Modifications to CUHP 05

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Storm Water Approaches

- **Linear versus Nonlinear**
  Rational method vs Hydrograph method
- **Lumped versus Distributed**
  Single watershed vs Several subareas
- **Deterministic versus In-deterministic**
  Constant soil infiltration vs Soil antecedent moisture
- **Statistic versus Stochastic**
  Independent event vs dependent event in time series
- **Event-based versus Long-term Simulation**
  100-yr flow prediction vs reservoir operation
- **Annual Series versus Complete Data Series**
  Extreme, partial, and complete data series
- **Small Watershed versus Large Watershed**
  Point rainfall depth vs Area average with a reduction
- **Others**

Storm Water Models

- **Physical Model -- Laboratory Data**

  Laboratory test -- shower + sprinkler man-made rainfall

  Major problem: scale effect in laboratory settings
- **Probabilistic Model -- Historical Data**

  Time-dependent vs Time-independent

  Homogeneous vs Non-homogeneous data

  Major problem: watershed continuous development
- **Empirical Model - Local Data**

  Regional analysis for a hydrologic zone ($Q = a A^b S^c$)

  Major problem: how to generalize the local empirical formula
- **Numerical Model - Numerical Data**

  A. Unit Hydrograph

  B. Kinematic Wave (KW) Overland Flow

  Numerical models provide consistent predictions among events and various watershed conditions, and can be calibrated for accurate predictions.

Unit Hydrograph Approach - field data

- **Definition** (Sherman 1932) -- release from 1-inch shallow, flat reservoir

  UH is the watershed outflow (Q vs t) resulting from 1-inch or 1-cm of uniform rainfall excess over the watershed area (A) for a specified rainfall duration (D)

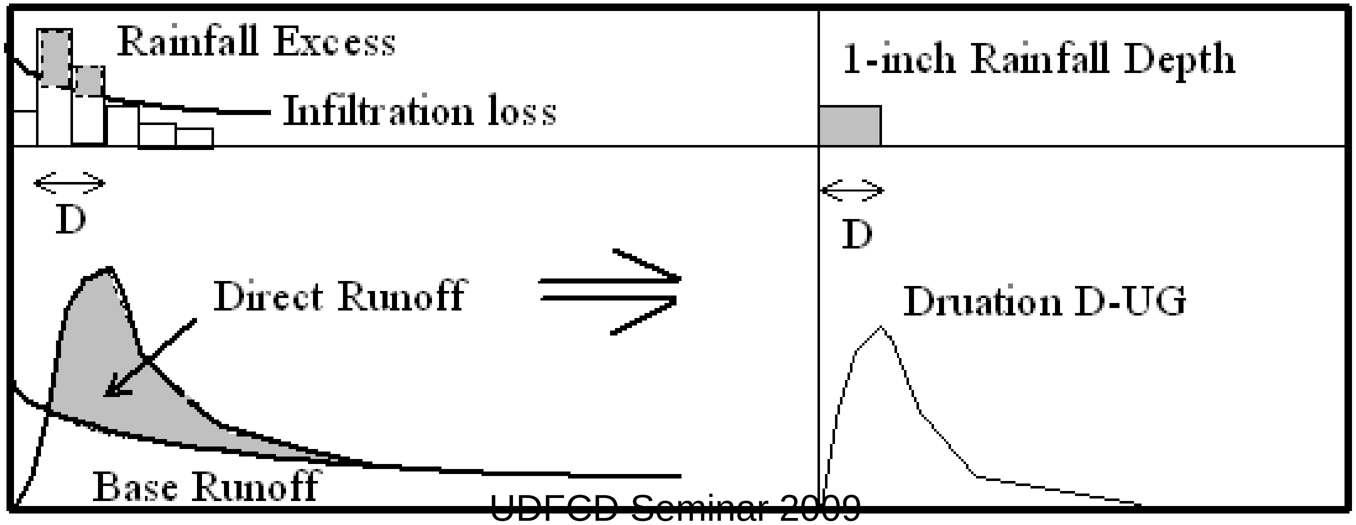
- **Problems in Practice**

  How to determine the rainfall excess (soil loss? base flow?)

  What if there existed a lake for storage effect?

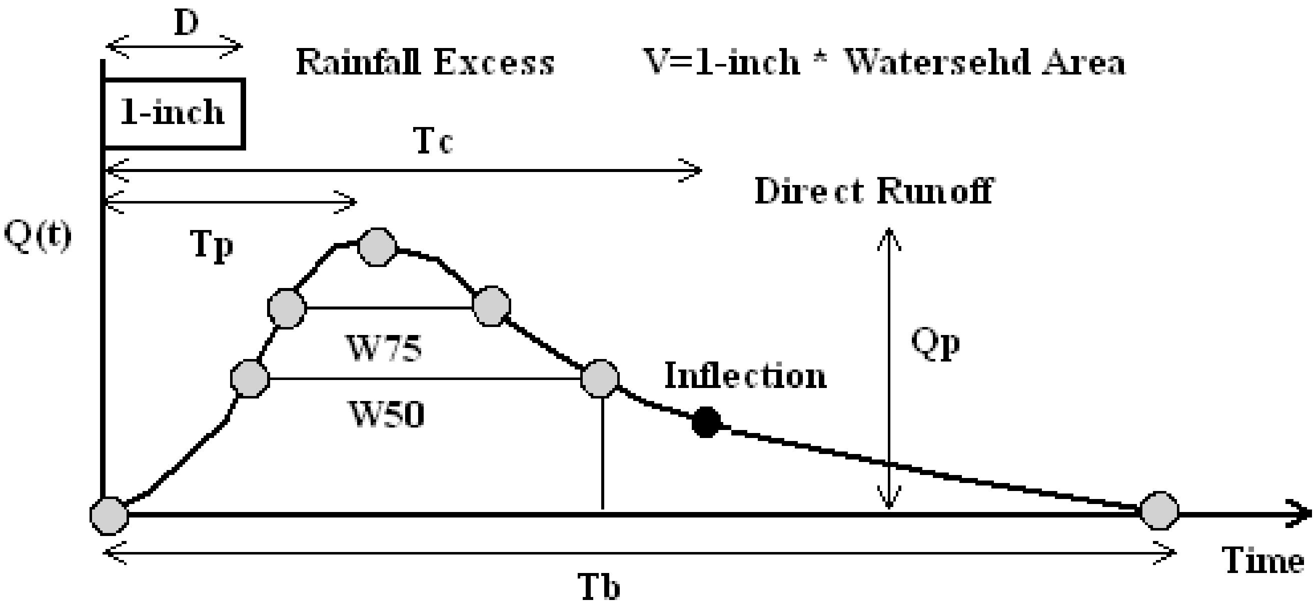
  What if there existed a flow diversion?

- **Major problem in this approach is that the historical data CANNOT represent the urbanized watershed for the future !**



Synthetic UH Methods - regression analysis

- **Snyder UH method** (Snyder 1938) was derived to apply empirical formulas to predict a unit hydrograph using six points based on the watershed drainage characteristics, including A, S, L, and Lc.
- **Problems**: how to define design rainfall, loss function, and urbanization impacts.



Major Developments in Synthetic UH

SCS UH method (1964) --- **Rural Unit-graph method**

It was calibrated using large rural watersheds. SCS-TR20 empirical UH formulas can work with 6- and 24-hr rainfall distributions, curve number loss functions, and SCS flow time through the watershed. In the 1980s, SCS-TR55 was an effort to add urbanization impact into the SCS procedure.

CUHP method (1970) --- **Urban Unit-graph method**

It was derived as the Colorado Unit Hydrograph Procedure for the Denver metro areas. The major improvement to the UH method is to add "watershed development condition, i.e. **imp %**" into the empirical formulas. Horton's formula is used to estimate the soil loss. CUHP applies an event-based lumped-parameter approach to areas from 1 to 3000 acres. For watersheds larger than 10 sq miles, the 2-hr design rainfall curve can be extended to 6 hours with consideration of NOAA's rainfall depth-area reduction factors.

Challenges in CUHP Method

Model Development

1. How to set up consistent hydrologic loss function -- C, Imp%, and fc-fo

3. How to correlate the IDF curve with the design rainfall distribution?

4. How to define small watershed to agree with the Rational method?

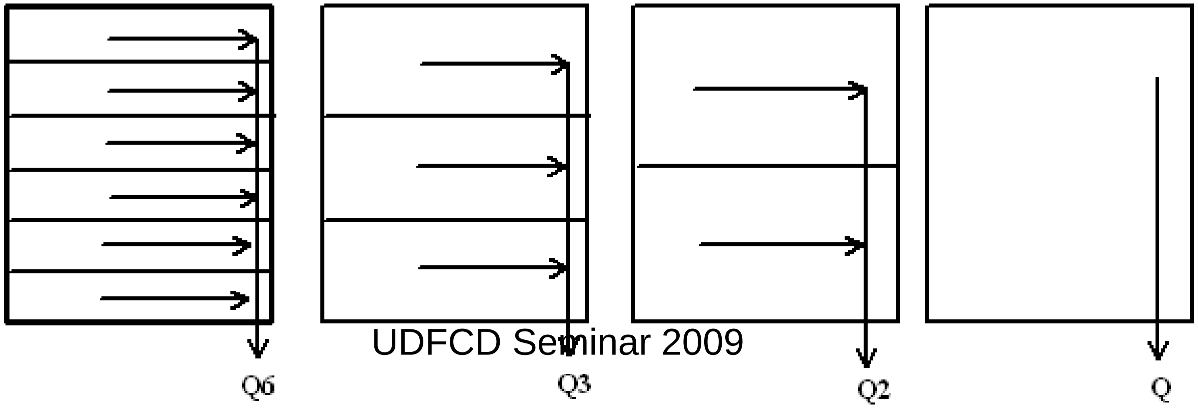
5. How to define large watershed to apply the Point-Depth-Area-Reduction-Factor (DARF) to storm centering?

6. How to quantifiably evaluate the various BMP practices? (Levels 0, 1, 2)

7. How to divide a large watershed into subareas? Q6>Q3>Q2>Q

Model Calibration

Monitoring urban catchments for gage data collection and analyses



CUHP 2000 vs CUHP 2005

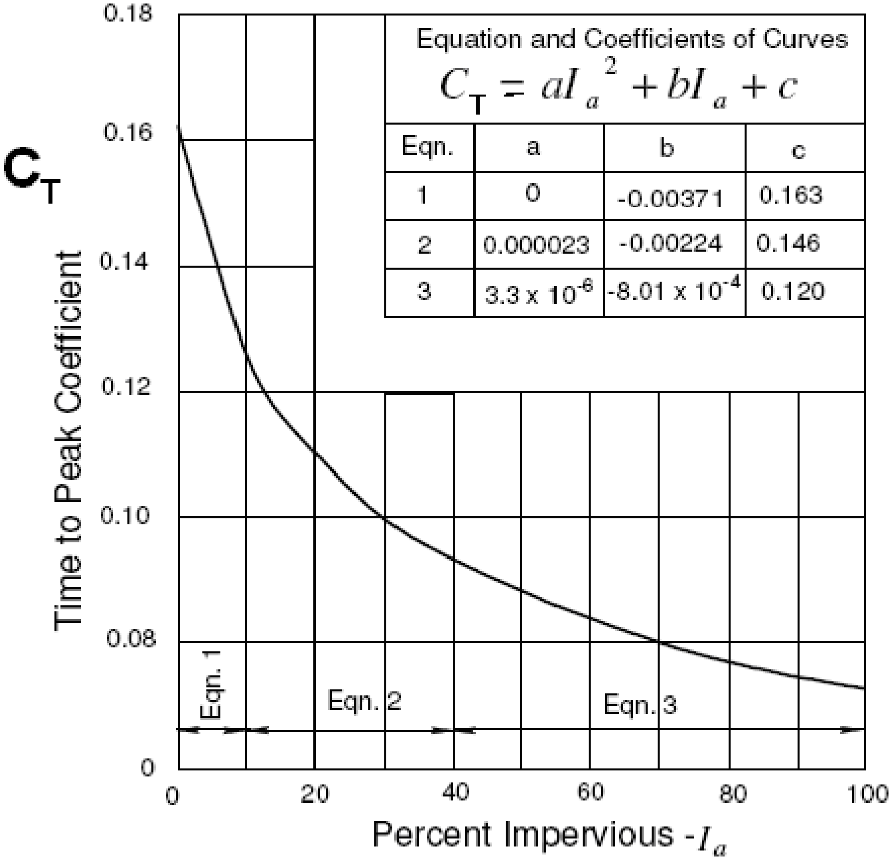
- Definition of small watershed -- 90 acres
- Tc versus Tp -- empirical formulas
- User-defined time of concentration versus regional time of concentration
- Runoff coefficients -- EPA field data versus CUHP calculation
- Stormwater BMP - Levels 0, 1, and 2
- Empirical D and R curves
- Watershed Runoff between CUHP05 and SWMM05
- Waterway Routing between SWMM05 and UDSWMM2000

Peak Time Coefficient C_t In CUHP2000

The time to peak for the unit-graph is calculated as (USDCM 2001):

$$t_p = C_T \left(\frac{LL_{cs}}{\sqrt{S}} \right)^{0.48}$$

C_T is related to the flow time through the watershed. It decreases when watershed imperviousness increases. On the other hand, C_T increases when watershed size increases. Therefore, the empirical formula for C_T used in CUHP 2000 is modified to include watershed area as a parameter.



Equation and Coefficients of Curves

$$C_T = aI_a^2 + bI_a + c$$

Eqn.	a	b	c
1	0	-0.00371	0.163
2	0.000023	-0.00224	0.146
3	3.3×10^{-6}	-8.01×10^{-4}	0.120

Peak Time Coefficient C_t Modified in CUHP05

The time to peak for the unit-graph is calculated as (USDCM 2001):

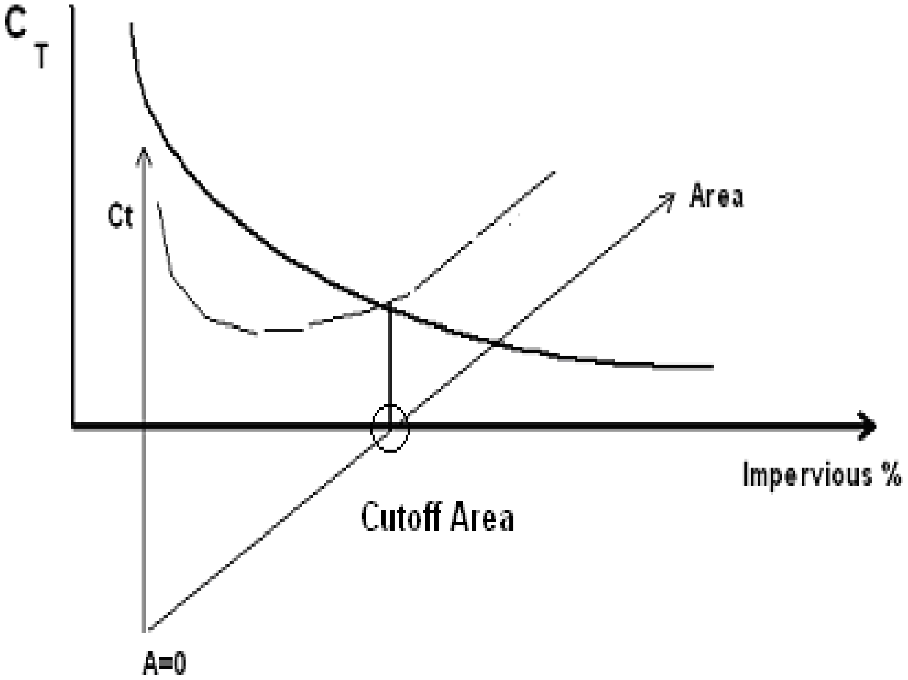
$$t_p = C_t \left(\frac{L L_{CS}}{\sqrt{S}} \right)^{0.48} \quad \text{and} \quad C_t \geq C_T$$

as a function of imperviousness

$$C_t = C_T$$

as a function of area

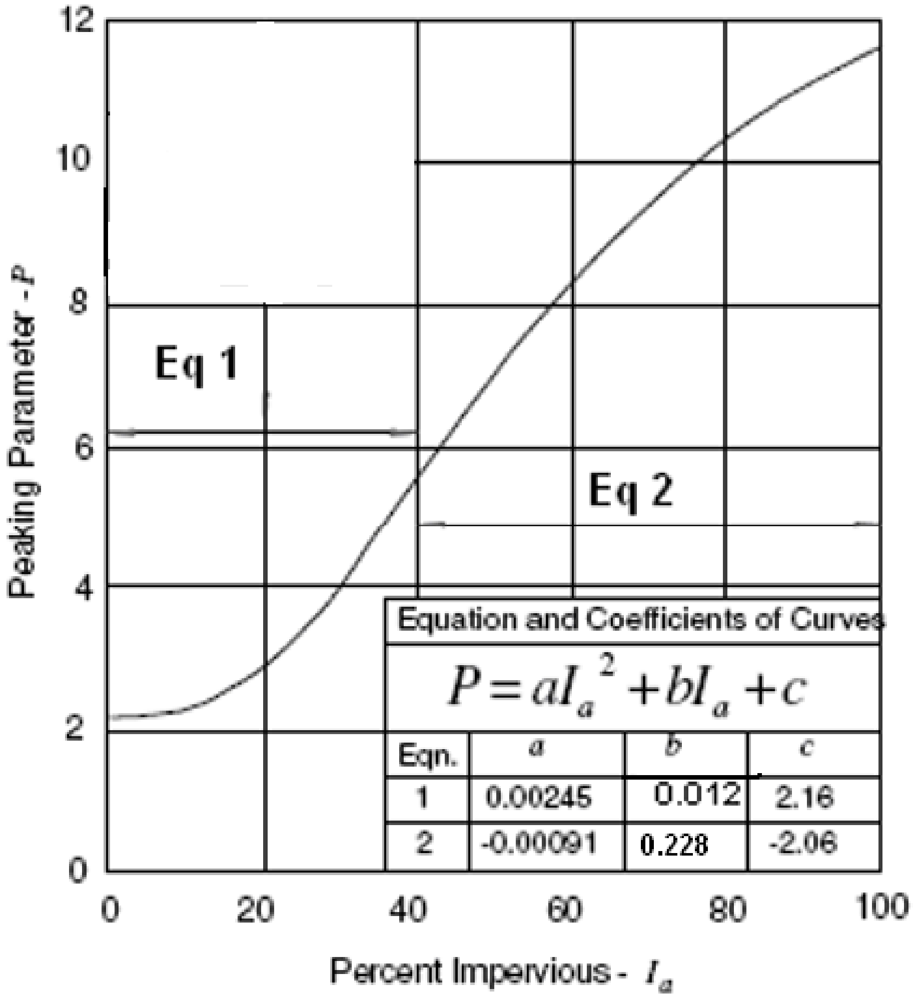
$$C_t = C_T (0.65 A^{-0.31})$$



Peak Parameter C_p Modified in CUHP05

The unit-graph peaking coefficient, C_p, reflects the watershed development or a function of imperviousness.

$$C_p = P C_T A^{0.15}$$

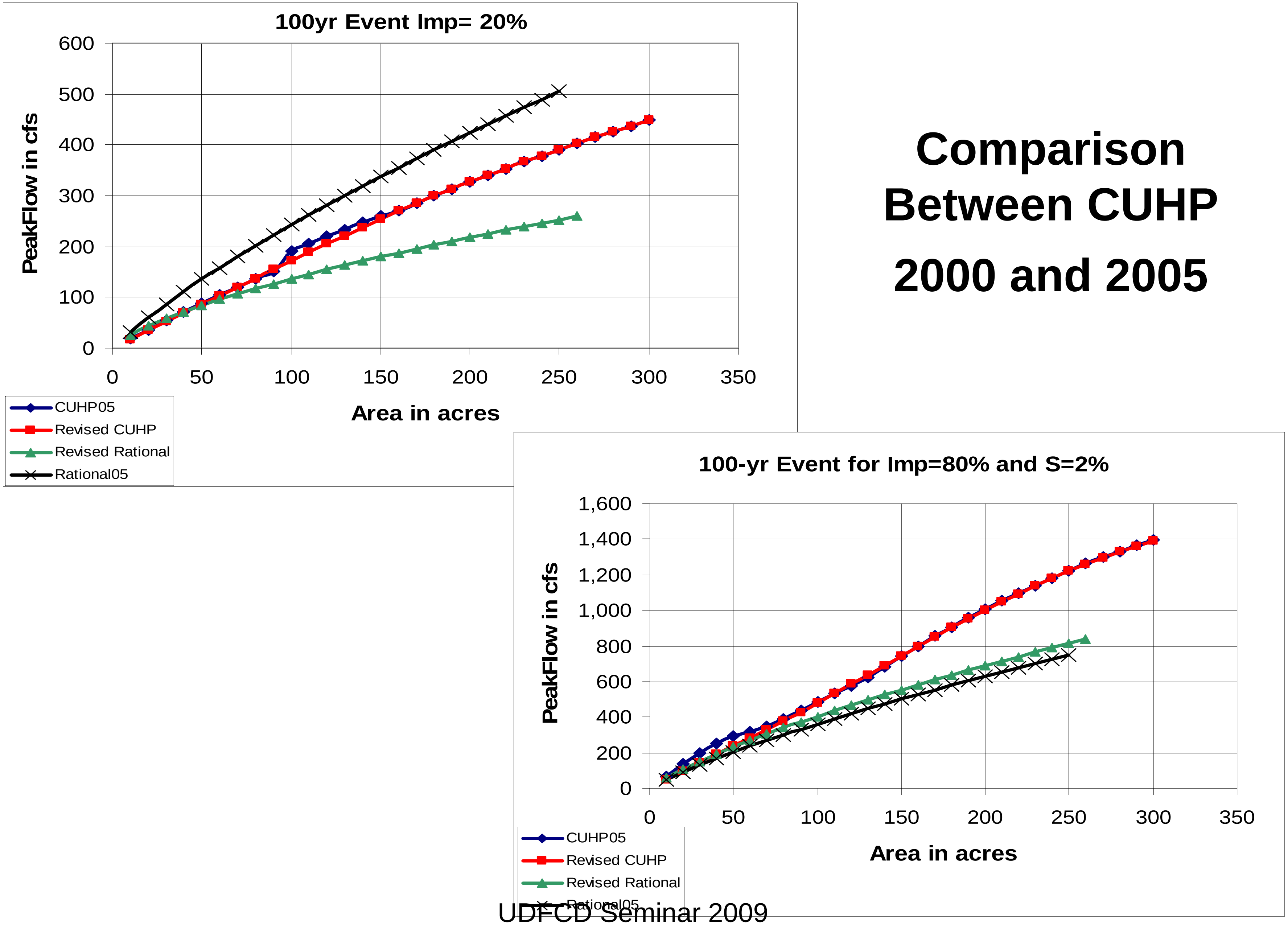


Equation and Coefficients of Curves

$$P = aI_a^{\,2} + bI_a + c$$

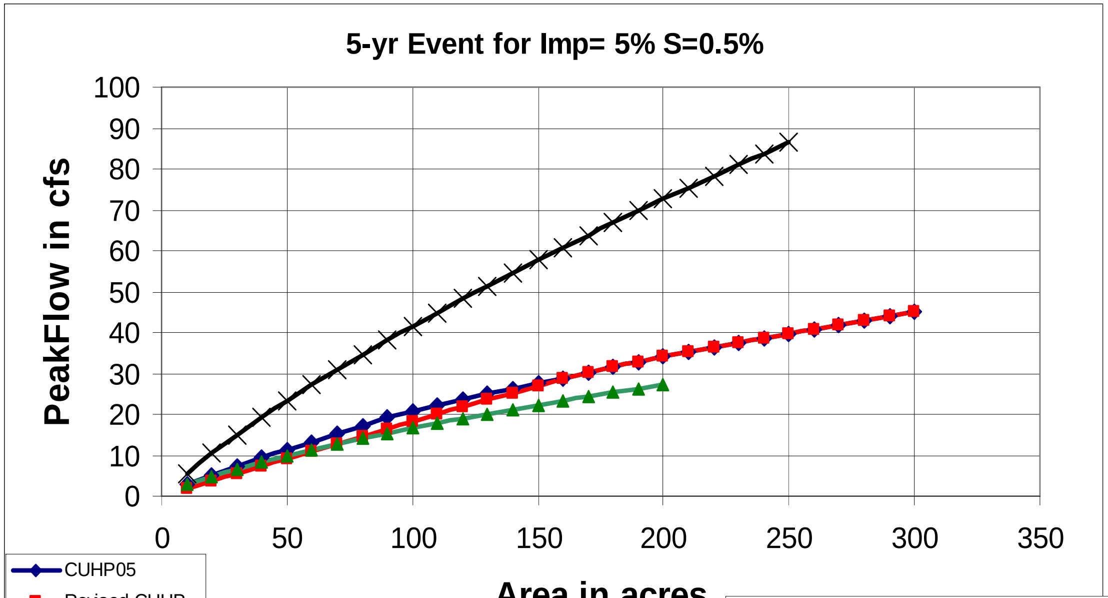
Eqn.	*a*	*b*	*c*
1	0.00245	0.012	2.16
2	-0.00091	0.228	-2.06

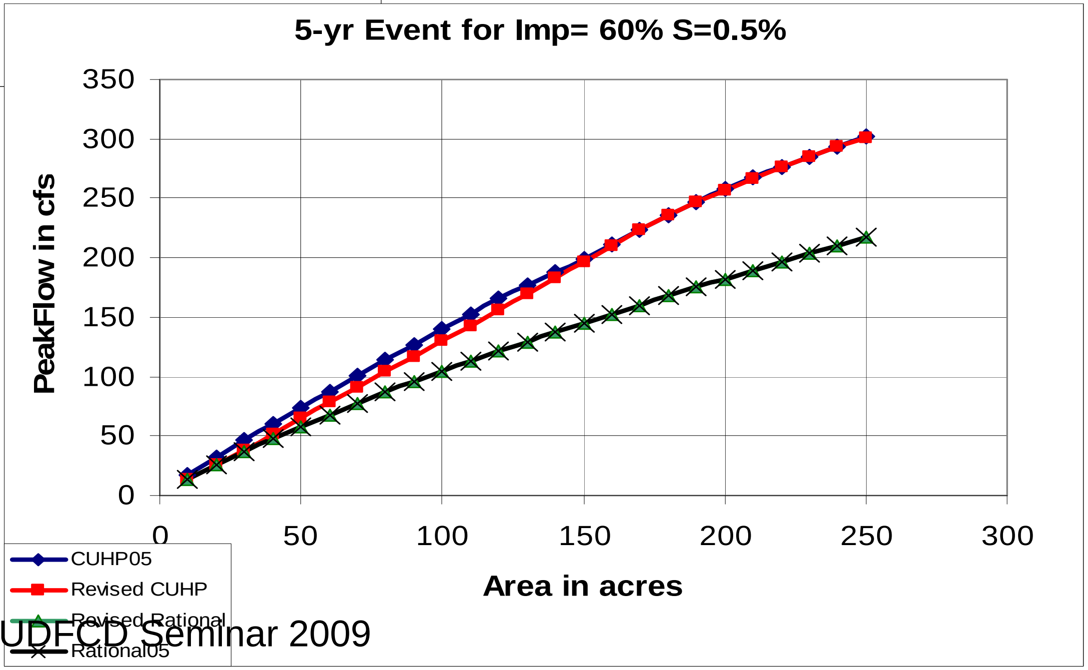
Comparison Between CUHP
2000 and 2005



Comparison with Rational Method

-- more work to do





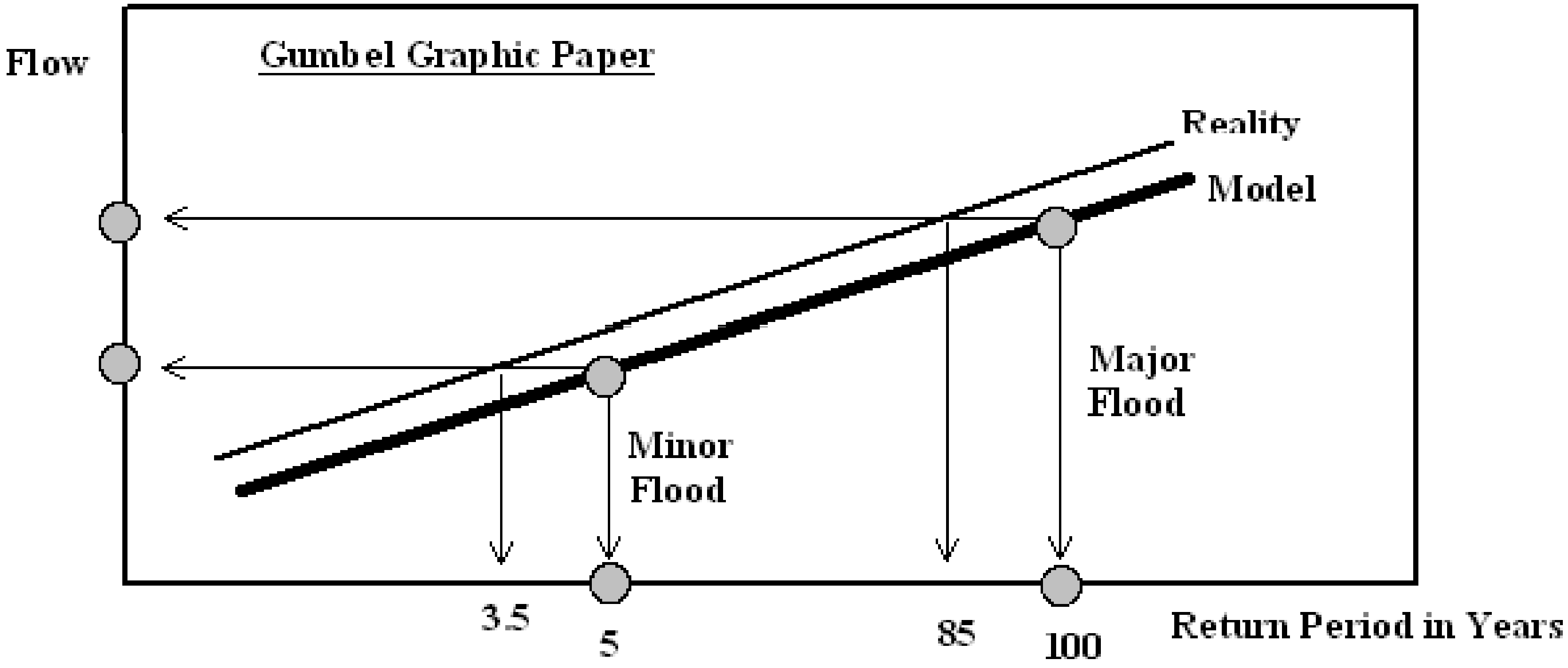
Watershed Discretization

The test square watershed has a total area of 300 acres on a slope of 2.0% and imperviousness of 40%. Four cases were developed for testing. They are:
Case 1. The watershed is divided into **6 sub areas of 50 acres**
Case 2. The watershed is divided into **3 sub areas of 100 acres**
Case 3. The watershed is divided into **2 subareas: 200- and 100-acre**
Case 4. The watershed is modeled as **a 300-acre single tributary area**
All sub-areas are modeled as a square with a diagonal waterway on a 2.0% slope. Between sub-areas, the channel was defaulted to be a 5-ft trapezoidal channel of 500-ft in length.

Cases	CUHP2005-now Q in cfs	CUHP2005-revised Q in cfs	Comments
Six Areas of 50 acres	947	761	six small basins
Three Areas of 100 acres	885	763	a small + a large basin
Two Areas of 200 and 100 acres	833	793	mixed sizes
Single Area of 300 acres	718	718	a large basin

Cheers !

CONCLUSION



Inherent inaccuracy in a computer model will 'SHIFT" the level of risk
Random procedure to use a computer mode "OFF-SETs" the level of risk

Since it is necessary and inevitable to continuously improve CUHP, UDFCD will have to trace this progressive process.

END for KW Review Session

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