Bridging the Gap between Numerical Sediment Modeling and Reality for Dam Removal Investigations

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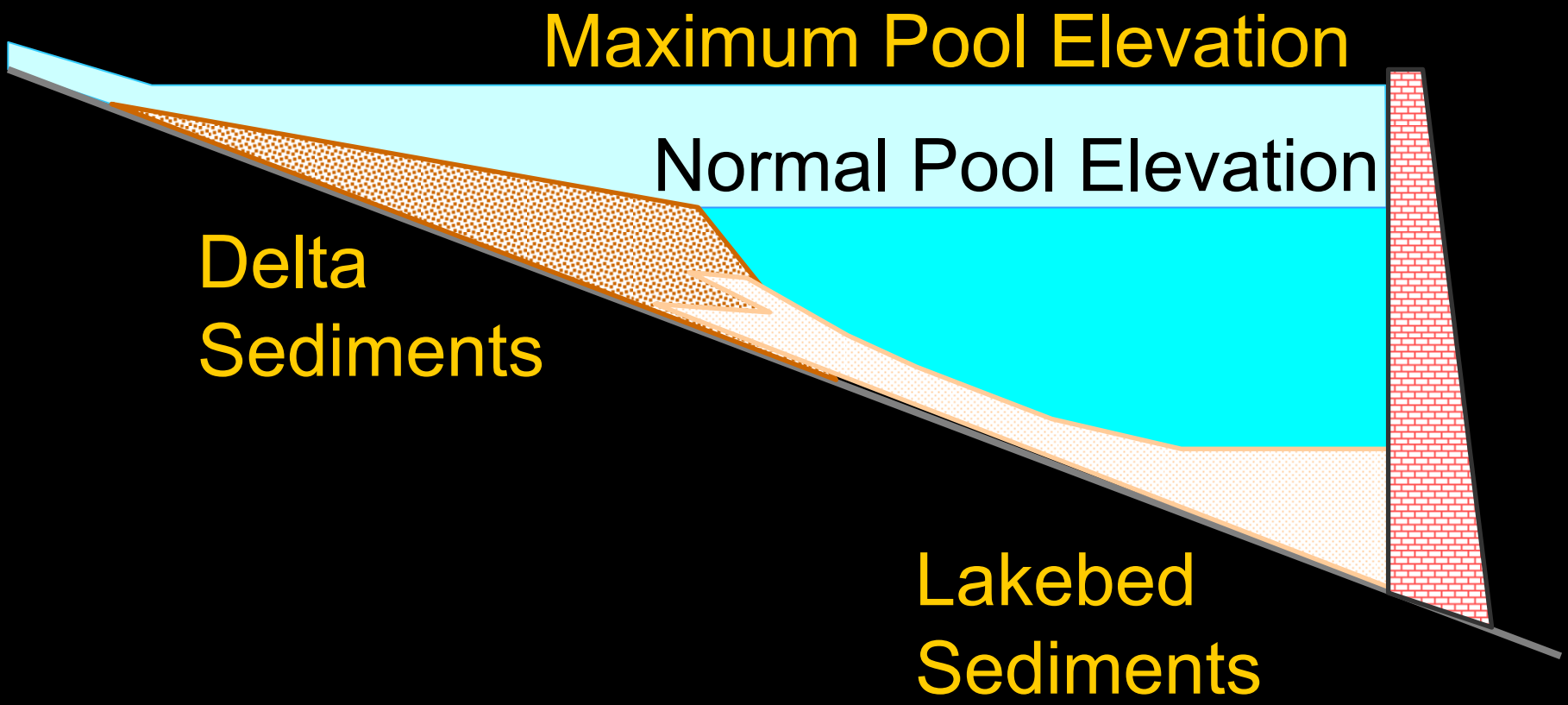
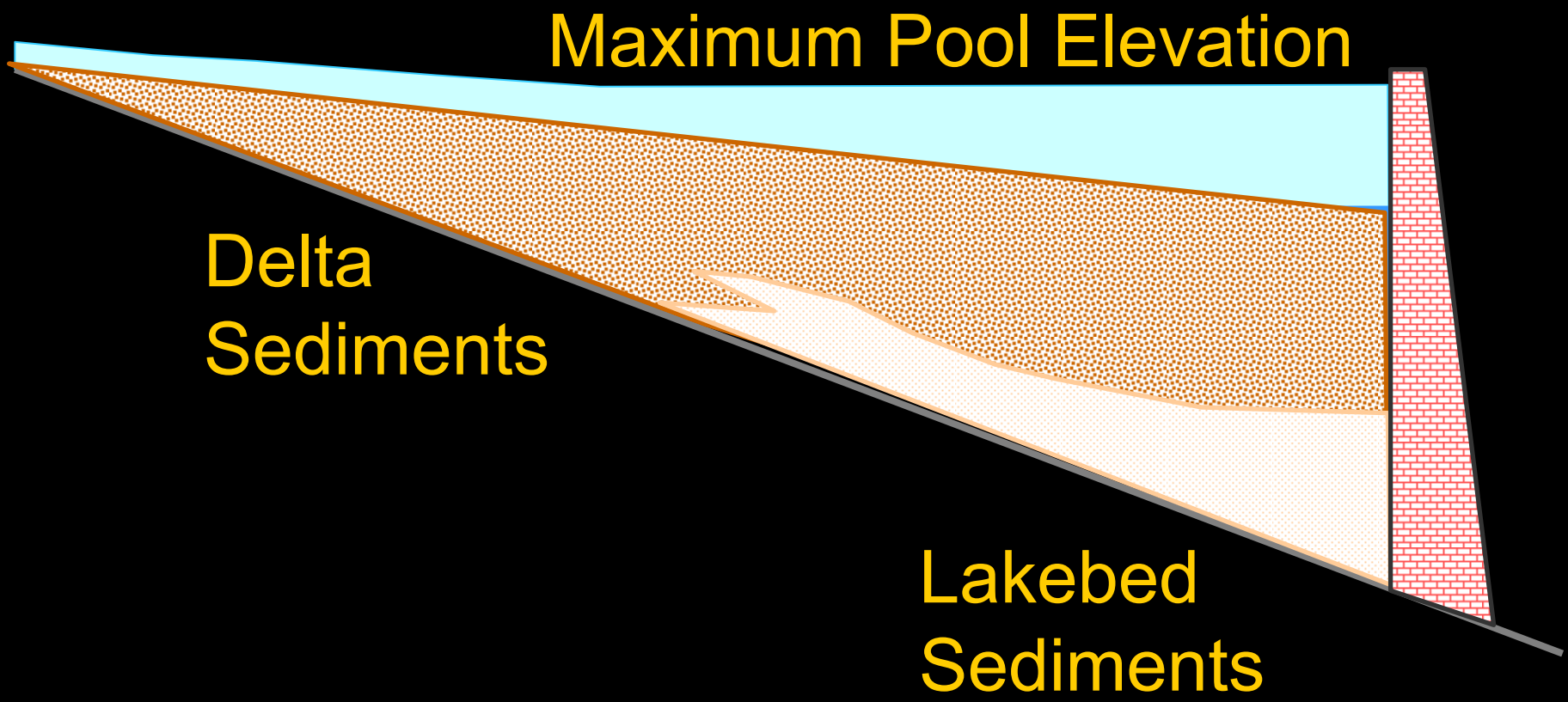
Reservoir Considerations

- Reservoir sediment volume and particle size distribution
- Cohesive properties
- Chemical composition
- Reservoir delta

Conceptual Model of Reservoir Delta



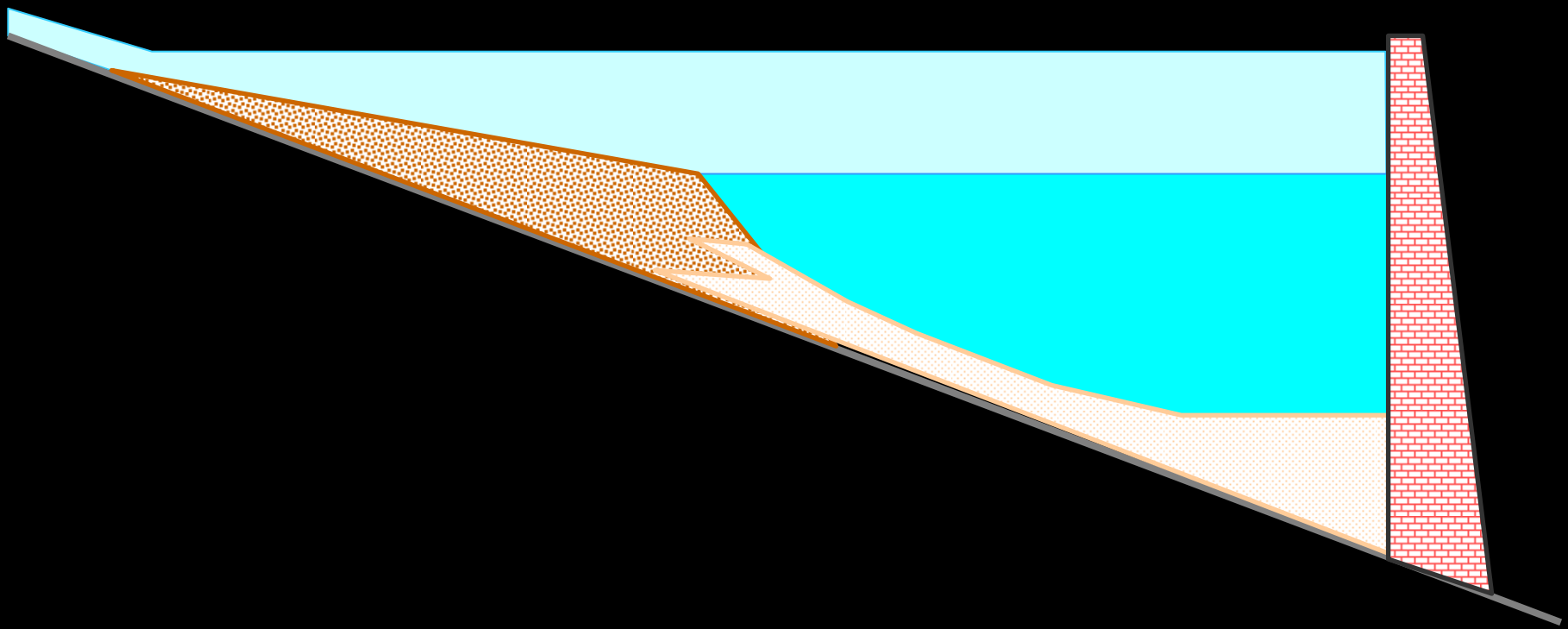
Conceptual Model of Reservoir Delta



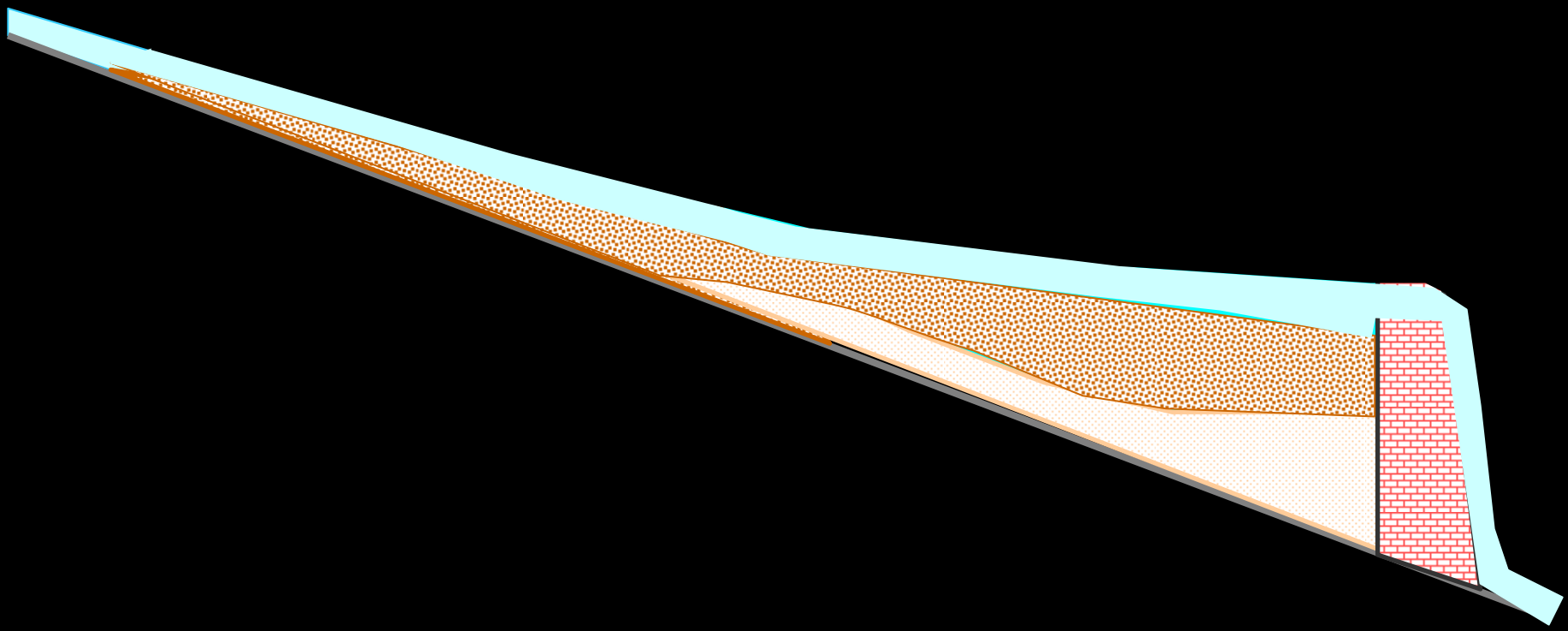
Reservoir Considerations (continued)

- Extent of dam removal
- Portion of reservoir sediment expected to erode

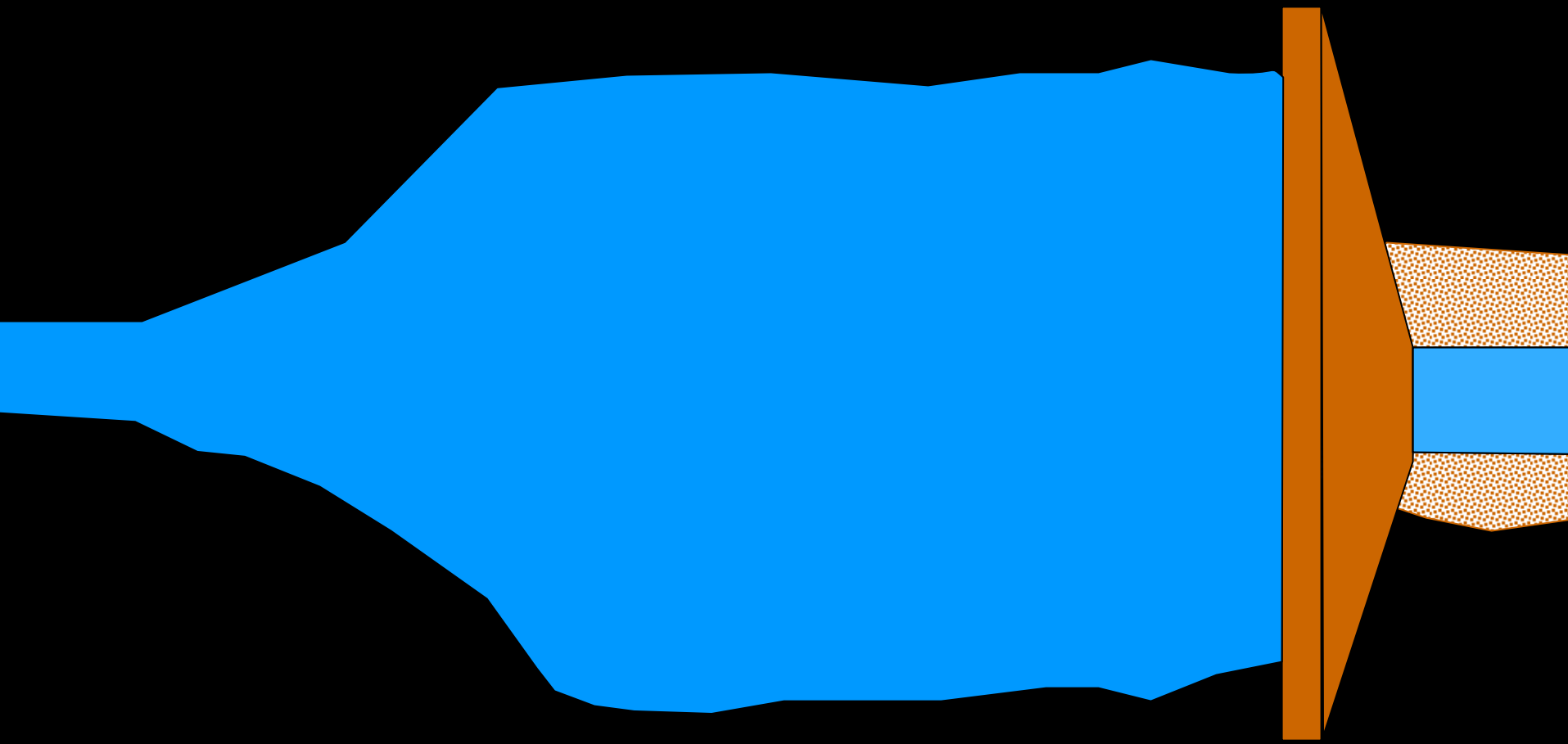
Extent of Dam Removal



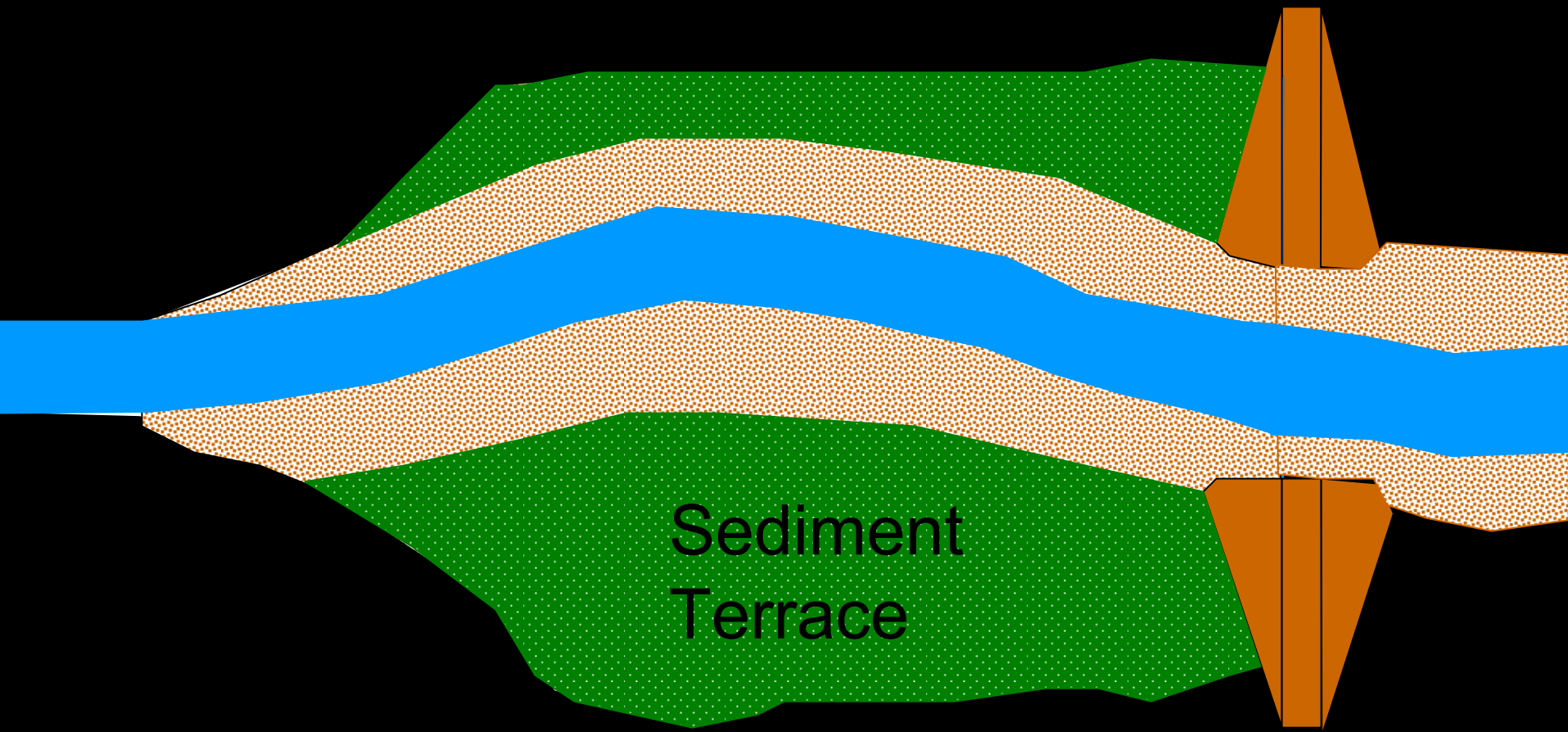
Partial Dam Removal



Extent of Dam Removal



Partial Dam Removal



Downstream Considerations

- Altered flow regime
- Reservoir sediment trap efficiency
- Channel degradation or aggradation
- Reservoir sediment volume relative to annual transport capacity
- Proposed rate of dam removal
- Existing river-channel planform
- Downstream tributaries
- Presence of pools and riffles or rapids

Downstream Considerations (continued)

- Likely depositional environments
- Potential for bank erosion and channel migration
- Existing suspended sediment concentration and turbidity
- Existing water quality
  - Aquatic environment
  - Water users

Downstream Conceptual Models may Include:

- Sediment transport without aggradation
- Sediment aggradation
  - Bank erosion
  - Channel migration
  - Avulsion
- Temporary, but large increase in turbidity
  - Impact to aquatic environment
  - Water quality impact to water users

Sediment Analysis Approaches

- Field Tests
- Physical Modeling
- Numerical Modeling
  - Mass Balance
  - One-dimensional
  - Two-dimensional
- Monitoring

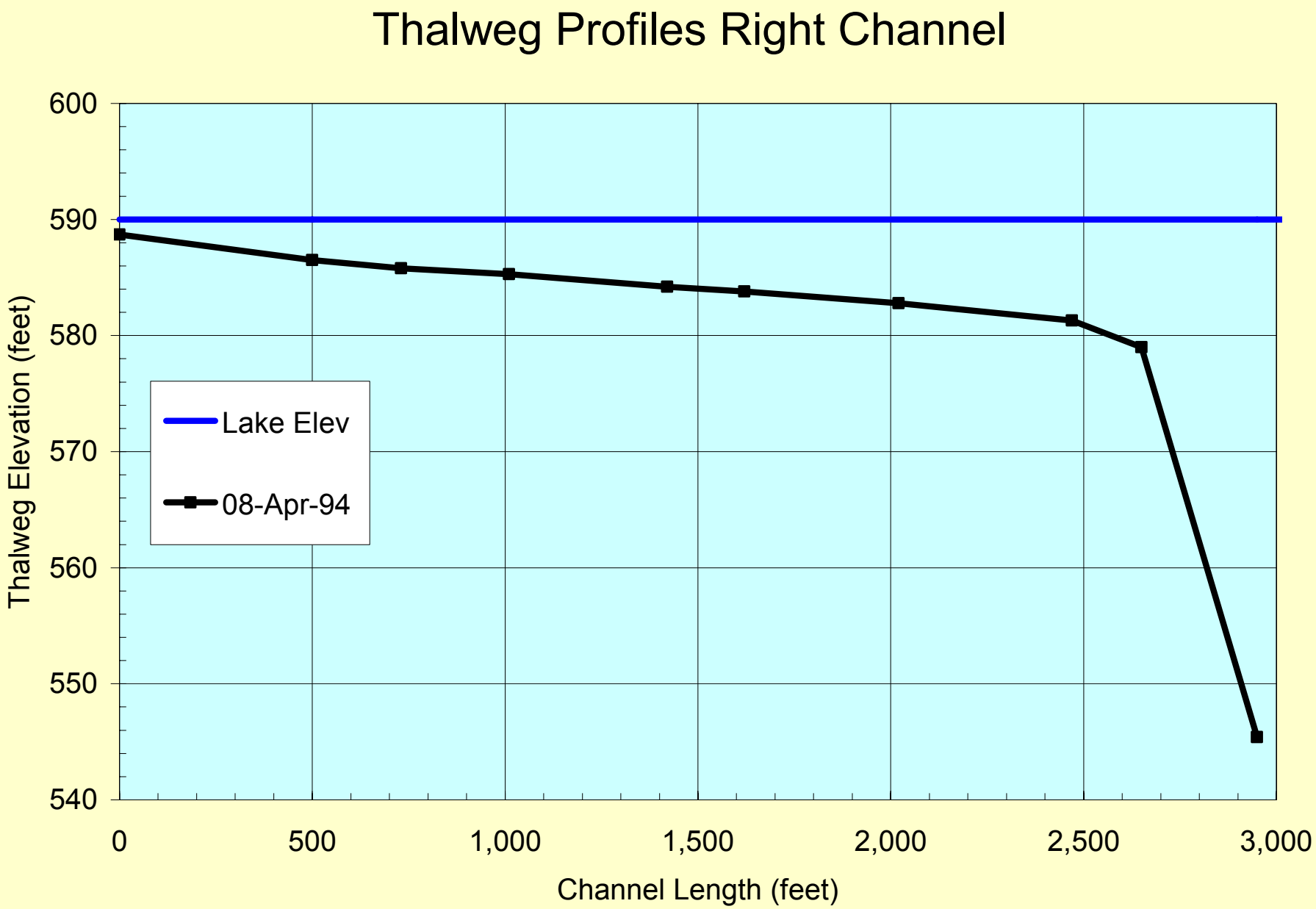
Numerical Models

- Mass Balance Models
- One-dimensional Models
  - Sediment Wave Model
  - HEC-6, GSTARS, FLUVIAL
- Two-dimensional Models

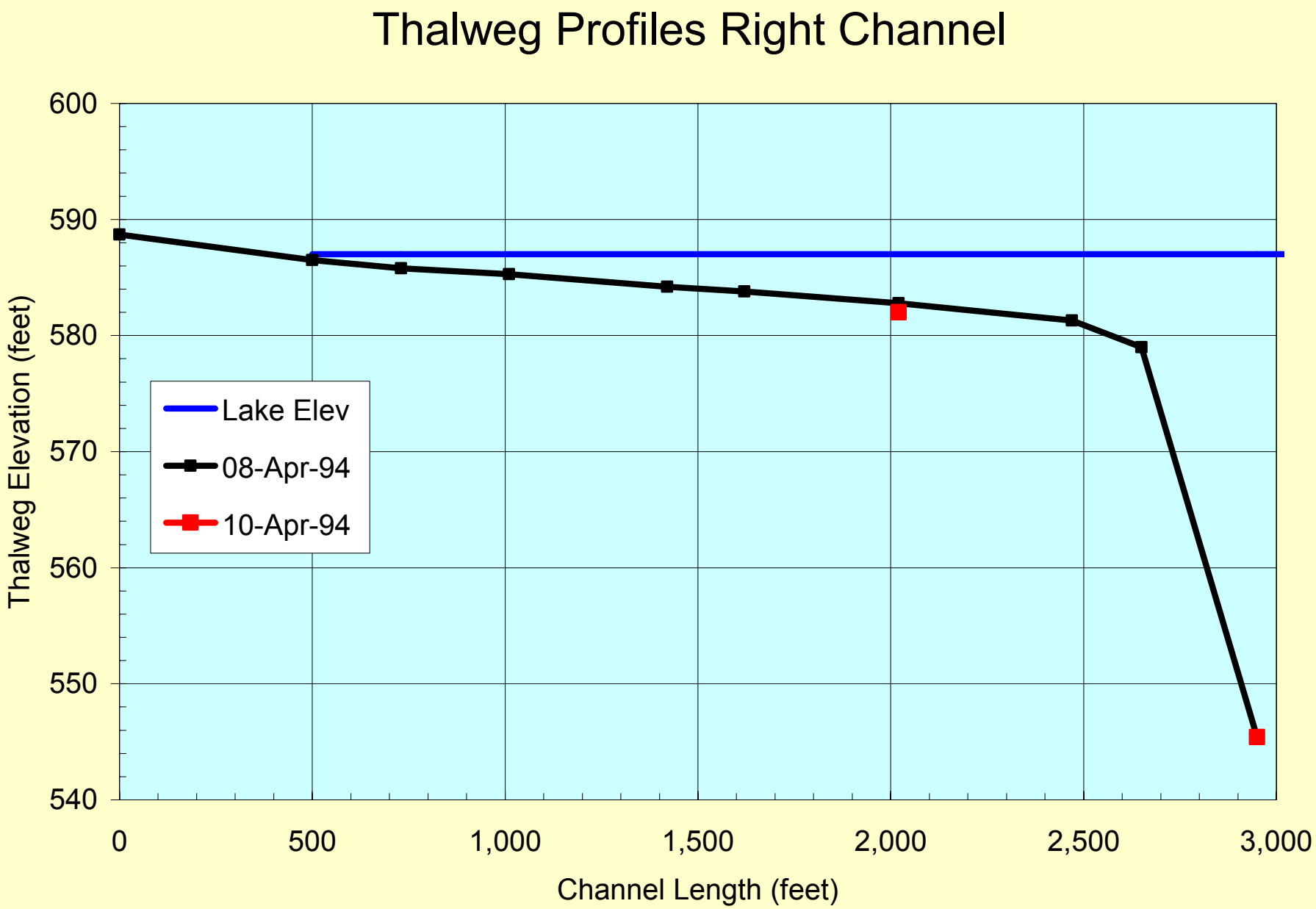
Modeling Reservoir Sediment Erosion

- Headcut erosion
- Erosion of sediment layers
- Erosion channel width
- Channel migration

Headcut Erosion



Headcut Erosion



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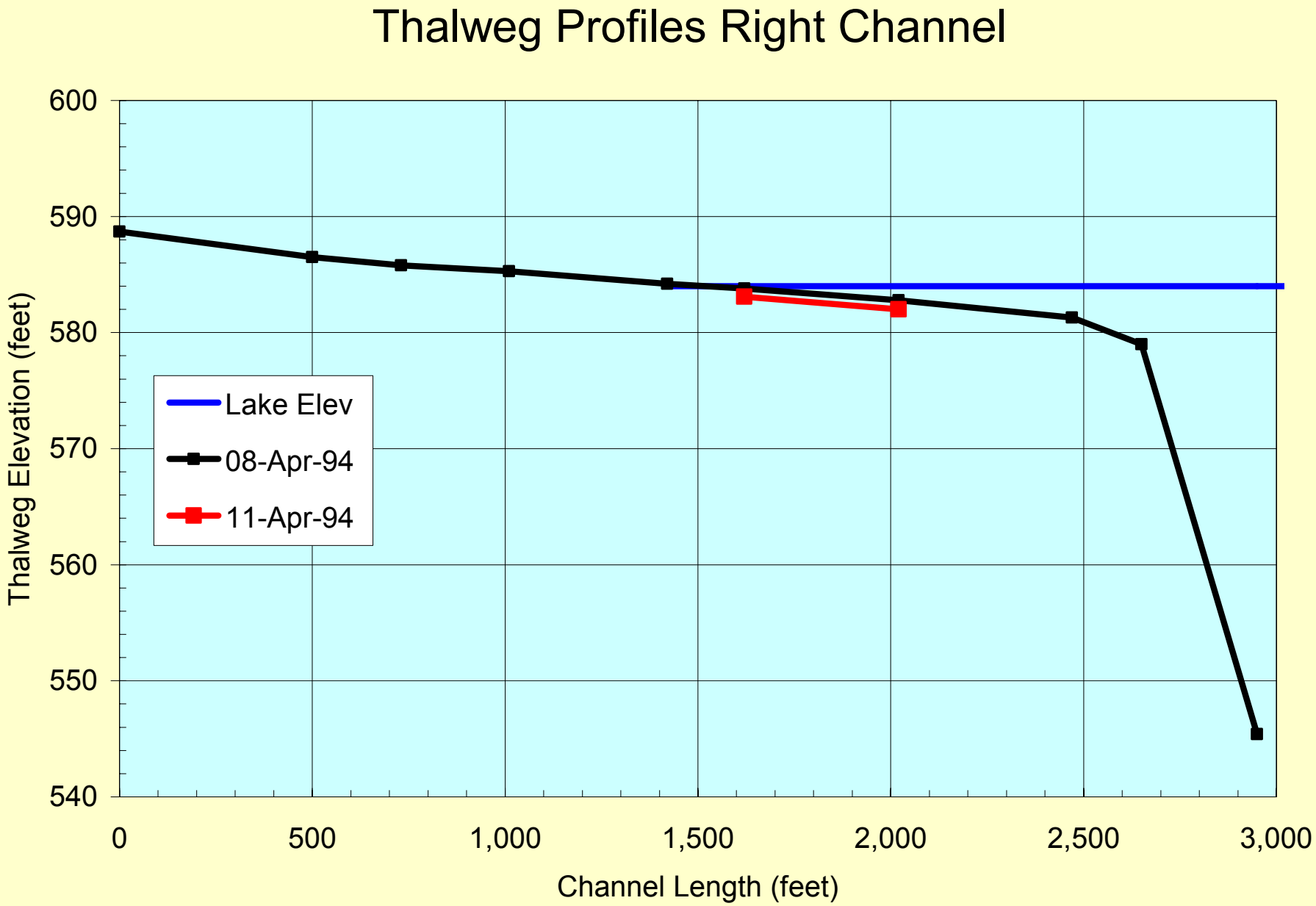

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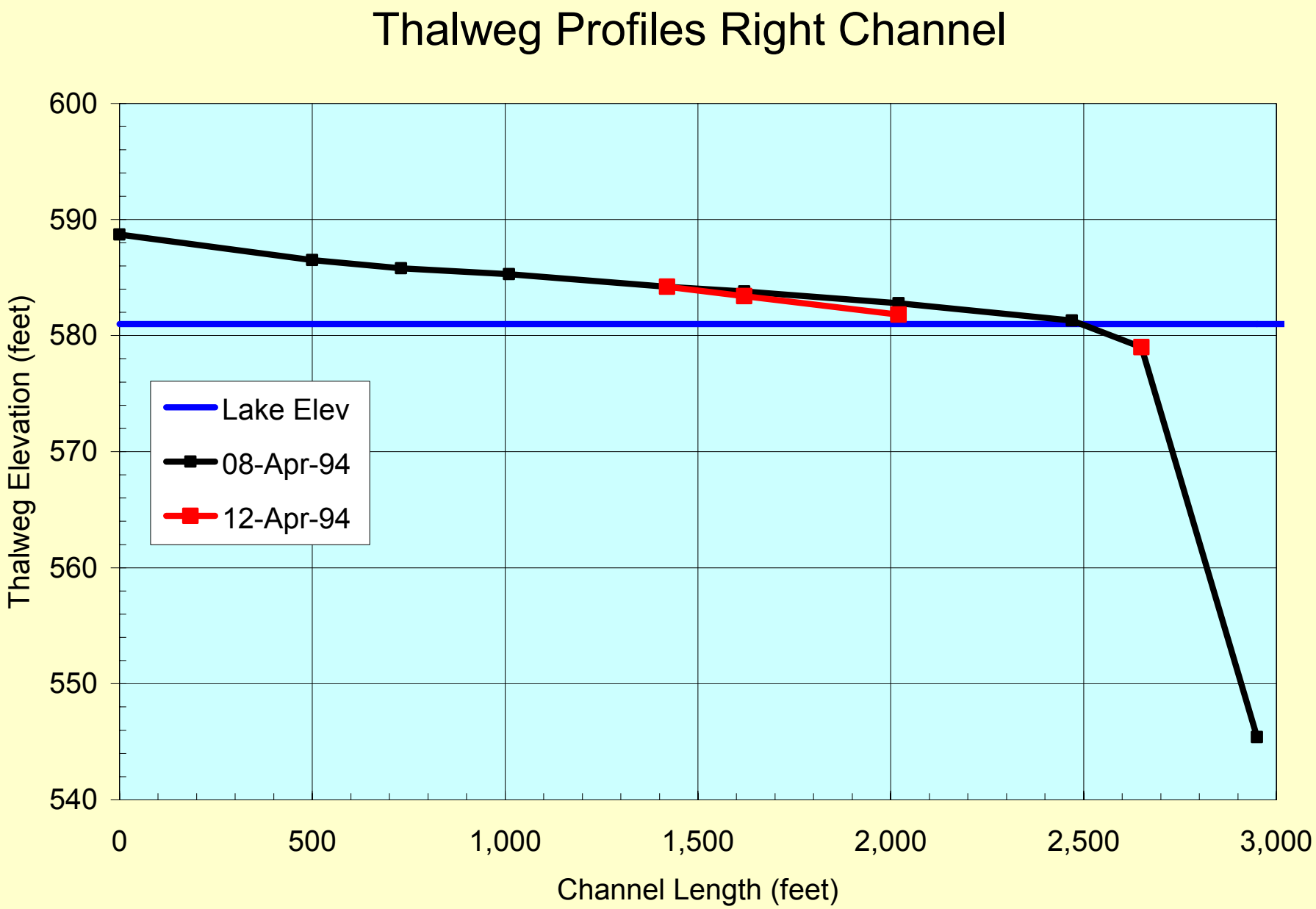

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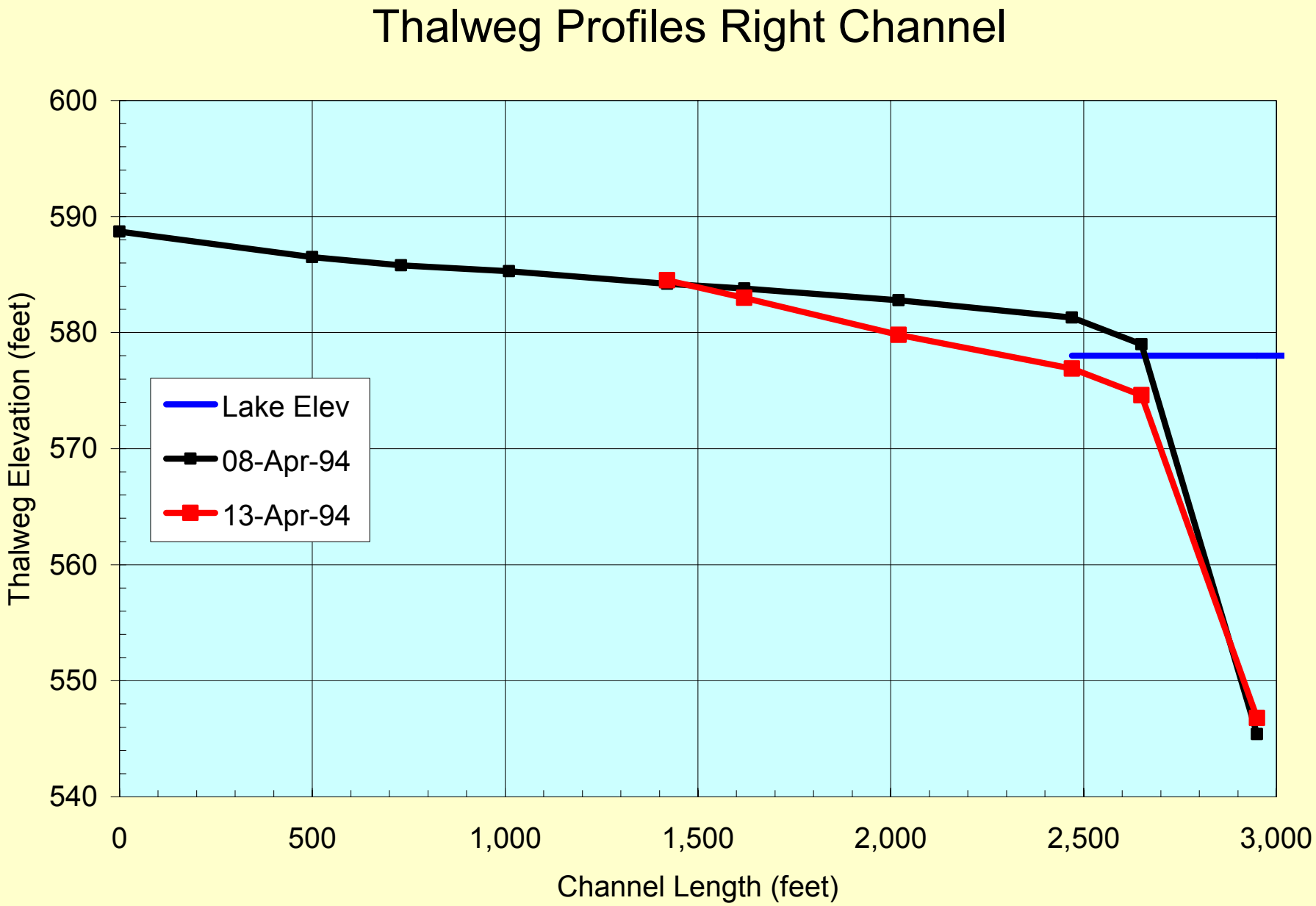

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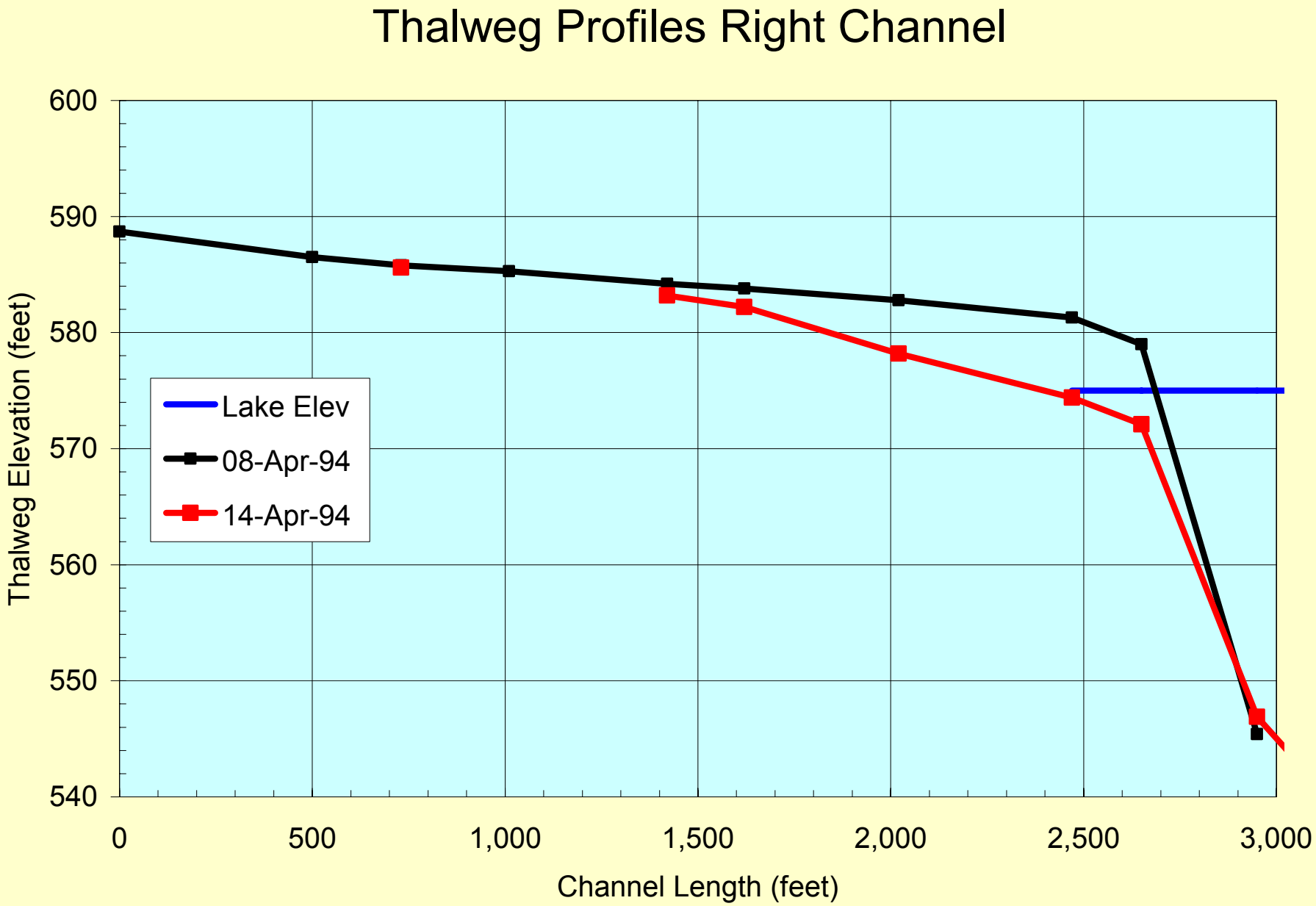

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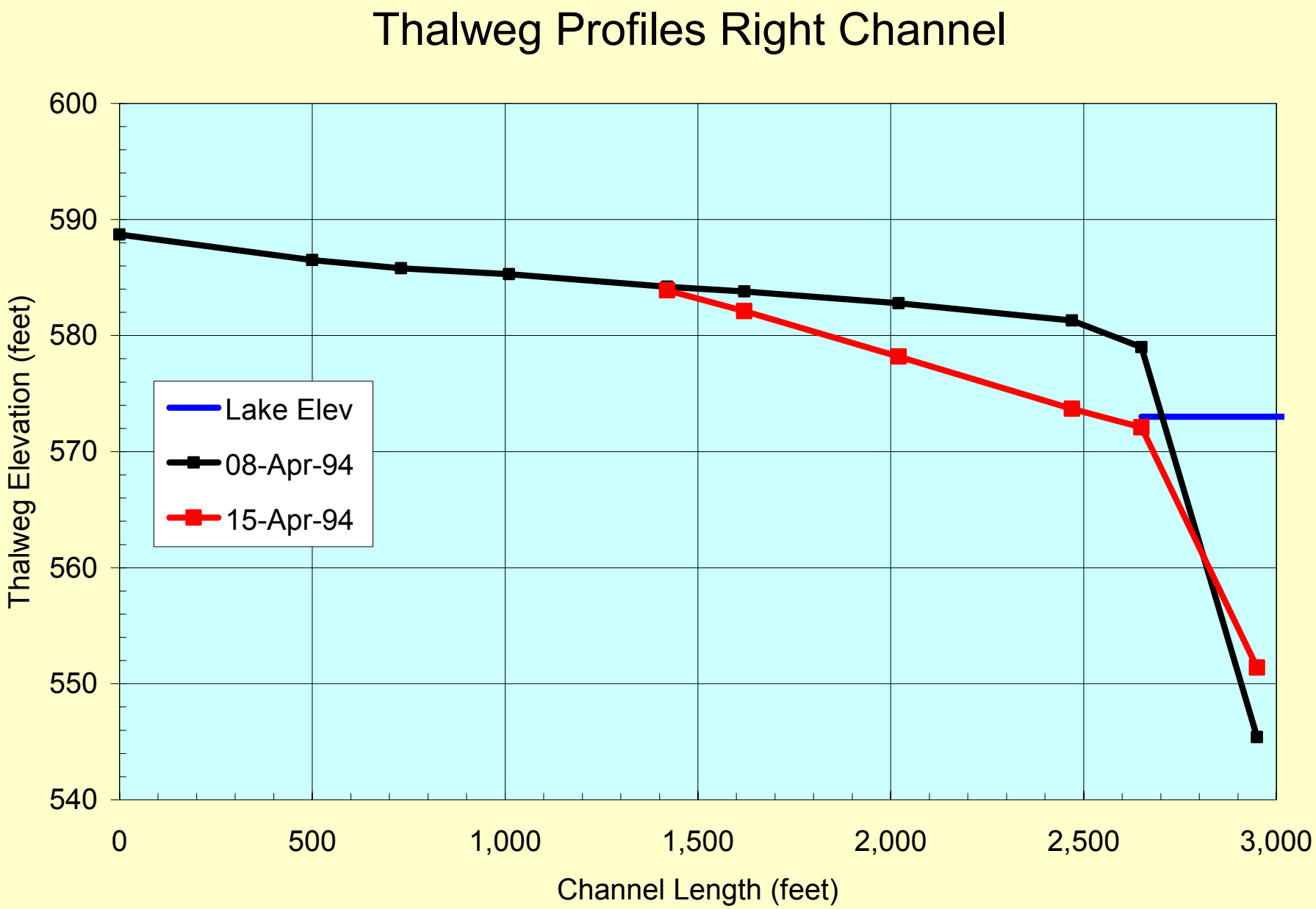

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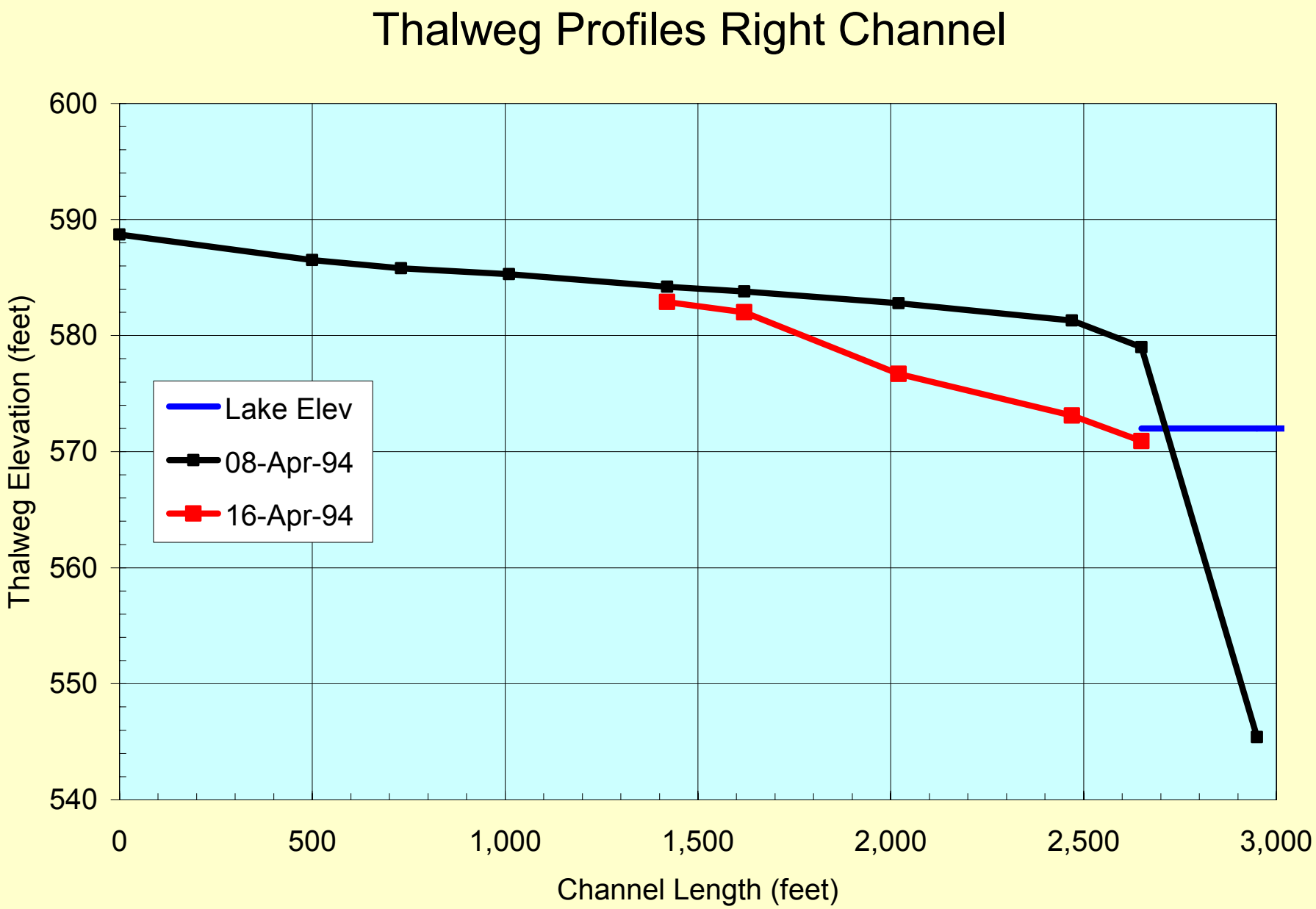

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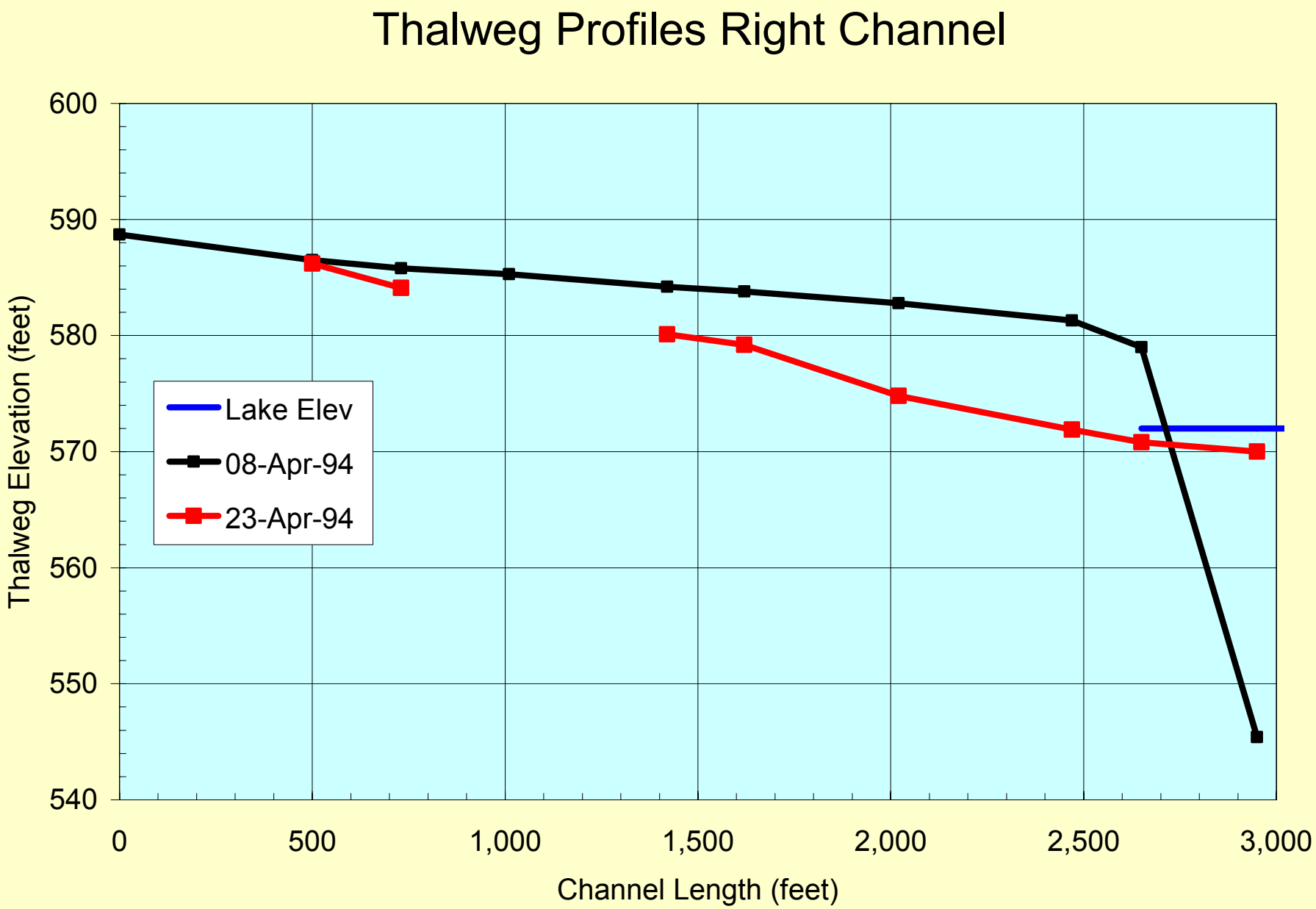

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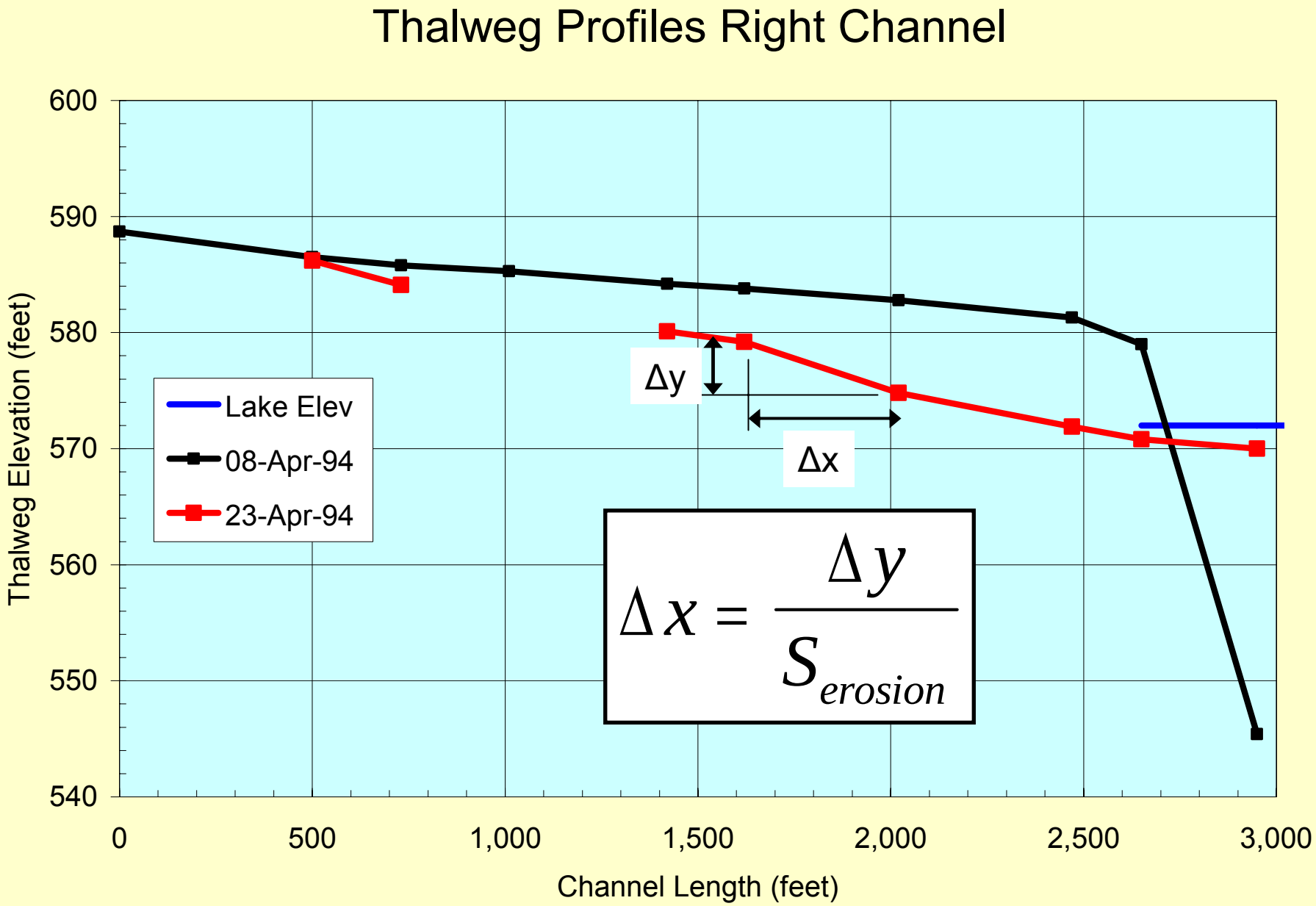

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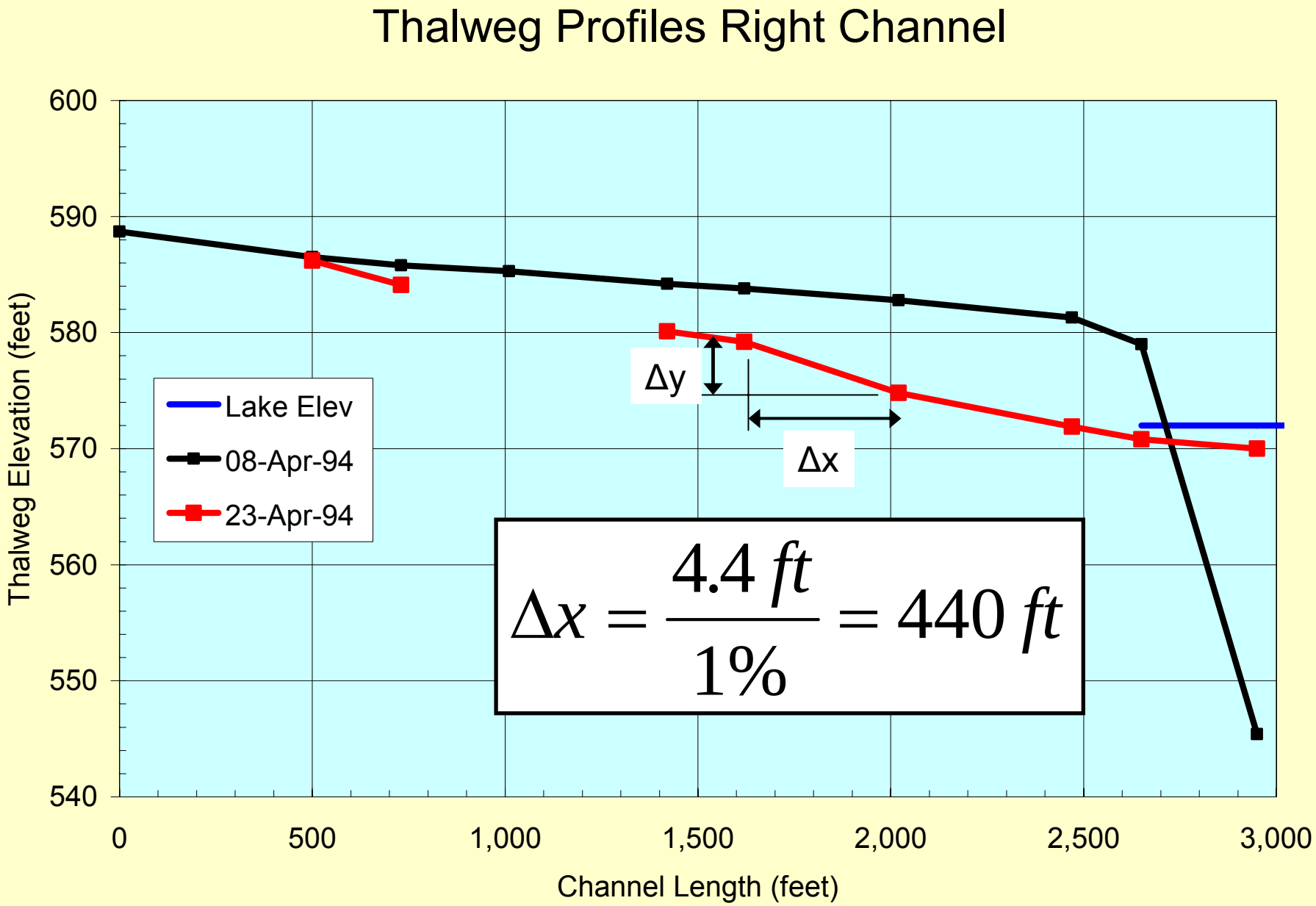

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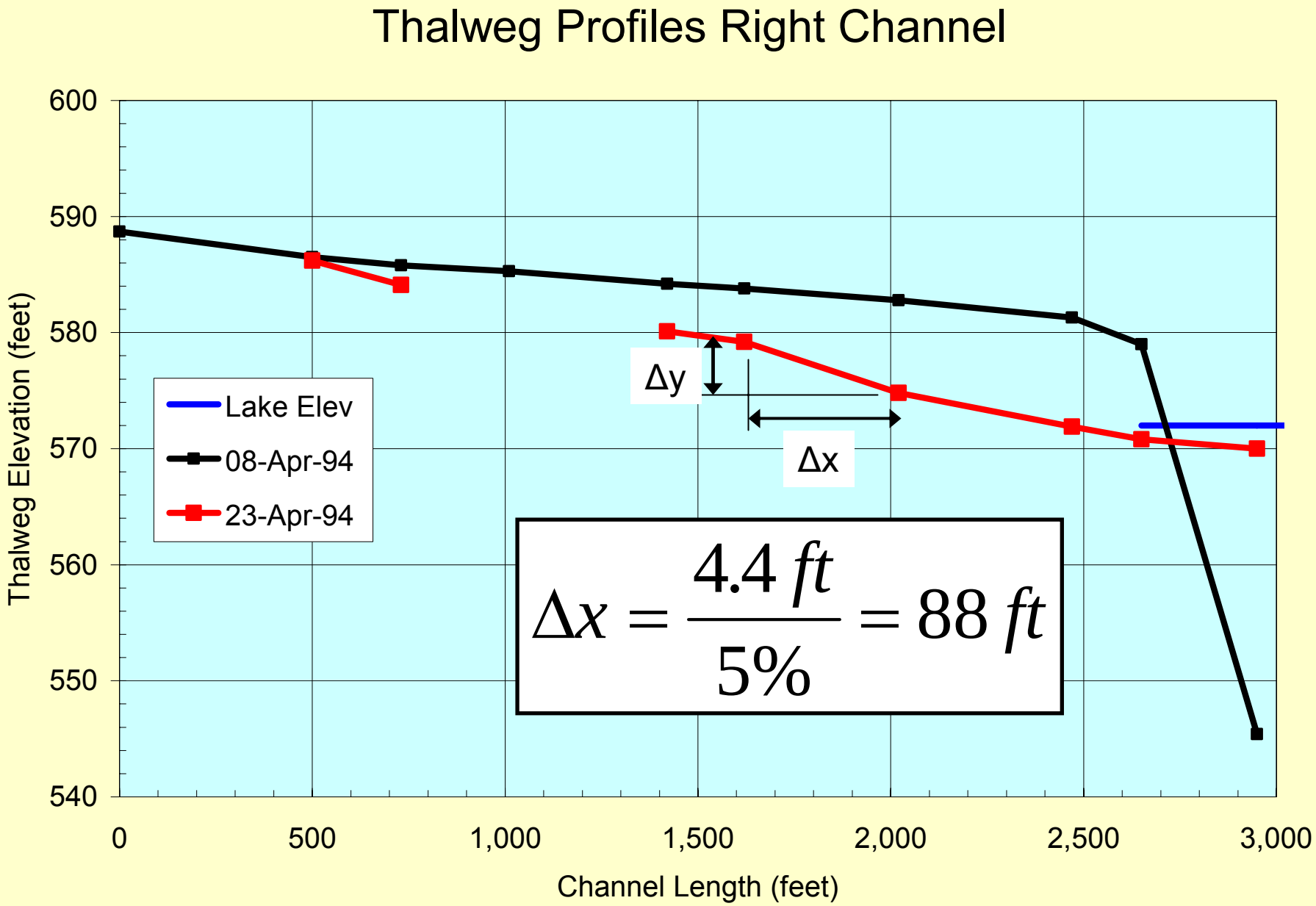
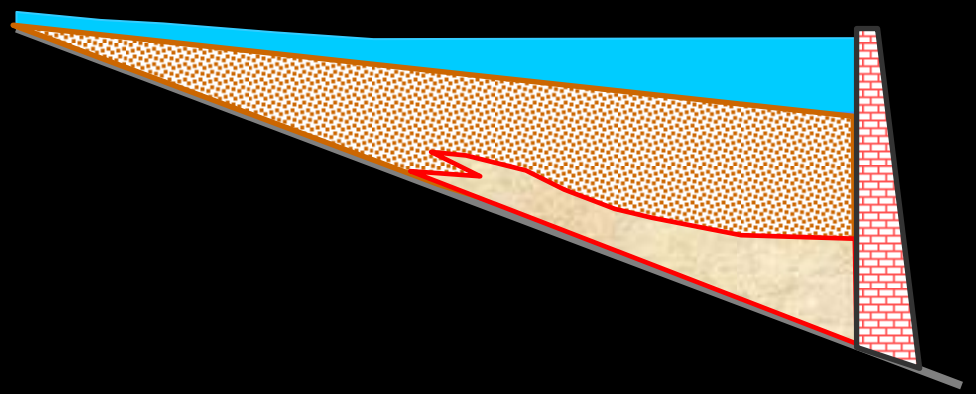
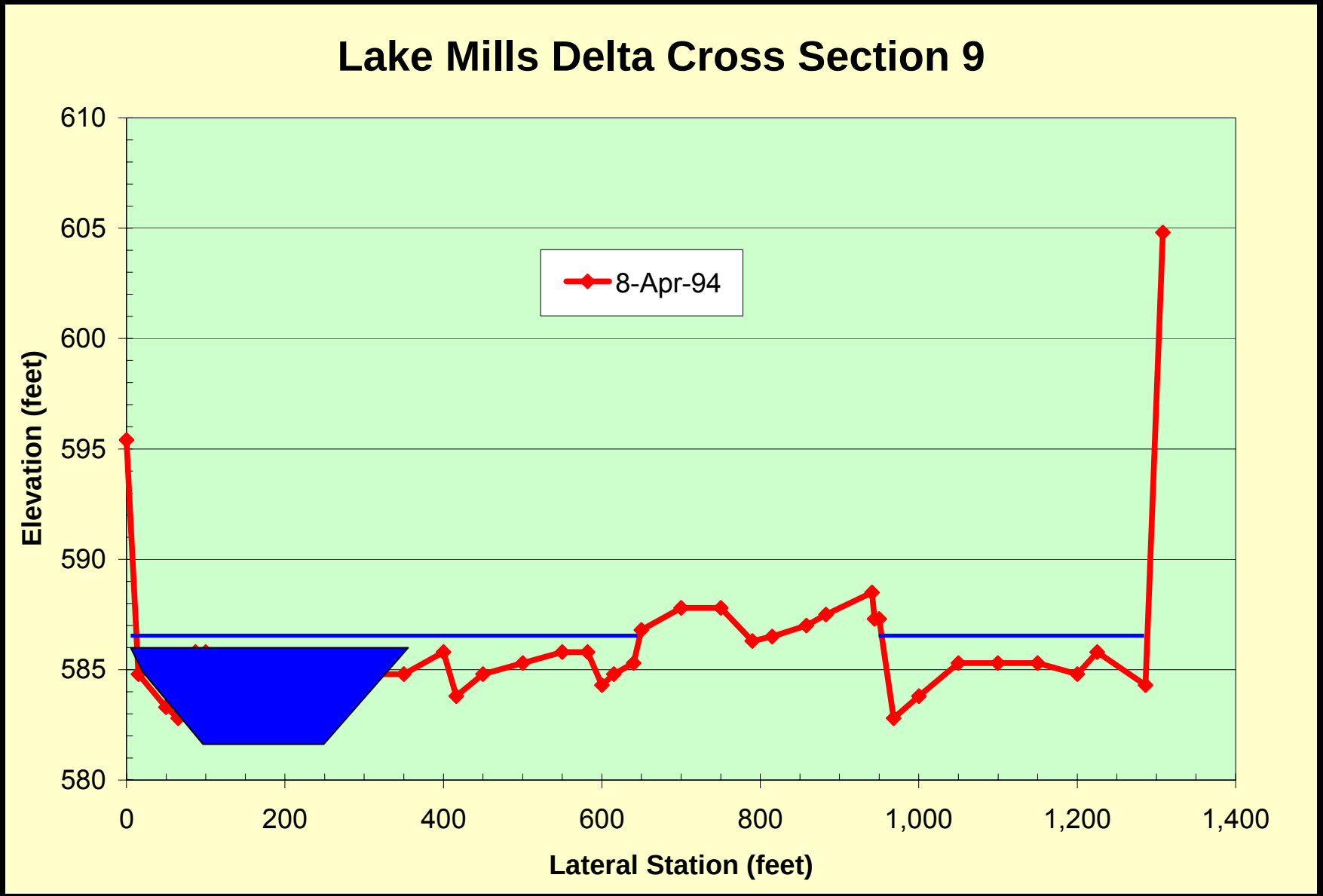


Erosion of sediment layers



Erosion channel width



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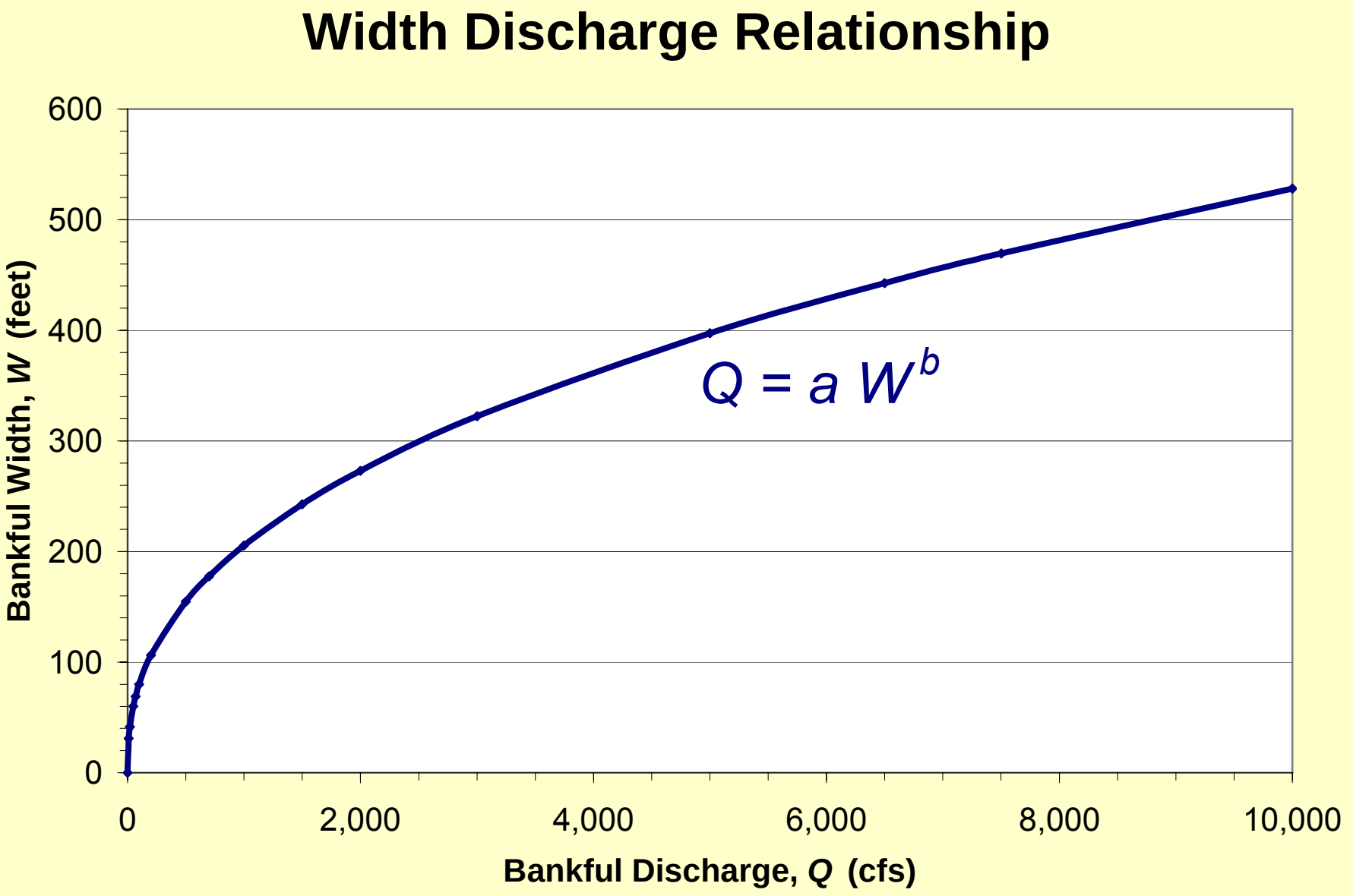
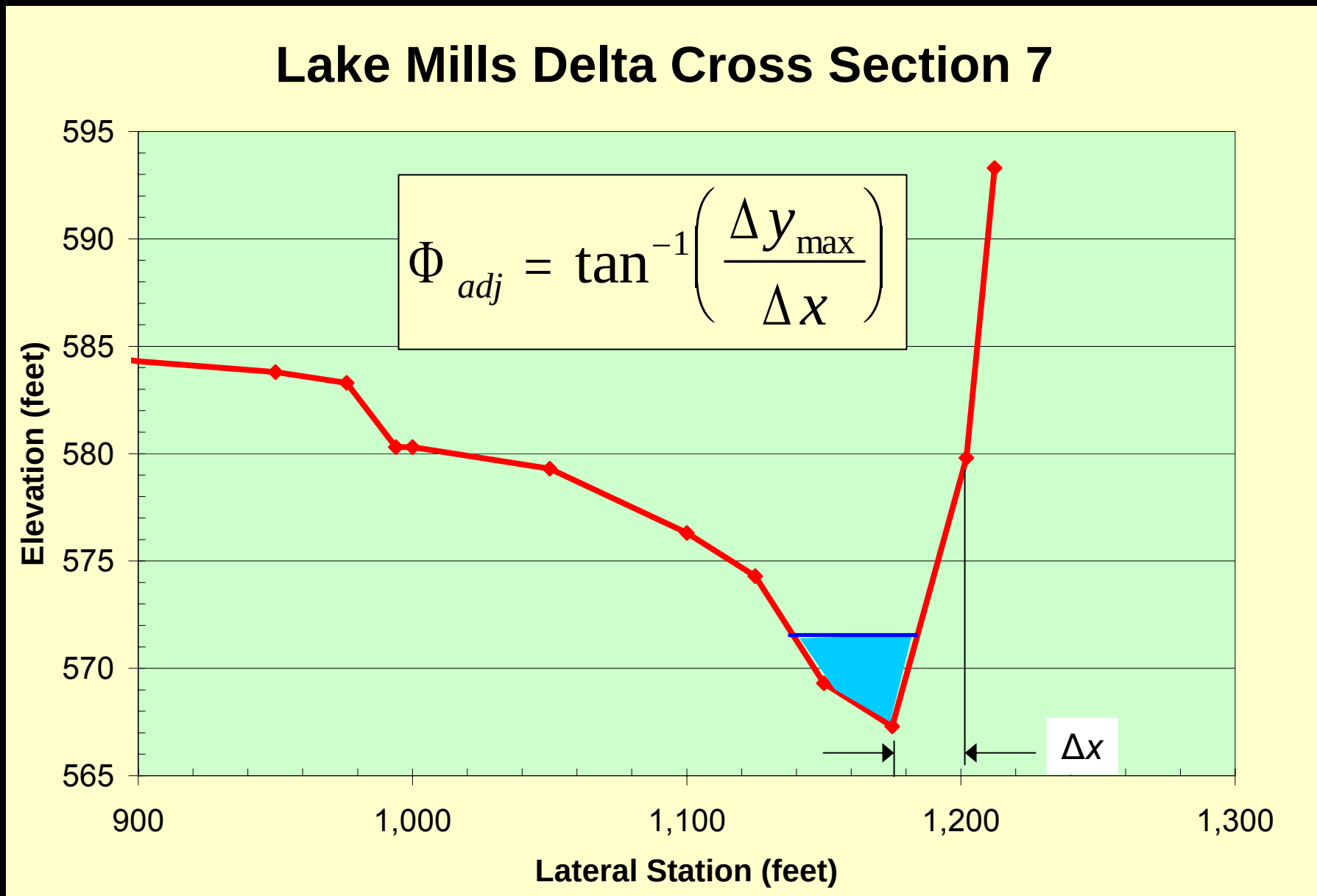
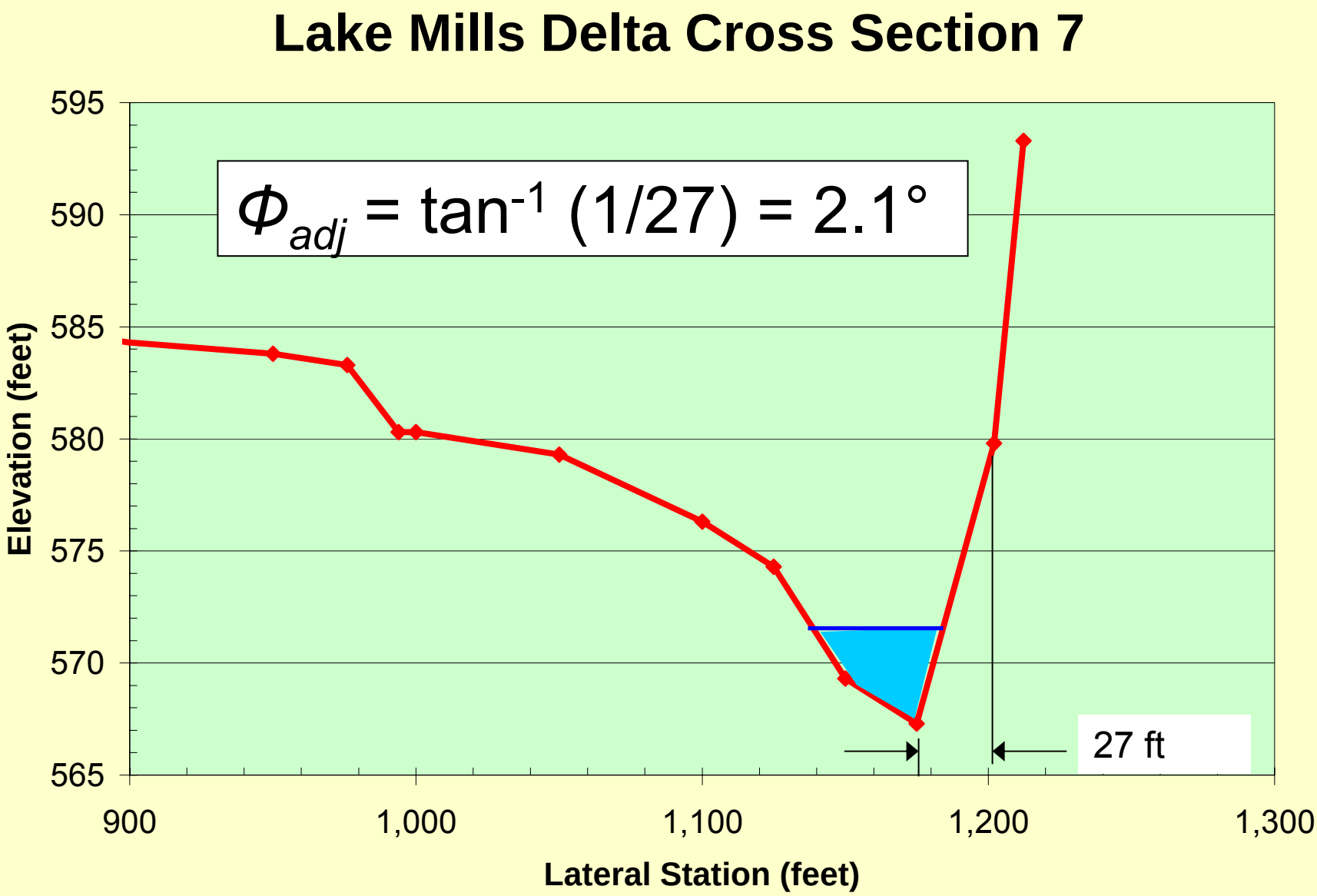


Erosion channel width



Erosion channel width



Delta Channel Migration

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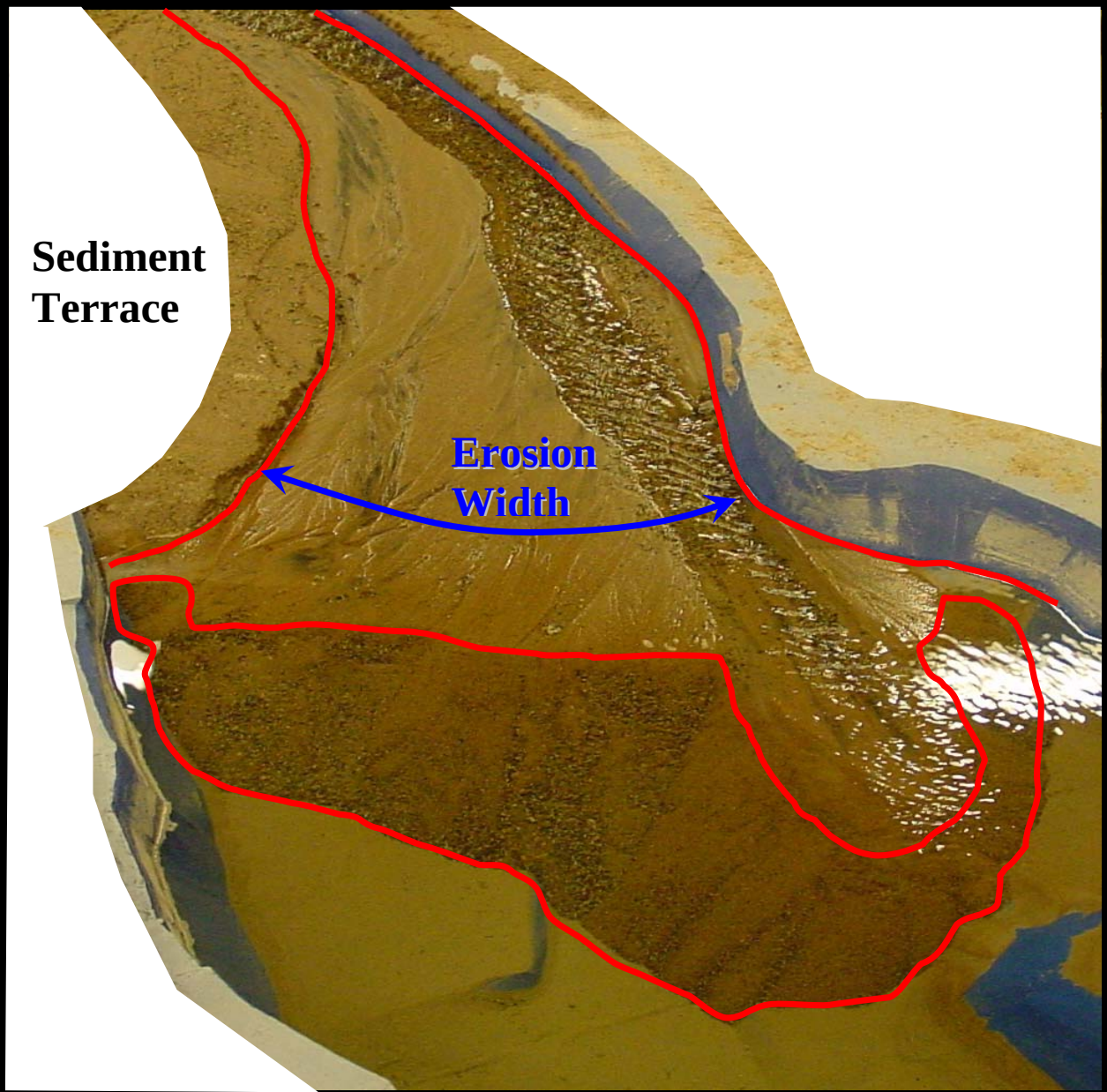

Lake Mills Physical Model Experiment:

Initial reservoir drawdown and delta erosion (Chris Bromley)

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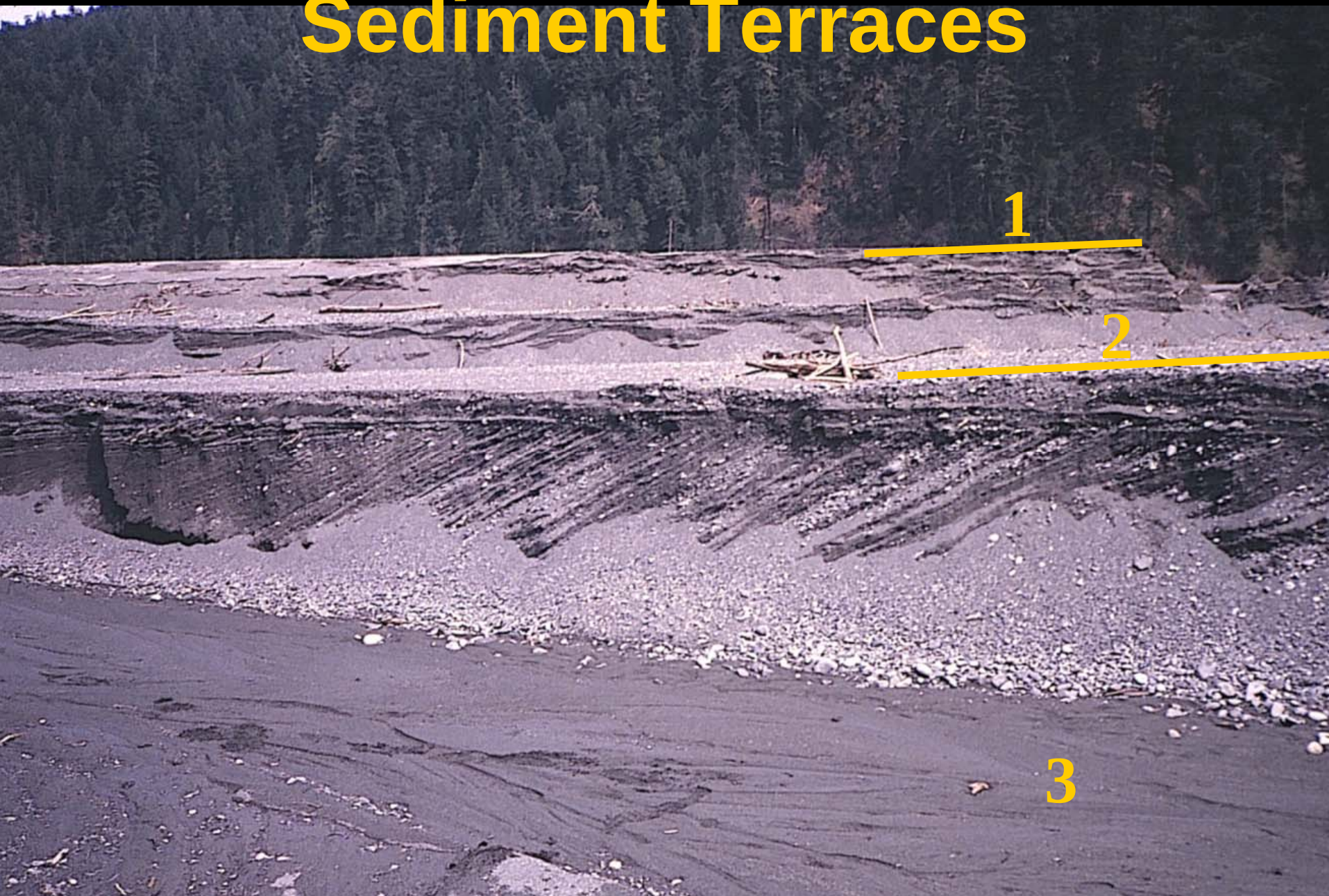
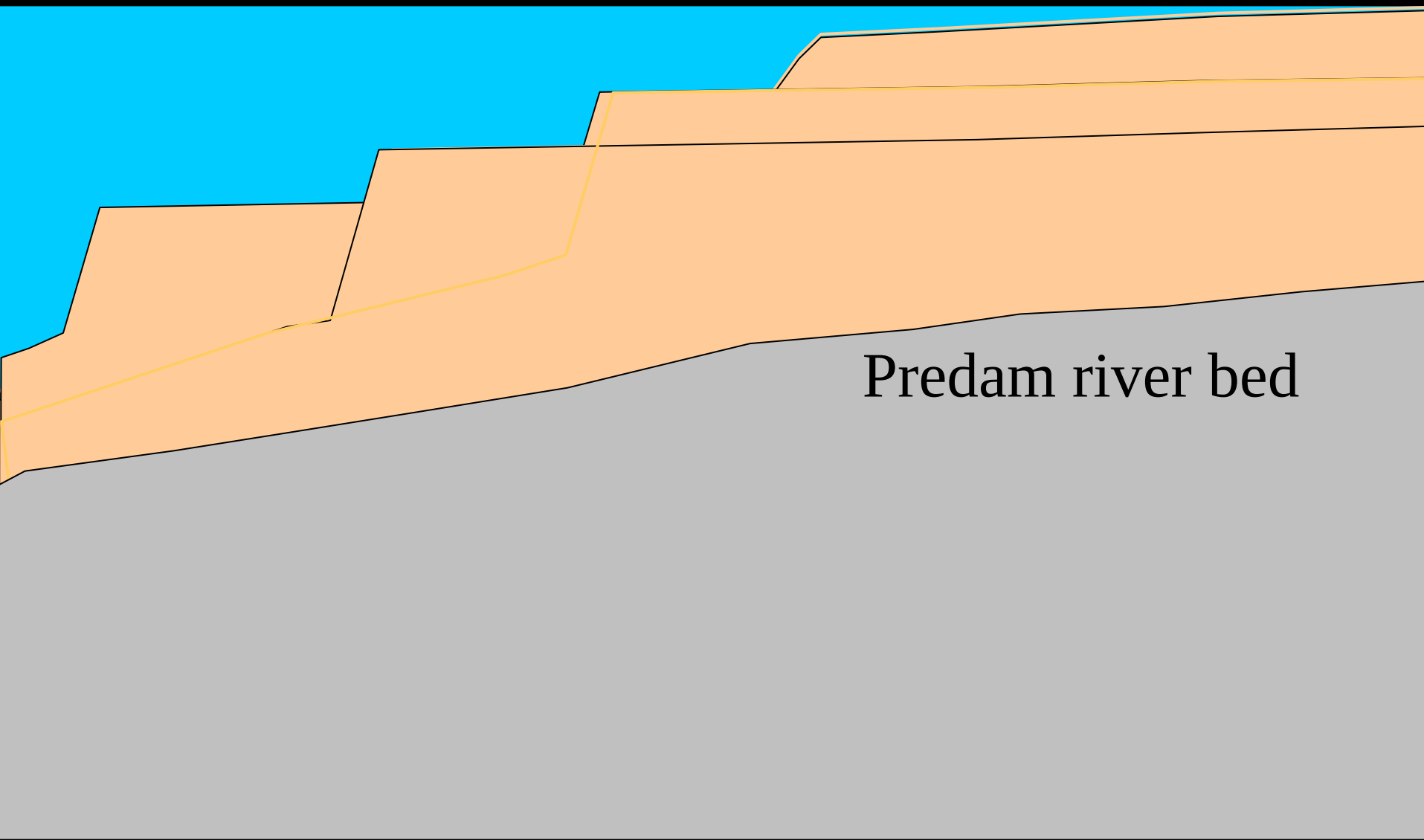
Sediment Terraces

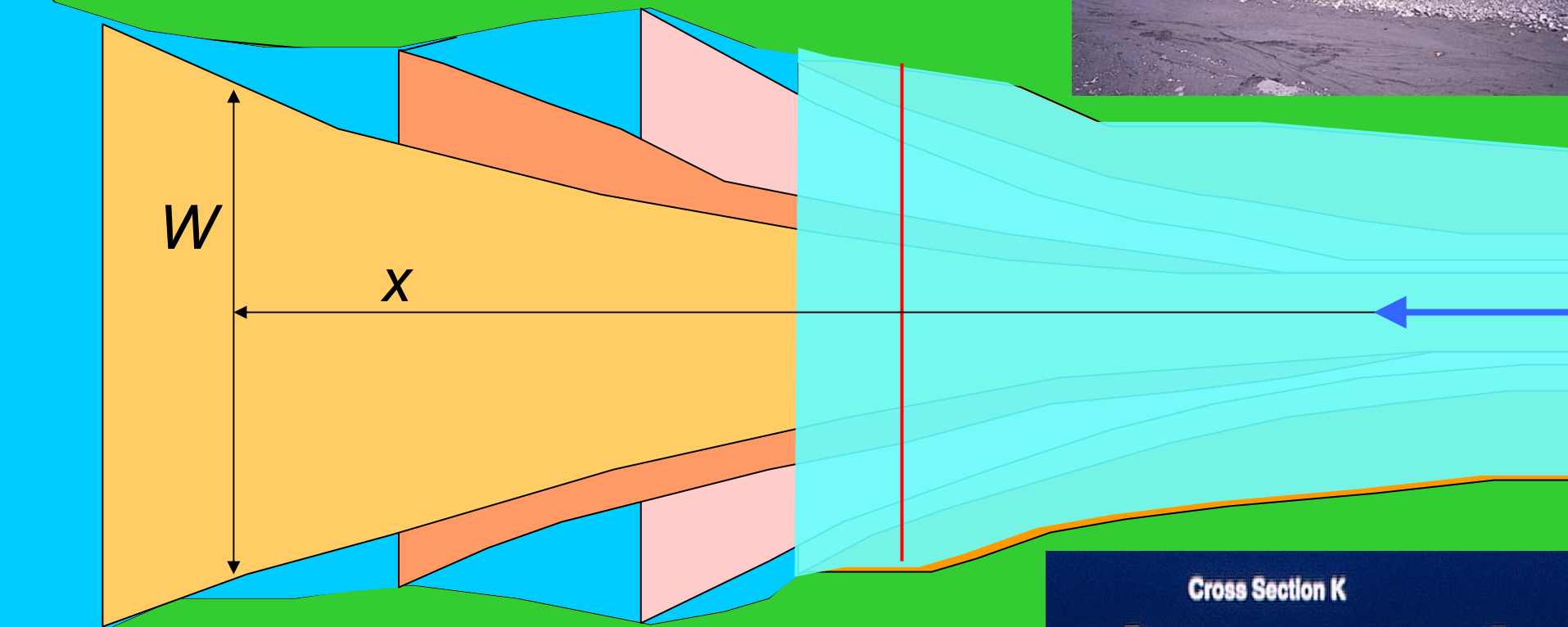


Lake Mills Profile



Lake Mills Planform

$$W = 2\,a\,x^2 + W_{min}$$



Channel Planform Change

Physical Model by
Chris Bromley

Channel Planform Change

Physical Model by
Chris Bromley

Channel Planform Change

Physical Model by
Chris Bromley

Channel Planform Change

Physical Model by
Chris Bromley

Modeling Downstream Sediment Transport and Deposition

Wash load and bed-material load

Sediment Deposition

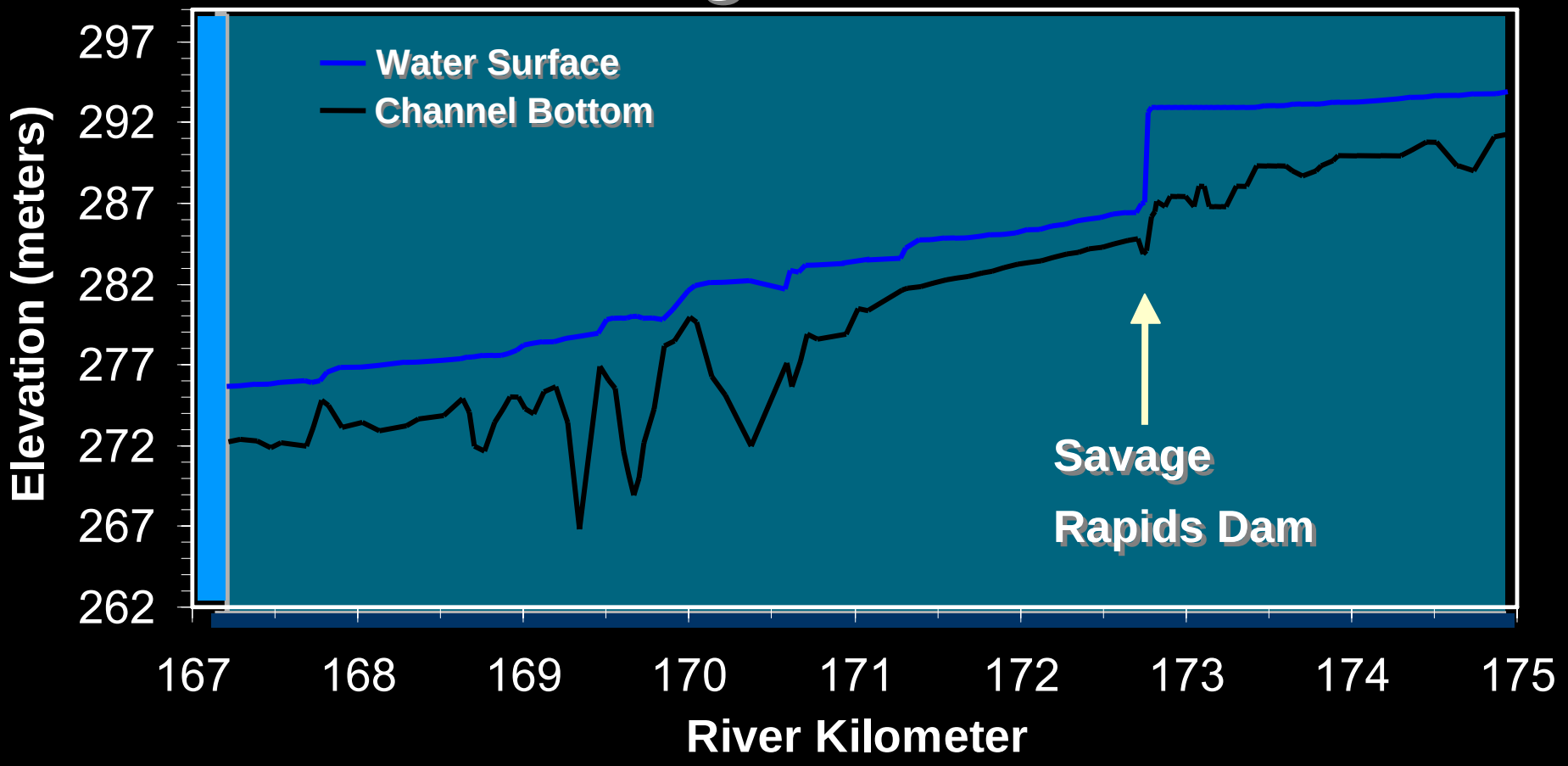
- Eddies
- Pools
- Riffles
- Increased flood stage
- Bank erosion
- Channel migration
- Channel avulsion

HEC-6 Model Example

Erosion and transport of reservoir sediments following the removal of Savage Rapids Dam

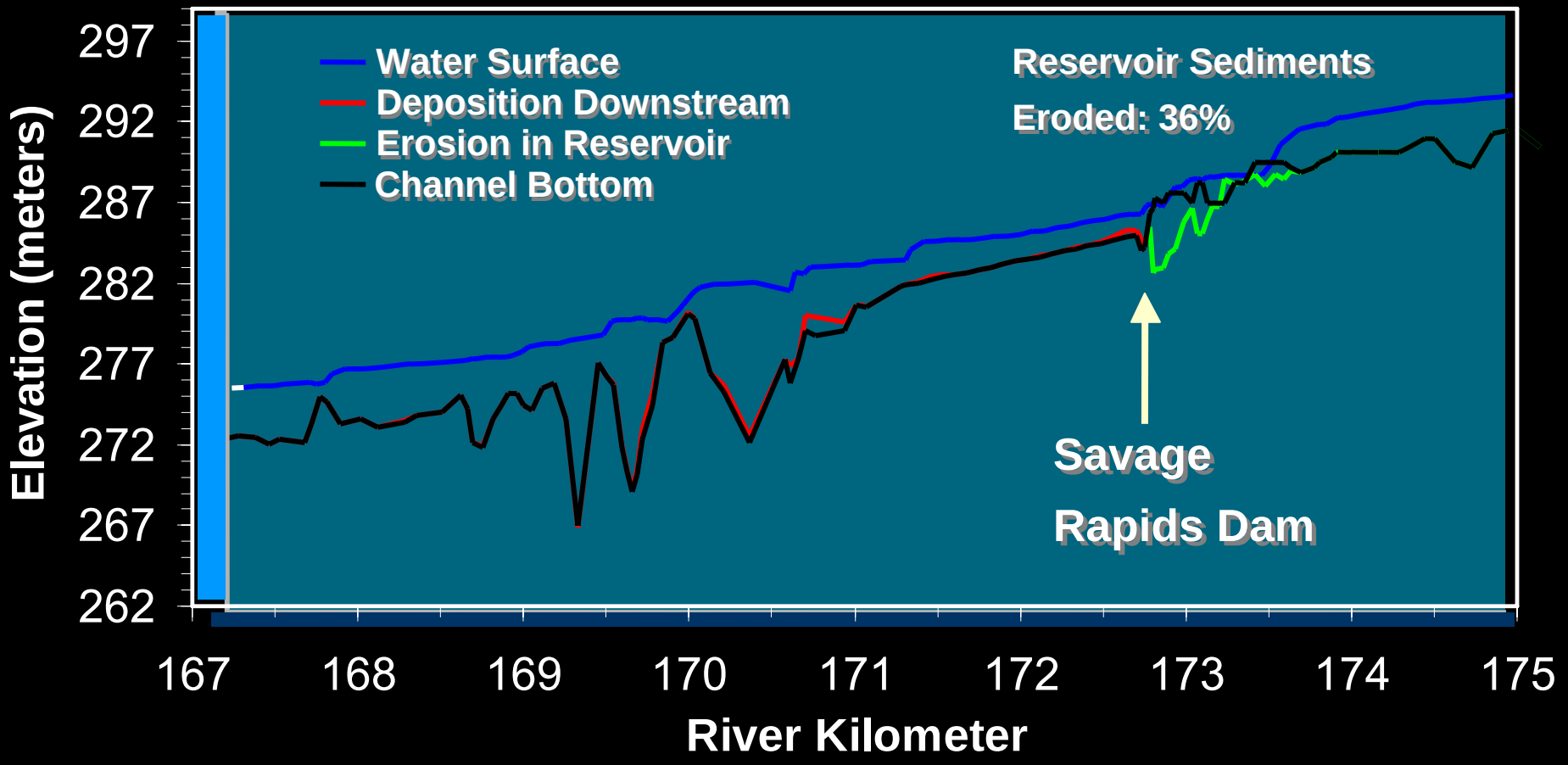
Sediment Erosion and Deposition Following Dam Removal

Existing Conditions



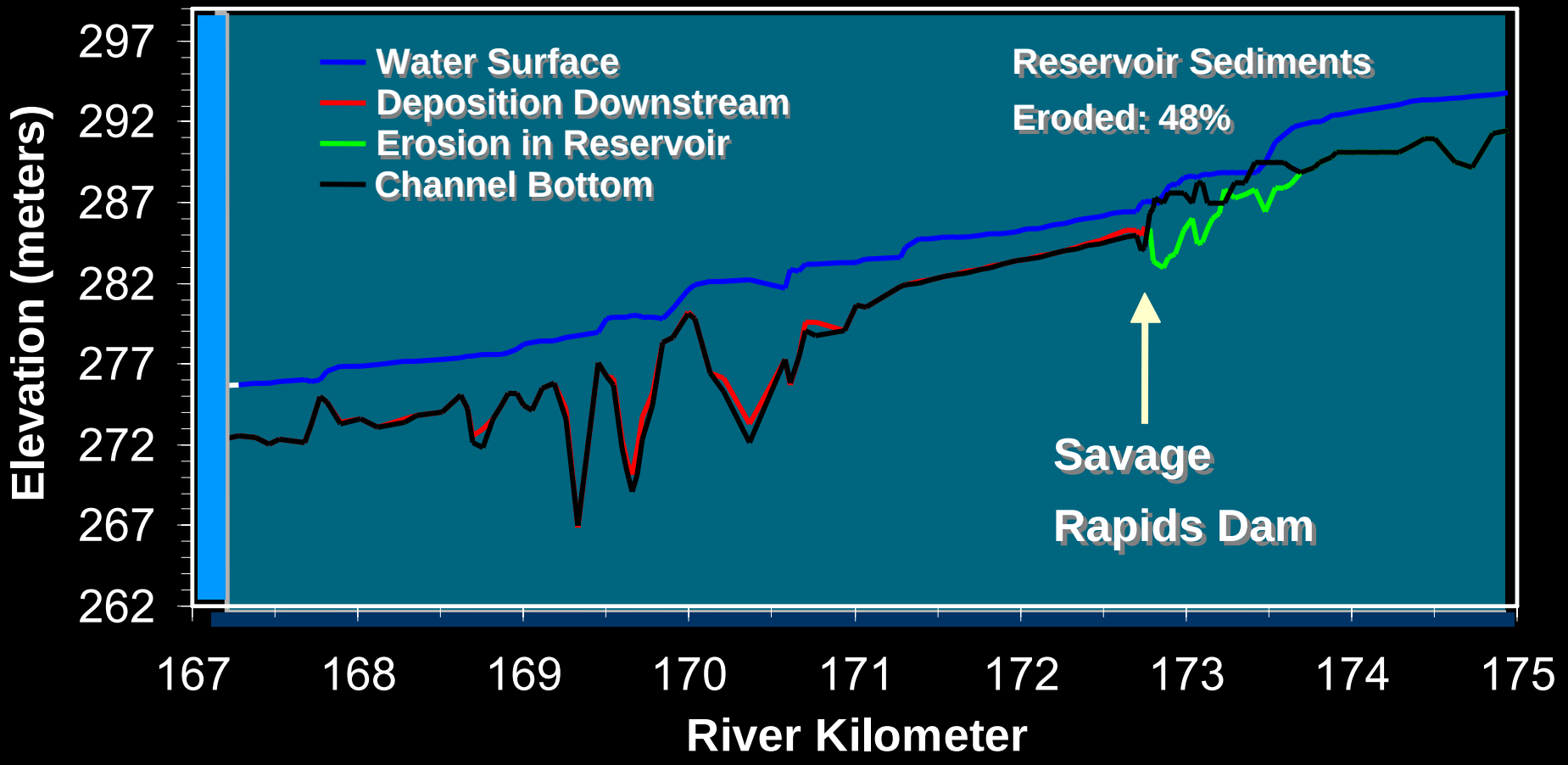
Sediment Erosion and Deposition Following Dam Removal

1 Week After Removal



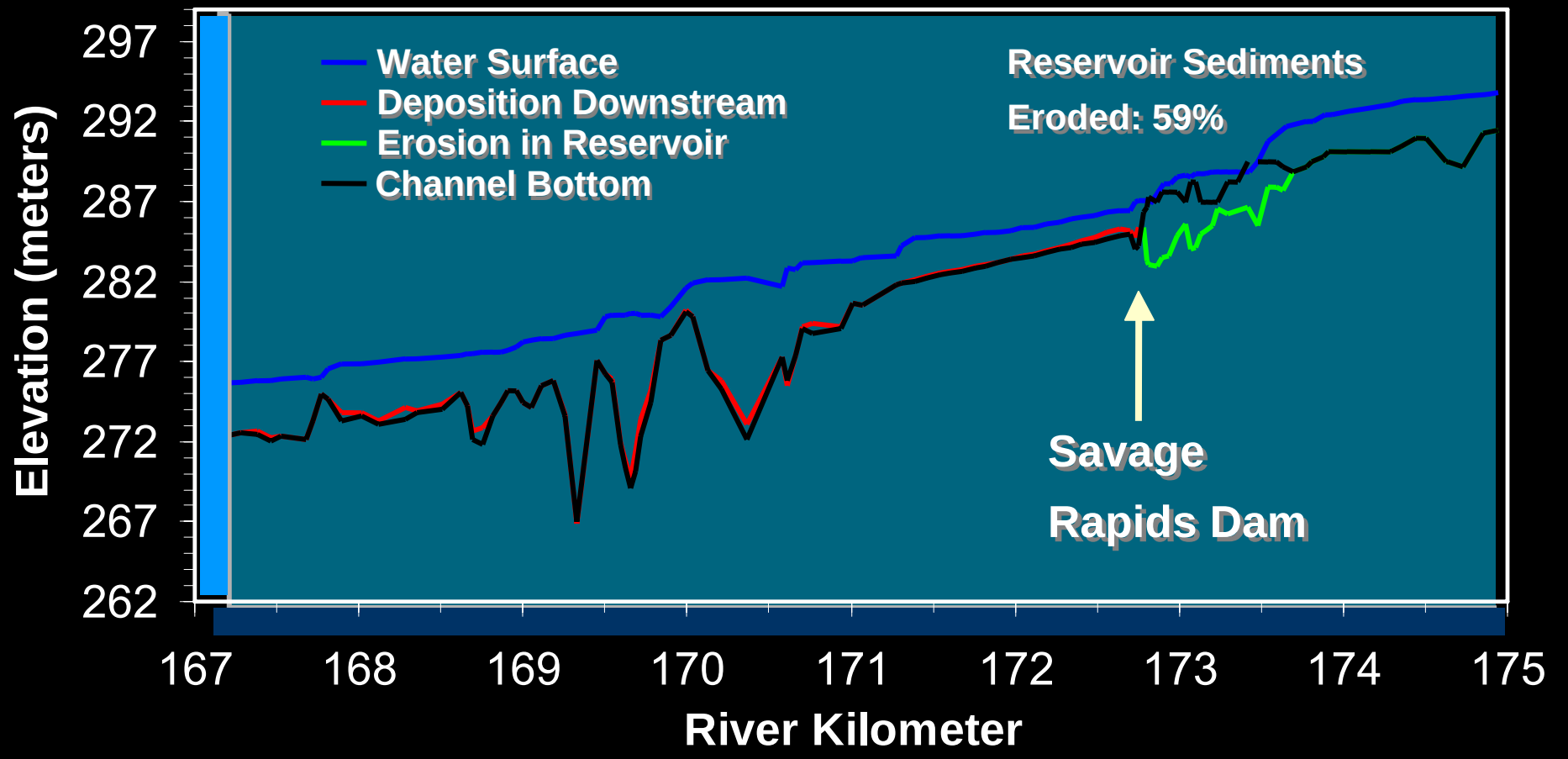
Sediment Erosion and Deposition Following Dam Removal

1 Month After Removal



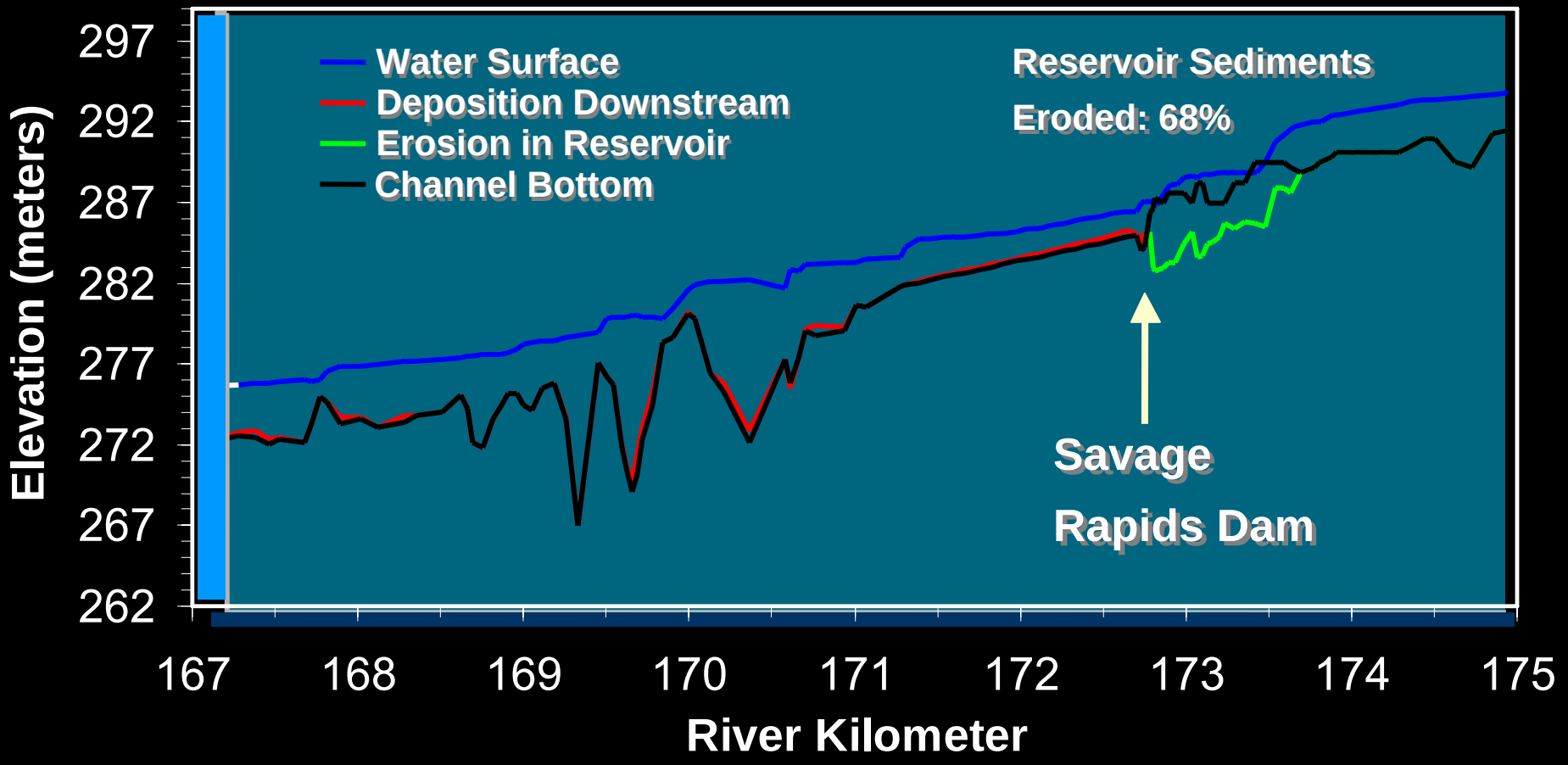
Sediment Erosion and Deposition Following Dam Removal

2 Months After Removal



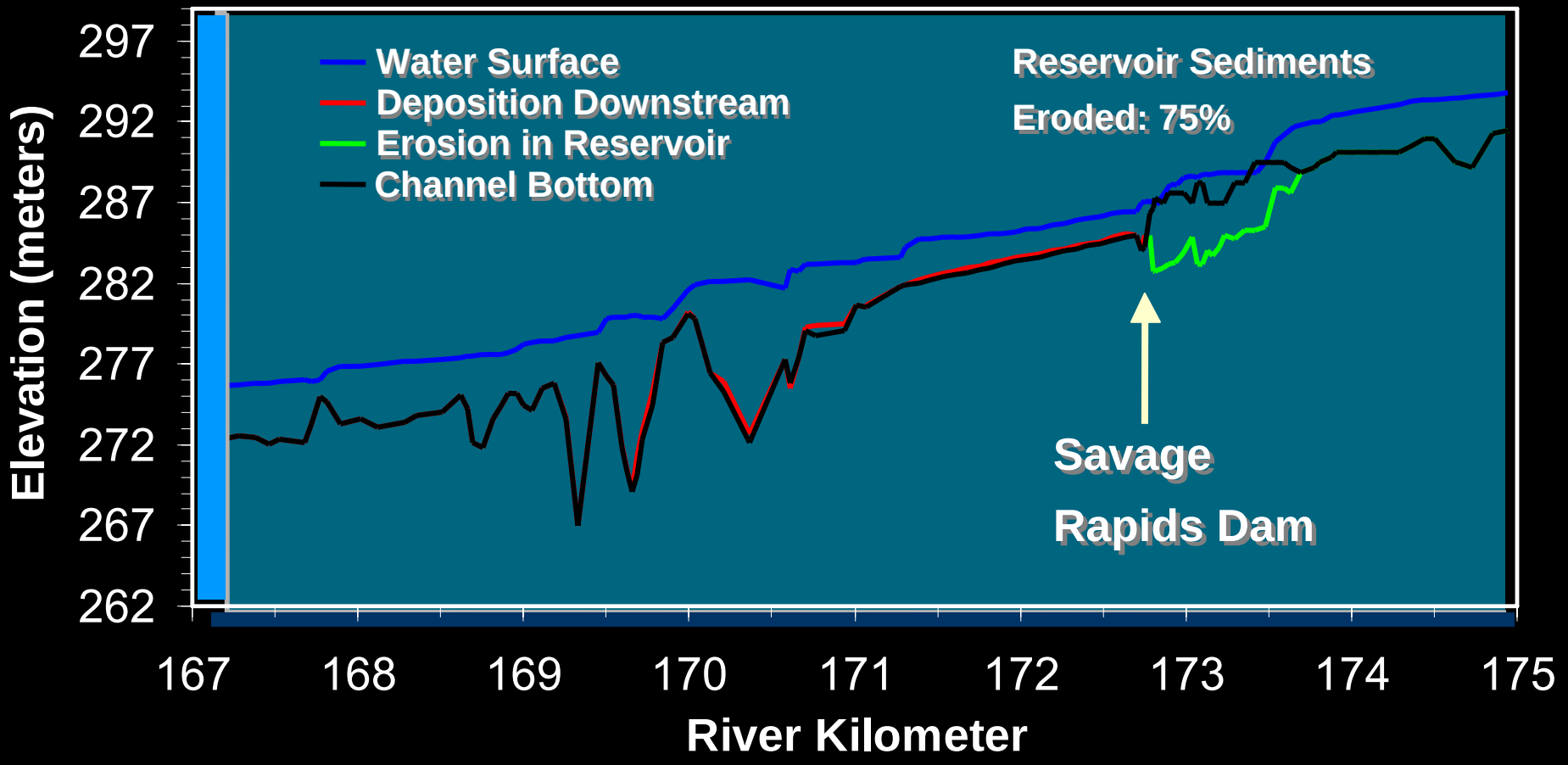
Sediment Erosion and Deposition Following Dam Removal

3 Months After Removal



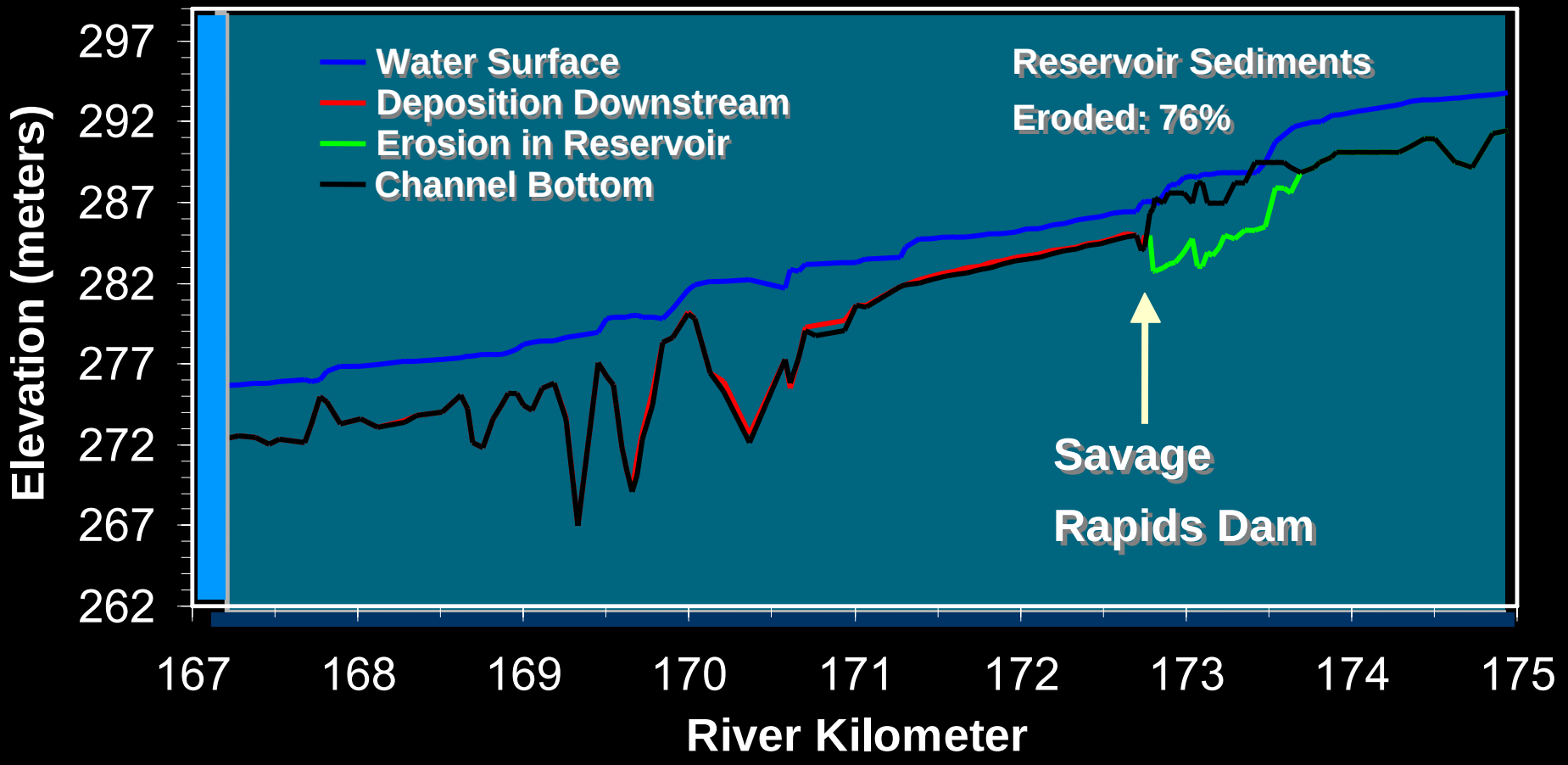
Sediment Erosion and Deposition Following Dam Removal

5 Months After Removal



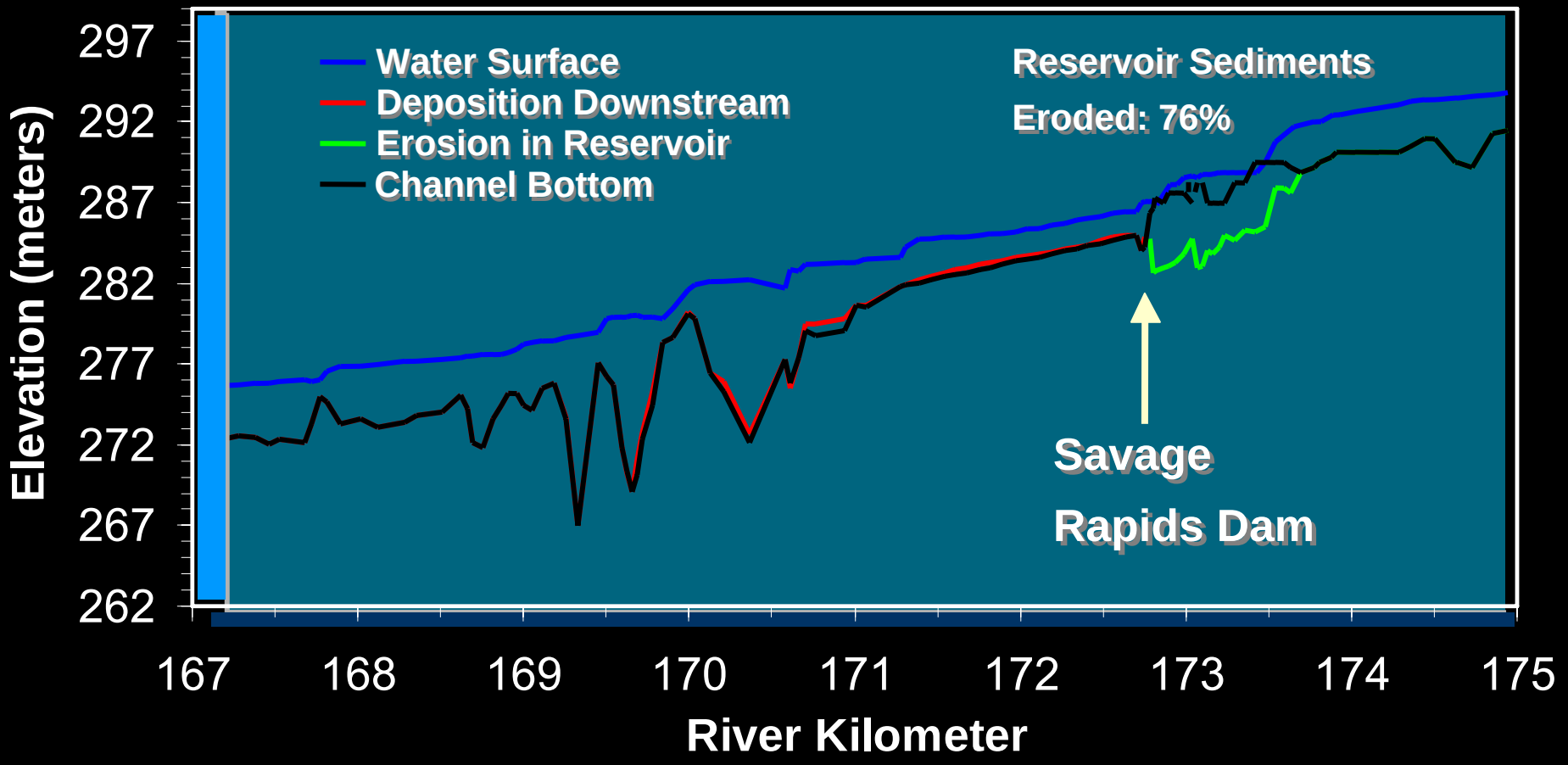
Sediment Erosion and Deposition Following Dam Removal

6 1/2 Months After Removal



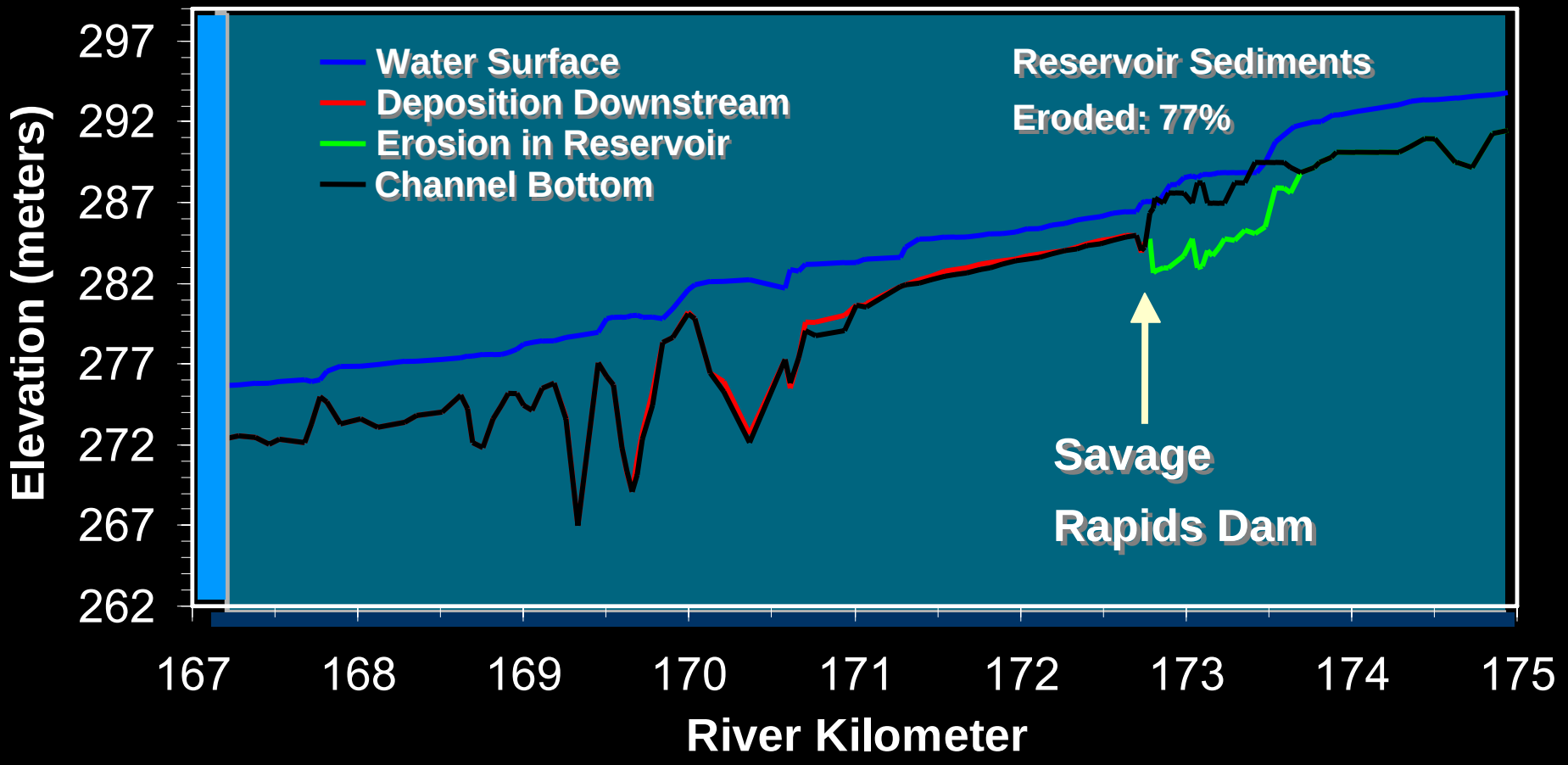
Sediment Erosion and Deposition Following Dam Removal

7 1/2 months After Removal



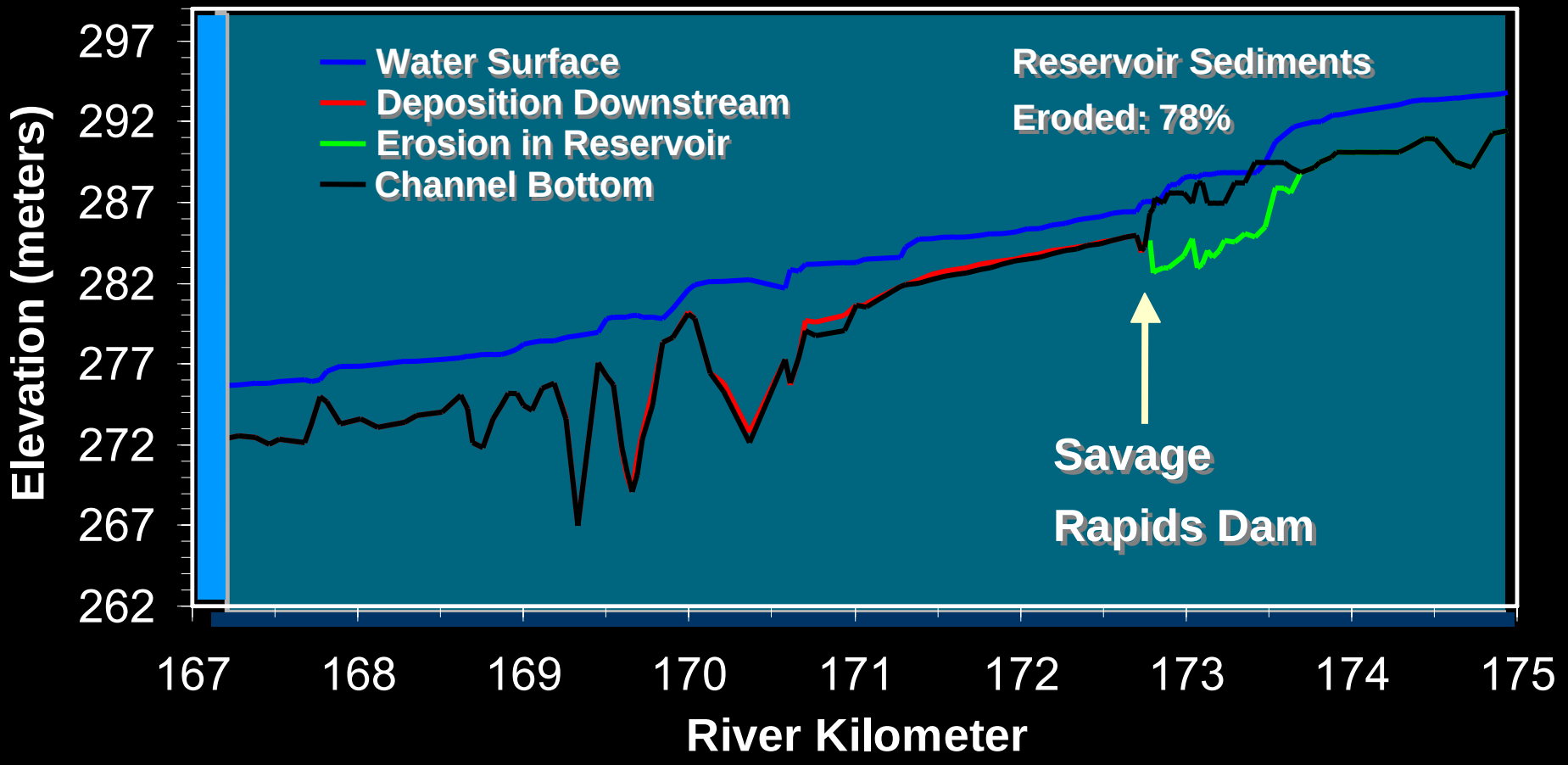
Sediment Erosion and Deposition Following Dam Removal

8 months After Removal



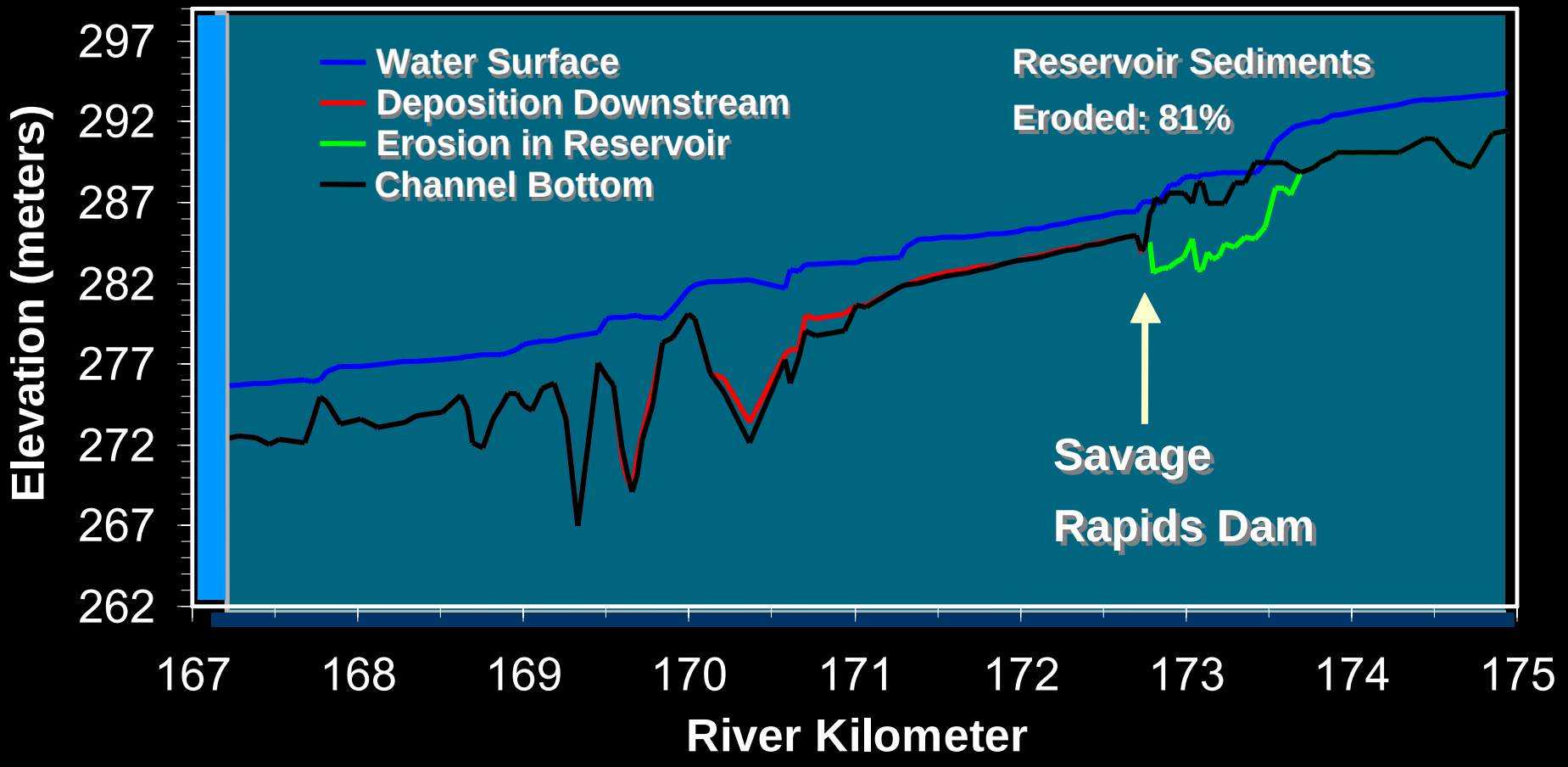
Sediment Erosion and Deposition Following Dam Removal

9 months After Removal

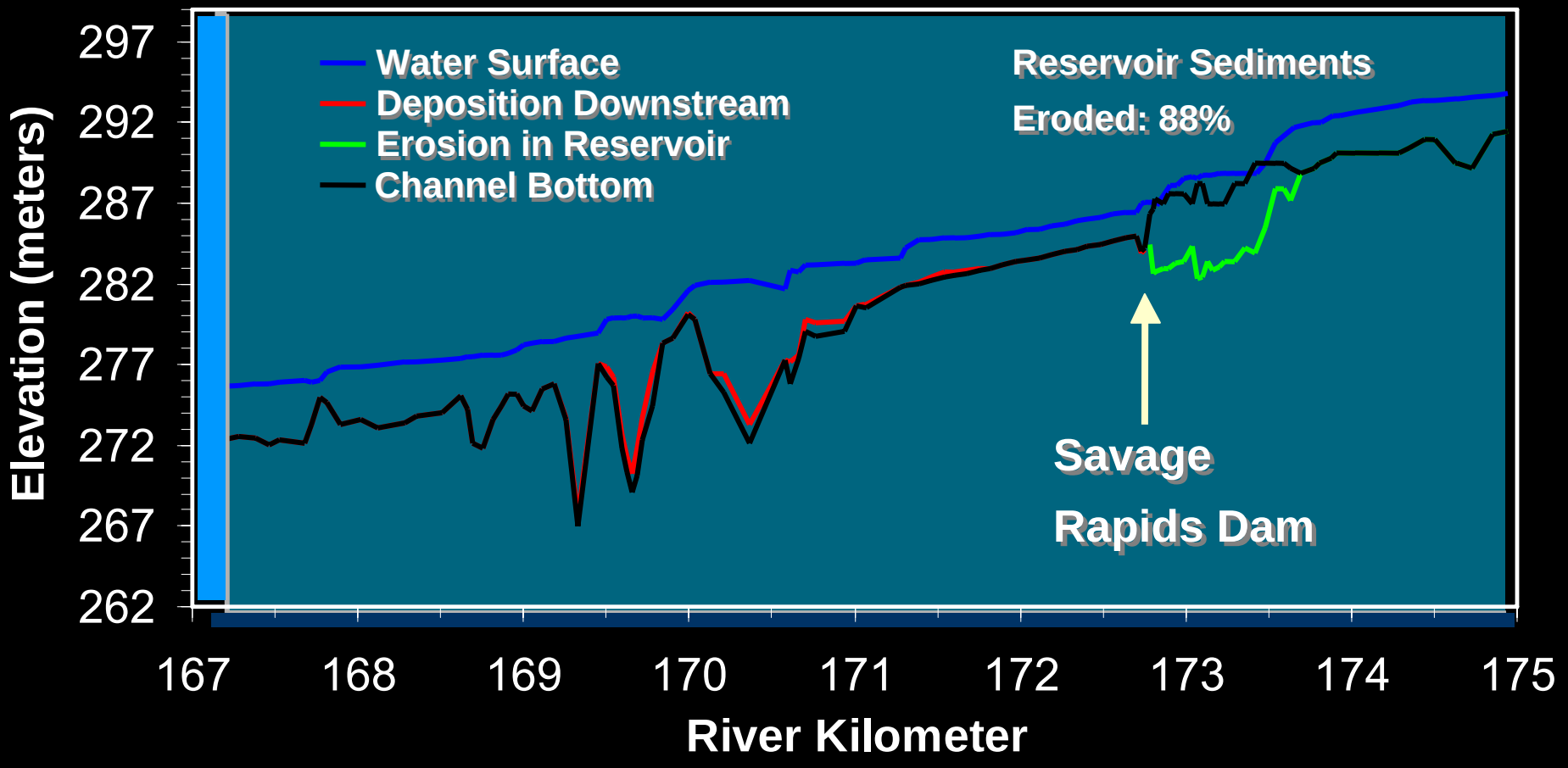


Sediment Erosion and Deposition Following Dam Removal

1 1/2 Years After Removal

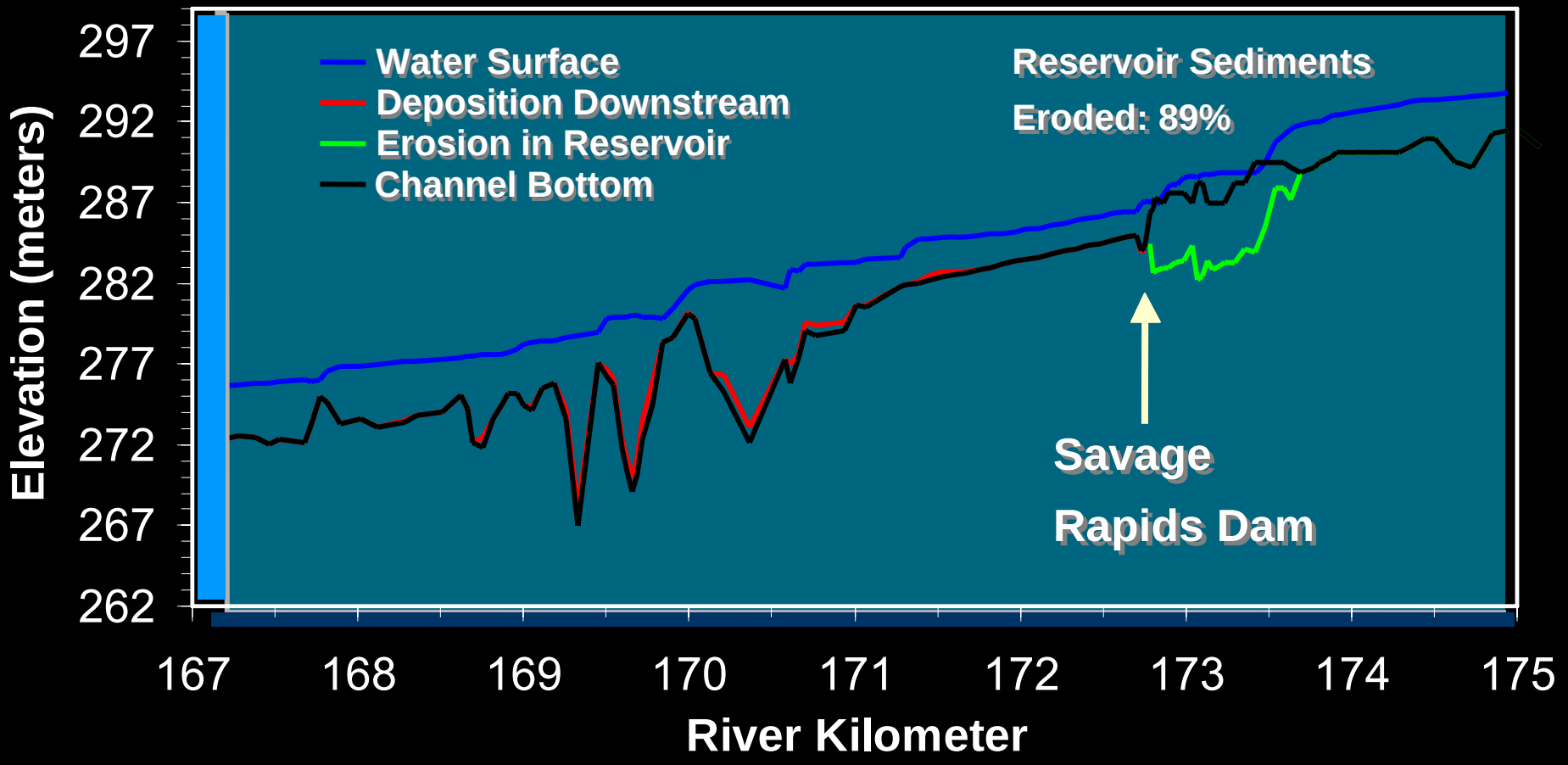


Sediment Erosion and Deposition Following Dam Removal "4 Years After Removal"

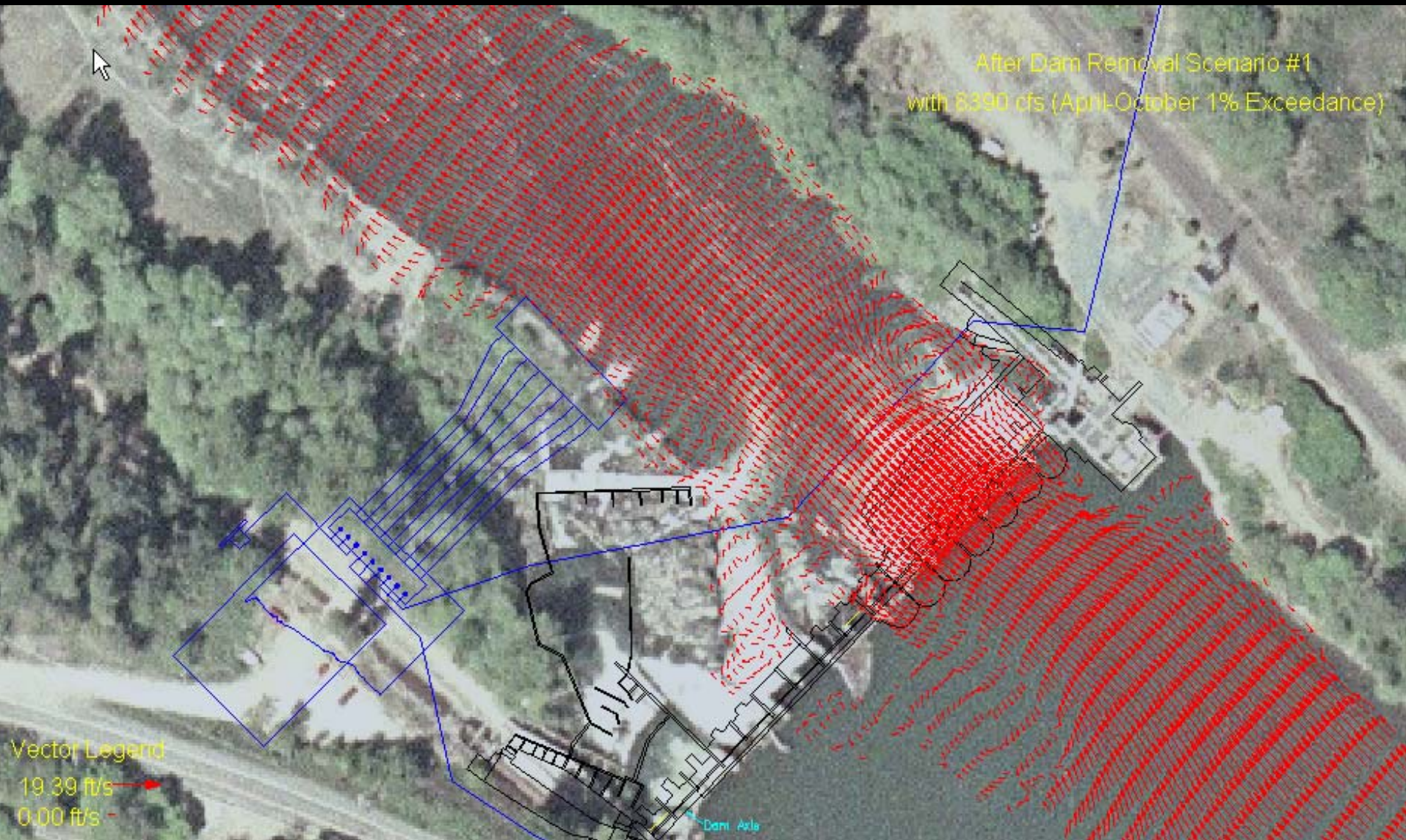


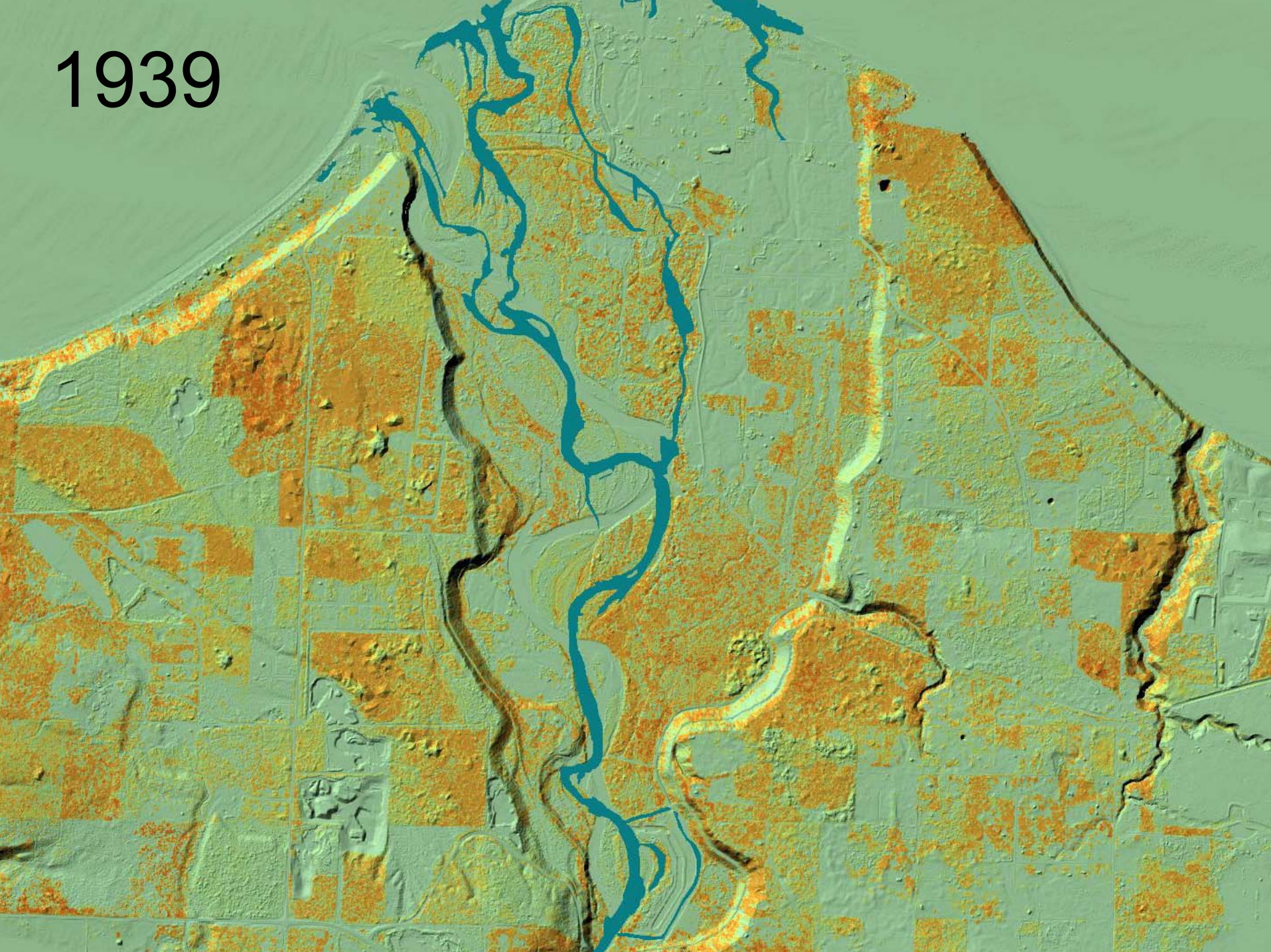
Sediment Erosion and Deposition Following Dam Removal

6 Years After Removal



2-D Hydraulic Modeling

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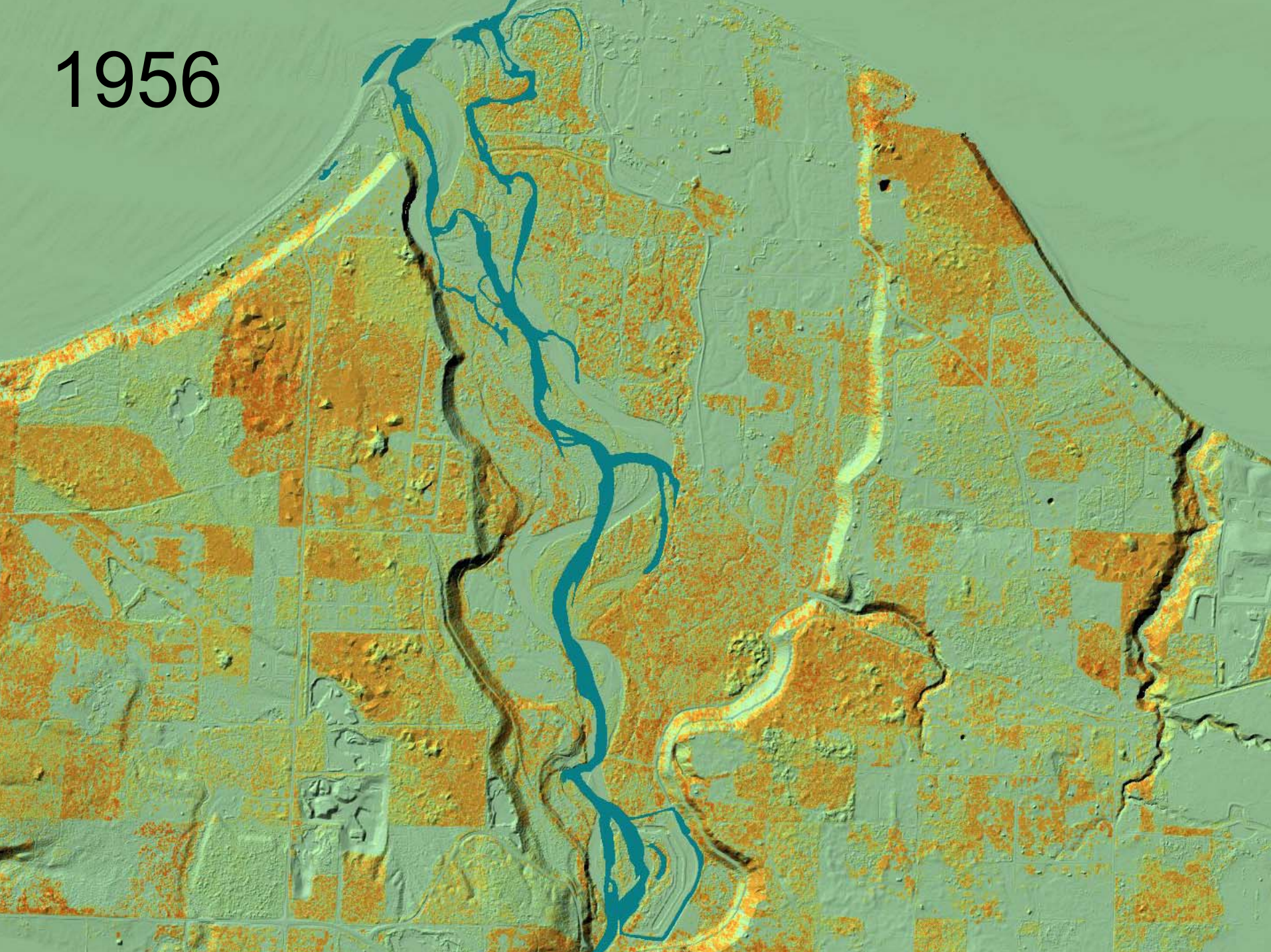
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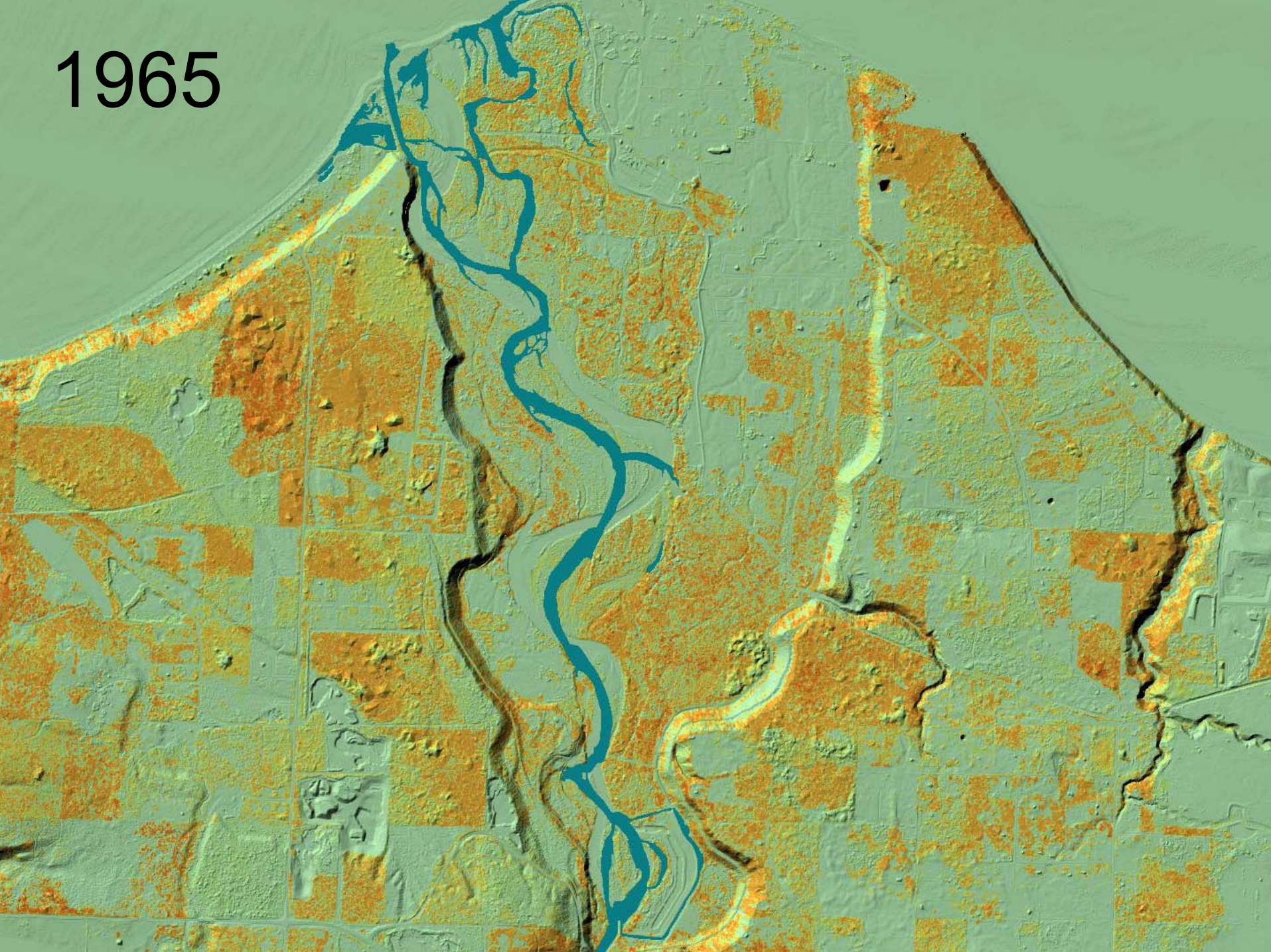
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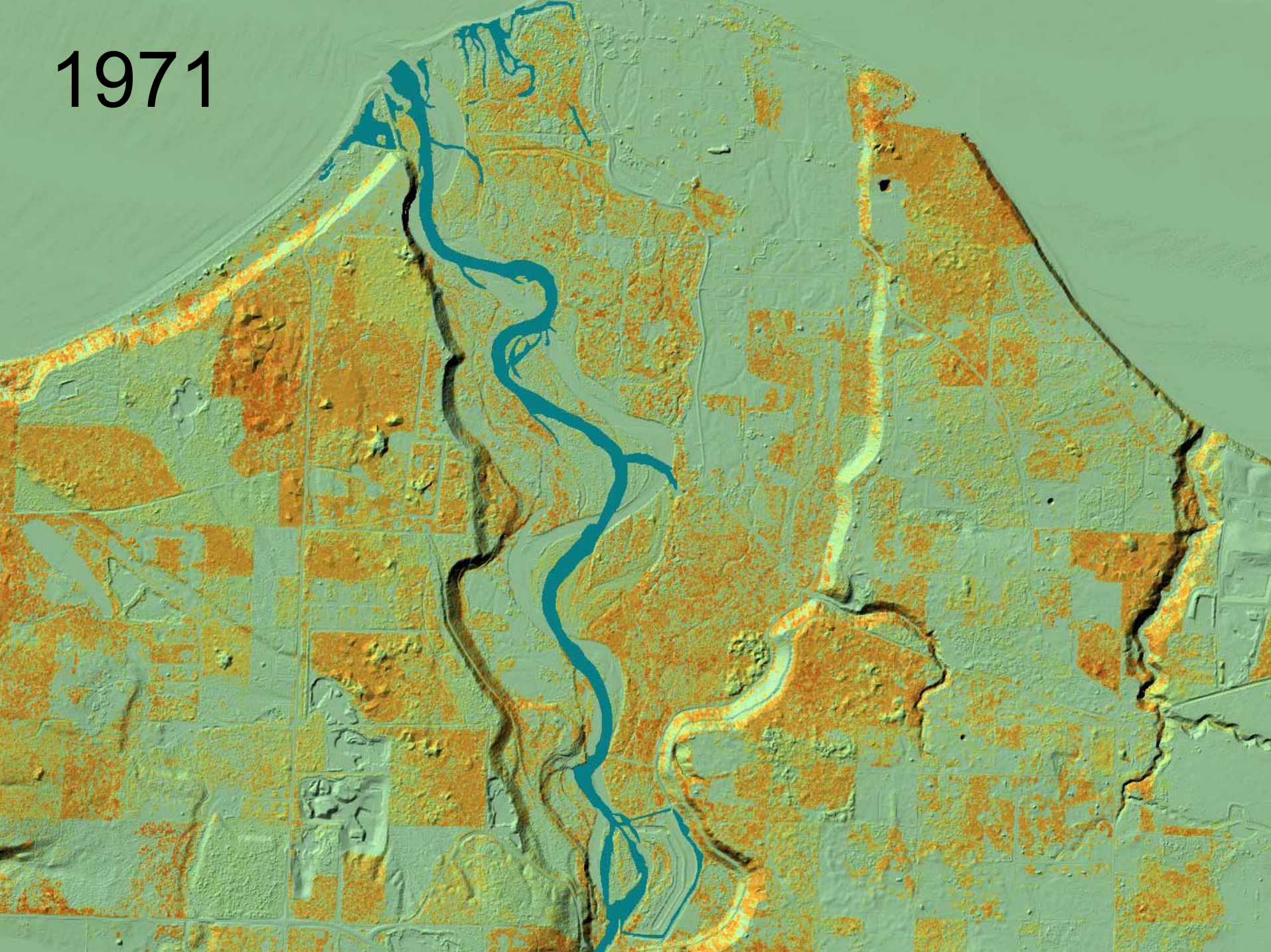
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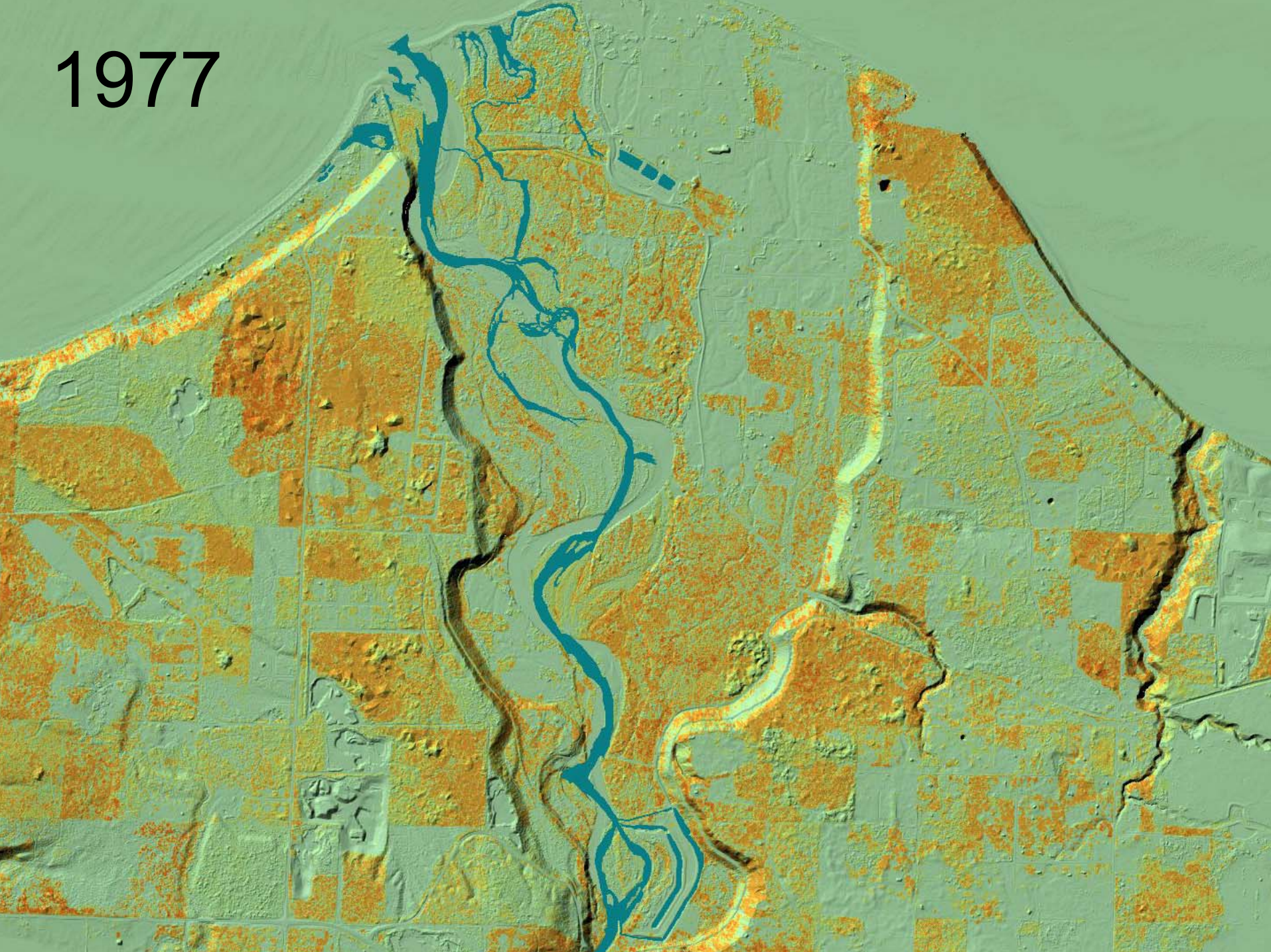
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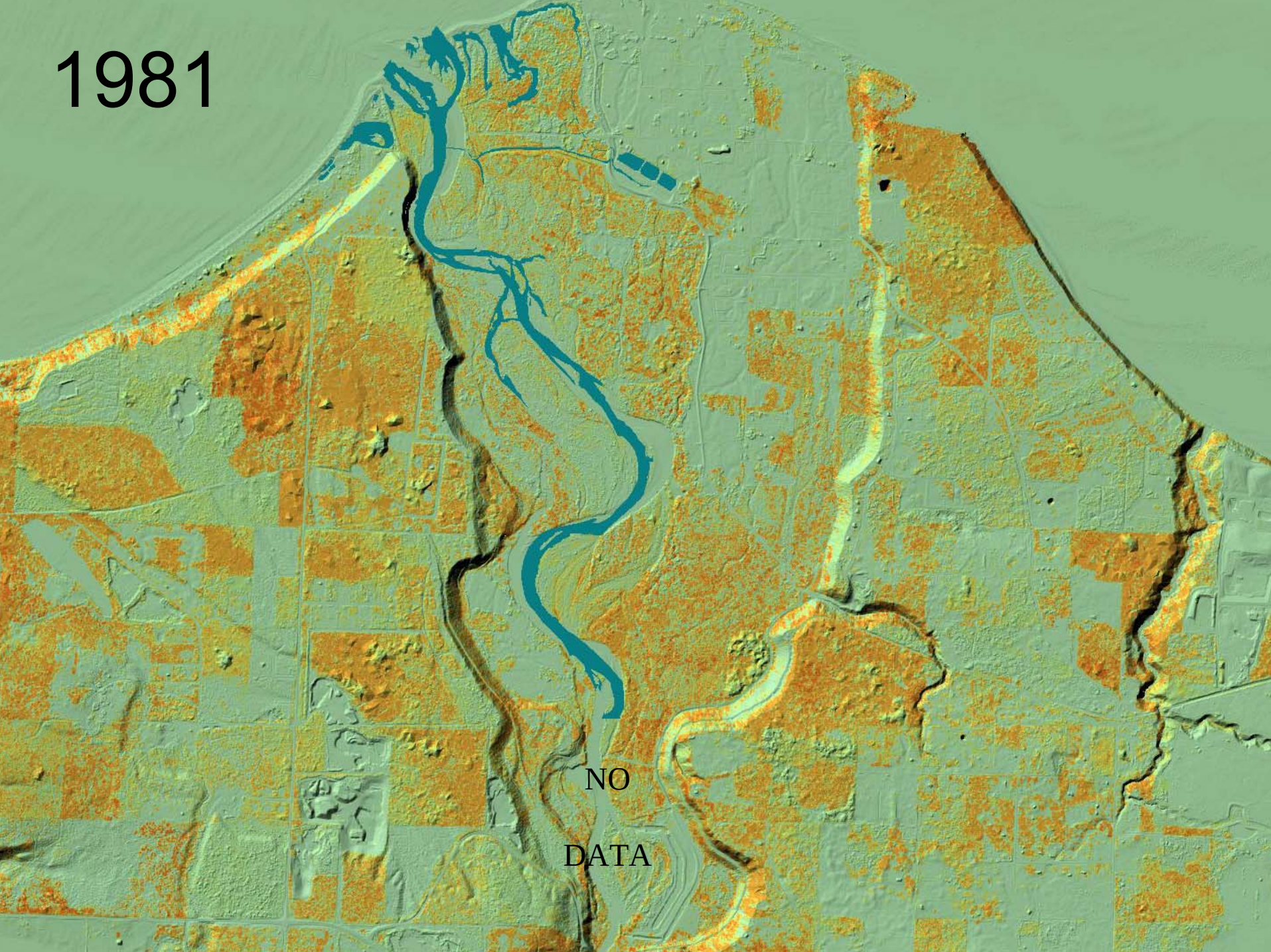
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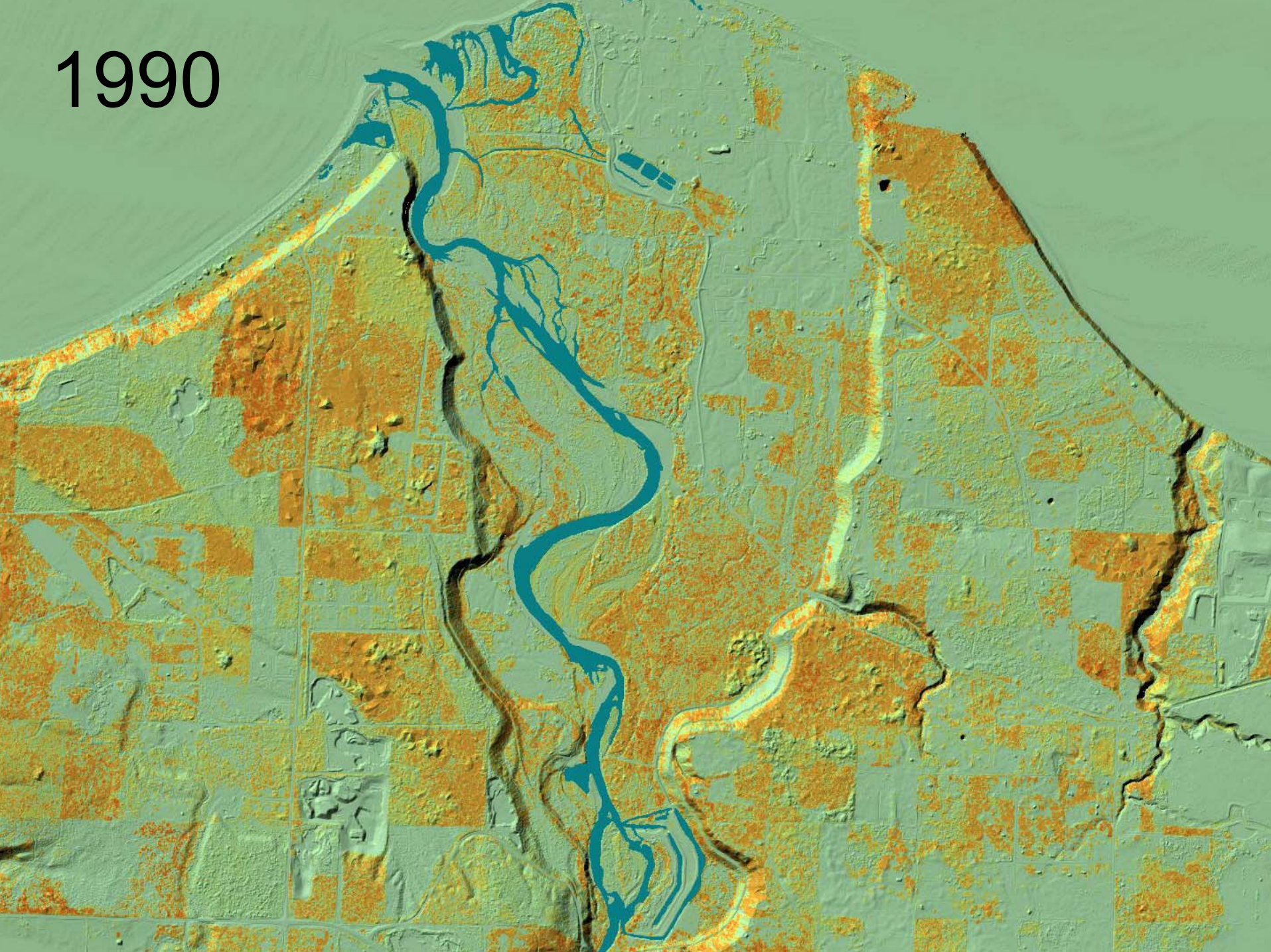
DATA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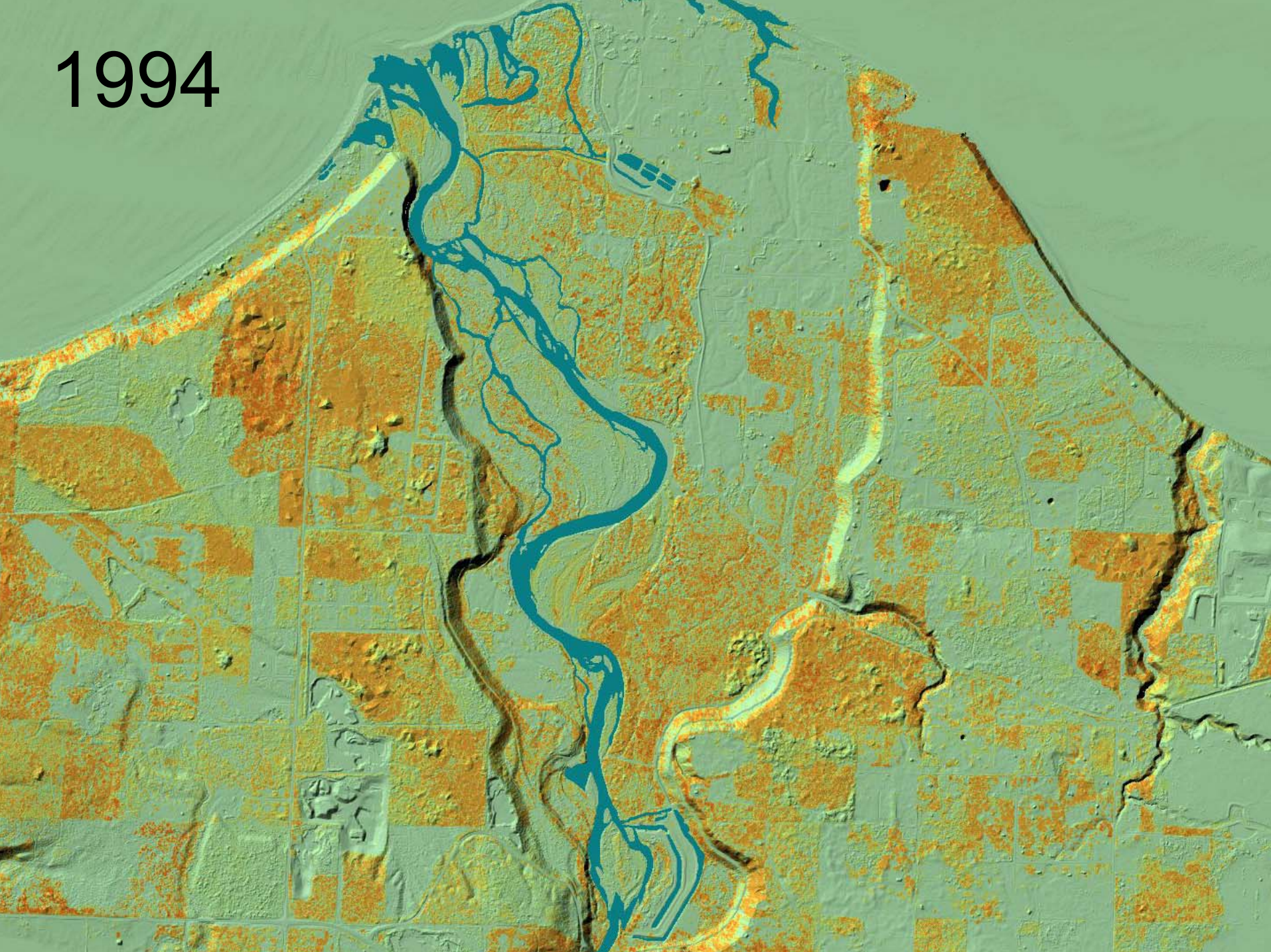
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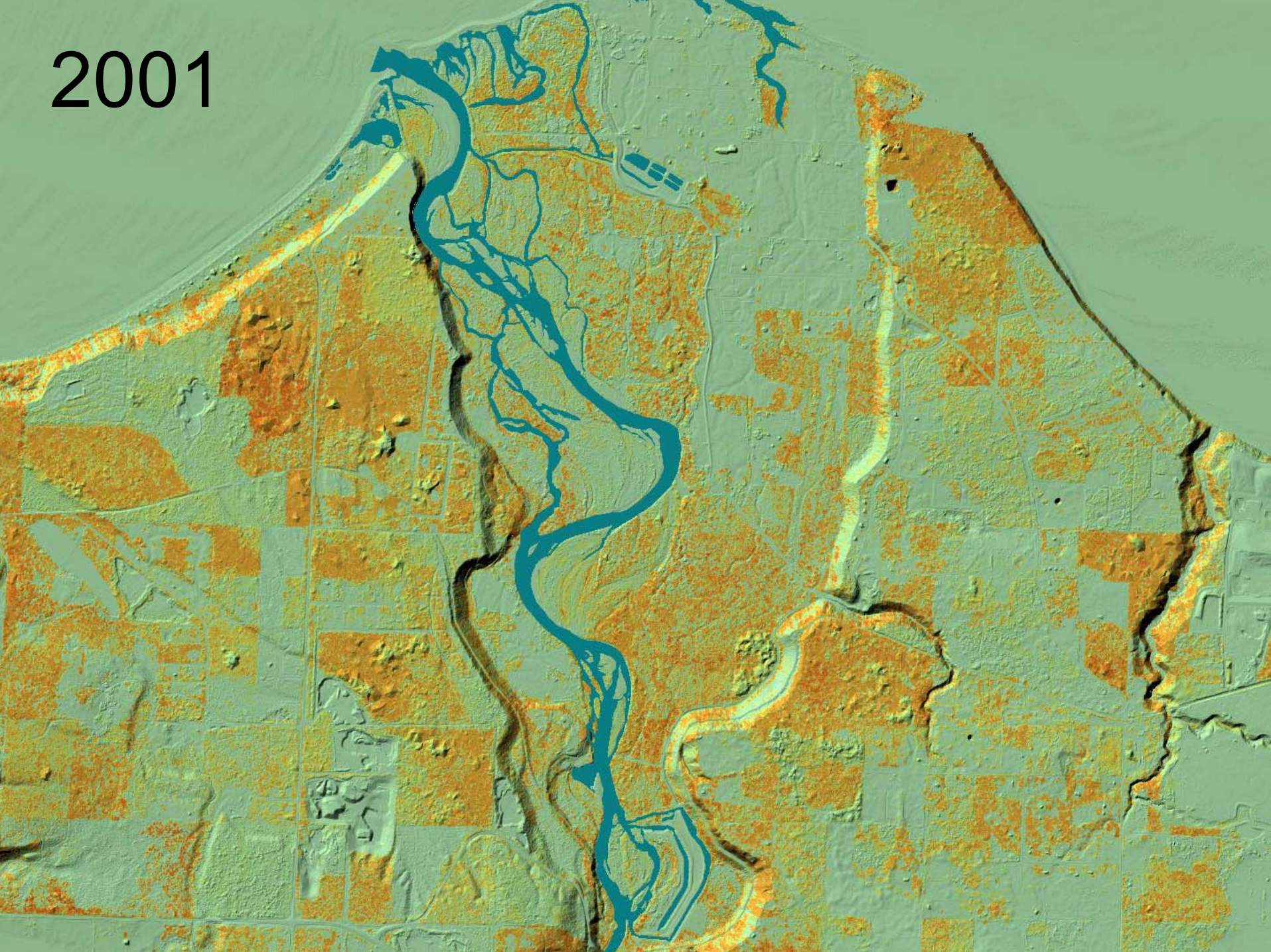
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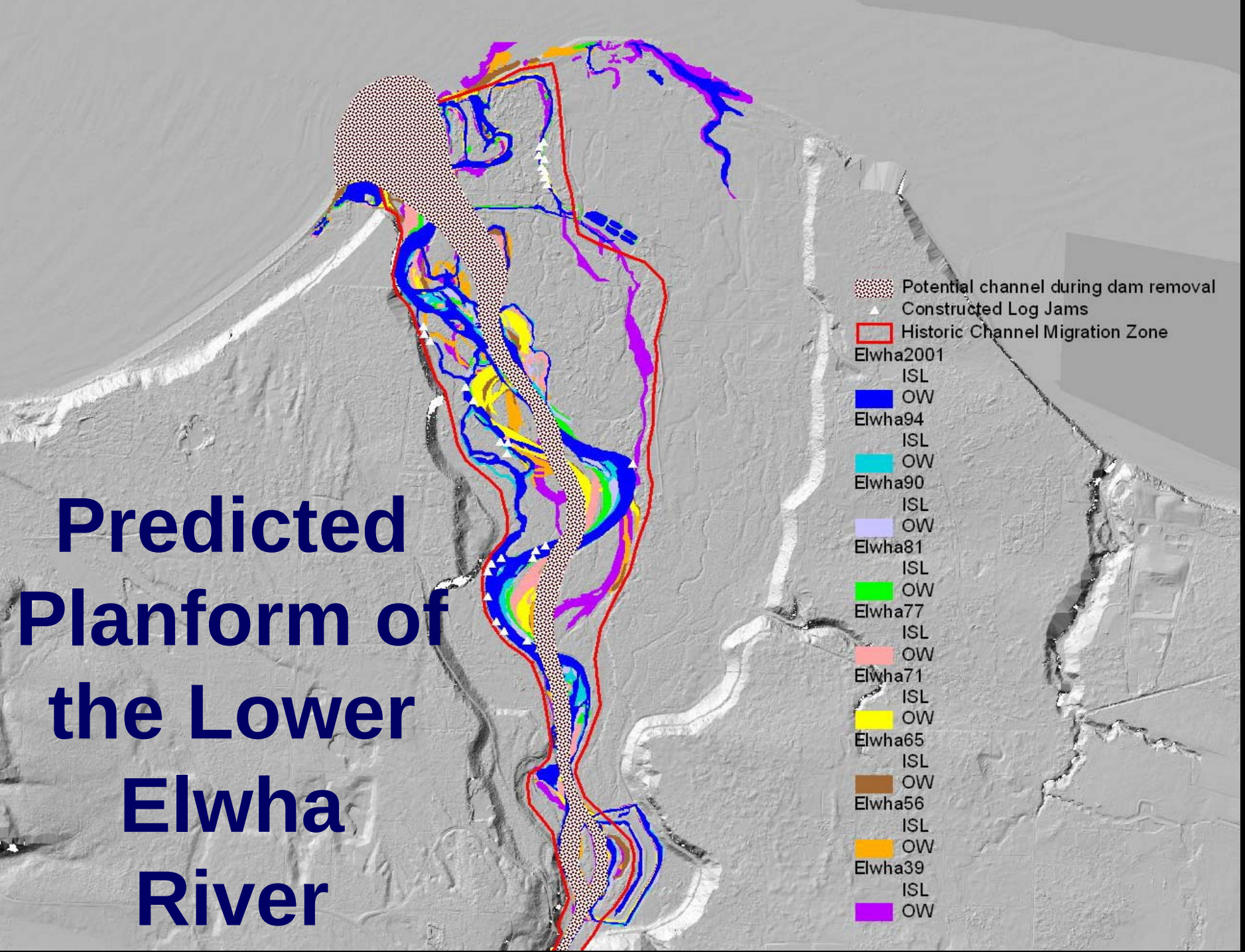

Predicted Planform of the Lower Elwha River

Model Uncertainty

- Multiple Approaches
  - Case studies
  - Reservoir drawdown tests
  - Numerical modeling
  - Physical modeling
- Adaptive Management

Adaptive Management Objectives

1. Release erodible reservoir sediments in controlled increments during dam removal.
2. Detect and avoid severe impacts related to flooding, erosion of infrastructure, and water quality
3. Assess project performance
4. Obtain scientific information applicable to other projects

Adaptive Management Monitoring

- Real time information
- Verify or modify dam removal scheduling
- Trigger actions to protect downstream water quality, property, and infrastructure

Adaptive Management Responses

- Trigger the next increment of monitoring activities, locations, or frequencies
- Improve water treatment techniques
- Locally mitigate flooding and bank erosion
- Slow rate of dam removal
- Temporarily halt dam removal

Restoration Monitoring

- Provide scientific knowledge applicable to understanding and interpreting natural river restoration and healing
- Design of future river restoration projects in other locations

Monitoring Categories

- Reservoir sediment erosion & redistribution
- Water quality (stream gaging)
- Riverbed aggradation & flood stage
- Aquifer characteristics
- Hillslope stability
- River channel planform & channel geometry
- Large woody debris
- Coastal Processes