Reservoir Sediment Management & Analysis for Engineers

Non-modeling Techniques to Develop the Future Without Project (FWOP)

University of Kansas
LEEP2 Building – Room G415
June 11-15, 2018

ERDC
Engineer Research and Development Center

Outline

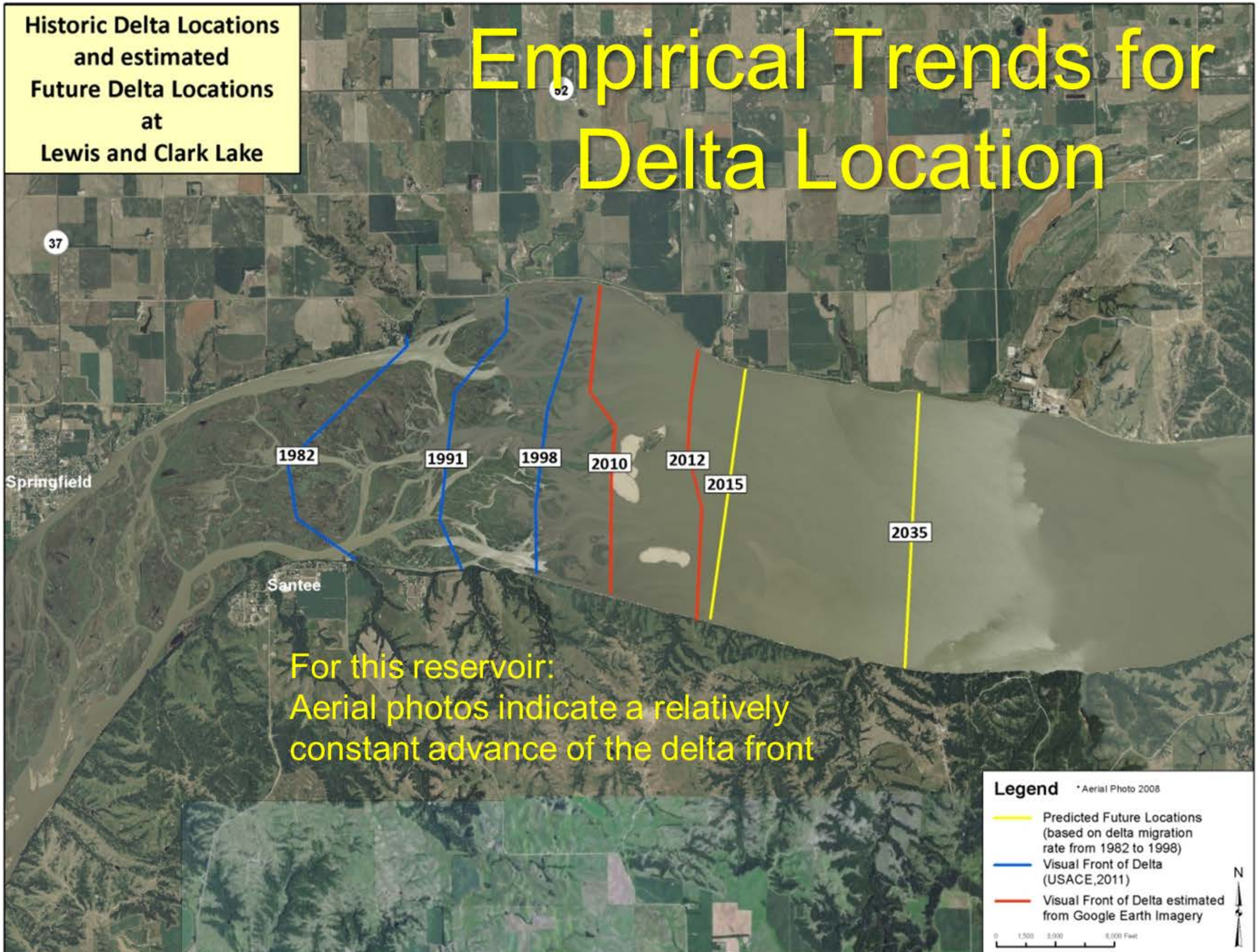
- Future Without Project (FWOP)
- Trendline
- Brune Curve
- To model or not to model?

Future Without Project

- Future Without Project (FWOP)
  - Future Reservoir Condition (Typ. 50 Years)

- “Without Project” means continuation of the current sedimentation processes without changed management (not “without dam” or “without reservoir.”)

- Specific Questions
  - How much reservoir will be left in 50 years?
  - How long until the reservoir volume shrinks to defined levels (that trigger lost benefits)?
  - How much sediment will annually pass downstream in 50 years?
  - When will the delta reach the service gates, dam, spillway, boatramp, water intake, etc.?


Empirical Trends for Delta Location
Historic Delta Locations and estimated Future Delta Locations at Lewis and Clark Lake
52
37
1982
1991
1998
2010
2012
2015
2035
Springfield
Santee
For this reservoir:
Aerial photos indicate a relatively constant advance of the delta front
Legend
* Aerial Photo 2008
Predicted Future Locations (based on delta migration rate from 1982 to 1998)
Visual Front of Delta (USACE,2011)
Visual Front of Delta estimated from Google Earth Imagery
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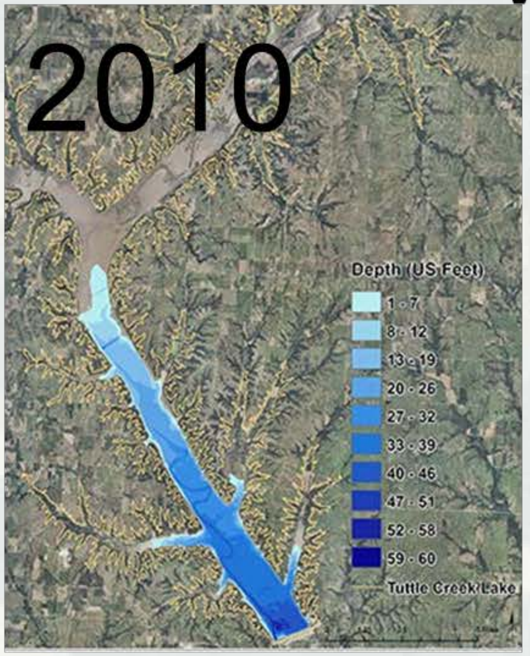
Trend Line Projection for Volume Loss



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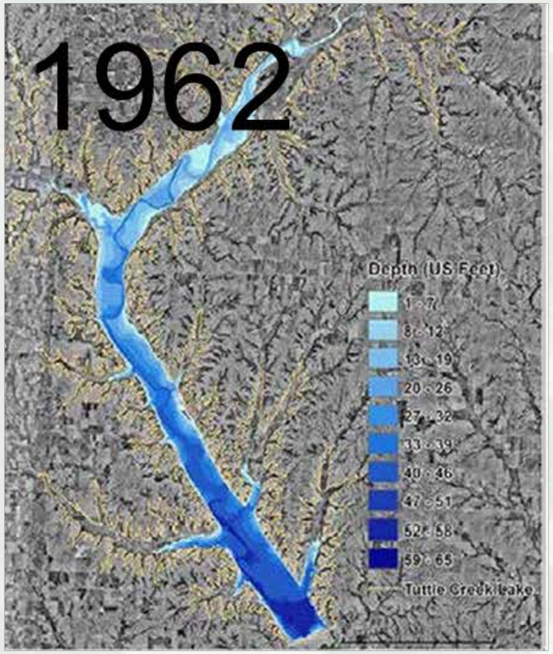

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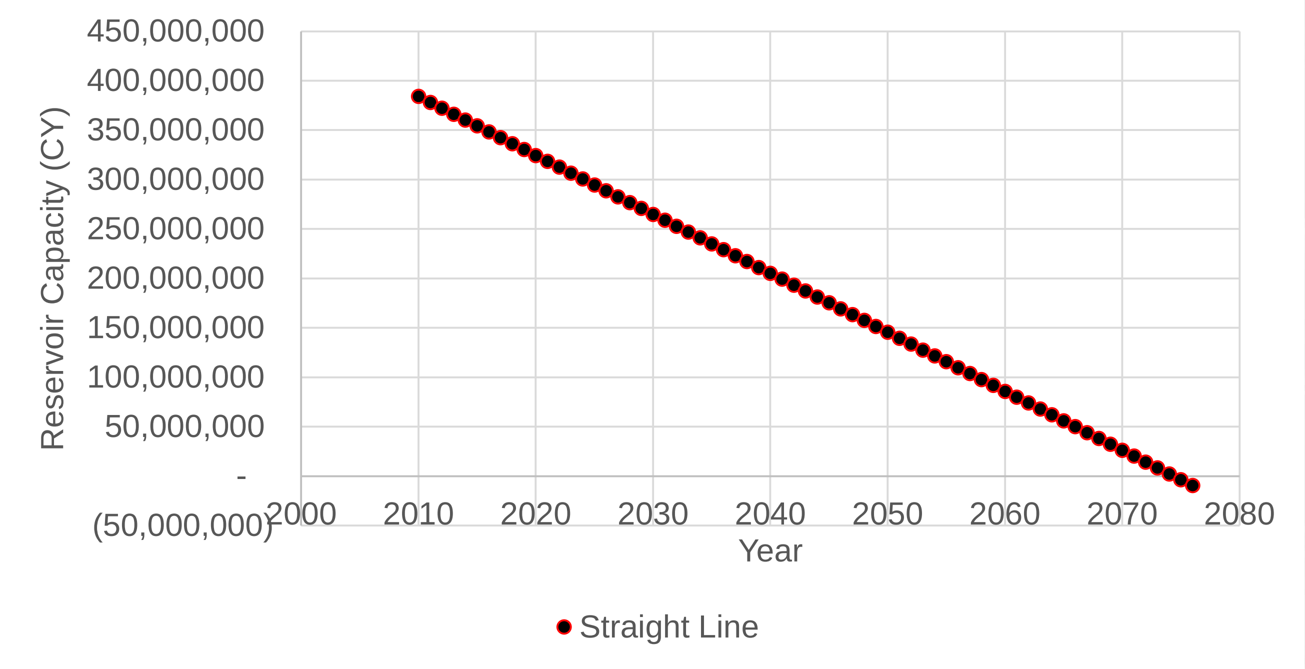
296 M CY

Note: Pre-impoundment survey from 1957 but dam closure in 1962.

- Original Capacity = 686 M CY
- Current (2010) Capacity = 390 M CY
- 296 M CY / (2010-1962)
  - = 6.2 M CY/year
- 2060 year capacity = 85 M CY (15% of original pool remains)



What are potential problems with a simple trend line?

Trend Line Issues: Blue = trend line will overpredict deposition, red = trend line will underpredict deposition, green= uncertain

- Sediment inflow rates equivalent
- Sediment trapping efficiency constant
- Hydrologically representative time period between surveys (i.e. extreme events in the right frequency)
- Ignores measurement error in bathymetry (particularly in the old survey!)
- Ignores further consolidation of old material
- Assumes no trend in hydrology or sediment (i.e. no climate change)

A more robust (still non-modeling) approach

1. Estimate future annual sediment load
    - Account for changes due to land use and climate change, and account for extreme events
2. Transform into a volume via unit weight
3. Estimate trapping efficiency changes over time with the Brune Curve

Trapping Efficiency

- The percentage of the incoming sediment that stays in the reservoir
- Does the trapping efficiency go up or down as the reservoir fills?

Trapping Efficiency

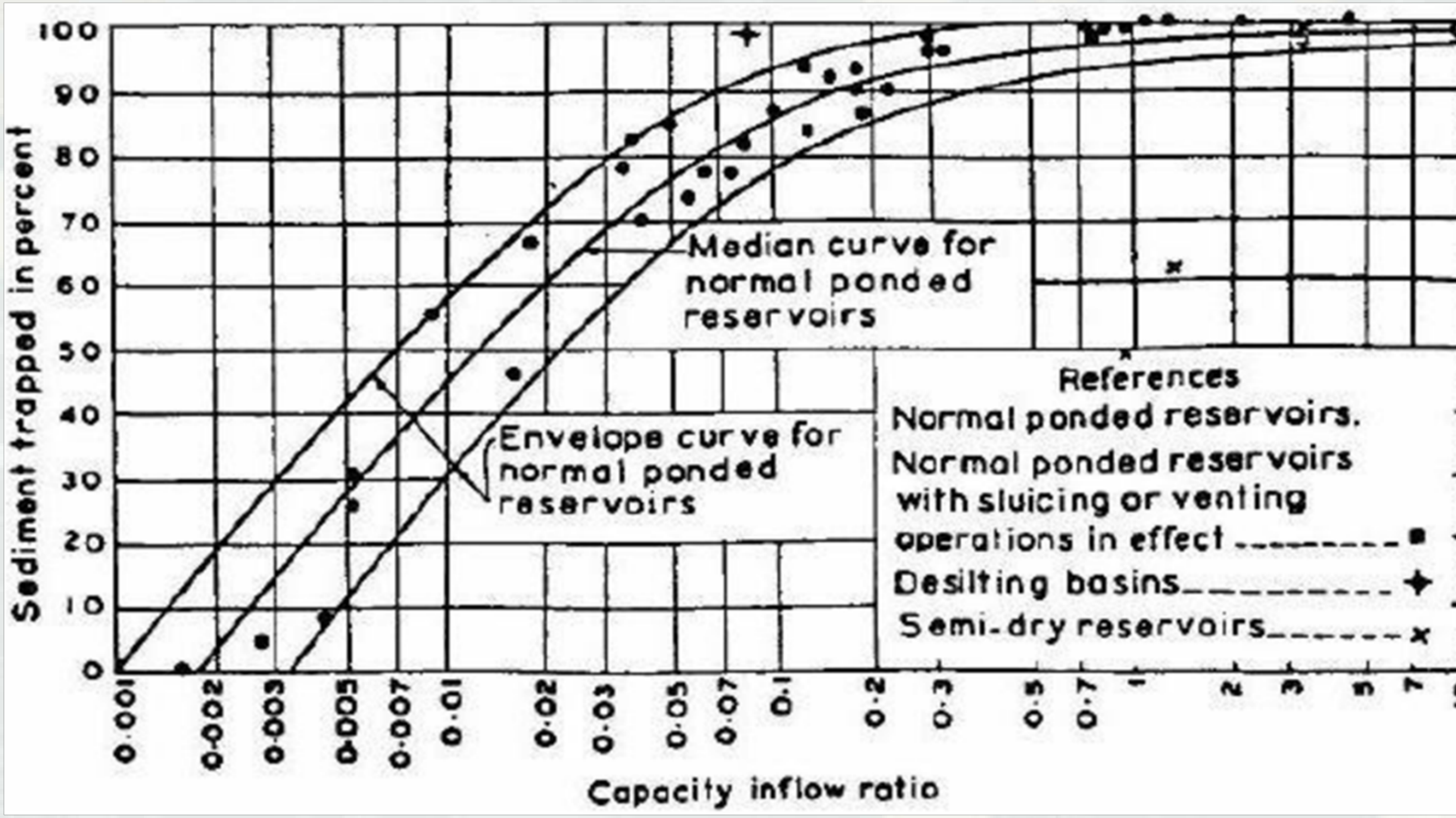
- As a reservoir fills with sediment:
  - The residence time of the water decreases.
  - The average velocity in the reservoir increases.
  - The distance a particle has to travel before it reaches the outlet decreases.

  - The trapping efficiency <u>decreases.</u>

Brune Curve

- Brune (1953) related trapping efficiency to the the reservoir volume divided by incoming flow volume.
- The Brune Curve can be used to
  - Provide initial estimate of trapping efficiency and reservoir life
  - Iteratively calculate trapped sediment year by year for a more refined estimate
- We will do both of these in an Excel-based workshop

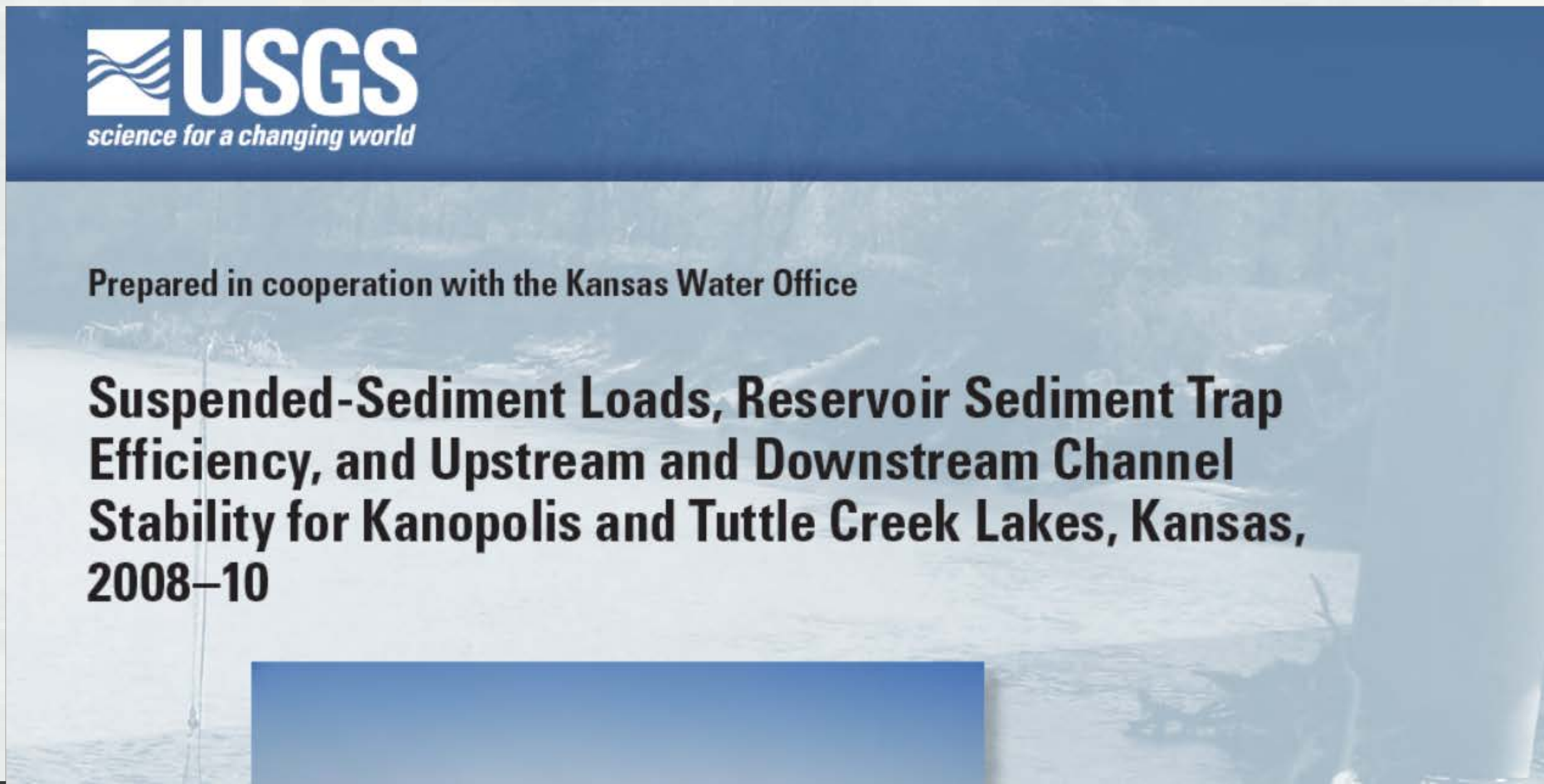
Brune Curve



Sediment trapped in percent
100
90
80
70
60
50
40
30
20
10
0
0.001
0.002
0.003
0.005
0.007
0.01
0.02
0.03
0.05
0.07
0.1
0.2
0.3
0.5
0.7
1
2
3
5
7
10
Capacity inflow ratio
Median curve for normal ponded reservoirs
Envelope curve for normal ponded reservoirs
References
Normal ponded reservoirs.
Normal ponded reservoirs with sluicing or venting operations in effect
Desilting basins
Semi-dry reservoirs

Measured Trapping Efficiency at Tuttle Creek Lake

- Measured Trapping Efficiency = 98%

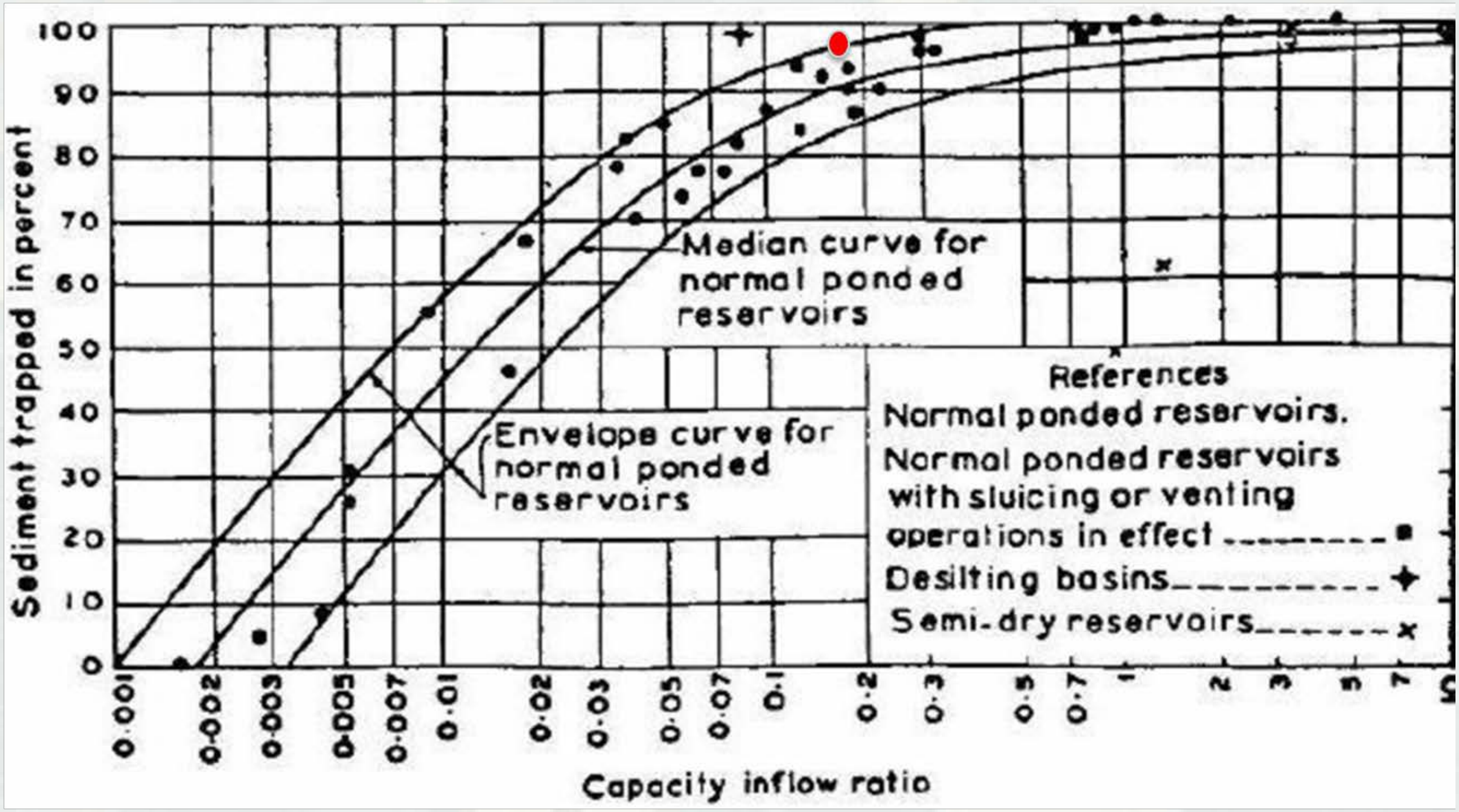


USGS
science for a changing world

Prepared in cooperation with the Kansas Water Office

Suspended-Sediment Loads, Reservoir Sediment Trap Efficiency, and Upstream and Downstream Channel Stability for Kanopolis and Tuttle Creek Lakes, Kansas, 2008–10

Brune Curve

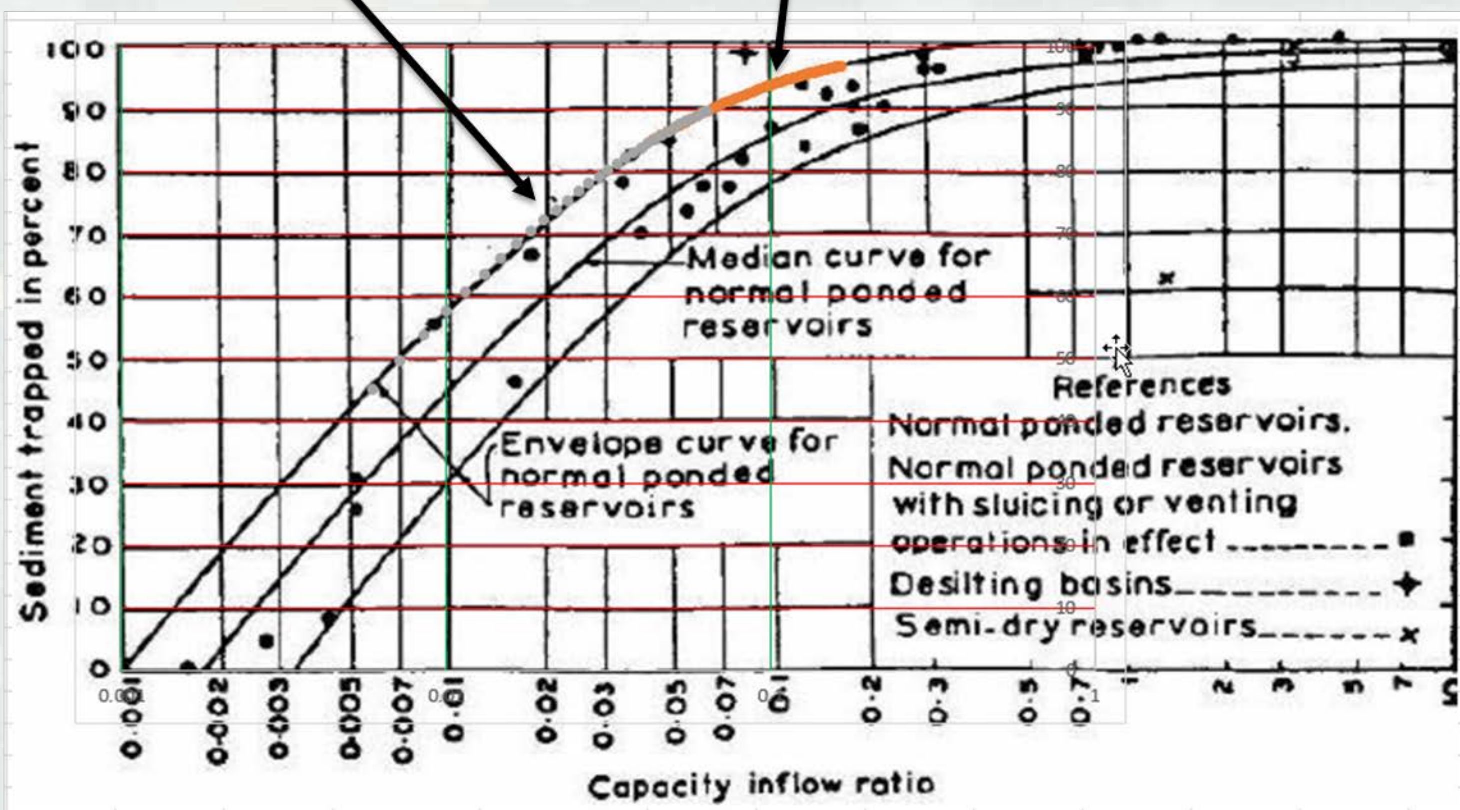


Tuttle Creek Lake Average Annual Inflow = 2,341 M CY
Capacity (2010) = 390 M CY
C/I = 0.17
TE = 97.5

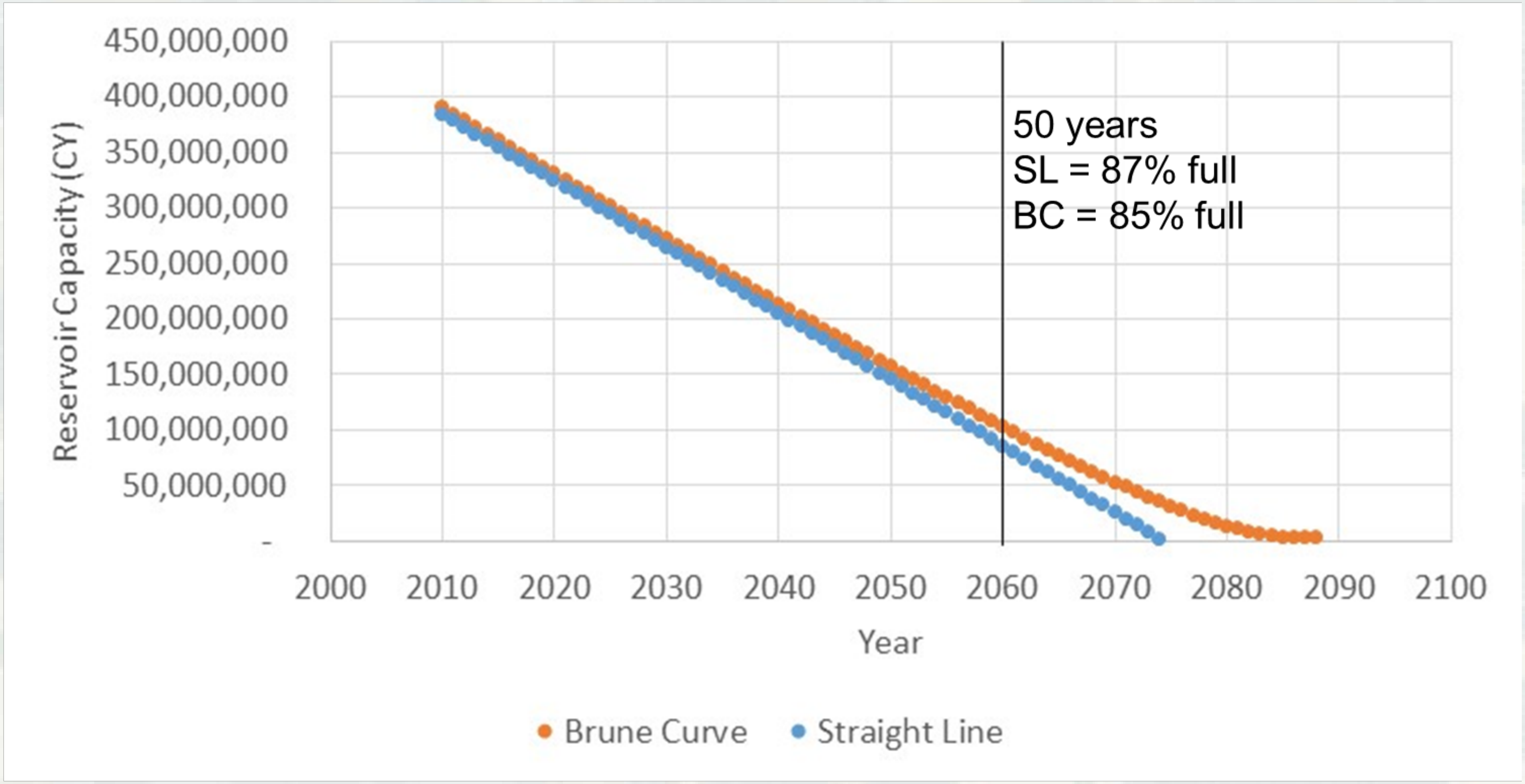
Trapping Efficiency Changes Over Time

TE computed iteratively over 50 years

Next 40 years



Straight Trend Line vs Brune Curve



For large reservoirs with high trapping efficiencies, results are very similar

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Empirical Approaches

- Provide recon-level analyses
  - How big a problem do we actually have?
- Provide a future condition for other analyses (where sediment management is not the subject of the analysis)
- Initial screening of measures to reduce the number of alternatives to model
- Where sufficient data is lacking for good modeling anyway (and there is no time and/or budget to collect it)

Modeling

- To create a FWOP where sediment management is the “project”
  - Provides a consistent analysis method to compare alternatives to the FWOP
- Situations with unique conditions, large implementation costs, high failure consequences

Questions?