Advanced Design Workshops

Stormwater Basics: Quality vs. Quantity

Note: This course is available as online training on ELMS: https://learning.dot.ga.gov

Georgia DOT's Stormwater Management Program

Always check the current edition of the GDOT Drainage Design for Highways Manual for current policies.

This presentation shall not supersede any policies in the GDOT Drainage Design for Highways Manual (current edition) or any other GDOT policy publications.

Why Are We Here?

…to discuss **Post-Construction Stormwater Quantity and Quality**:

- How are they different?
- How are they related?
- Why are they both important for GDOT projects?

Points of Discussion

Stormwater Quantity and Quality

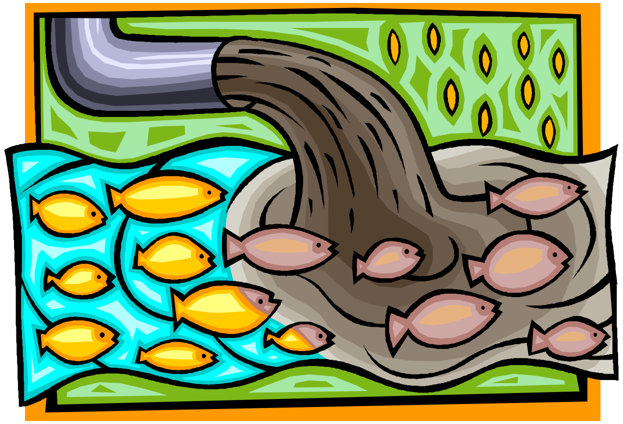
- Definition and Importance
- Predominant Stormwater Management Issues
- Current Requirements/Minimum Standards
- GDOT-Specific Stormwater Requirements
- Strategies for Successful GDOT MS4 Compliance

Definition and Importance

Stormwater **Quantity**: How much?

Stormwater **Quality**: How clean?

Quality** is directly related to **Quantity



Predominant Stormwater Issues

- **Point/Non-Point Source Discharges**
- Impaired Waters/TMDL
- Hydrologic Conditions/Effects of Urbanization
- Stream Degradation
- Flooding
- Threatened and Endangered Species

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- Point/Non-Point Source Discharges
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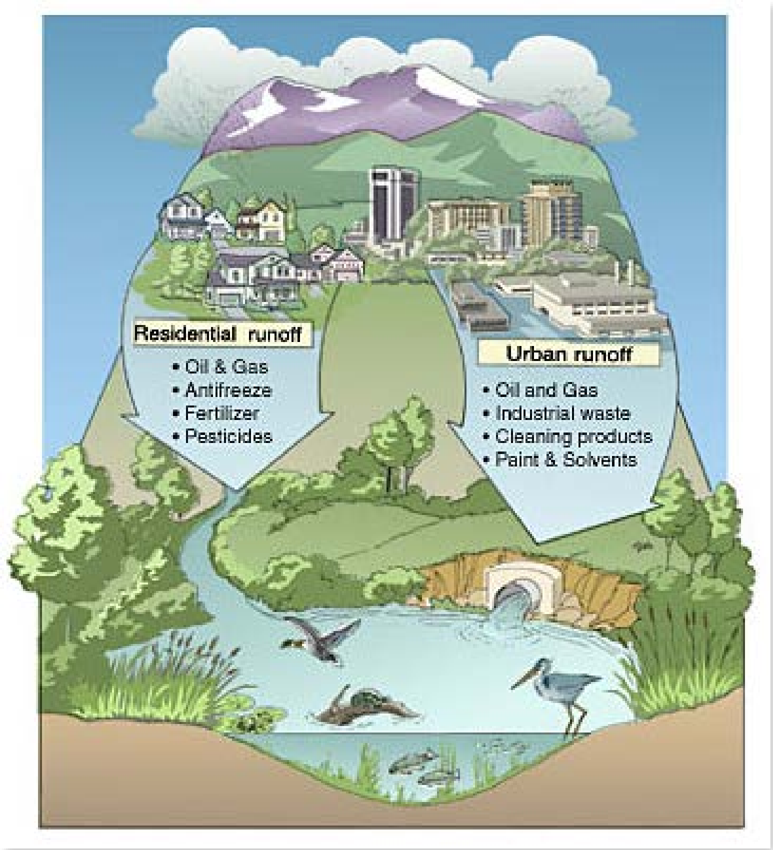
- Stream Degradation
- Flooding
- **Threatened and Endangered Species**

Stormwater Quality

How Does Stormwater Affect Water Quality?

- Pollutants are carried by stormwater when it rains…
- Stormwater flows directly to nearby waterways…
- **Pollution occurs in our streams, rivers and oceans!**



How Does Stormwater Affect Water Quality?

There are two types of discharges from an MS4:

- **Point Sources**: Concentrated flows usually from pipe or channel
- **Non-Point Sources**: Discharges are broad based, overland flows

Impaired Waters

- Each receiving water has a designated use.
  - *Fishing*
  - *Recreation*
  - *Drinking*

- EPD assigns each water body assessed one of the following categories:
  - *Supporting designated use*
  - *assessment pending additional data*
  - *not supporting designated use (or impaired)*

- Water that does not meet its designated use is considered **impaired**.

Why is this Important?

- 2.5% of earth’s water is freshwater (Source: USGS)
- < 1% earth’s freshwater is potable

Georgia rivers & streams

Total Maximum Daily Load (TMDL)

- TMDLs quantify the maximum pollutant load a water can handle and still meet designated use
- TMDL Implementation Plans establish procedures/activities to bring water back into compliance with designated use

$$TMDL = \sum WLA + \sum LA + MOS$$

WLA = Point Source Waste Load Allocation

LA = Nonpoint source Waste Load Allocation

MOS = Margin of Safety

***Note**: GDOT does not currently have WLA requirements, but this could change in the future.*

Impaired Waters

How do I know if my project affects impaired waters?

– GDOT TMDL tool (MicroStation format) http://www.dot.ga.gov/PS/DesignManuals/DesignGuides

Roadway

Title	Revised	Contact
Category : Construction Stormwater (Erosion Control)		
Category : Design Policy		
Category : Drainage		
Category : Fish Passage		
Category : Stormwater Permit (MS4) & Special Design Post-Construction Details		
Chief Engineer - Letter 01-20-12	1/20/2012	Brad McManus
Georgia's MS4 Areas Map		Brad McManus
MS4 Concept Level Design Spreadsheet	3/9/2016	Brad McManus
MS4 Concept Report Summary	12/30/2016	Brad McManus
MS4 Post-Letting PDP Process	7/12/2017	Brad McManus
MS4 Preconstruction PDP Process	3/8/2017	Brad McManus
Post-Construction Stormwater Report Attachment B	12/30/2016	Brad McManus
Post-Construction Stormwater Report Help File	12/30/2016	Brad McManus
Post-Construction Stormwater Report Template	12/30/2016	Brad McManus
Special Design Post-Construction Details	8/2/2017	Brad McManus
TMDL stream locator and Drainage structure inventory map service	3/11/2016	Brad McManus
Worksheet J-1_Phase 1 Screening Assessment of Stormwater Infiltration	12/30/2016	Brad McManus

Impaired Waters

How do I know if my project affects impaired waters?

- EPD 305(b)/303(d) (impaired waters) list & GIS shapefile:

  http://epd.georgia.gov/georgia-305b303d-list-documents

  http://epd.georgia.gov/geographic-information-systems-gis-databases-and-documentation

- Google Earth (.KMZ file format)

Imp

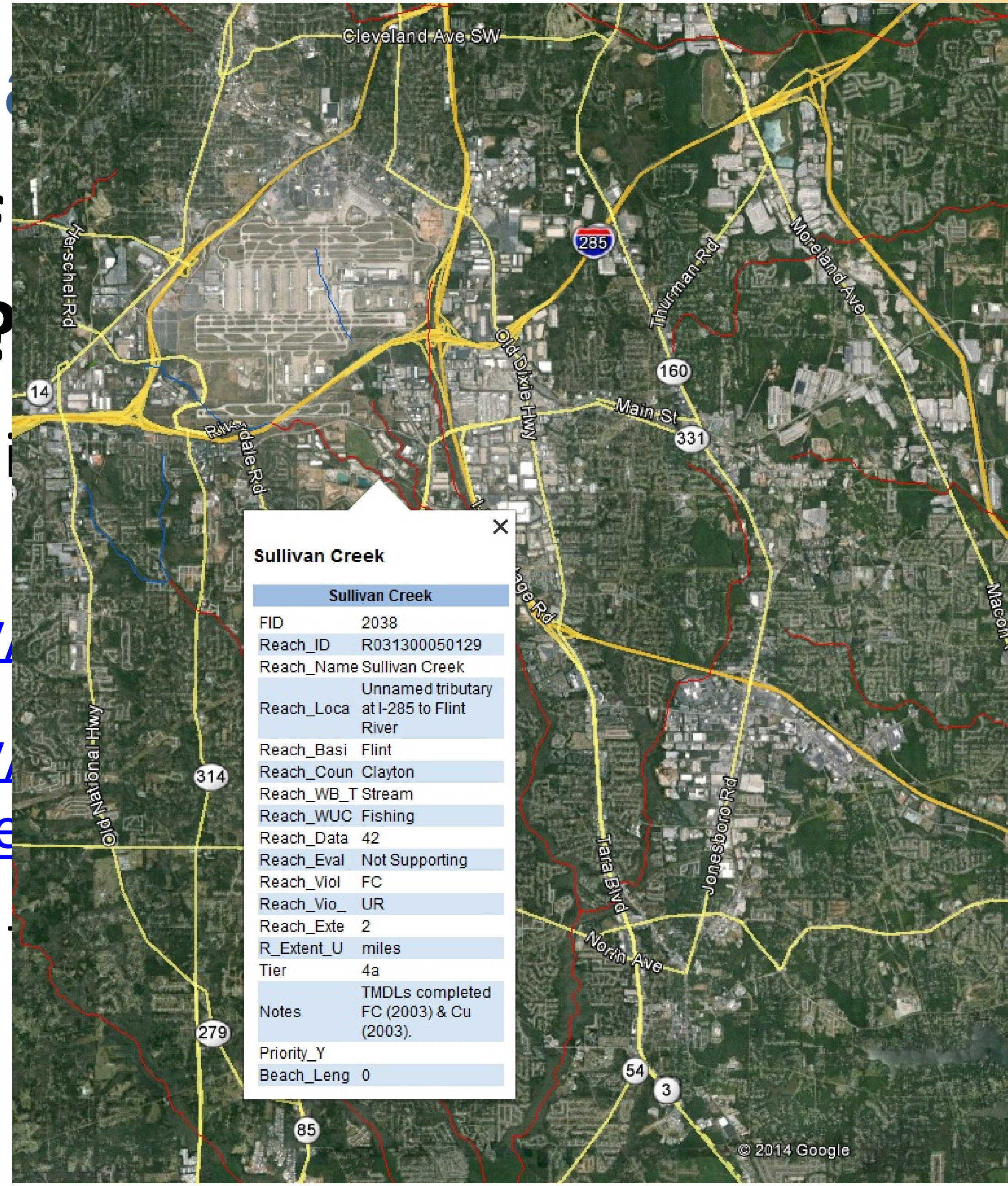
How do I know if impaired waters?

- EPD 305(b)/303(d) (i shapefile:

http://epd.georgia.gov/

[http://epd.georgia.gov/ databases-and-docume](http://epd.georgia.gov/)

- Google Earth (.KMZ



Stormwater Quantity

Stormwater Quantity Control

- Factors that affect the amount of runoff:
  - Precipitation
  - Soils
  - Land use *(impervious area, vegetation, etc.)*
- What designers can control with detention:
  - Peak Flow Rate
  - Flow Velocity

Stormwater Quantity Issues

Increasing impervious surfaces cause higher runoff volume leading to:

- Habitat and property loss

Source: GSWCC

Stormwater Quantity Issues

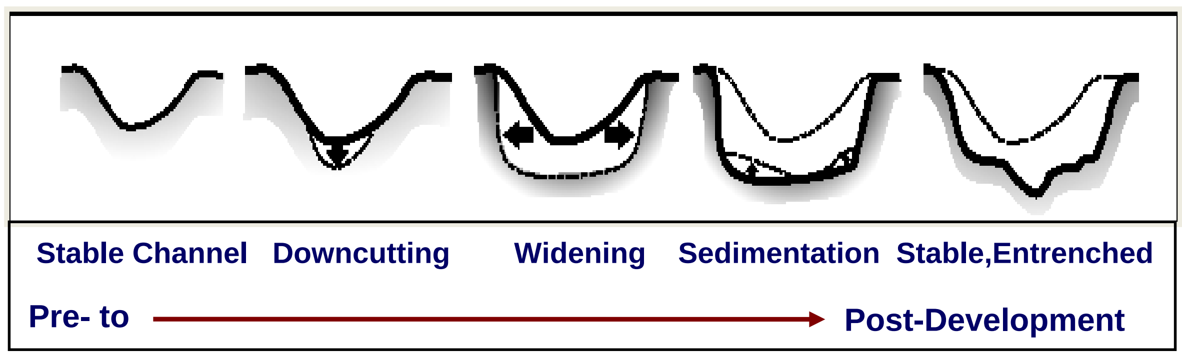
Increasing impervious surfaces cause higher runoff volume leading to:

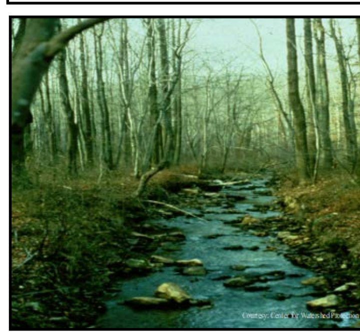
- Habitat and property loss
- Exposed or undermined utilities

Stormwater Quantity Issues

Increasing impervious surfaces cause higher runoff volume leading to:

- Habitat and property loss
- Exposed or undermined utilities
- Streambank erosion





Source: All Images from GSWCC

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Stormwater Quantity Issues

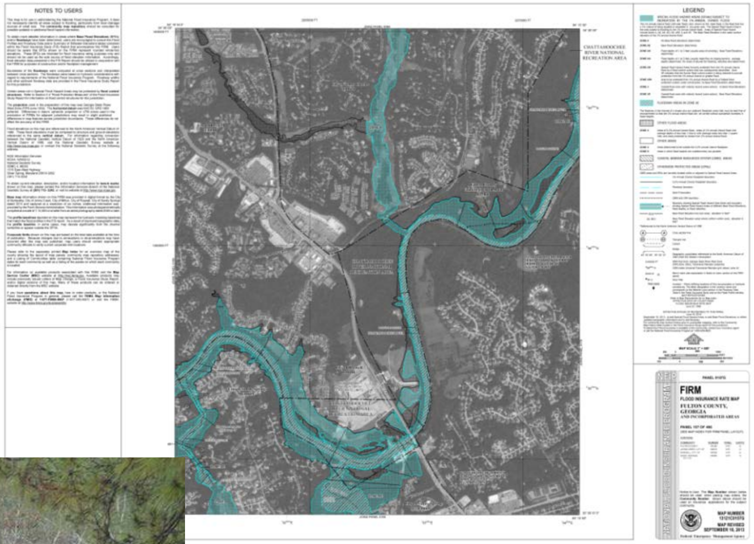
Increasing impervious surfaces cause higher runoff volume leading to:

- Habitat and property loss
- Exposed or undermined utilities
- Channel degradation
- Increased pollutants

Stormwater Quantity Issues

Increasing impervious surfaces cause higher runoff volume leading to:

- Increased Flooding



Stormwater Quantity Issues

Increasing impervious surfaces cause higher runoff volume leading to:

- Increased Flooding
- Infrastructure and property damage

Stormwater Quantity Issues

Increasing impervious surfaces cause higher runoff volume leading to:

- Increased Flooding
- Infrastructure and property damage

A washed out bridge is shown Monday, Sept. 21, 2009 in Douglasville, Ga. Heavy rain caused flooding in and around the Atlanta area. (AP Photo/John Bazemore)

Stormwater Quantity Issues

Increasing impervious surfaces cause higher runoff volume leading to:

- Increased Flooding
- Infrastructure and property damage

Tributary to Snake Creek, near Whitesburg, Georgia, showing a washed out bridge. Heavy rain caused flooding in and around the Atlanta area. (Photo from USGS)

Post-Construction Stormwater

Water quality and quantity concerns led to stormwater policy and permit requirements (MS4):

- GDOT policy requires analysis to determine if stormwater detention is required to mitigate peak flow increases <u>for all projects</u>

- MS4 permit requires analysis to determine if post-construction water quality measures and detention are needed <u>in MS4 areas</u>

GDOT's MS4 Permit

Minimum Control Measures

Public Education and Outreach on Stormwater Impacts	Public Involvement / Participation	Illicit Discharge Detection and Elimination (IDDE)
Construction Site Stormwater Runoff Control	**Post-Construction Stormwater Management**	Pollution Prevention/Good Housekeeping for Municipal type Operations

GDOT's MS4 Permit

- 5-year terms: (Jan 2012 – Jan 2017) (Jan 2017 – Jan 2022)
- Permit goals and requirements for the 6 Minimum Control Measures (MCMs) each permit year
- Annual reports ensure MCM goals are met
- Future permit cycles could become more stringent (2022-2027)….
- Goal is to protect the quality of Georgia's waters

GDOT's MS4 Permit

Green Infrastructure/Low Impact Development BMPs	1st Permit Term					2nd Permit Term…		
	2012	2013	2014	2015	2016	2017	2018	2019…
Develop a program for conducting a low impact development (LID) / green infrastructure (GI) feasibility study, and implementing low impact developments/green infrastructure where feasible.		X						
Develop the program, including a checklist of possible green infrastructure practices to be considered during the design phase. Submit the proposed program to EPD for review and approval.		X						
Submit a copy of the completed checklist to EPD with each set of plans. The checklist must show which LID/GI practices are included in the project and must detail why each listed practice was not considered feasible for the project.			X	X	X	X	X	X
Track the type and number of each LID/GI practice incorporated into each set of plans.			X	X	X	X	X	X
Inspect and maintain the GI/LID structures. Provide documentation of inspections conducted and maintenance performed during the reporting period in each annual report.						X	X	X

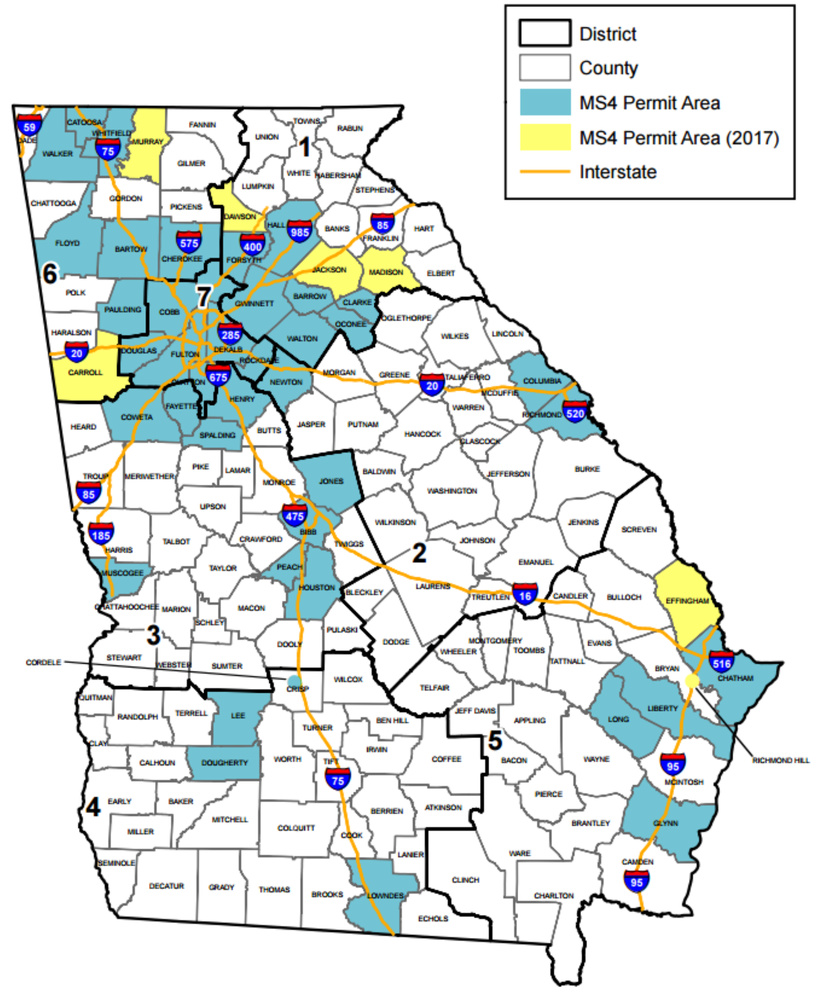
GDOT's MS4 Permit

GDOT's MS4 Post-Construction Requirements apply in areas designated by EPD as MS4 (Phase I and Phase II) to:

- Linear roadway projects disturbing ≥ 1 acre

  OR

- Site development projects adding ≥ 5,000 square feet of impervious area



MS4 Areas in 2012 Permit

One year to phase in the 2017 post-construction stormwater requirements

If one of the following occurs by January 2, 2018, you must comply with the post-construction stormwater requirements in the 2012 permit.

- Received Environmental Approval (Georgia Environmental Policy Act Notice of Decision or National Environmental Policy Act Record of Decision

OR

- Submitted right-of-way plans for GDOT review and approval

OR

- Received concept approval (start of preliminary engineering)

New MS4 Areas in 2017 Permit

One year to phase in the 2017 post-construction stormwater requirements

Project receives concept approval on or before January 2, 2018

EXEMPT

Post-Construction Stormwater

Stormwater post-construction BMPs can be utilized to provide both quantity and quality control. Remember…

- Stormwater ***quantity*** (detention) control requirements apply to **all** GDOT projects
- Stormwater ***quality*** requirements apply to projects located **within an MS4 area** or for specific environmental considerations

How Do We Improve Stormwater Quality?

We can <u>treat</u> stormwater with BMPs:

90% of stormwater pollutants are carried in the first 1/2" of rainfall, often called "first flush" (Source: EPA)

BMPs can improve stormwater runoff quality by:

- Treating runoff to remove pollutants
- Providing quantity control in some cases

Enhanced Dry Swale

How Do We Control Stormwater Quantity?

Peak flow rates for a drainage basin increase once it has been disturbed or developed

BMPs can control stormwater quantity by:

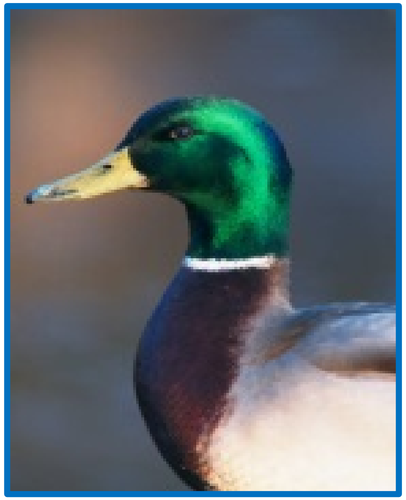
- Attenuating post-project peak flows
- Controlling discharge velocities

Post-Construction Stormwater
Other Considerations

Are post-construction BMPs ever required outside of an MS4 area?

- *Special environmental concerns may require water quality and quantity management for protection of water and natural resources.*





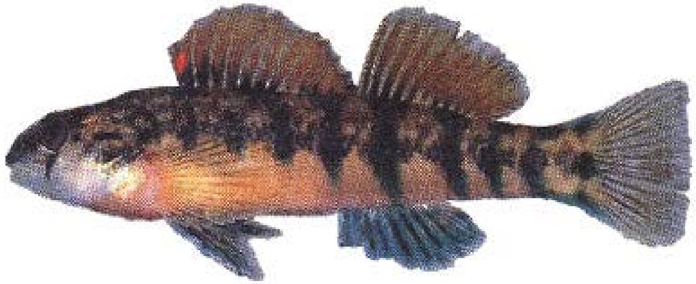
Post-Construction Stormwater
Other Considerations

Special Environmental Requirements…

Some watersheds have specific requirements from

- *Georgia EPD Stream Buffer Rules*
- *Army Corps of Engineers*
- *US Fish and Wildlife*

These requirements are often due to specific impairments or Threatened and Endangered (T&E) species native to that area



Post-Construction Stormwater
Other Considerations

Non-MS4 Project Locations with Potential Special Environmental Considerations:

Lake Lanier – Nutrient Concern (increased algae population) and TMDL

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Post-Construction Stormwater
Other Considerations

Non-MS4 Project Locations with Potential Special Environmental Considerations:

Lake Allatoona – Habitat Conservation Plan (HCP) and T&E species

When is PCS Management Required?

What if my project is not in an MS4 area and has no specific environmental considerations?

- Stormwater ***quality*** treatment is not required but quantity still needs to be evaluated
- Stormwater ***quantity*** should be controlled for no adverse impacts (downstream analysis)
  - Designer must ensure downstream system has adequate capacity

Tools to Mitigate Quality and Quantity Issues

- Stormwater Planning & Management
- Know the Requirements
- LID/GI
- Unified Sizing Criteria

Stormwater Planning & Management

Incorporating Stormwater Early in Design

- Once the project scope is defined, Conceptual Design **AND** Stormwater Design begin to:
  - Avoid potential redesigns of projects
  - Plan ahead for post-construction stormwater structures
  - Avoid project delays

Water Quality Requirements:
MS4 Permit Compliance – Is the project located in a MS4 area? ☐ No ☐ Yes

For projects within a designated MS4 (Municipal Separate Storm Sewer Systems) area, at a minimum, the conceptual project cost estimate (PE, ROW, UTIL, CST, ENV MIT, etc.) shall include preliminary, estimated costs related to MS4 post construction stormwater BMPs. In addition, the PLE Evaluation in the MS4 Concept Report Summary shall be attached to the report. If sufficient project information is known, the following items may be attached to the report at the discretion of the Project Engineer:

- *MS4 Concept Level Design Spreadsheet*
- *MS4 Drainage Area Layout*

These items can be found on the GDOT External Webpage under Partner Smart – Design Manuals – Manuals and Guides – Roadway – Category: Stormwater Permit (MS4). No other MS4 information shall be submitted at Concept. For more information regarding GDOT's MS4 permit, please contact the Hydraulic Studies Group in the Office of Design Policy & Support.

LID and GI

GDOT's MS4 permit requires the consideration of Low Impact Development (LID) and Green Infrastructure (GI) during design.

Low Impact Development (LID) , as defined by EPA, is

> *"A management approach and set of practices that can reduce runoff and pollutant loadings by managing runoff as close to its source(s) as possible."*

LID and GI

Common LID practices include…

- Avoiding environmentally sensitive areas
- Reducing project footprint
- Minimizing site impacts
- Adjusting the design with the terrain, while still providing a safe design

LID and GI

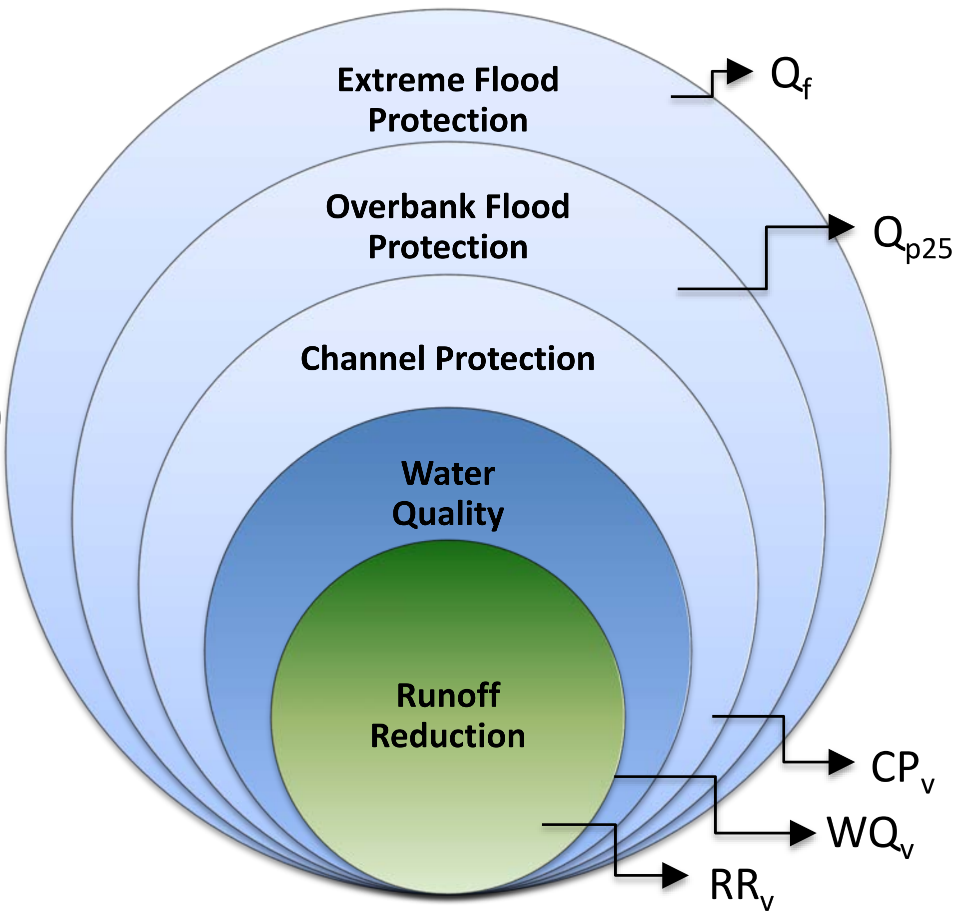
Green Infrastructure (GI), as defined by EPA, is

"An adaptable term used to describe an array of products, technologies, and practices that use natural systems – or engineered systems that mimic natural processes – to enhance overall environmental quality and provide utility services."

Unified Sizing Criteria

A set of five engineering-based criteria:

- Runoff Reduction (RR_v)
- Water Quality (WQ_v)
- Channel Protection (CP_v)
- Overbank Flood Protection (Q_{p25})
- Extreme Flood Protection (Q_f)



Runoff Reduction (RRv) is a new criteria that was added to GDOT's 2017 MS4 permit.

Unified Sizing Criteria

A set of five engineering-based criteria:

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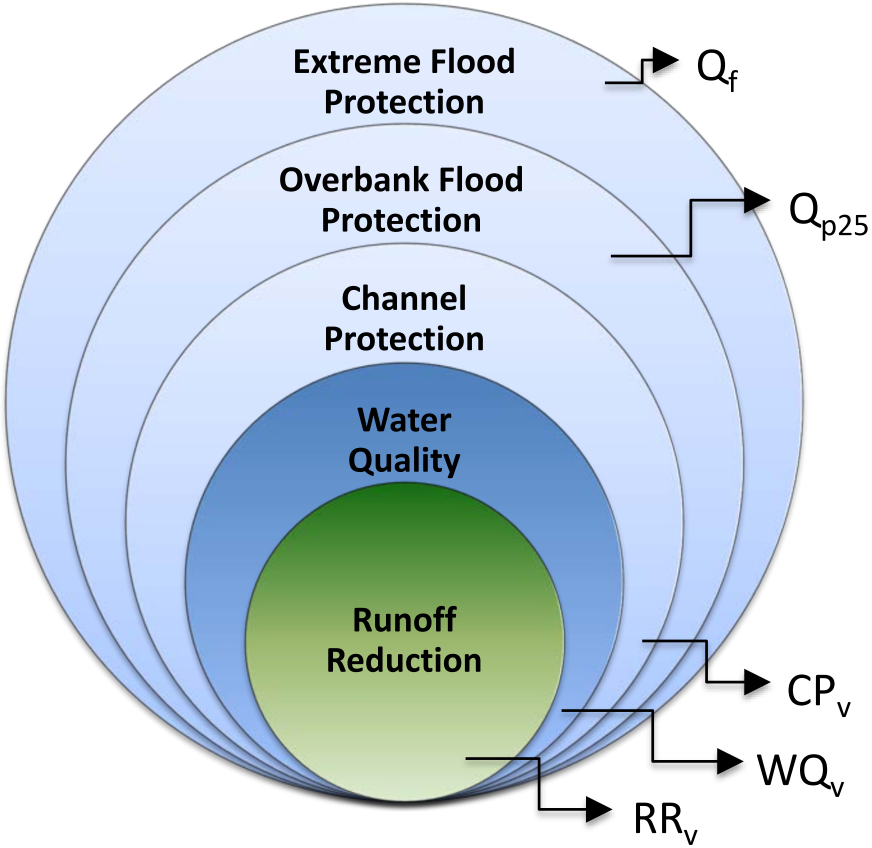


When applied together as a whole, provide:

- Quality Control
- Quantity Control

AND….

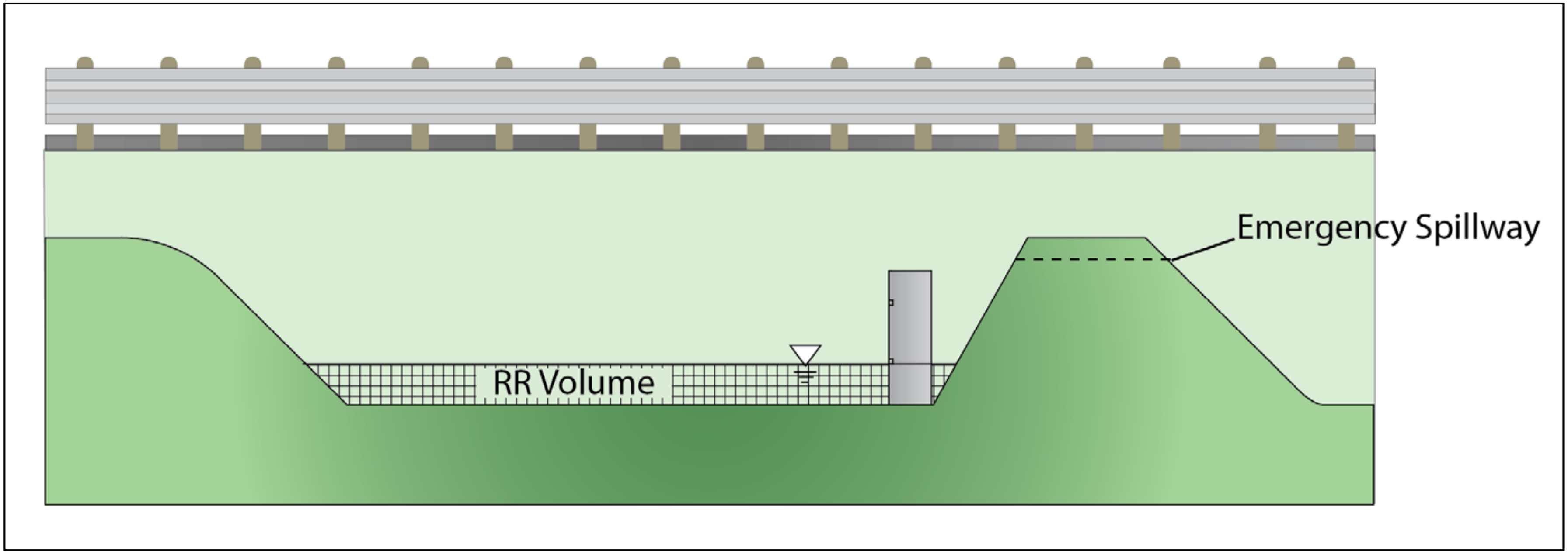
- Mitigation of Downstream Adverse Impacts

Unified Sizing Criteria

RR_v: Retain up to the first 1.0 inch of rainfall on the site

– Removes runoff along with the pollutants dissolved or suspended in it.

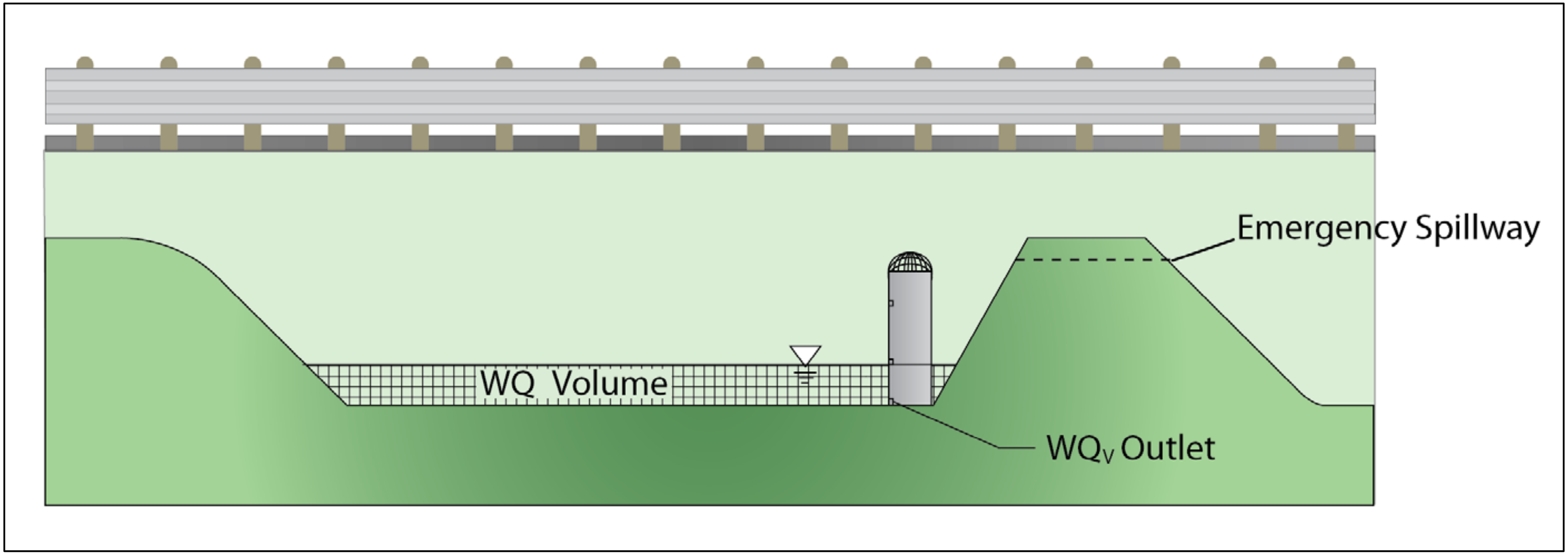
– If the 1.0 inch cannot be retained onsite the remaining runoff from a 1.2 inch rainfall event must be treated for water quality



Unified Sizing Criteria

WQ_v: Remove 80% of total suspended solids (TSS) from the runoff generated by a 1.2" rainfall event

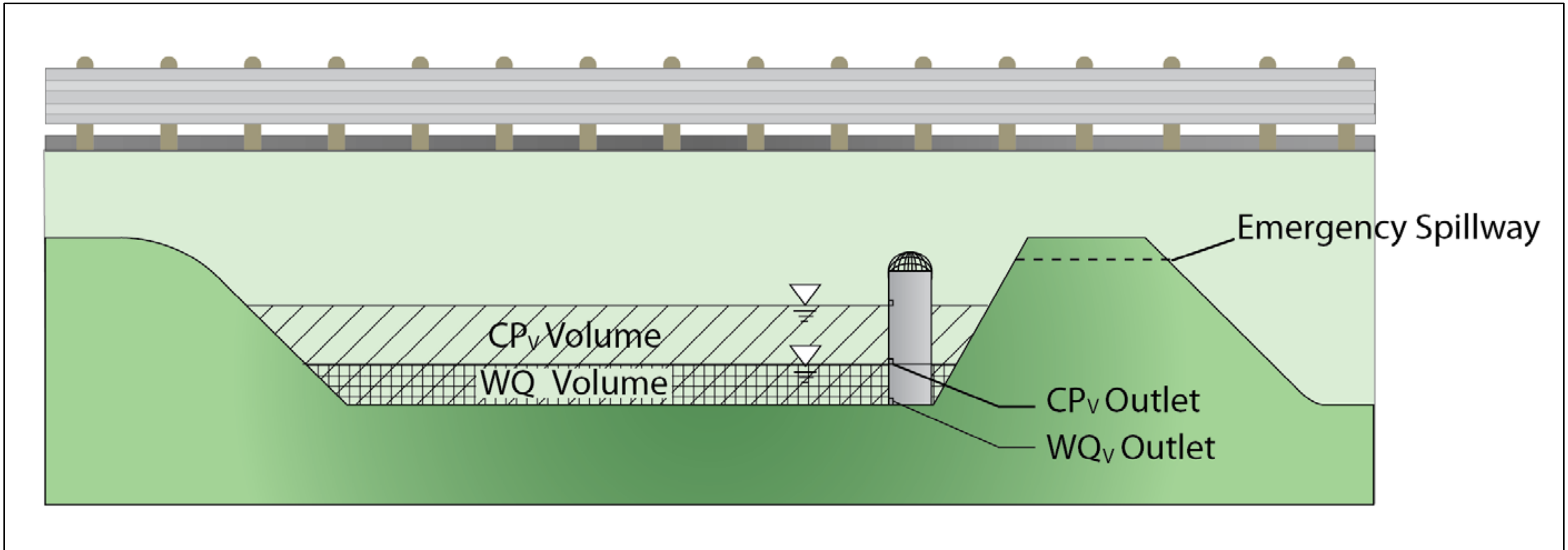
- 85th percentile storm
- Treats "first flush"
- Directly related to impervious cover of basin



Unified Sizing Criteria

CP_v: Detain the 1-year 24-hour storm event for 24 hours

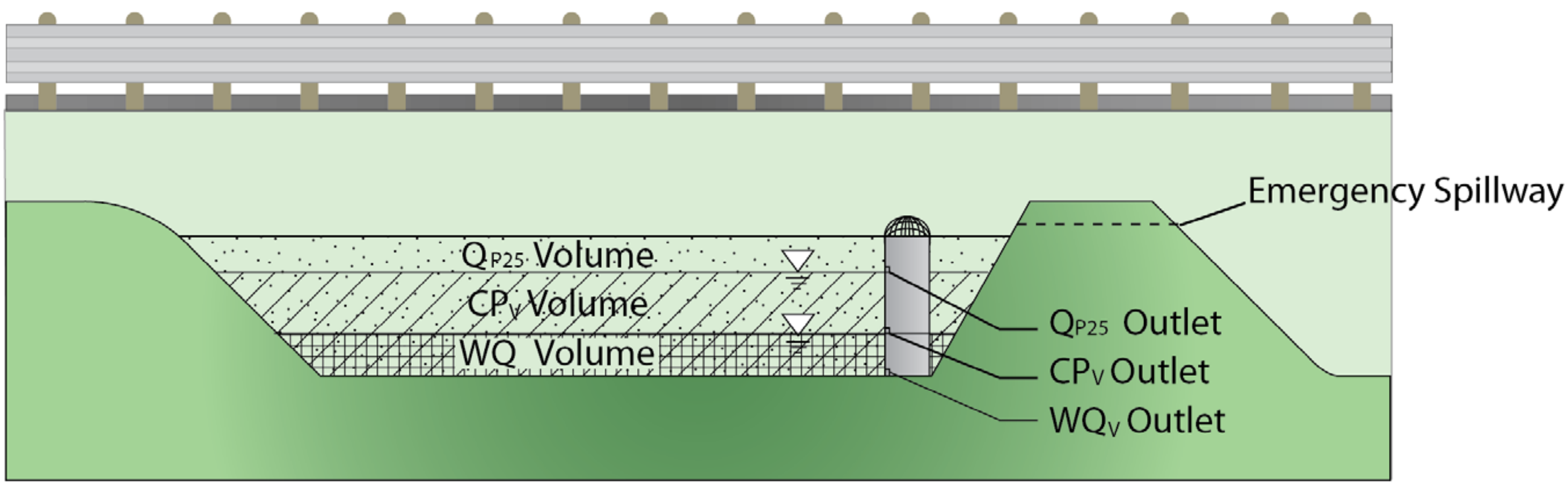
- Protects downstream channels
- Not required for post-development flows <2.0 cfs
- The extent of the WQ_v determines the invert elevation of the CP_v orifice



Unified Sizing Criteria

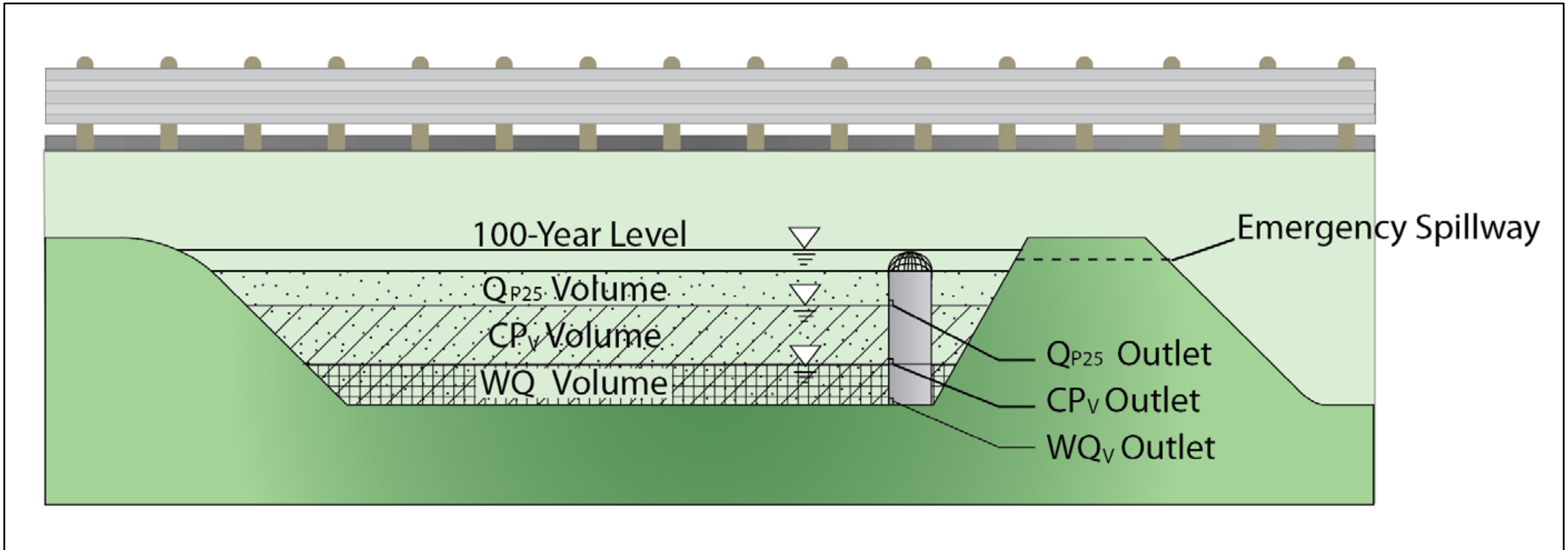
Q_{p25}: Detain for the 25-year 24-hour storm event (match post-developed flow rates with pre-developed)

- Larger storms partially controlled through control of Q_{p25} event
- The top of the CP_v volume determines the elevation of the subsequent Q_{p25} outlet(s)



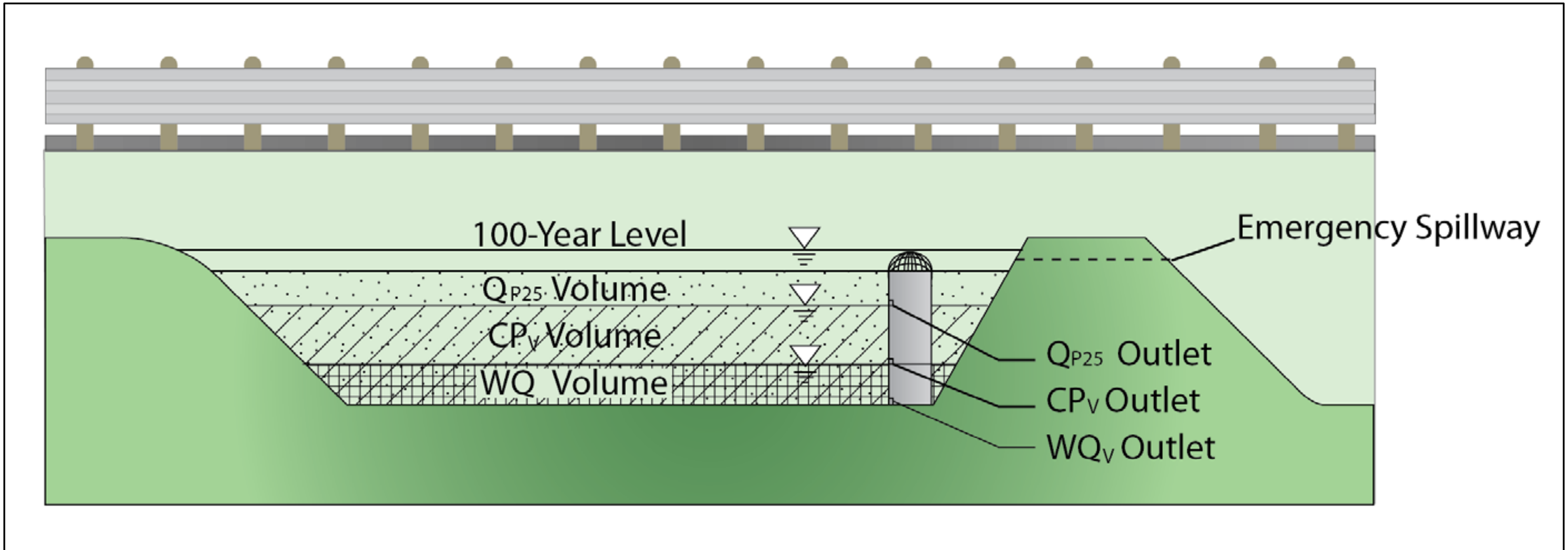
Unified Sizing Criteria

- **Q_f: Safely convey the 100-year storm and evaluate the effects on the storm system, adjacent property and downstream facilities and properties.**
  - A separate analysis is performed comparing 100_{pre} and 100_{post} flows to see negative effects on downstream channels/ structures



Unified Sizing Criteria

- All components of the BMP (storage area and outlet structures) work together to meet water quality and quantity requirements
- Flows should be **routed through all BMP components** to accurately reflect its performance



Unified Sizing Criteria

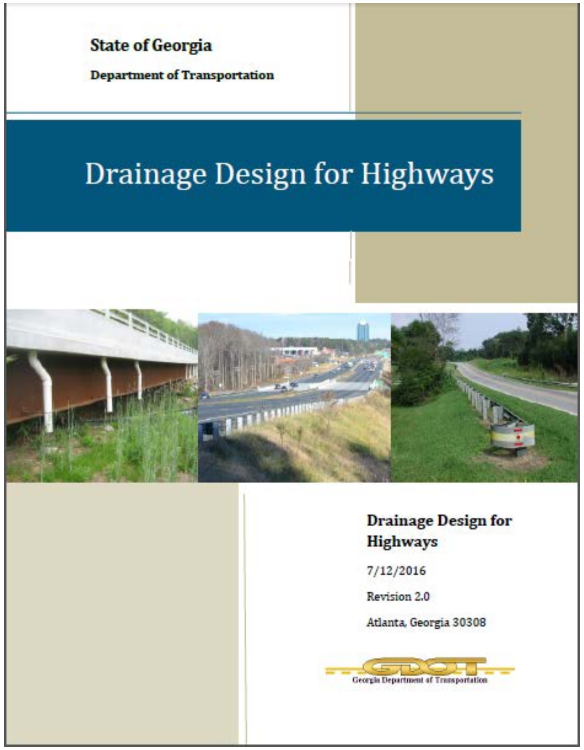
Detention Requirements May be Waived if:

- Site discharges drain directly to channel with drainage area larger than 5 square miles (waiver for CP_V, Q_{P25}, and Q_f)
- Post-development 1-year 24-hour storm event discharges are less than 2 cfs (waiver for CP_V only)
- Downstream analysis shows detention may cause adverse impacts

Unified Sizing Criteria

Hydrologic methods:

- Post-construction practices require *NRCS TR-55* (*SCS Curve Number Method*) instead of Rational Method
- Chapters 4 and 10 of the GDOT Drainage Manual present detailed information on the GDOT required hydrologic methods



Water Quality Volume

WQ_V How to calculate water quality volume

*WQv is based on basin area and **new** impervious area percentage*

WQ_V = 1.2 * R_V * A / 12

(ac-ft) (inch) (acre) (inch/ft)

R_v = volumetric runoff coefficient
= 0.05+0.009*I

A = total basin area (acre)

I = impervious area (%)

to obtain WQ_V in ft^3, convert A (acres) to ft^2:

WQ_V = 1.2 * R_V * A * 43,560/12

(ft^3) (inch) (acre) (ft^2/acre) (inch/ft)

Water Quality Volume (WQ_V) Example

Given (new construction example):

- Site Area: 1.5 acres
- Existing Conditions: undeveloped, wooded/grassed, 0% impervious
- Proposed Conditions: grassed/paved, 80% impervious

R_v = volumetric runoff coefficient

= 0.05+0.009*I

A = total basin area (acre)

I = impervious area (%)

Compute the water quality volume

$$R_V = 0.05 + 0.009 * I$$
$$= 0.05 + 0.009 * 80$$
$$= 0.77$$

$$WQ_V = 1.2 * R_V * A * 43{,}560/12$$
$$= 1.2 * 0.77 * 1.5 * 43{,}560/12$$
$$= \mathbf{5{,}032\ ft^3}$$

Water Quality Volume (WQ_V) Example

Given (redevelopment/improvement example):

- Site Area: 1.5 acres
- Existing Conditions: grassed/paved, 60% impervious
- Proposed Conditions: grassed/paved, 80% impervious

Compute the water quality volume

$$R_{Vexist} = 0.05 + 0.009 * I = 0.05 + 0.009 * 60 = 0.59$$

$$R_{Vprop} = 0.05 + 0.009 * I = 0.05 + 0.009 * 80 = 0.77$$

$$R_{vnet} = R_{vprop} - R_{vexist} = 0.77 - 0.59 = 0.18$$

$$WQ_V = 1.2 * R_V * A * 43{,}560/12 = 1.2 * 0.18 * 1.5 * 43{,}560/12$$

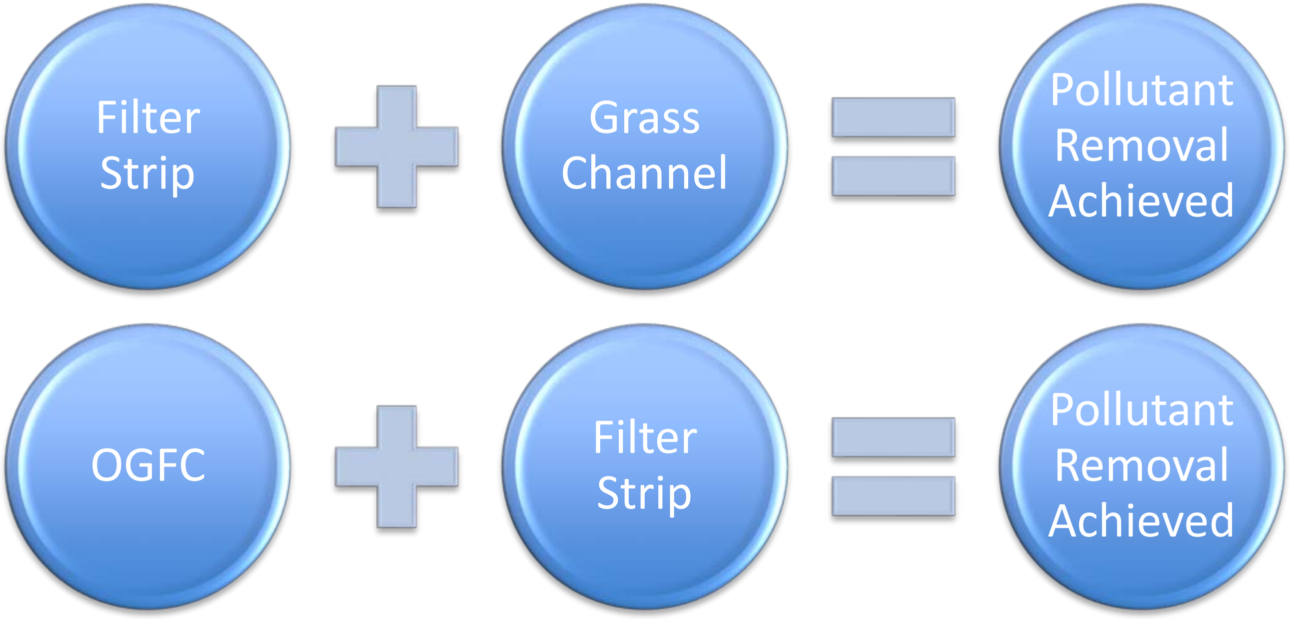
$$= \mathbf{1{,}176\ ft^3}$$

Post-Construction Stormwater BMPs

BMP	TSS	Total Phosphorus	Total Nitrogen	Fecal Coliform	Metals
Filter Strip	60 %	20 %	20 %	----------	40 %
Grass Channel	50 %	25 %	20 %	----------	30 %
Enhanced Dry Swale	80-100%	50-100 %	50-100 %	----------	40-100 %
Enhanced Wet Swale	80 %	25 %	40 %	----------	20 %
Infiltration Trench	100 %	100 %	100 %	100 %	100 %
Sand Filter	80 %	50 %	25 %	40 %	50 %
Dry Detention Basin	60 %	10 %	30 %	----------	50 %
Wet Detention Pond	80 %	50 %	30 %	70 %	50 %
Stormwater Wetland – Level I	80 %	40 %	30 %	70 %	50 %
Stormwater Wetland – Level II	85 %	75 %	55 %	85 %	60 %
Bioslope	85 %	60 %	25 %	60 %	75 %
OGFC	50 %	----------	----------	----------	----------
Bioretention	85 %	80-100 %	60-100 %	90-100 %	95-100 %

Post-Construction Stormwater BMPs

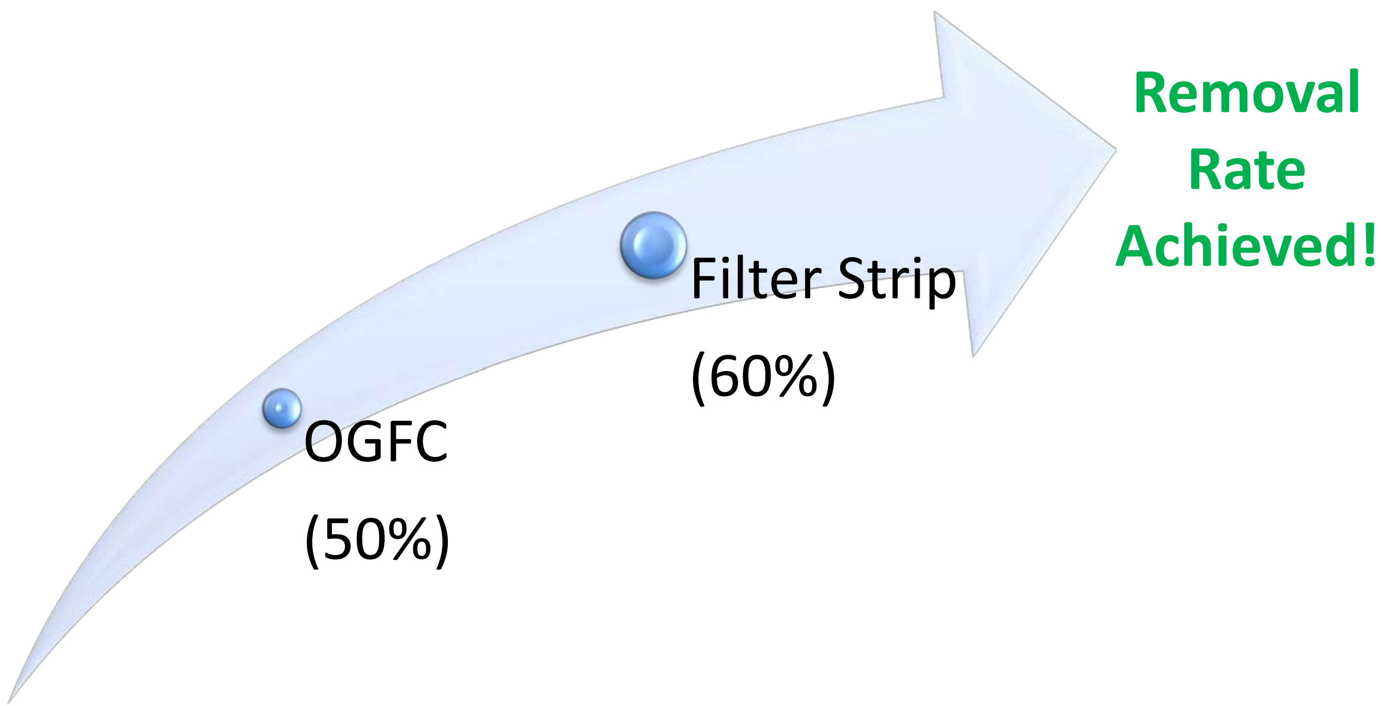
If pollutant removals are not achieved by one BMP alone, multiple BMPs in series can achieve the required removal rates.



Post-Construction Stormwater BMPs

Total TSS removal = BMP1 removal rate + [(remaining TSS)(BMP2 removal rate)]+…

OGFC + Filter Strip in series: **50% + [(50%)(60%)] = 80%**



Post-Construction Stormwater BMPs

Common BMPs used in series to obtain 80% TSS removal:

Filter strip + grass channel:	60% + [(40%)(50%)] = **80.0%**
Grass channel + filter strip:	50% + [(50%)(60%)] = **80.0%**
OGFC* + filter strip:	50% + [(50%)(60%)] = **80.0%**
OGFC* + dry detention:	50% + [(50%)(60%)] = **80.0%**

**OGFC must first be approved by GDOT Office of Materials*

Channel Protection Volume

CP_V How to calculate channel protection volume

*CPv is based on basin area and 1-yr, 24-hr **post-developed** runoff depth:*

$$CP_V = Q_{1,24} * A / 12$$

(ac-ft) (inch) (acre) (inch/ft)

CP_V = channel protection volume (ft^3)
$Q_{1,24}$ = 1yr, 24hr runoff depth (inches)
A = basin area (acres)

to obtain CP_V in ft^3, convert A (acres) to ft^2:

$$CP_V = Q_{1,24} * A * 3{,}630$$

(ft^3) (inch) (acre) (ft^3/ac-in)

Multi-step process to calculate $Q_{1,24}$:

- determine post-developed CN and initial abstraction
- determine rainfall depth
- determine runoff volume

Georgia Department of Transportation

Channel Protection (CP_v) Example

1. Compute CN, S, Ia
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6. Compute Vs/Vr
7. Compute Vs

Given:

- Site near Savannah, GA
- Total drainage area: 1.5 acres
- Land cover: 0.3 acres grass (CN 61), 1.2 acres pavement (CN 98)
- Impervious area: 80%
- Tc: 6 minutes

Compute the channel protection volume

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Curve Number

$$\mathrm{CN} = \frac{(1.2*98)+(0.30*61)}{1.5} = 91$$

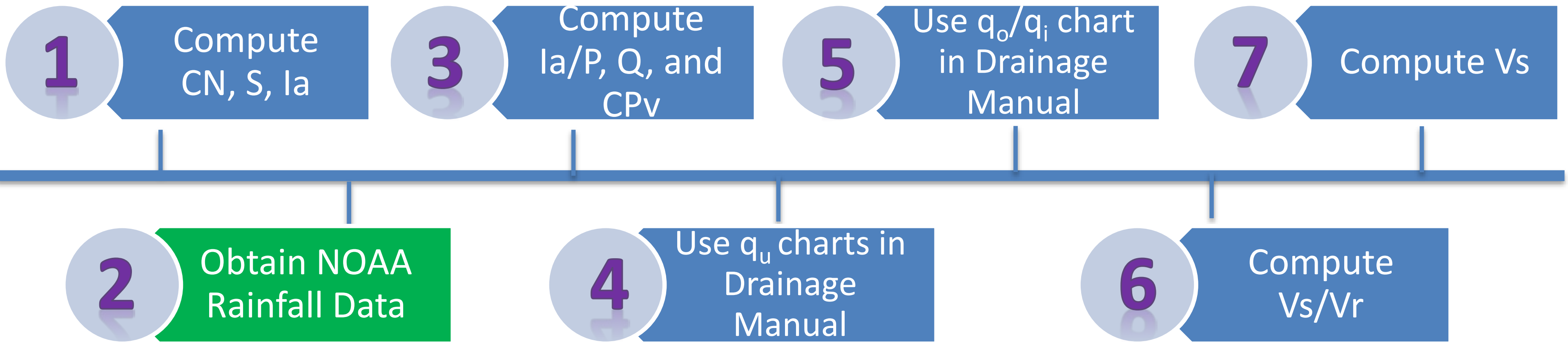
Ultimate Abstraction

$$\mathrm{S} = \frac{1000}{\mathrm{CN}} - 10 = \frac{1000}{91} - 10 = 0.99 \text{ inches}$$

Initial Abstraction

$$\mathrm{I_a} = 0.2 * \mathrm{S} = 0.198 \text{ inches}$$

Channel Protection (CP_v) Example



PF tabular | PF graphical | Supplementary information | Print Page

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.550 (0.474-0.649)	0.620 (0.534-0.732)	0.734 (0.629-0.869)	0.829 (0.705-0.985)	0.960 (0.781-1.17)	1.06 (0.839-1.31)	1.16 (0.879-1.48)	1.27 (0.907-1.65)	1.41 (0.957-1.88)	1.51 (0.994-2.05)
10-min	0.806 (0.695-0.951)	0.908 (0.781-1.07)	1.07 (0.921-1.27)	1.21 (1.03-1.44)	1.41 (1.14-1.72)	1.55 (1.23-1.93)	1.70 (1.29-2.16)	1.86 (1.33-2.42)	2.06 (1.40-2.75)	2.21 (1.46-3.00)
15-min	0.983 (0.847-1.16)	1.11 (0.953-1.31)	1.31 (1.12-1.55)	1.48 (1.26-1.76)	1.72 (1.40-2.10)	1.90 (1.50-2.35)	2.08 (1.57-2.63)	2.26 (1.62-2.94)	2.51 (1.71-3.35)	2.70 (1.77-3.66)
30-min	1.39 (1.20-1.64)	1.58 (1.36-1.87)	1.89 (1.62-2.24)	2.15 (1.83-2.55)	2.50 (2.03-3.05)	2.77 (2.19-3.43)	3.04 (2.29-3.85)	3.31 (2.37-4.30)	3.67 (2.50-4.90)	3.94 (2.59-5.35)
60-min	1.79 (1.55-2.12)	2.04 (1.75-2.40)	2.44 (2.09-2.89)	2.79 (2.38-3.32)	3.29 (2.68-4.04)	3.69 (2.92-4.58)	4.09 (3.10-5.21)	4.52 (3.24-5.91)	5.11 (3.48-6.84)	5.56 (3.66-7.55)
2-hr	2.20 (1.91-2.58)	2.49 (2.16-2.92)	3.00 (2.58-3.52)	3.44 (2.94-4.06)	4.08 (3.35-5.00)	4.60 (3.67-5.70)	5.15 (3.93-6.53)	5.74 (4.14-7.46)	6.54 (4.49-8.73)	7.18 (4.76-9.69)
3-hr	2.43 (2.11-2.84)	2.75 (2.39-3.22)	3.32 (2.87-3.89)	3.84 (3.29-4.51)	4.61 (3.81-5.65)	5.25 (4.21-6.50)	5.93 (4.54-7.52)	6.67 (4.84-8.67)	7.72 (5.33-10.3)	8.56 (5.70-11.5)
6-hr	2.83 (2.47-3.28)	3.23 (2.82-3.75)	3.97 (3.45-4.62)	4.65 (4.01-5.43)	5.68 (4.74-6.95)	6.56 (5.29-8.10)	7.51 (5.79-9.48)	8.54 (6.24-11.1)	10.0 (6.96-13.3)	11.2 (7.51-15.0)
12-hr	3.22 (2.83-3.71)	3.77 (3.30-4.34)	4.74 (4.14-5.48)	5.63 (4.88-6.54)	6.98 (5.85-8.49)	8.12 (6.58-9.96)	9.34 (7.24-11.7)	10.7 (7.84-13.7)	12.6 (8.79-16.6)	14.1 (9.51-18.7)
24-hr	3.71 (3.27-4.25)	4.35 (3.83-4.98)	5.50 (4.82-6.31)	6.55 (5.71-7.56)	8.16 (6.88-9.87)	9.52 (7.76-11.6)	11.0 (8.57-13.7)	12.6 (9.31-16.1)	14.9 (10.5-19.5)	16.7 (11.3-22.0)

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Initial Abstraction Fraction

$$\frac{I_a}{P} = 0.05$$

Runoff Depth

$$Q''_{1,24} = \frac{(P-0.2S)^2}{(P+0.8S)} = \frac{(3.71-0.2*0.99)^2}{(3.71+0.8*0.99)} = 2.74 \text{ inches}$$

Channel Protection (CP_v) Example

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Channel Protection Volume

$$CP_V = Q_{1,24} * A * 3,630$$

$$CP_V = 2.74 \text{ inches} * 1.5 \text{ acres} * 3,630$$

$$CP_V = 14,919.3 \text{ ft}^3$$

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CPv Released over 24 hours

$$14{,}919 \text{ ft}^3 \div 24\frac{Hrs}{Day} \div 60\frac{Min}{Hr} \div 60\frac{Sec}{Min} = 0.17 \text{ cfs average}$$

Maximum Peak Discharge

$$0.17 \text{ cfs average} \times 2 = 0.34 \text{ cfs}$$

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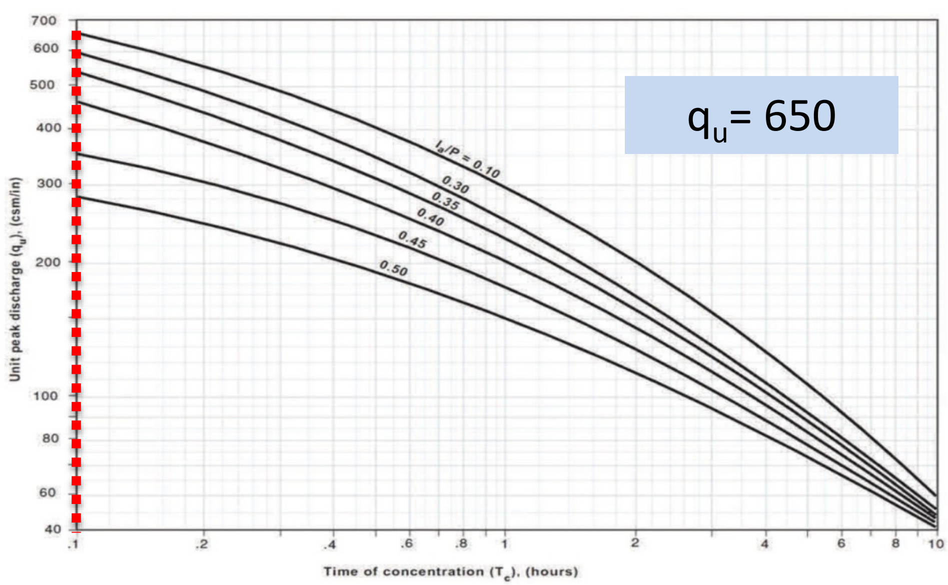

Channel Protection (CP_v) Example

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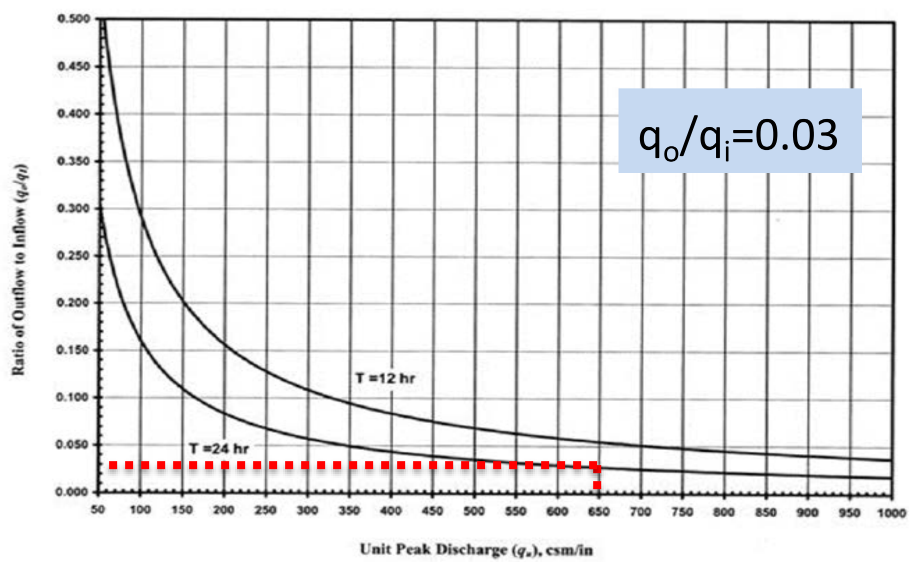

This chart is for CPv calculations only, do not use for other detention calculations.

Georgia Department of Transportation

Channel Protection (CP_v) Example

1 Compute CN, S, Ia

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7 Compute Vs

Required Storage Volume to Runoff Volume Ratio

$$\frac{V_S}{V_R} = 0.682 - 1.43\left(\frac{q_o}{q_i}\right) + 1.64\left(\frac{q_o}{q_i}\right)^2 - 0.804\left(\frac{q_o}{q_i}\right)^3$$

$$\frac{V_S}{V_R} = 0.682 - 1.43(0.03) + 1.64(0.03)^2 - 0.804(0.03)^3 = \mathbf{0.64}$$

Channel Protection (CP_v) Example

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Required Storage Volume

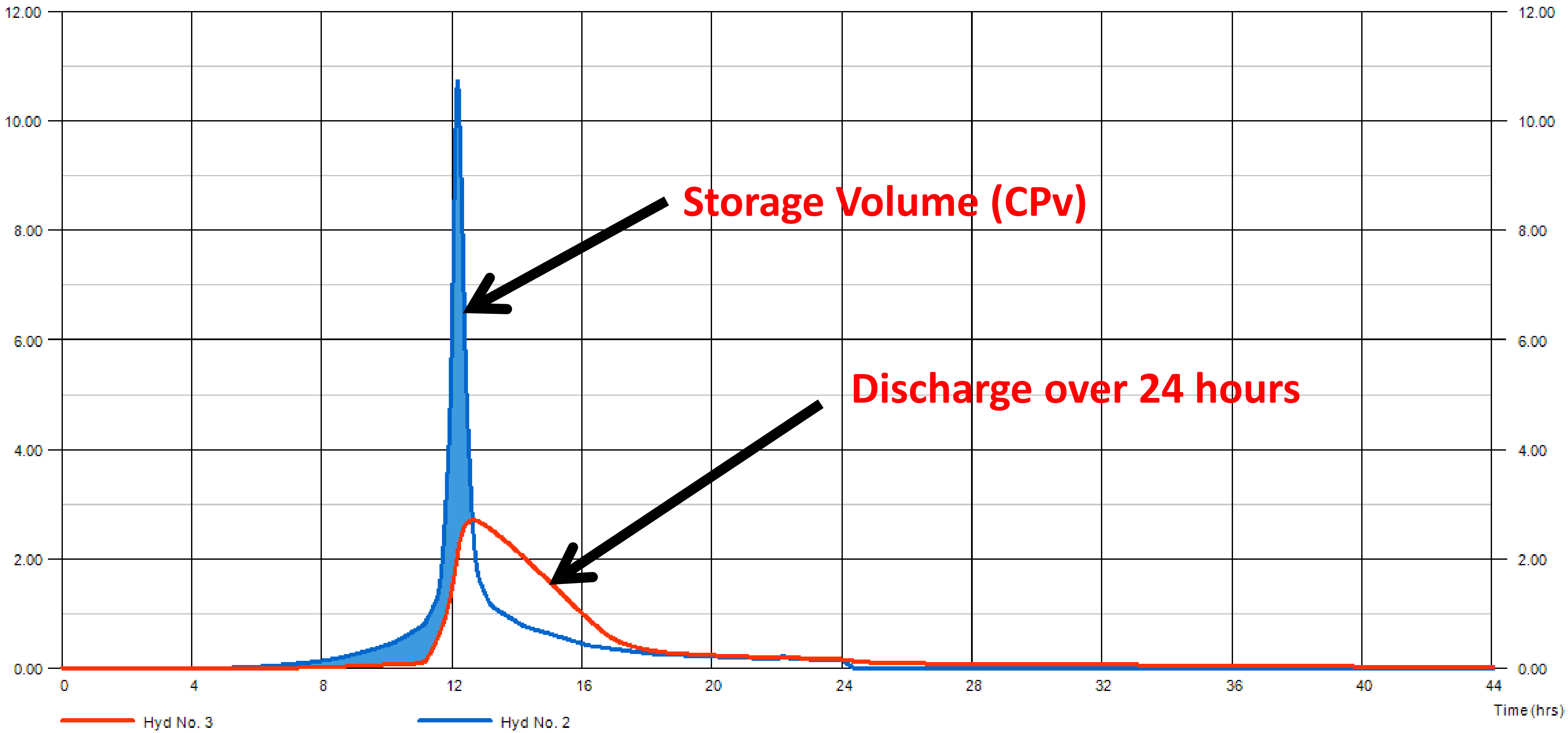
$$V_S = \left(\frac{V_S}{V_R}\right) * Q * A * 3630$$

$$= 0.64 * 2.74 * 1.5 * 3630$$

$$= \mathbf{9,548\ ft^3}$$

Channel Protection Volume

CPv What does channel protection look like?



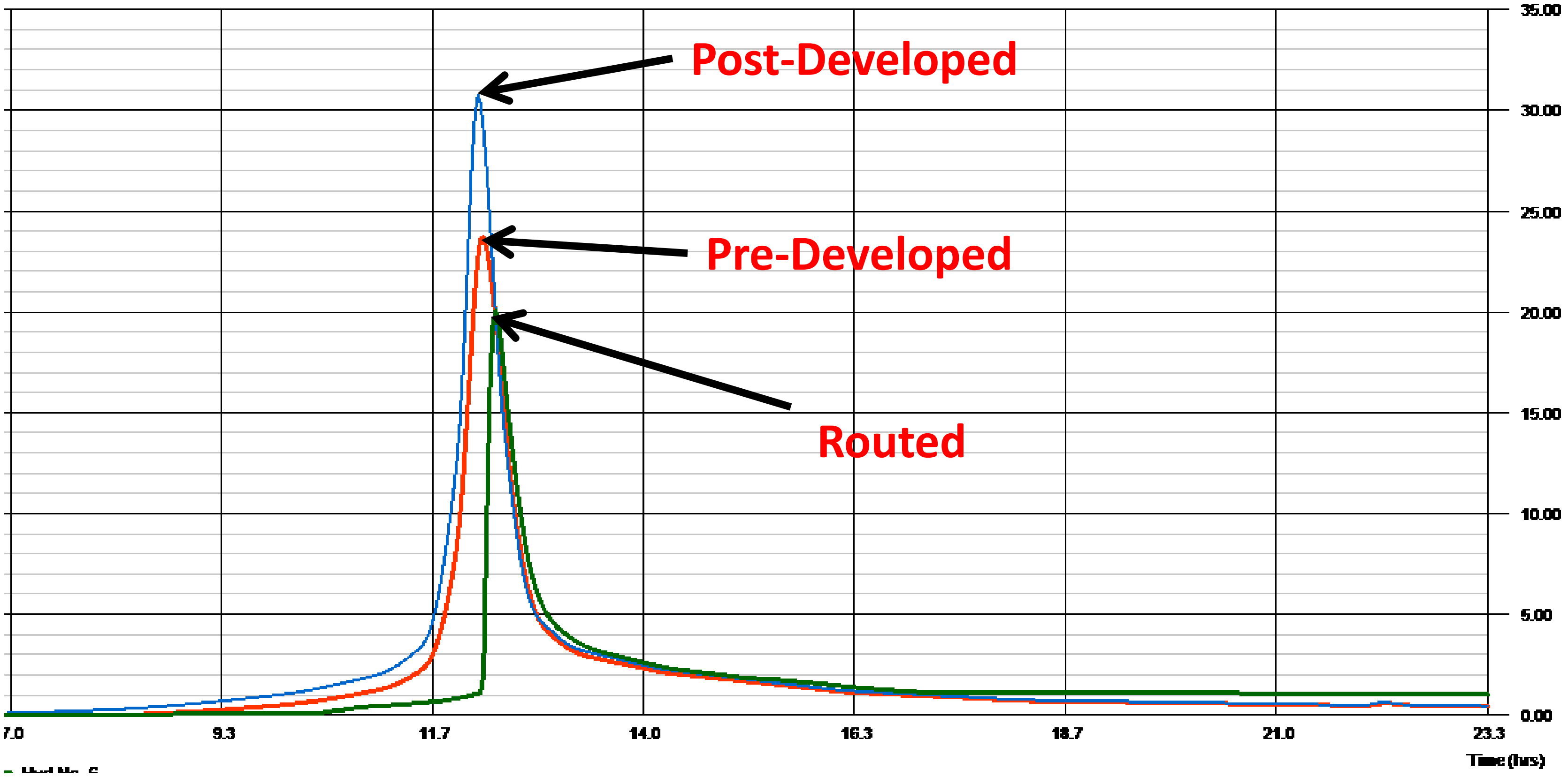
Overbank Flood Protection

Pre- vs. post-developed comparison of peak flows

- Use NRCS method (hand calculations or modeling software) to determine 25-year peak flow for both conditions
- Determine storage volume and outlet control necessary to match pre-developed flow
- Note: Channel protection volume attenuation typically provides a significant portion of the volume required for overbank flood protection

Overbank Flood Protection

Q_{P25} What does overbank flood protection look like?



Extreme Flood Protection

Pre- vs. post-developed comparison of peak flows

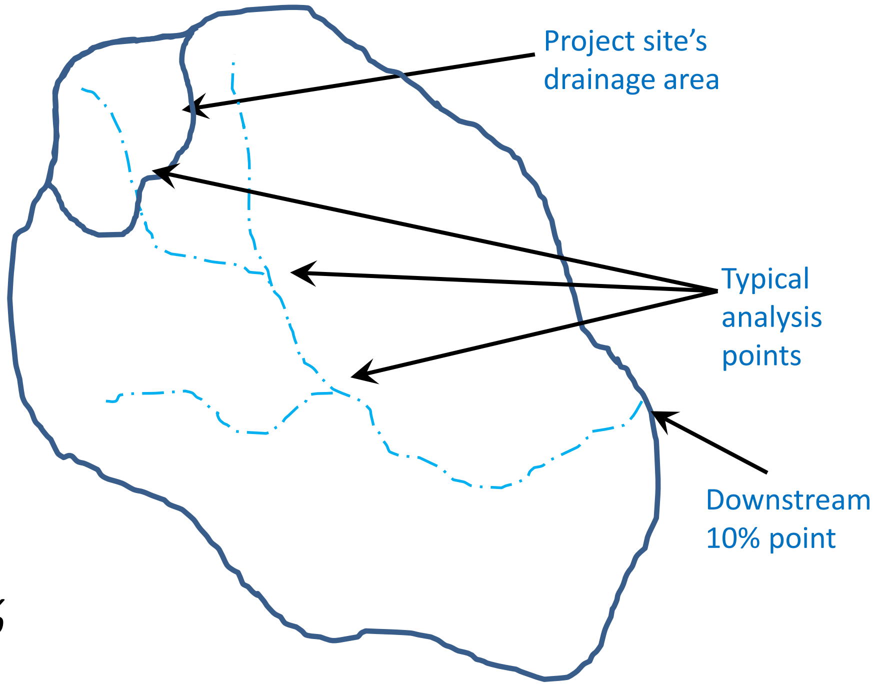
- Use NRCS method (hand calculations or modeling software) to determine 100-year peak flow for both conditions
- Check for safe conveyance of 100-year flows
- Ensure downstream flooding is not exacerbated
- Ensure downstream infrastructure is not impacted by increased 100-year flows

Downstream Analysis

When using detention, perform a downstream analysis to ensure no adverse impacts to properties/structures downstream:

- Identify potential impact locations downstream
- Evaluate impacts on those locations

<u>*Note:*</u> *In Georgia, we analyze impacts at locations up to a point where the project's outfall basin makes up 10% of a larger basin*

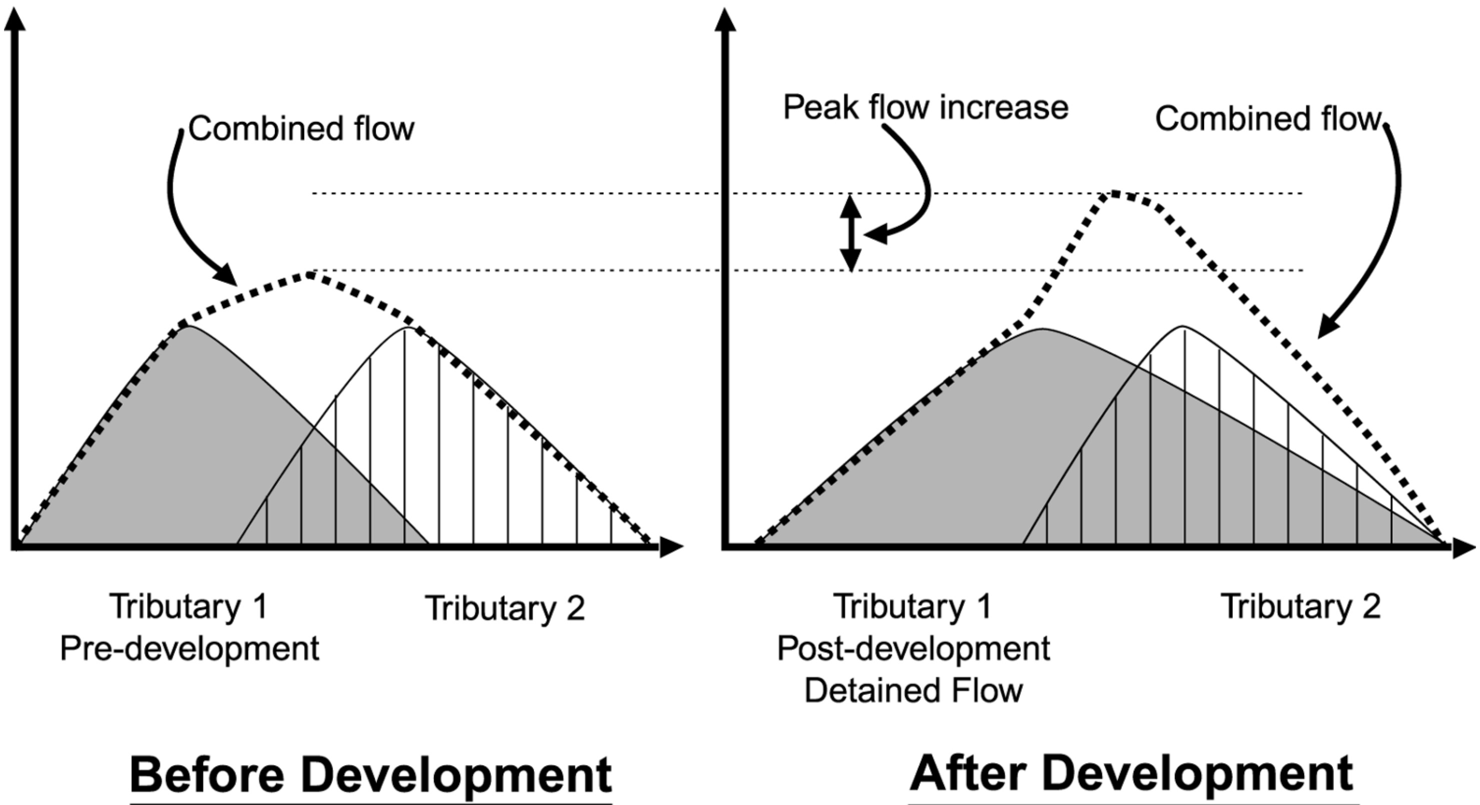


Downstream Analysis

DA

Why we perform downstream analysis

Check for adverse impacts created by peak timing shift due to detention



Questions

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