INTRO TO DETENTION BASIN

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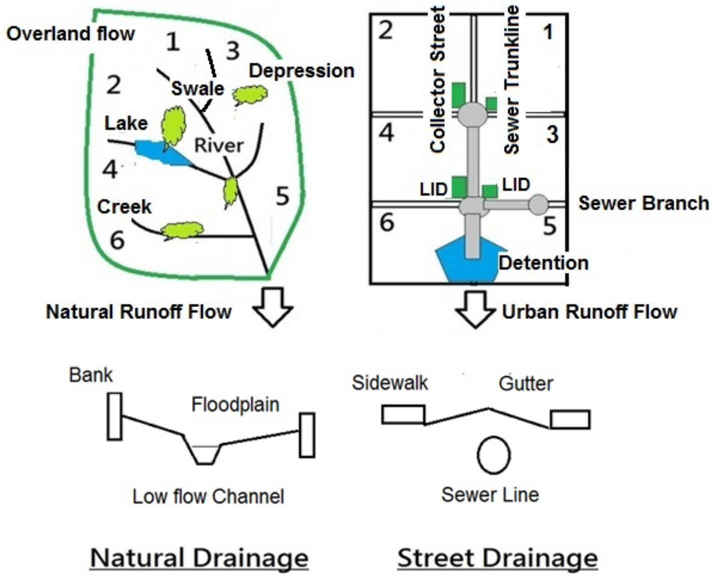
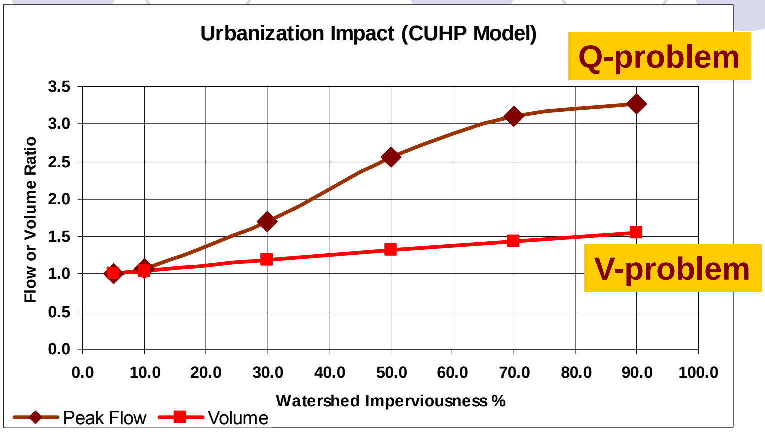
Comparison between natural and urban watersheds

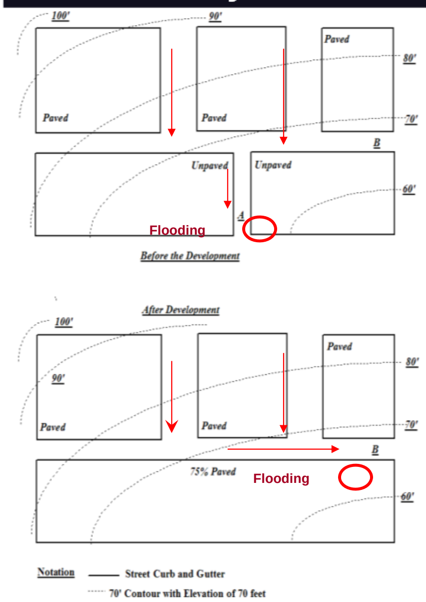


Urbanization Impact On Runoff Rate and Volume



Watershed urbanization results in "hydro-modification" that increases runoff volume and adversely impact on water quality.
Urban Stormwater Problems: (1) V-problem (2) Q-problem

Why need Stormwater Detention



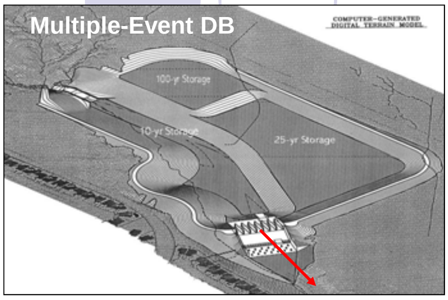
PROBLEMS

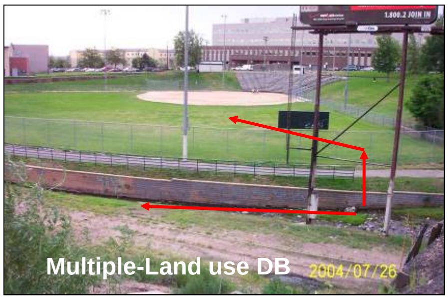
- New land developments
- Increase of paved area
- Change of Historic Path
- Transfer of Flood Problems

- Increase of Runoff Peak
- Increase of Runoff Volume
- Increase of Flow Velocity
- Increase of Sediment Load
- Increase of Pollutants
- Shockwave of Pollutants to Downstream Stream
- Decrease of Groundwater Recharge
- Others

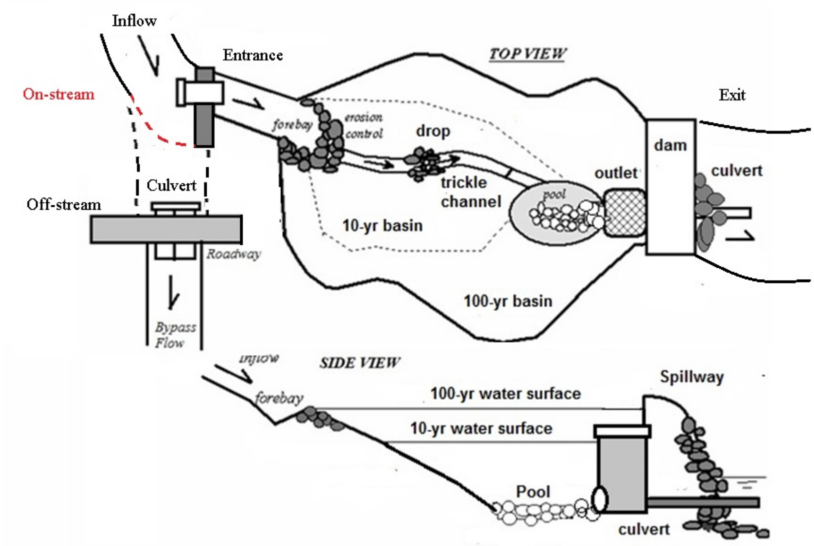
SOLUTION?

Various Types of Flood Control DBs

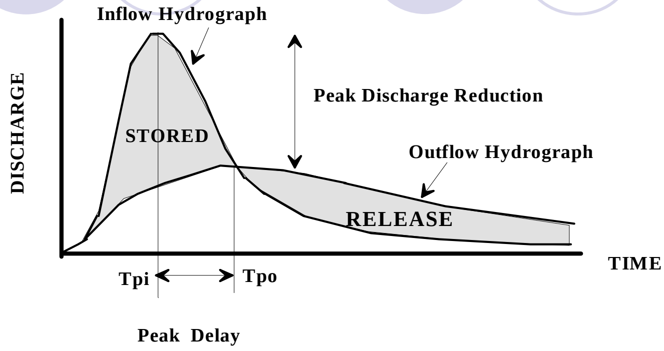




Layout of Detention Basin

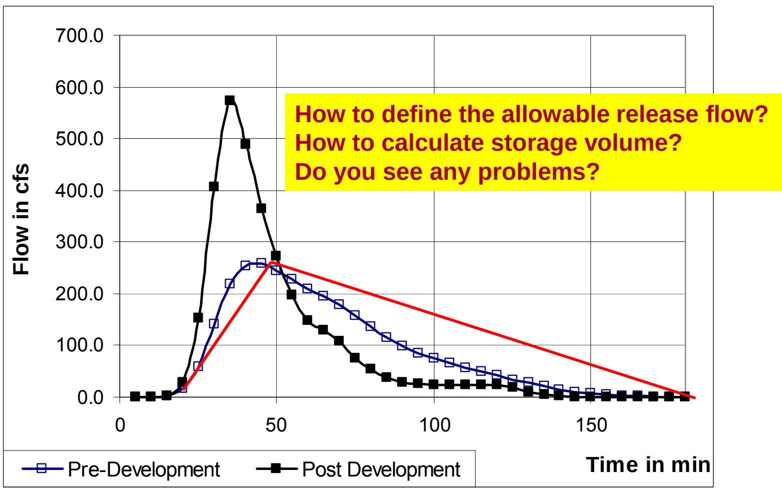


Concept of Detention Process

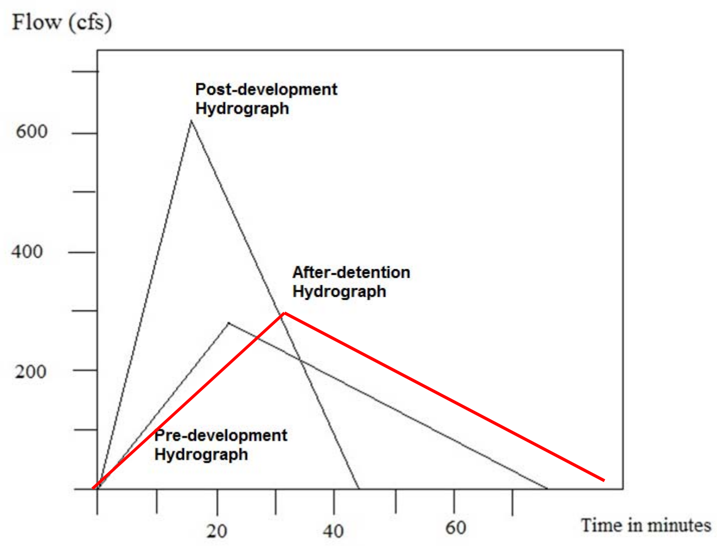


1. Set the target release:
   Historic rate, Pre-development rate, Design criteria rate
2. Provide detention volume to store the excess water
3. Reduce the peak flow rate
4. Delay "the time to peak"

A watershed of 0.19 sq mile was developed from Io=5% to Io=60%. The 100-yr peak flow increases from 275 cfs to 580 cfs. To maintain the historic peak flow, suggest a target release hydrograph from the proposed detention basin. (Hint: use the triangular hydrograph)



Determine detention storage volume



Allowable Release Rate and Drain Time

Release Rate = min (1, 2, and 3)

(1) Pre-development or historic (undeveloped) peak discharge
(2) Critical capacity of the downstream existing drainage facility,
(3) Regional flood control criteria recommended for the Denver areas:

Design Event	Catchment Soil Type A	Catchment Soil Type B	Catchment Soil Type C and D
2-yr	0.02 cfs/acre	0.03 cfs/acre	0.04 cfs/acre
5-yr	0.07 cfs/acre	0.13 cfs/acre	0.17 cfs/acre
10-yr	0.13 cfs/acre	0.23 cfs/acre	0.30 cfs/acre
25-yr	0.24 cfs/acre	0.41 cfs/acre	0.52 cfs/acre
50-yr	0.33 cfs/acre	0.56 cfs/acre	0.68 cfs/acre
100-yr	0.50 cfs/acre	0.85 cfs/acre	1.00 cfs/acre

Drain Time

12 to 24 hours for water quality control volume
No more than 72 hours for detention volume (extended release)
No more than 14 day for retention volume (no physical outlet)

Detention Volume by HYDROGRAPH METHOD

Peak Inflow = 1000 cfs.
Allowable Peak Release = 500 cfs.
Time to Peak Release = 50 min on the recession limb
Set the Linear Outflow Hydrograph as:

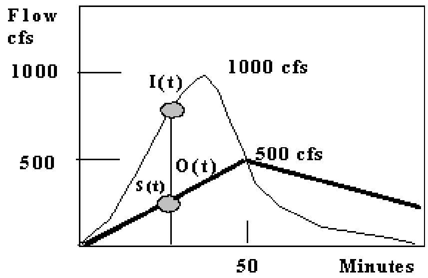
$$Q(t) = \frac{500}{50}t = 10t$$

(Outflow)

Use dt = 5 minutes to calculate the detention volume as:

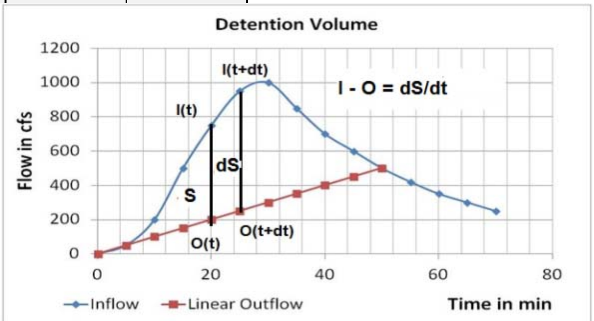
(Storage)

$$S(t) = \sum_{t=0}^{t=50}[I(t) - \frac{500}{50}t] \times (5 \times 60) / 43560$$

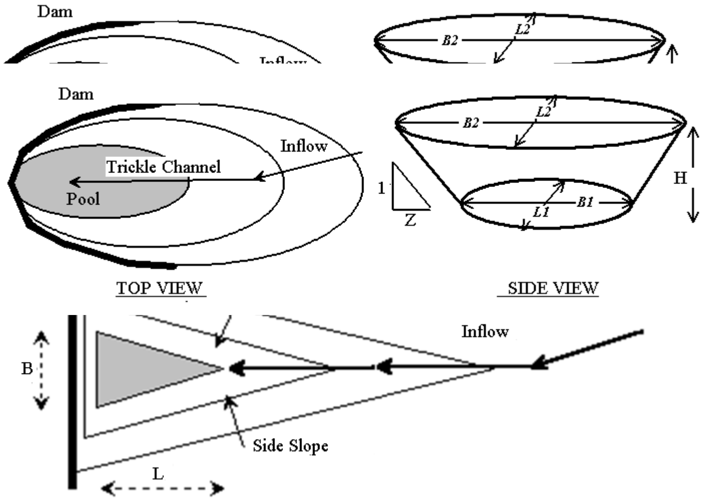


Time	100yr flow	Linear Outflow	Incremental Volume	Acc. Volume
min	cfs	cfs	acre-ft	acre-ft
0	0	0.0	0.00	0
5	50	50.0	0.00	0.00
10	200	100.0	0.69	0.69
15	500	150.0	2.41	3.10
20	750	200.0	3.79	6.89
25	950	250.0	4.82	11.71
30	1000	300.0	4.82	16.53
35	850	350.0	3.44	19.97
40	700	400.0	2.07	22.04
45	600	450.0	1.03	23.07
50	500	500.0	0.00	23.07
55	420	0.0		
60	350	0.0		
65	300	0.0		
70	250	0.0		

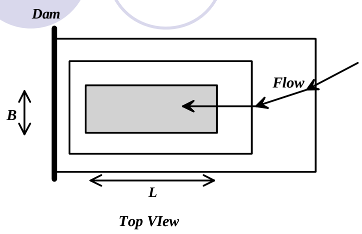
Example for Hydrograph Method

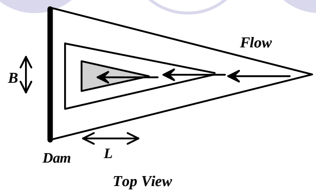


DB Pre-Shaping (Stage-Area-Volume)



DB Pre-Shaping (Stage-Area-Volume)





$$L_2 = L_1 + 2zH$$

$$B_2 = B_1 + 2zH$$

$A_2 = B_2 L_2$ for a rectangular shape

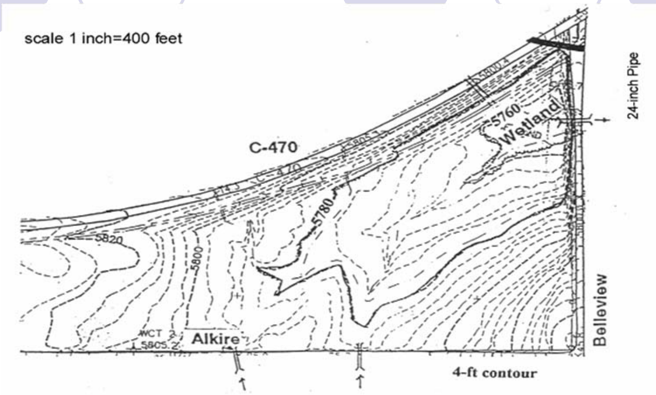
$A_2 = 0.5 B_2 L_2$ for a triangular shape

$A_2 = \dfrac{\pi B_2 L_2}{4}$ for an elliptical shape

$$V = \tfrac{1}{3}(A_1 + A_2 + \sqrt{A_1 A_2})H$$

Or $V = \dfrac{1}{2}(A_1 + A_2)H$

Final Grading (Stage-Area-Volume)



$$\Delta S_{i+1} = \frac{1}{2}(A_{i+1} + A_i)(h_{i+1} - h_i)$$

$$S(h) = \sum_{h=h_o}^{h=h} \Delta S_i$$

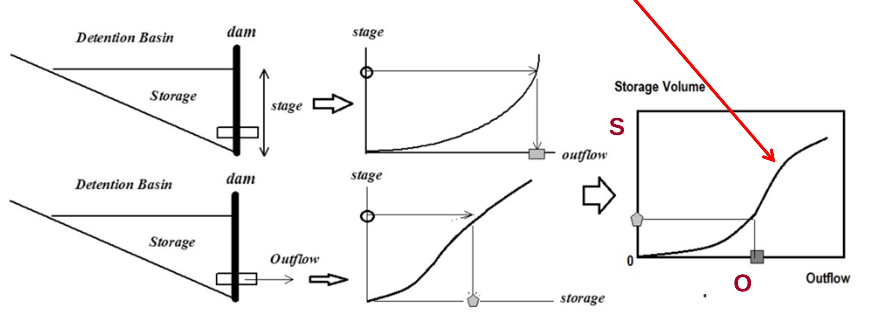
Stage-Storage and Stage-Outflow Curves

$$I - O = \frac{dS}{dt} \qquad \Delta t = 5\text{min}$$

$$\frac{I(t)+I(t+\Delta t)}{2} - \frac{O(t)+O(t+\Delta t)}{2} = \frac{S(t+\Delta t)-S(t)}{\Delta t}$$

$$S(t+\Delta t) = aO(t+\Delta t)^3 + bO(t+\Delta t)^2 + cO(t+\Delta t) + d$$

There are two unknowns: outflow rate, *O(t+dt)*, and storage, *S(t+dt)*, at time *t+dt*. As illustrated, both unknowns are related to stage, *h(t+dt)*.



Stage-Outflow Curve for Detention Basin

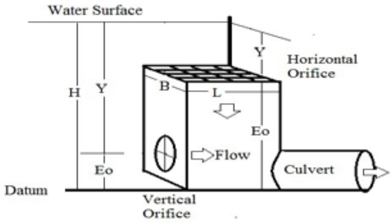
(1) ORIFICE and Overtopping WEIR – No backwater at all

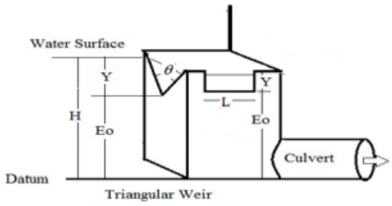
Weir Type	Cross Section Shape	Flow Formula
Transverse	Rectangular	$Qw=CwLH^{3/2}$
Side flow	Rectangular	$Qw=CwH^{5/2}$
V-notch	Triangular	$Qw=CwSH^{5/2}$
Trapezoidal	Trapezoidal	$Qw=CwLH^{3/2}+CsSH^{5/2}$

Cw = weir discharge coefficient, *L* = weir length, *S* = side slope of V-notch or trapezoidal weir, *h* = head difference across the weir, *Cs* = discharge coefficient through sides of trapezoidal weir.

(3) Culvert and Overtopping Weir --- Under a Backwater Effect

(4) User-defined stage-outflow curve --- special designs

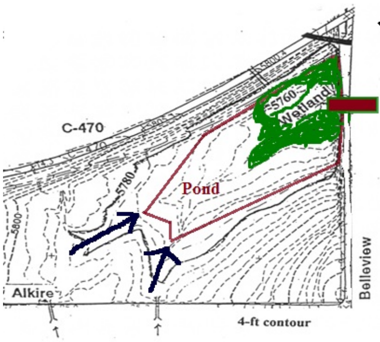


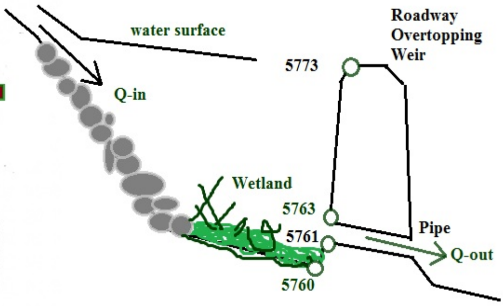


Types of Outlet Structures – Special Designs

Example: Wetland-Detention Basin

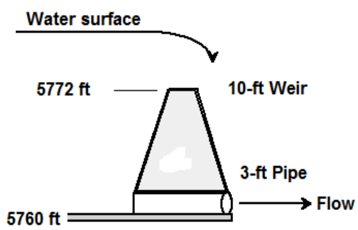
- A detention system is to designed and built near Interstate C470 and W. Belleview Avenue in the City of Denver, Colorado. The maximum water depth for this basin is 14 feet including one foot of freeboard. The bottom of this basin from elevation of 5760 to 5761ft is operated as a wetland. The invert of the box pipe (2x2 ft) for this basin is placed at elevation 5761 feet. The overflow weir is 20 ft wide and installed at elevation 5773 feet. The tributary watershed to this basin has a total area of 187 acres, slope of 2.0%, and imperviousness of 53%.



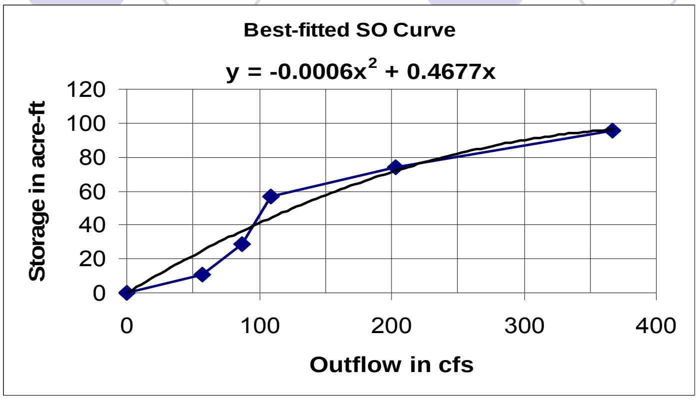


Stage-Storage-Outflow Curve for Belleview DB

Stage elevation Ft	contour area acre	accumulated volume acre-ft	water depth ft	orifice flow cfs	weir flow cfs	Total Outflow cfs
5,760.00	1.77	0.00	0.00	0.00	0.00	**0.00**
5,764.00	3.45	10.44	4.00	56.48	0.00	56.48
5,768.00	5.83	29.00	8.00	91.07	0.00	91.07
5,772.00	8.02	56.70	12.00	115.74	0.00	115.74
5,774.00	9.60	74.32	14.00	126.28	84.85	211.14
5,776.00	11.30	95.22	16.00	136.01	240.00	376.01



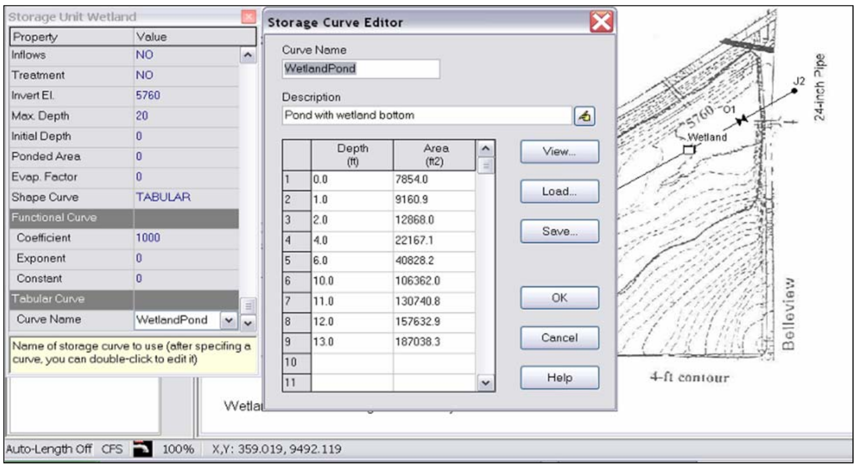
Example for Reservoir Routing Scheme



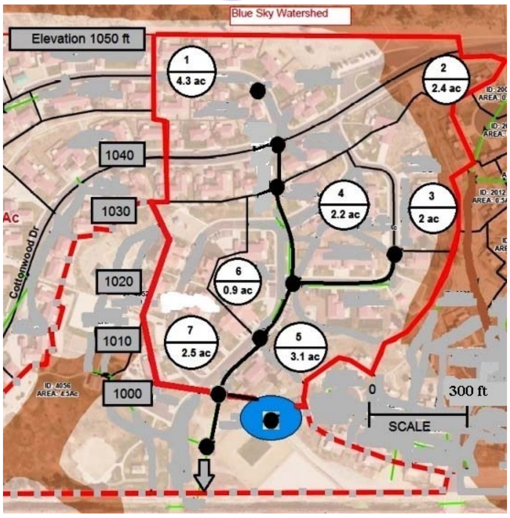
$$S = -0.0006\,O^2 + 0.4677\,O \qquad \Delta t = 5\text{ min}$$

$$\frac{I_1 + I_2}{2} - \frac{O_2 + Q_1}{2} = \frac{43560}{300}\left[(-0.0006\,O_2^{\,2} + 0.4677\,O_2) - S_1\right]$$

Stage-X Area Curve for DB



Workshop on Detention Basin



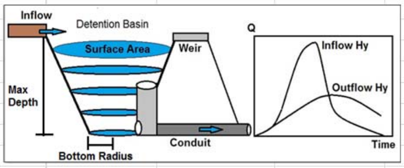
Build a detention KW and DW model. The maximum allowable release from this area is set to be 6 cfs. Use the following contours to model the detention basin located at the outfall point.

The outfall conduit is set to be a concrete box culvert with its invert at 0.5 foot above the basin floor (try BCB with HxB=0.5x1.0-ft).

A 10-ft weir will be installed on the top of the dam at 6 feet above the basin floor. Verify that the given detention basin works.

Detention Basin In SWMM

Stormwater Detention Pond -- Pre-sizing and Pre-shaping



Pond Bottom Radius	40.00	ft
Pond max depth	6.00	ft (including freeboard)
Incremental depth	1.00	ft

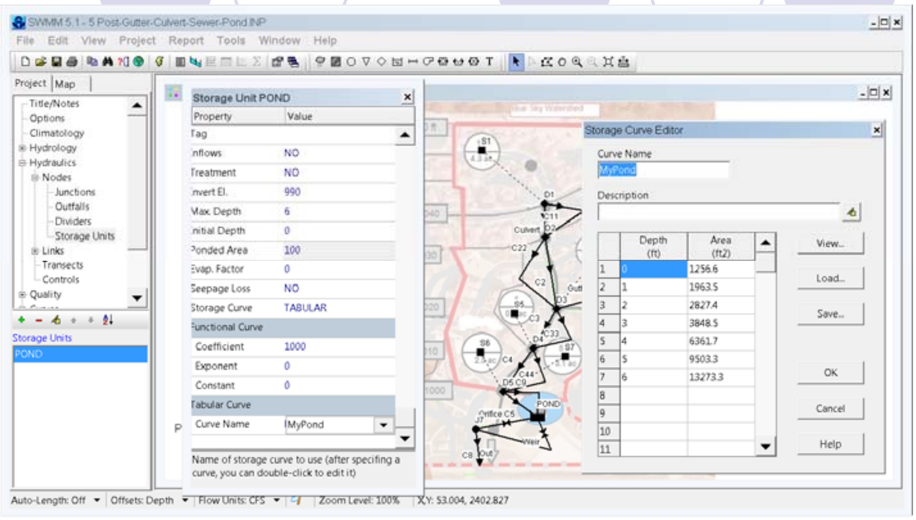
Enter pond's side slope

Water Depth ft	Side Slope ft/ft	Equivalent Diameter ft	X-section Area Sq ft	Storage Volume Acre-ft
0.00	5.00	40.00	1256.6	0.00
1.00	5.00	50.00	1963.5	0.04
2.00	5.00	60.00	2827.4	0.09
3.00	5.00	70.00	3848.5	0.17
4.00	10.00	90.00	6361.7	0.29
5.00	10.00	110.00	9503.3	0.47
6.00	10.00	130.00	13273.3	0.73

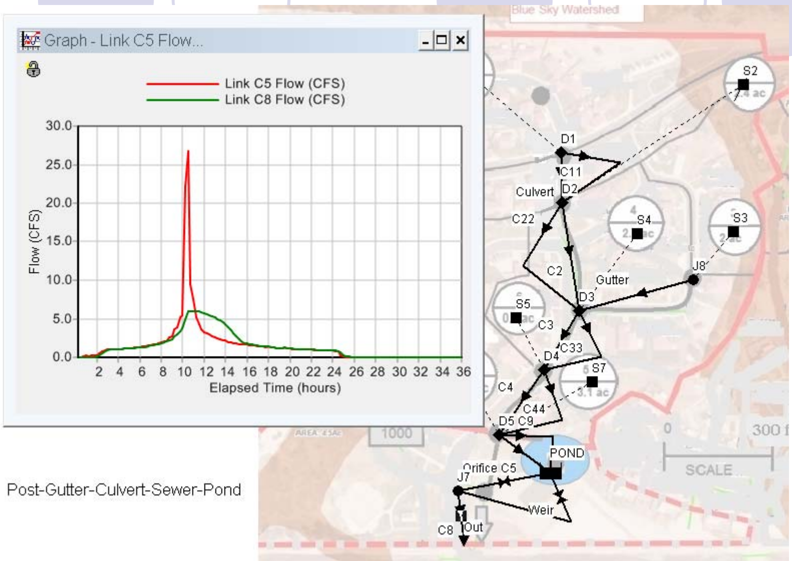
Data for SWMM
POND stage-area curve
Copy rows up to max depth

Water Depth ft	X-section Area Sq ft
0.00	1256.6
1.00	1963.5
2.00	2827.4
3.00	3848.5
4.00	6361.7
5.00	9503.3
6.00	13273.3

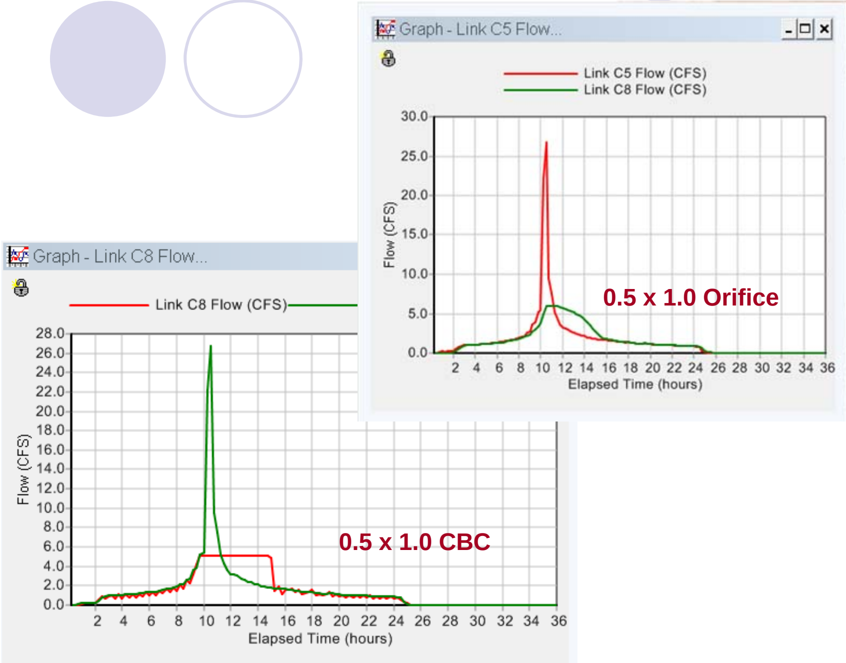
Detention Basin with Orifice and Weir



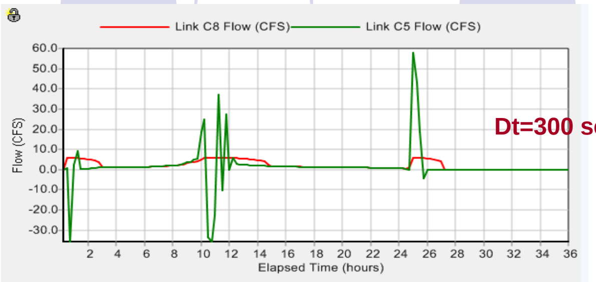
Preservation of pre-Q100 peak flow

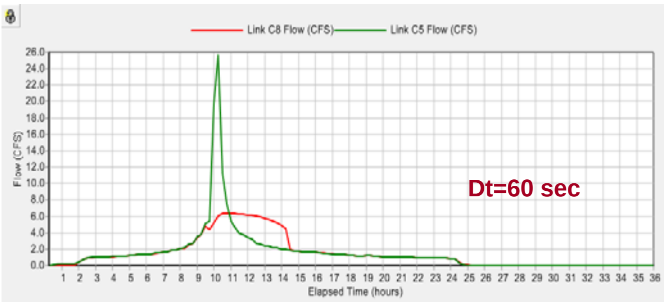


Post-Gutter-Culvert-Sewer-Pond



Instability of DW with respect to Δt used in computation

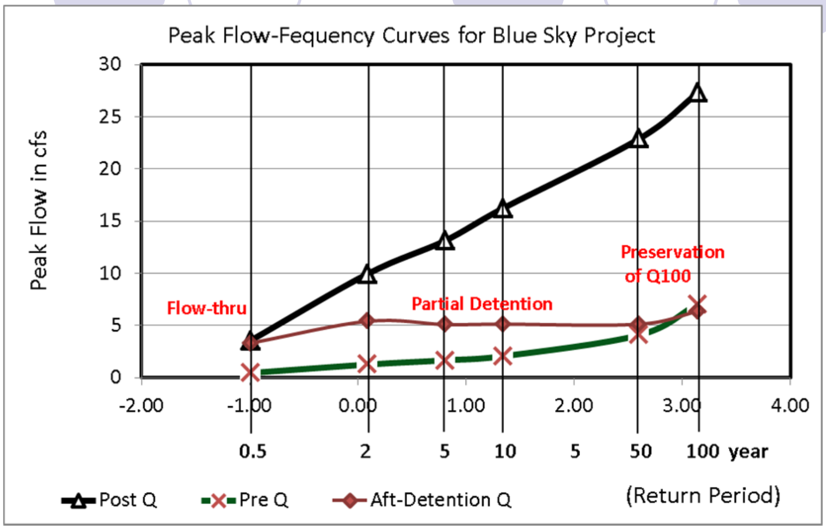




Workshop on Detention Basin Modeling

- ❑ Build pond-orifice-weir KW model
  - Numerical stability problem
  - Tailwater problem
- ❑ Build pond-culvert-weir DW model
  - Backwater problem
- ❑ Build drop-Inlet channel-pond-outlet model
  - **remove double counting storage volumes**
  - **remove backwater storage volumes**
- ❑ Build pond-SSO curve DW model
  - stage-storage-outflow curve defined by the user
- ❑ Introduce the necessary evaporation rates to the pond
- ❑ Add an infiltration loss to the pond operation
- ❑ Long-term simulation if wet land involved.
  - use the 12 monthly evaporation rates
  - infiltration without a liner at the pond bottom

Effectiveness of Detention Basin



Q and A:

Underground
Detention
in Japan

FOR MORE INFORMATION

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WWW.UCDENVER.EDU/~Jguo -- Website
WWW.UDFCD.ORG -- Free Software
WWW.URBANWATERSHEDS.ORG – Training Classes

Water Marks in a Detention Basin