Houston-Moore Group, LLC

In conjunction with

BARR | HDR | Kadrmas Lee & Jackson | SRF Consulting Group, Inc

# Probabilistic Evaluation of a Meandering Low-Flow Channel

February 24th, 2014

## *2014 UMSRS*

# acknowledgments



USDA ARS United States Department Of Agriculture Agricultural Research Service

US Army Corps of Engineers®

University of Pittsburgh Veritas Virtus 1787

HMG Houston-Moore Group

Moorhead Minnesota

City of Fargo

Flood Diversion Authority

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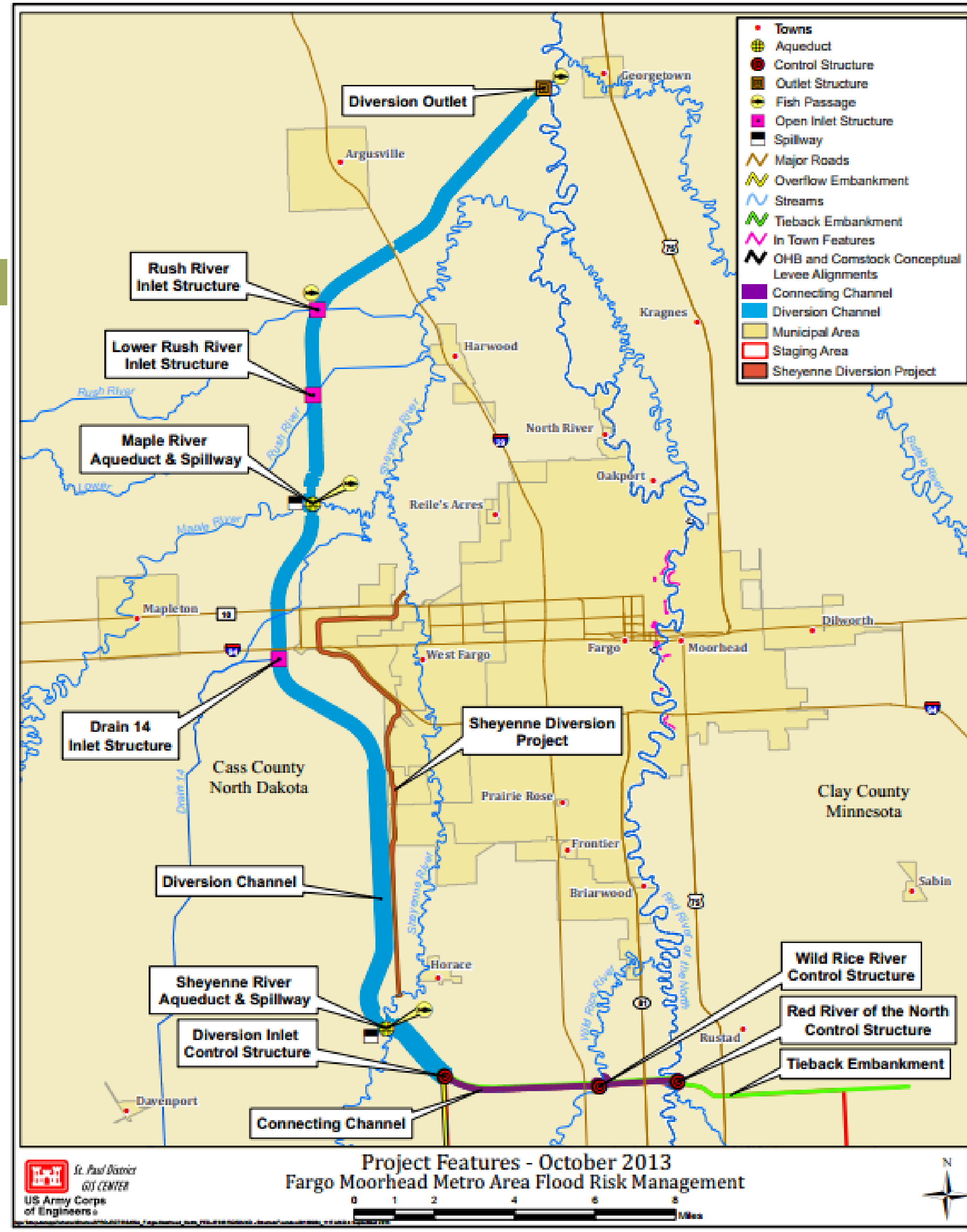
# Low- Flow Channel (LFC) overview

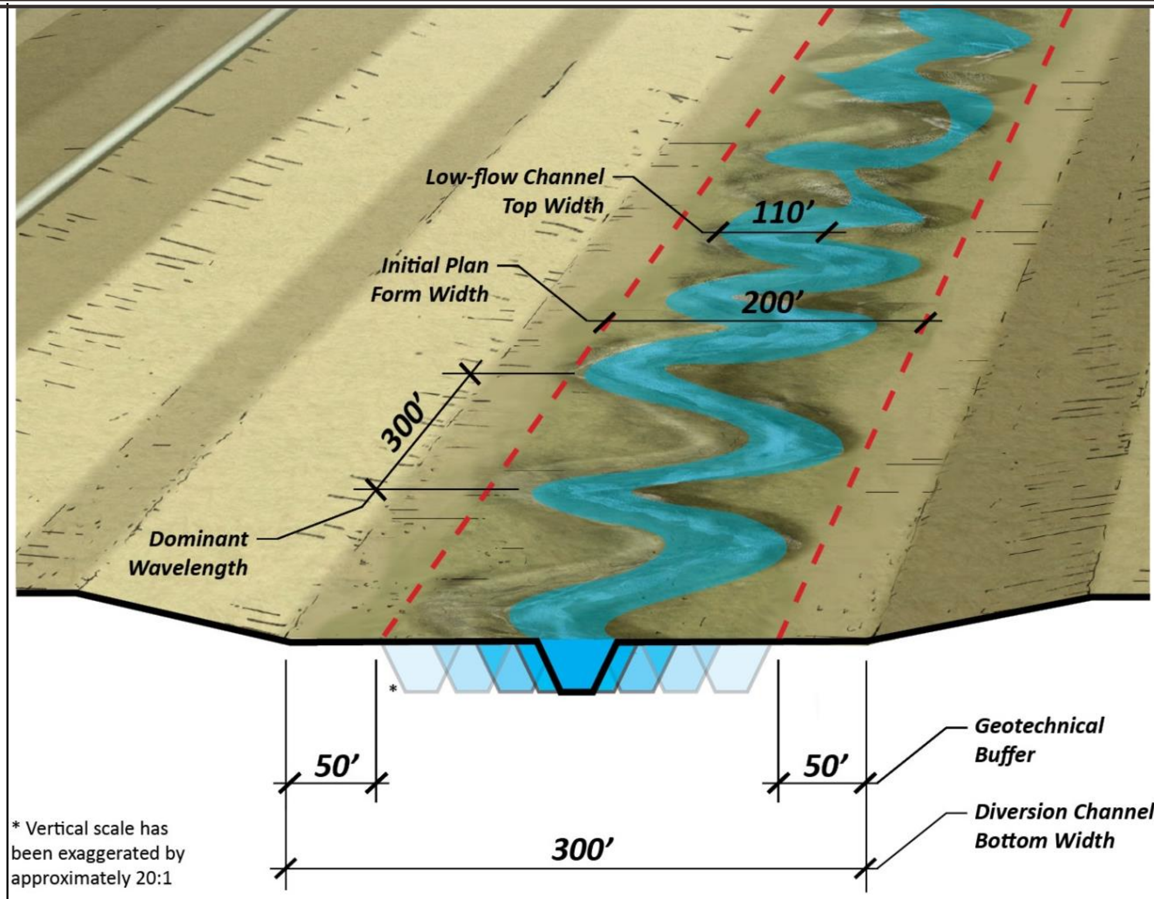
- **Proposed Diversion Channel collects runoff from:**
  - The Rush and Lower Rush Rivers
  - Eleven county and local drainage ditches
  - High flows from the Maple, Sheyenne, Wild Rice, and Red Rivers
- **A meandering Low-Flow Channel is planned for the bottom of the Diversion Channel**
  - The Low-Flow Channel will be sized to convey water and sediment downstream to the Red river



# the big question



*“What is the probability that the LFC will remain within a prescribed meander belt width?”*



# RVRMeander overview & analysis methodology




USDA

### RVR Meander Overview

1. **Hydrodynamics** – water surface elevations & velocities
2. **Bed morphodynamics** – transverse bed slope
3. **Bank erosion** – hydraulic erosion as well as mass failure (e.g. cantilever or planar bank failure)

### Analysis Methodology

1. **Model Calibration** – Deterministic simulations of rivers near the proposed Diversion Channel
2. **Monte Carlo Analysis** – Probabilistic evaluation of Low-Flow Channel reaches
3. **Application to Design Reach 1**
4. **Summary of Results**

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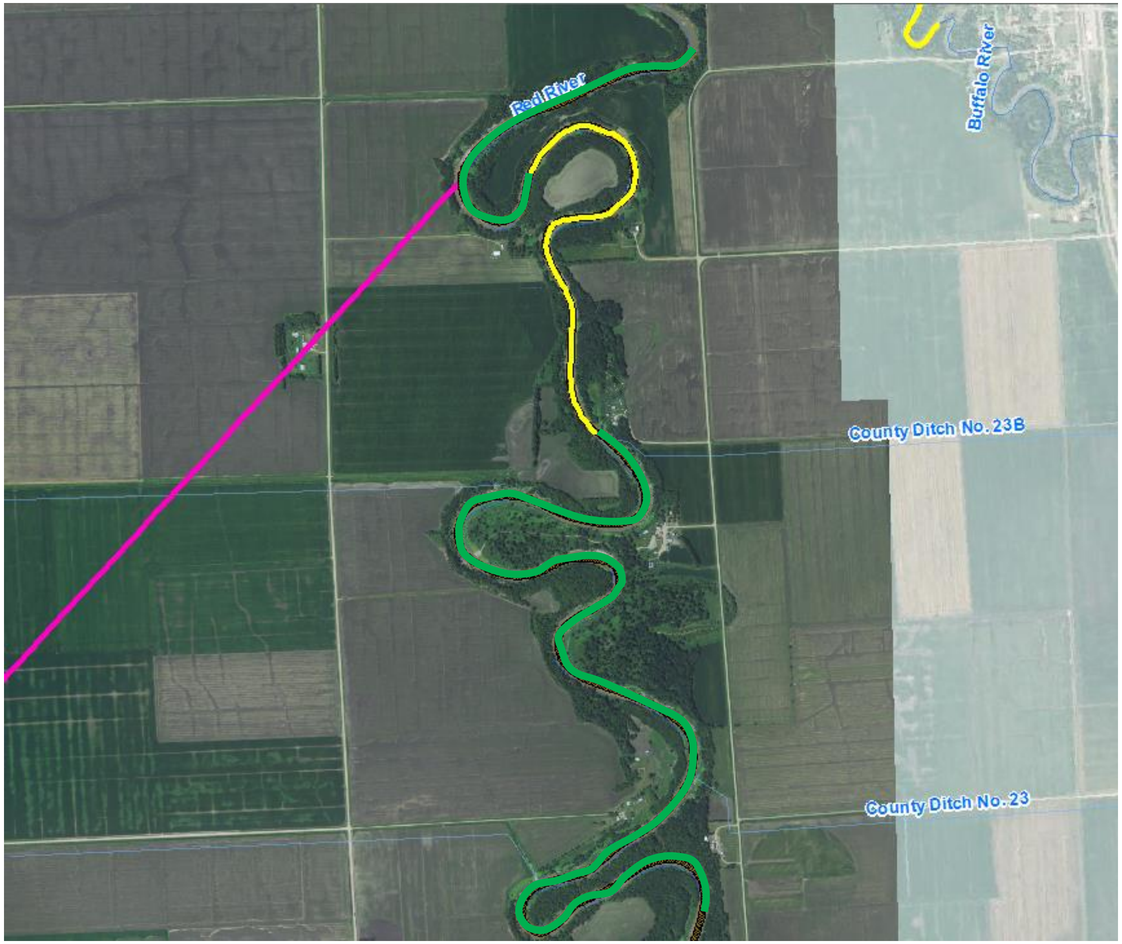
# RVRMeander model calibration **methodology**



- **Step 1: Site Selection**
  - Channel movement?
  - Human impacts?
- **Step 2: Calibrate Hydrodynamics**
  - Match transverse bed slope
  - Match HEC-RAS water surface elevations
- **Step 3: Calibrate Migration Rate**
  - Match historical aerial photographs

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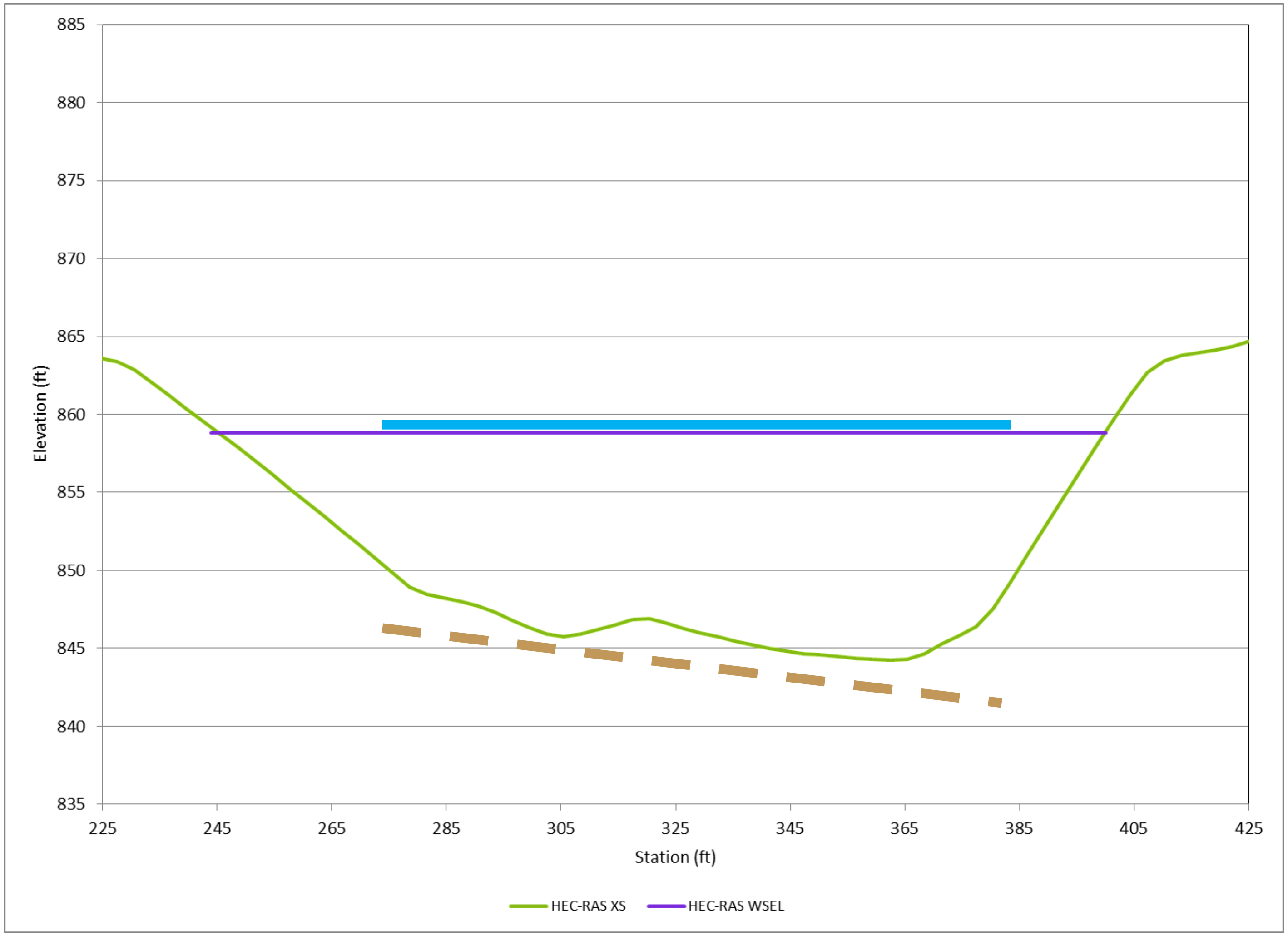
# RVRMeander model calibration - hydrodynamics

## compare RVRMeander results to available data



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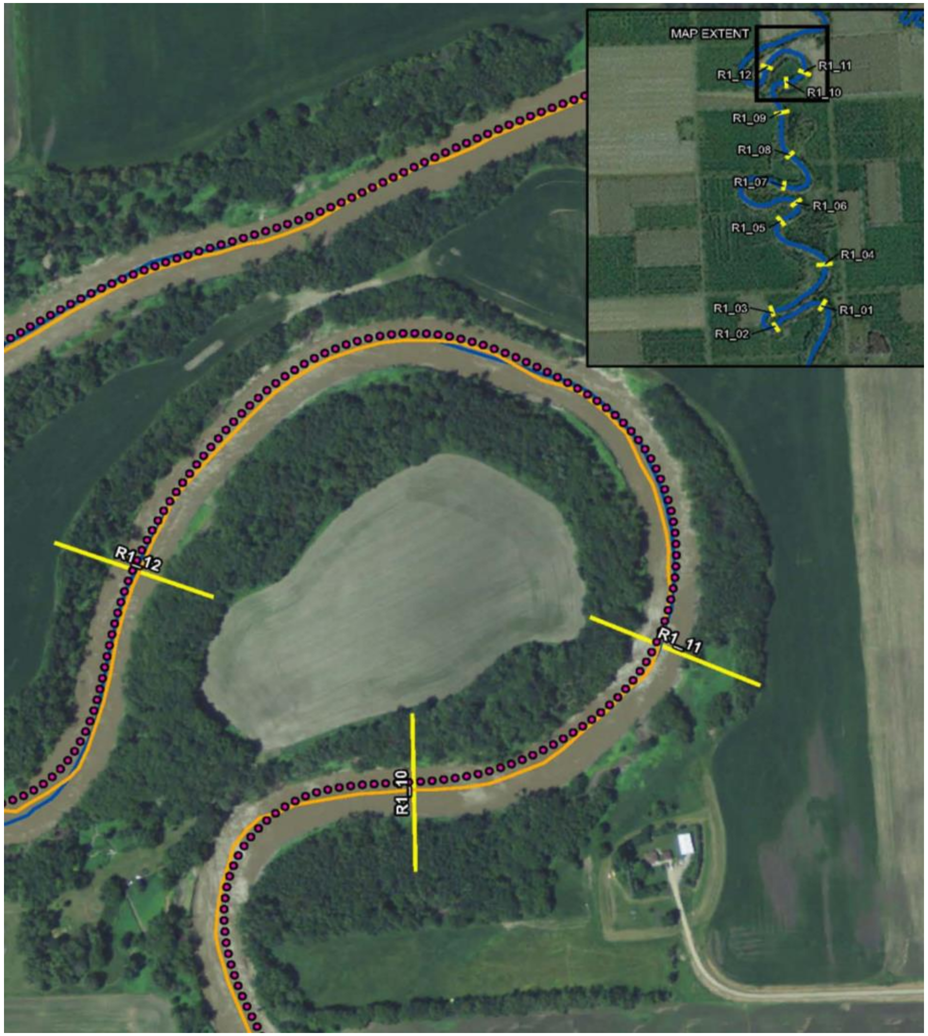
# RVRMeander model calibration
## **calibrate river migration**



- Adjust scour factor (A), bed transfer coefficient (ϕ), critical shear stress (τ) and erosion rate coefficient (M)
- Compare migration distance of river centerlines from model (dots) and historical aerial photography (solid orange and blue lines)

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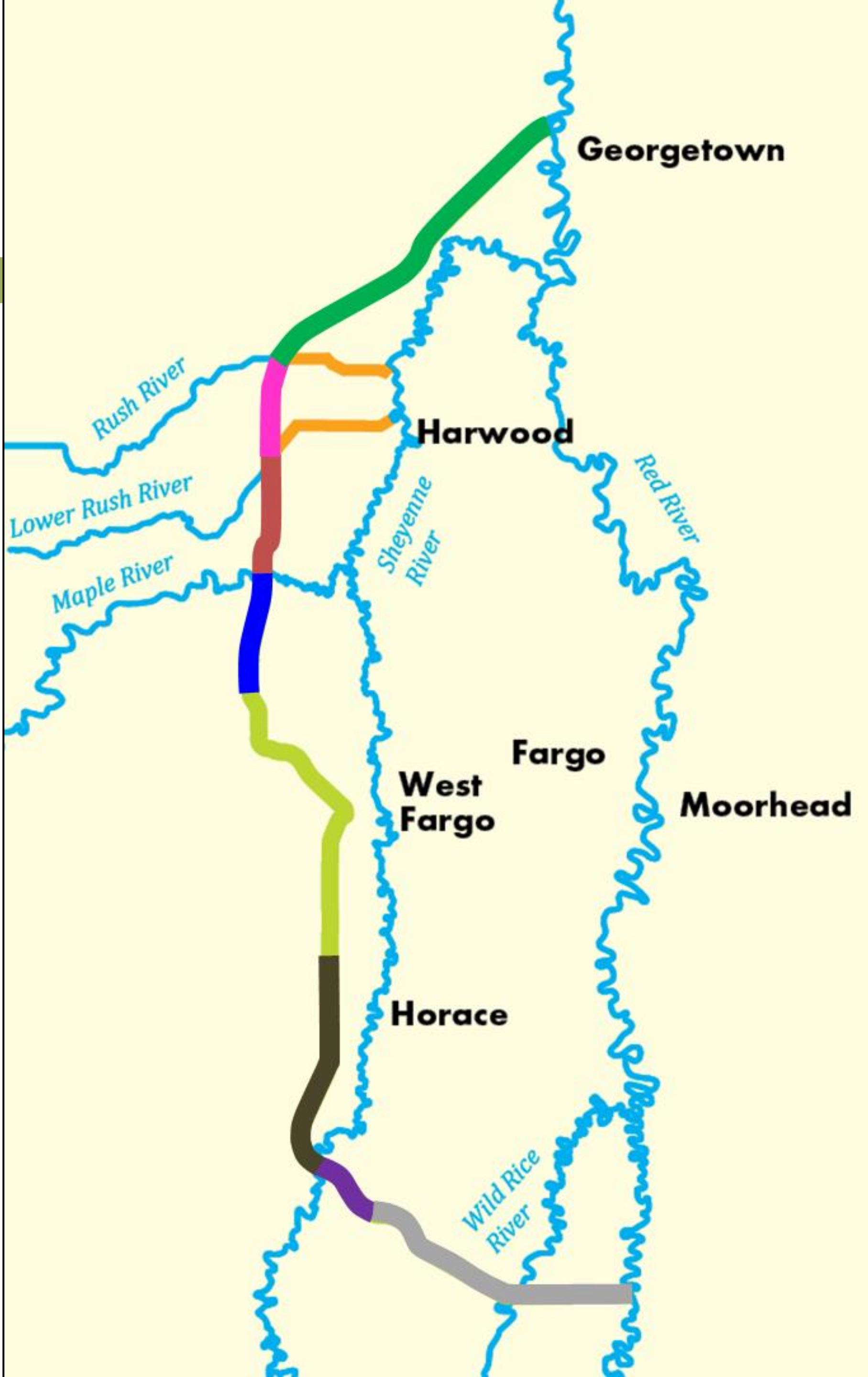
# probabilistic evaluation of the LFC



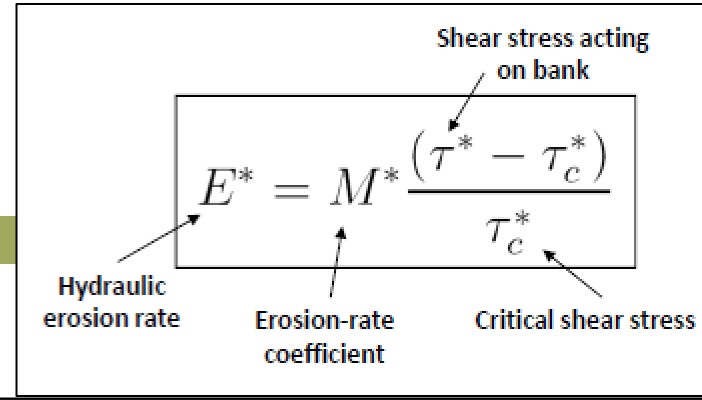
- **Reach Definition Considerations**
  - Divided based on proposed inlets to Diversion Channel – constant flow and LFC geometry
  - Try to begin and end at locations where the LFC is assumed to be fixed – bridges or hydraulic structures



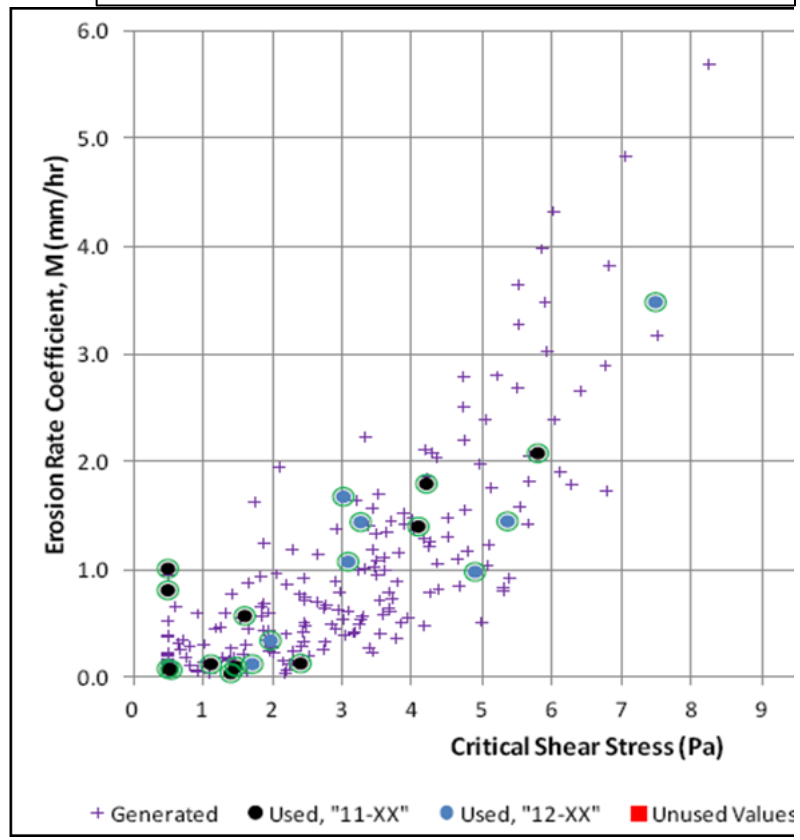
# probabilistic model input parameters



- **Calibrated Parameters**
  - Scour Factor *(Uniform Distribution)*
  - Bed Shear Stress Transfer Coefficient *(Discrete)*
- **Erodibility Parameters (from USACE/Texas A&M test work)**
  - Critical Shear Stress *(Normal Distribution)*
  - Erosion Rate Coefficient *(Exponential Distribution)*
- **Hydrodynamic Parameters**
  - Manning's Coefficient *(Triangular Distribution)*
  - Flows *(Log-Normal Distribution)*




$$E^* = M^* \frac{(\tau^* - \tau_c^*)}{\tau_c^*}$$

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# *"What is the probability that the LFC will remain within a prescribed meander belt width?"*

## Definition of Planform Width

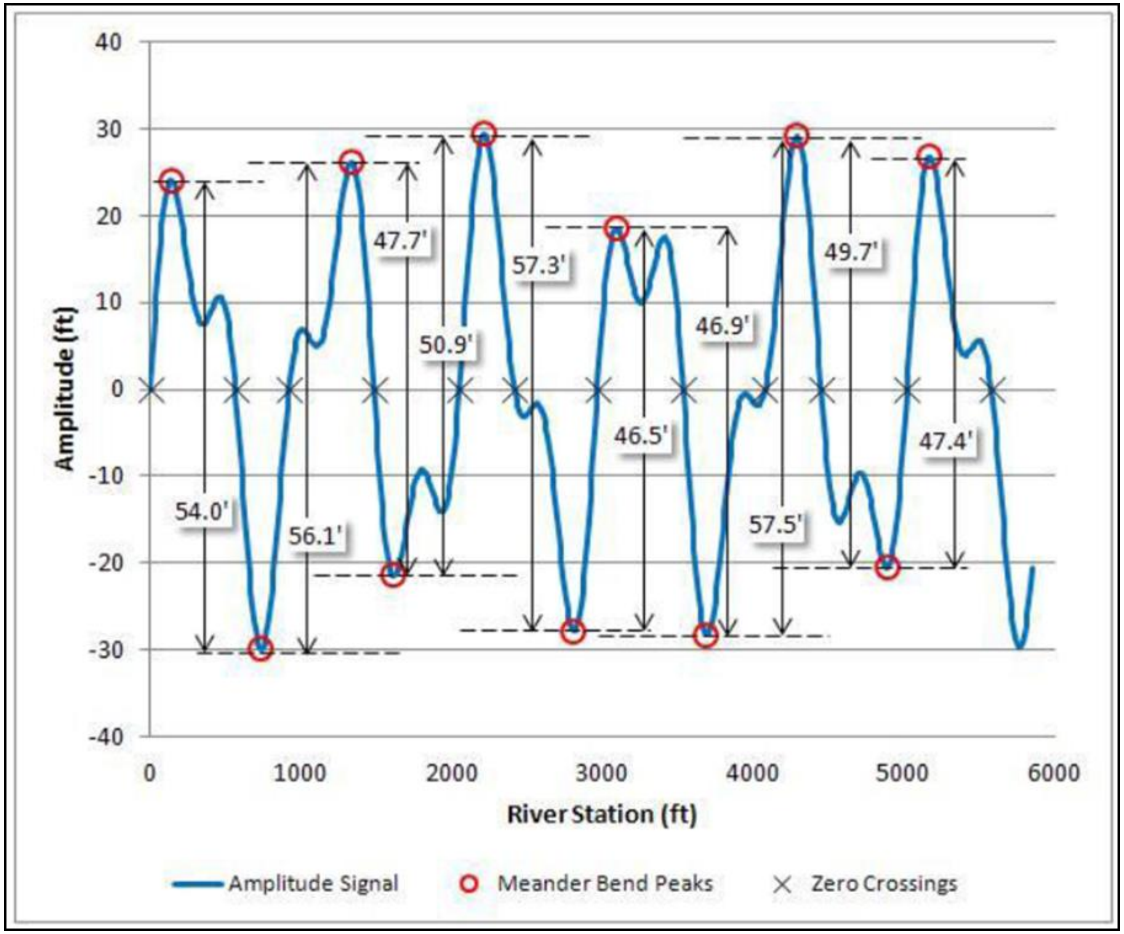


### Calculation Methodology

- Peak amplitude of one meander bend to the next over the entire reach
- Planform Width is the 90th percentile

### Benefits of using Planform Width

- Allows for filtering of large, potentially localized, meander bends
- Acknowledges that O&M for the LFC will be required periodically



# probabilistic evaluation of the Low-Flow Channel

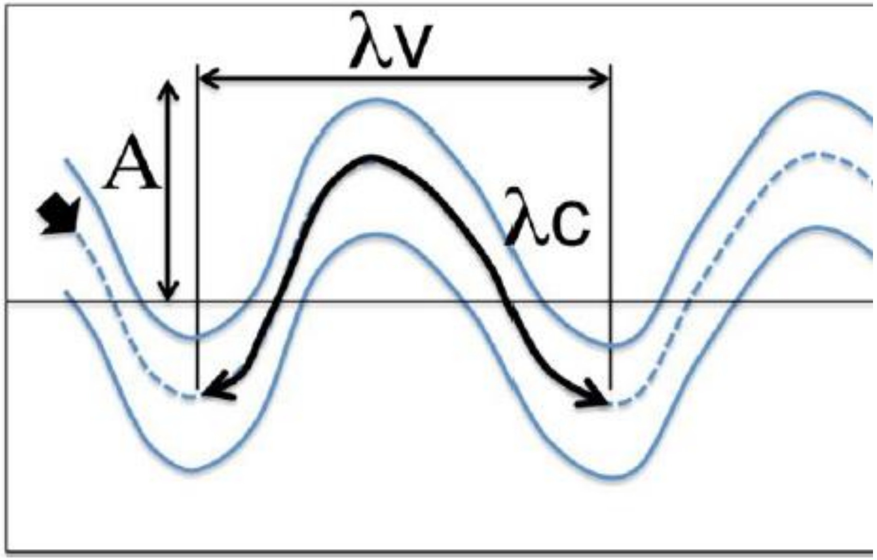
## Monte Carlo simulations



- **Reach 1 Simulations**
  - Discharge (i.e. hydrograph timing)
  - Side Slopes
  - Bottom Width
  - **Wavelength**
  - **Amplitude**
  - Scour Factor
  - Intermediate Fixed Points
  - Construction Phasing
- **Reach 5 Simulations**
  - **Wavelength**
  - Amplitude
  - Scour Factor
  - Intermediate Fixed Points

Base Simulation Parameters

| | Reach 1 | Reach 5 |
|---|---|---|
| Bottom Width | 48-ft | 24-ft |
| Side Slopes | 4H :1V | 4H :1V |
| Wavelength | 880-ft | 880-ft |
| Amplitude | 50-ft | 70-ft |
| Flows | No Reduction | No Reduction |

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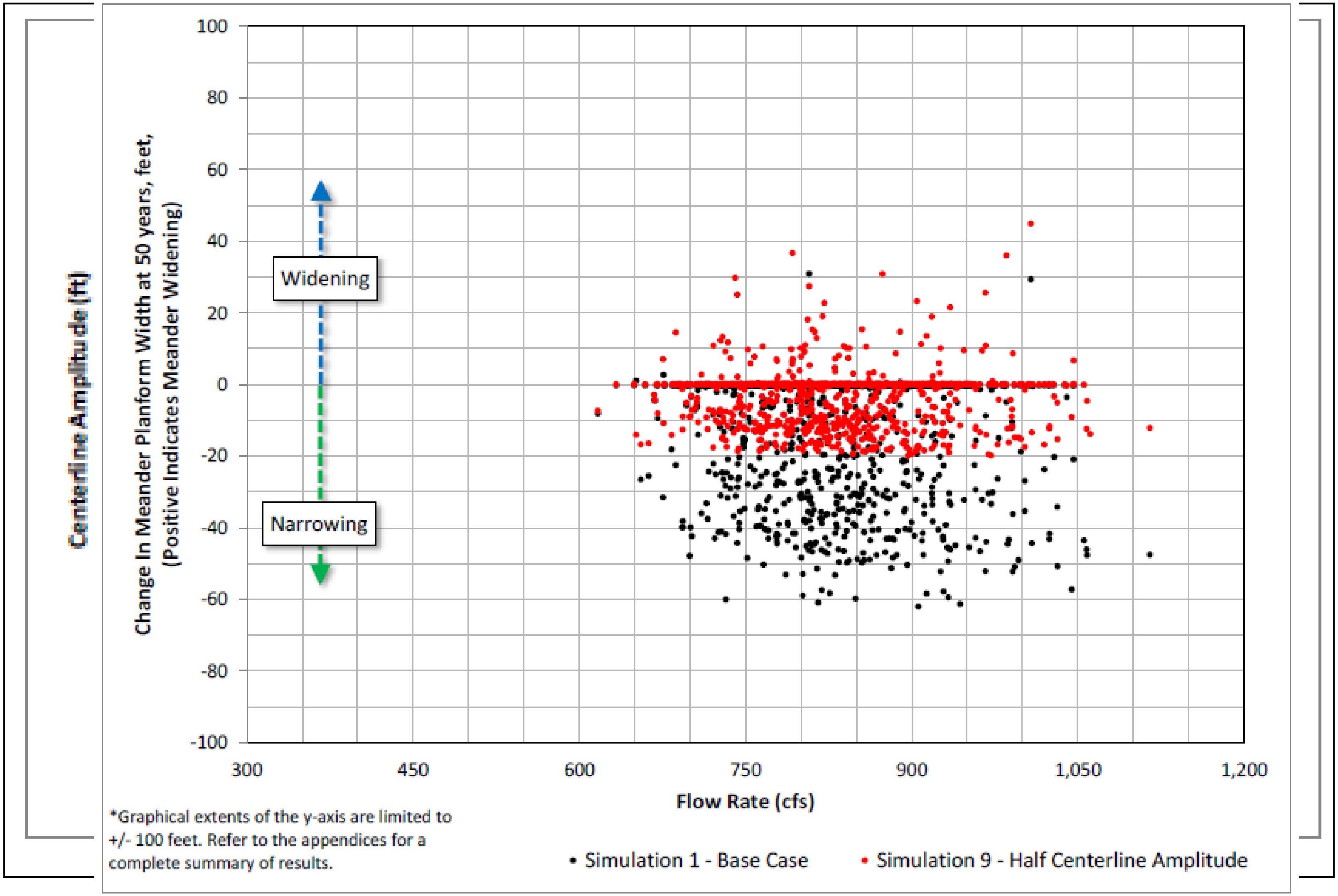
# probabilistic evaluation of the Low-Flow Channel

## Reach 1: impact of amplitude



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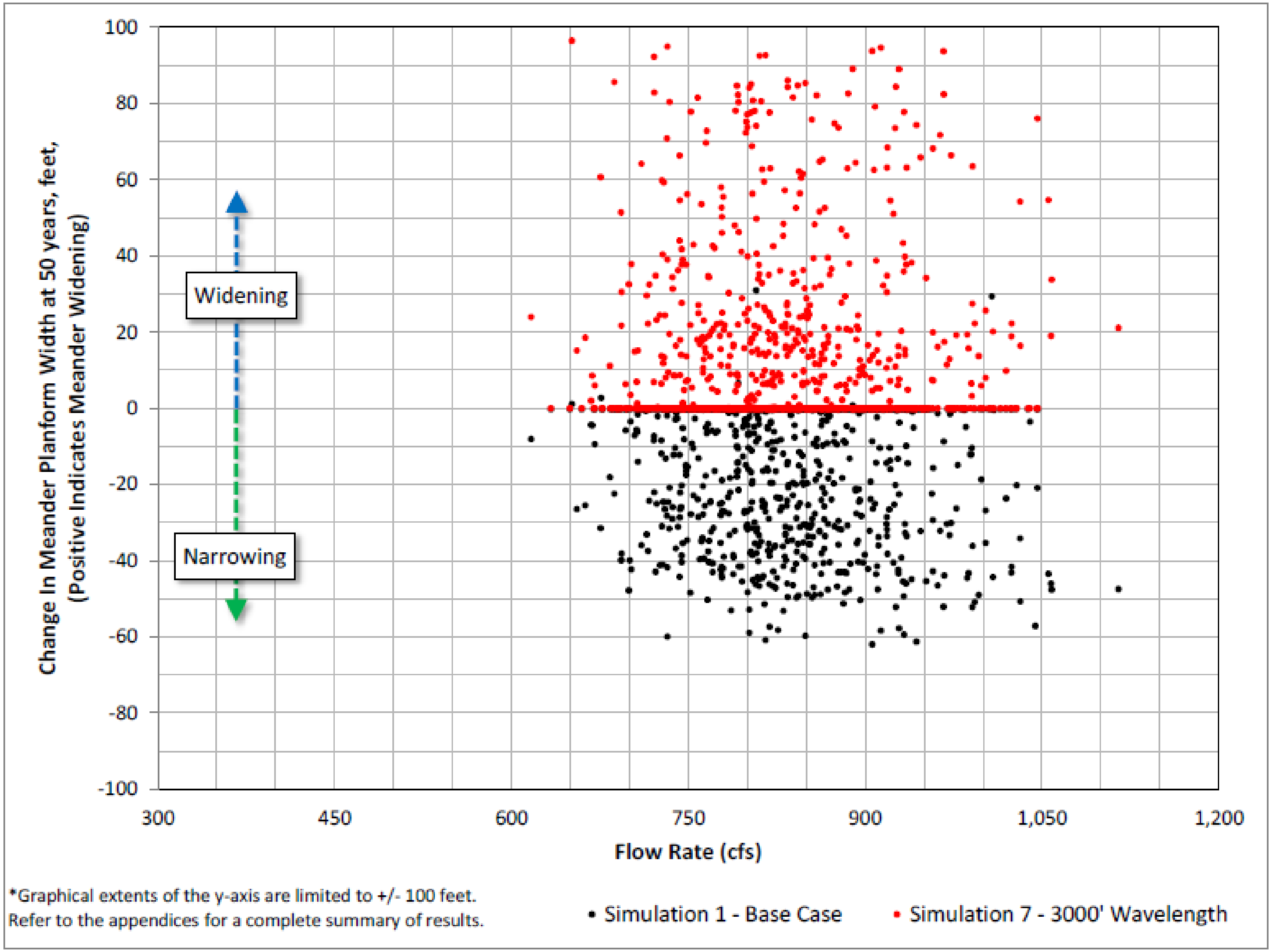
# probabilistic evaluation of the Low-Flow Channel

## Reach 1: impact of wavelength



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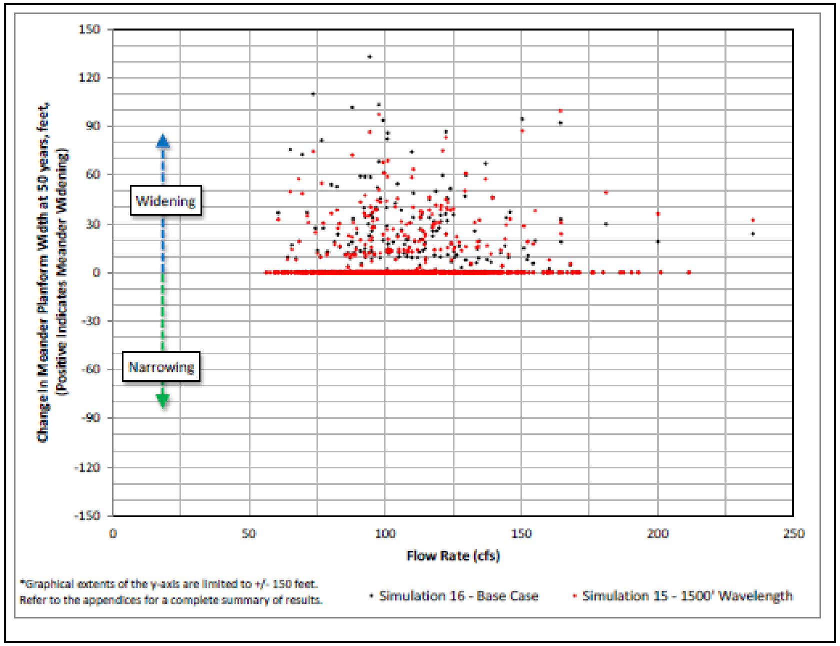
# probabilistic evaluation of the Low-Flow Channel

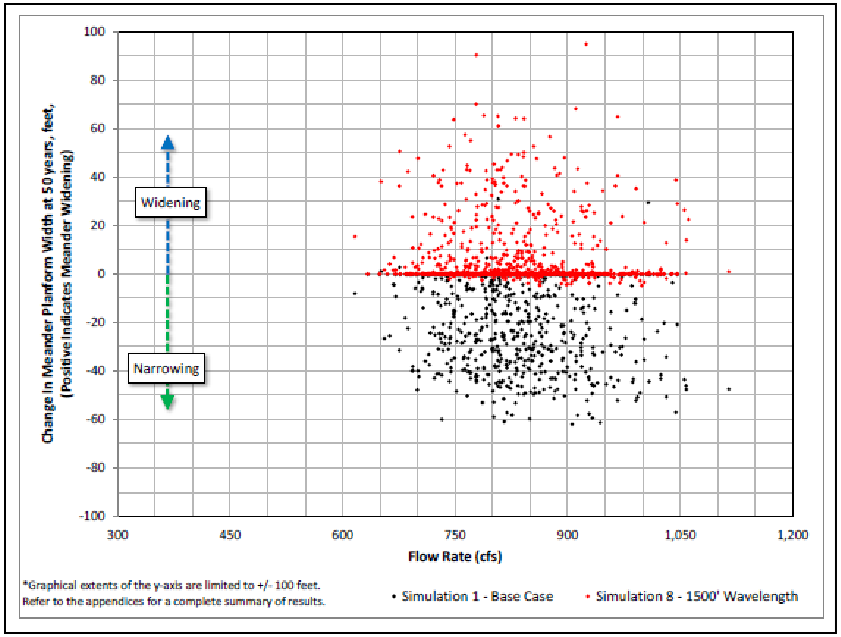
## identifying trends in the results






### Reach 1

- For the majority of the realizations the planform width does not change
- 880-ft wavelength has a tendency to **Narrow**
- 1500-ft wavelength has a tendency to **Widen**




### Reach 5

- For the majority of the realizations the planform width does not change
- 880-ft wavelength has a tendency to **Widen**
- 1500-ft wavelength has a tendency to **Widen**

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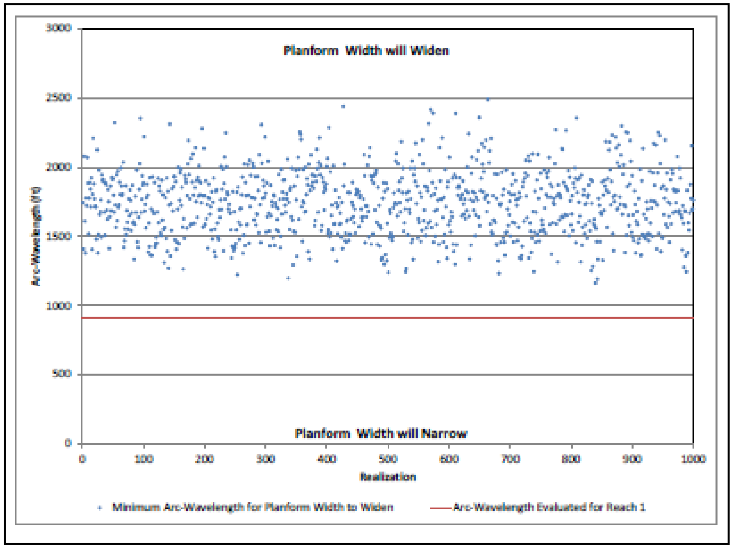
# predicting potential migration patterns in intermediate LFC reaches



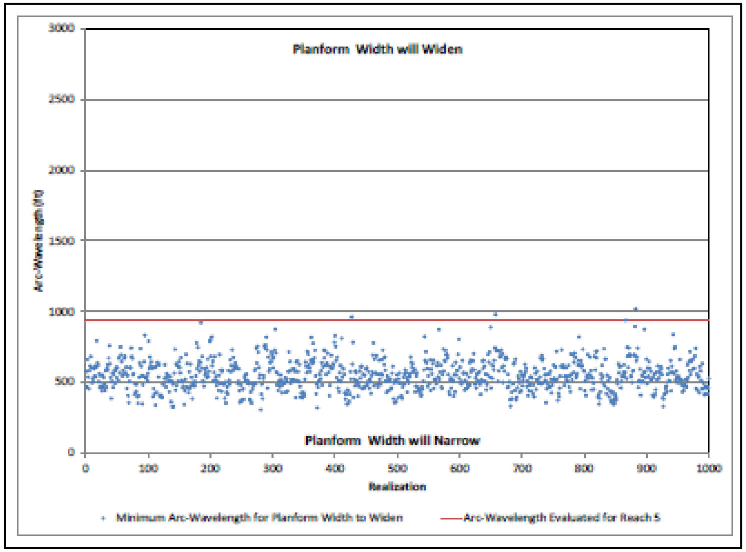
$$\lambda_{min} = \frac{2\pi B}{(\sqrt{2}C_f\beta(A - 1 + F_{ch})^{.5}}$$

- Where:
  - $\lambda_{min}$ is the arc wavelength required for the planform width to widen
  - $B$ is the LFC half-width
  - $C_f$ is the friction coefficient
  - $\beta$ is the ratio of the LFC half width ($B$) and depth
  - $A$ is the scour factor
  - $F_{ch}$ is the Froude number

*(Equation from work done by Johannesson and Parker, 1985)*




Reach 1




Reach 5

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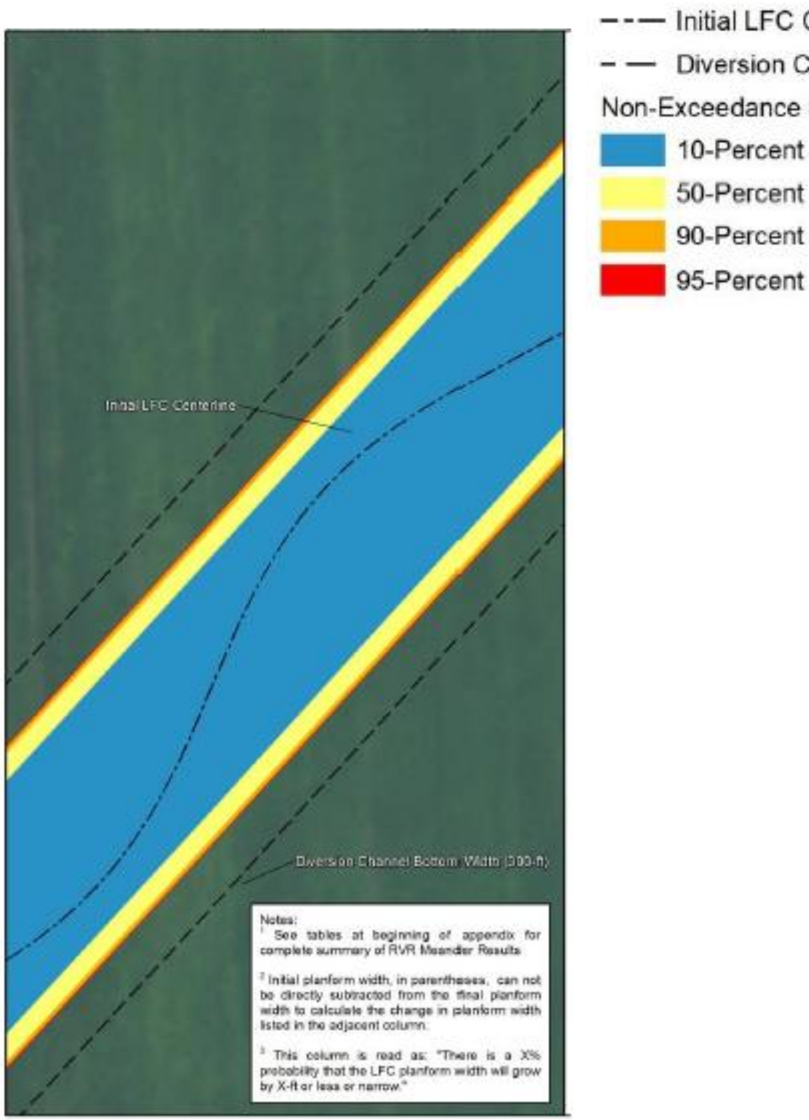
# probabilistic evaluation of the Low-Flow Channel






- Address the question:

  *"What is the probability that the LFC will remain within a prescribed belt width?"*

- Model results can be used to begin to address inherent uncertainty in the magnitude of lateral migration

- Stakeholders can use model results to determine the amount of risk they are willing to accept and plan for future operation and maintenance costs

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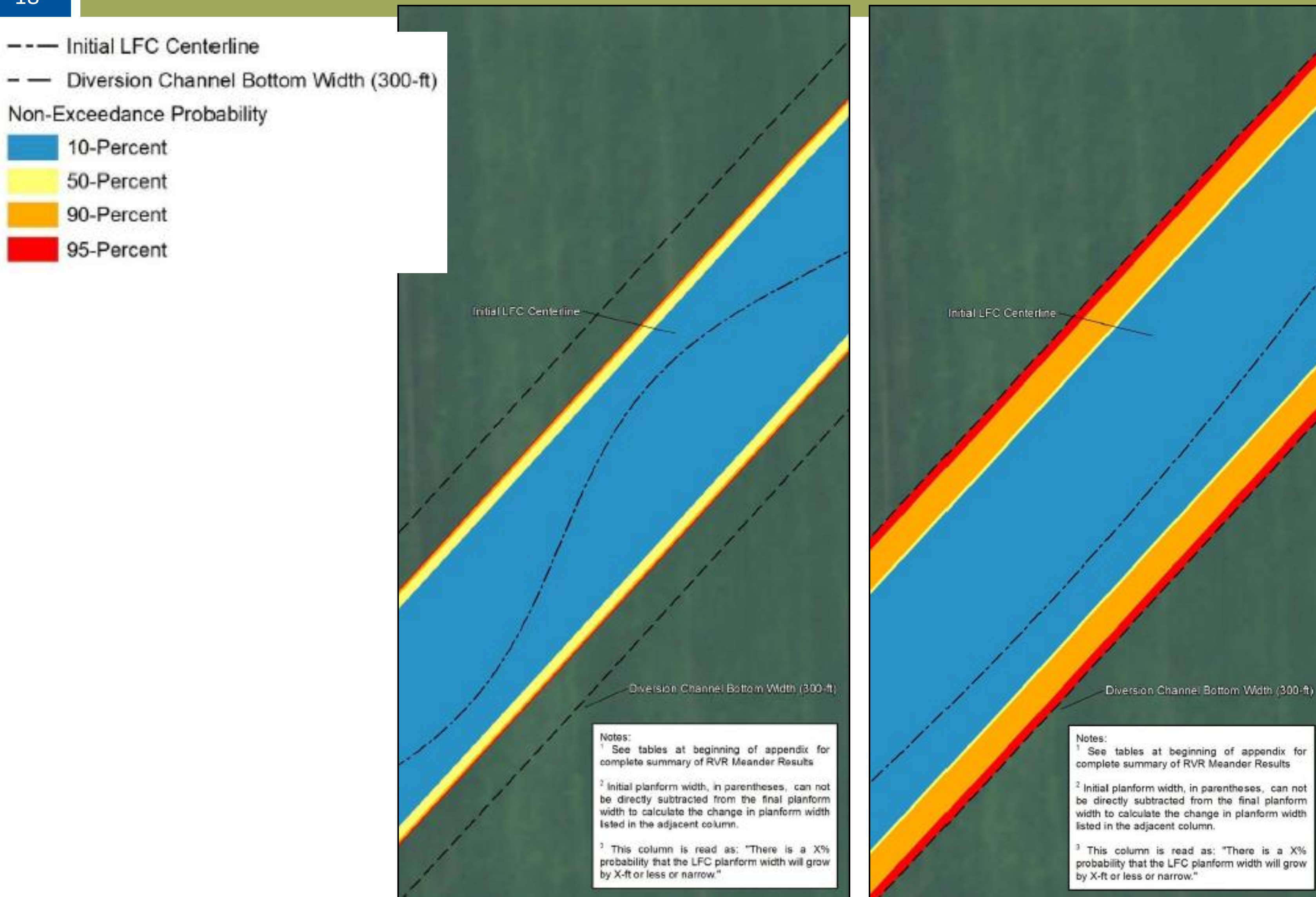
# probabilistic evaluation of the Low-Flow Channel





# probabilistic evaluation of the Low-Flow Channel

## applying results of probabilistic evaluation



### Determine the required LFC cross section geometry

- The probabilistic evaluation indicated that the cross section geometry may not be a sensitive parameter in determining lateral migraiton
- Therefore, the design of the cross section should be based on other design considerations – hydraulic conveyance, sediment transport capacity, geotechnical requirements, etc.

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# probabilistic evaluation of the Low-Flow Channel

## applying results of probabilistic evaluation



### Select a wavelength

- Select a wavelength that does not promote widening of the planform width

$$\lambda_{min} = \frac{2\pi B}{(\sqrt{2}C_f\beta(A - 1 + F_{ch})^{.5}}$$

# probabilistic evaluation of the Low-Flow Channel

## applying results of probabilistic evaluation



### Select initial amplitude

- Select initial amplitude based on the desired “buffer” determined by the Local Sponsors and the USACE

# probabilistic evaluation of the Low-Flow Channel

## applying results of probabilistic evaluation

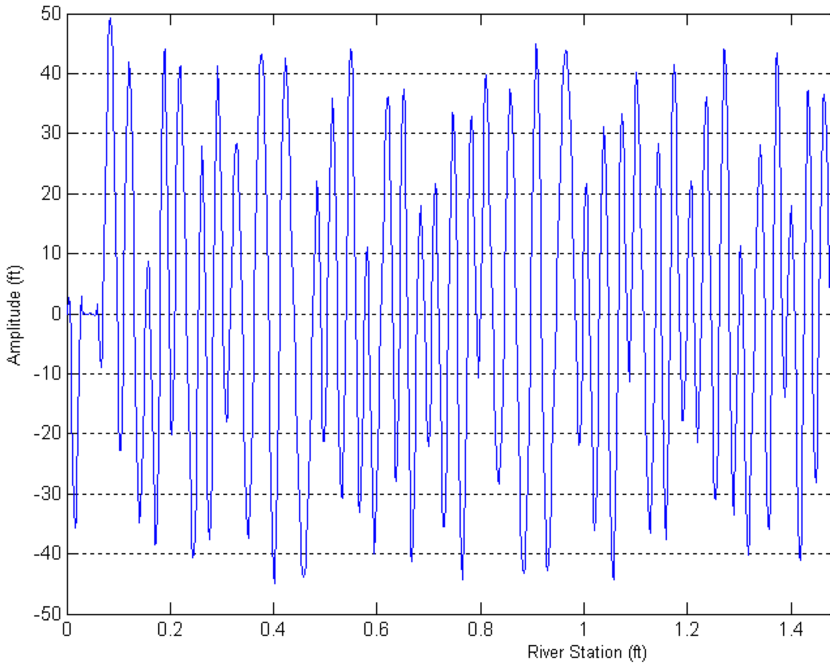


### Verify the selected LFC planform

- Check the selected initial planform using RVRMeander

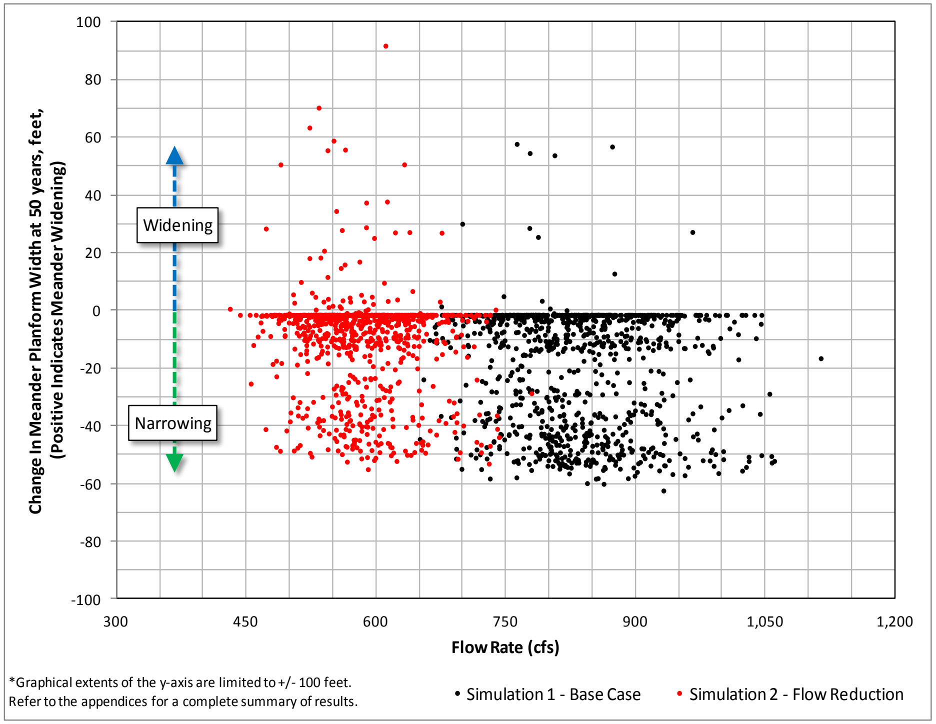
# application to Design Reach 1 designed planform

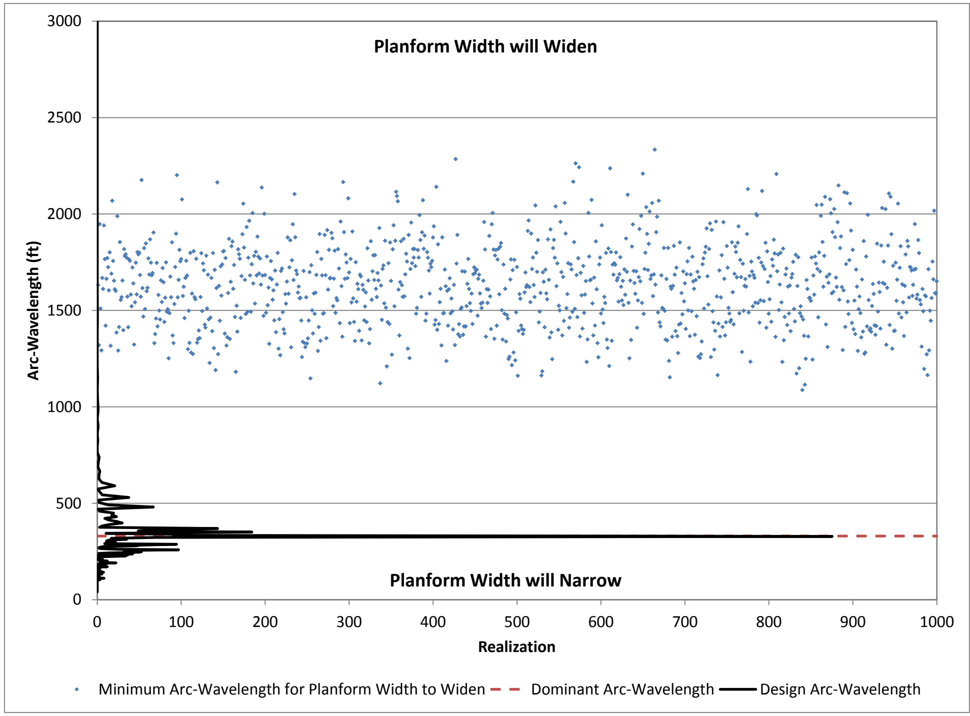





# modeling results of Design Reach 1

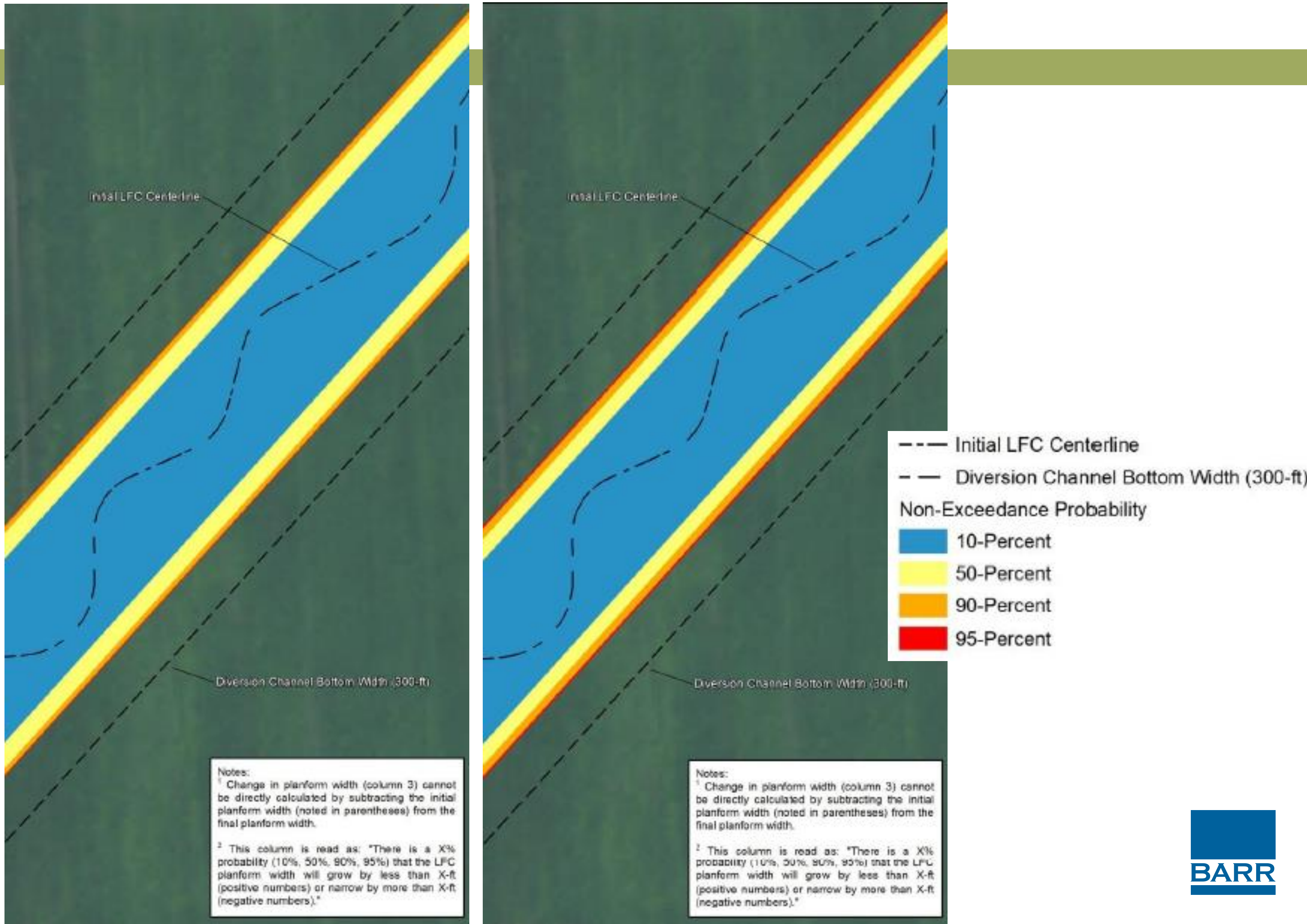




# probability of meander belt width



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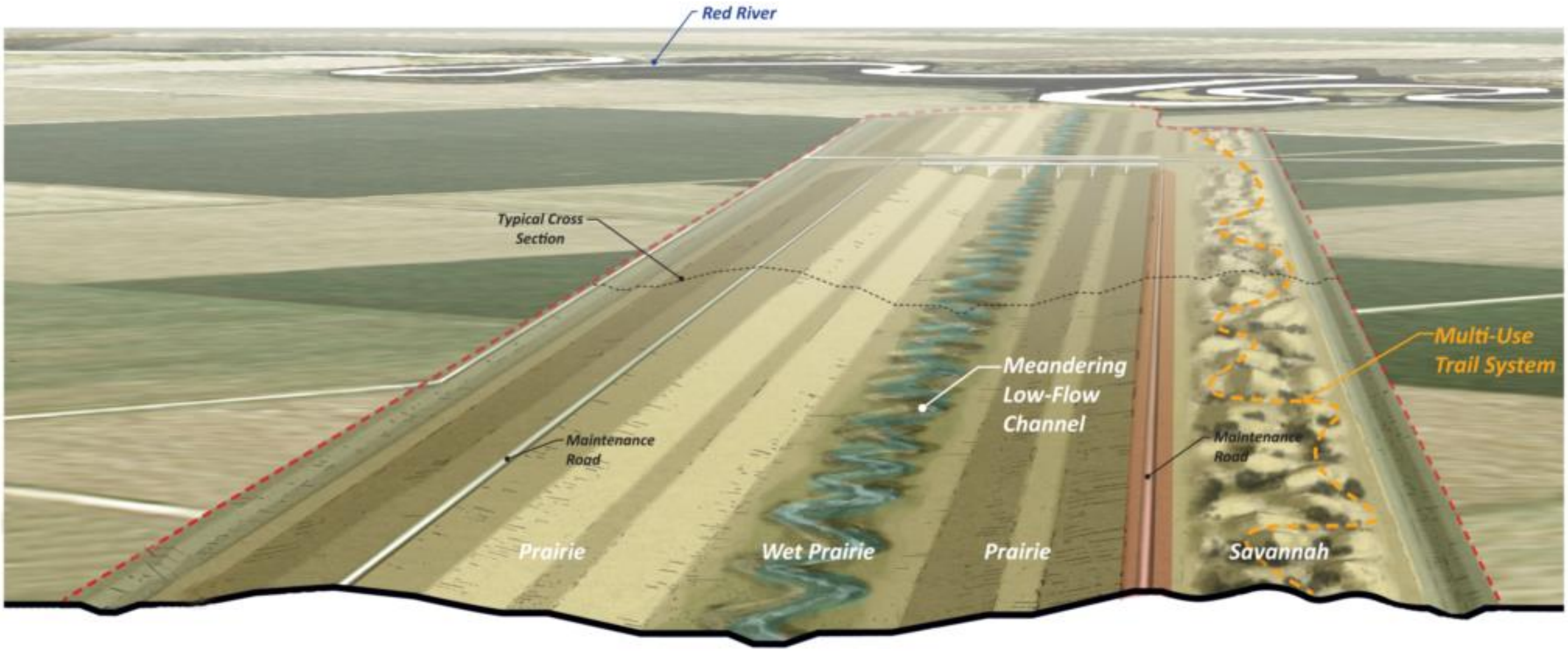
# Thank you for your time.



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