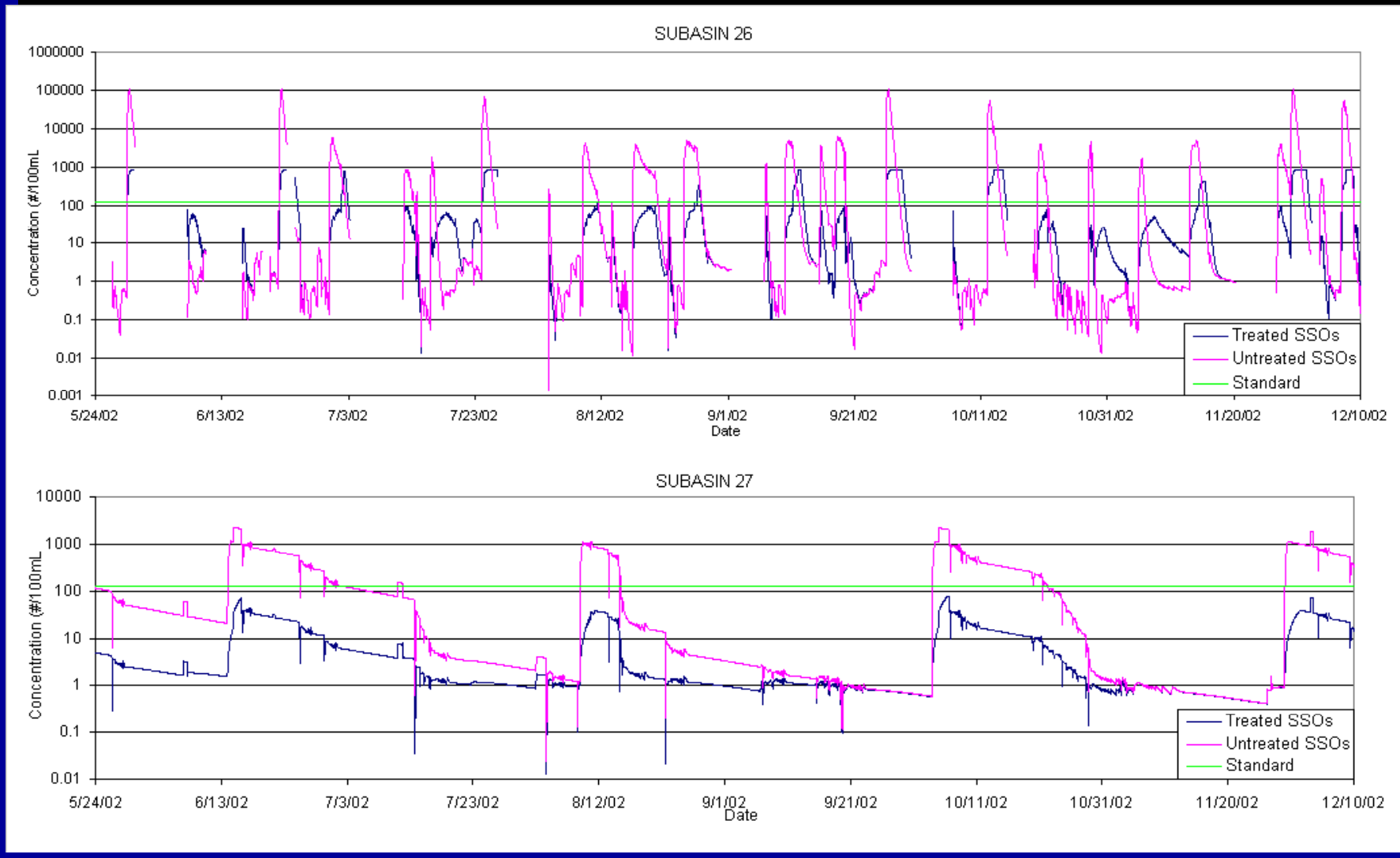
Wet Basin Effectiveness

Stream *E. coli* concentrations With 7 Day Detention and 50% Removal



Wetland Effectiveness

Stream *E. coli* concentrations With 7 Day Detention and 90% Removal



Use of Inline BMPs to Treat SSOs

Percent of Days that Exceed the Bacteria Standard (126MPN/100mL)

Subbasin	Efficiency	Normal discharge	2 Day Detention	7 Day Detention
Sbsn 26	0% reduction	29%	29%	24%
Sbsn 26	50% reduction	15%	26%	21%
Sbsn 26	90% reduction	10%	16%	7%
Sbsn 27	0% reduction	45%	15%	29%
Sbsn 27	50% reduction	33%	33%	18%
Sbsn 27	90% reduction	7%	7%	2%

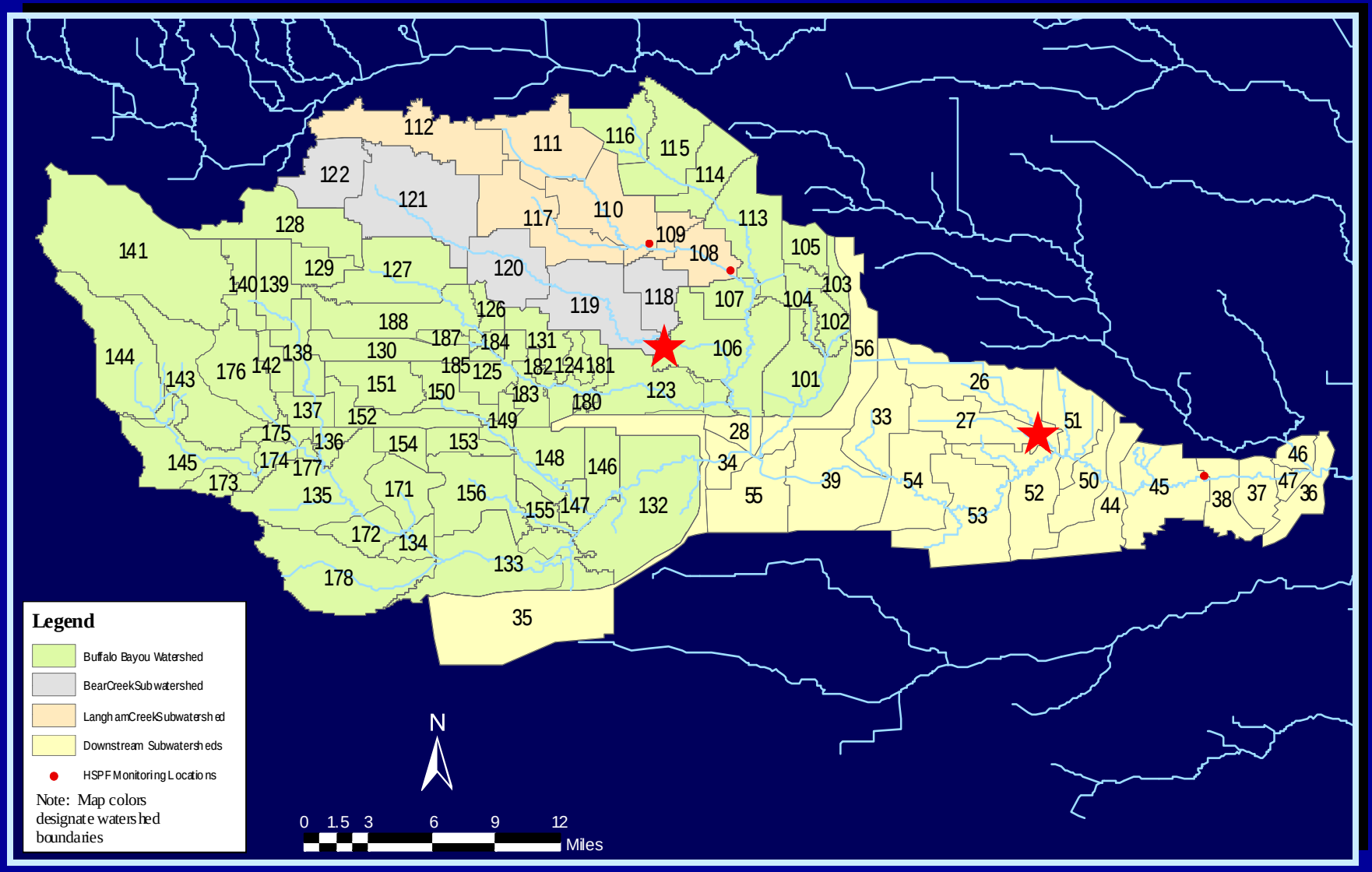
The Geometric Mean at Subbasins 26 and 27

Subbasin	Efficiency	Normal discharge	48 hour detention	7 day detention
Sbsn 26	0% reduction	11	28	19
Sbsn 26	50% reduction	10	22	15
Sbsn 26	90% reduction	7	12	9
Sbsn 27	0% reduction	51	52	23
Sbsn 27	50% reduction	30	30	14
Sbsn 27	90% reduction	9	9	5

Basin Modeling Scenarios

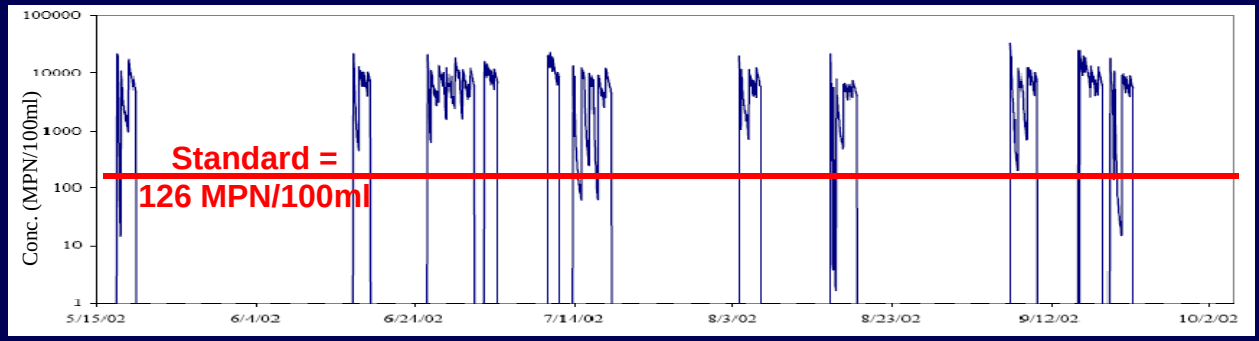
- Numerous model runs developed to test the effects of basins on stream water quality
- Two sets of analyses were performed:
  - Set 1:
    - type of basin (dry vs. wet)
    - number of basins implemented
    - type of drainage area (pervious vs. impervious)
    - efficiency of basin
  - Set 2:
    - locations of basins
    - type of basin and discharge rate

Locations for HSPF Analysis - Set One

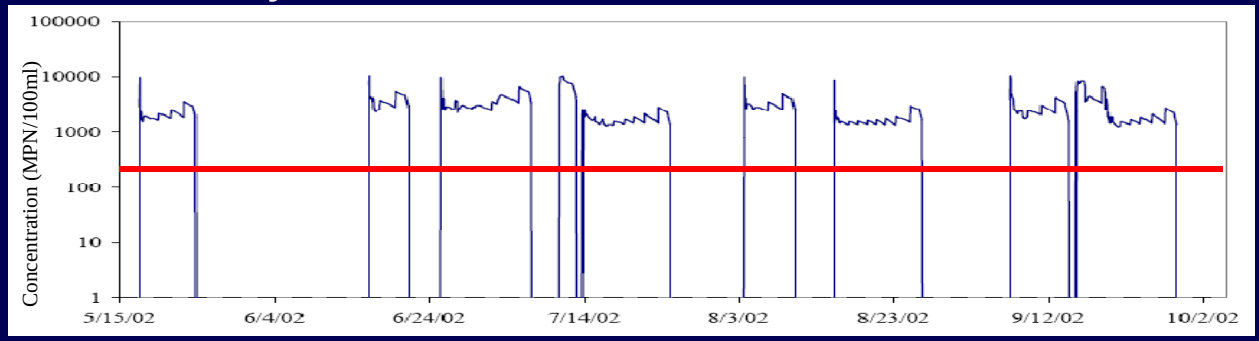


Effect of Basins on Runoff

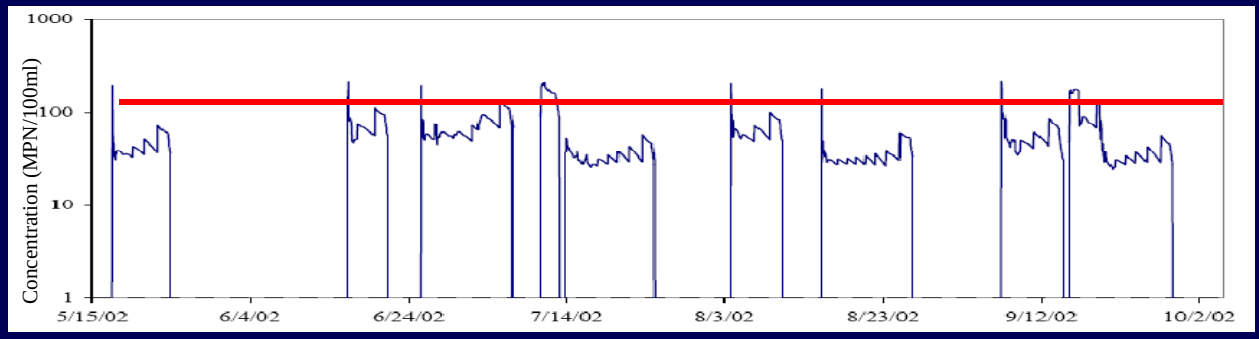
No Basins



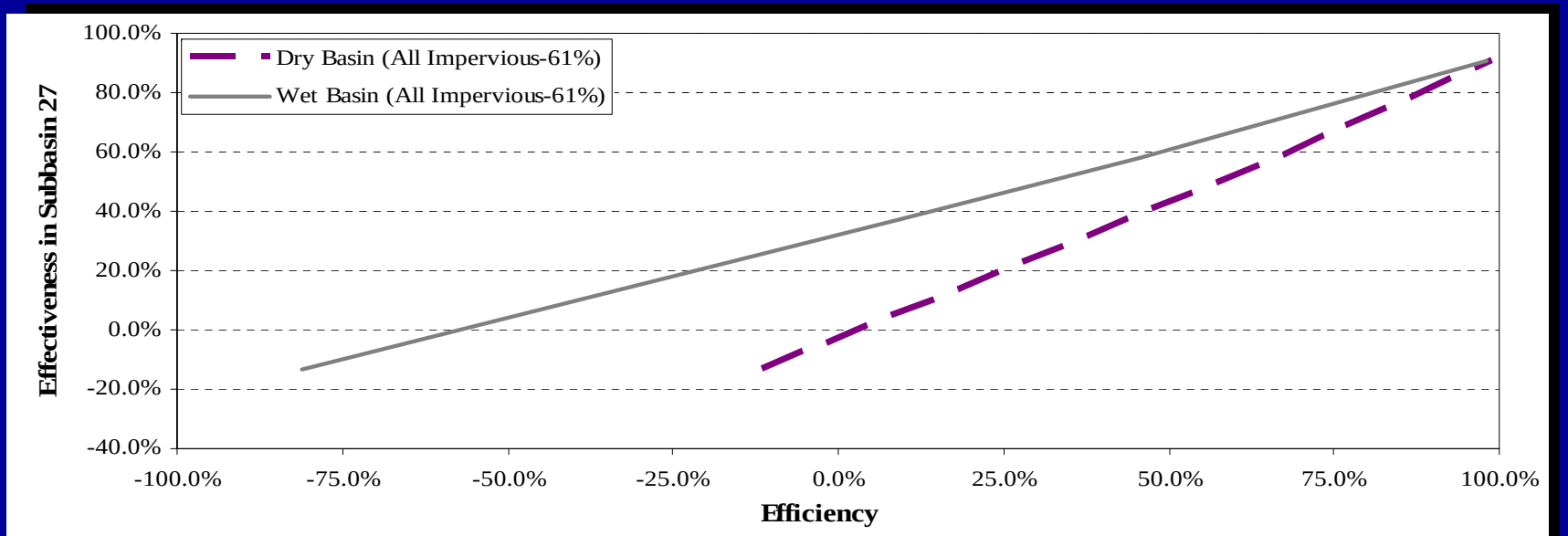
5% Efficiency; 10% Effectiveness

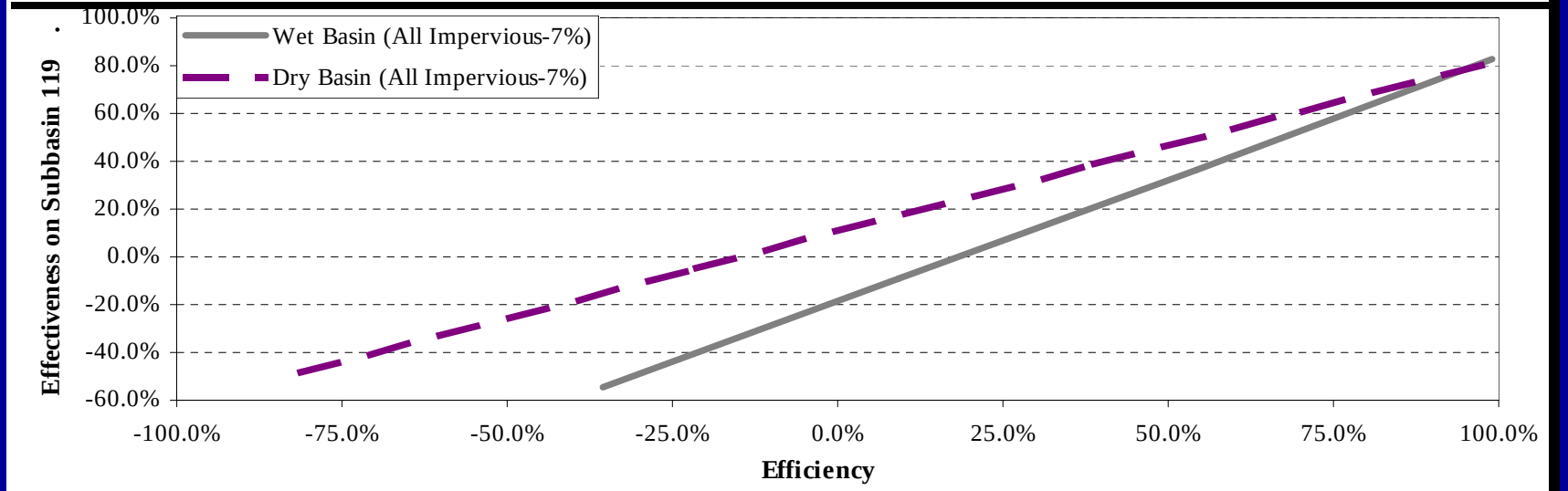


98% Efficiency; 52% Effectiveness

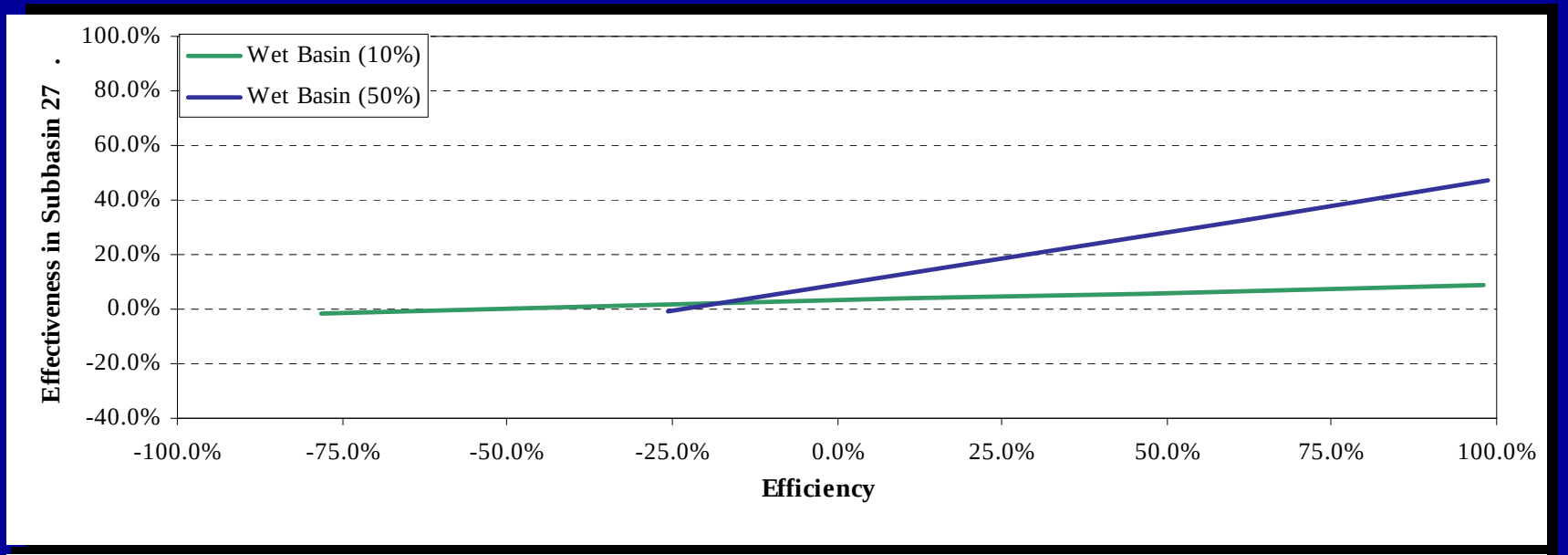


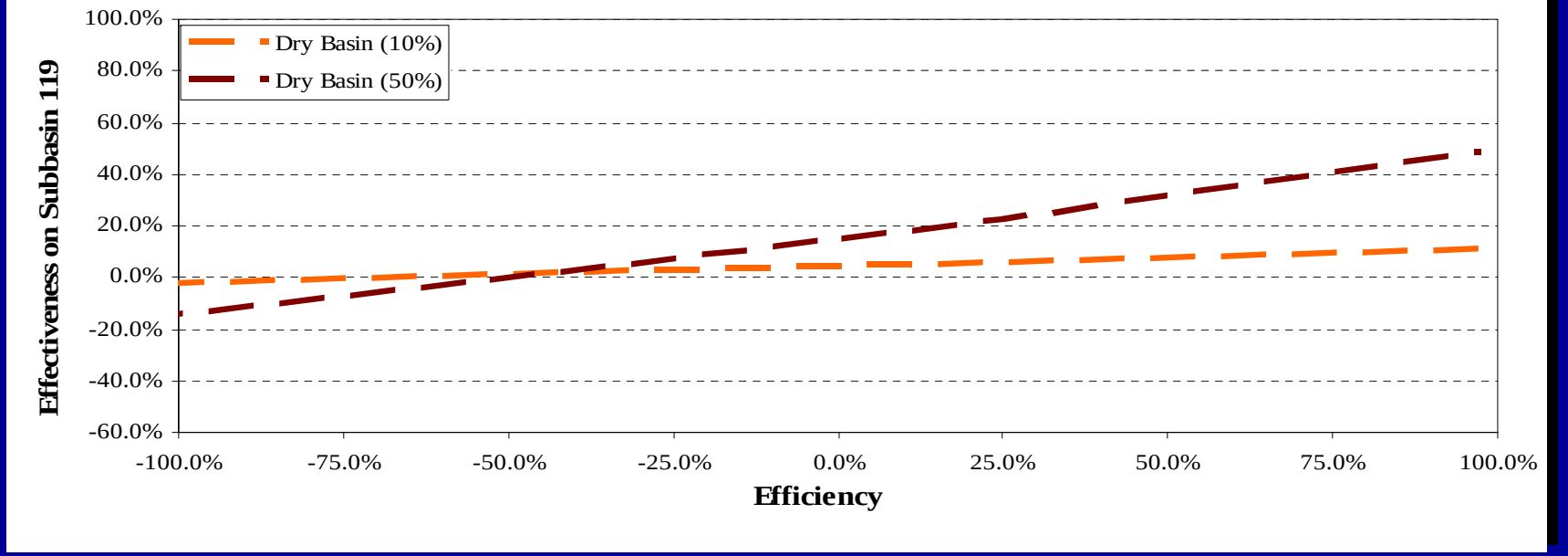
Effectiveness Versus Basin Type



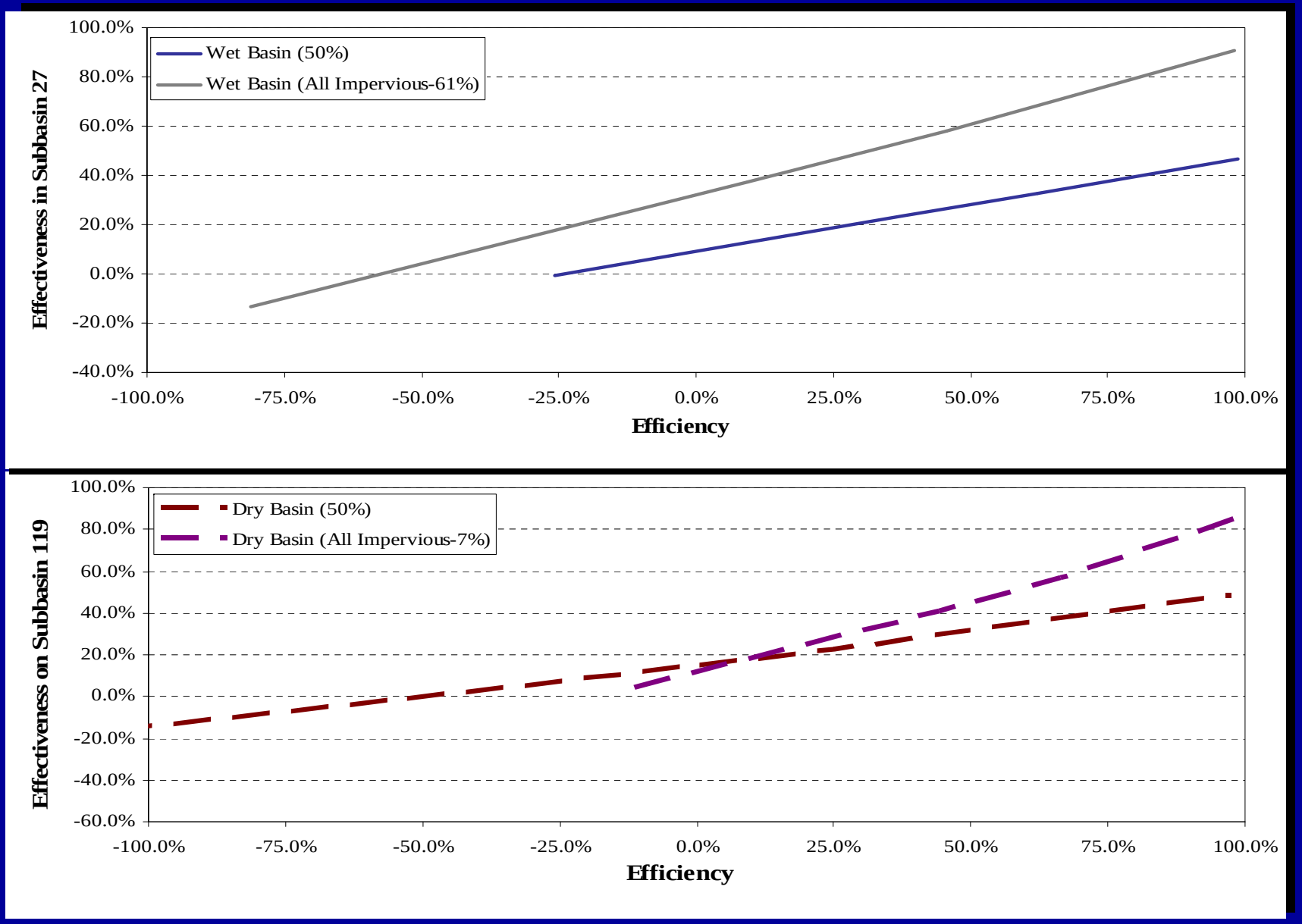


Effectiveness Versus Number of Basins

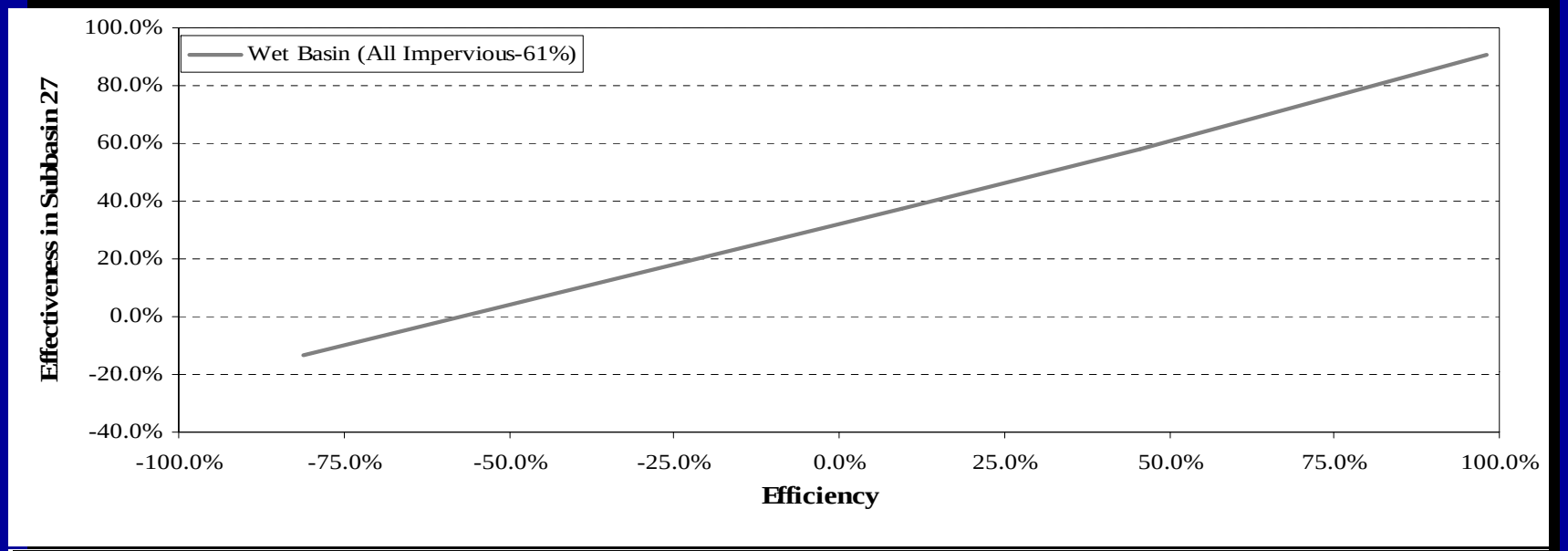


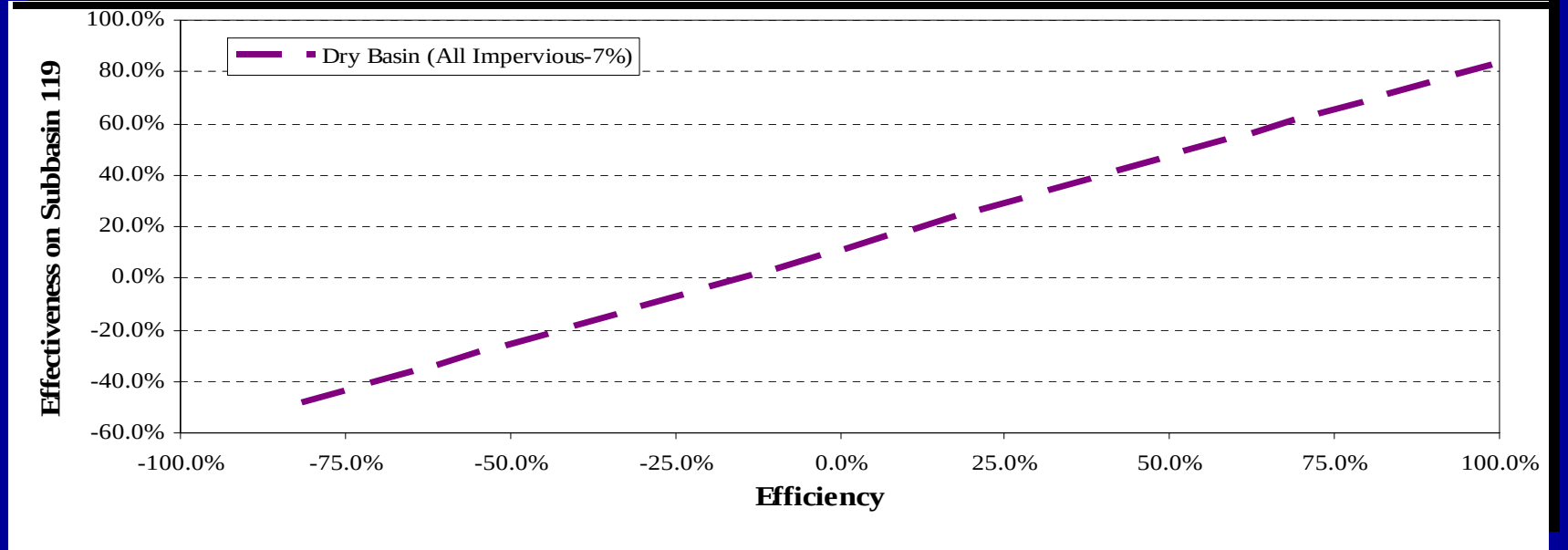


Pervious or Impervious

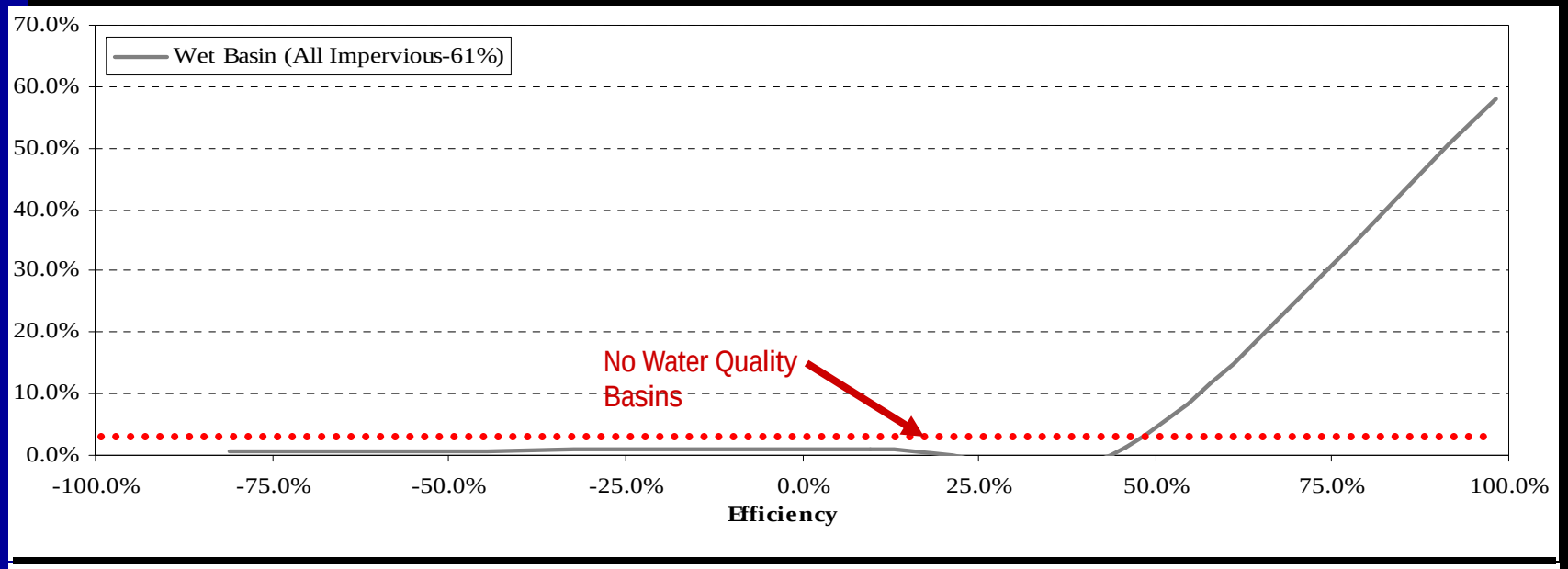


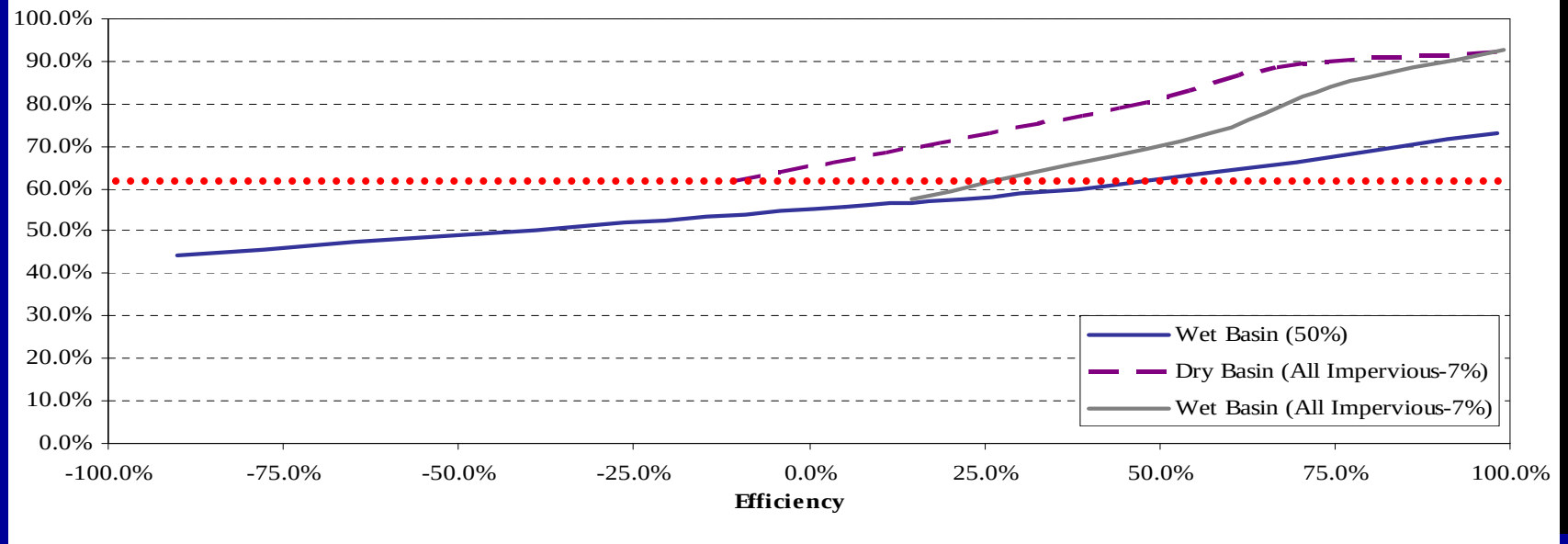
Effectiveness Versus Efficiency





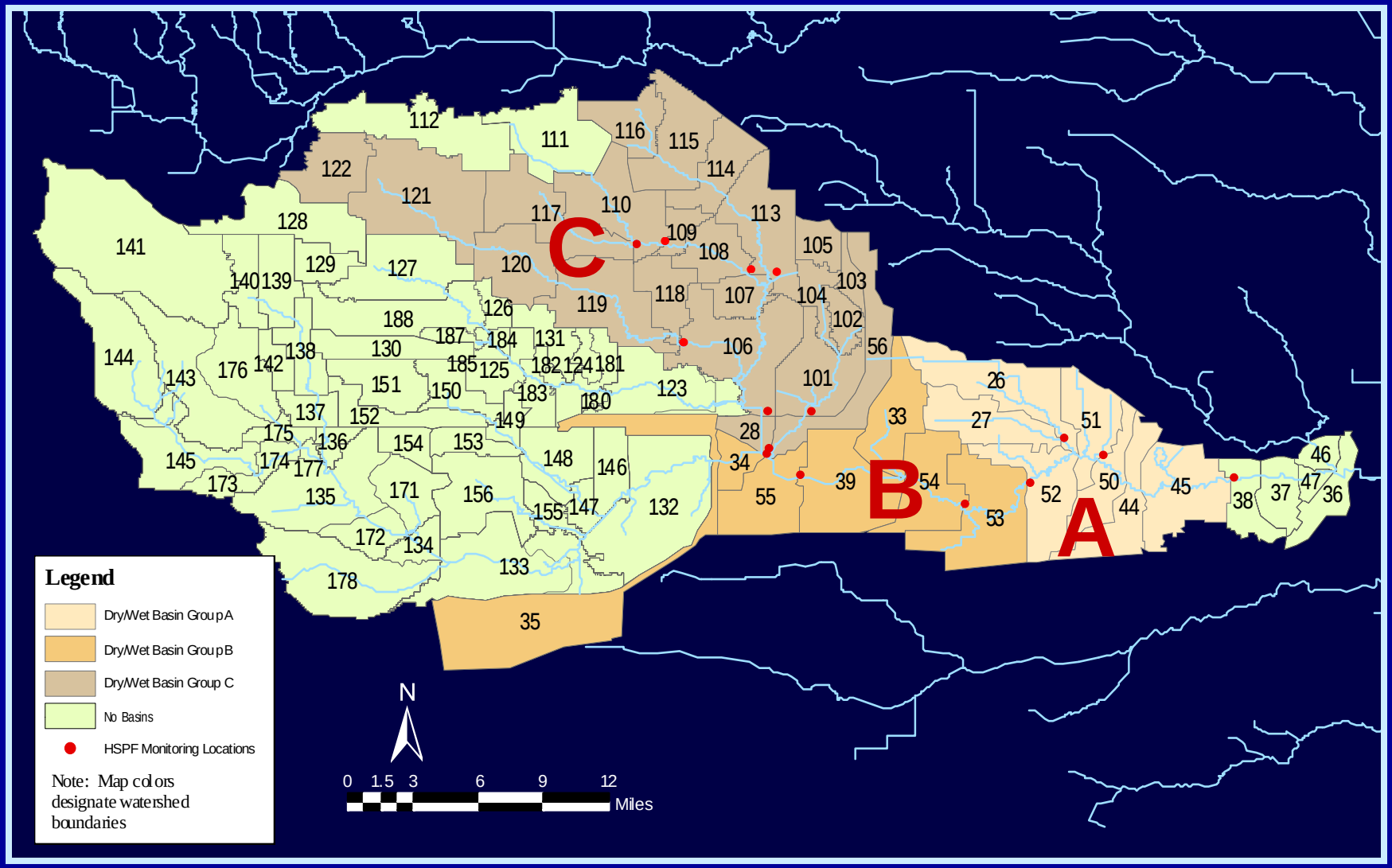
How Often Is the Standard Met?





Single Sample Limit – 394 MPN/100ml

Locations for HSPF Analysis - Set Two



Location and Basin Type

Group	Downstream Average	Midstream Average	Upstream Average
A	32%	0%	0%
B	11%	38%	0%
C	7%	26%	92%

Basin	Downstream Average	Midstream Average	Upstream Average
DB	15%	21%	30%
DB2	15%	20%	30%
WB	20%	24%	32%

Values for most effective scenarios highlighted

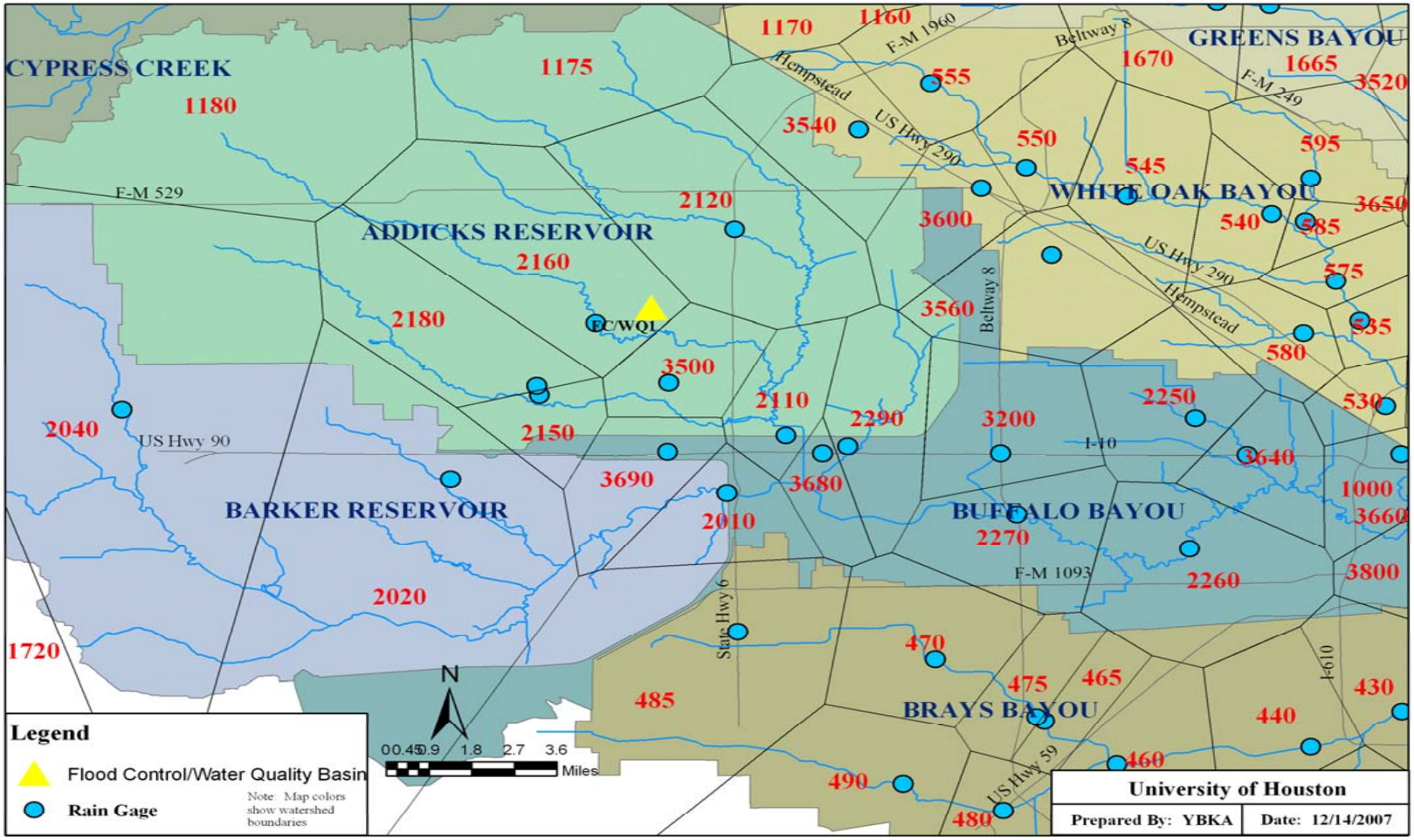
[1] DB – detention basin
DB2 – detention basin with twice observed discharge rate
WB – wet basin

[2] Group refers to the location of the water quality basins

Summary for Wet & Dry Basins

- Wet basins efficiencies from 95% to 99%
- Dry basins efficiencies ranged from 67% to 72% for extended detention and -34% to -1858% for conventional basin
- Implementation/Stabilization and temporal variation in Dry Basins have important effects on efficiency
- Effectiveness depends upon type, number, location, drainage area (pervious and impervious), and efficiency
- Due to the extension of the hydrograph, basins may worsen water quality when not performing efficiently
- Greatest water quality benefit for impervious regions

Location of FC/WQ Basin



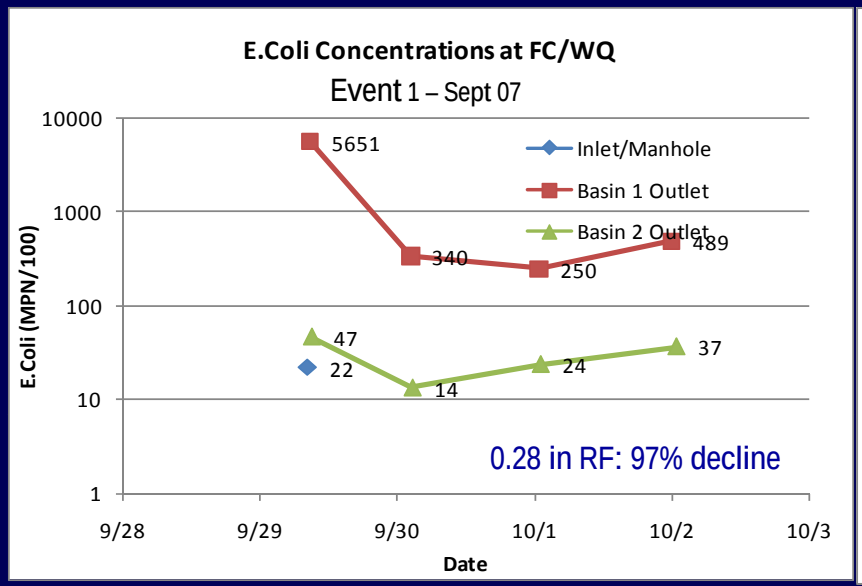
A Map of Rain Gages and Flood Control /Water Quality Basin

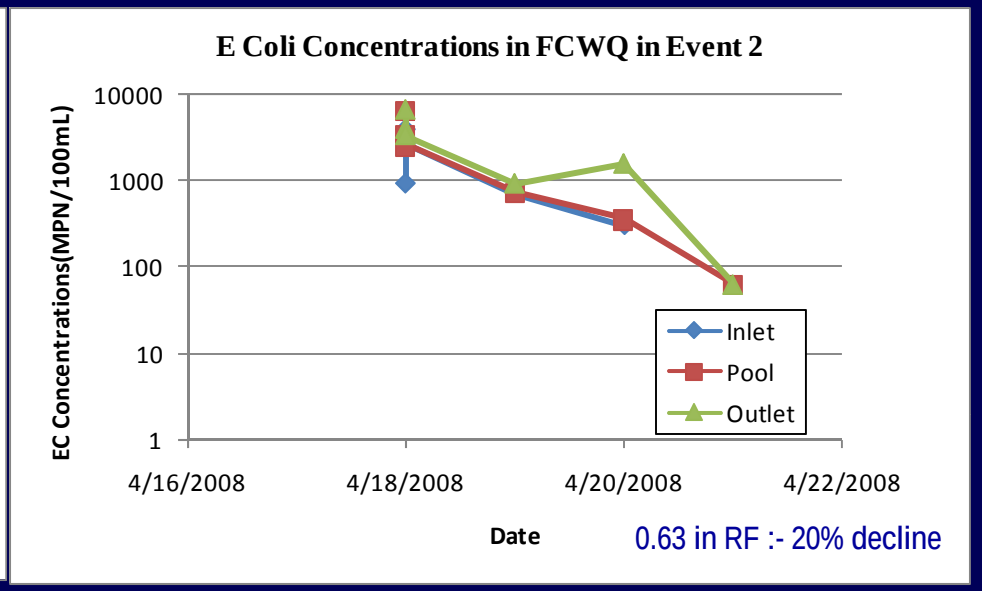
FC/WQ Basin

Outlet Structure

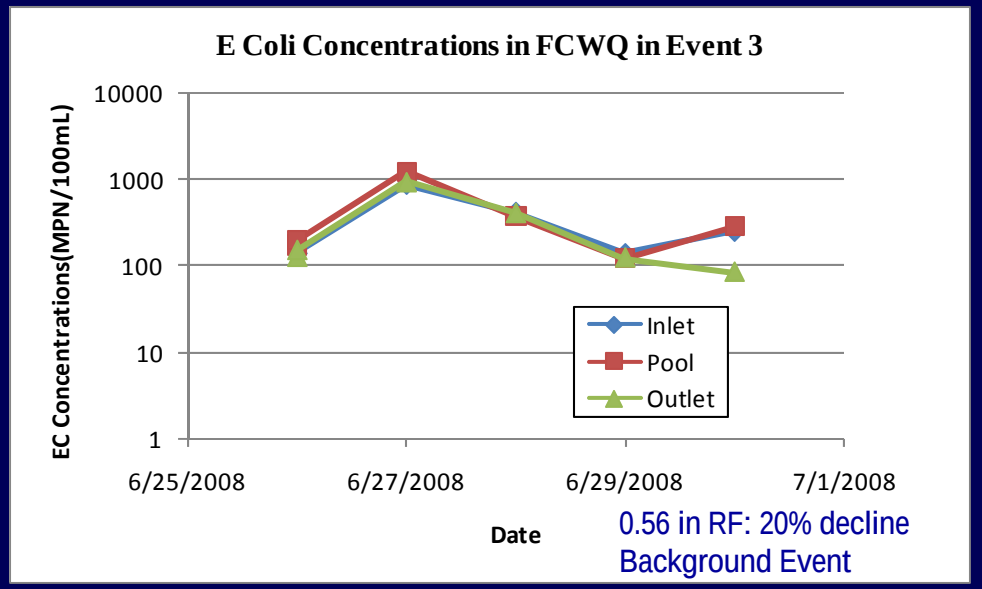
Interconnecting
Concrete Channel

E. coli concentrations during 4 events

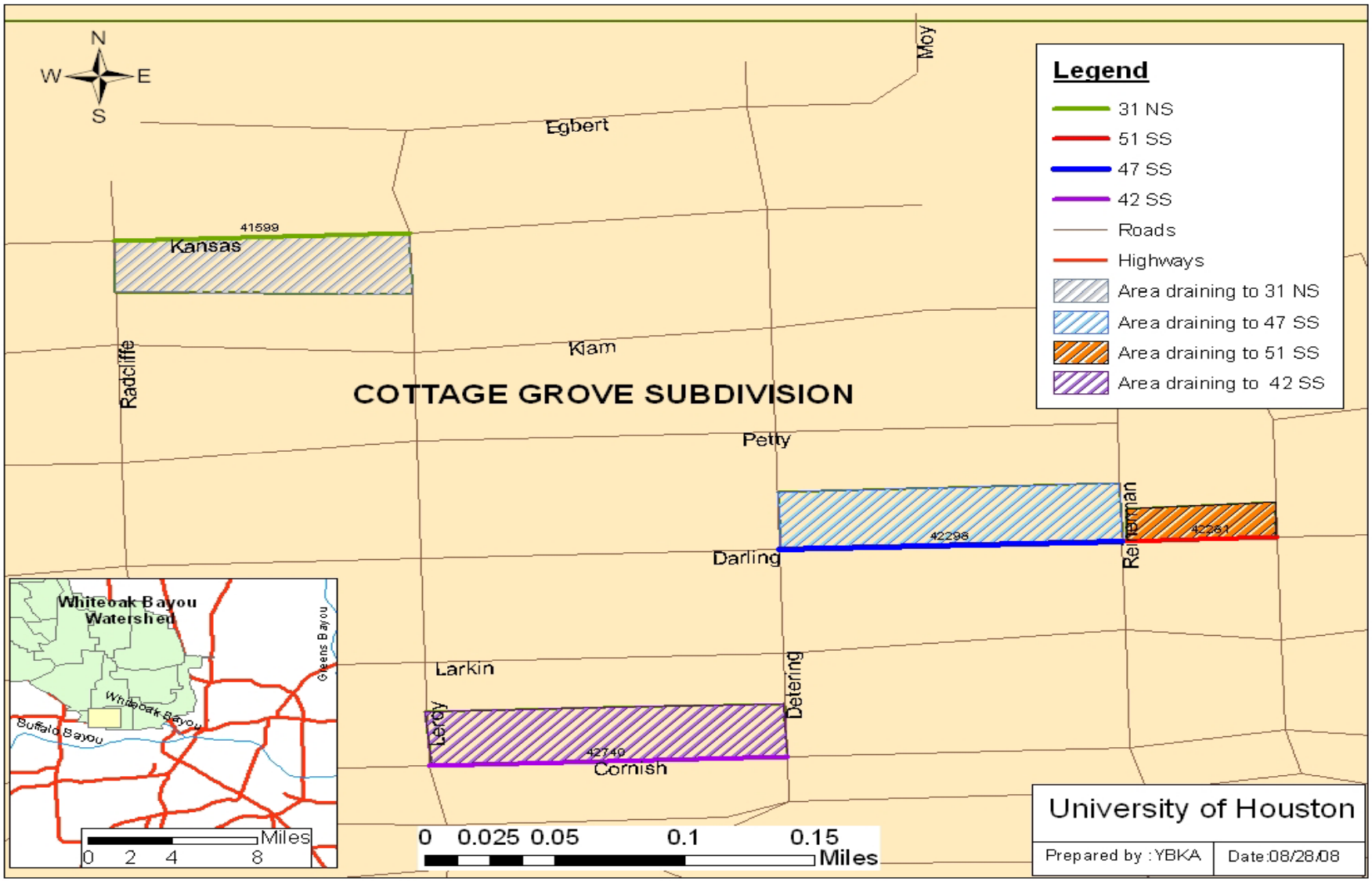




Event 4 lasted 1 day Interrupted by Maintenance.



Swales in Cottage Grove



Studied Swale 1

Studied Swale 2

42SS

Studied Swale 3

Studied Swale 4

Swale Design Characteristics

Grass Swale ID	Length (ft)	Average Channel Side Slope (%)	Vegetative Height(ft)	Drainage Area (Acres)
31 NS	510.1	3.1	5	1.3
47 SS	667.4	3	6	1.6
51 SS	226.7	2.7	4	0.6
42 SS	603.3	4.1	5	1.4

Efficiencies of Grass Swales

	31 NS	42 SS	47 SS	51 SS
Event 1 June 19, 08	99%	-631%		
Event 2 June 23, 08 – 0.83 in	98%	-294%		
Event 3 June 26, 08 – 0.16 in	56%	-717%		
Event 4 July 24, 08 – 1.04 in			97%	-1010%
Event 5 Aug 15, 08 – 0.91 in				
Event 6 Aug 16, 08 – 0.35 in			93%	-3726%
Event 7 Aug 20, 08			-428%	38%

Summary FC/WQ & Swales

- Variable efficiencies
- Highly dependent on maintenance & vegetation
- Swale residence time may be too small for pathogen removal
- Effectiveness for in-stream concentration reduction unknown