Downstream Sediment Interception

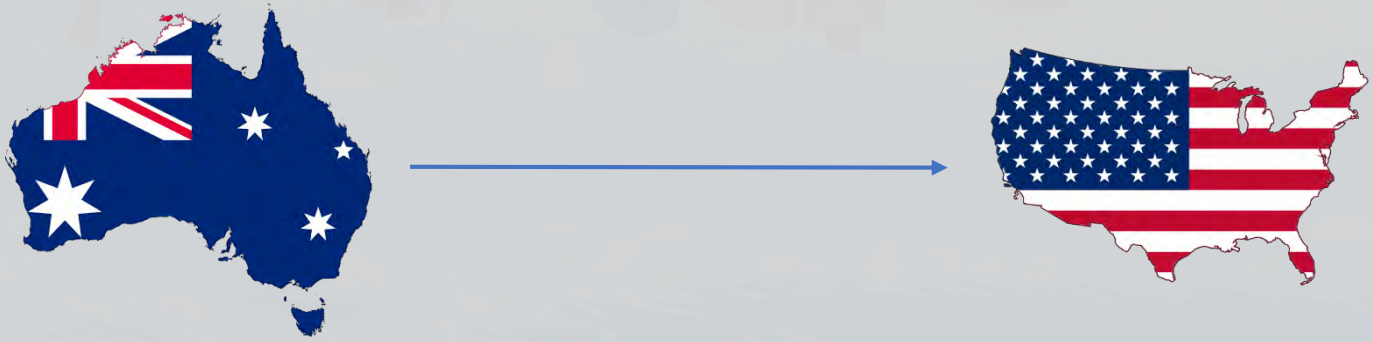
A Unique Application for Proprietary Best Management Practice (BMP) Technology

Peter Enright

My Background

Role at WSP

- Civil Site and Infrastructure Group
- 6.5 years in the water/engineering industry
- Design of water/wastewater/stormwater infrastructure
- Master planning and hydraulic/hydrologic modelling



Rainfall, Runoff and Water Quality

Catchment Response

Storm Event

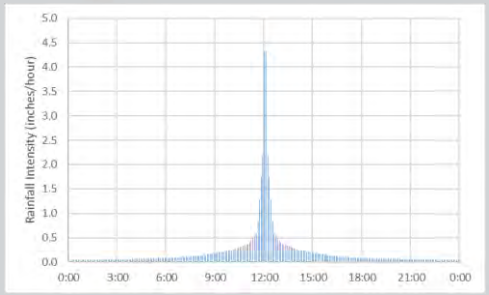
- Total Depth of Rainfall
- Distribution Over Time

Surface Runoff

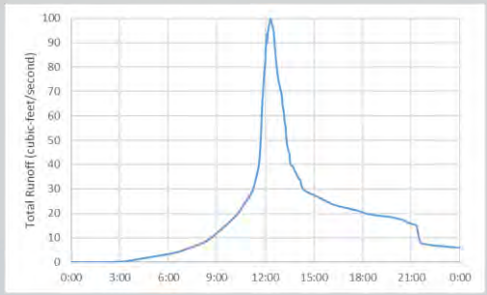
- Cover Type
- Topography
- Infiltration
- Connectivity

Stormwater

- Hydrology
- Inlet Types
- Land Use
- Pretreatment



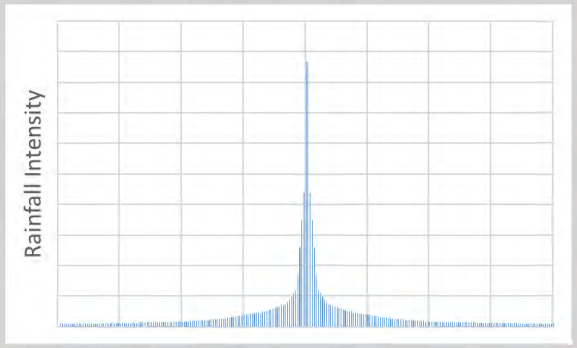
Hyetograph

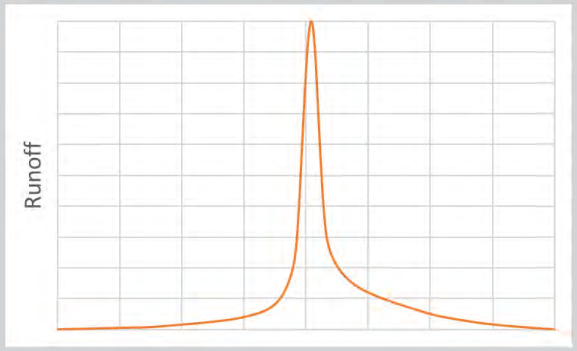


Hydrograph

Catchment Response Examples

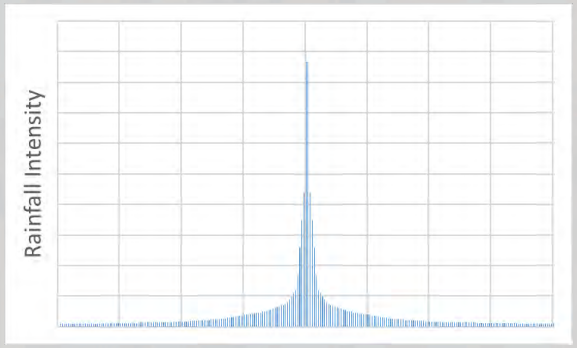
Parking Lot

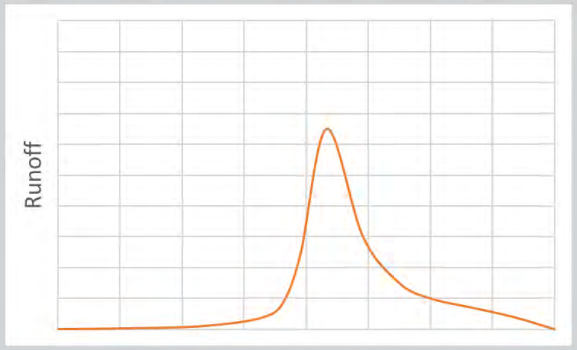




Catchment Response Examples

Sports Field

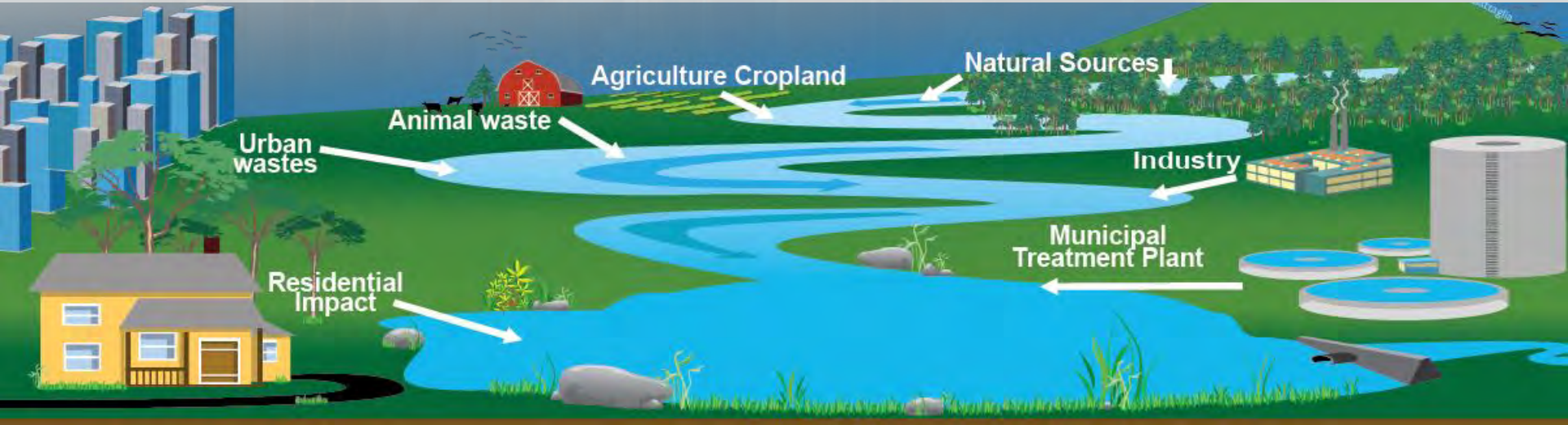




Water Quality Overview

Typical Stormwater Pollutants

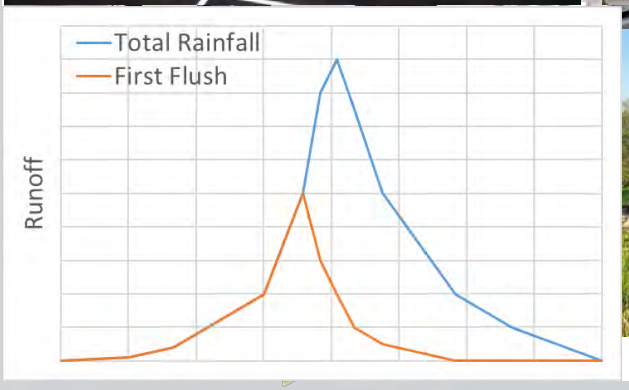
- Sediment AKA Total Suspended Solids (TSS)
- Nitrogen, Phosphorus, Chloride, and Hydrocarbons
- Micro-organisms and Toxic Organics



Predicting Water Quality

Factors Effecting Stormwater Pollutant Load

- Land Use/Type of Pollutants Present
- Frequency of Cleaning/Flushing Rainfall
- Hydrodynamics of Treatment Train
- Intensity and Duration of Rainfall Event



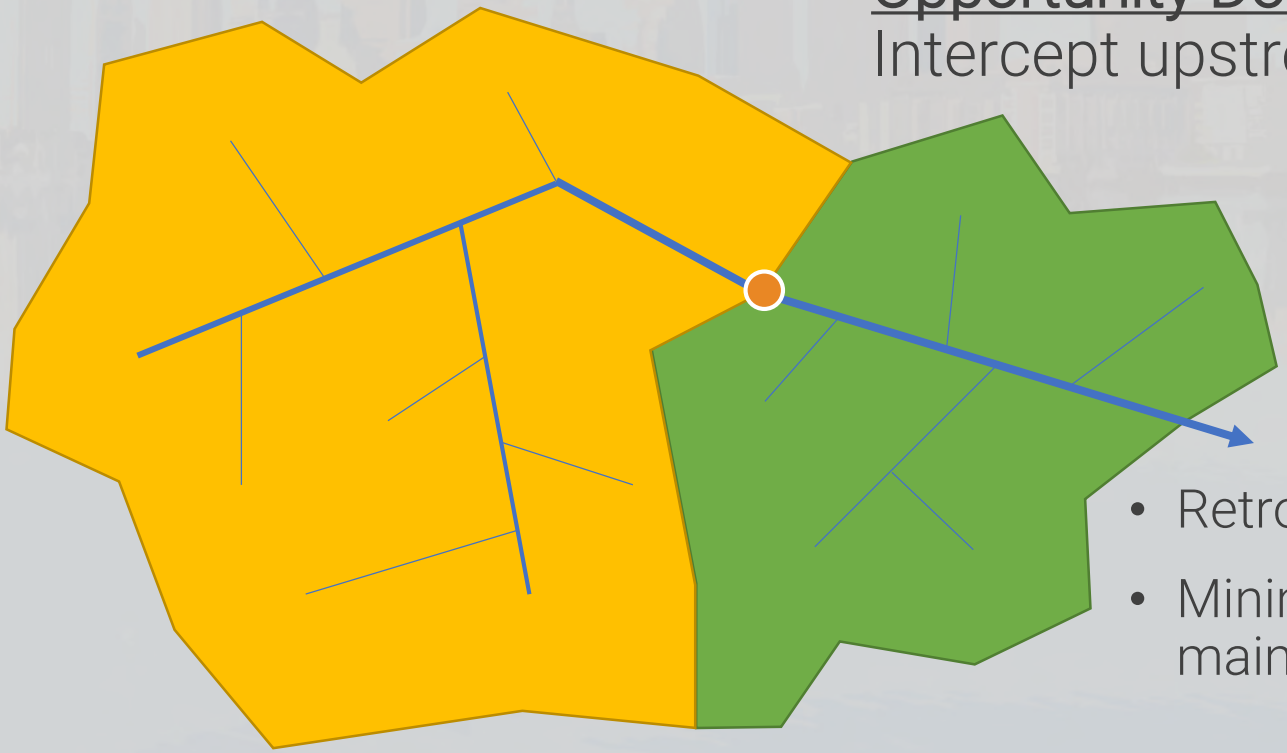
Concept of "First Flush"

- Pollutant concentration varies over time

Unique BMP Application

<u>Existing Upstream Catchment Area</u>
Minimal TSS removal

<u>Opportunity Downstream</u>
Intercept upstream TSS



- Retroactive treatment
- Minimize downstream maintenance

Regulation of TSS and Sediment Removal

MassDEP Stormwater Management Standards

- 10 Stormwater Standards

Standard 4: Stormwater management systems shall be designed to remove 80% of the average annual post-construction load of Total Suspended Solids (TSS). This standard is met when:

a) Suitable practices for source control and pollution prevention are identified in a long-term pollution prevention plan, and thereafter are implemented and maintained;

b) Structural stormwater best management practices are sized to capture the required water quality volume as determined in accordance with the Massachusetts Stormwater Handbook; and

c) Pretreatment is provided in accordance with the Massachusetts Stormwater Handbook.

- Water Quality Volume (WQV) → MA Stormwater Handbook
- Proprietary BMP Evaluation Guidance → Vol. 2, Ch. 4

Sizing of Flow-Based Proprietary BMPs

MassDEP Standard Method to Convert Required Water Quality Volume to a Discharge Rate

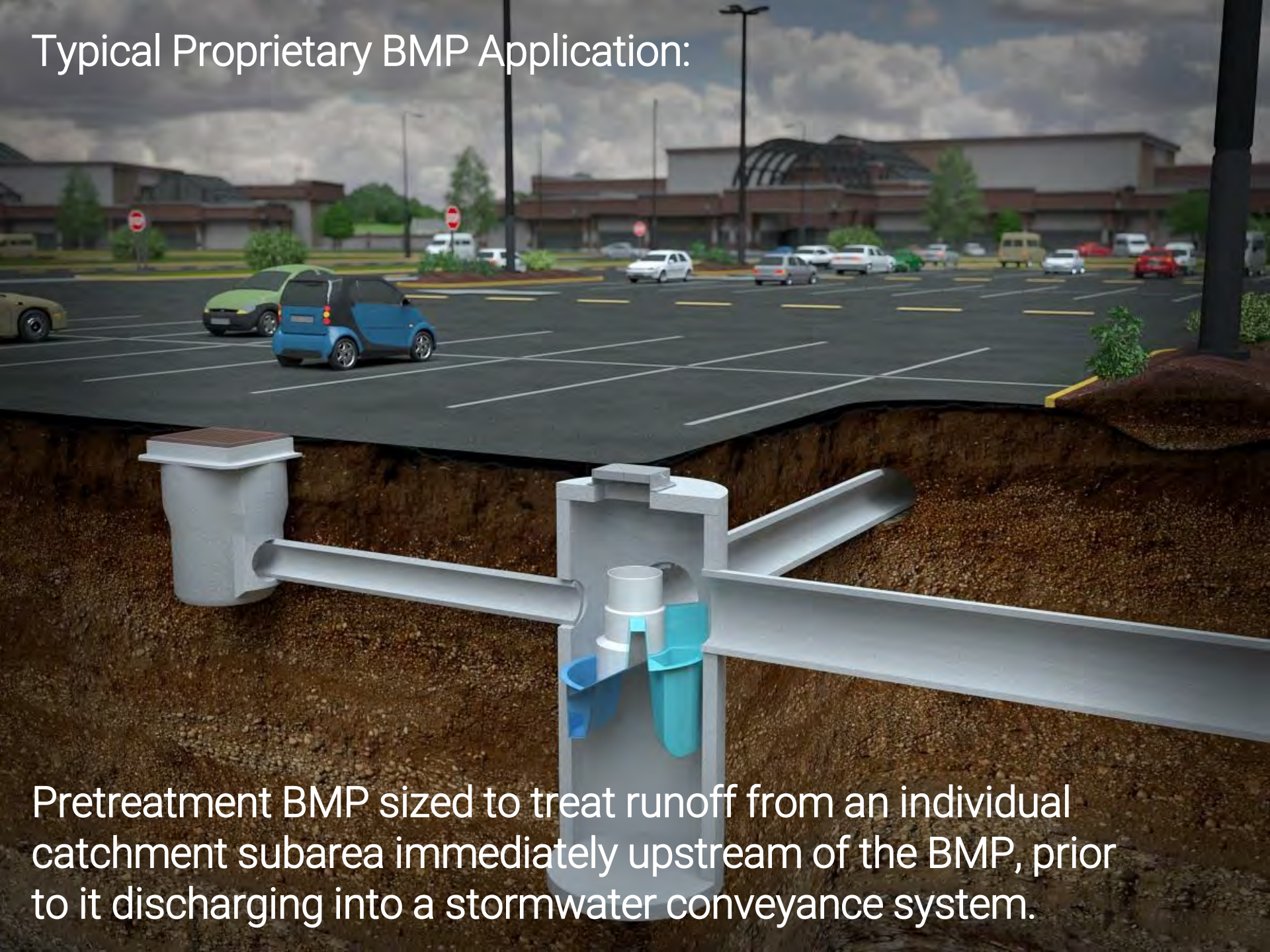
$$Q = (qu)(A)(WQV)$$

where:

Q	=	design discharge rate (cfs)
qu	=	unit peak discharge (cfs/mi^2.inches)
A	=	impervious surface drainage area (mi^2)
WQV	=	water quality volume (watershed inches)

…Intended for Typical Proprietary BMP Applications…

Typical Proprietary BMP Application:



Pretreatment BMP sized to treat runoff from an individual catchment subarea immediately upstream of the BMP, prior to it discharging into a stormwater conveyance system.

MassDEP Standard Method

$$Q = (qu)(A)(WQV)$$

Q = design discharge rate (cfs)

qu = unit peak discharge (cfs/mi^2.inches)

A = impervious surface drainage area (mi^2)

WQV = water quality volume (watershed inches)

MassDEP Standard Method

$$Q = (qu)(A)(WQV)$$

Q = design discharge rate (cfs)
qu = unit peak discharge (cfs/mi^2.inches)
A = impervious surface drainage area (mi^2)
WQV = water quality volume (watershed inches)

The required water quality volume equals 1.0 inch of runoff times the total impervious area of the post-development project site for a discharge

- from a land use with a higher potential pollutant load;
- within an area with a rapid infiltration rate (greater than 2.4 inches per hour);
- within a Zone II or Interim Wellhead Protection Area;
- near or to the following critical areas:
  - Outstanding Resource Waters,
  - Special Resource Waters,
  - bathing beaches,
  - shellfish growing areas,
  - cold-water fisheries.

OR

The required water quality volume equals 0.5 inches of runoff times the total impervious area of the post-development site for all other discharges.

MA Stormwater Handbook Vol. 1, Ch. 1

MassDEP Standard Method

$$Q = (qu)(A)(WQV)$$

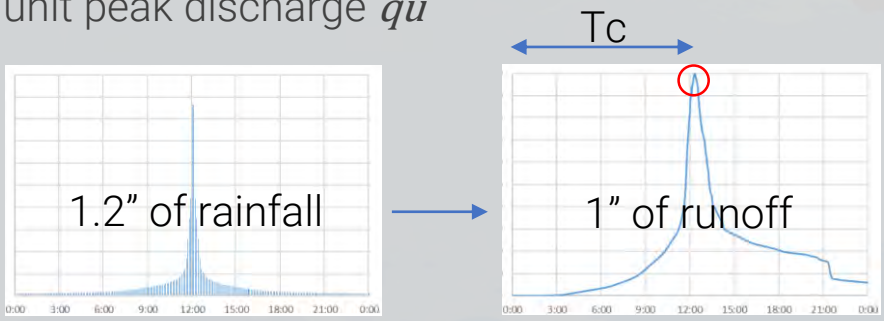
Q = design discharge rate (cfs)

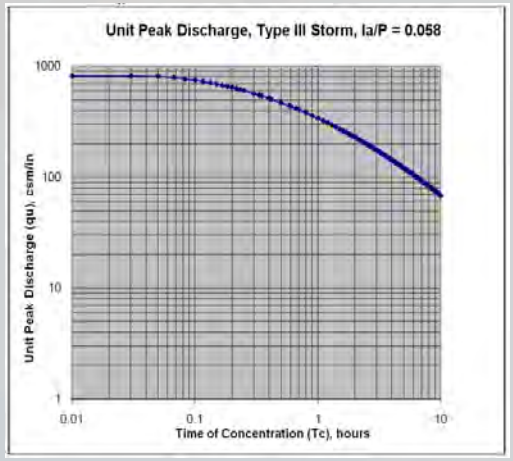
qu = unit peak discharge (cfs/mi^2.inches)

A = impervious surface drainage area (mi^2)

WQV = water quality volume (watershed inches)

- Assumes Curve Number (CN) 98 to represent runoff potential for impervious surfaces
- Compute Time of Concentration (Tc) based on TR-55
- Use MassDEP-derived Ia/P curves to determine unit peak discharge qu





MassDEP Standard Method

Fundamental Assumptions

- First flush passes through BMP immediately upon entering the drainage system
- No distinction between the hydrological time of concentration and the time it takes for the WQV to be conveyed to the BMP
- No additional inflow to BMP not associated with the WQV

Defines a static design flow rate based on first flush – not a direct assessment of the average annual TSS removal rate

Applicability of MassDEP Standard Method

Methodology and Use-Case Comparison

- First flush does not passes immediately through BMP
- Hydrological time of concentration is not equivalent to the time it takes for the WQV to be conveyed to the BMP
- Additional inflow, not associated with the WQV, will pass through BMP alongside WQV

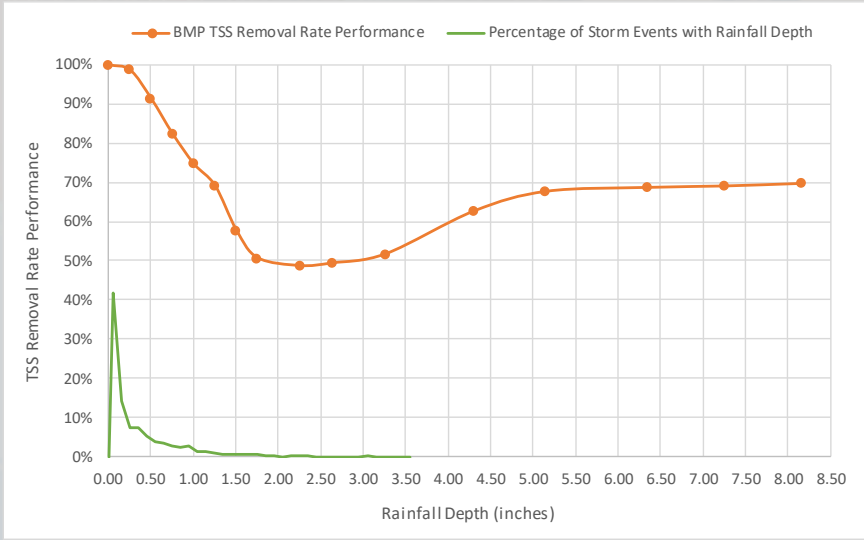
Standard Method Assumptions Are Not Valid for this Use-Case

Alternative Analysis Methodology

Overall Approach

Per MassDEP Standard 4, BMP performance is defined by the average annual TSS removal rate – not only the removal rate for an idealized first flush rainfall event:

1. Evaluate storm event removal rate performance for range of storms
   - ➢ Drainage model temporal analysis
2. Weight removal rates based on annual event frequency
3. Weight removal rates by proportion of WQV flushed by event



Rainfall

Storm Event Magnitude / Rainfall Depth
Over NRCS Type III Storm Distribution

Catchment Hydrology

TR-55 Curve Number and Time of Concentration

Runoff

Upstream Drainage Network Hydraulics

BMP Inflow Hydrograph

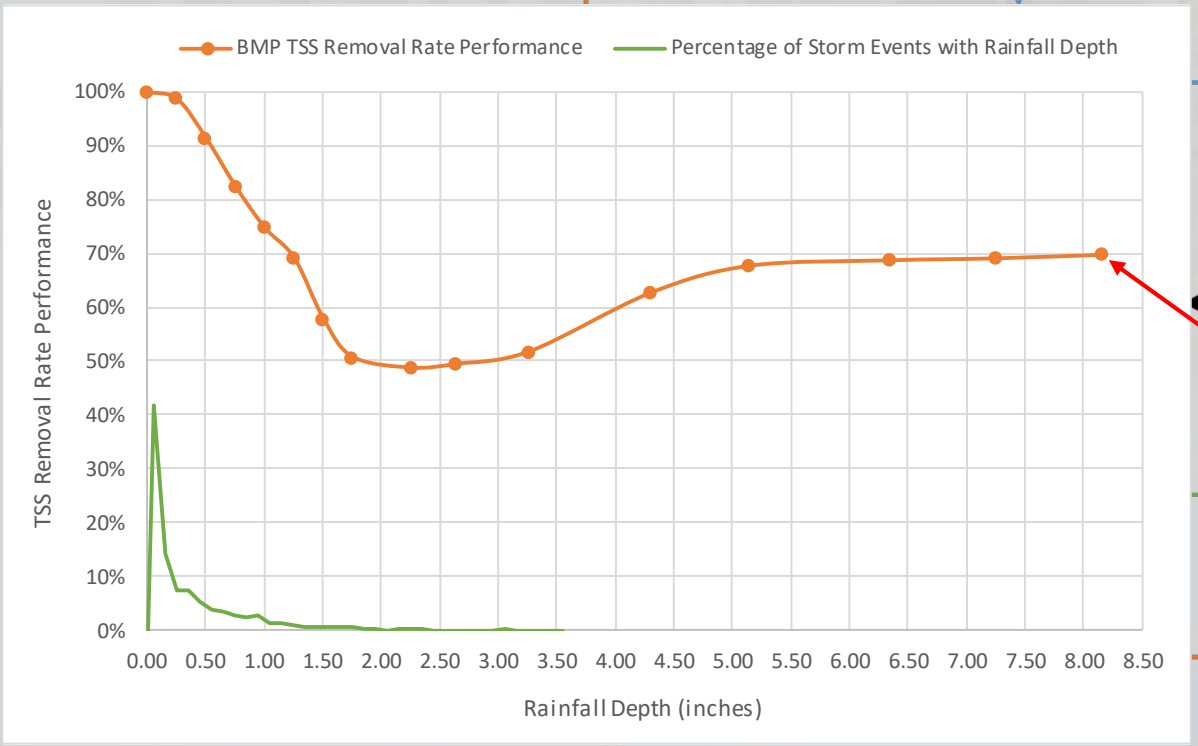
BMP Inlet Weir

Bypassed Flow

Treated Flow

Design TSS Removal Rate

Storm Event Removal Rate Performance



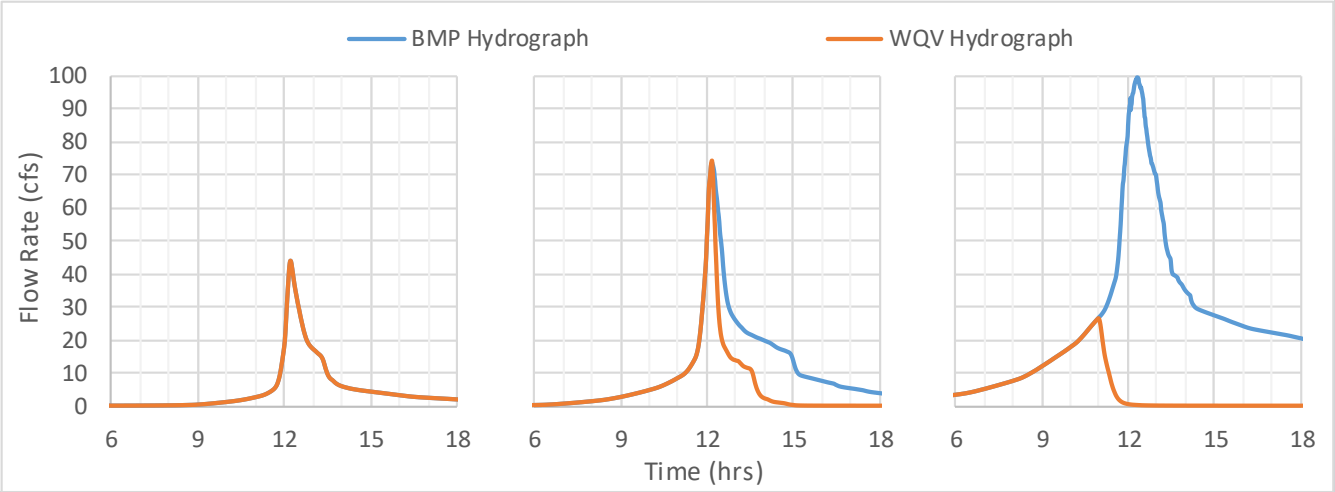
Rainfall ← Storm Event Magnitude / Rainfall Depth Over NRCS Type III Storm Distribution

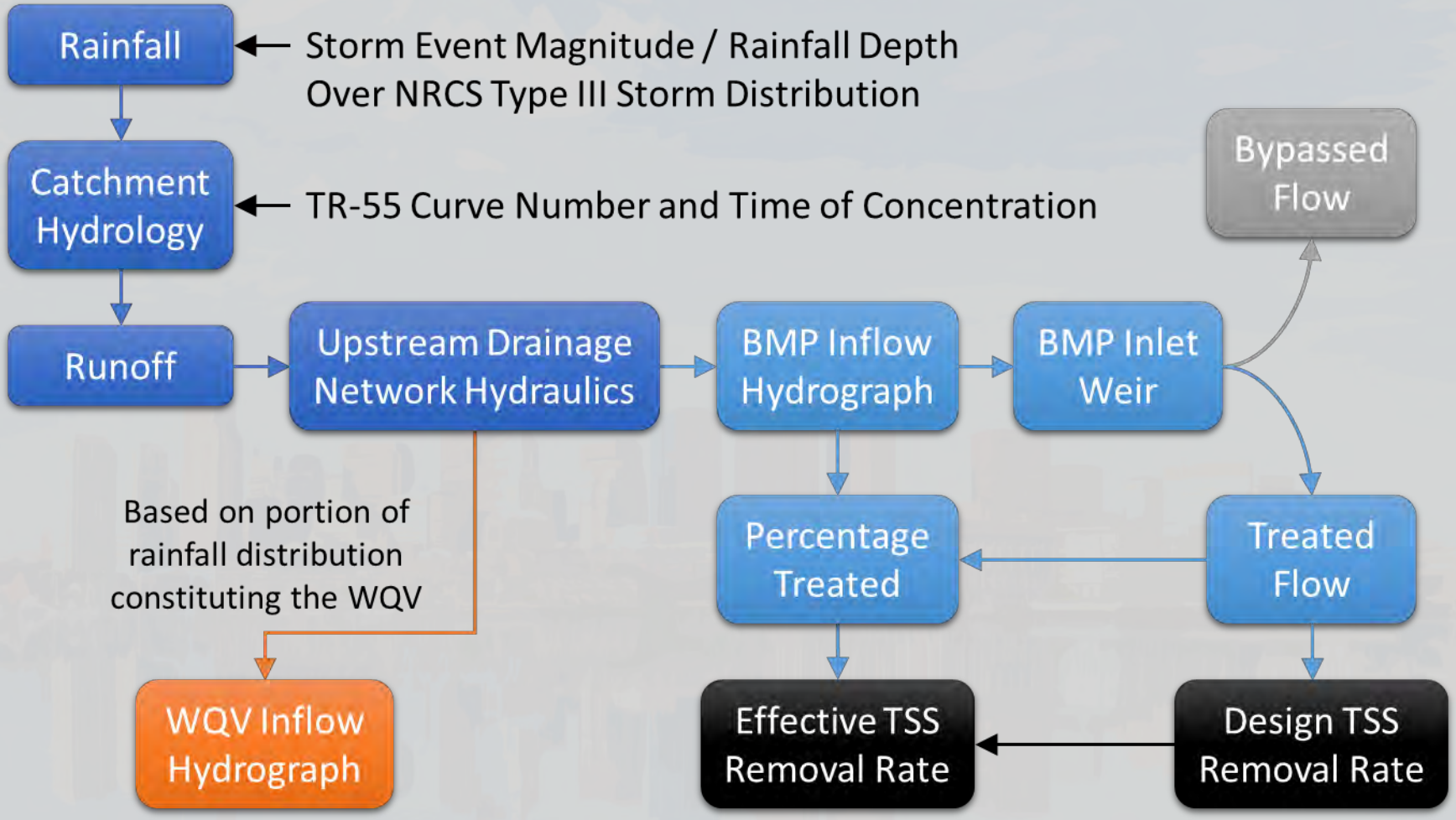
Catchment Hydrology ← TR-55 Curve Number and Time of Concentration

Runoff → Upstream Drainage Network Hydraulics → BMP Inflow Hydrograph

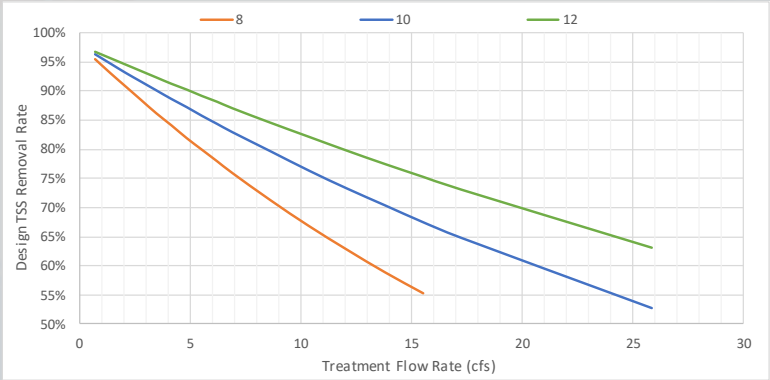
Based on portion of rainfall distribution constituting the WQV

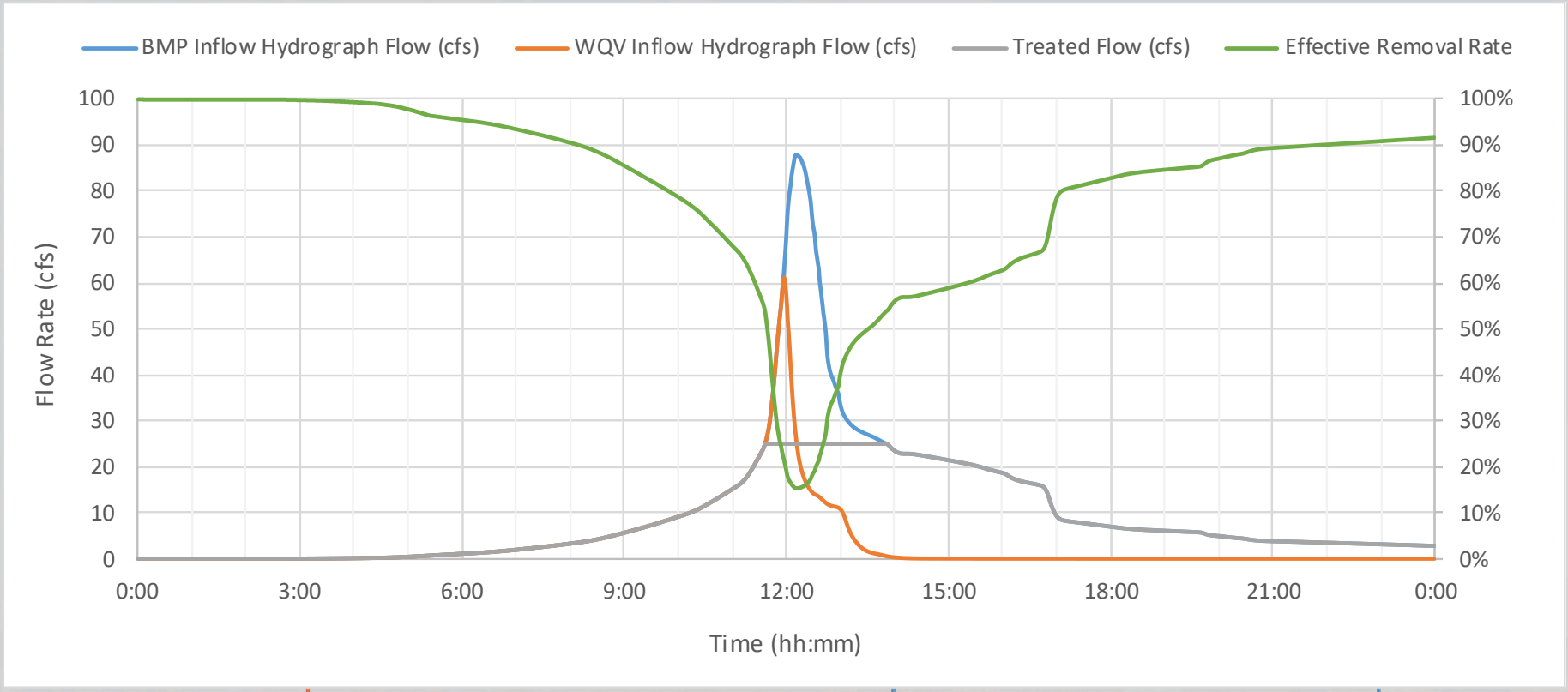
WQV Inflow Hydrograph

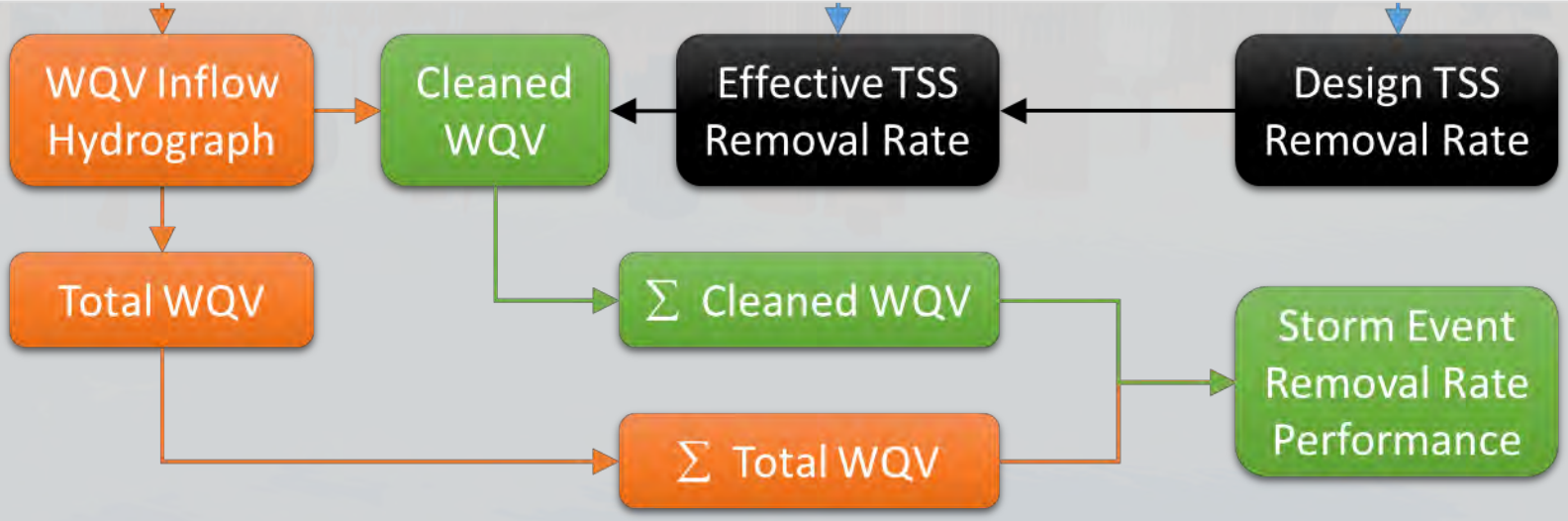


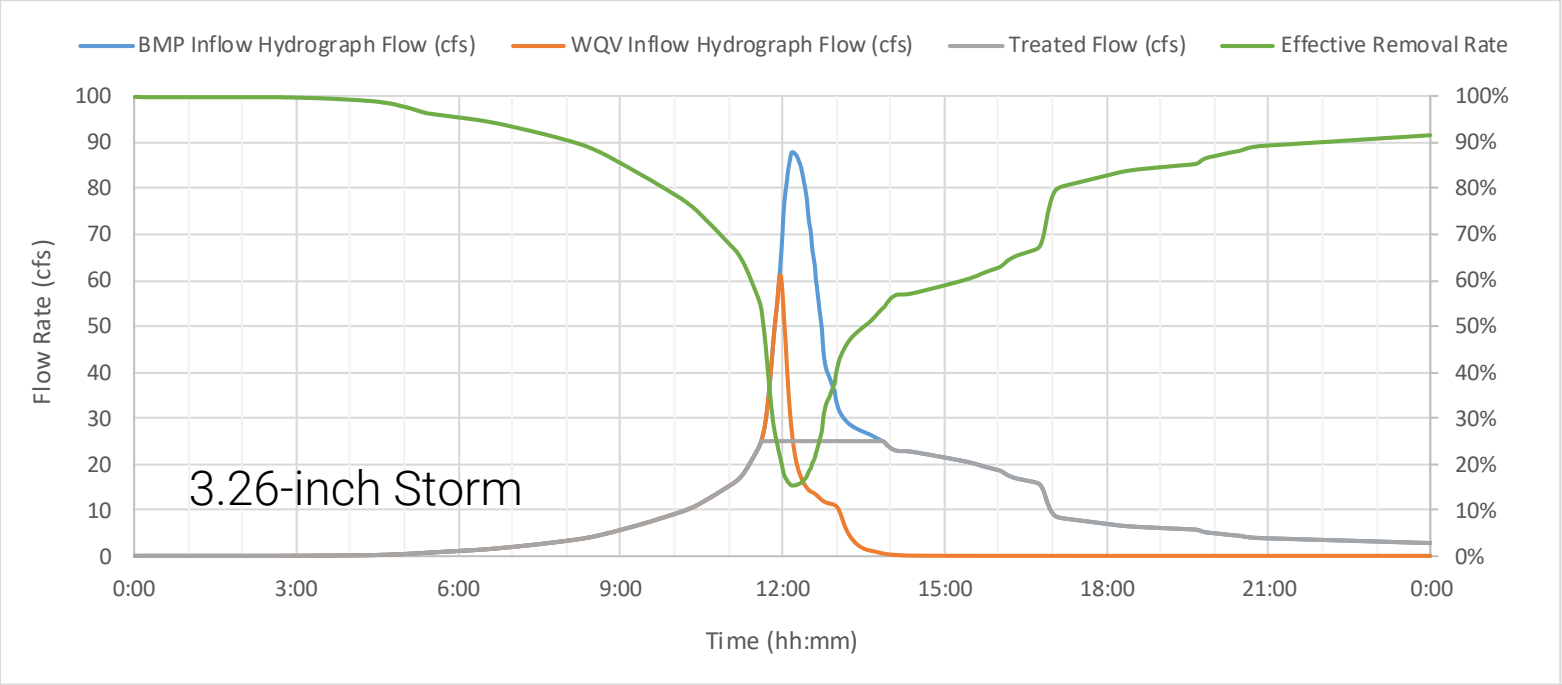


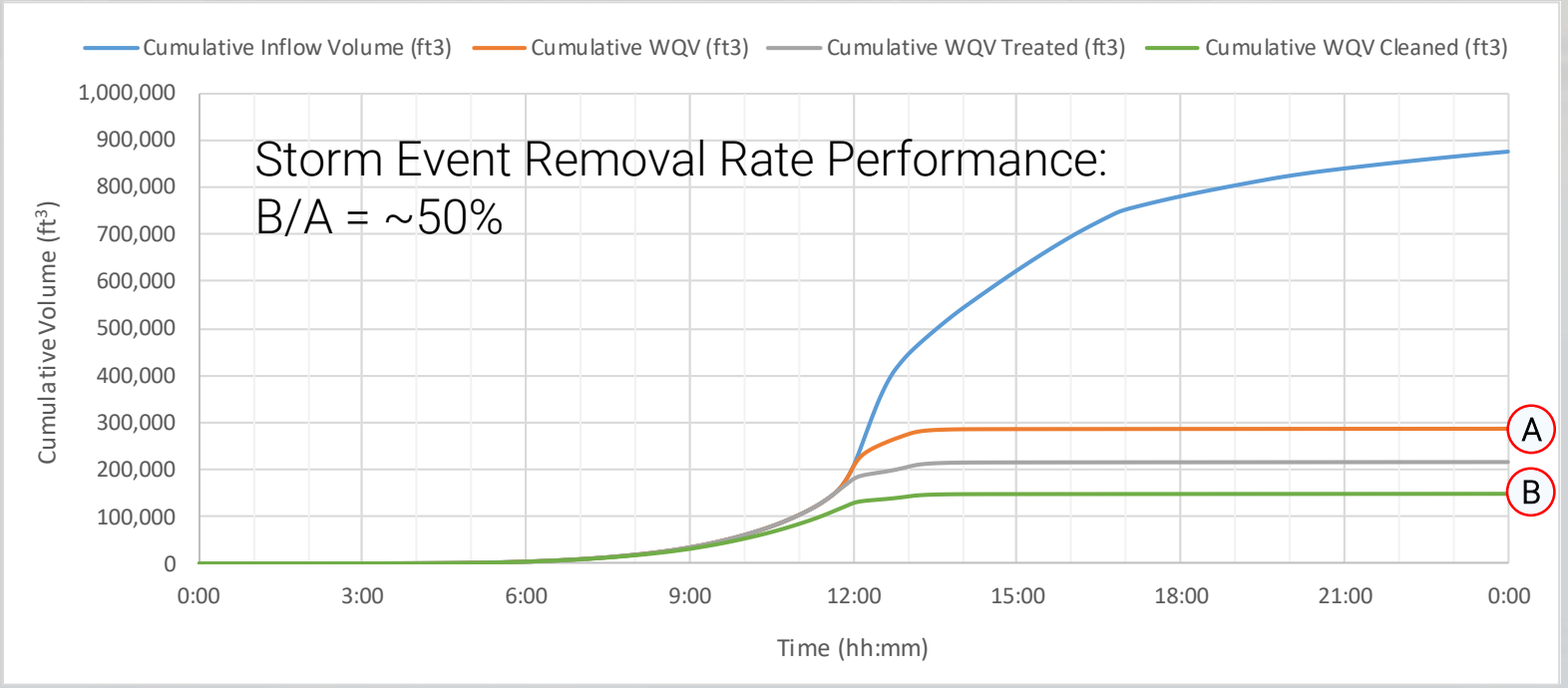
- Sediment Particle Size Distribution (PSD)
  - Uniform: OK-110, Broad: NJDEP PSD
- Target Particle Size for Removal
  - Pretreatment: Coarse Particles ~100µm
  - Terminal Treatment: Fine Particles ~50µm




BMP Inflow Hydrograph Flow (cfs)
WQV Inflow Hydrograph Flow (cfs)
Treated Flow (cfs)
Effective Removal Rate
Flow Rate (cfs)
100
90
80
70
60
50
40
30
20
10
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
0:00
Time (hh:mm)


WQV Inflow Hydrograph
Cleaned WQV
Effective TSS Removal Rate
Design TSS Removal Rate
Total WQV
∑ Cleaned WQV
Storm Event Removal Rate Performance
∑ Total WQV

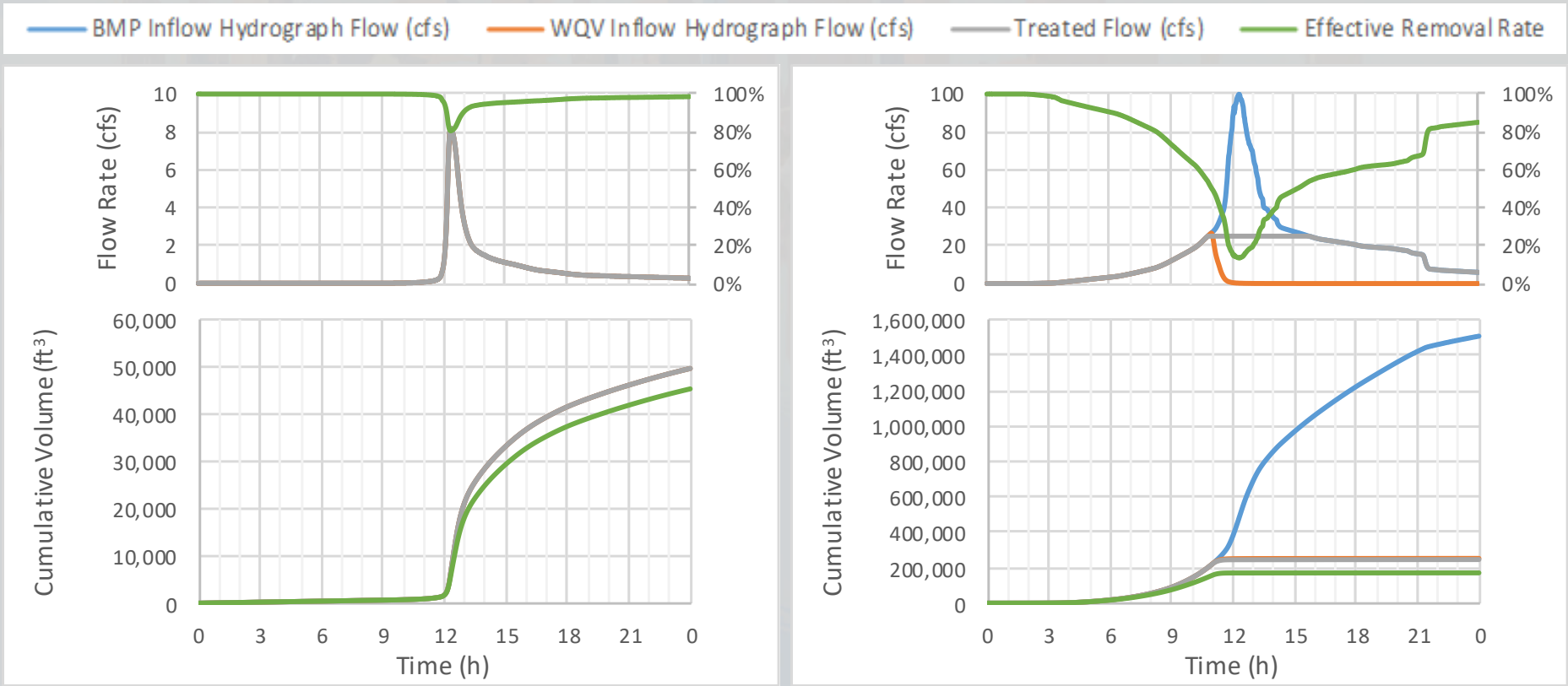

BMP Inflow Hydrograph Flow (cfs)
WQV Inflow Hydrograph Flow (cfs)
Treated Flow (cfs)
Effective Removal Rate
Flow Rate (cfs)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
100
90
80
70
60
50
40
30
20
10
0
3.26-inch Storm
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
0:00
Time (hh:mm)


Cumulative Inflow Volume (ft3)
Cumulative WQV (ft3)
Cumulative WQV Treated (ft3)
Cumulative WQV Cleaned (ft3)
Cumulative Volume (ft³)
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
Storm Event Removal Rate Performance:
B/A = ~50%
A
B
0:00
3:00
6:00
9:00
12:00
15:00
18:00
21:00
0:00
Time (hh:mm)

Temporal Analysis
Other Storm Examples

0.50-inch storm: ~90%

5.15-inch storm: ~70%



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← Storm Event Magnitude / Rainfall Depth Over NRCS Type III Storm Distribution

Catchment Hydrology

← TR-55 Curve Number and Time of Concentration

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BMP Inlet Weir

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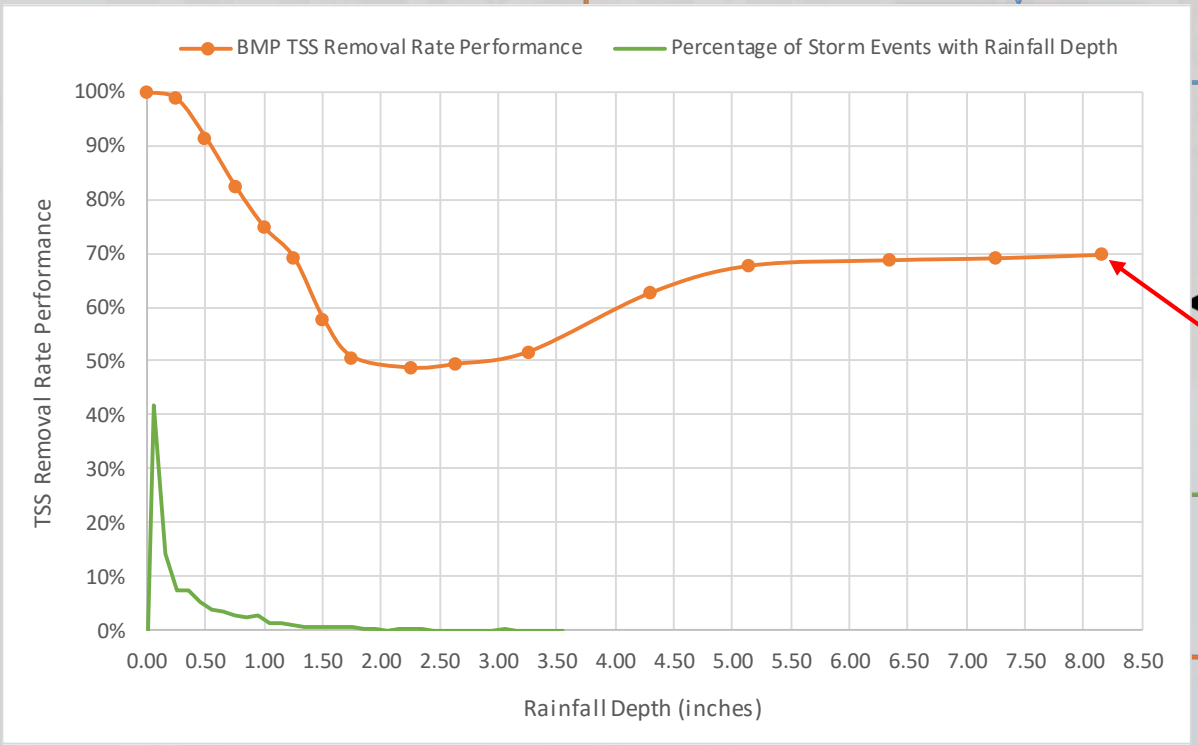
Design TSS Removal Rate



Storm Event Removal Rate Performance

Alternative Analysis Methodology

Limitations

- Requires Drainage Model
- Variability in Storm Event Duration and Rainfall Pattern
- Geospatial Differences in Rainfall Intensity
- Future Changes to Upstream Drainage System
- Climate Change Escalation of Historic Rainfall Data

Conclusions

- MA Stormwater Handbook provides guidance to size proprietary flow-based BMPs for typical applications, but the underlying assumptions don't generalize more broadly
- The proposed alternative methodology:
  - Requires a drainage model to undertake but offers advantages over the Standard Methodology for unique applications where the assumptions of the Standard Methodology are not valid
  - Is suitable for analyzing the long-term performance of and sizing proprietary BMPs for TSS removal, consistent with regulatory requirements enforced by MassDEP

Thank You

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