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A Dam Safety Study Involving Cascading Dam Failures

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Policy / Technical Issues

- How to account for the failure of "other" dams in the drainage basin

- How to account for the behavior of all basin dams acting as a system

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Outline

- Describe the physical situation
- Describe how the Kansas City District is addressing the problem
- Discuss the policy and technical issues

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Republican River Basin

Kansas , Nebraska and Colorado

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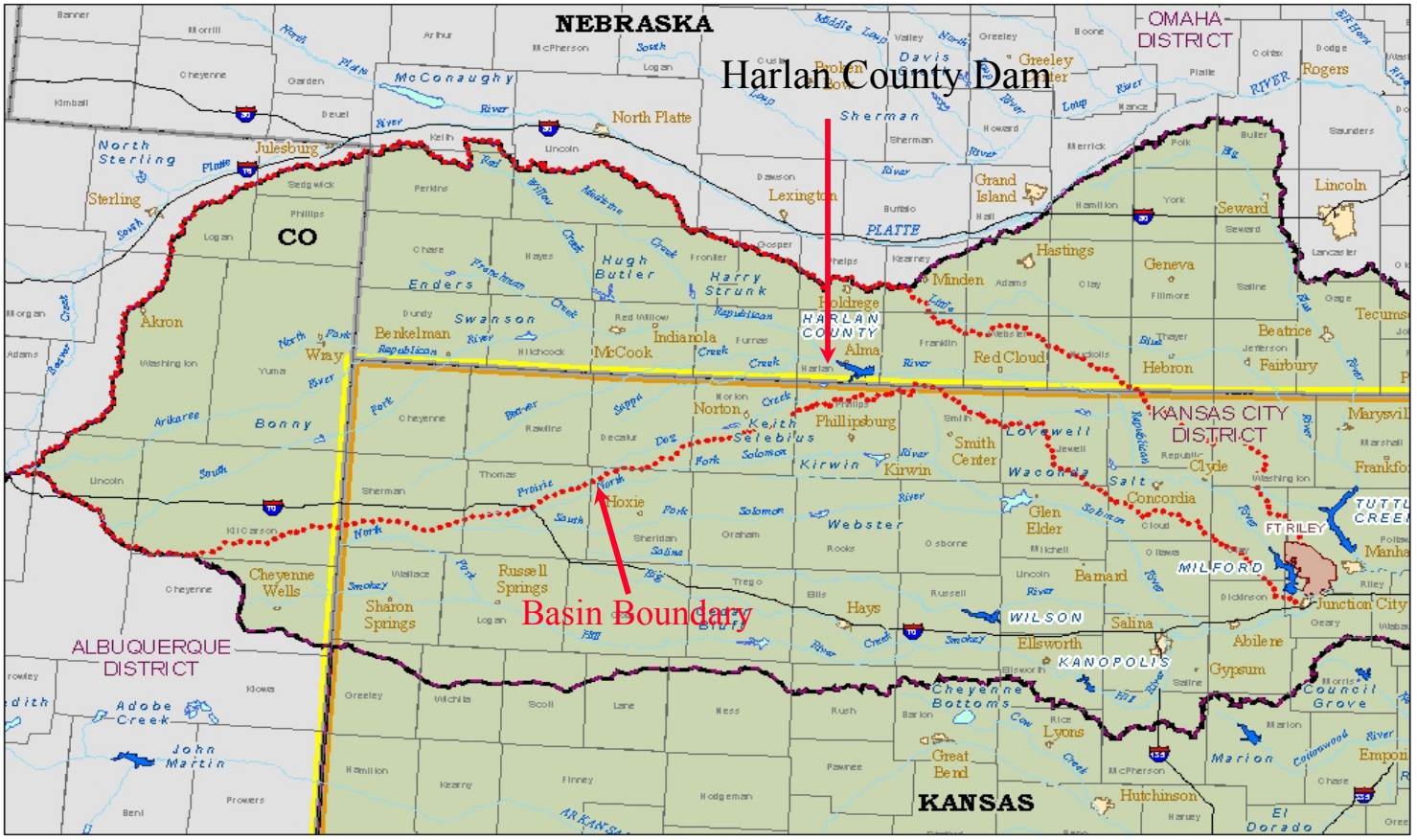
Republican River Basin



Mapped and edited by the U.S. Army Corps of Engineers, Kansas City District, GeoSpatial Data Systems Team
Lambert Conformal Conic Projection
1983 North American Datum
False Northing: 0
Central Meridian: -98
Latitude of Origin: 40

Harlan County Dam Safety Assurance Evaluation

Republican River Basin

DEPARTMENT OF THE ARMY
KANSAS CITY DISTRICT
CORPS OF ENGINEERS

November 2002

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The Great Republican River Flood of 1935

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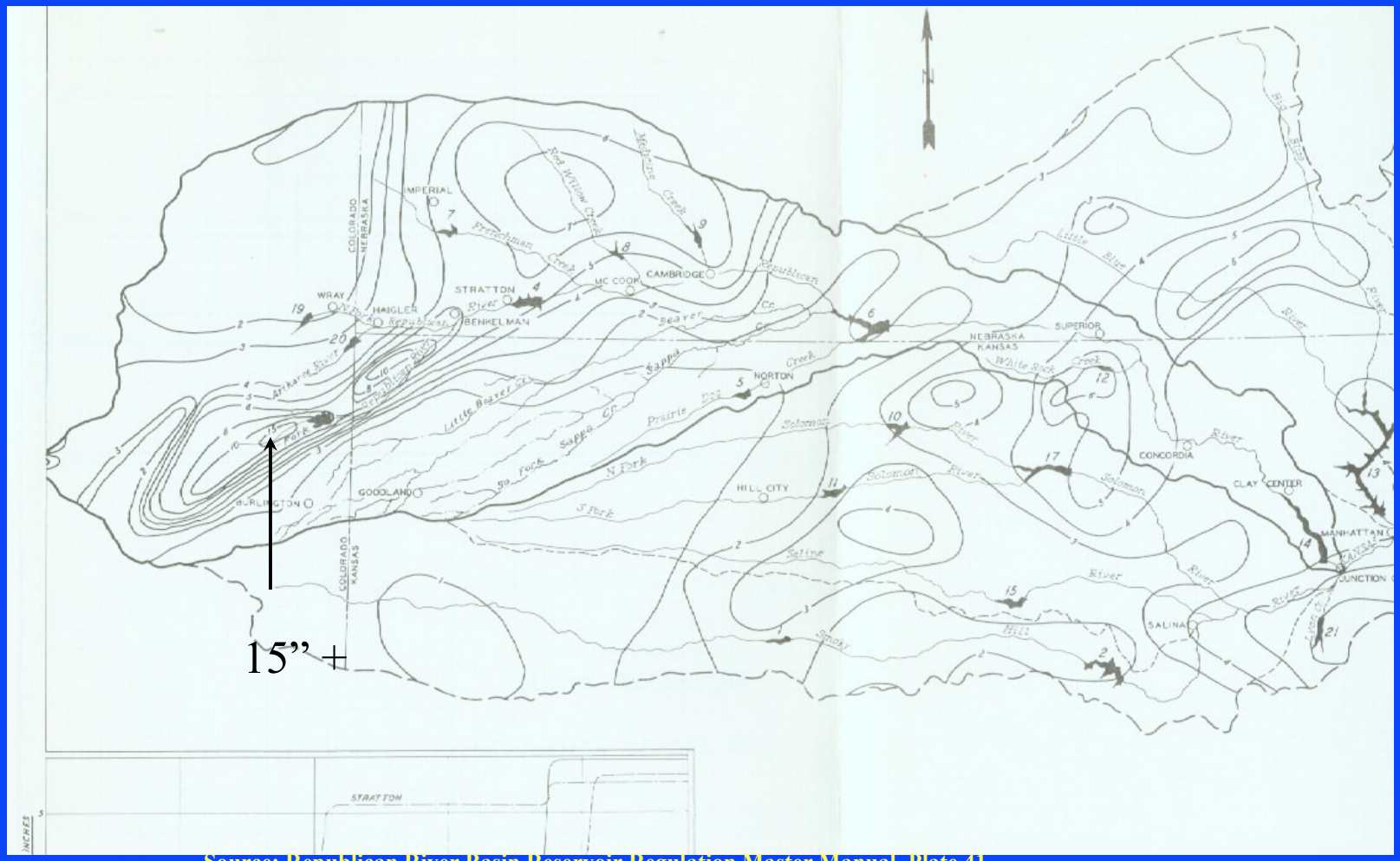
Rainfall, 1935 Flood



Source: Republican River Basin Reservoir Regulation Master Manual, Plate 41

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1935 Flood

- Up to 24” (bucket survey)
- 113 people killed
- “Sunny Day” flood…..”Walls” of water
- Basin is kinematic
- At Harlan County damsite
  - Peak discharge…..280,000 cfs
  - Mean discharge for peak day……144,000 cfs

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COE Dam Safety Study
Harlan County Dam

Harlan County , Nebraska

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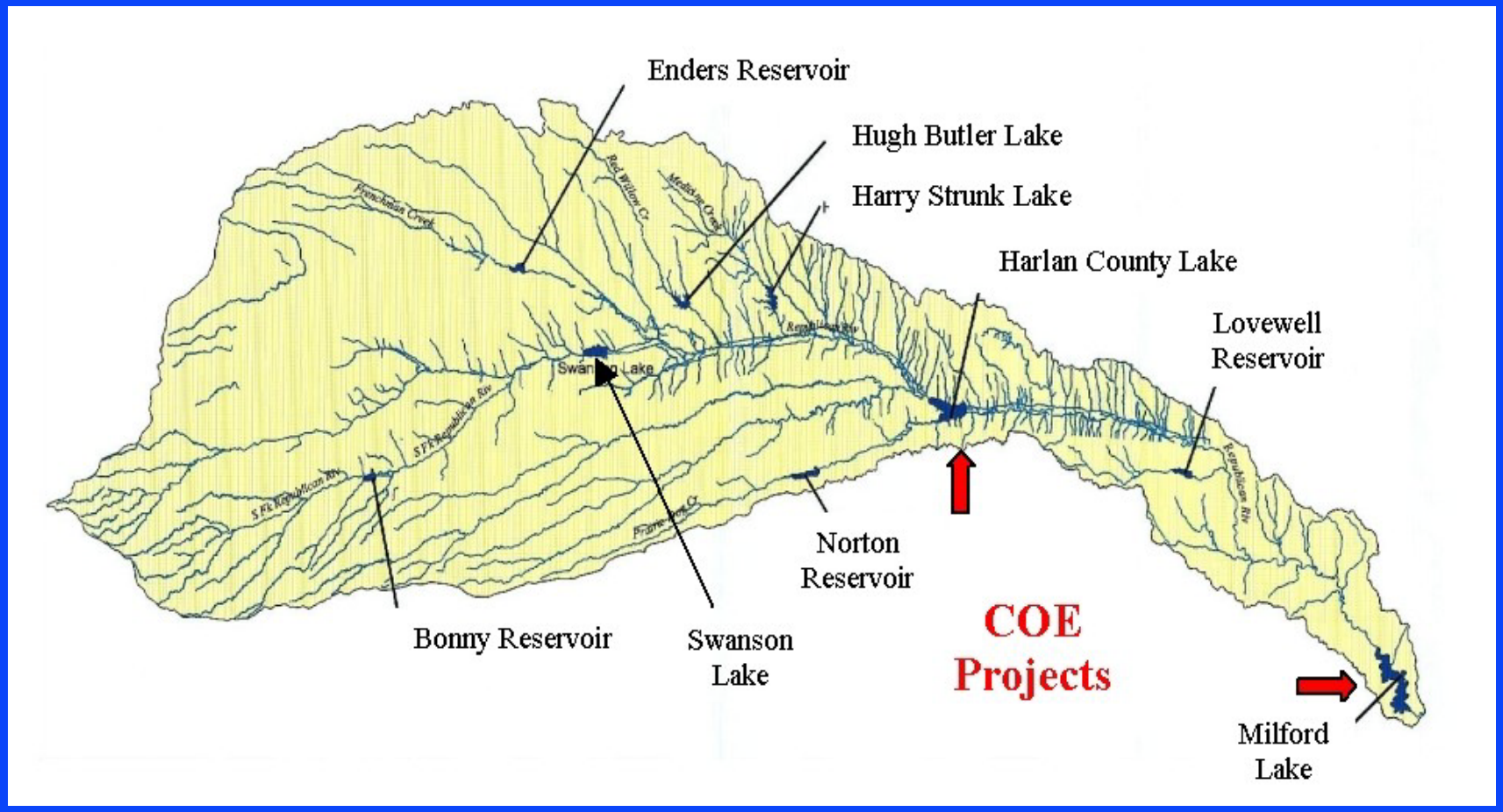
Dams in the Republican River Basin



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Two Corps of Engineers Flood Control Projects

- Milford Dam (near mouth of Republican River)
- Harlan County Dam (near midpoint of River)

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Seven Bureau of Reclamation Irrigation/Flood Control Reservoirs

- Bonny
- Swanson
- Enders
- Harry Strunk
- Hugh Butler
- Keith Sebelius
- Lovewell

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Four Dams in Series
(Cascade of Failing Dams)

- Bonny
- Swanson
- Harlan County
- Milford

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Critical population centers and high value economic locations are downstream of Milford Dam in the Kansas River Valley….

Therefore, to fully evaluate impacts of a dam failure, the performance of the entire system must be analyzed

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Overall Objective of ER 1110-8-2(FR)

Inflow Design Floods for Dams and Reservoirs

Find the worst possible hydrologic event applicable to a dam or reservoir

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"Normal" COE Dam Safety Study Procedure

- Determine Probable Maximum Precipitation (HMR 51)
- Develop Runoff Model of Basin
- "Center" PMP in Basin to Produce Maximum Depth of Rainfall in Basin (HMR 52)
- Apply Rainfall to Model to Produce Inflow Hydrograph
- Peak Hydrograph by 25-50 %
- Determine Project Response to Peaked Hydrograph

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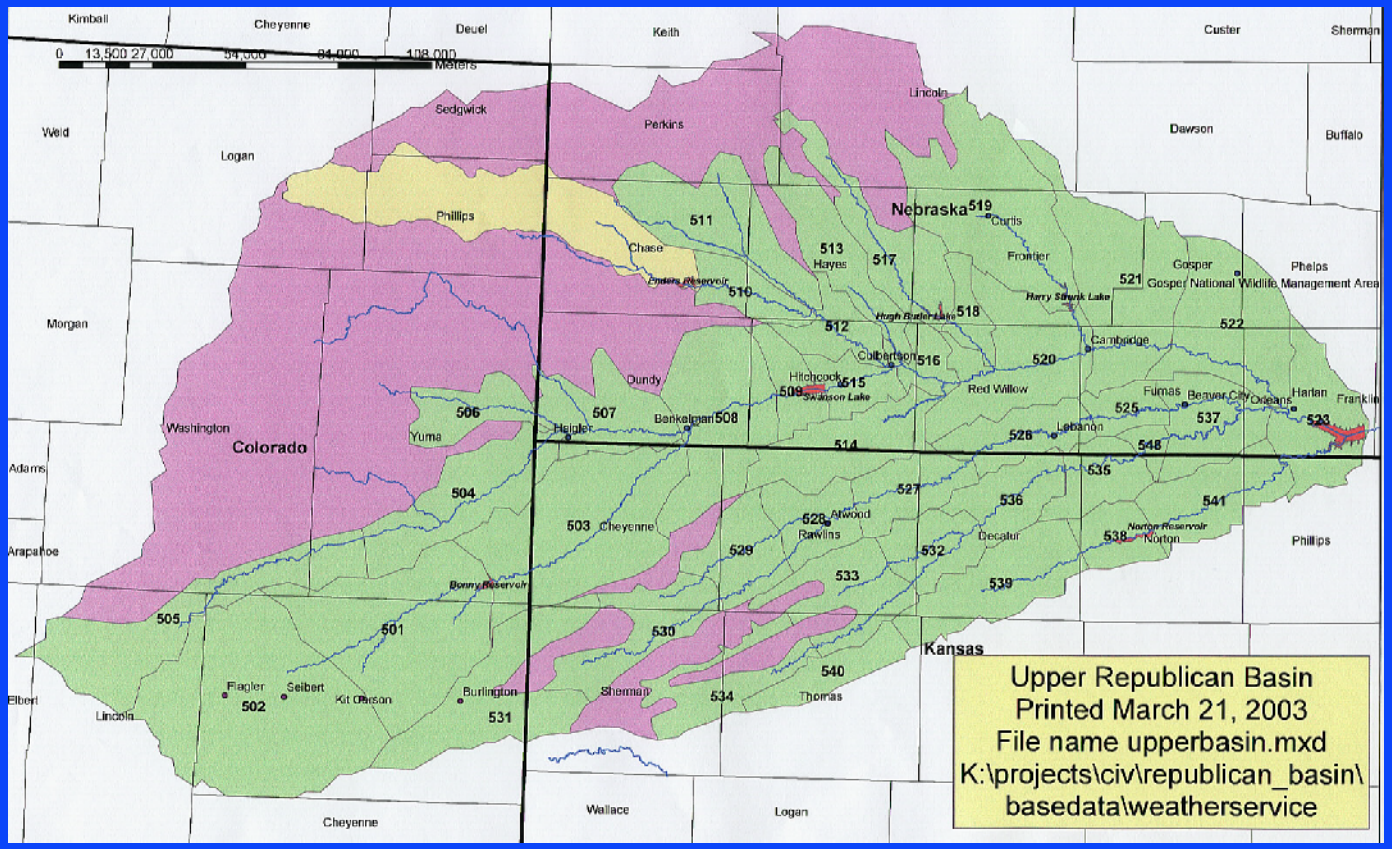
One Complicating Factor
Non-Contributing Areas



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Kansas City District's Study Methodology

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PMP Rainfall

- Determined Maximum Rainfall Depth using HMR 51 for Harlan County Dam
- Determined Critical Center of Rainfall for Harlan County Dam
  - Only Contributing Drainage Area
  - Upstream Dams Were Ignored..(but performance of these dams was accounted for in the HMS model)

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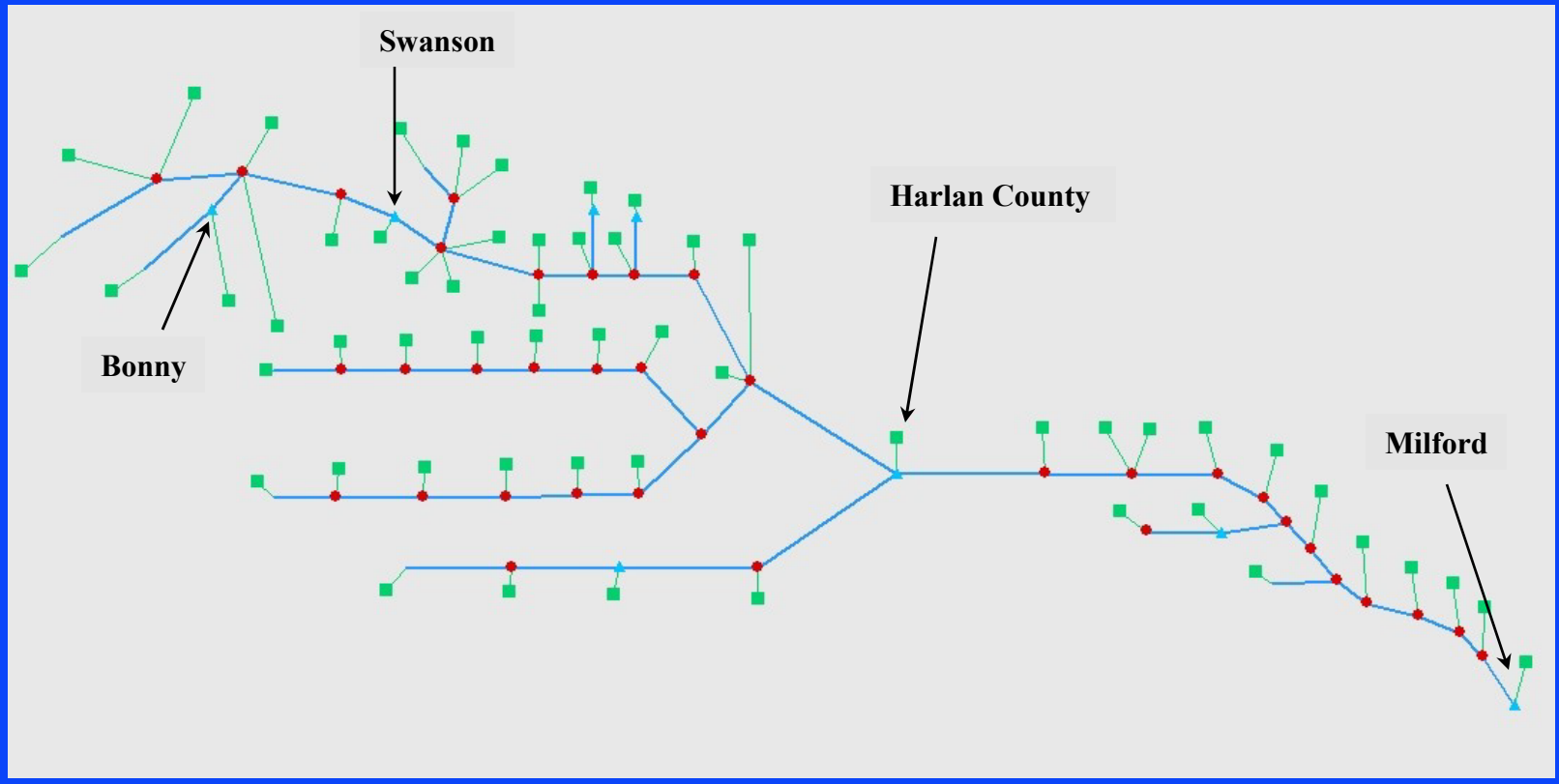
Developed Republican River HEC-HMS Model



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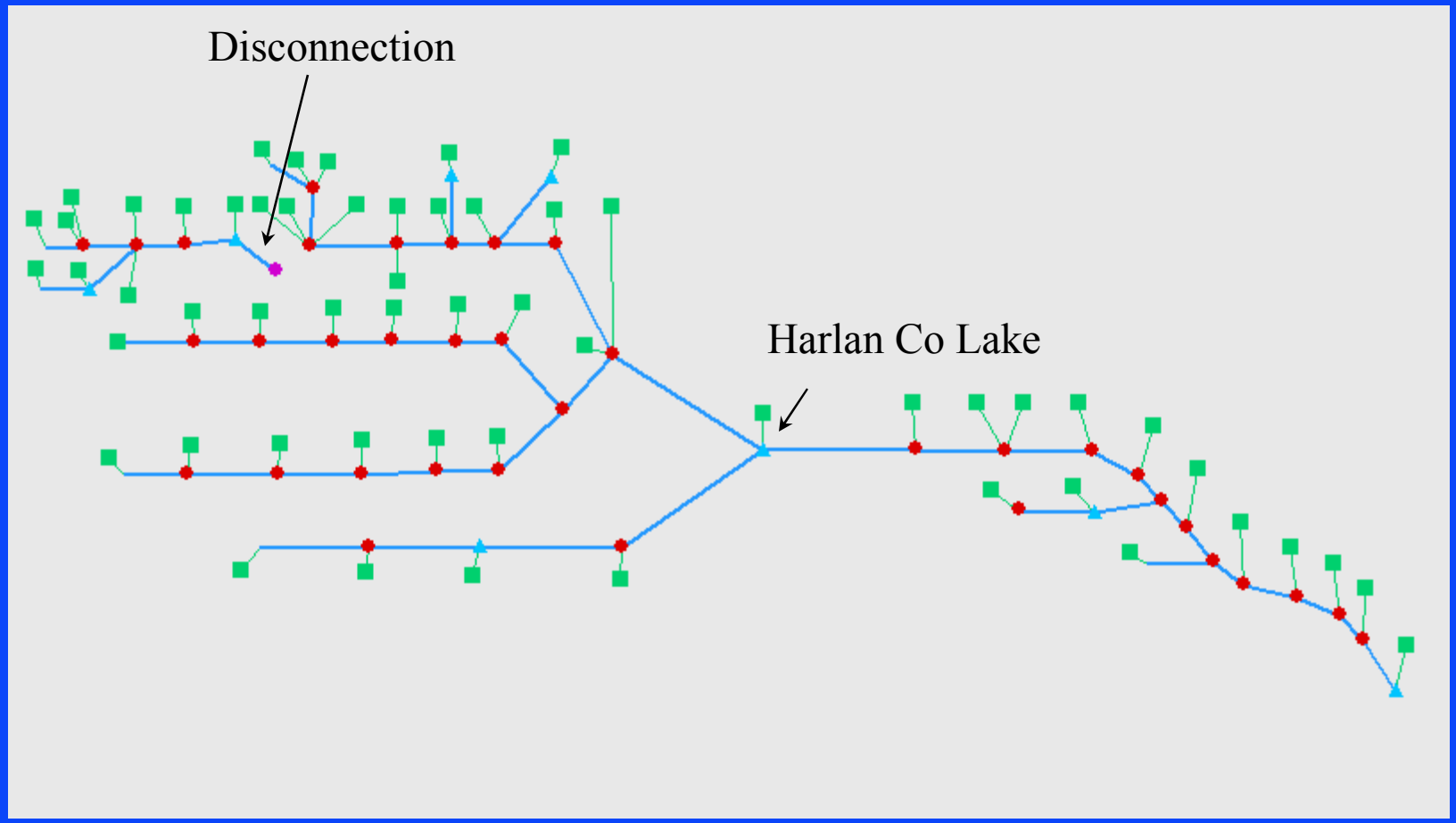
Swanson Sink Version



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Using Swanson Sink Model and HMR52 Rainfall…..

- The Inflow Hydrograph to Swanson Dam Was Computed
  - (Would Swanson Dam be Overtopped?)
- The Inflow Hydrograph(s) From All Subbasins Between Swanson Dam and Harlan County Dam Were Computed

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If Swanson Dam Failed……

- The Rupture of Swanson Dam and the Movement of the Resultant Floodwave was Routed to Harlan County Dam using UNET (DOS Version)
  - Reservoirs treated as storage areas
  - EF (Embankment Failure) record used

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Inflow Hydrograph

Combine Hydrographs

Check Peak Discharge and Compute Volume

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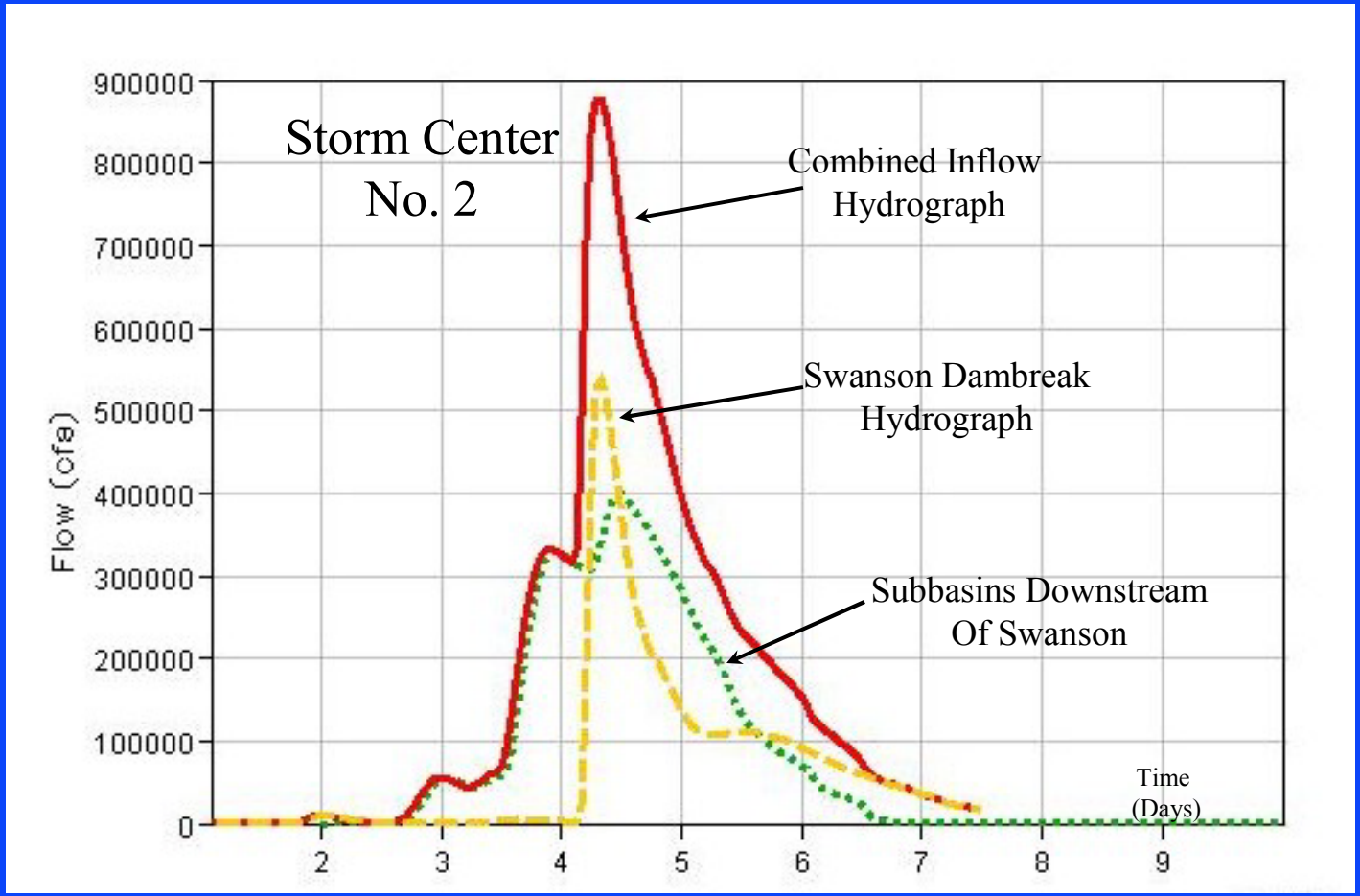
Representative Hydrograph



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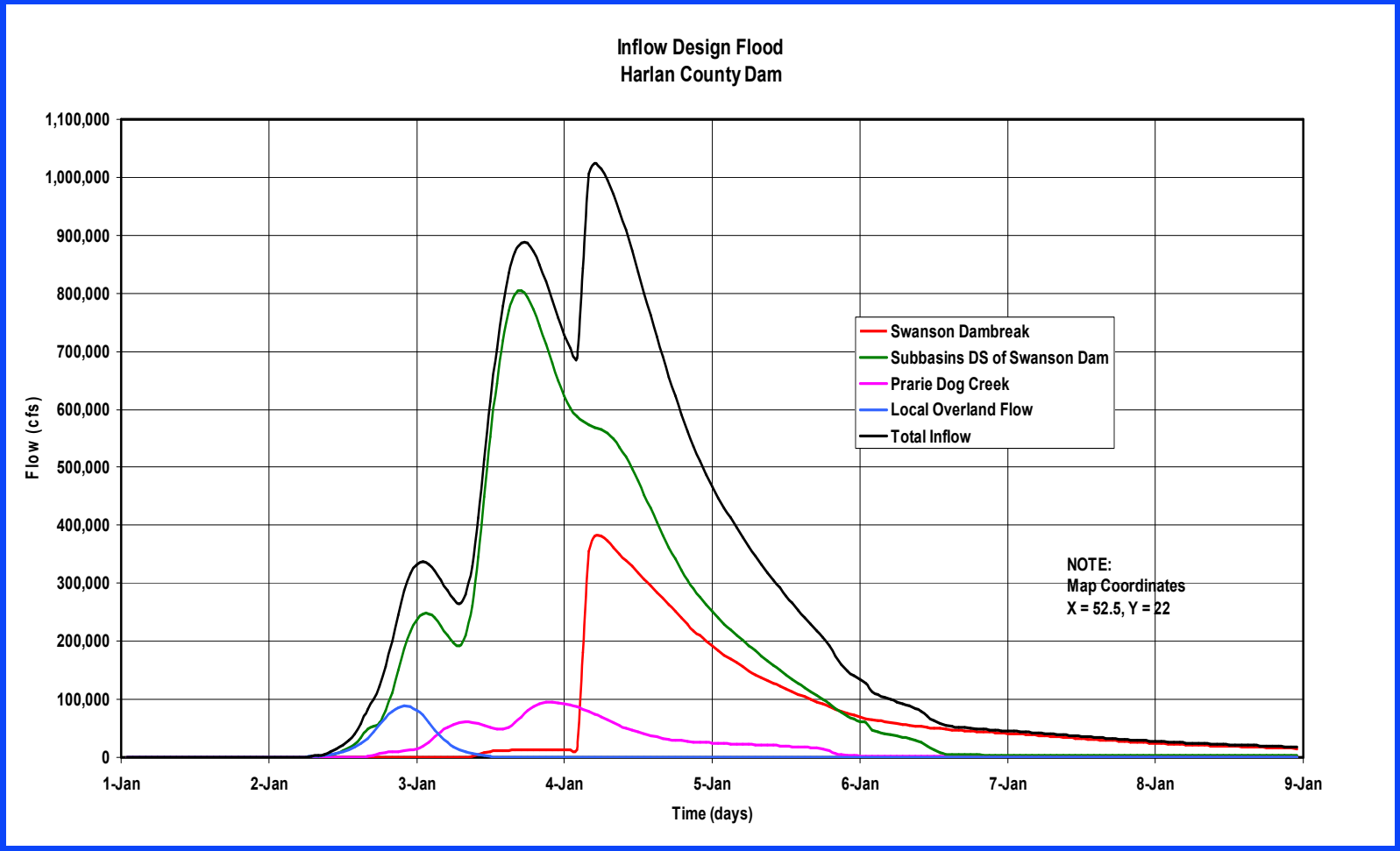
Critical Hydrograph



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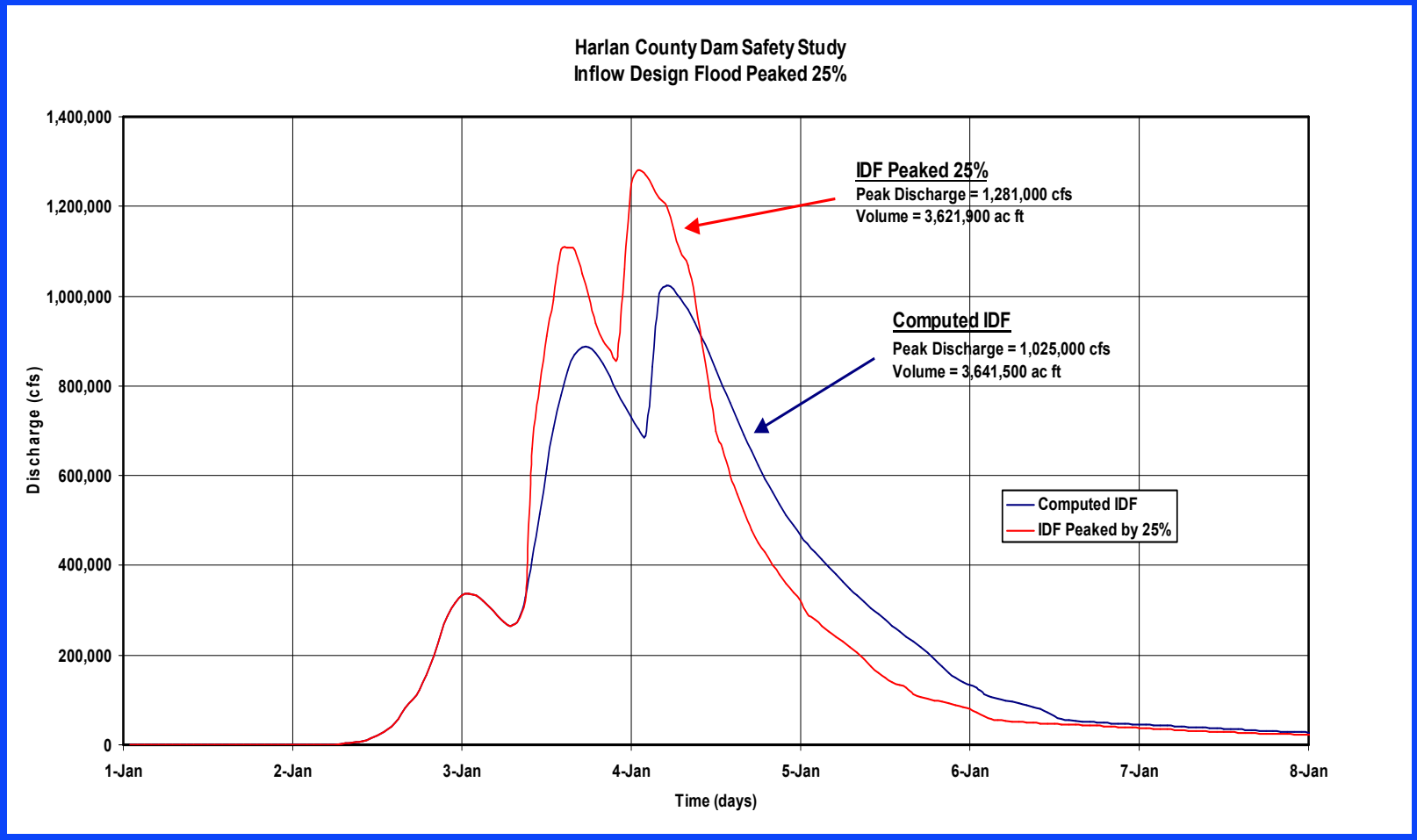
Critical Hydrograph Peaked 25%



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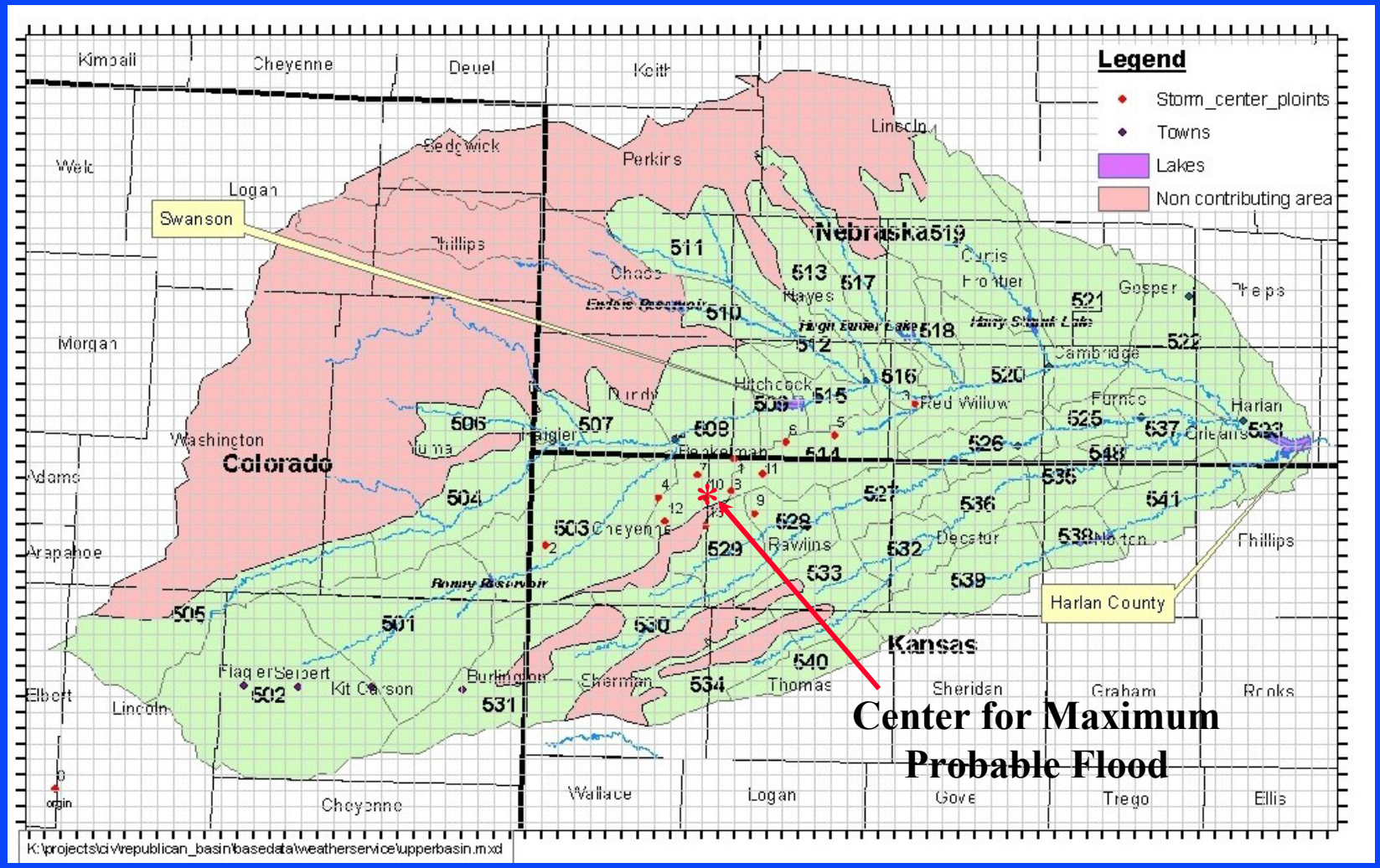
Storm Centers



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Lessons Learned

- Watch the volumes
  - When using UNET, make sure that extra storage above the top of dam does not find its way into the outflow hydrographs
- When using an HEC-HMS model to determine reservoir inflow. The proper inflow is the sum of the inflows from the tributaries.

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Observations

- The Kansas City District is reasonably content with the methodology used to compute the inflow hydrograph
- A UNET model will be used to track the failure of Harlan County Dam and the movement of the floodwave into the Milford Dam pool
- Milford Dam is not expected to fail

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Observations

- To the area downstream of Milford Dam, the difference between a failure and non-failure of Harlan County Dam is the release of the volume of water stored by Harlan County Dam into the Milford pool. This affects the discharge through the spillway at Milford Lake.

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Observations

- Since the population centers and high damage areas (mostly protected by levees) are downstream of Milford Lake, the response of the entire system is critical
- To properly account for the system response, the initial condition of Milford Lake is critical

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Two Approaches to Antecedent Conditions Suggested in ER 1110-8-2(FR)

- Assume the reservoir pool is at the top of the flood control pool at the onset of the IDF
- Assume the reservoir pool is at its normal elevation, then a storm equal to ½ PMP occurs, followed by a five day lag, then the full PMP occurs
- Use whichever condition is “most appropriate”

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Kansas City District Approach

- Exploring second antecedent condition option
- Preliminary flood has been developed using ½ PMP rainfall
- It was fortunate that Swanson Dam did not fail for the ½ PMP because it will fail later under the full PMP
- The ordinates of the preliminary storm are less than ½ ordinates for the full PMP due to storage effects of the BOR reservoirs

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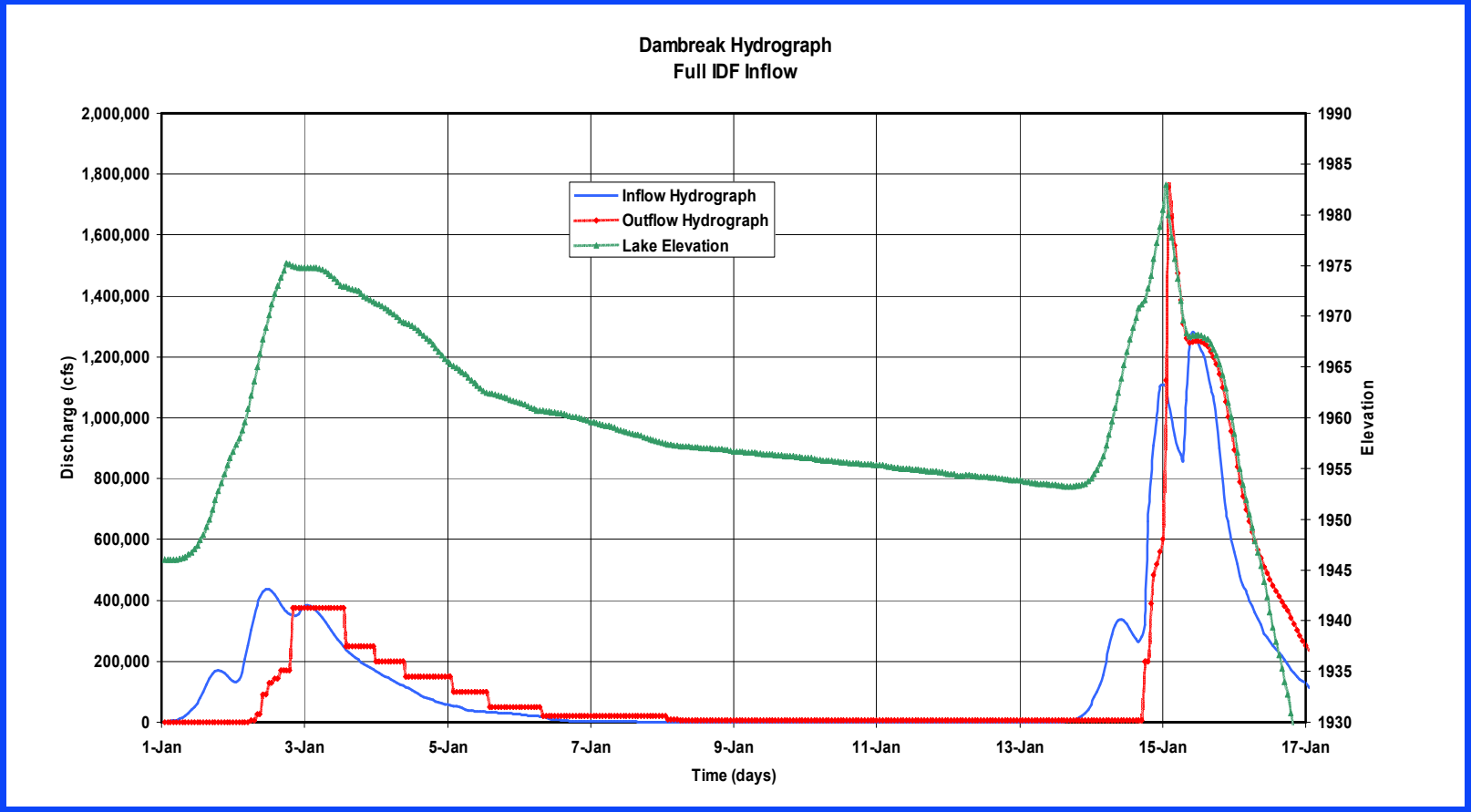
Use of Preliminary Storm at Harlan County Dam



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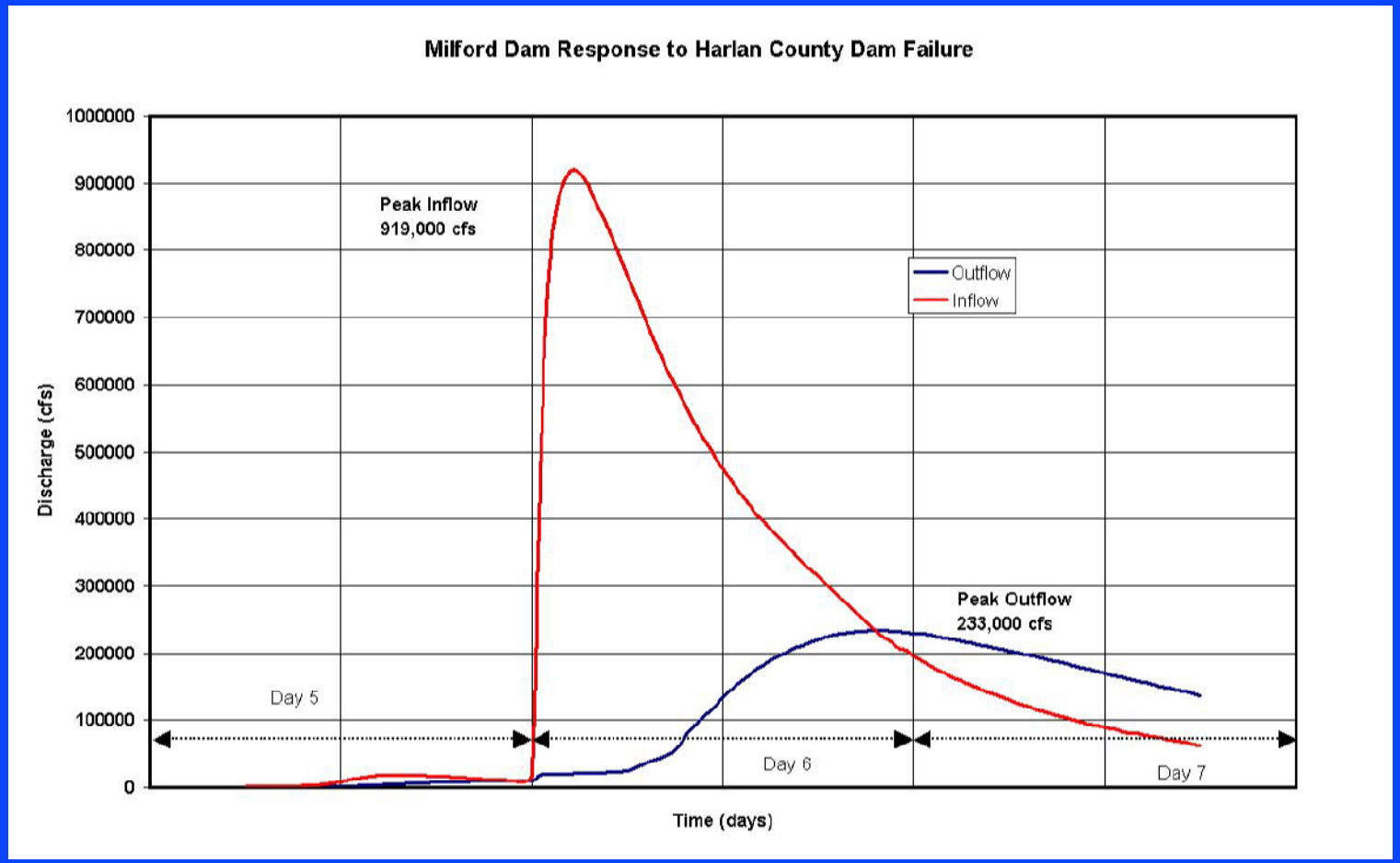
Milford Dam Response (Preliminary)



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While this "preliminary storm" approach seems reasonable for the full PMP, it may present problems in the determination of the Base Safety Condition, where fractions of the Inflow Design Hydrograph are evaluated

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This presentation is not intended to be a "how-to-do-it", but rather is a "how-we-did-it"…..

We believe this effort is in compliance with the spirit of the USACE Dam Safety Regulation

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However, this study raises important technical/policy issues…….

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Issue No. 1
How to evaluate other dams in the basin that do not pass the PMP

- Owned/operated by responsible public body (BOR, TVA, COE, States, etc.)
  - Assume they will be brought up to standard
  - Evaluate them as you find them
- Owned/operated by others (private, homeowners association, local park board, etc.)

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Issue No. 2

When multiple dams are present in a basin, what assumptions should be made with respect to the initial condition and performance of the other dams in the basin?

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Side Issue

There could be an issue with the owners of the other dams in the basin. No one likes to have their dam labeled "unsafe" by an outside party. Some sensitivity, particularly in public meetings, is required

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Side Issue

Could repairs to other dams be eligible for Federal funding, if repairs to that structure are part of the least cost solution ?


Questions?