LOWER DES PLAINES RIVER
DETAILED WATERSHED STUDY

CALIBRATION AND VERIFICATION
USING
CLARK'S UNIT HYDROGRAPH METHODOLOGY

Presented by:

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PRESENTATION OVERVIEW

- District Detailed Watershed Plan
  - Development and purpose
  - Watershed Planning Council participation
  - Implementation
- Lower Des Plaines River Watershed
  - Detailed Watershed Plan tasks and goals
  - Discussion of Unit hydrograph options and selection
  - Calibration examples
  - Summary

DETAILED WATERSHED PLAN DEVELOPMENT

- Cook County Stormwater Management Plan (CCSMP) adopted by Board of Commissioners in February 2007
- Chapter 6 of the CCSMP provides guidance for Detailed Watershed Plan (DPW) development
- DWPs developed for Poplar Creek, Upper Salt Creek, North Branch Chicago River, Lower Des Plaines River, Calumet Sag, and Little Calumet River Watersheds
- District enlisted Christopher B. Burke Engineering, Ltd. to assist in preparing Lower Des Plaines River DWP
- District led information-gathering effort by requested existing stormwater related background data, studies, and problem area locations from stakeholders

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DETAILED WATERSHED PLAN PURPOSE

- Identify the stormwater related problems in the watersheds
  - Flooding
  - Erosion
  - Water quality
- Classify identified problems as Regional, Modeled, or Local
  - Regional :
    - Multi-jurisdictional waterways with at least ½ mi^2 drainage area
    - Roadways and bridges impacted by overbank flooding of regional waterways at depths exceeding 0.5 feet
    - Erosion along regional waterway posing imminent risk to structures or critical infrastructure
  - Modeled:
    - Structures, roadways, and bridges within inundation area meeting regional problem criteria
  - Local:
    - Not related to overbank flooding of regional waterway

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DETAILED WATERSHED PLAN PURPOSE

- Develop alternative solutions to Regional and Modeled problems
- Evaluate alternative solutions to determine most effective
- Provide report summarizing:
  - stormwater problem areas
  - comprehensive evaluation
  - Listing proposed regional capital improvement projects

DETAILED WATERSHED PLAN PHASES

- Phase A
  - Gather existing background information on current watershed conditions and past studies
  - Analyze the suitability of existing information
- Phase B
  - Develop hydrologic and unsteady hydraulic models of the watershed
  - Identify potential projects to address stormwater problems
  - Evaluate alternative projects
  - Quantify benefits through economic analysis of property damage from flooding, streambank erosion damage, and transportation damages

WATERSHED PLANNING COUNCIL PARTICIPATION

Watershed Planning Council Workshops

- Workshop #1:
  - Classification of reported problems
  - Draft inundation maps
  - Open space discussion
- Workshop #2:
  - Preliminary alternatives
- Workshop #3:
  - Final alternatives

DETAILED WATERSHED PLANS TO CAPITAL IMPROVEMENT PROJECTS

- Draft watershed plan report reviewed by Watershed Planning Council
- Recommended capital improvement projects reviewed on countywide basis
- Priority for project implementation determined by District's Board of Commissioners
- District will enlist assistance of consultants to develop detailed design documents for project implementation

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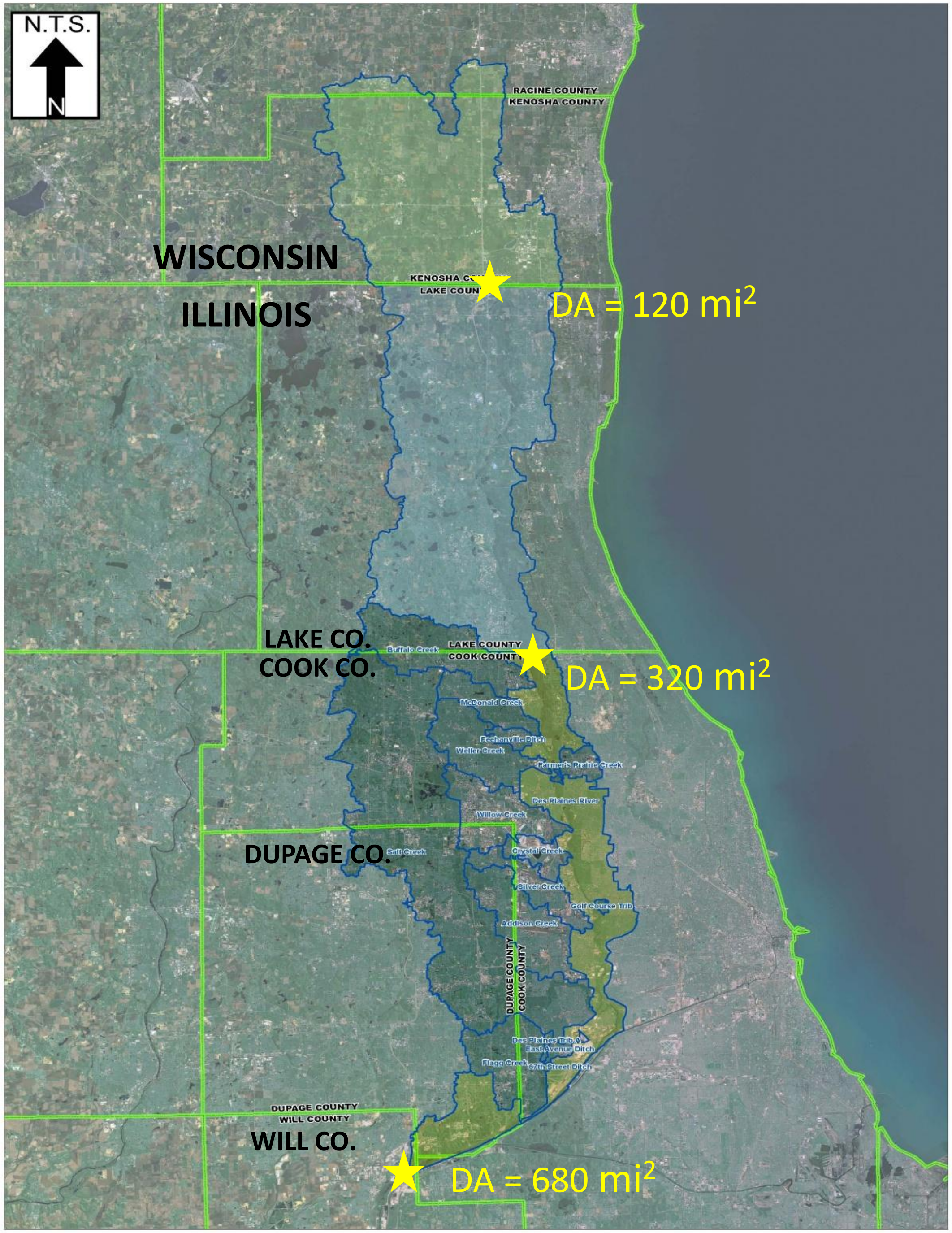
DES PLAINES RIVER WATERSHED



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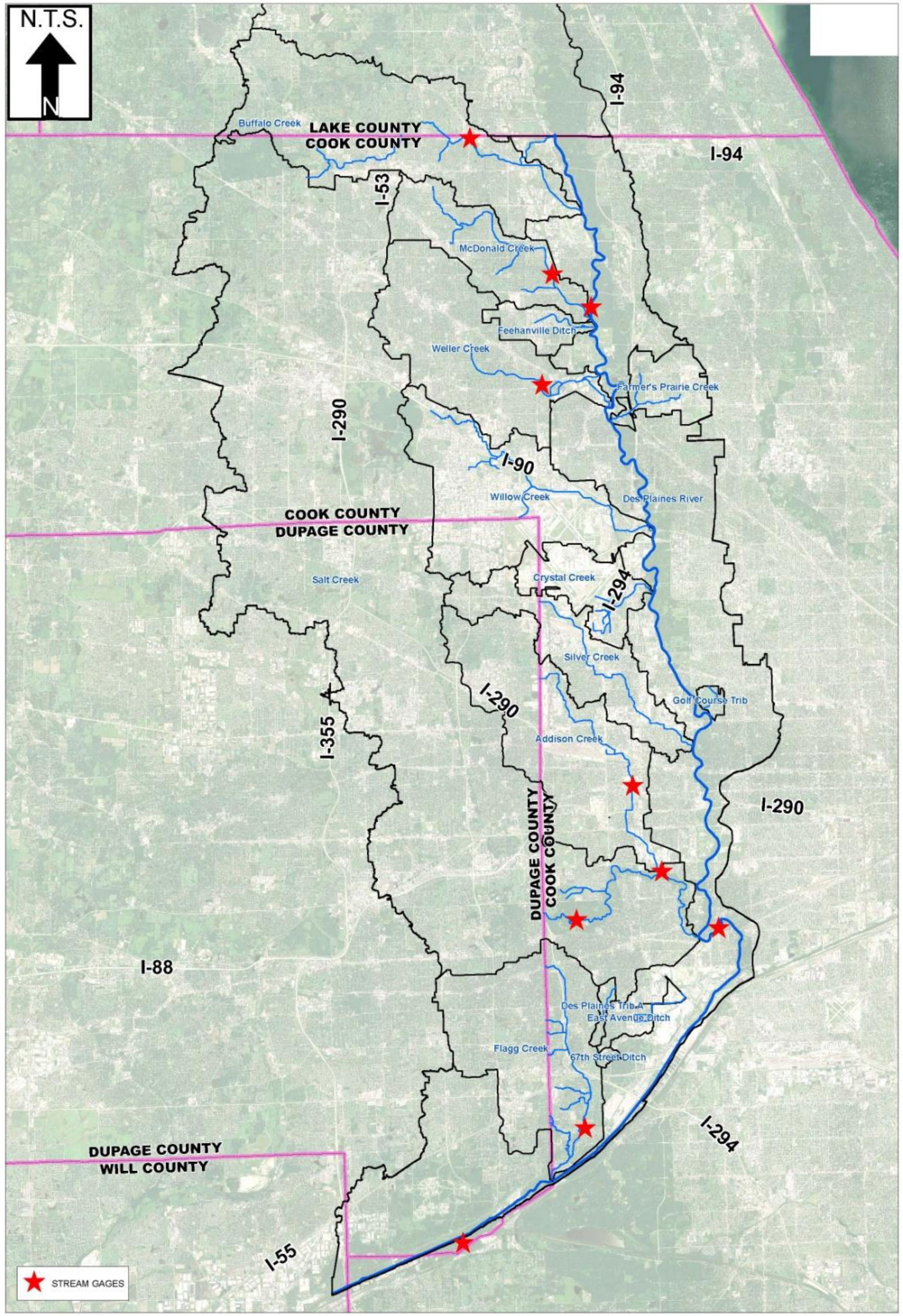
- 15 Tributaries +

  Mainstem Des Plaines River

- USGS Stream Gages:
  - Tributaries: 6
  - Des Plaines River: 4

- Watershed areas:
  - Varied from 0.26 mi^2 to 27.0 mi^2
  - Salt Creek Watershed = 150 mi^2
  - Des Plaines River = 680 mi^2

DES PLAINES RIVER WATERSHED



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PHASE B BREAKDOWN

- Prepare hydrologic (HEC-HMS) and hydraulic (Unsteady HEC-RAS) models
- Calibrate/verify models using available USGS gage records and surveyed HWM's
- Develop 2-, 5- ,10- ,25- ,50- ,100- , and 500-year flood profiles
- Prepare 100-year storm event flood inundation maps
- Calculate economic damages for structure/property, streambank erosion, and transportation
- Develop alternatives to address Regional and Modeled Problem Areas
- Alternative analysis:
    - determine flood damage reduction benefits
    - develop conceptual cost estimate
    - determine Benefit-Cost ratio

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THE LOWER DES PLAINES RIVER WATERSHED STUDY

- H&H Modeling Goals:
  - Evaluate runoff hydrograph options
  - Develop H&H models
  - Calibrate/verify gaged watersheds models to September 13-14, 2008 storm event
  - Apply adjustment factor to ungaged watersheds

UNIT HYDROGRAPH OPTIONS
SCS DIMENSIONLESS UNIT HYDROGRAPH

- SCS Dimensionless Unit Hydrograph
  - Derived from a large number of natural unit hydrographs from agricultural watersheds varying widely in size and geographic location
  - $q_p = \frac{KAQ}{T_p} = \frac{484AQ}{0.5\triangle D + 0.6\,T_c}$

Where: q_p = Peak Discharge (cfs)

A = Area (mi^2)

Q = Runoff (inches)

T_p = Time to Peak (hours)

$\triangle D$ = Duration of unit excess rainfall

K = Peak Factor Rate (controls shape of unit hydrograph)

(K = 484: standard default for TR-20, HEC-1, and HEC-HMS hydrologic models)

- Required parameter: Time of Concentration (T_c)

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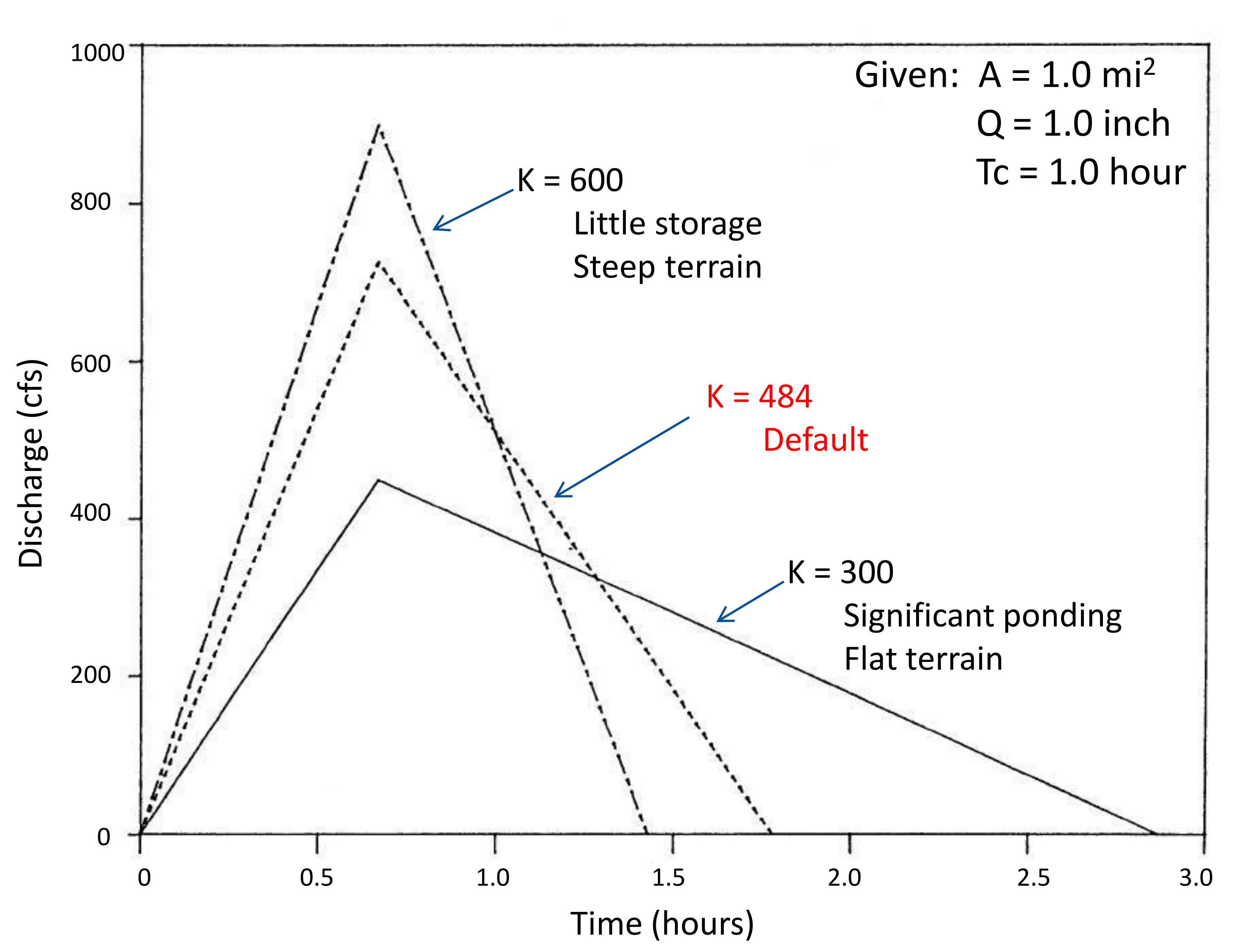
Sensitivity of SCS Triangular Unit Hydrograph to K



UNIT HYDROGRAPH OPTIONS
SCS DIMENSIONLESS UNIT HYDROGRAPH

Example:

- SCS Des Plaines River Floodwater Management Plan – 1976
- SCS developed a TR-20 hydrologic model of Willow Creek Watershed
  - Calibrated to USGS Gage (Willow Creek at Orchard Place, discontinued 1979)
- Calibration achieved using K = 218
- Entered into TR-20 using dimensionless unit hydrograph
- If HEC-1, modification of subroutine in source code calculating dimensionless unit hydrograph. Recompile to make new executable HEC-1 file.

UNIT HYDROGRAPH OPTIONS

Clark's Unit Hydrograph

- Explicitly represents two critical processes in transformation of excess precipitation to runoff:

Translation:

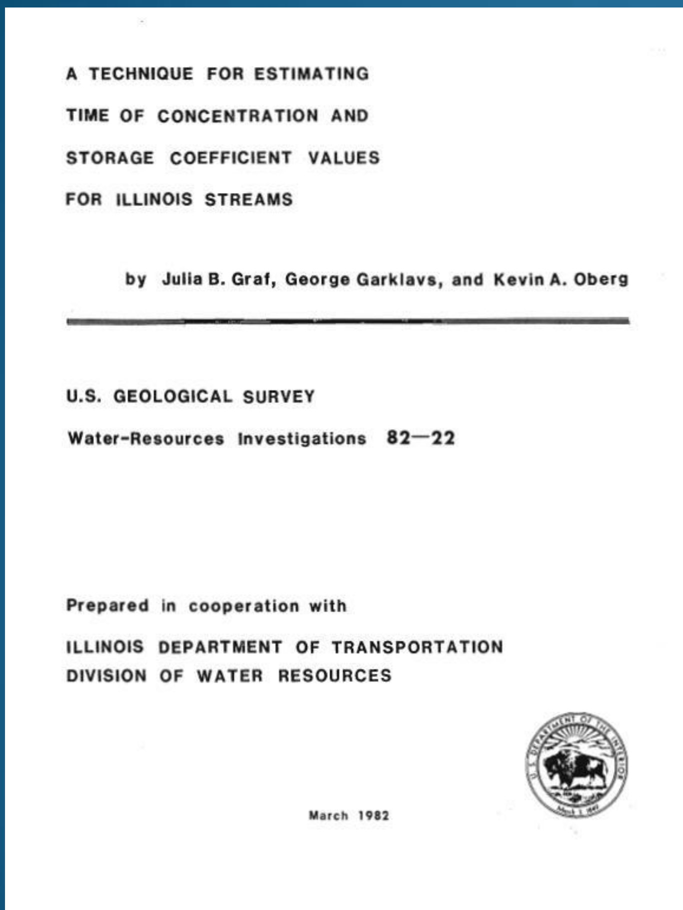
- Movement of the excess from origin, throughout the drainage area, to watershed outlet
- represented by time-area relationship

Attenuation:

- Reduction of magnitude of discharge as the excess is stored throughout watershed
- represented by linear storage reservoir (allows for accounting of natural storage areas located within watershed)

- Required parameters are Time of Concentration (T_c) and the Storage Coefficient (R)

INITIAL R COEFFICIENT DETERMINATION



A TECHNIQUE FOR ESTIMATING
TIME OF CONCENTRATION AND
STORAGE COEFFICIENT VALUES
FOR ILLINOIS STREAMS

by Julia B. Graf, George Garklavs, and Kevin A. Oberg

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations 82—22

Prepared in cooperation with
ILLINOIS DEPARTMENT OF TRANSPORTATION
DIVISION OF WATER RESOURCES

March 1982

- Method to estimate Clark's Unit Hydrograph parameters (T_c and R)
- Regression equations based on results from 98 gaged watersheds in Illinois
- HEC-1 hydrologic models developed and calibrated for each gaged watershed
- Watersheds included both rural and urban conditions
- Study concluded method could be used for rural and urban watersheds
- $(TC + R) = 35.2\ L^{0.39}\ S^{-0.78}$ where:
- L = Stream Length
- S = Slope
- R/(TC+R) = Regional values (LDPR watershed used 0.7)

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INITIAL R COEFFICIENT DETERMINATION

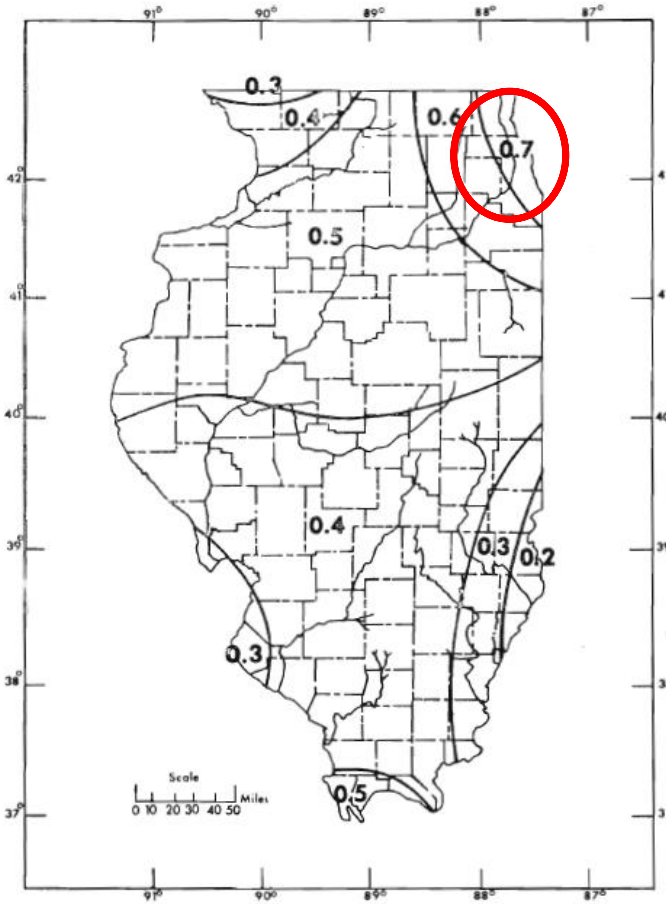

Figure 1.--Regional values of R/(TC + R).

CLARK'S UNIT HYDROGRAPH METHOD
Application to LDPR Watershed

- USGS Regression Equations used to establish T_c and R
- R chosen as calibration parameter
- R multiplier uniformly applied to all subbasins in a sub-watershed (HMS)
- Calibration checked at USGS gage location in Unsteady HEC-RAS
- For the 6 gaged tributaries, R multiplier varied from 1.65 to 3.00
- Relationship between the R multiplier and stream slope was developed for gaged tributaries
- Relationship then used to establish R multiplier for ungaged watersheds

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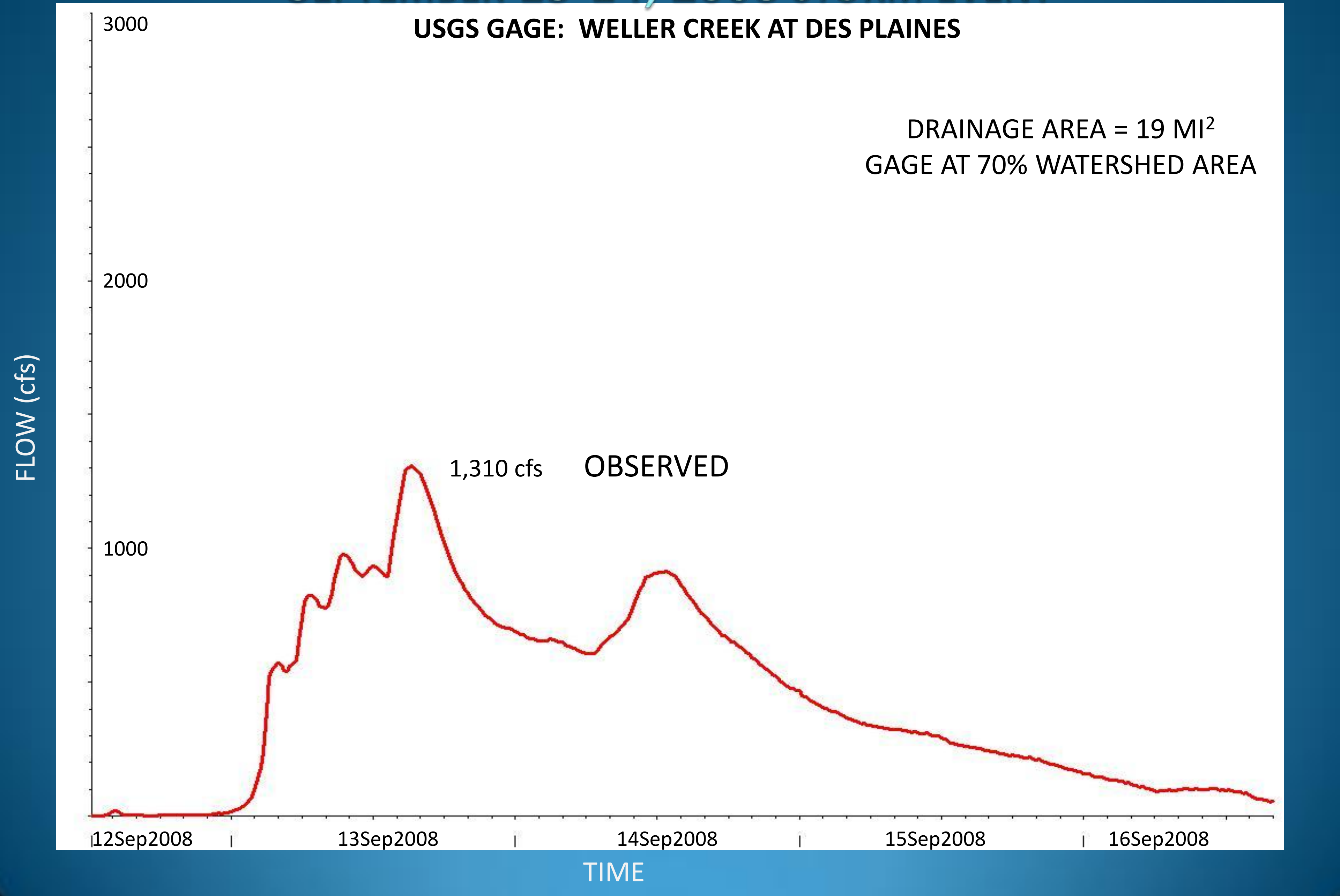
Example Calibration: September 13-14, 2008 storm event



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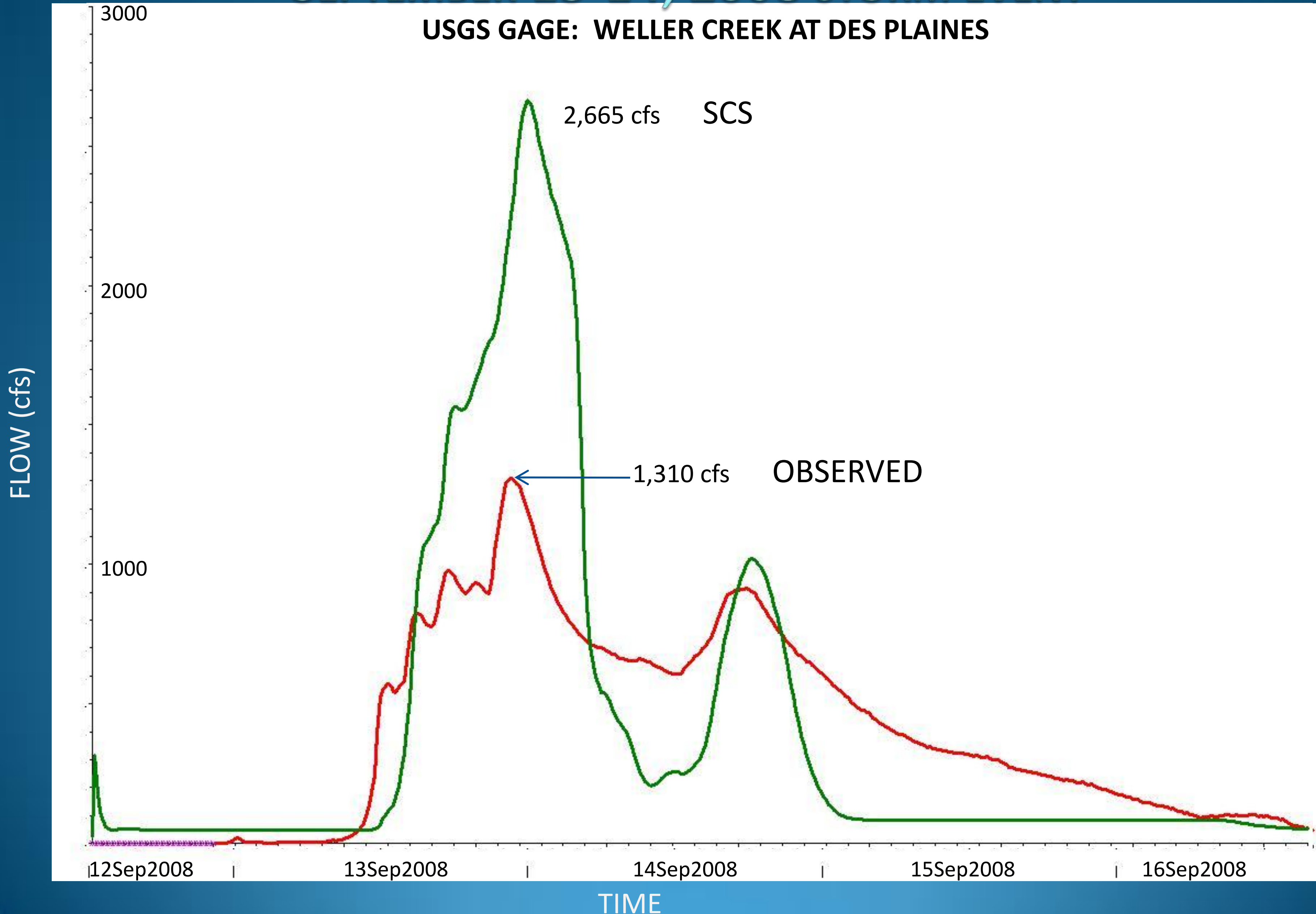

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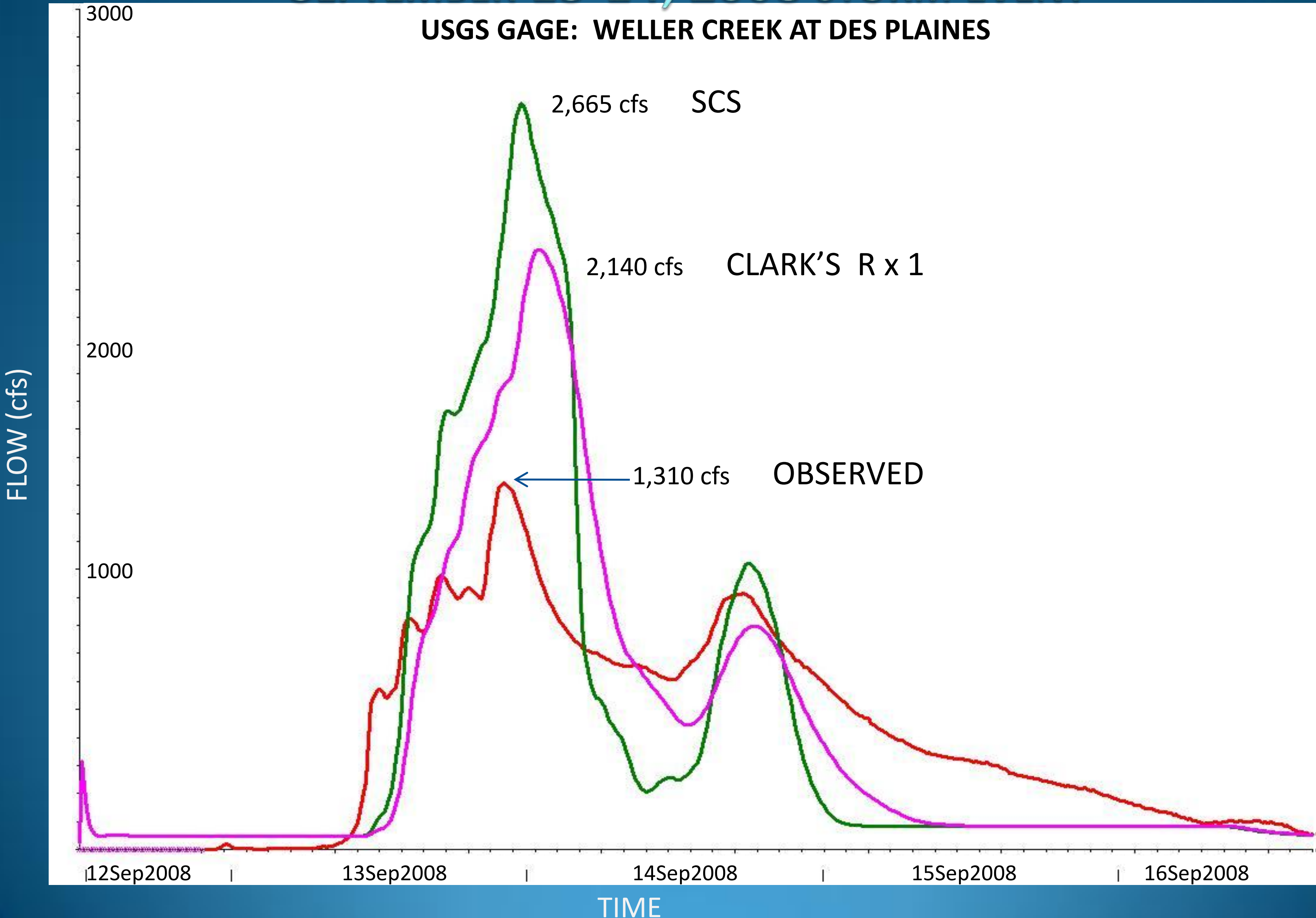

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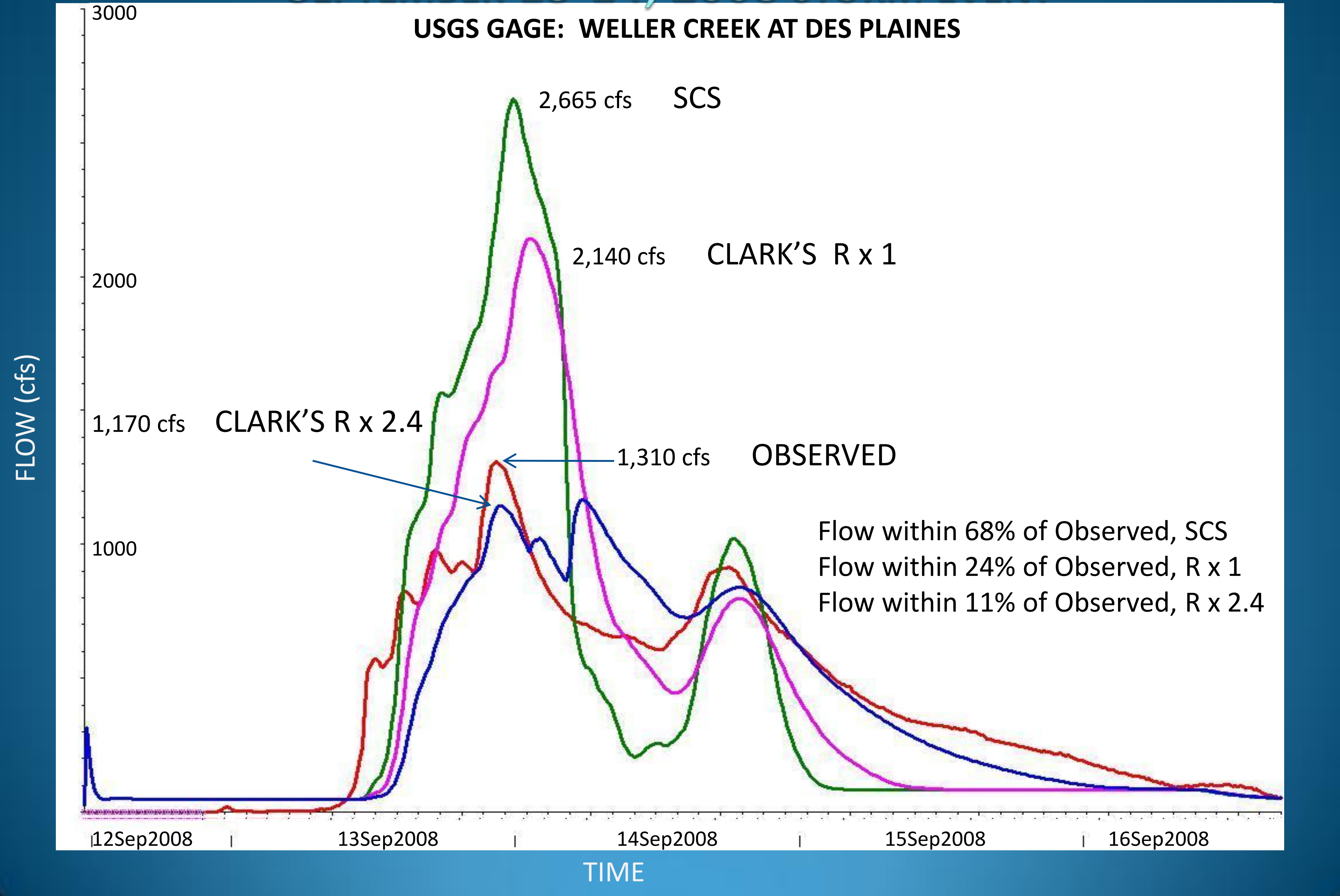

UNIT HYDROGRAPH SELECTION
SCS vs. Clark's

- SCS Dimensionless Unit Hydrograph
  - K = 484 does not represent properties of all LDPR watersheds
  - Difficult to modify K value in hydrologic modeling to account for natural storage routing
  - Resultant combined hydrograph peak discharges can be over estimated do to "peak on peak" addition
  - Adjustment of K should be based on natural surface storage rather than watershed slope (T. Suphunvorranop, 1985)
- Clark's Unit Hydrograph
  - Previously applied to several LDPR tributaries
  - Accounts for natural storage routing
  - Accepted process for calculating Runoff Curve Number (CN) and T_c
  - R coefficient could be used as a calibration parameter for gaged watersheds
  - Relationship for R vs. stream slope could be applied to ungaged watersheds

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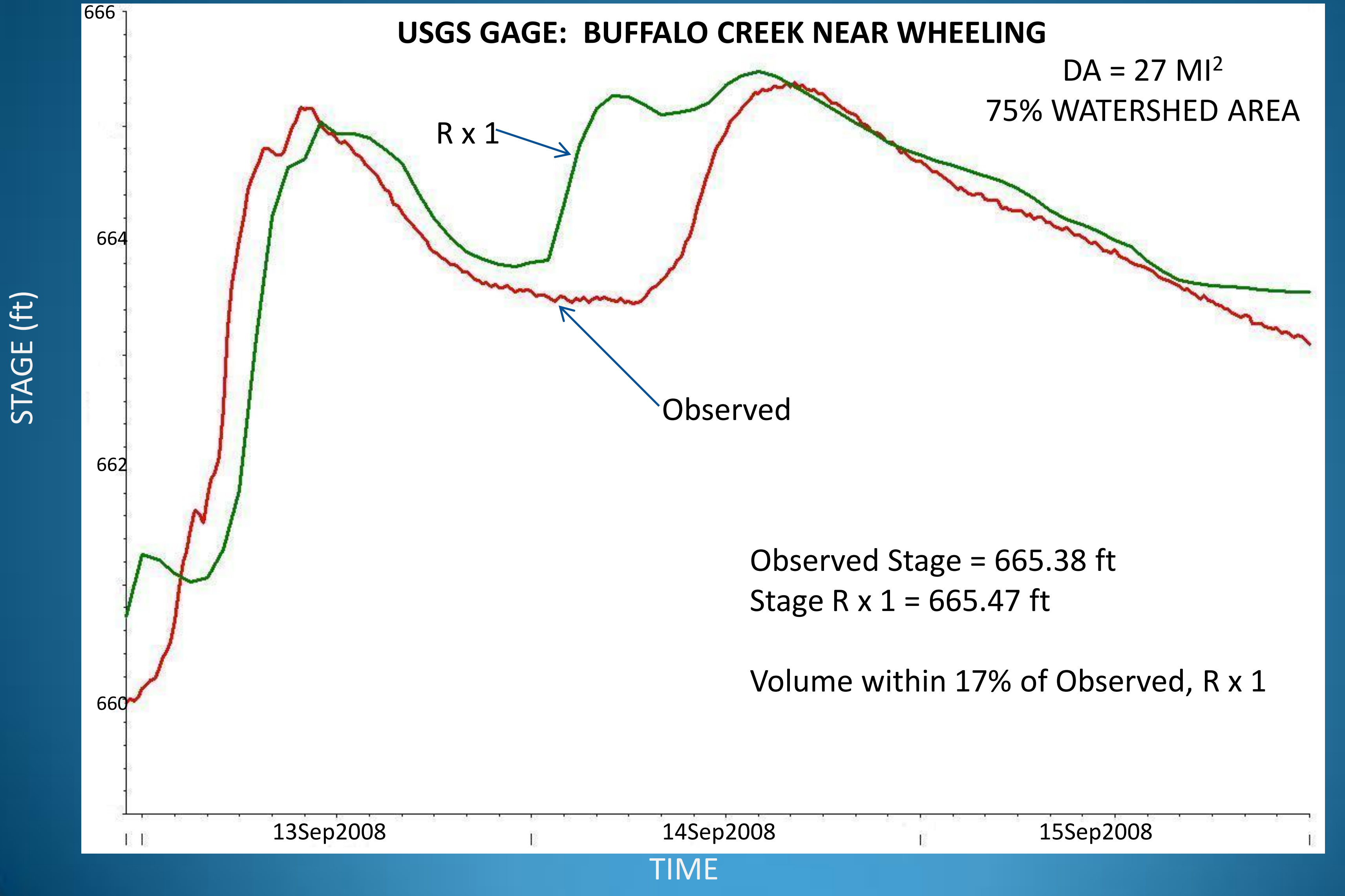
BUFFALO CREEK WATERSHED
CLARK'S R COMPARISON



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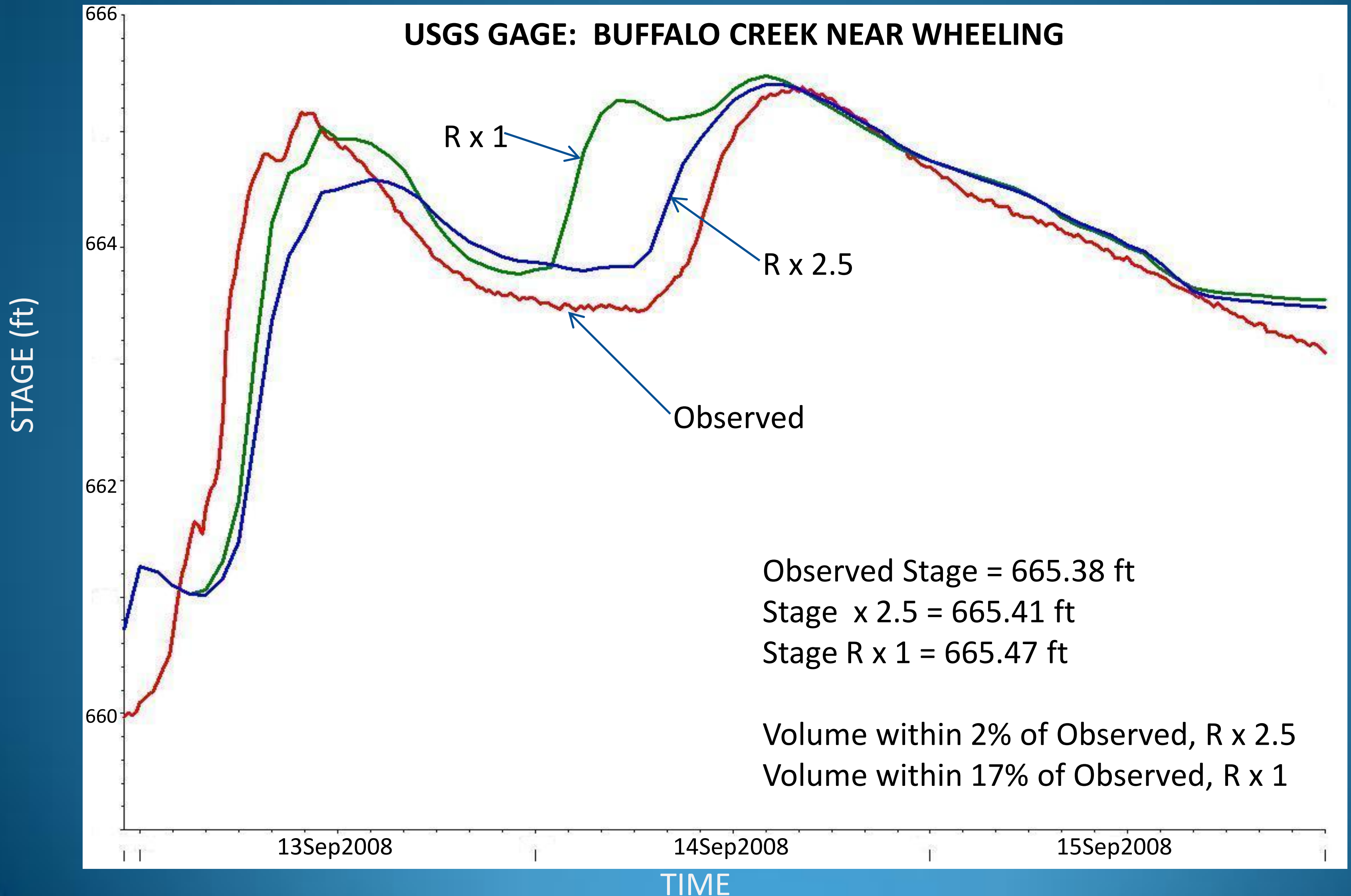
CLARK'S R COMPARISON



OBSERVATIONS

- Clark's Unit Hydrograph calibration
  - R resulting from standard calculation was insufficient
  - R multiplier improved hydrograph shape compared to observed data
  - No need for additional calibration using parameters with accepted calculation methodologies such as of CN or T_c
  - R multiplier calibration can vary based on:
    - Stream slope
    - Watershed shape
    - Number of modeled storage areas (including ponds, flood control reservoirs, natural storage)
  - Tributaries with higher percent of storage areas modeled required lower R multiplier

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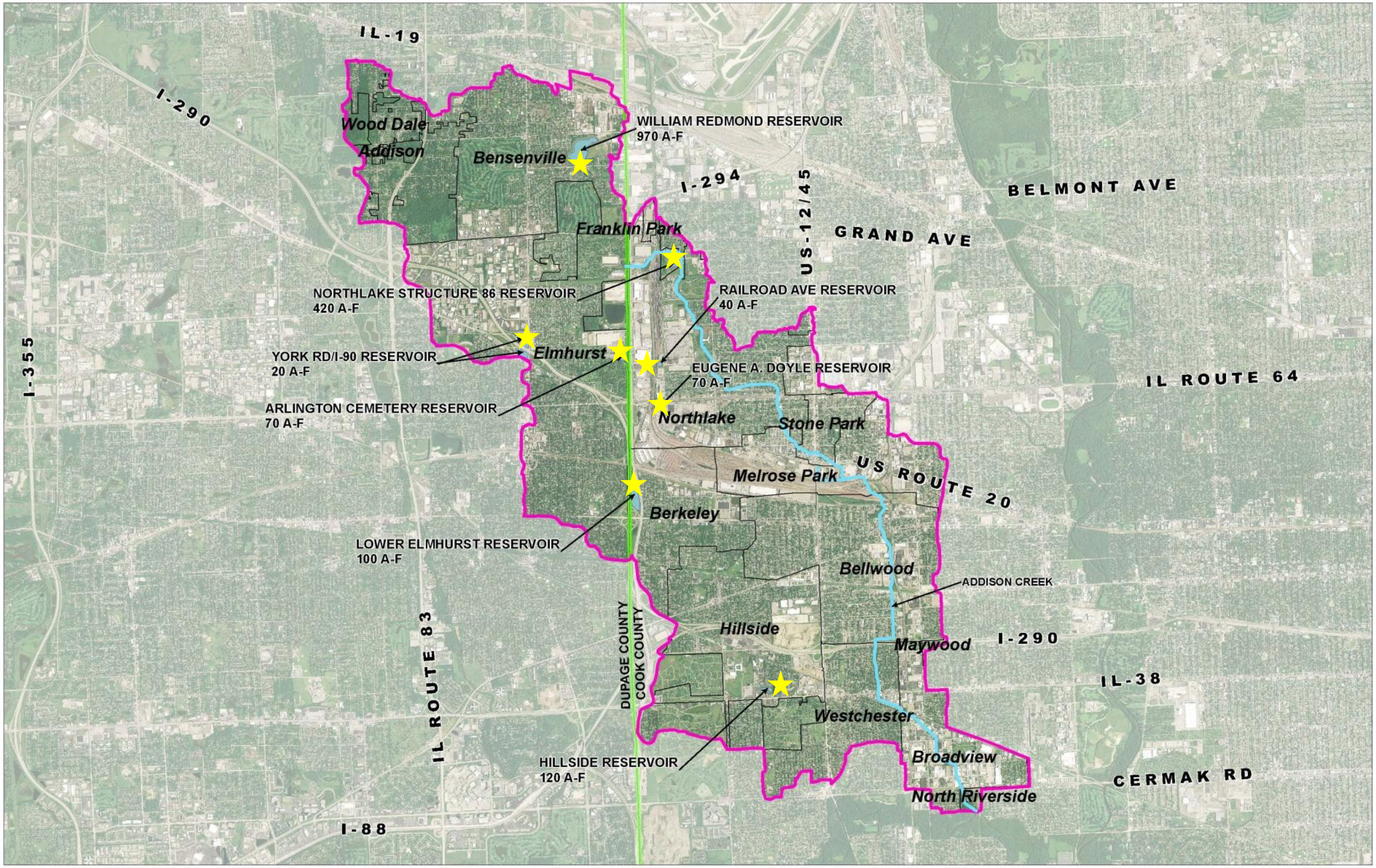
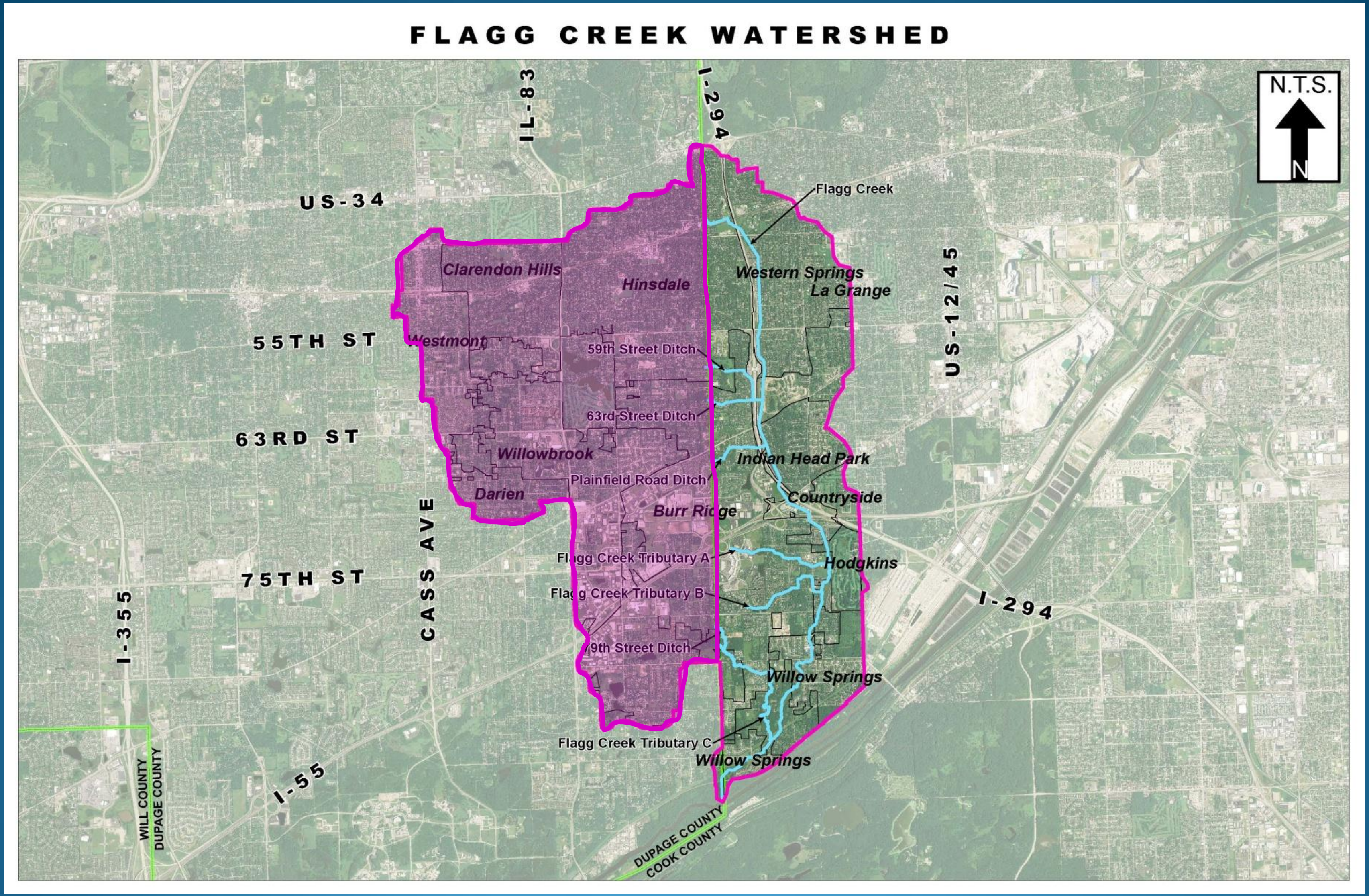
ADDISON CREEK WATERSHED



22 MI², 8 FLOOD CONTROL RESERVOIRS

APPROXIMATELY 1,800 A-F

R X 1.65



22 mi², 60% of Watershed in DuPage County

Limited modeling of storage areas

R x 3.00

CLARK'S UH CALIBRATION ADVANTAGES

- LDPRDWP Advantages:
  - Continued use of Clark's Unit Hydrograph per previous studies
  - Methodology applicable throughout entire study area
  - No need for additional calibration using parameters with uniform calculation methodologies such as of Runoff Curve Number or T_c
  - Considers storage factors not explicitly evaluated in H & H modeling efforts
  - Use caution when applying strictly to ungaged watersheds and model storage in detail.

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