# CRITICAL DURATION ANALYSIS USING THE PONDS© VERSION 3.IX COMPUTER PROGRAM: How The FDOT 48 Storm Matrix Was Conquered

**PRESENTATION TO:**
**ASCE GEOTECHNICAL & WATER RESOURCES TECHNICAL GROUPS**
**SEPTEMBER 18, 1997**


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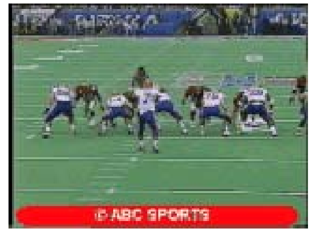
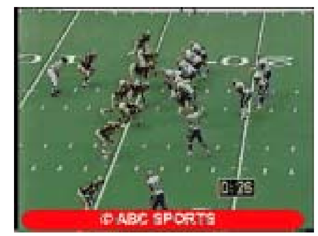
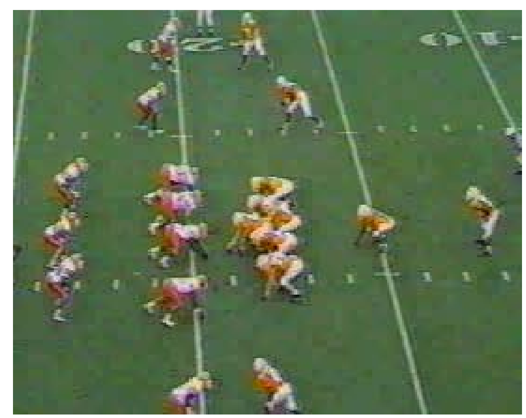
# The Gators Tribute







# AGENDA

## ROUTING MULTIPLE HYDROGRAPHS USING PONDS 3.1

- Review the chronology of development of the PONDS computer program leading up to Version 3.1
- Review the list of stormwater design applications of the PONDS computer program
- Focus on today's special topic: The benefit of being able to route and sort up to 100 hydrographs at once. Review hydrograph requirements of FDOT, SJRWMD, and Orange County.
- Demonstrate PONDS 3.1 using an actual project as an example

# PONDS 3.1x FOR WINDOWS 95/NT - A CHRONOLOGY

- January 1993: First version of PONDS/FILTER Version 1.0 computer program released
- June 1995: last DOS Version of PONDS released (PONDS Version 2.26). This software is now used by over 250 engineering consultants & regulatory agencies in the state of Florida.
- August 1995: Windows 95 operating system released by Microsoft
- November 1995: Started development of PONDS Version 3 for Windows 95
- September 1996: PONDS Version 3 for Windows 95/NT approved by SJRWMD and released to public.
- Sept 1996-present: About 25% of the PONDS 2.26 user base has switched to Version 3 including SJRWMD, SWFWMD, & FDEP. This is a true Windows 95/NT software; it will not work under Windows 3.11 or lower.
- August 1997: PONDS 3.1 released. This is the version that will be demonstrated today. The main difference between Version 3.0x and 3.1x is the ability to simultaneously route up to 100 hydrographs and automatically sort these routed hydrographs by parameter such as peak discharge rate, discharge volume, etc.

# APPLICATIONS OF PONDS VERSION 2.26 & 3

## WATER QUALITY RECOVERY ANALYSES

- ★ Dry retention & wet retention ponds (unlined or partially lined)
- ★ Exfiltration trenches
- ★ Wet detention ponds (with & without ground water baseflow component)
- ★ Dry detention ponds (with & without percolation)
- ★ Underdrain ponds (with & without ground water baseflow component)
- ★ Filtration systems including side-bank, pond-bottom, and VVRS filters
- ★ Swales

# APPLICATIONS OF PONDS VERSION 2.26 & 3

## HYDROGRAPH GENERATION

- ★ SCS Unit hydrographs (can include recovery time following storm)
- ★ Water quality recovery volume hydrographs (automatic setup of time steps for SJRWMD & SWFWMD criteria)
- ★ Continuous simulation hydrographs
- ★ Manually input a hydrograph in a spreadsheet type environment or cut & paste from another application such as Excel or Quattro
- ★ Wastewater percolation pond hydrographs (not applicable for stormwater)

# APPLICATIONS OF PONDS VERSION 2.26 & 3

## ROUTING HYDROGRAPHS

- ★ True routing can be performed with or without credits for infiltration during the storm event. True routing means that the model can predict the peak stage, discharge rates, etc. like adICPR.
- ★ PONDS is limited to: ① a single pond situation with up to 3 discharge structures, and ② cases where the tailwater condition does not rise up and submerge the overflow structure during the routing (i.e., free discharge).
- ★ Critical duration analysis now possible with Version 3.1 where up to 100 hydrographs can be routed and critical hydrograph identified based on parameter.
- ★ For interconnected ponds, the model can interface directly with adICPR & read adICPR hydrographs

# APPLICATIONS OF PONDS VERSION 2.26 & 3

## WATER TABLE DEWATERING & DRAWDOWN

- ★ **Compute dewatering rates and water table drawdown impact distances for the following applications:**
  - ▸ **Borrow pits,**
  - ▸ **Ditches,**
  - ▸ **Interceptor trenches,**
  - ▸ **Wet detention ponds,**
  - ▸ **Road underdrains,**
  - ▸ **Utility line dewatering**
- ★ **Assess setback distances from wetlands**

# APPLICATIONS OF PONDS VERSION 2.26 & 3

## OTHER APPLICATIONS - ADD ONS

- Retention pond fill berm slope stability analysis
- Channel lining analysis (HEC 15)

# TODAY'S SPECIAL TOPIC

## ROUTING MULTIPLE HYDROGRAPHS USING PONDS 3.1

- **The approach to critical duration analysis in PONDS 3.1x is one of brute-force and not one of finesse. With the present & future price of computing, this is the way to go....Remember "Deep Blue" vs. Kasparov.**

- **Why do we need this capability? Consider a project in Orange County (within SJRWMD) which discharges to an FDOT system. How many routed hydrographs do we need to satisfy all three (3) regulatory entities?**

- **Let us take a look first at FDOT, then SJRWMD, and finally Orange County to see how many hydrographs we are dealing with......**

# FDOT RULES, CHAPTER 14-86: DRAINAGE CONNECTIONS

## DEFINITIONS

- Critical duration means the duration of a specific storm event which creates the largest volume or highest rate of net stormwater runoff for typical durations up through and including the 240 hr (10 day) duration event.
- The critical duration is determined by comparing various durations of the specified storm and calculating the peak rate and volume of runoff for each. The duration resulting in the highest peak rate or largest total volume is the "critical duration" storm.
- Net stormwater runoff = postdevelopment runoff less predevelopment runoff
- Drainage connection means any structure, pipe, culvert, device, ..., whether natural or created which conveys runoff to an FDOT facility.

# FDOT RULES, CHAPTER 14-86: DRAINAGE CONNECTIONS

## ASSURANCE REQUIREMENTS

- Peak discharge rate and/or total volume are those provided for in an approved stormwater management plan or master drainage plan. Otherwise, the post-improvement stormwater discharge from the property shall not exceed the more stringent of the following:
  - peak discharge rates and/or total volumes allowed by local regulations; or
  - pre-improvement peak stormwater runoff discharge rates shall not be increased; in addition, in watersheds which do not have positive outlet, the post-improvement stormwater runoff total volumes shall not be increased above the pre-improvement total volume of runoff considering the worst case storms for each frequency within the 48 storm matrix.
- For closed basins, the retention volume required will be the post-improved less the pre-improved runoff volume for the 100 year critical duration (1 hr to 240 hr) event. 50% of retention volume must recover within 7 days and 100% within 30 days.
- Recovery of water quality volume

# FLORIDA DEPARTMENT OF TRANSPORTATION

## SCS UNIT HYDROGRAPHS TO BE ROUTED

### RAINFALL TOTALS (in inches)

FREQUENCY

| DURATION | 2 yr | 5 yr | 10 yr | 25 yr | 50 yr | 100 yr |
|---|---|---|---|---|---|---|
| 1 hr | 2.4 | 2.9 | 3.2 | 3.7 | 4.1 | 4.5 |
| 2 hr | 2.8 | 3.5 | 3.9 | 4.5 | 5.0 | 5.5 |
| 4 hr | 3.3 | 4.1 | 4.7 | 5.4 | 6.0 | 6.6 |
| 8 hr | 3.8 | 4.8 | 5.6 | 6.5 | 7.3 | 8.0 |
| 24 hr | 4.9 | 6.2 | 7.4 | 8.6 | 9.8 | 10.6 |
| 72 hr | 6.0 | 8.0 | 9.0 | 10.5 | 12.0 | 14.0 |
| 168 hr | 7.5 | 9.5 | 11.0 | 13.0 | 15.0 | 17.0 |
| 240 hr | 8.5 | 11.0 | 13.0 | 15.0 | 17.0 | 19.0 |

USE FDOT RAINFALL DISTRIBUTIONS

# ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

## SCS UNIT HYDROGRAPHS TO BE ROUTED

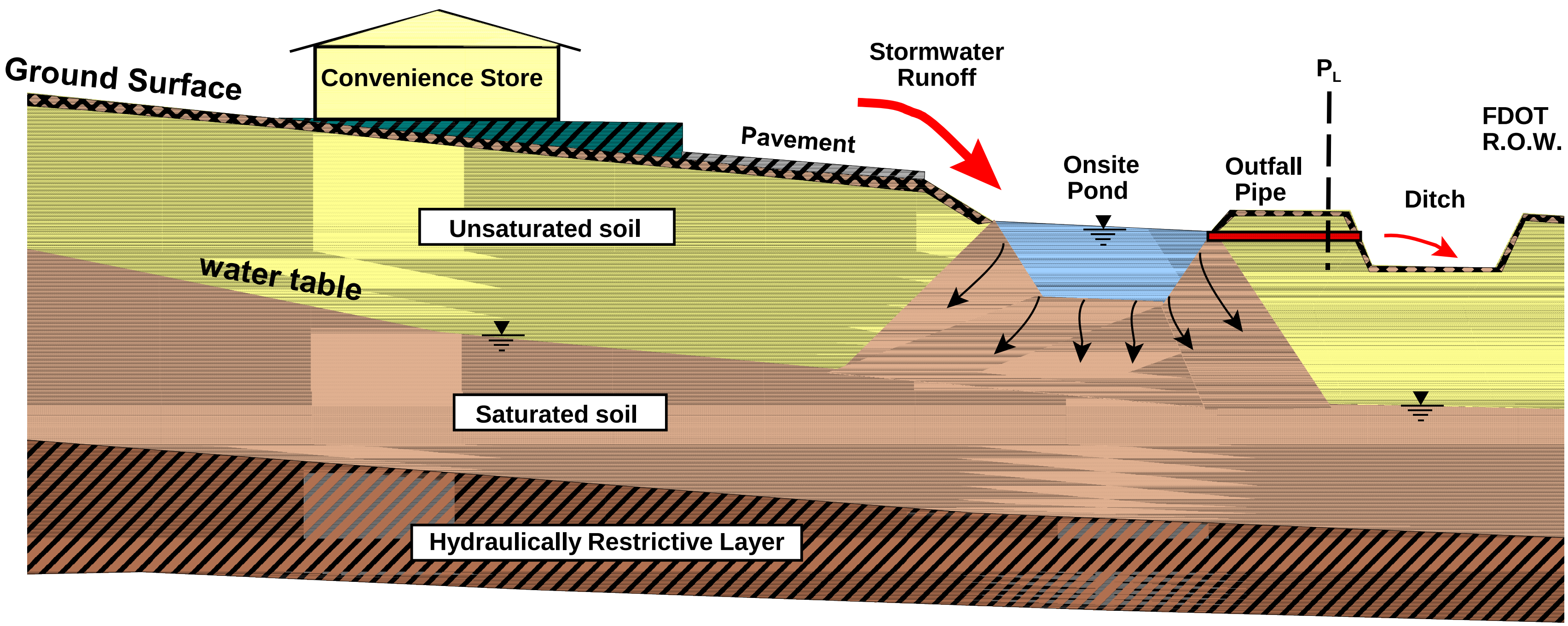
- **25 yr-24 hr storm with SCS II (Fl Modified) Rainfall Distribution**
  - District-wide for systems with positive outfall (rate difference)
- **25 yr - 96 hr storm with SJRWMD 25 yr - 96 hr Rainfall Distribution**
  - District wide for systems which discharge to land-locked basins (volume difference and sometimes rate difference)
  - For pumped discharges in the upper St. Johns River Basin (volume difference)
- **2.3 yr - 24 hr storm with SJRWMD Mean Annual Rainfall Distribution**
  - MSSW in Econ Basin for systems with positive outfall (rate difference)
  - 40C-42 permits district-wide with projects which have >50% impervious (rate difference)
- **10 yr - 24 hr storm with SCS II (Fl Modified) Rainfall Distribution**
  - Projects with positive outfall within in Ocklawaha Basin & Upper St. Johns River Basin (rate difference)

# ORANGE COUNTY (FLORIDA)

## SCS UNIT HYDROGRAPHS TO BE ROUTED

- **100 yr-24 hr storm with Orange County 100 yr-24 hr Rainfall Distribution**
  - For systems where there is no positive outfall or discharge is into a lake without a positive outfall (retention & 14 day recovery, not volume difference)
  - Also used for areas of special flood hazard to establish 100 year base flood elevation, compensating storage, and demonstrate that the flood carrying capacity of the floodway is maintained without increasing the base flood elevations.
- **25 yr - 24 hr storm with Orange County 25 yr - 24 hr Rainfall Distribution**
  - For systems with positive outfall and time of concentration is more than 30 minutes
- **25 yr - 6 hr storm with Orange County 25 yr - 6 hr Rainfall Distribution**
  - For systems with positive outfall and time of concentration is less than 30 minutes
- **10 yr - 24 hr storm with Orange County 10 yr - 24 hr Rainfall Distribution**
  - For design of storm sewer for roadways

# Example Project With Positive Outfall

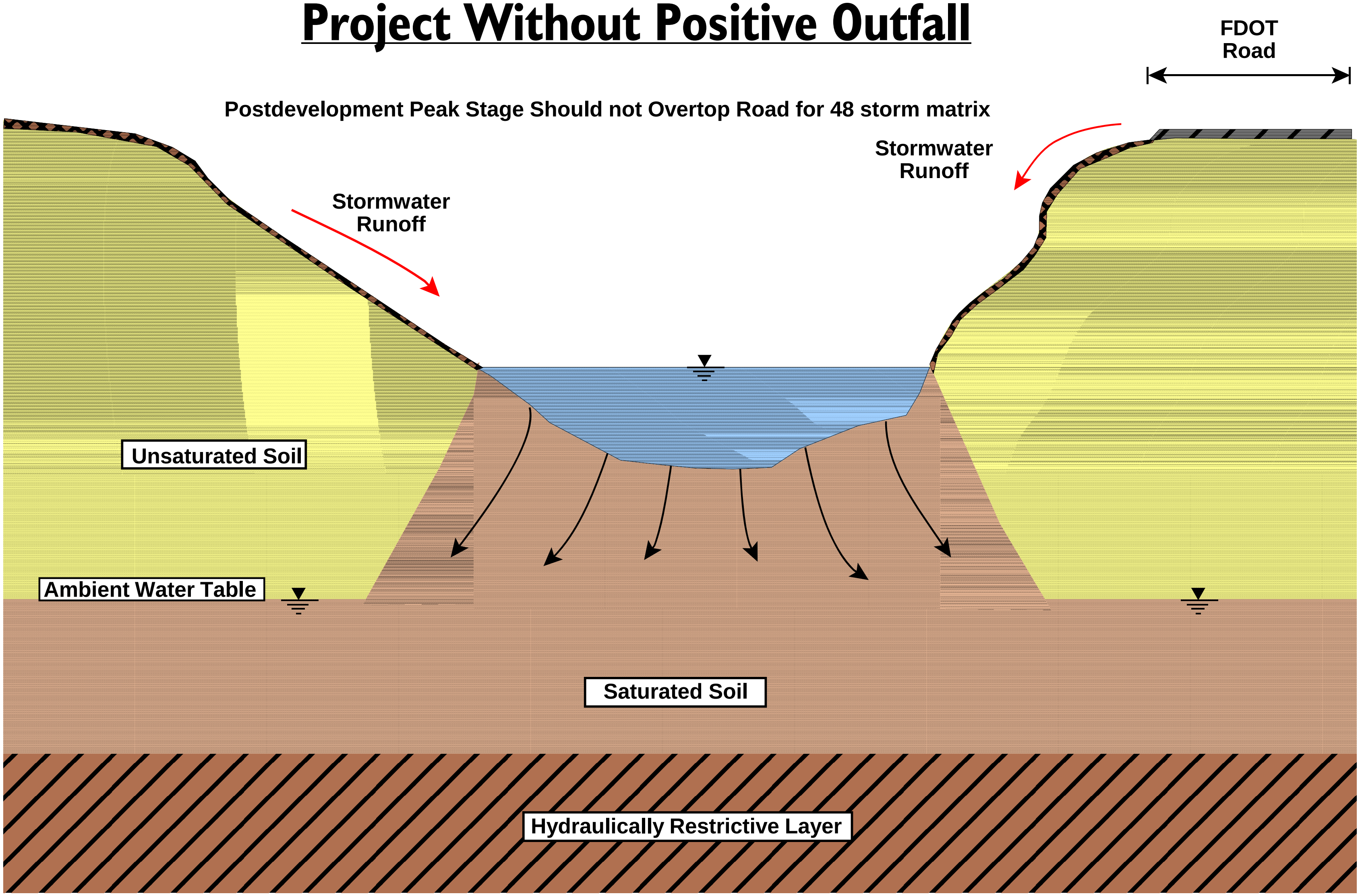



**NOTES:**

① **Infiltration can be deactivated to get pure surface water routing, but FDOT allows Infiltration during routing**

② **Need to regulate peak discharge rate & discharge volume if ultimate receiving water body is closed**

# Project Without Positive Outfall




## Notes:

① Duration of Strom Influences Infiltration Volume

② If no infiltration during routing, 100 yr - 240 hr strom will produce the highest stage

# Example Problem - Project With Positive Outfall

Drainage Basin Parameters for Pre- & Post-Development Conditions

| PARAMETER | UNIT | MAGNITUDE | |
|---|---|---|---|
| | | PRE | POST |
| Area of contributing drainage basin | $ft^2$ | 35,031 | 35,031 |
| Area of contributing drainage basin | acre | 0.804 | 0.804 |
| Time of concentration | min | 8 | 8 |
| Area of lawn on HSG "A" Soil (outside pond) | $ft^2$ | 9,674 | 8,996 |
| Curve Number (CN) for lawn on HSG "A" Soil | - | 49 | 49 |
| 1-story CBS building | $ft^2$ | 2,600 | 2,600 |
| Pavement & parking area | $ft^2$ | 19,457 | 20,135 |
| Pond area (treated as DCIA) | $ft^2$ | 3,300 | 3,300 |
| Curve Number (CN) for impervious area | - | 98 | 98 |
| Directly connected impervious area | % | 72.38% | 74.32% |
| Water quality volume [50% of 1.25" × impervious area] | $ft^3$ | 2,298 | 2,368 |

# Example Problem - Project With Positive Outfall

Geometric Parameters for Pond

| Parameter | Unit | PRE & POST |
|---|---|---|
| Equivalent pond length | ft | 120 |
| Equivalent pond width | ft | 25 |
| Maximum area available for unsaturated infiltration | $ft^2$ | 3,000 |

Stage-Area Data

| PRE-DEVELOPMENT | | | POST-DEVELOPMENT | | |
|---|---|---|---|---|---|
| Stage (ft NGVD) | Area ($ft^2$) | Volume ($ft^3$) | Stage (ft NGVD) | Area ($ft^2$) | Volume ($ft^3$) |
| 104.6 | 0 | 0 | 104.0 | 756 | 0 |
| 105.0 | 678 | 136 | 105.0 | 1,484 | 1,120 |
| 106.0 | 2,419 | 1,684 | 106.0 | 2,738 | 3,231 |
| 106.3 | 3,326 | 2,546 | 107.0 | 3,876 | 6,538 |
| 106.9 | 5,214 | 5,108 | | | |

# Example Problem - Project With Positive Outfall

## Discharge Structures

| Description | Parameter | Unit | Magnitude | |
|---|---|---|---|---|
| | | | PRE | POST |
| SIDE CONTROL WEIR | Discharge elevation | ft NGVD | 105.89 | 106.09 |
| | Weir length | ft | 1.83 | 1.83 |
| | Weir coefficient | - | 3.13 | 3.13 |
| | Weir exponent | - | 1.5 | 1.5 |
| TOP CONTROL WEIR | Discharge elevation | ft NGVD | 106.22 | 106.22 |
| | Weir length | ft | 7.83 | 7.83 |
| | Weir coefficient | - | 3.13 | 3.13 |
| | Weir exponent | - | 1.5 | 1.5 |
| DROP CURB TO ENTRY POINT BLVD | Discharge elevation | ft NGVD | 106.90 | 106.90 |
| | Weir length | ft | 30 | 30 |
| | Weir coefficient | - | 2.861 | 2.861 |
| | Weir exponent | - | 1.5 | 1.5 |

# Example Problem - Project With Positive Outfall

**Aquifer Parameters for Pond**

| Parameter | Unit | Magnitude |
|---|---|---|
| Base of mobilized aquifer | ft NGVD | +99 |
| Seasonal high water table | ft NGVD | +101 |
| Horizontal hydraulic conductivity | ft/day | 40 |
| Fillable porosity | % | 30 |
| Unsaturated vertical infiltration rate (routing with infiltration) | ft/day | 25 |
| Unsaturated vertical infiltration rate (routing without infiltration) | ft/day | .00001 |

# Example Problem - Project With Positive Outfall

Hydrographs uses 484 shape factor, FDOT Rainfall
Distributions & the following rainfall totals:

**RAINFALL TOTALS (in inches)**

| | | FREQUENCY | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2 yr | 5 yr | 10 yr | 25 yr | 50 yr | 100 yr |
| DURATION | 1 hr | 2.4 | 2.9 | 3.2 | 3.7 | 4.1 | 4.5 |
| | 2 hr | 2.8 | 3.5 | 3.9 | 4.5 | 5.0 | 5.5 |
| | 4 hr | 3.3 | 4.1 | 4.7 | 5.4 | 6.0 | 6.6 |
| | 8 hr | 3.8 | 4.8 | 5.6 | 6.5 | 7.3 | 8.0 |
| | 24 hr | 4.9 | 6.2 | 7.4 | 8.6 | 9.8 | 10.6 |
| | 72 hr | 6.0 | 8.0 | 9.0 | 10.5 | 12.0 | 14.0 |
| | 168 hr | 7.5 | 9.5 | 11.0 | 13.0 | 15.0 | 17.0 |
| | 240 hr | 8.5 | 11.0 | 13.0 | 15.0 | 17.0 | 19.0 |

# Example Problem - Project With Positive Outfall

**PEAK DISCHARGE RATES (in cfs) WITHOUT INFILTRATION CREDITS**

| Duration ⇩ | FREQUENCY | | | | | |
|---|---|---|---|---|---|---|
| | 2 yr | 5 yr | 10 yr | 25 yr | 50 yr | 100 yr |
| | PRE → POST | PRE → POST | PRE → POST | PRE → POST | PRE → POST | PRE → POST |
| 1 hr | 2.18 → 1.03 | 2.96 → 2.04 | 3.40 → 2.63 | 4.12 → 3.61 | 4.69 → 4.35 | 5.26 → 5.04 |
| 2 hr | 1.72 → 0.70 | 2.38 → 1.75 | 2.73 → 2.41 | 3.23 → 3.19 | 3.67 → 3.71 | 4.10 → 4.19 |
| 4 hr | 0.93 → 0.84 | 1.22 → 1.14 | 1.45 → 1.46 | 1.71 → 1.74 | 1.93 → 1.98 | 2.16 → 2.21 |
| 8 hr | 0.94 → 0.97 | 1.25 → 1.28 | 1.49 → 1.53 | 1.78 → 1.81 | 2.04 → 2.07 | 2.27 → 2.30 |
| 24 hr | 0.29 → 0.30 | 0.39 → 0.40 | 0.47 → 0.49 | 0.57 → 0.58 | 0.66 → 0.67 | 0.72 → 0.73 |
| 72 hr | 0.20 → 0.20 | 0.28 → 0.28 | 0.32 → 0.32 | 0.38 → 0.38 | 0.44 → 0.44 | 0.52 → 0.52 |
| 168 hr | 0.16 → 0.16 | 0.20 → 0.20 | 0.24 → 0.24 | 0.29 → 0.29 | 0.34 → 0.34 | 0.38 → 0.39 |
| 240 hr | 0.21 → 0.21 | 0.28 → 0.28 | 0.33 → 0.33 | 0.39 → 0.39 | 0.45 → 0.45 | 0.50 → 0.50 |

# Example Problem - Project With Positive Outfall

**PEAK DISCHARGE RATES (in cfs) WITH INFILTRATION CREDITS**

**FREQUENCY**

| Duration ⇩ | 2 yr | 5 yr | 10 yr | 25 yr | 50 yr | 100 yr |
|---|---|---|---|---|---|---|
| | PRE → POST | PRE → POST | PRE → POST | PRE → POST | PRE → POST | PRE → POST |
| 1 hr | 1.02 → 0.00 | 1.84 → 0.48 | 2.34 → 1.20 | 3.13 → 2.29 | 3.72 → 3.12 | 4.32 → 3.90 |
| 2 hr | 0.66 → 0.00 | 1.19 → 0.06 | 1.66 → 0.49 | 2.28 → 1.66 | 2.75 → 2.49 | 3.21 → 3.15 |
| 4 hr | 0.12 → 0.00 | 0.37 → 0.00 | 0.57 → 0.06 | 0.80 → 0.44 | 0.99 → 0.79 | 1.24 → 1.20 |
| 8 hr | 0.11 → 0.00 | 0.43 → 0.00 | 0.59 → 0.08 | 0.83 → 0.68 | 1.29 → 1.35 | 1.64 → 1.68 |
| 24 hr | 0.00 → 0.00 | 0.00 → 0.00 | 0.04 → 0.00 | 0.15 → 0.11 | 0.36 → 0.22 | 0.35 → 0.26 |
| 72 hr | 0.00 → 0.00 | 0.00 → 0.00 | 0.06 → 0.00 | 0.23 → 0.09 | 0.31 → 0.29 | 0.41 → 0.40 |
| 168 hr | 0.00 → 0.00 | 0.00 → 0.00 | 0.12 → 0.00 | 0.18 → 0.17 | 0.24 → 0.23 | 0.30 → 0.29 |
| 240 hr | 0.00 → 0.00 | 0.12 → 0.00 | 0.20 → 0.17 | 0.27 → 0.25 | 0.33 → 0.32 | 0.39 → 0.39 |