A Tale of Two Storms

How Understanding Your Collection System's Wet Weather Flows Affects Capital Upgrade Costs

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Introduction

1. This presentation will depict “a tale of two storms”.

2. Highlight the challenges that antecedent moisture effects presents in modeling wet weather flows.

3. Critical to understand the wet weather flows in your system, because of the significant impact they have on wet weather capital upgrade costs.

4. Some basic methodologies have been implemented, but we do not believe that they perform satisfactorily, given the costs of wet weather capital improvements involved.

5. Presentation highlights alternative methodologies that are more accurate and can save money.

Tale of Two Storms

Both storms are real data from the same sewershed

Storm #1 - Dry Conditions

- Bigger of two rains
- Occurs on dry ground conditions, such as might occur after several preceding dry days or during dry summer conditions
- Results in lower peak flows
- Results in a lower capture volume of the rain water

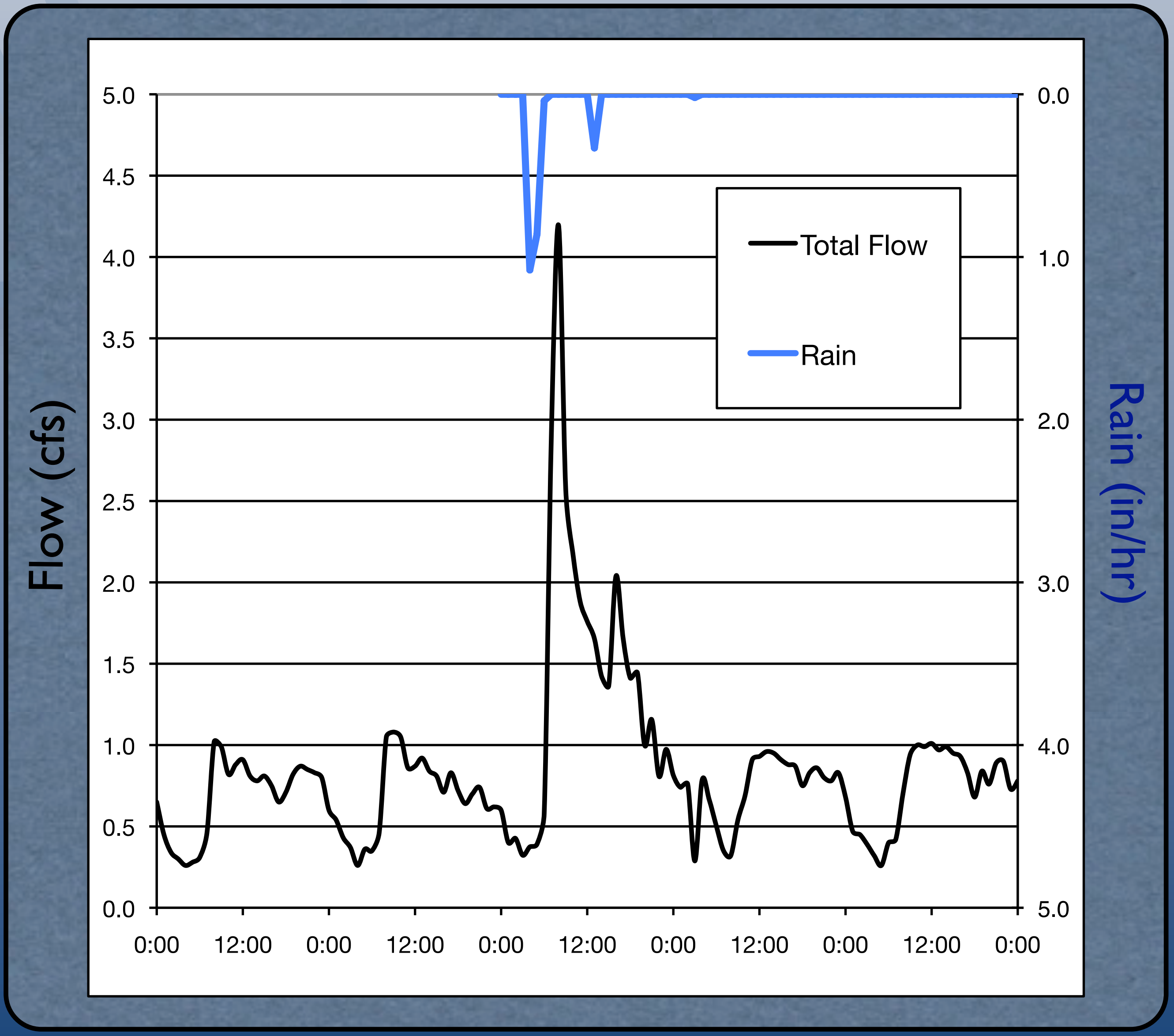
Storm #2 - Wet Conditions

- Smaller of two rains
- Occurs on wet ground conditions, such as might occur after several preceding wet days or during the early spring.
- Results in higher peak flows
- Results in a higher capture volume of the rain water

Storm #1 - Summer Event

2.33" rain in 10 hours
1.94" occurred in 2 hours
1.08" peak hour rain

Average DWF = 0.4 cfs
Peak flow = 4.2 cfs
Peaking factor = 10.5

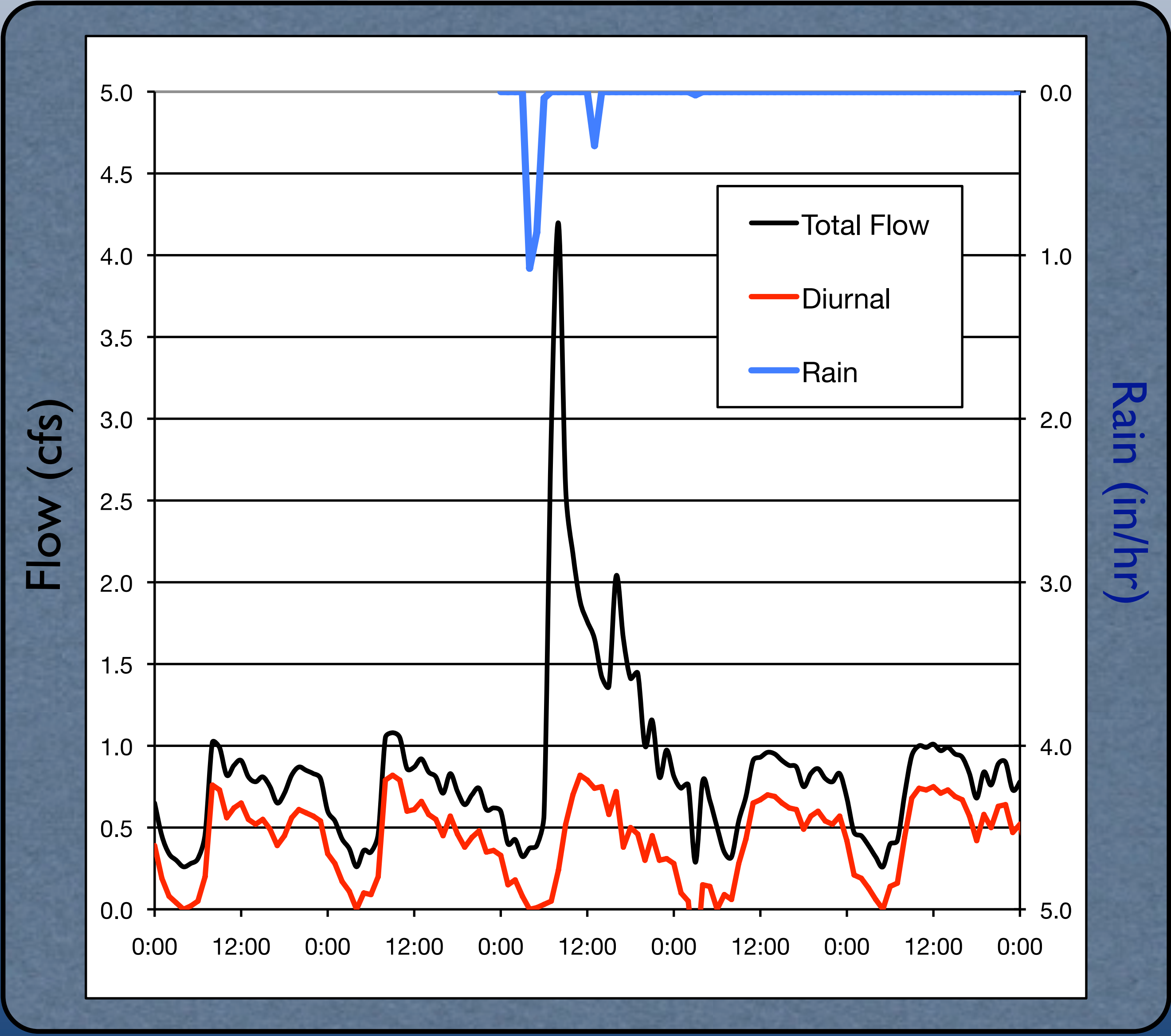


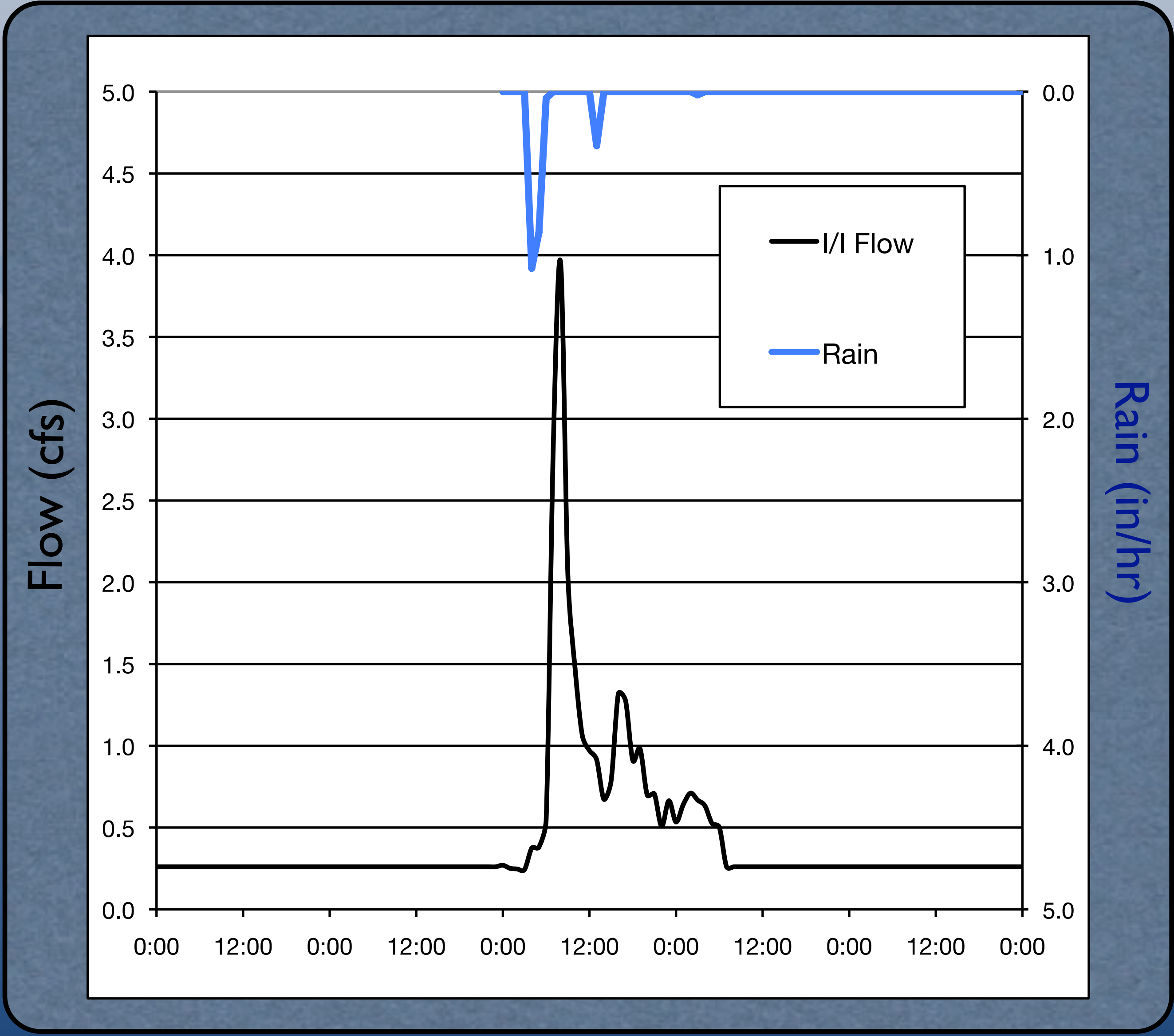
Storm #1 - Filter Diurnal Flow

Identify diurnal pattern (red line)

Subtract diurnal to extract I/I

Flat lines before / after storm are ground water infiltration

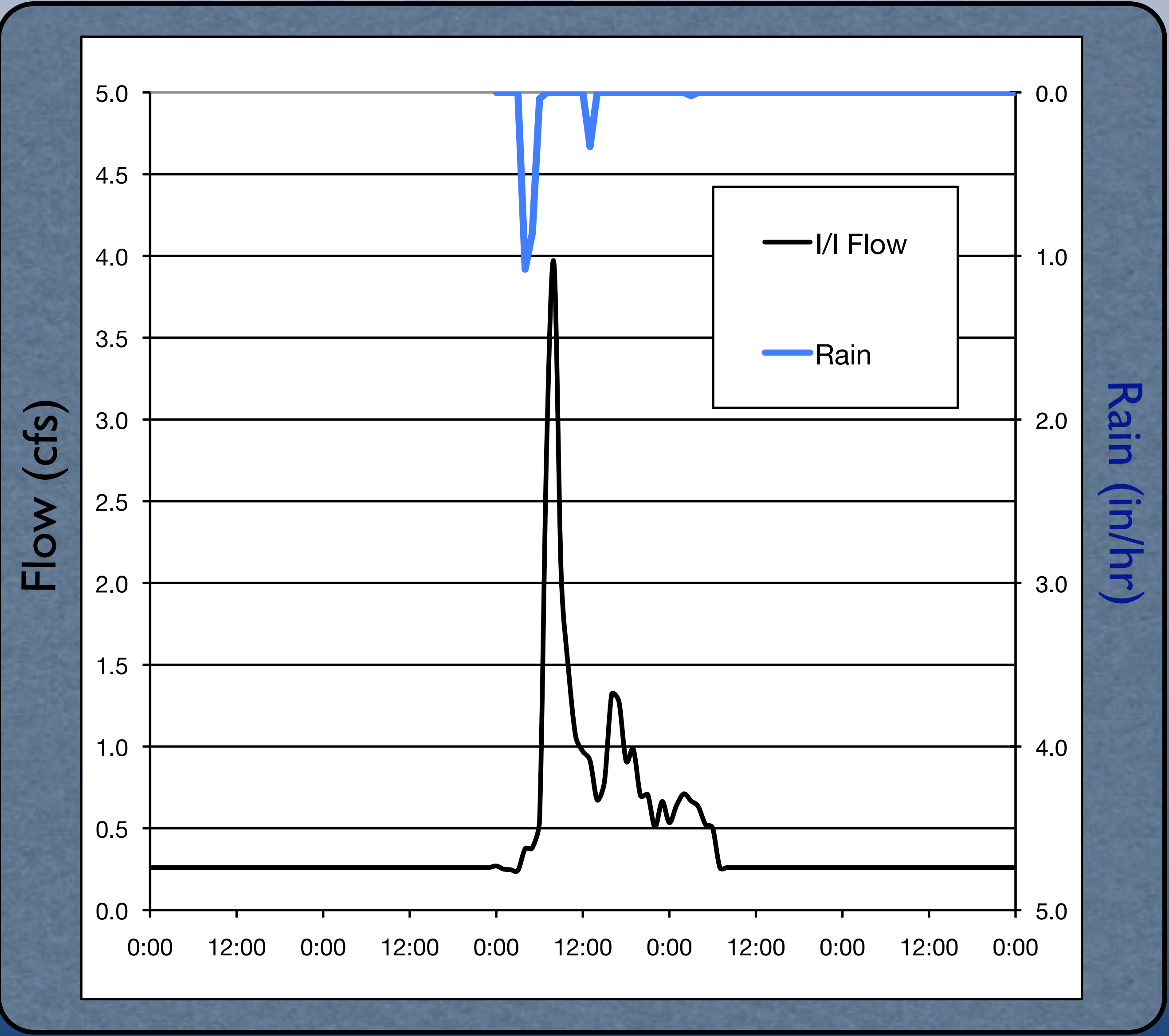


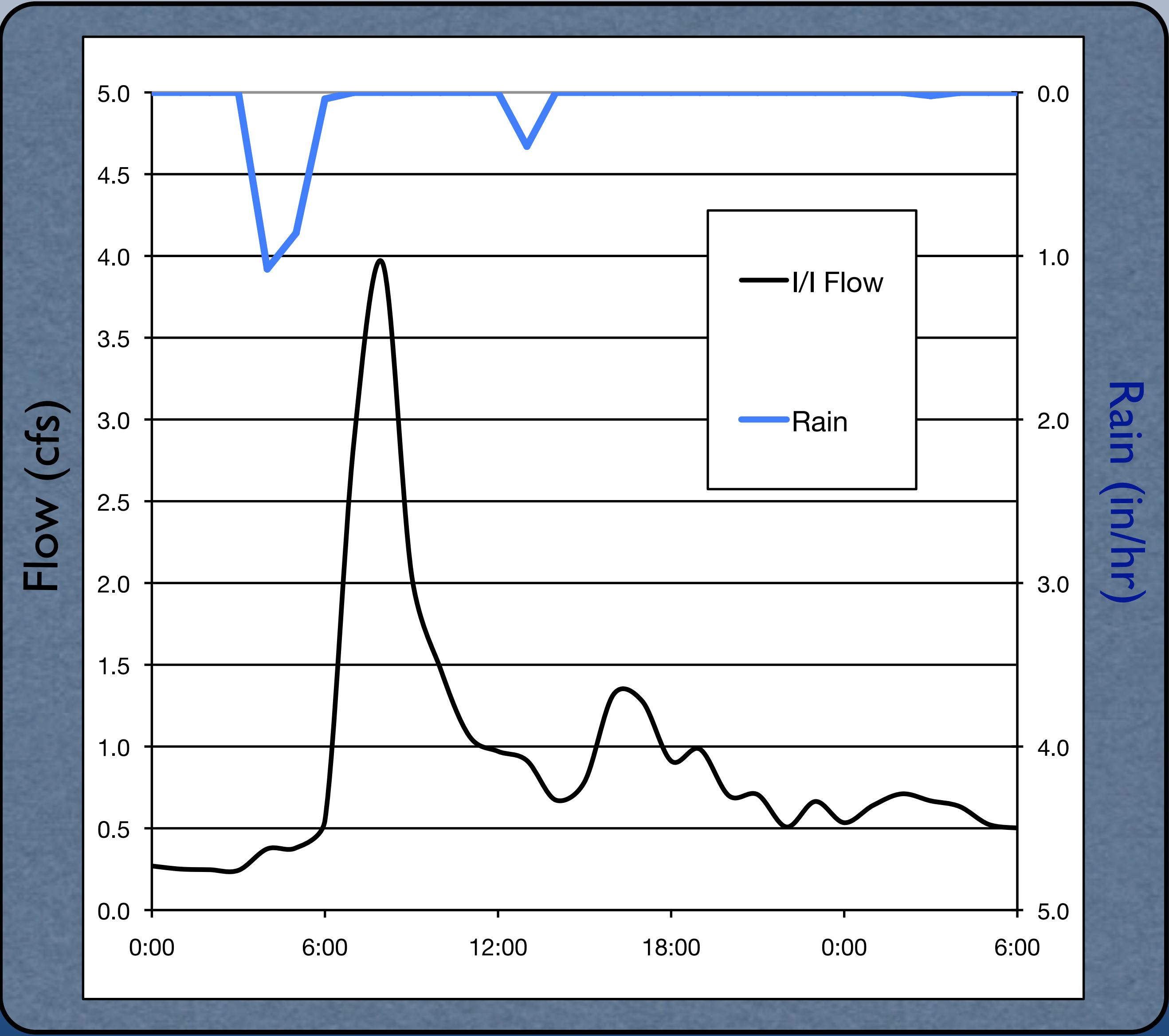


Storm #1 - Summer Event

I/I flow after diurnal extraction

Zoom in to storm to better see the dynamics





Modeling Procedure

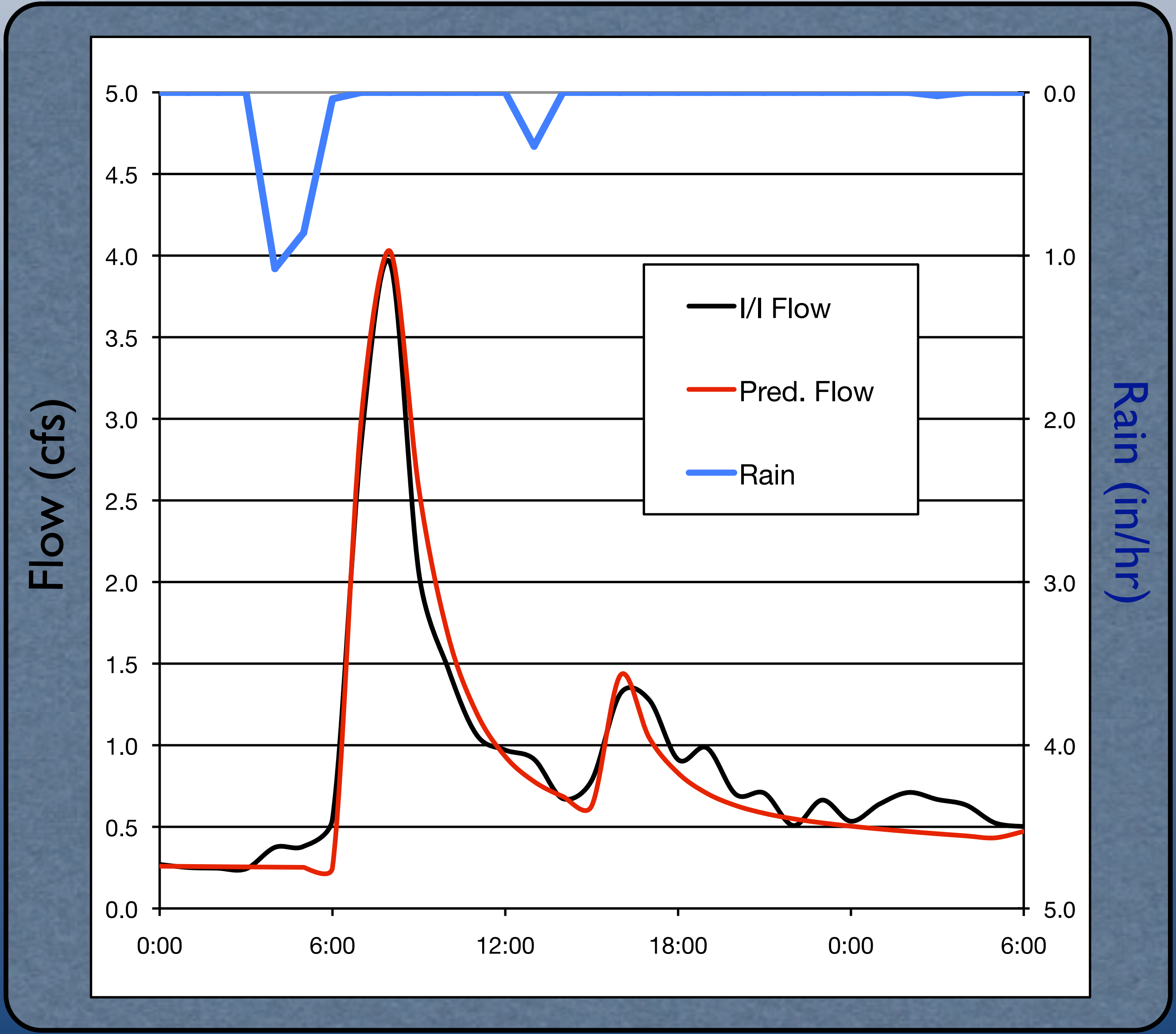
1. Calibrate an "event model" to the observed storm event (RTK, SCS, SWMM Runoff, etc.)
2. Run the calibrated model for other observed storm events
3. Validate the model through model performance on other observed storms
4. Use the model to extrapolate to a design rainfall event

- Very commonly used method
- Validation step provides confidence to decision makers
- Its the way many of us were trained to perform modeling

Storm #1 - Model Development

Red line shows "event model" calibration

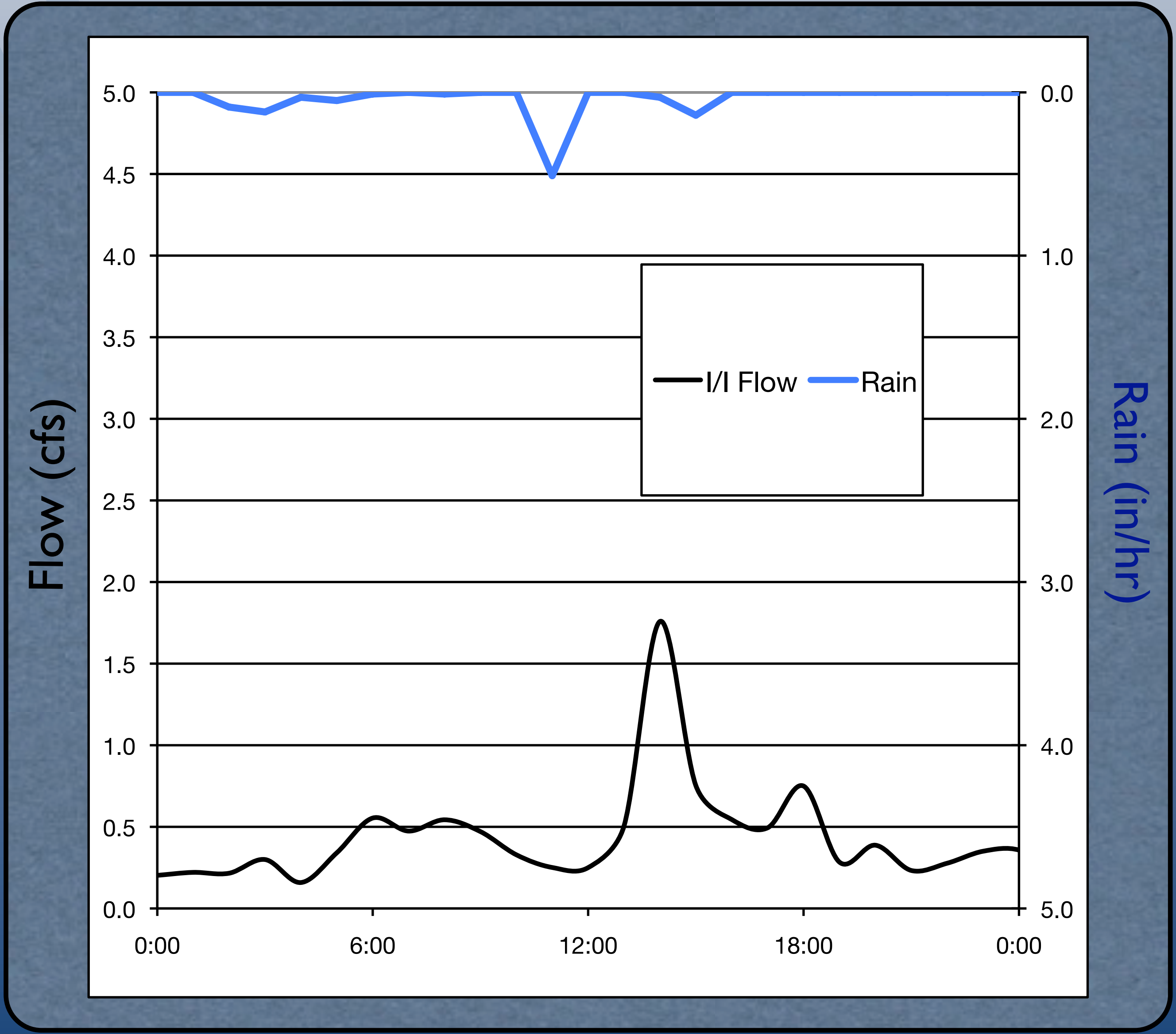
Calibration able to achieve high accuracy fit



Model Validation

Storm occurred in summer
0.99" rain in 10 hours
0.51" peak hour rain

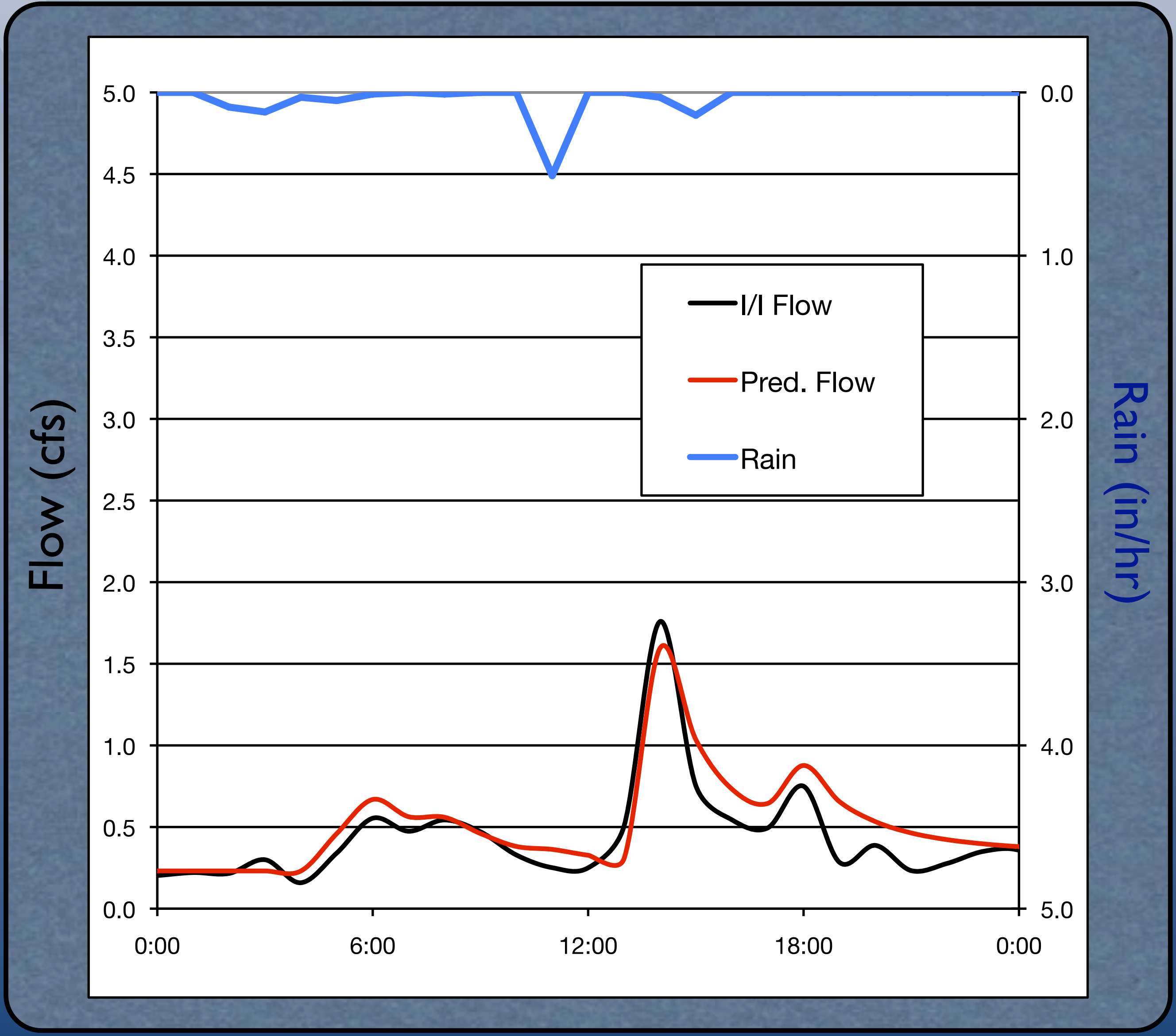
Average DWF = 0.4 cfs
Peak flow = 2.2 cfs
Peaking factor = 5.5



Model Validation

Model validates very well

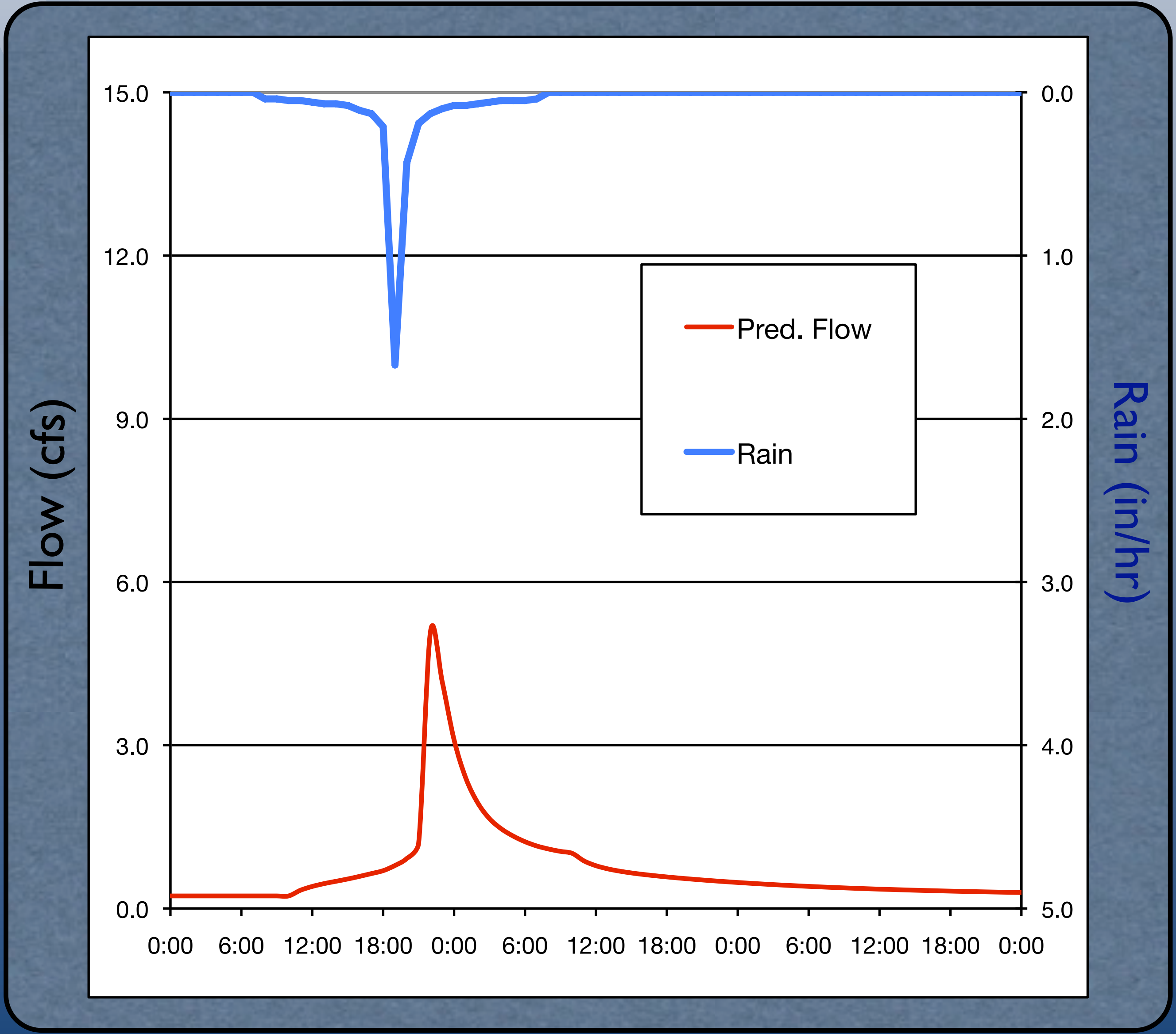
Other storms in the observations can be validated equally as well



Storm #1 - Design Storm

10-year, 24-hour design storm
SCS Type II Pattern

3.9 inches in 24-hours
1.7" peak hour rain

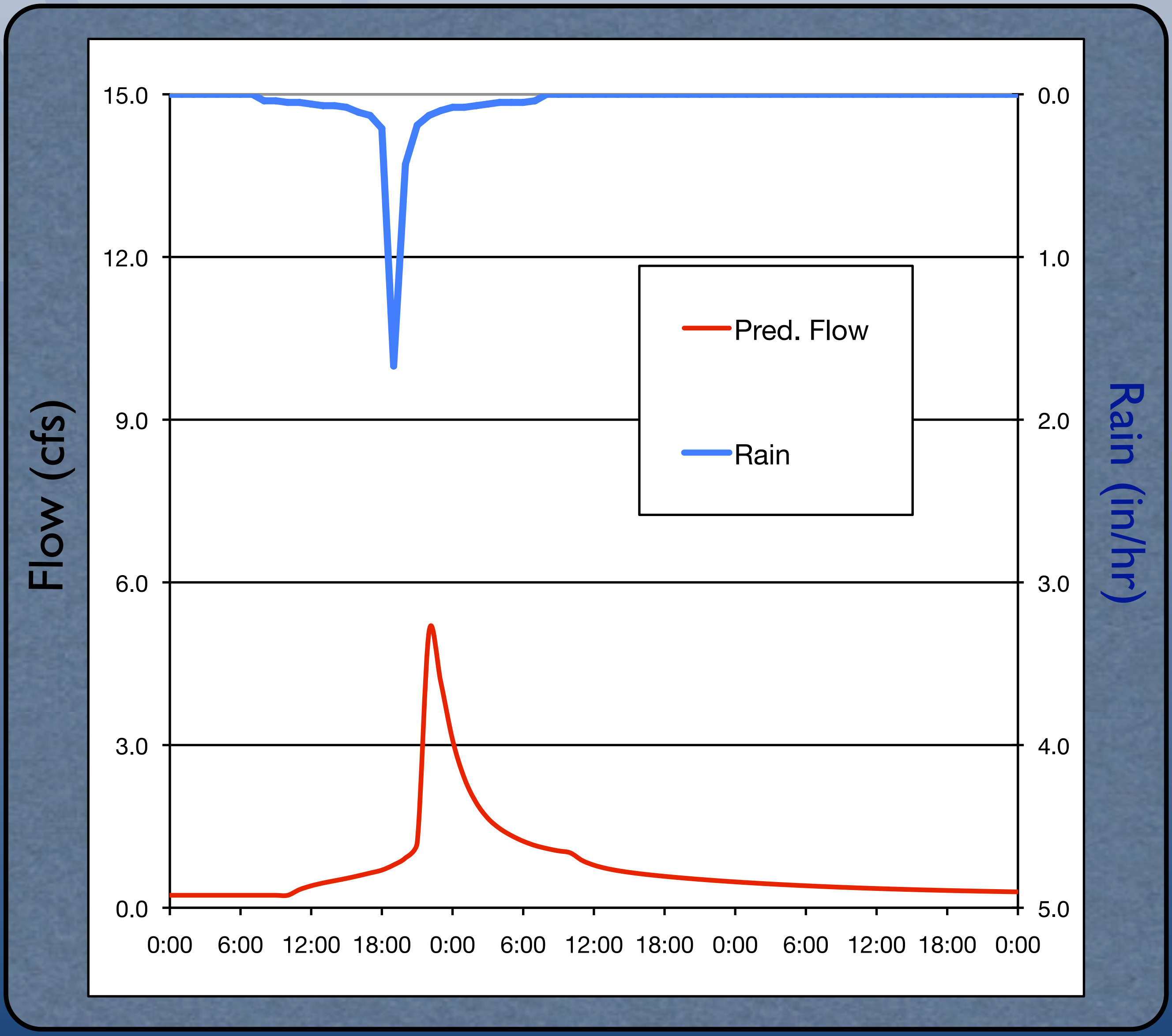


Storm #1 - Design Storm

Common Design Metrics

Peak I/I flow = 5.1 cfs

Volume over 3 cfs = 90,000 gallons



We've followed the procedure,

identified the "correct" answer,

and can proceed with design......

Right?

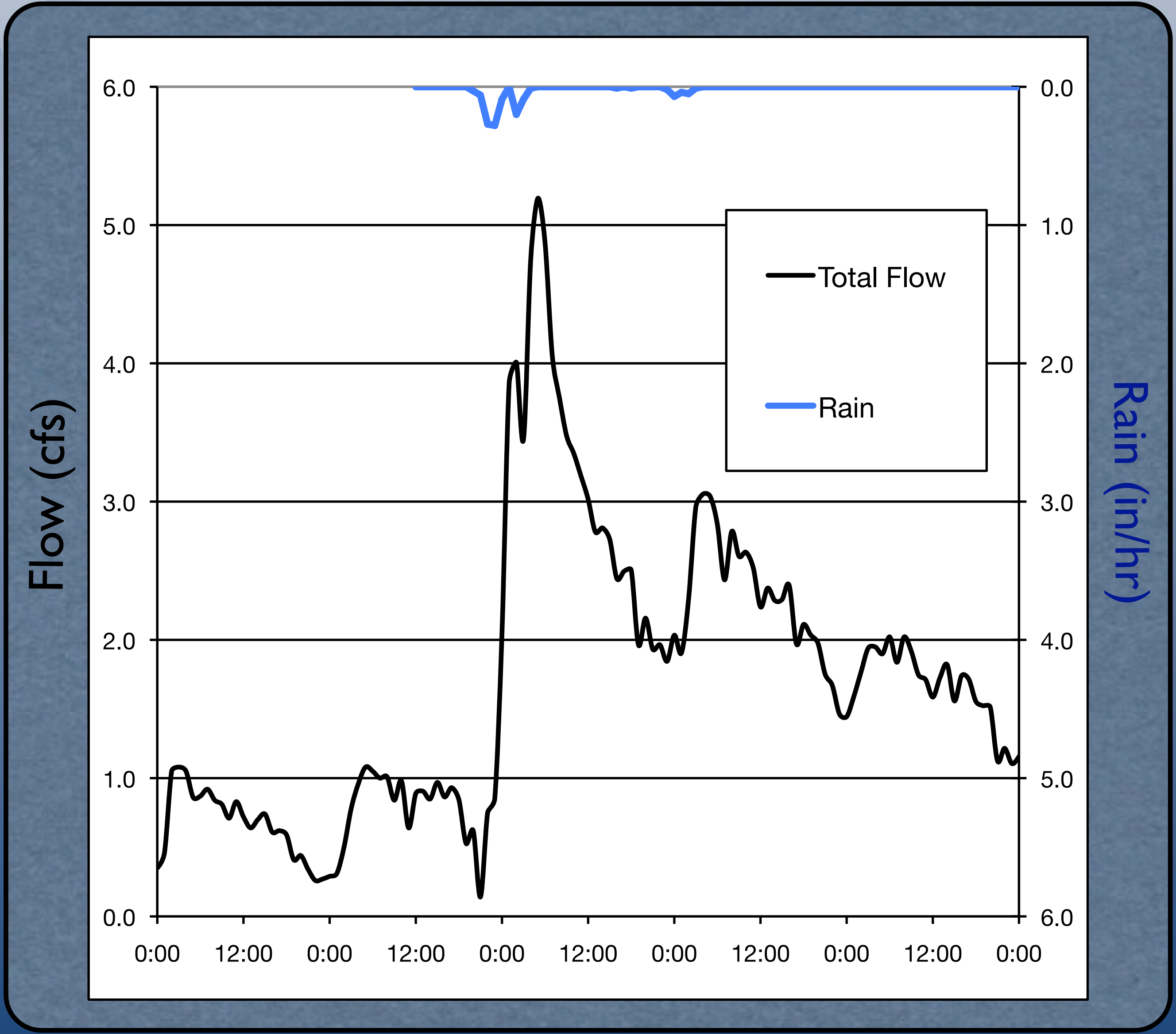
Let's check the model with the other storm first.

Storm #2 - Spring Event

1.24" rain in 32 hours
0.73" occurred in 5 hours
0.28" peak hour rain

Average DWF = 0.4 cfs
Peak flow = 5.2 cfs
Peaking factor = 13.0

A more mild rain event than #1



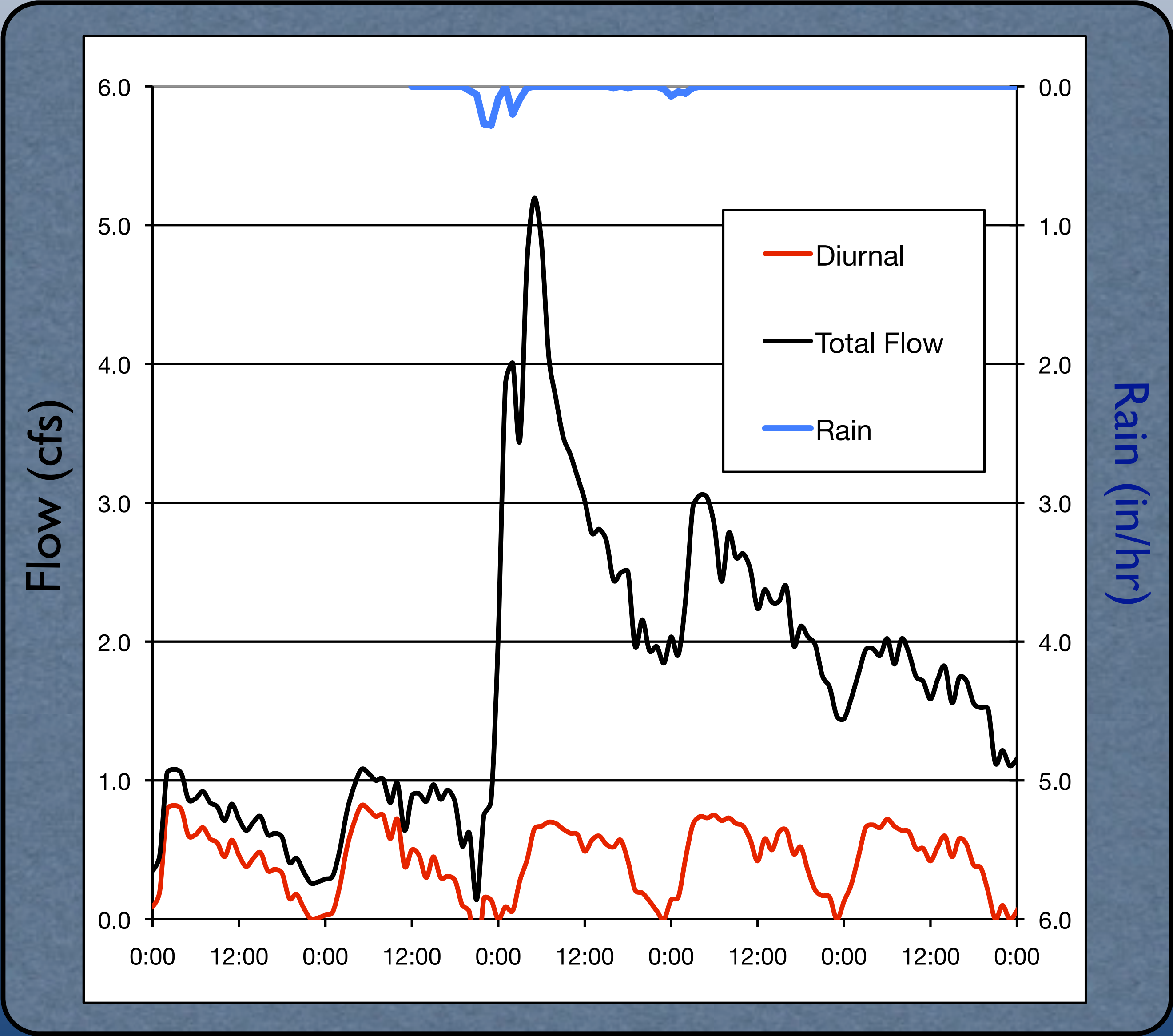
A higher peaking factor than #1

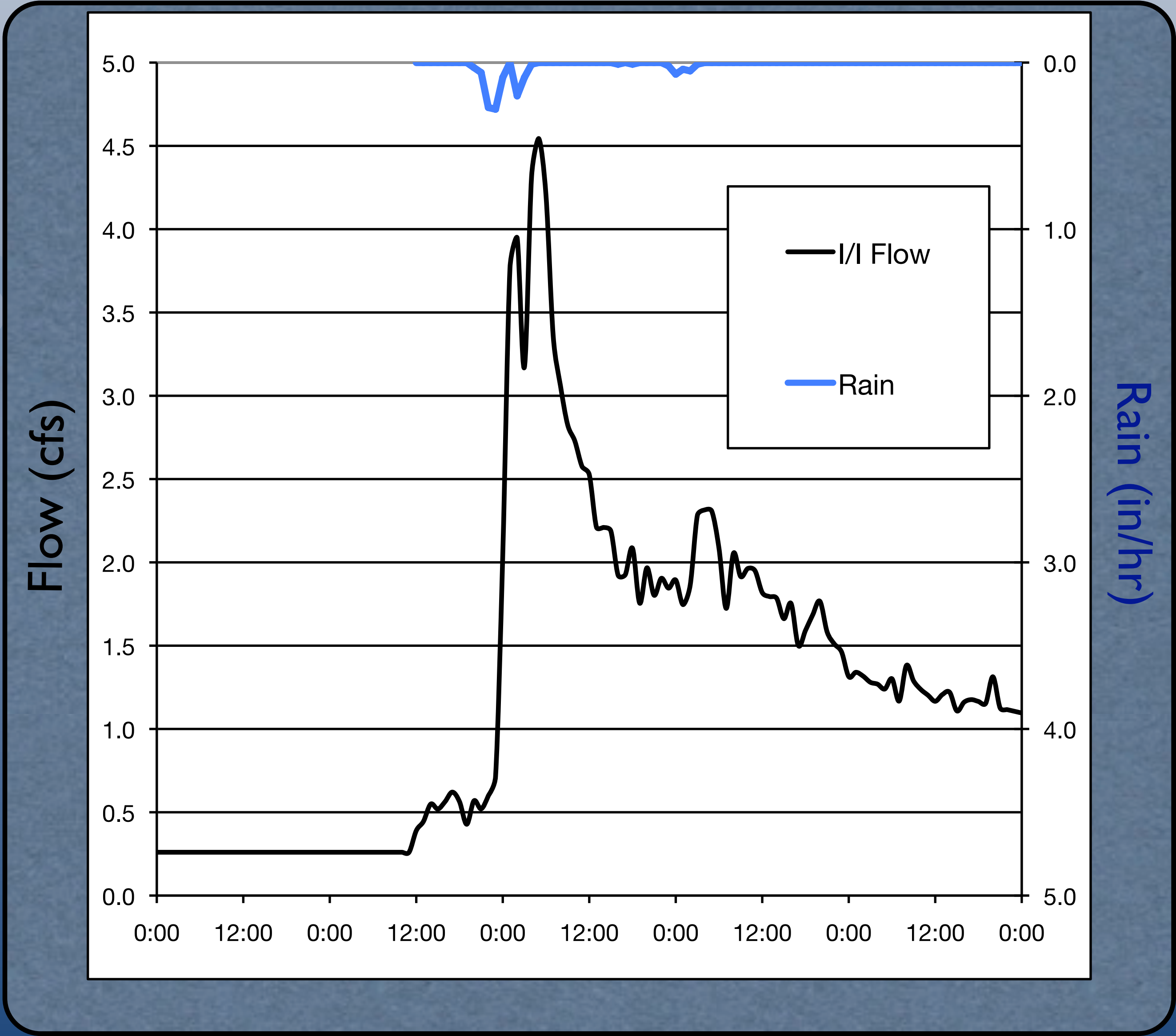
Storm #2 - Filter Diurnal Flow

Identify diurnal pattern (red line)

Subtract diurnal to extract I/I

Flat lines before / after storm are ground water infiltration

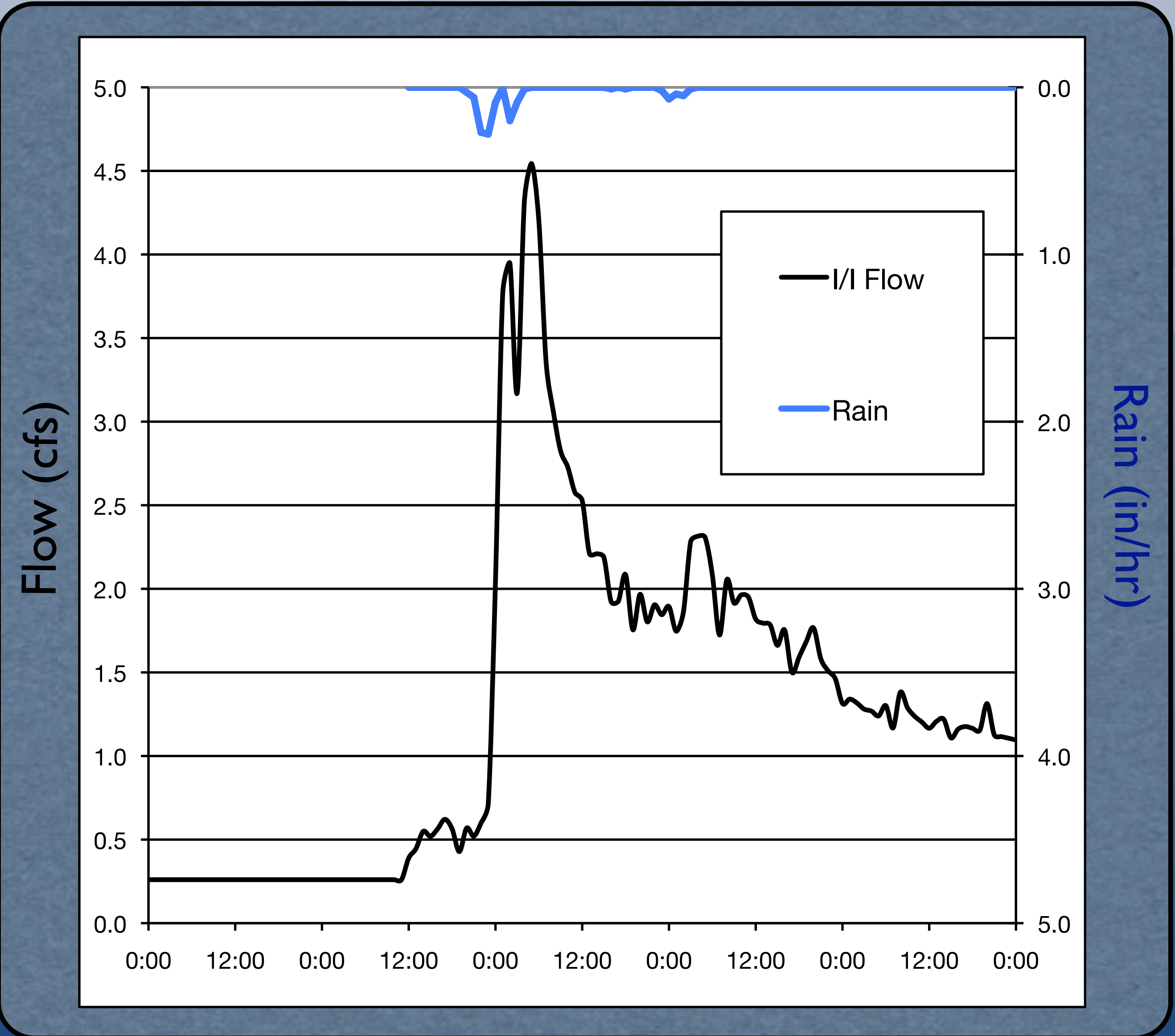


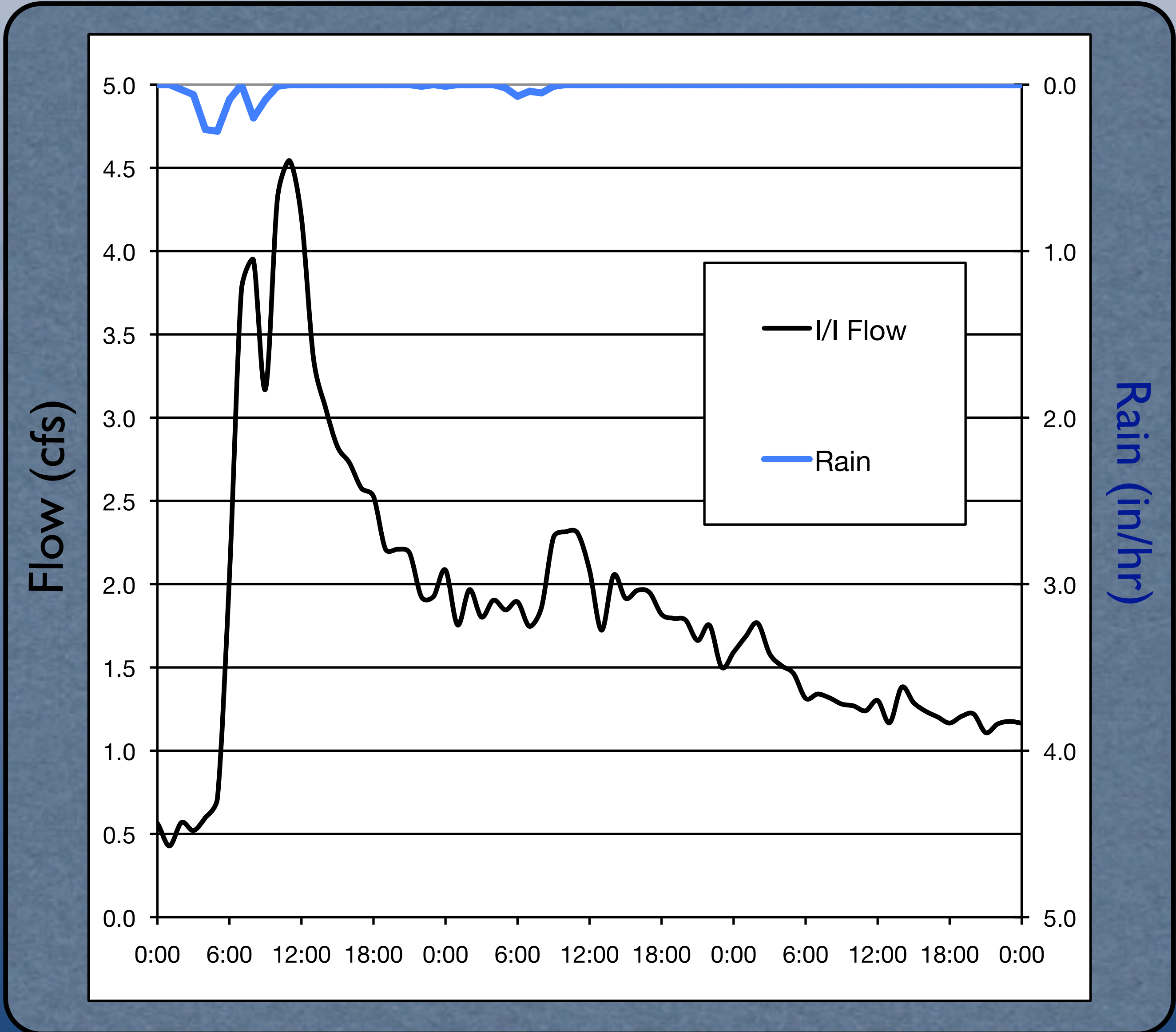


Storm #2 - Spring Event

I/I flow after diurnal extraction

Zoom in to storm to better see the dynamics

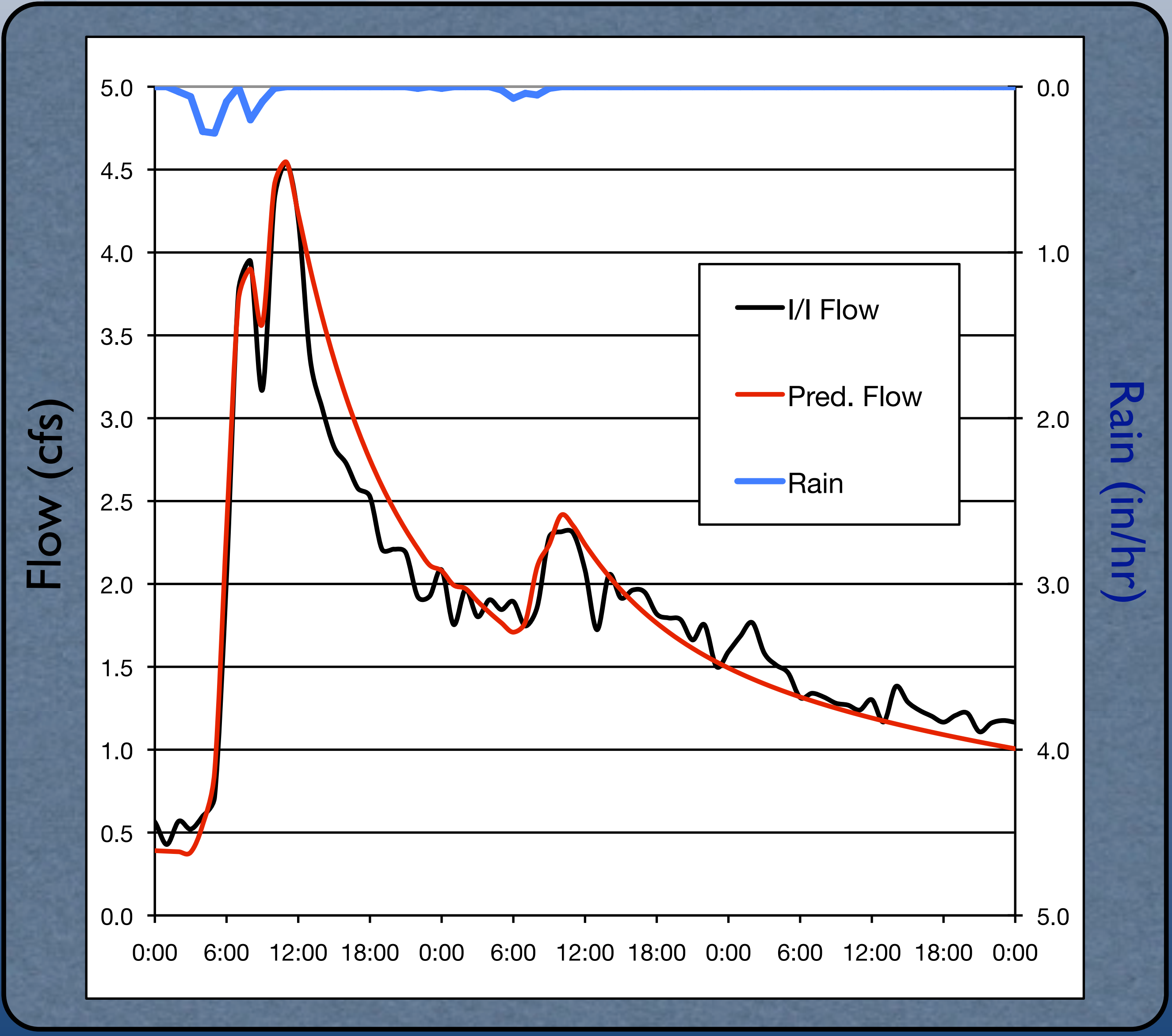




Storm #2 - Model Development

Red line shows "event model" calibration

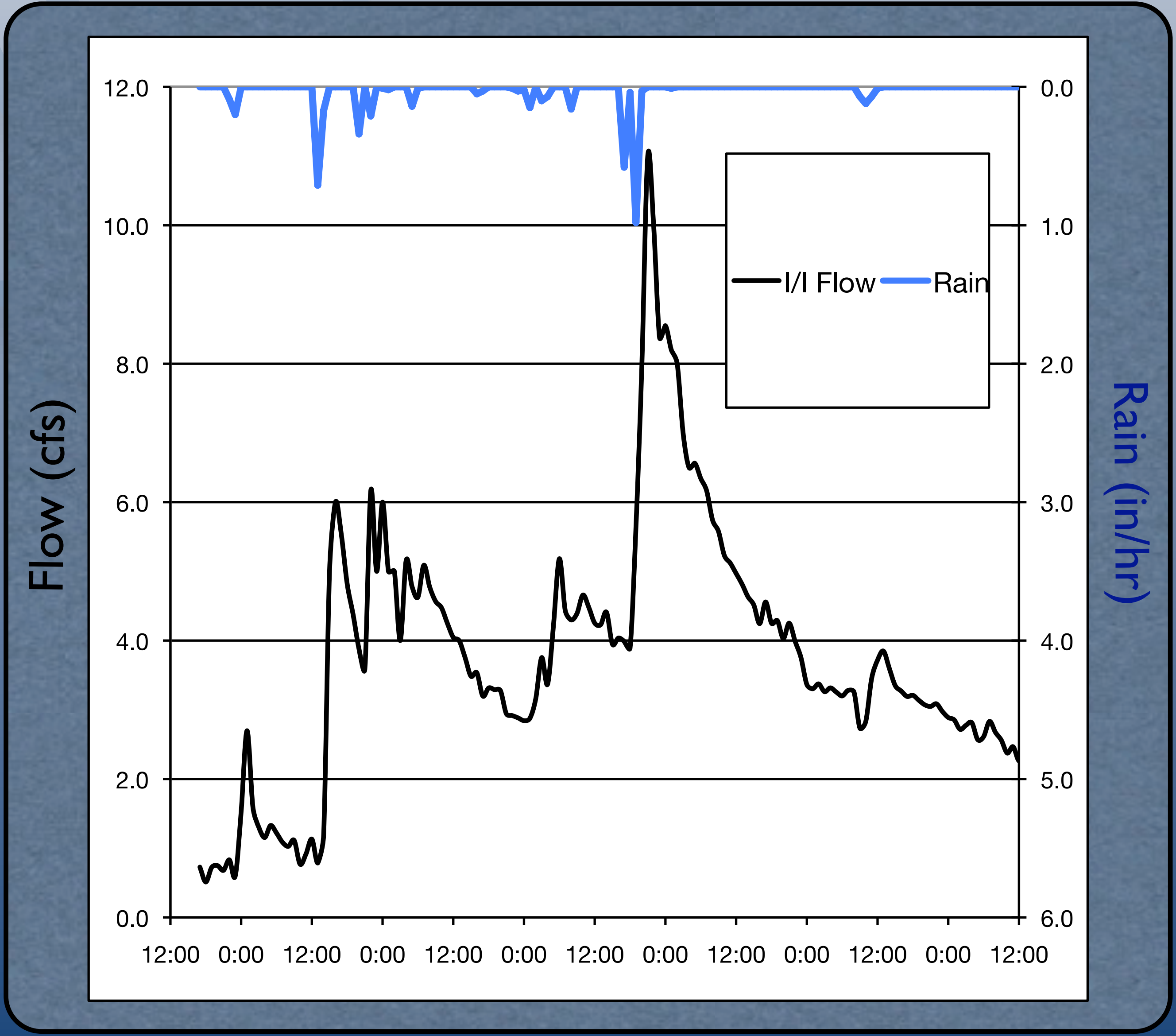
Calibration able to achieve high accuracy fit



Model Validation

3.86” rain in 54 hours
0.98” peak hour rain

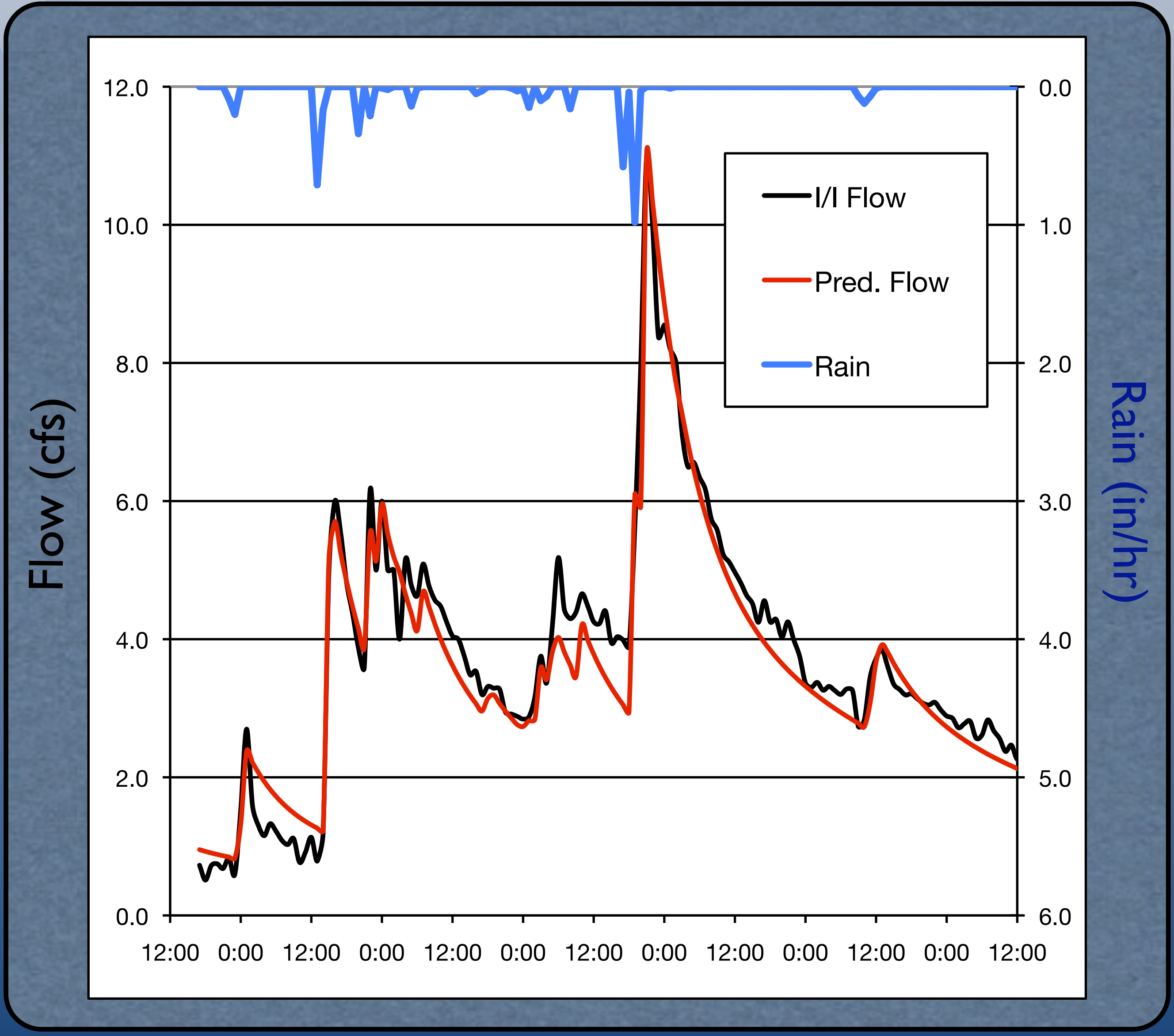
Average DWF = 0.4 cfs
Peak flow = 13.0 cfs
Peaking factor = 32.5



Model Validation

Model validates very well

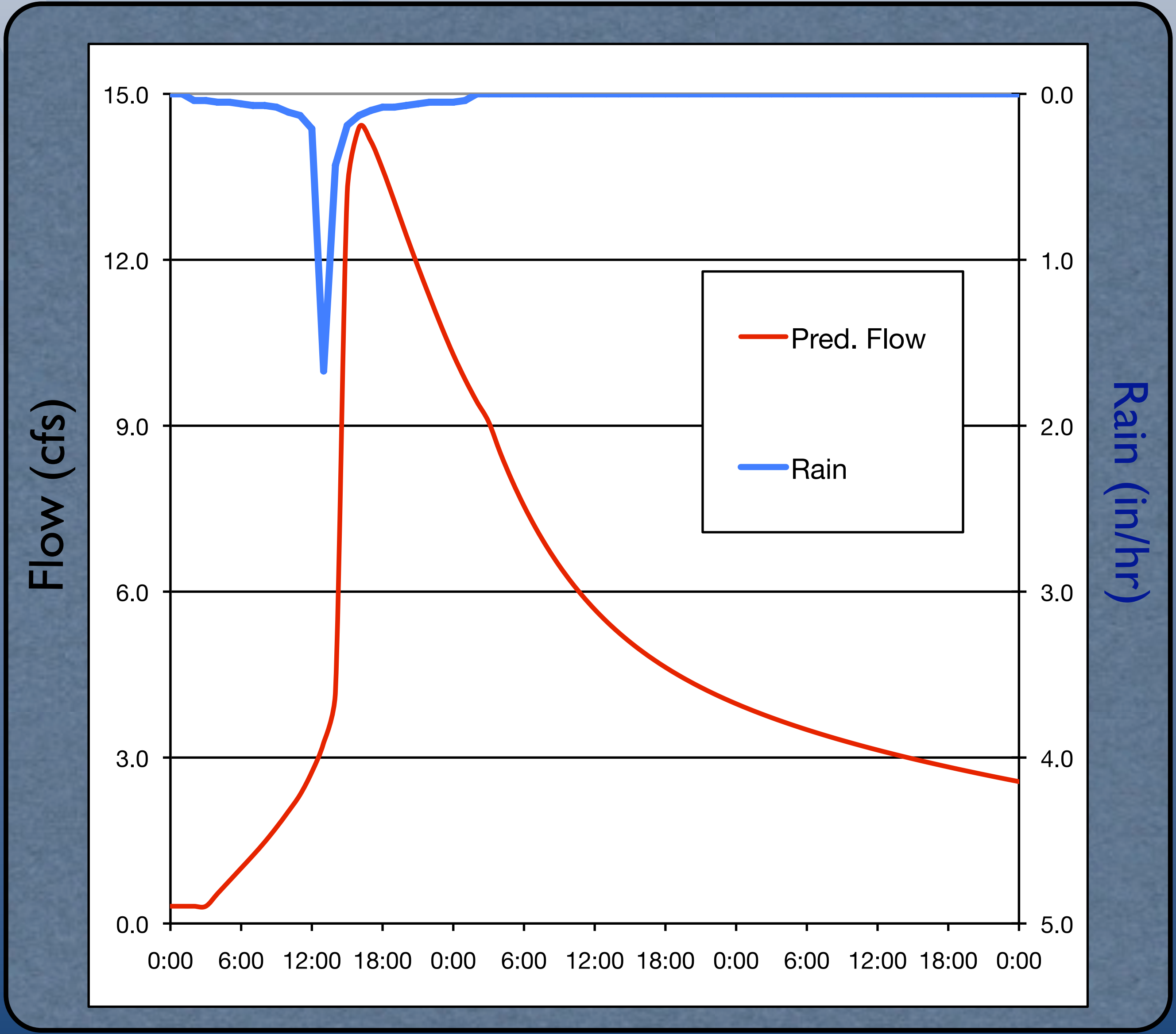
Other storms in the observations can be validated equally as well



Storm #2 - Design Storm

10-year, 24-hour design storm
SCS Type II Pattern

3.9 inches in 24-hours
1.7" peak hour rain

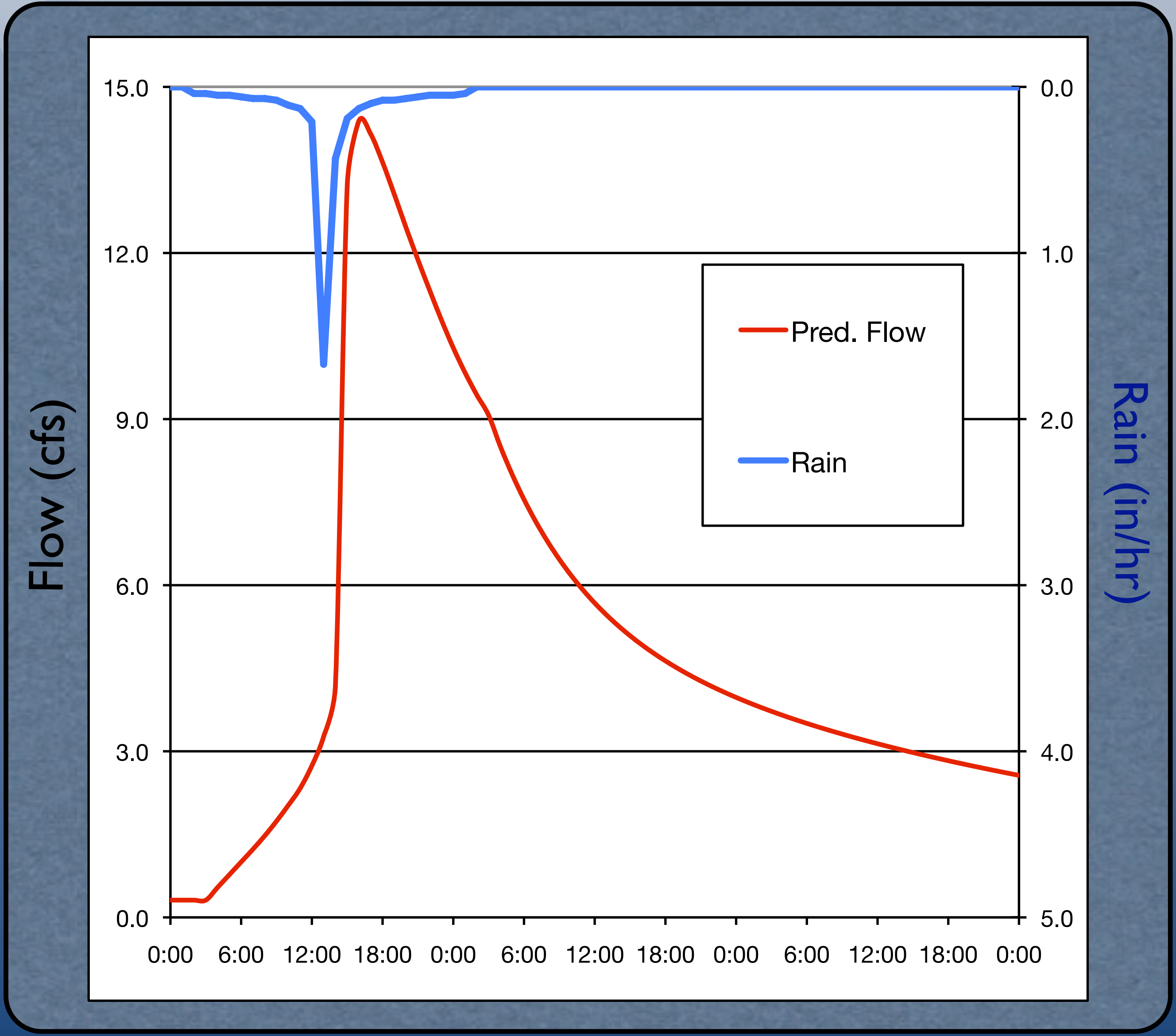


Storm #2 - Design Storm

<u>Common Design Metrics</u>

Peak I/I flow = 14.4 cfs

Volume over 3 cfs = 4,800,000 gallons



Side by Side Comparison

<u>Design from Storm #1</u>

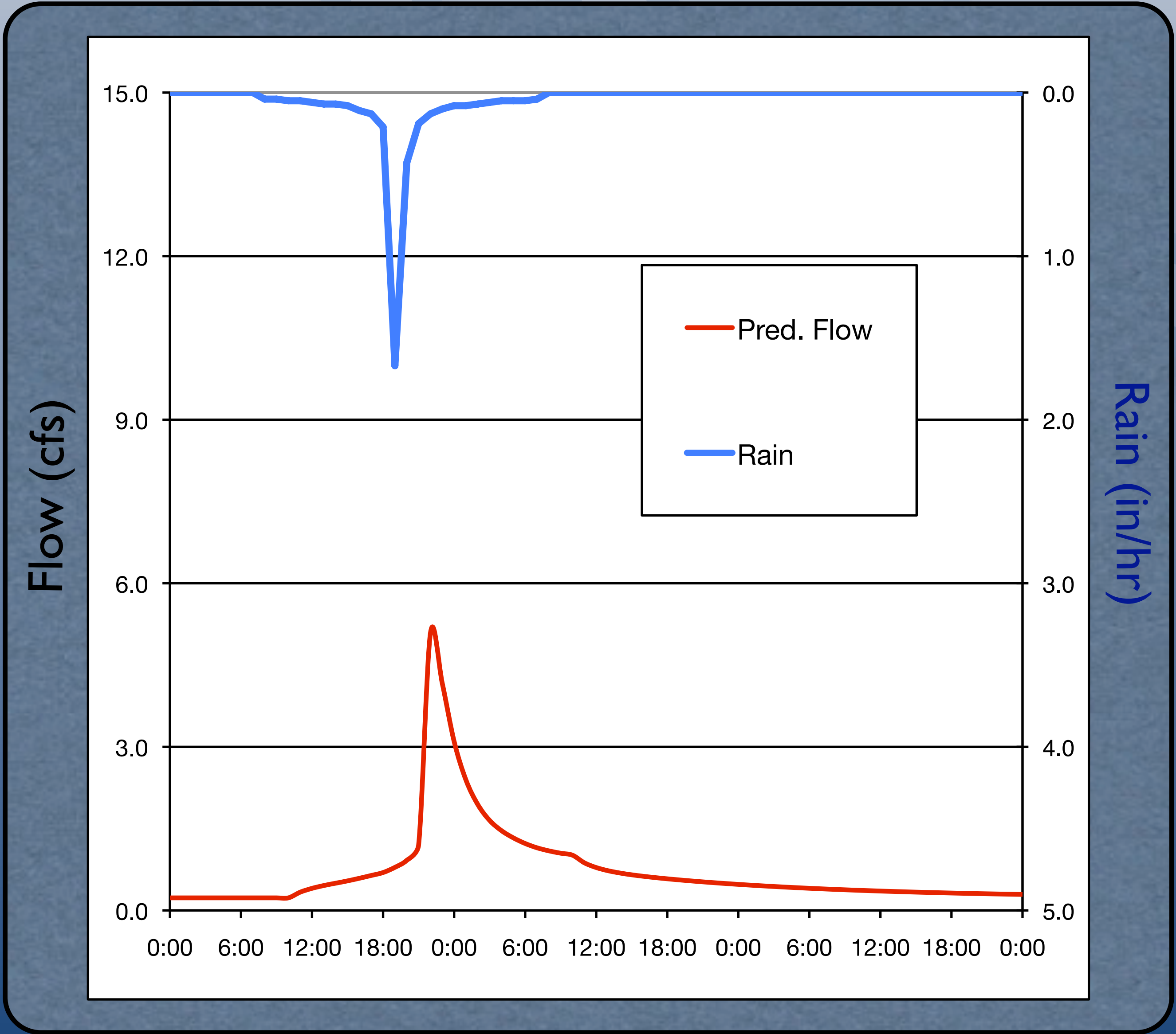
5.1 cfs

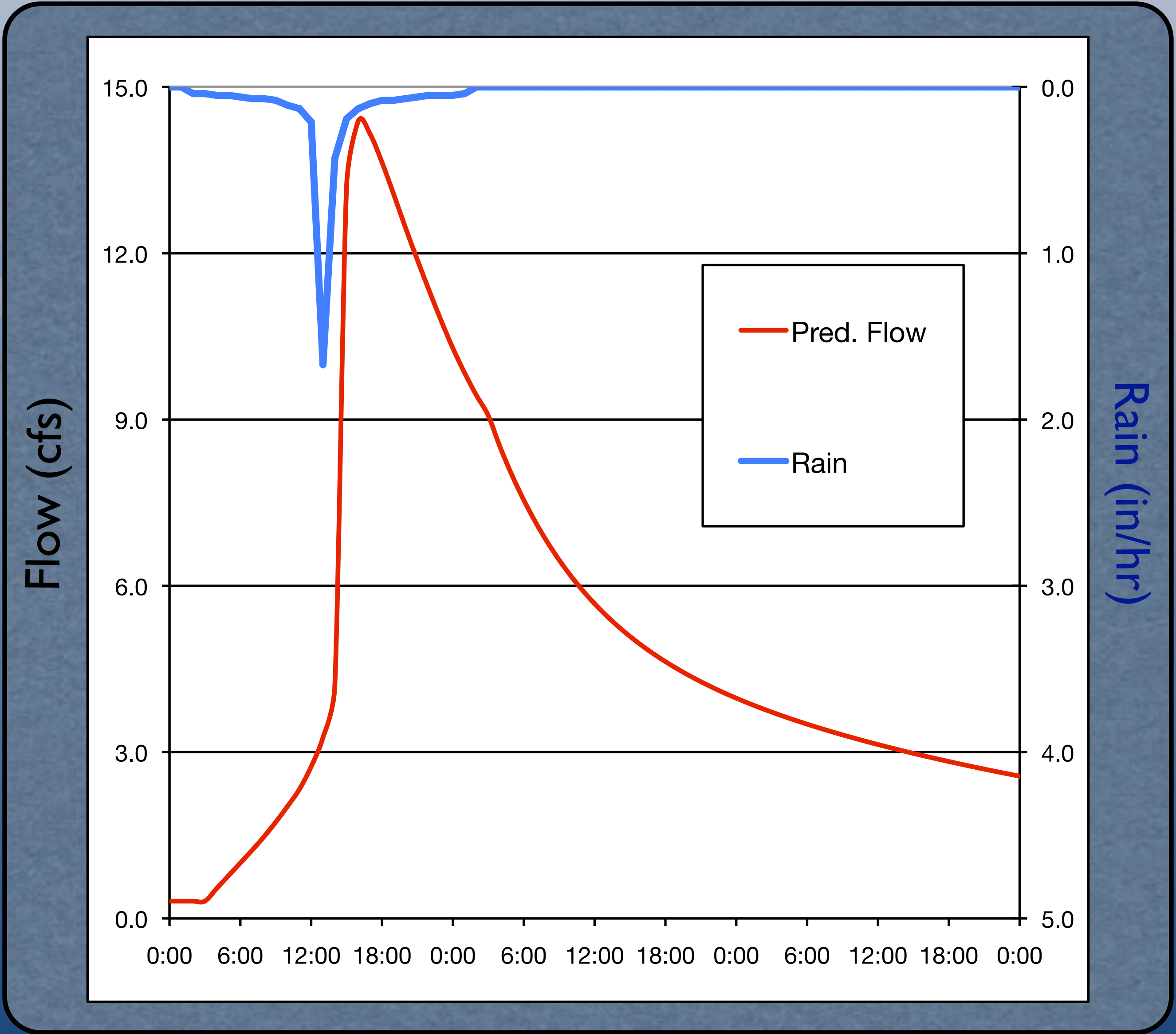
90,000 gallons

<u>Design from Storm #2</u>

14.4 cfs

4,800,000 gallons



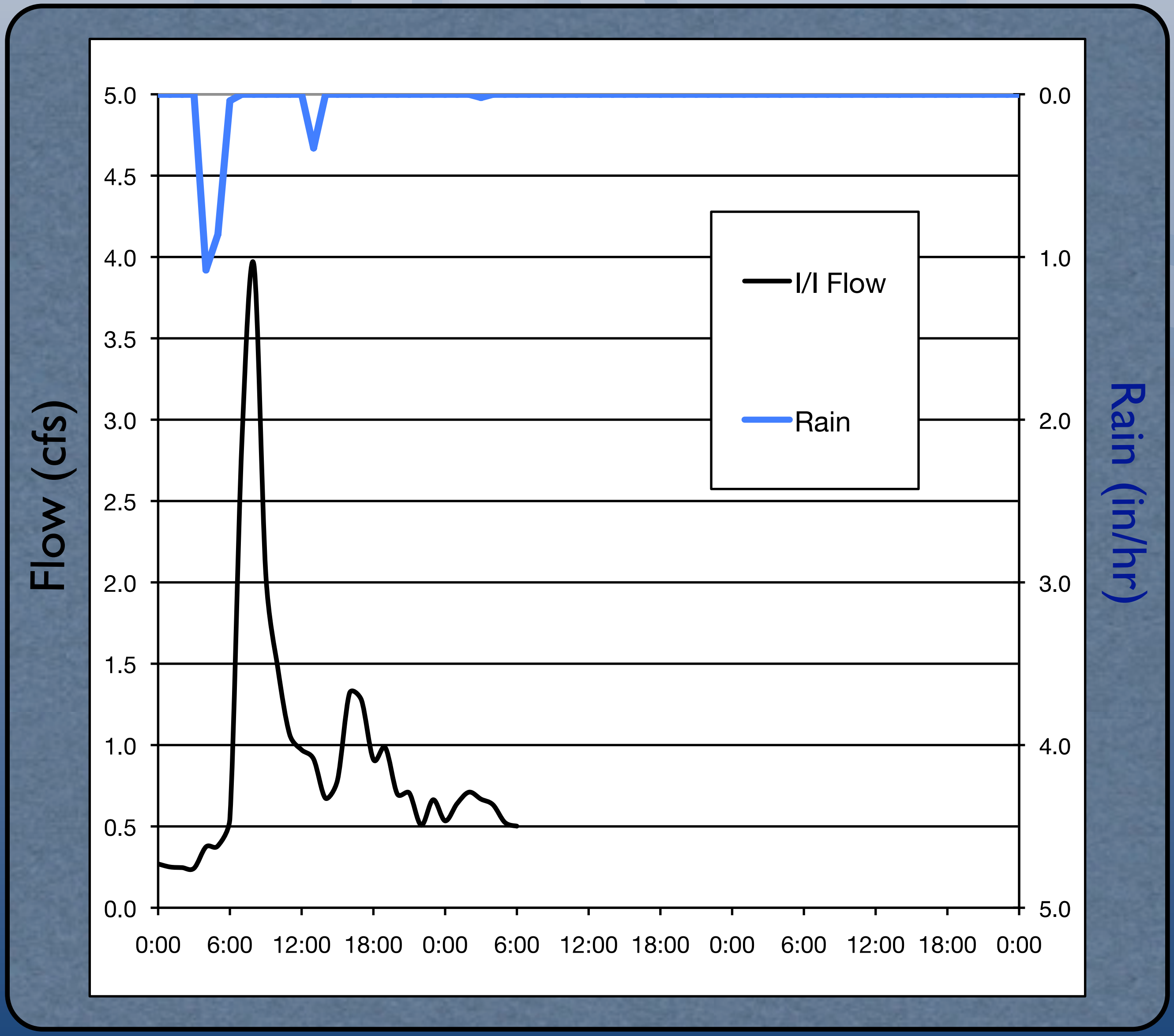


Why did this happen?

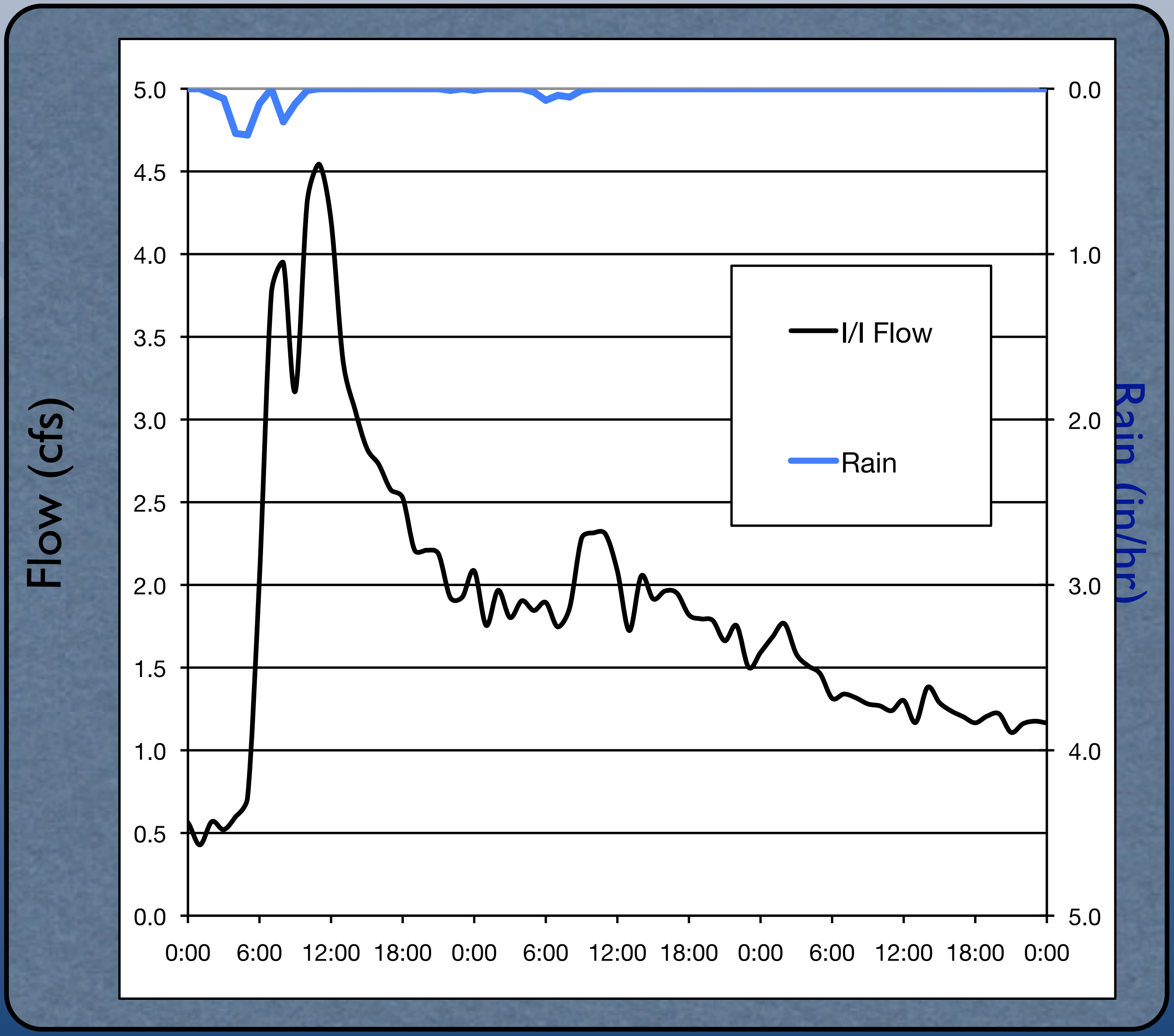
Antecedent moisture effects, or the relative wetness of the district, affected the observations

Side by Side Comparison

Storm #1
2.33” rain
RDII Volume = 72,000 cf
Capture % = 0.85%



Storm #2
1.24” rain
RDII Volume = 398,000 cf
Capture % = 8.8%



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Following the standard procedures can get you into big trouble!

Why not address this with seasonal or monthly factors that scale the model up?

Because antecedent moisture conditions vary continuously

Such “scaled” models don’t perform adequately compared to the magnitude of costs involved

How to deal with this?

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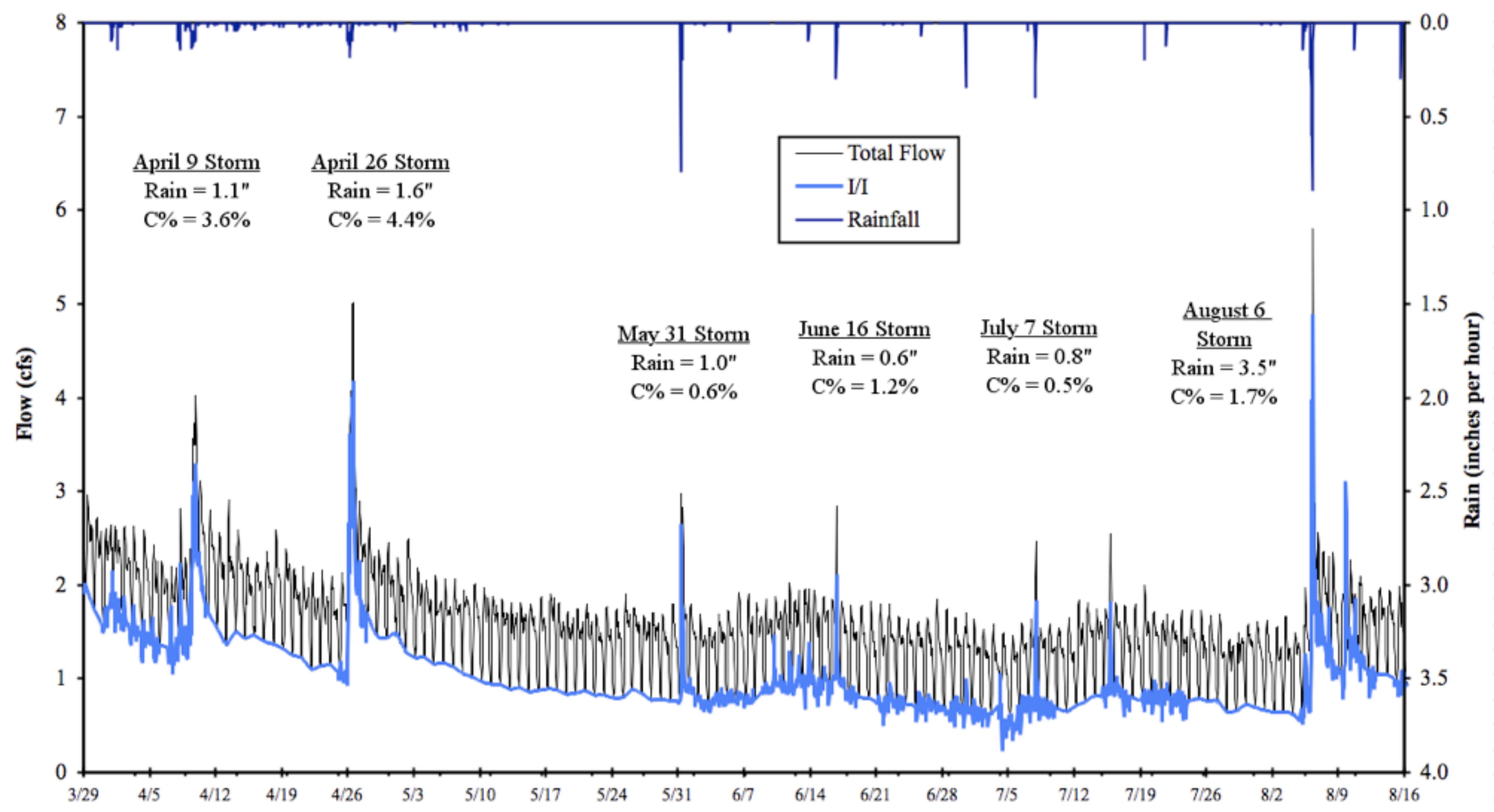
Use of a continuous Antecedent Moisture Model

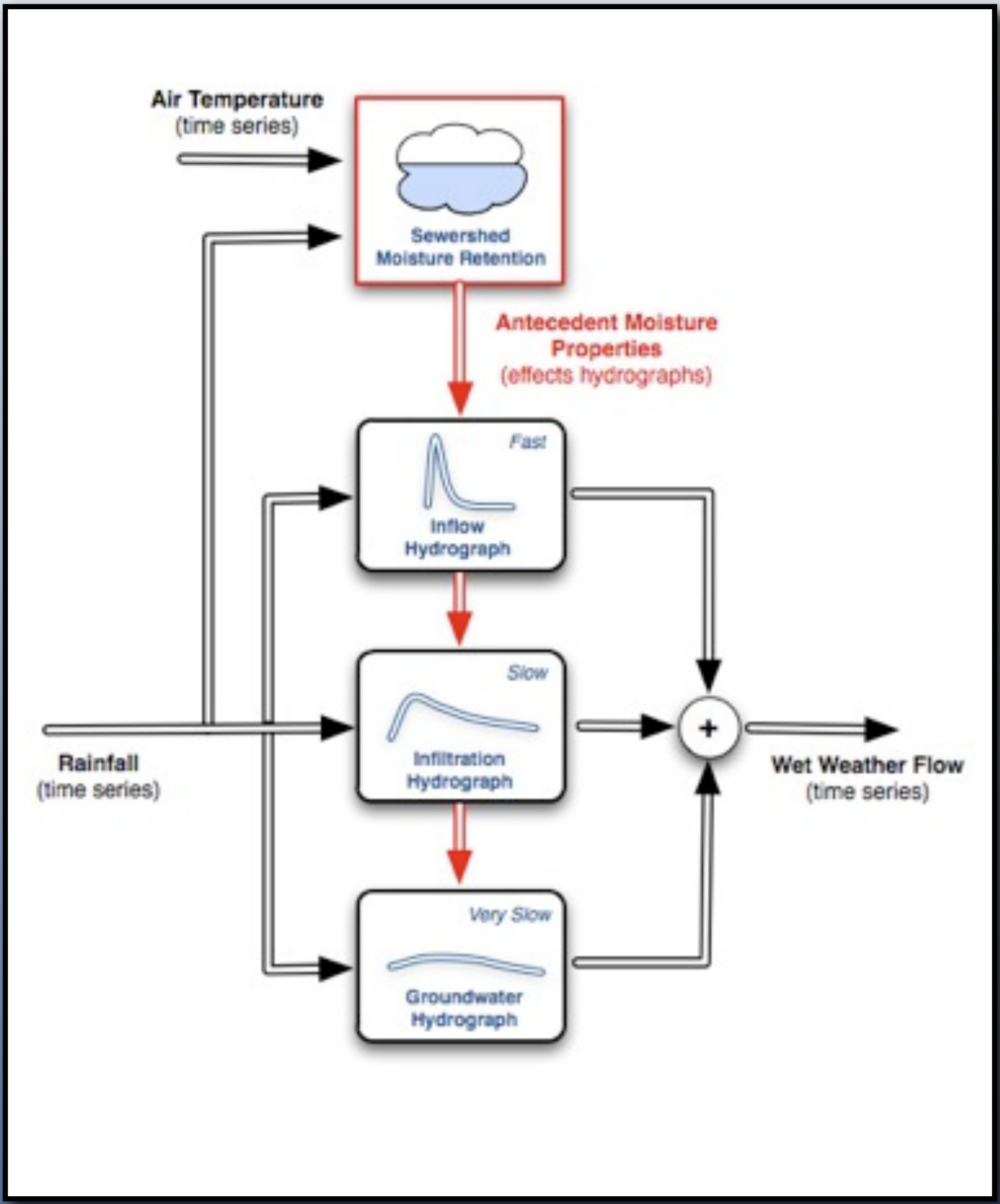
AM Effects on Wet Weather Flow

- System flow response constantly changes



i3D AM Model is the Solution

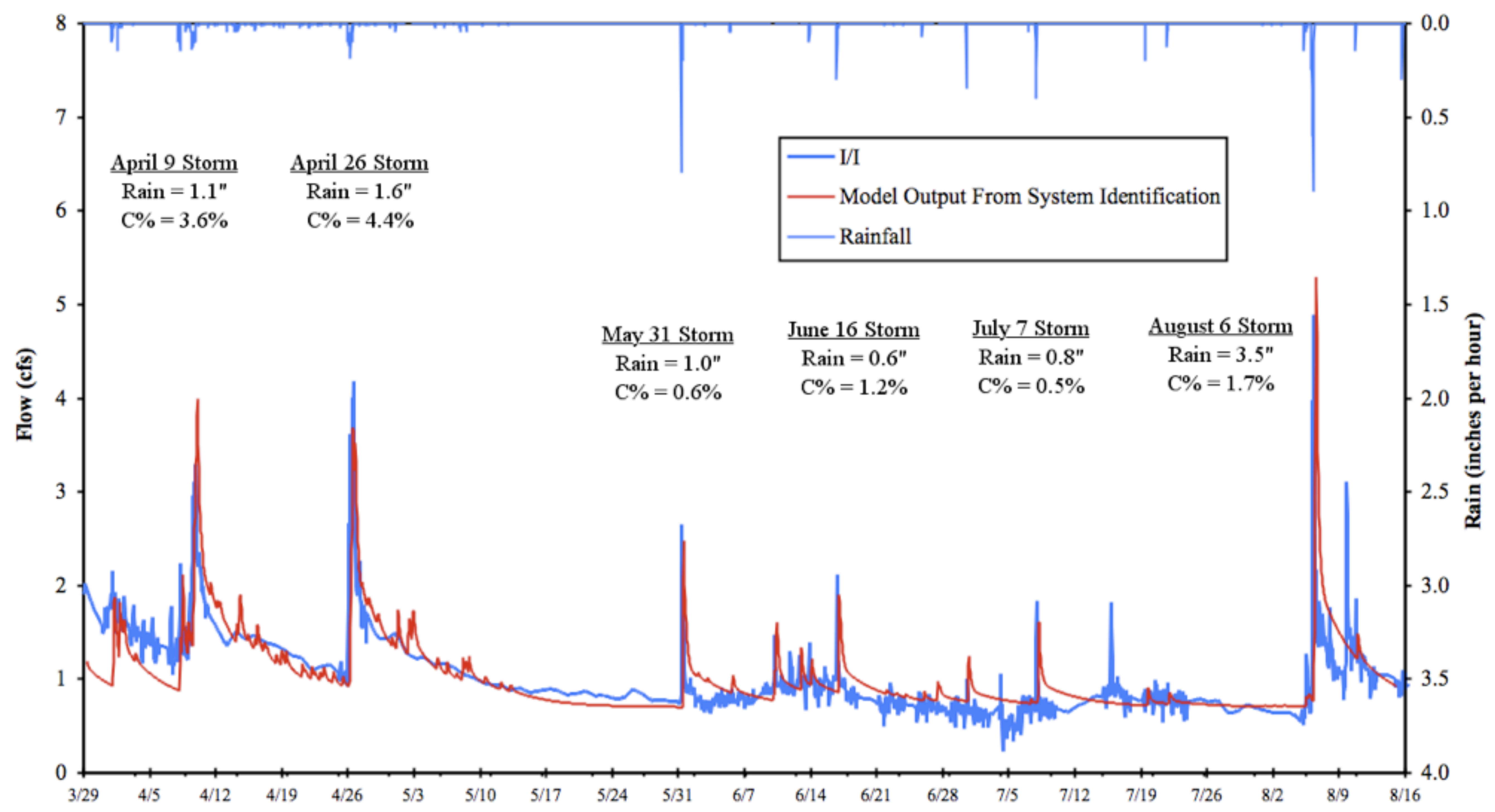
- combines fields of hydrology (civil) and system identification (aerospace)
- input-output, time series data (rainfall & flow data) drives the modeling process
- makes more extensive use of flow metering data
- gives decision makers greater confidence
- 100% regulatory approval (3 states and federal)



The i3D AM Model is capable of accurately predicting sewer flow under various AM conditions.

AM Model Results

- Continuous model matches years of data

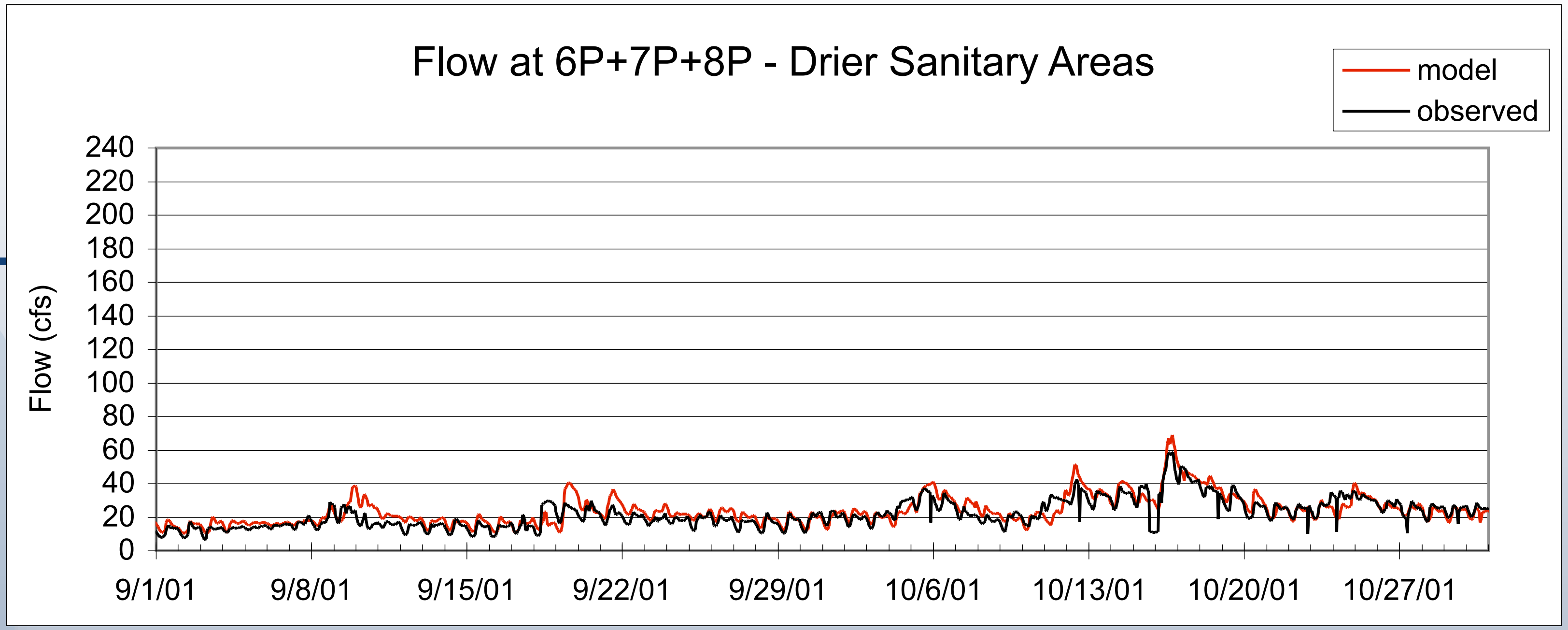


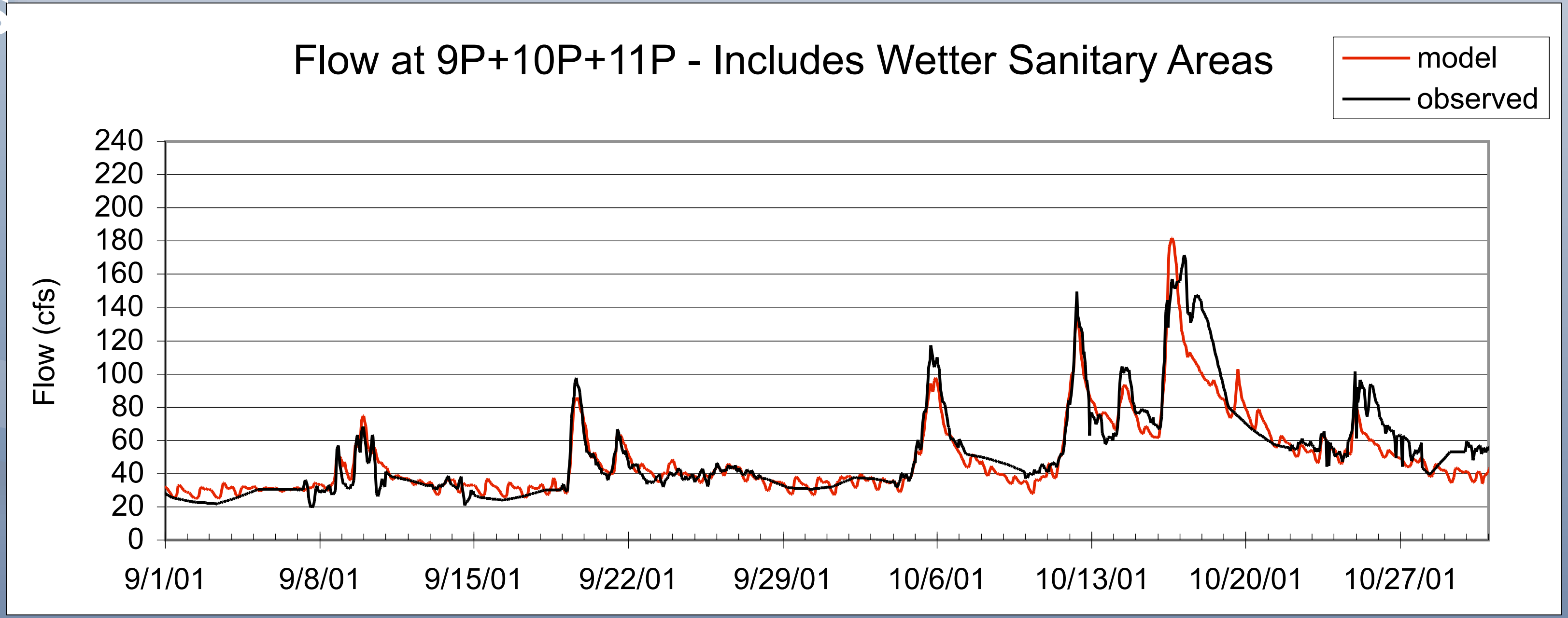
Wayne County Case Study

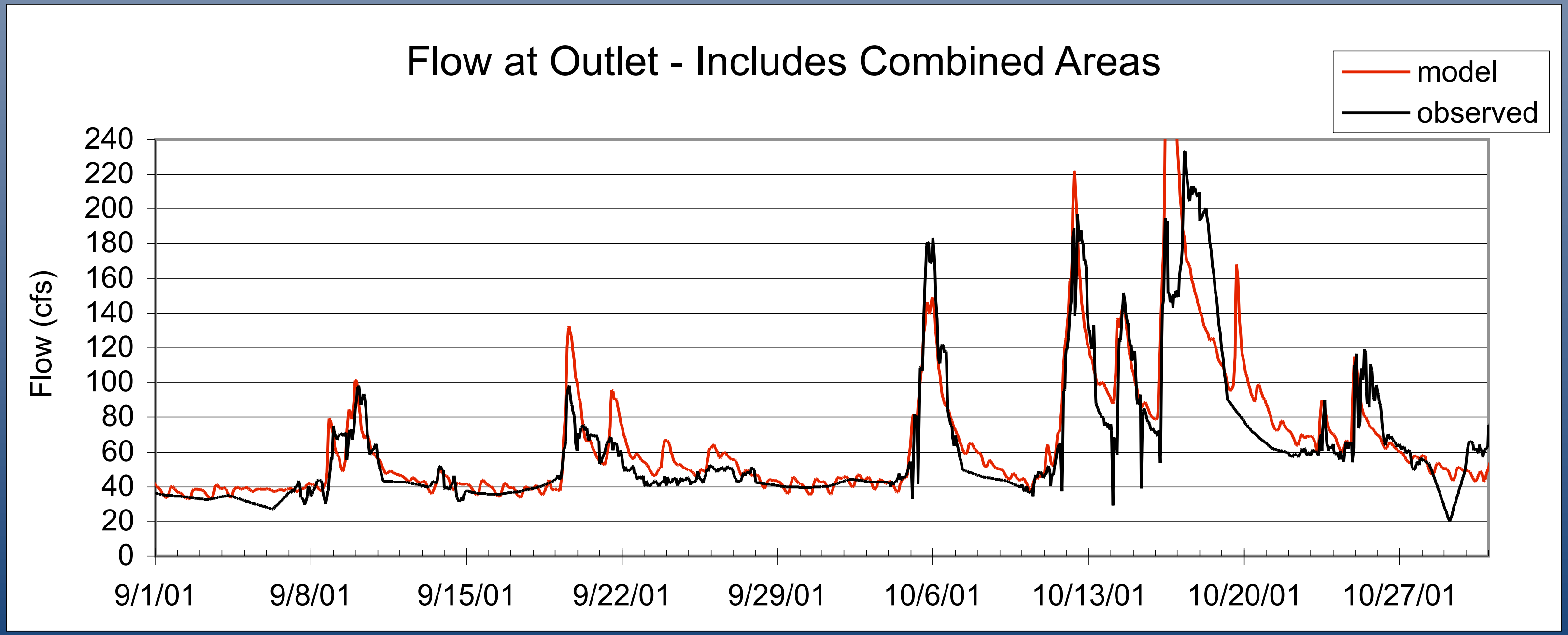
1. County was facing $265M upgrade to the North Huron Valley System.
2. Traditional modeling was performed to size upgrade of a regional transport / storage tunnel.
3. Model was calibrated to wet conditions, which led to overly conservative results.
4. The key was to use a continuous antecedent moisture model combined with a frequency analysis to replace the 25-year, 24-hour design storm.
5. Result reduced capital costs to $90M, resulting in a $275M savings.

Calibration Results

- Model calibrated to 2000-2001 observations

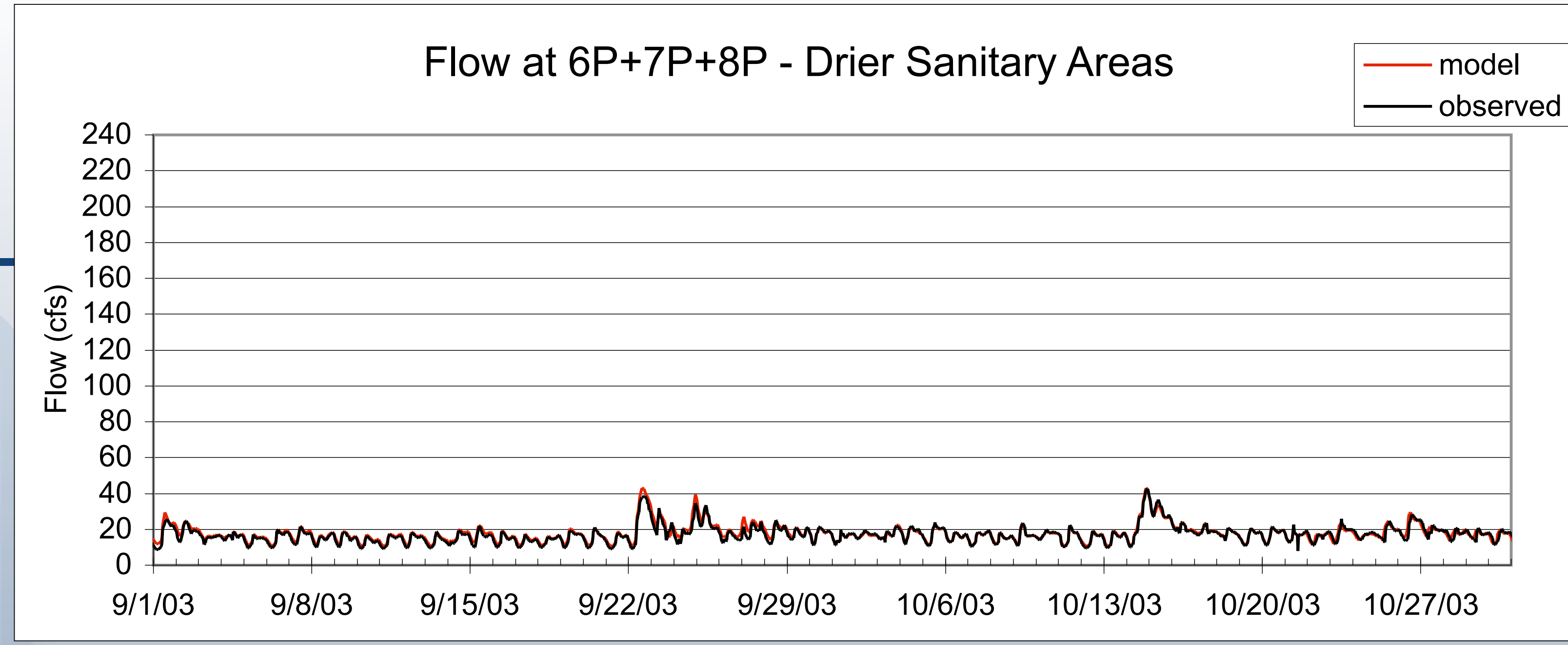


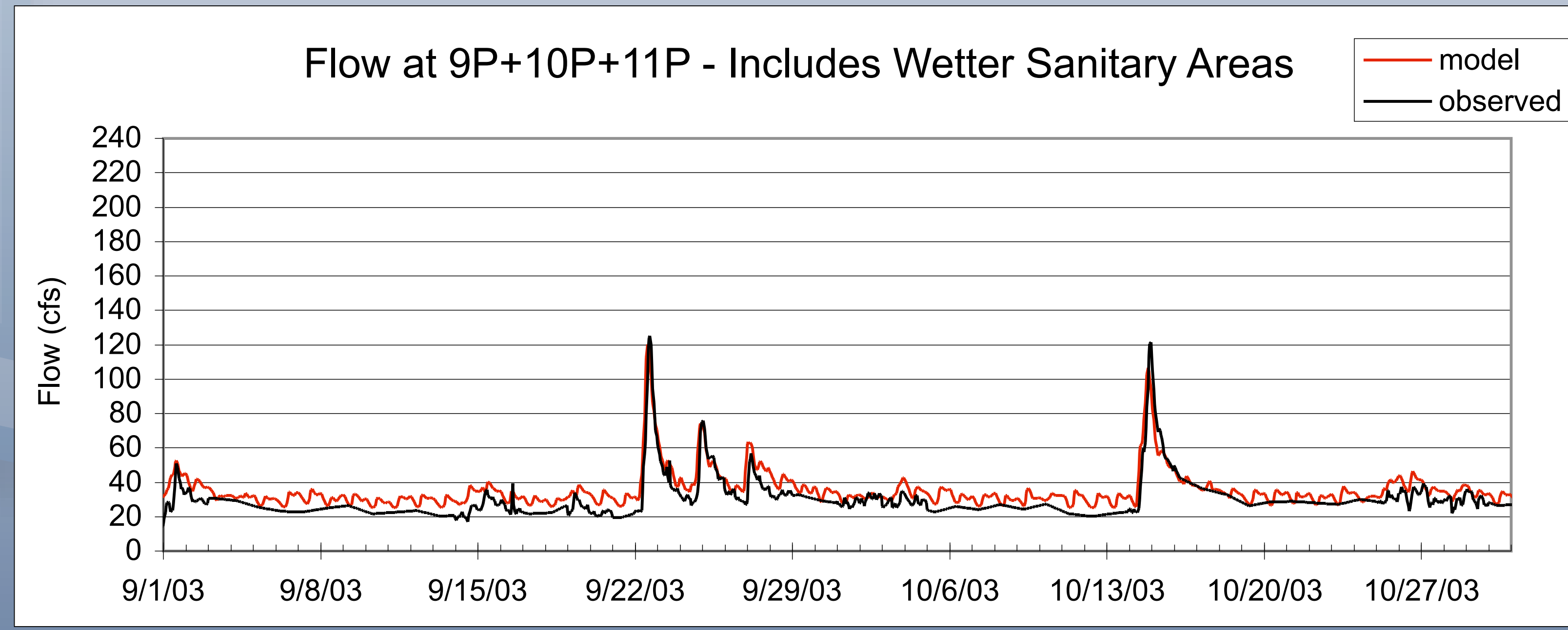


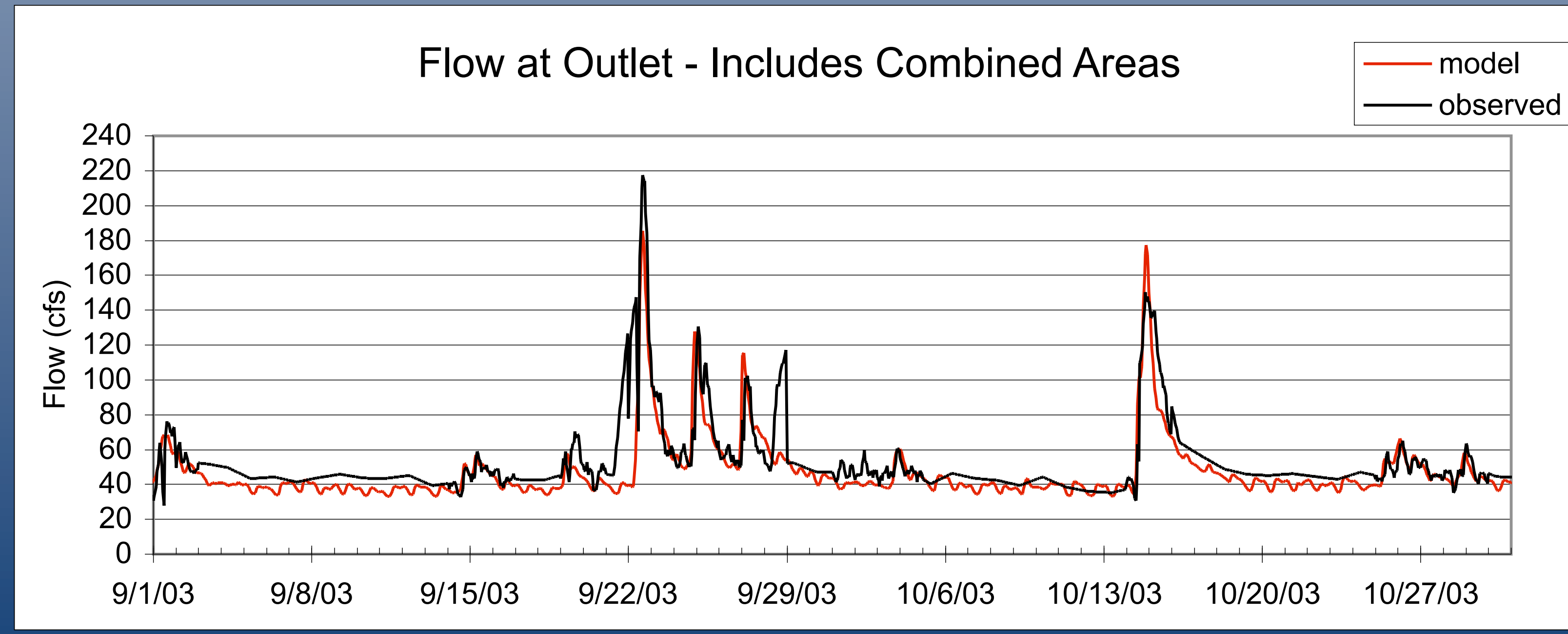


Validation Results

- Model validated to 2002-2003 observations
- Validation done to test model performance
- No changes to the model were made for the validation runs
- The accuracy of the validation runs provided confidence in the model

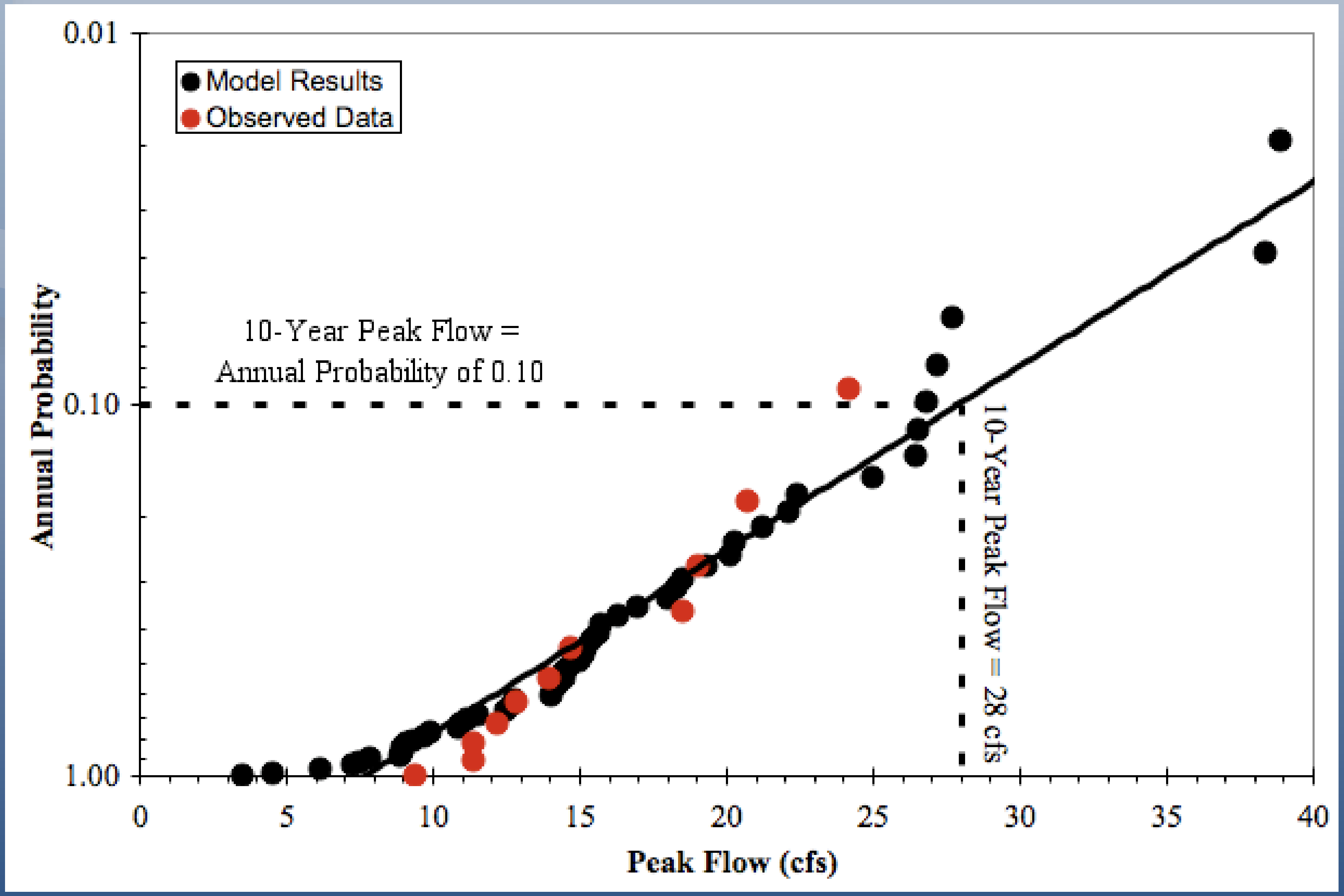






Frequency based design approach

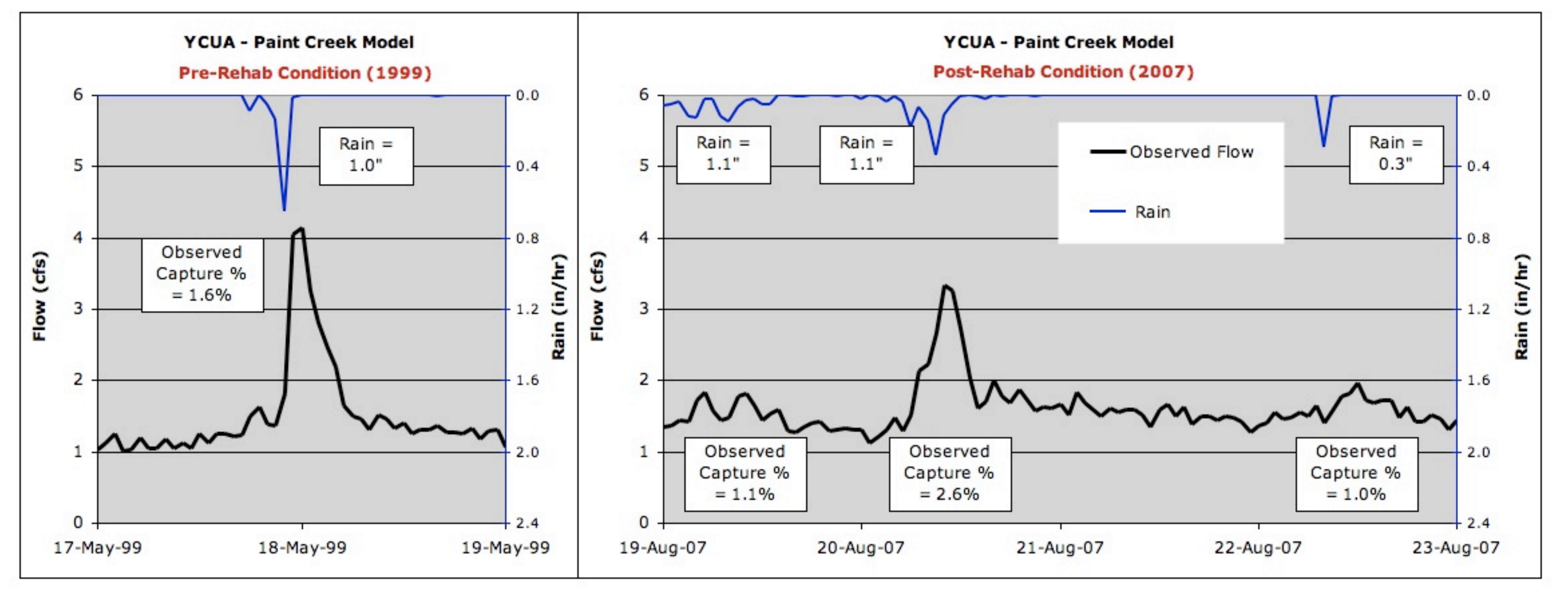
- Move away from the design event to a frequency based approach
- Decision can then be based on cost versus risk
- There will always be a bigger storm than your capacity
- How frequently will that happen?
- What are the consequences?
- How should you prepare for such an event?



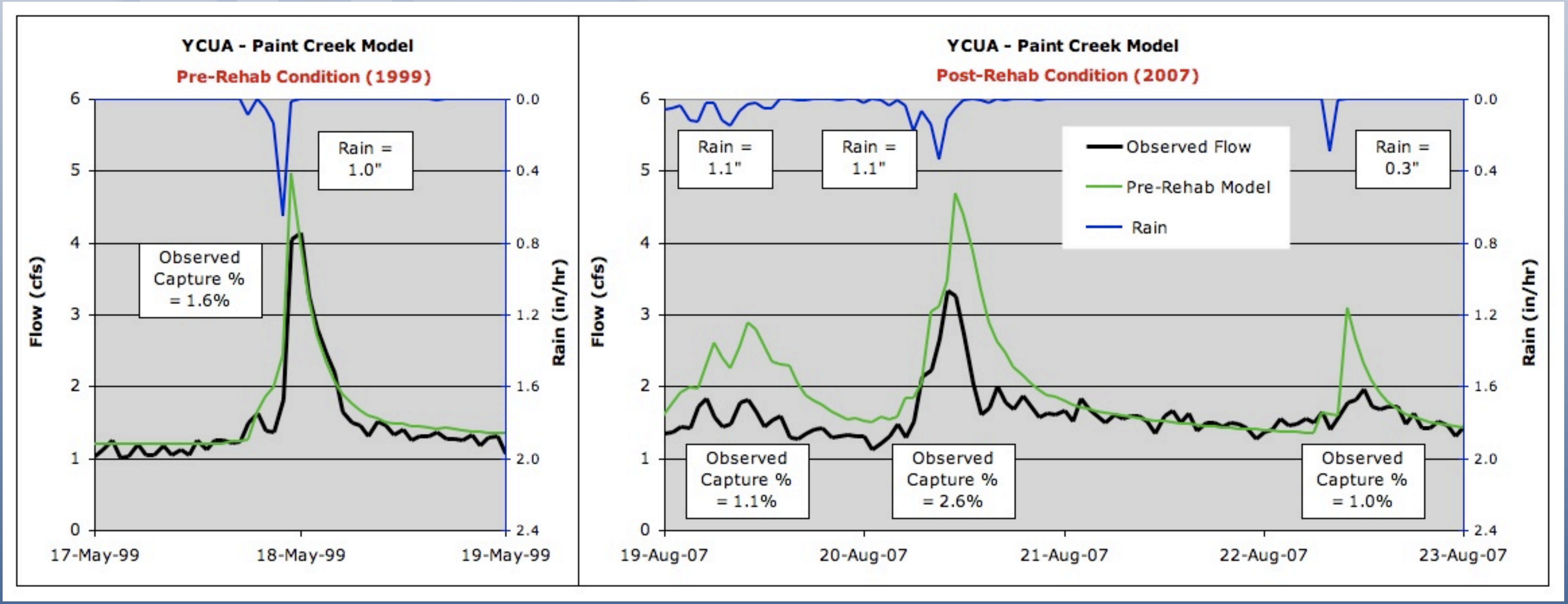
YCUA Rehabilitation Case Study

1. Rehab effectiveness not evident with traditional metrics
2. AM model revealed underlying I/I dynamics
3. Effectiveness quantified successfully

Pre- and Post-Rehab Flows



Pre- and Post-Rehab Flows

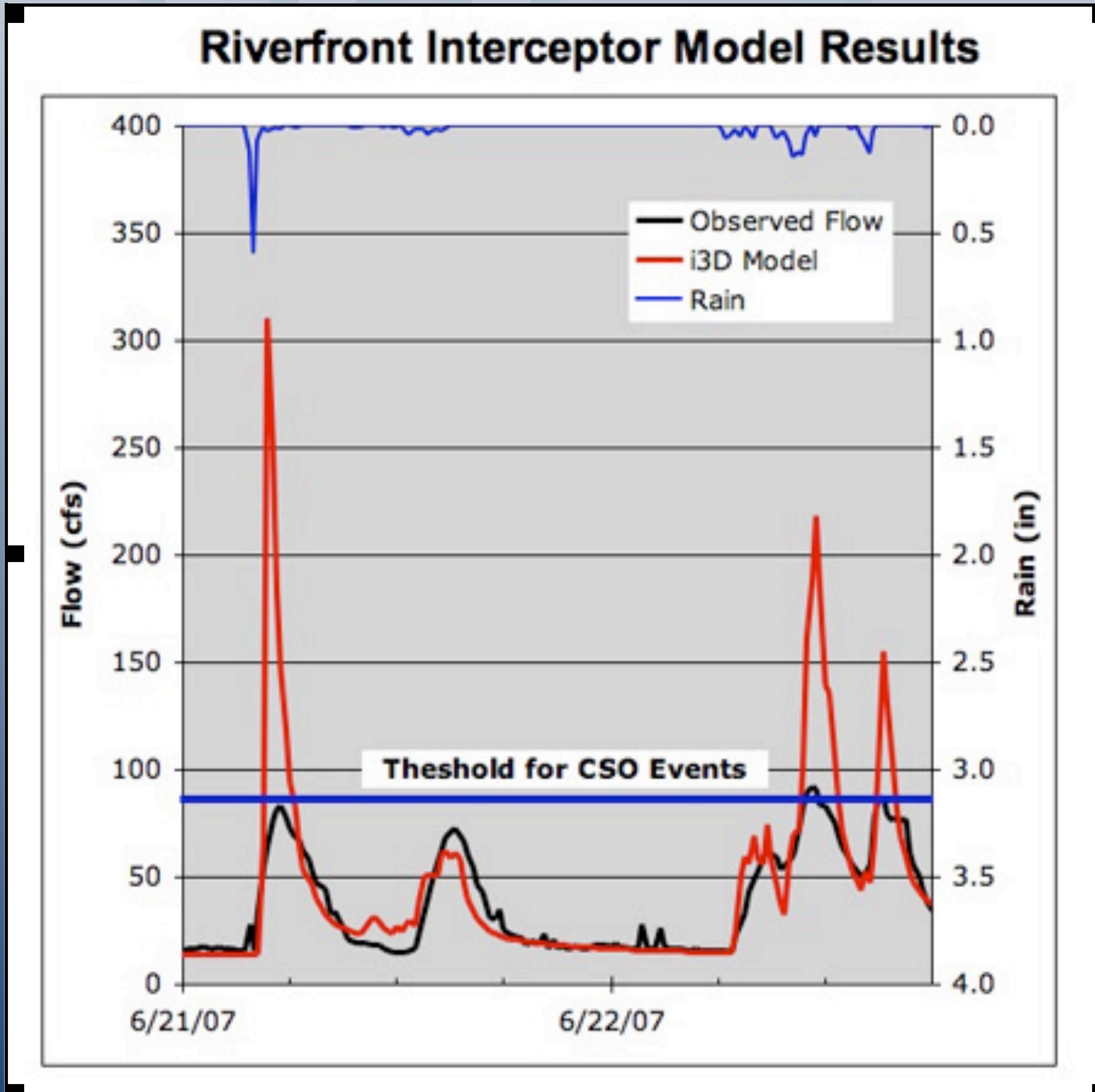


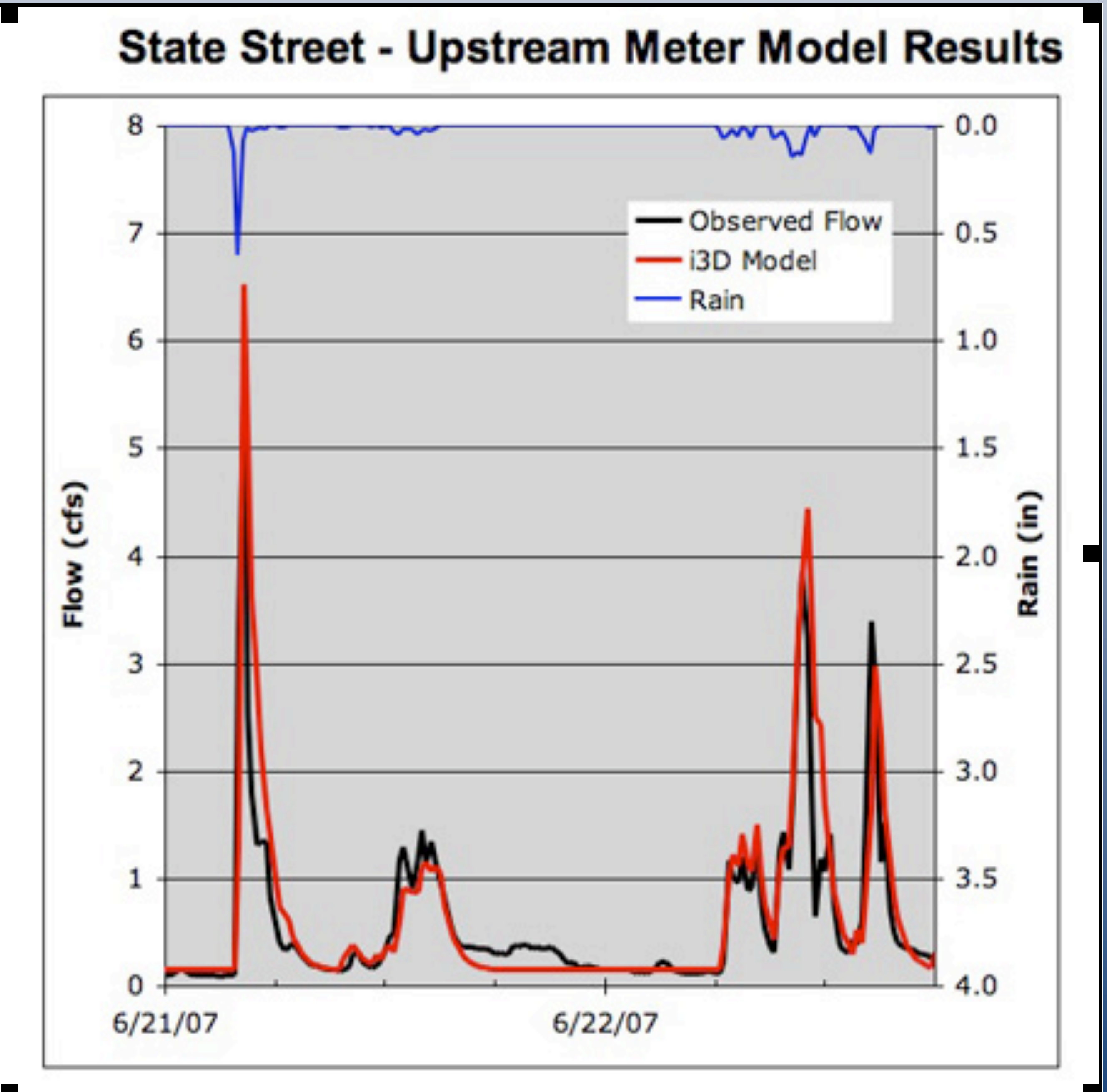
Peoria, IL CSO Case Study

1. Long-term flow meter was downstream of CSO points
2. This lead to a censoring, or a “chop off” in flows metered above the CSO point.
3. Useful information was extracted from the smaller, uncensored events.
4. Peak flows were validated with observations from short-term local metering upstream of the CSO points.

Peoria, IL CSO Case Study

- Accuracy of peak predictions for scaled model gave confidence in the parent model





Wrap-Up

2008 EPA Survey Results

- The Clean Water Act calls for complete prohibition of SSOs
- Ohio has adopted this policy as their own without further clarification
- Systems in Ohio historically designed to transport peak flow consisting of average flow, based on population, design density, an assumed peaking factor and an infiltration allowance
- Ohio EPA addresses SSOs through enforcement actions

2008 EPA Survey Results

1. 86 facilities in Ohio with sewage overflow problems
2. Investment of over $6 Billion to fix
3. $10 Billion needed for improvements to WWTPs
4. Few sources exist to fund these necessary improvements

How can we minimize these expenditures?

Lessons Learned

Common Expectations
"Tried and true" tools combined with engineering judgement can accurately size required facilities

Reality:
Uncertainty leads to use of conservative estimates that may not be obvious to the decision makers

Findings:
Advanced technology and confidence in the model results lead to less conservative estimates

Conclusions

1. Difficult economic times - what will we do differently?
2. Wet weather sewer system projects are often a community's largest capital expenditure
3. Existing tools do not perform adequately given the magnitude of capital costs involved
4. Consider alternative approaches and technologies that are now available

Questions

???