A Short River Model (Delft3D)

& DIVERSION ANALYSIS

presented by

Nina J. Reins, PE, PhD, PMP

State of the Coast May 30-June 1, 2018

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Overview of Presentation

- Problem Statement & Background
- Analysis
- Key Findings & Recommendations

UNO Dissertation Research
Committee Chair: Dr. Alex McCorquodale, Co-Chair: Dr. Ioannis Georgiou

Problem Statement

Expedited Analysis of independent and cumulative impacts of diversions. → Development of ***shortmodel*** from calibrated regional model

Identify impacts to bathymetric changes due to hydrograph variability → Conduct a comparison between a uniform and variable Mississippi River Discharge Hydrograph.

Identify independent and cumulative impacts of different diversion schemes → Analyze bathymetric river changes and diversion efficiencies

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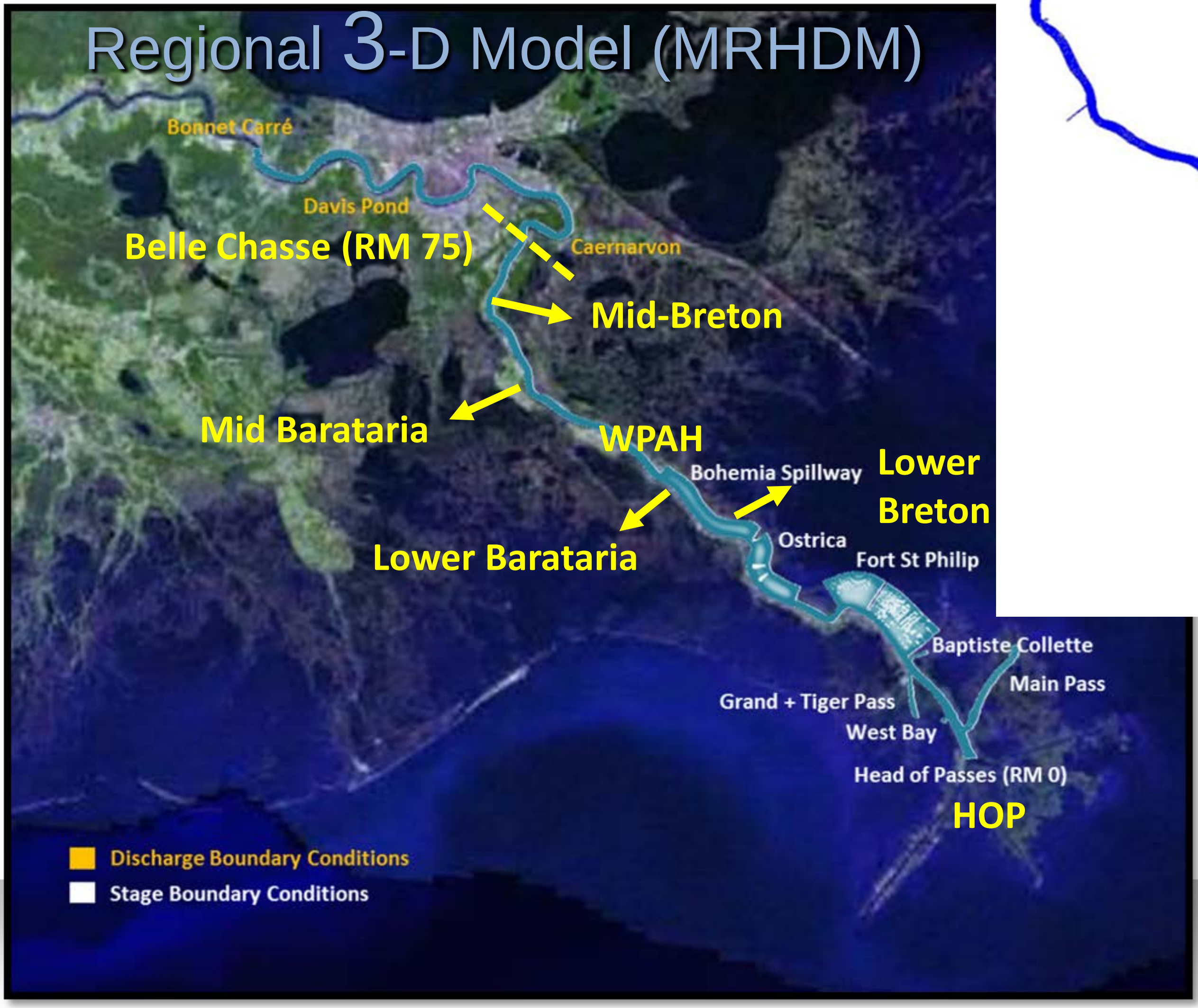
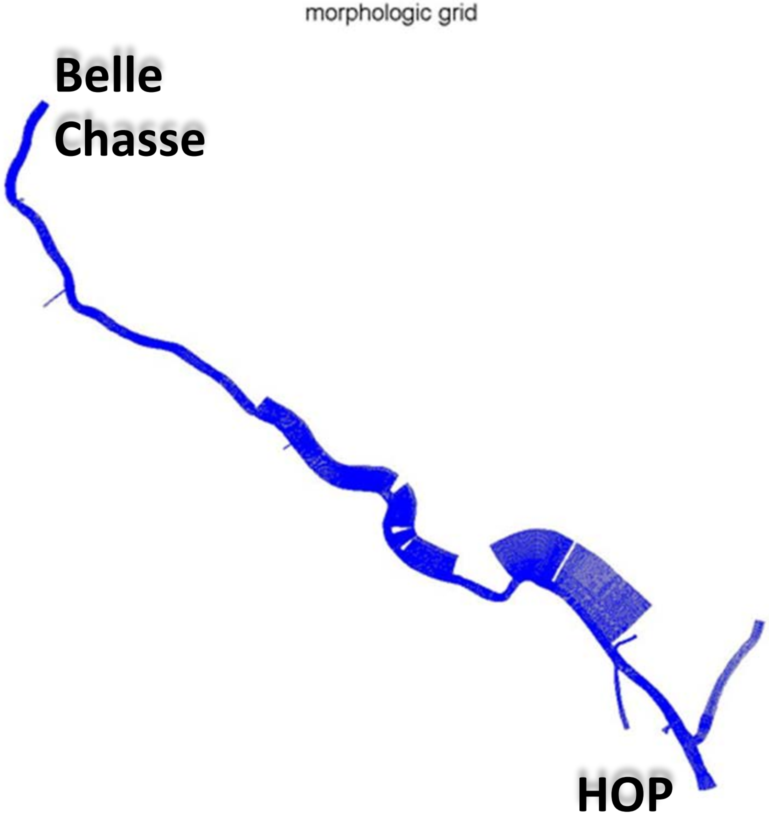
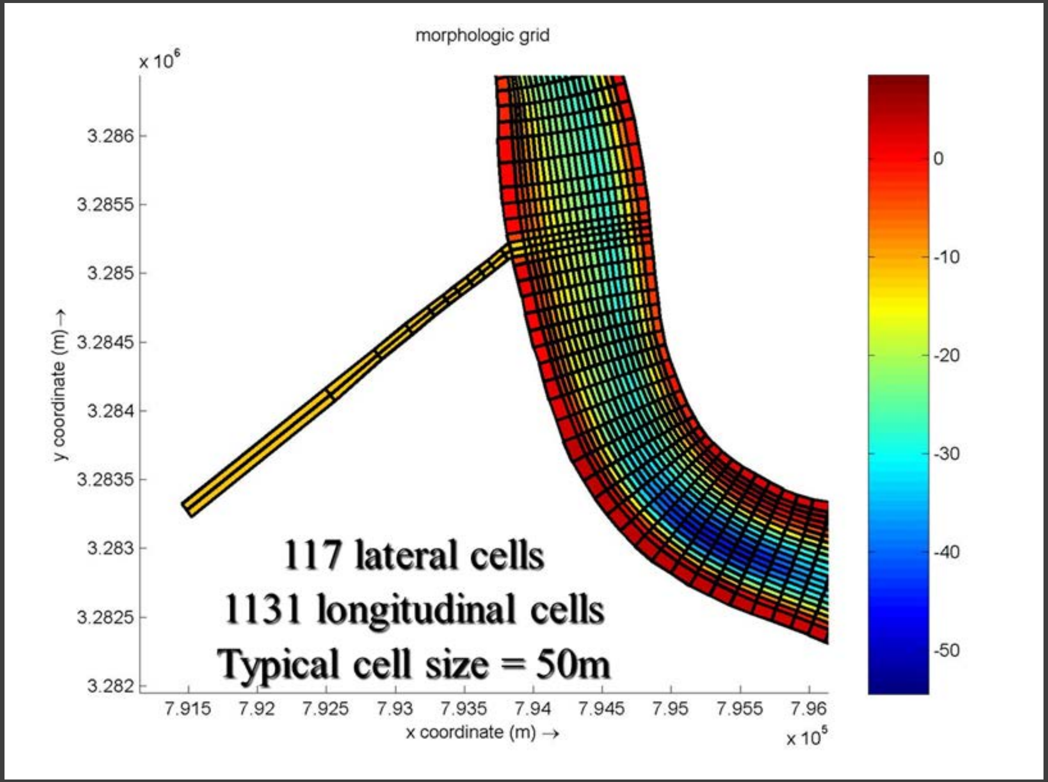
Background: Model Development





Background: Model Development

- **The model was calibrated as part of the Regional Model.**
- **No change in grid design between Regional and *shortmodel*.**
- **Diversion locations, orientations, inverts and widths based on Water Institute recommendations.**



Lateral grid sizes of the order of 50 m with 10 parabolically distributed sigma layers with refinement at the bed.

The lateral resolution was adjusted until the observed recirculation eddy in Dr. Mead Allison's Acoustic Doppler Current Profiler (ADCP) data were reproduced in the model. *(McCorquodale 2017)*

Background: Model Inputs

Model:
- Grid and Bathymetry *(USACE Decadal Surveys suppl. with ADCIRC data, data from Mississippi River Study & LPBF data)*
- **Cut at Belle Chasse (U/S Boundary)**

Bed Layer Input:
- Sand thickness distribution of bed (M. Allison, Tulane & USACE)
- Silt & Clay fraction in the bed (M. Allison, Tulane & USACE)

Suspended Sediment Inputs:
- Sand, Silt and Clay based on Dynamic Rating Curves based on USGS data (Baton Rouge and Belle Chasse).

Hydrograph:
- Water Institute Annual Discharge Hydrograph for Bonnet Carré Section (RM 127).
- **Upstream Boundary Belle Chasse (RM 75.5)**
- **Developed 12-Year Variable Hydrograph for comparison to Uniform Hydrograph**

Sea Level Rise/Subsidence:
- USACE River Stages **+ GOM Stage adjusted by 0.5 m ESLR over 50 years.**
- **NRC III Sea Level Rise Projection**
- **HEC6t (BCG/King) subsidence rates (up to 2.3 cm/yr).**

Diversion Discharges:
- Water Institute Discharge Curves for Diversions.

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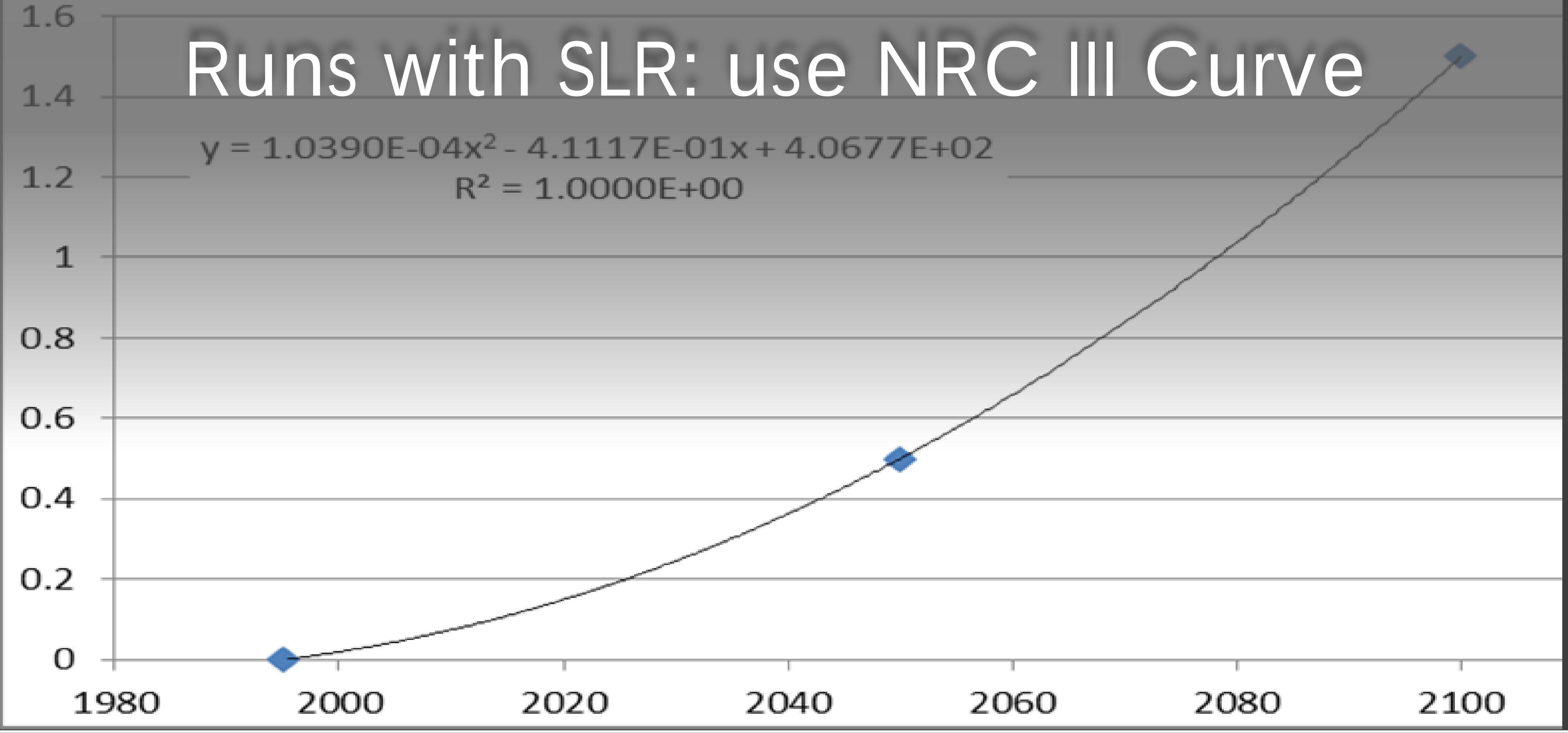
Runs with SLR: use NRC III Curve



Upstream Boundary:

- Discharge Hydrograph (Variable & Uniform)
- Suspended Sediment
  (5 sediment classes)
  Belle Chasse & Baton Rouge Gages

River Boundaries:

- Gulf Of Mexico Stage Condition (Source USACE – Southwest Pass)
- Controlled Diversions same as MRHDM (prescribed discharge)
- *Uncontrolled Diversion Runs to validate prescribed flows*

Simulation Conditions

12 years x 365d per year = 4,380 days
(Morphological Time)

12 years x 365 days per year / MORFAC (40) = 109.5 days
(Hydrodynamic Time)

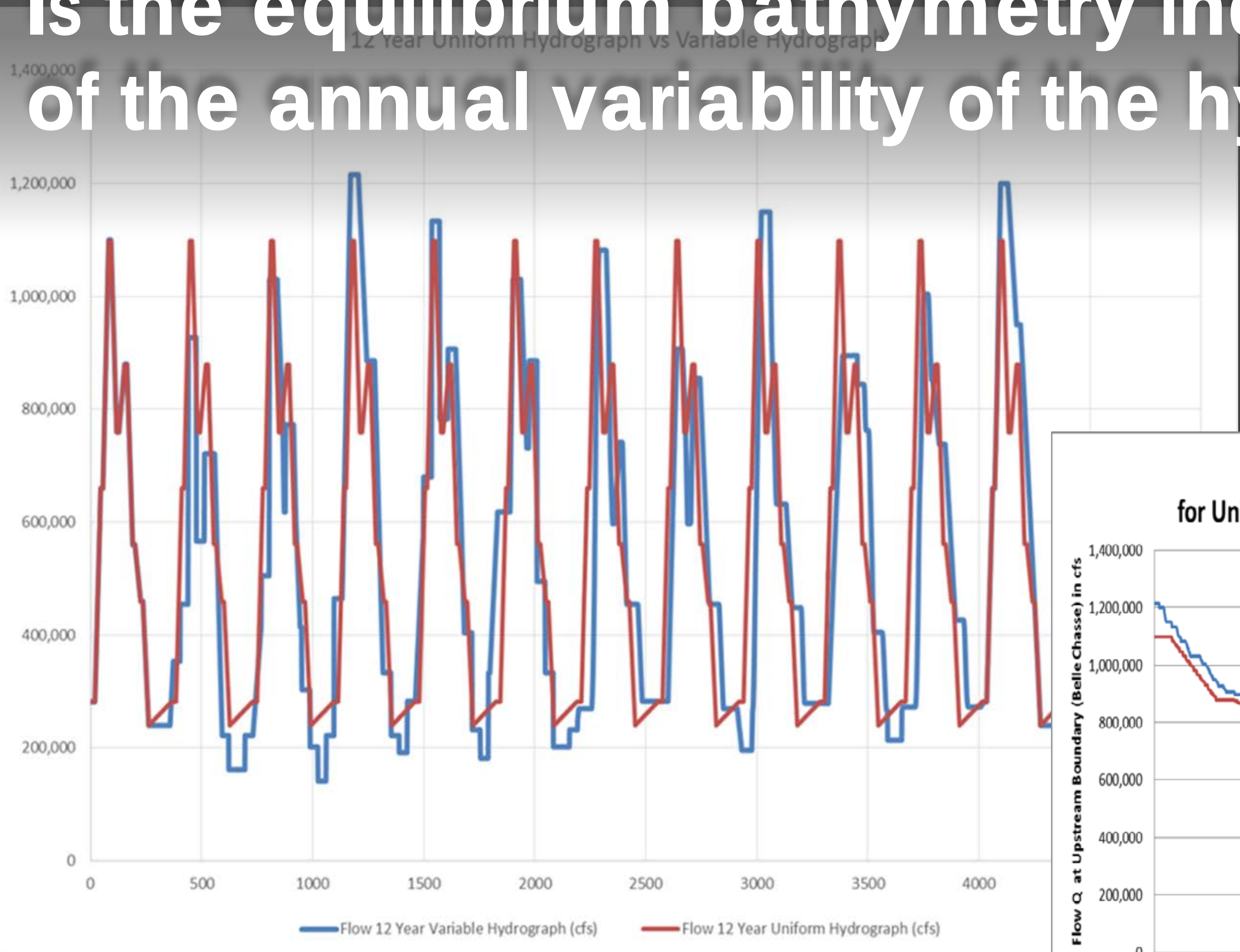
Morphological Factor (MORFAC) = 40

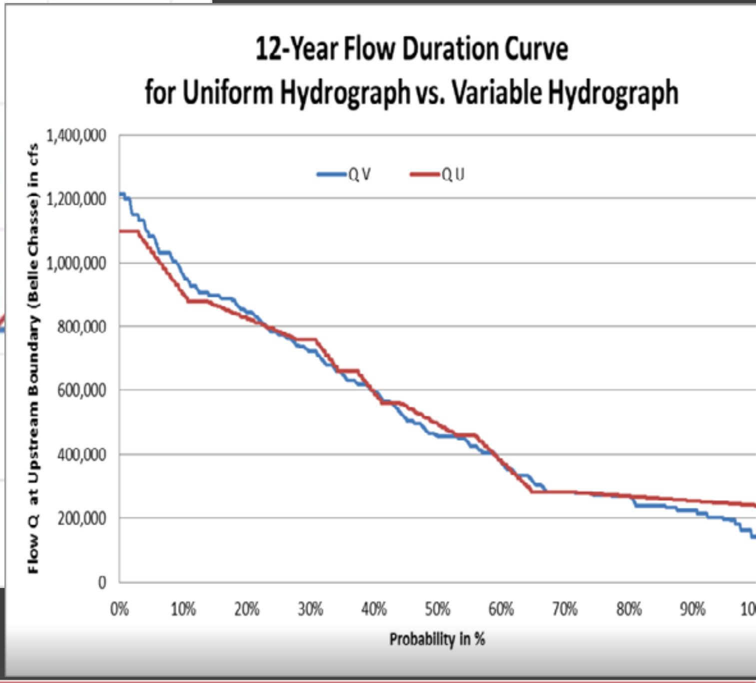
- same as MRHDM
- Yields the best compromise between turn-around and accuracy of the morphological predictions.

Sediment Transport Calculations = Van Rijn:

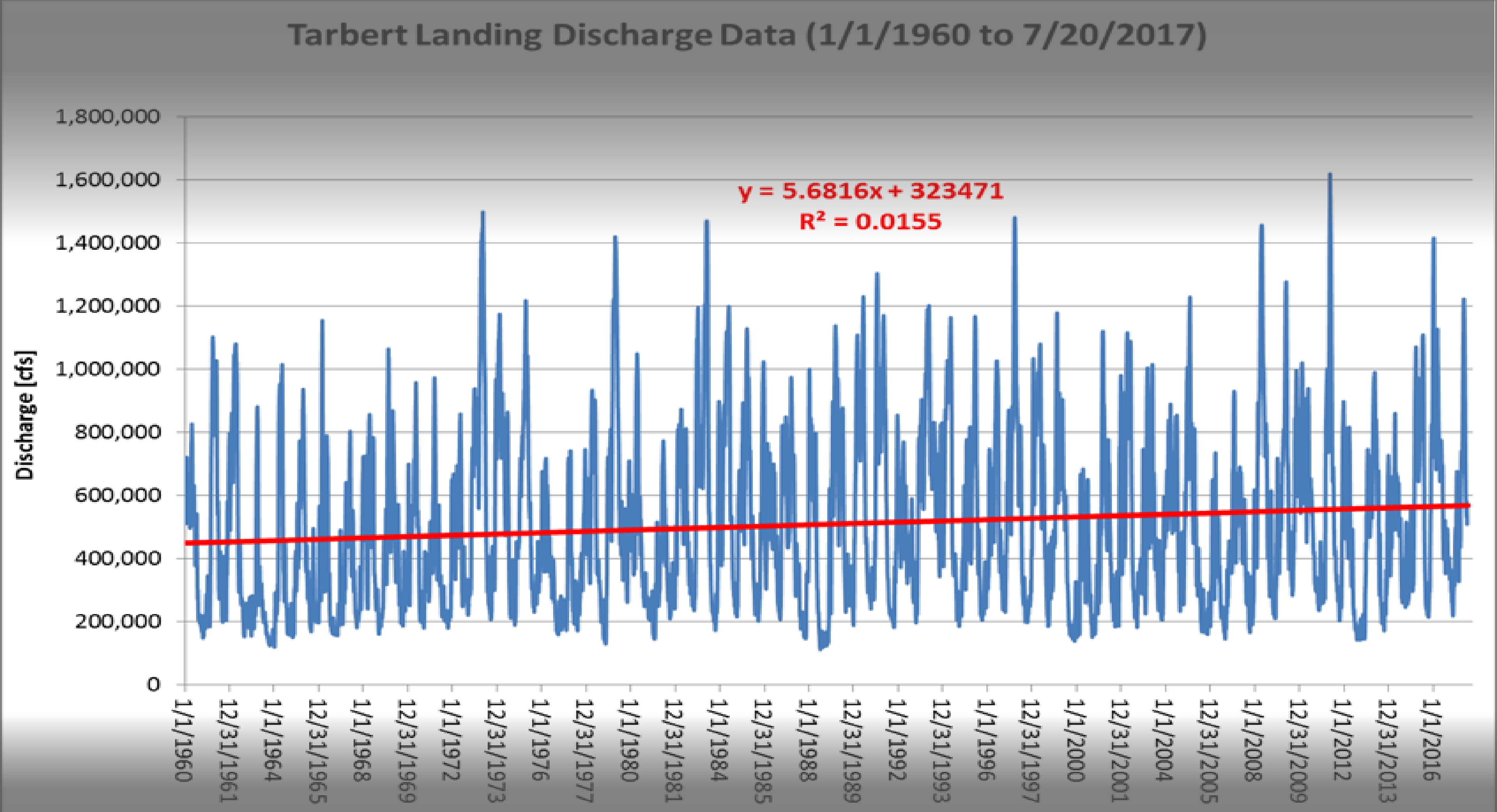
- same as MRHDM
- The Van Rijn 1984 sand transport model was used for the non-cohesive sediment
- Silt & Clay were based on Partheniades-Krone formulations

Is the equilibrium bathymetry independent of the annual variability of the hydrograph?



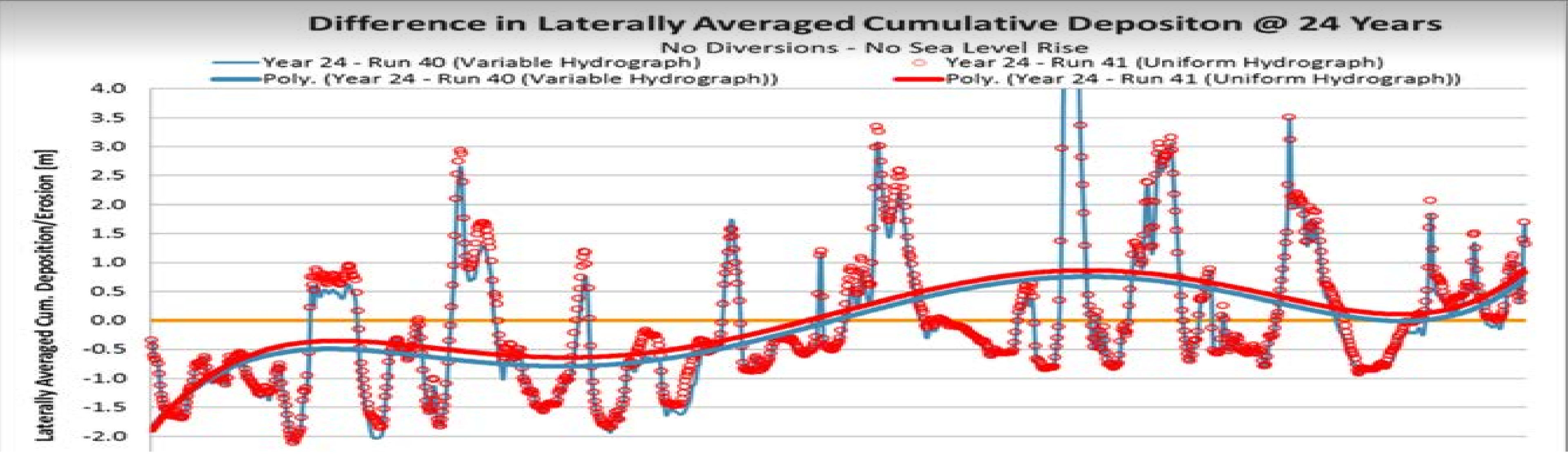


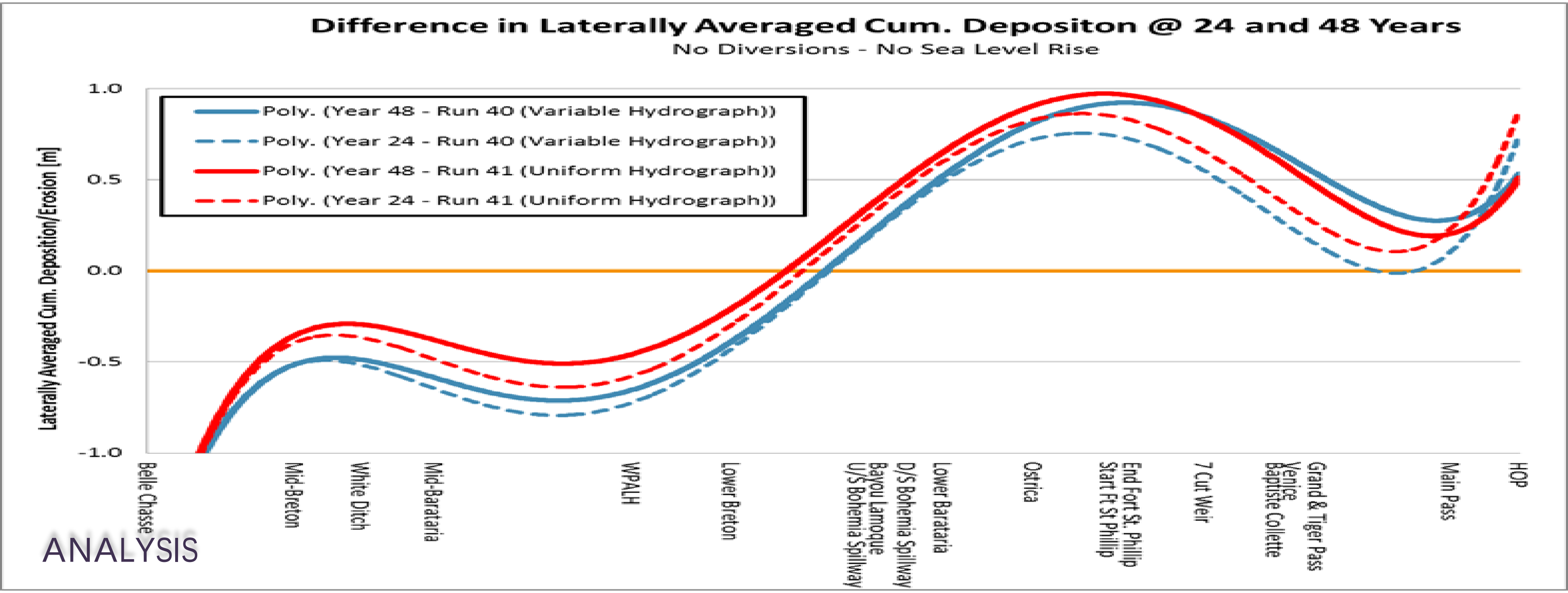
Hydrograph	Probability at 600,000 cfs mark	Probability at 800,000 cfs mark
Uniform	39.99	23.00
Variable	40.10	23.10



Observed Increase in Mean Flow

One potential explanation could be an increase in participation within the watershed due to climate change.





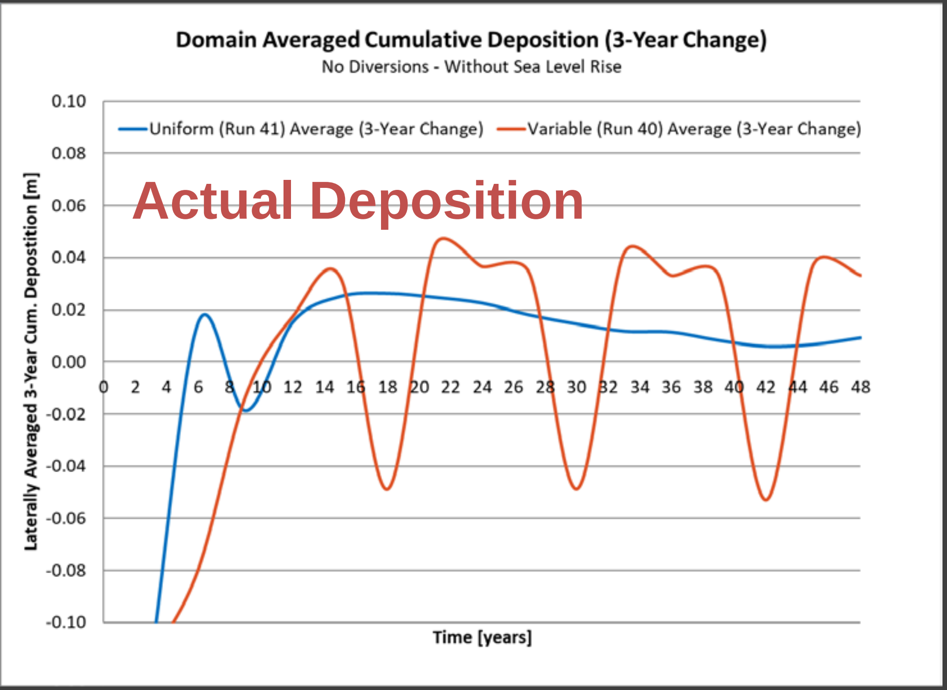
ANALYSIS

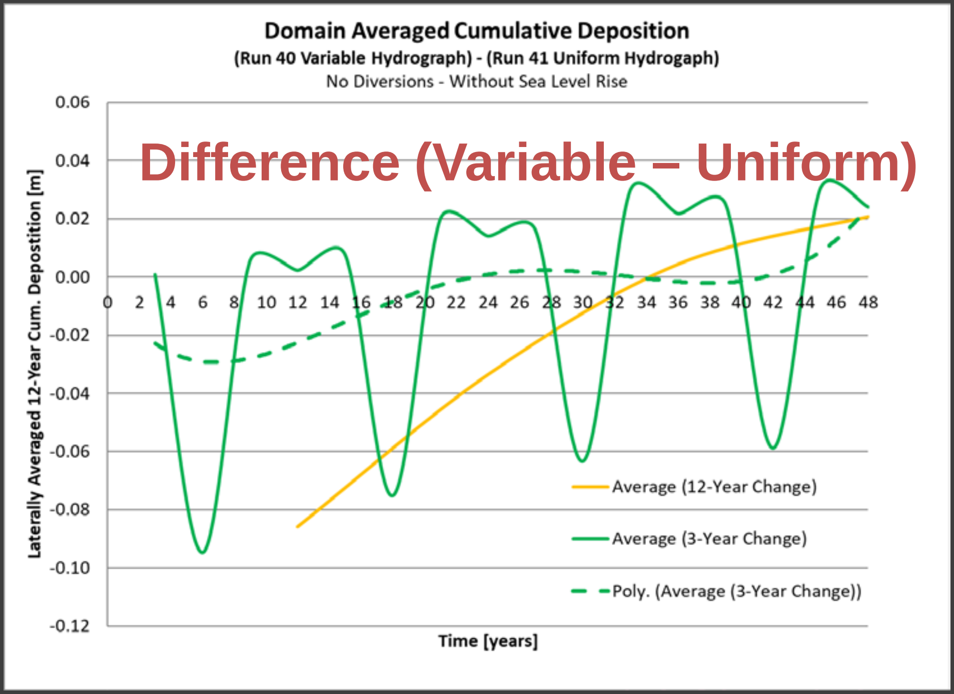
Both hydrograph cases result in similar erosion/deposition patterns

The uniform case has less erosion upstream and less deposition downstream at 48 years.

Analysis: Bathymetric Equilibrium

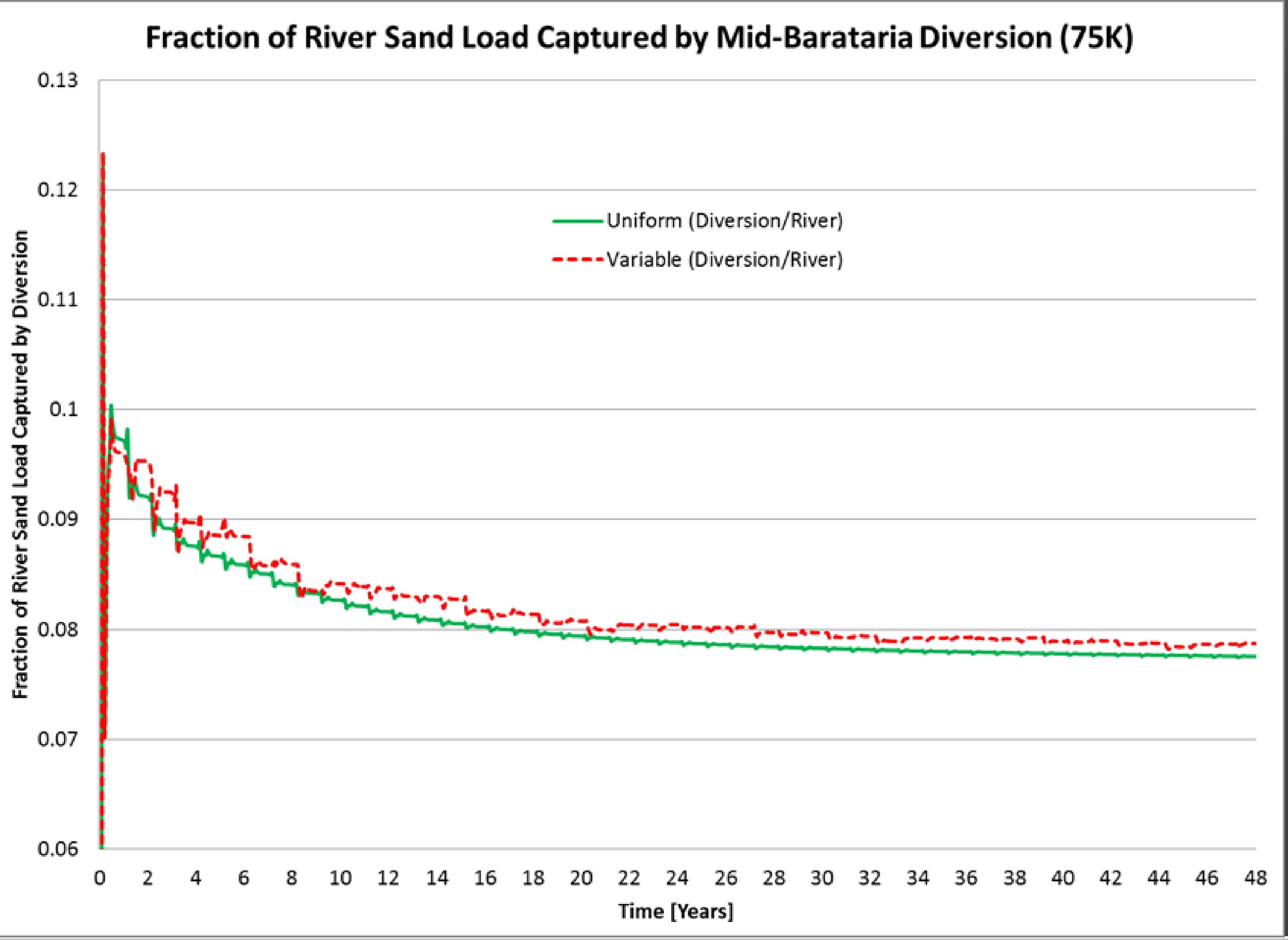
- **Morphological equilibrium** is defined as the condition at which the rate of change in deposition approaches zero.
- **Dynamic morphological equilibrium** is defined as the condition at which the mean rate of change approaches zero, but the derivative oscillates about the mean.





There is no absolute or dynamic equilibrium in the 48-year simulation.

Analysis: Diversion Sand Capture



This slight variance can be explained by the **slightly higher river flow peaks** occurring over time in the variable hydrograph case, providing **more energy** to transport sand in suspension and diverting it through a diversion structure.

Sand captured by the diversion depends on the availability of sand & the hydrograph pattern. The variable case captures approximately 2% more the available sand than the uniform case.

Analysis: Diversion Interdependencies

Diversion	Scenario 1	Scenario 2	Scenario 3	Scenario 4
No Diversions	0 cfs (Run 3)	0 cfs (Run 3)	0 cfs (Run 3)	0 cfs (Run 3)
Mid - Breton	35,000 cfs (Run 12)	25,000 cfs (Run 16)	35,000 cfs (Run 12)	40,000 cfs (Run 25)
Mid-Barataria	75,000 cfs (Run 6)	25,000 cfs (Run 17)	35,000 cfs (Run 21)	40,000 cfs (Run 26)
Lower Barataria	50,000 cfs (Run 13)	25,000 cfs (Run 18)	35,000 cfs (Run 22)	40,000 cfs (Run 27)
Lower Breton	50,000 cfs (Run 14)	25,000 cfs (Run 19)	35,000 cfs (Run 23)	40,000 cfs (Run 28)
Total	**210,000 cfs (Run 15)**	**100,000 cfs (Run 20)**	**140,000 cfs (Run 24)**	**160,000 cfs (Run 29)**

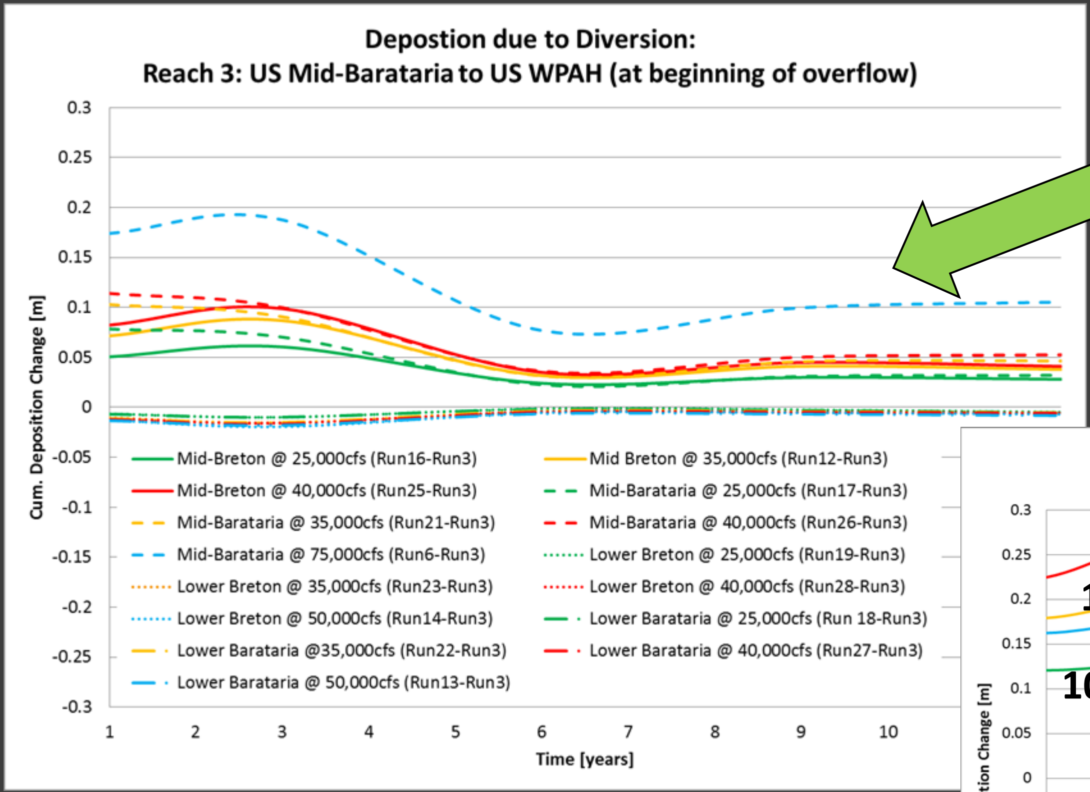
12-Year Runs with Variable Hydrographs

If the total flow diverted through multiple diversions is less than critical rate, does each diversion function as an independent structure in terms of local deposition and sedimentation captured?

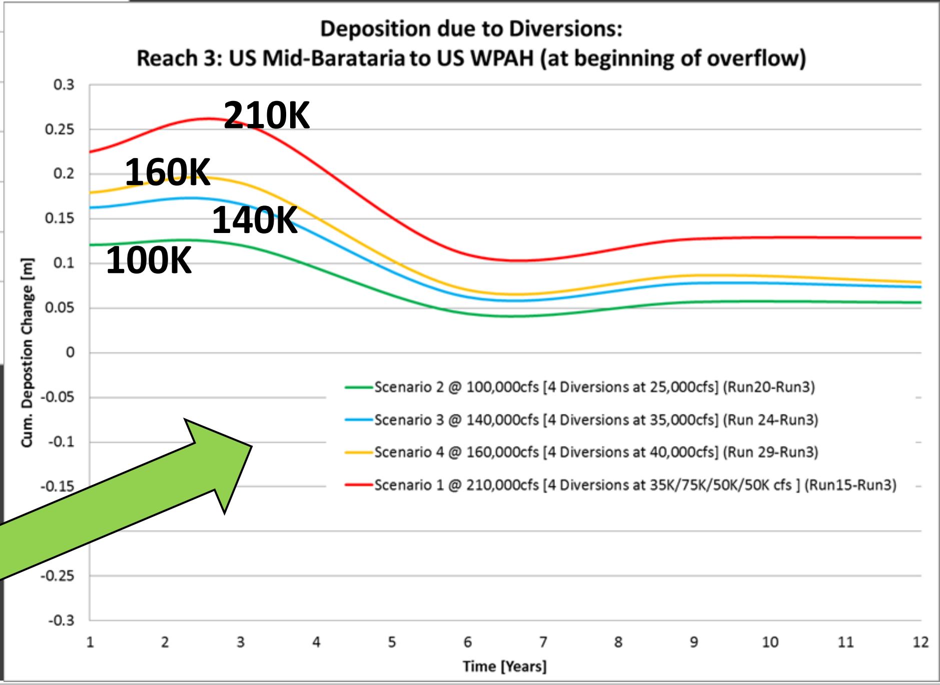
Analysis: Evaluation by Reach

Reach	DESCRIPTION
1	Belle Chasse to Upstream Mid-Breton
2	Upstream Mid-Breton to Upstream Mid-Barataria
3	Upstream Mid- Barataria to Upstream West Pointe à la Hache (WPAH) (at beginning of outflow)
4	Upstream West Pointe à la Hache (WPAH) (at beginning of overflow) to Upstream Lower Barataria
5	Upstream Lower Barataria to Upstream Lower Breton
6	Upstream Lower Breton to Upstream Fort St. Phillip
7	Upstream Fort St. Phillip to Head of Passes

Analysis: Deposition by Reach



Individual Diversion Impacts



Four (4) Diversion Scenario Impacts

Increase in deposition with increase in total flow is non-linear.
1 larger diversion impacts more reaches than a smaller diversion at the same location.

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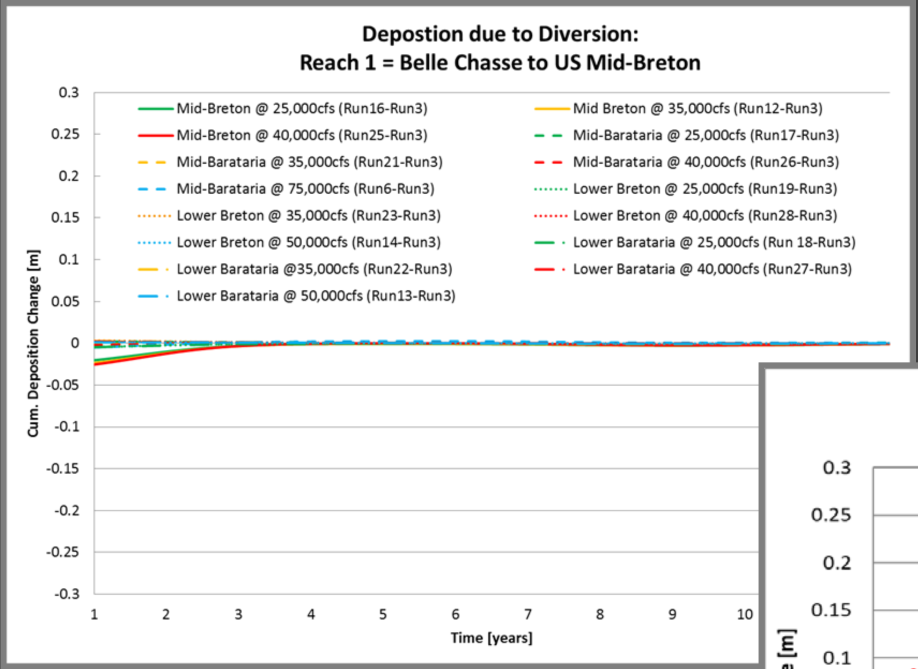
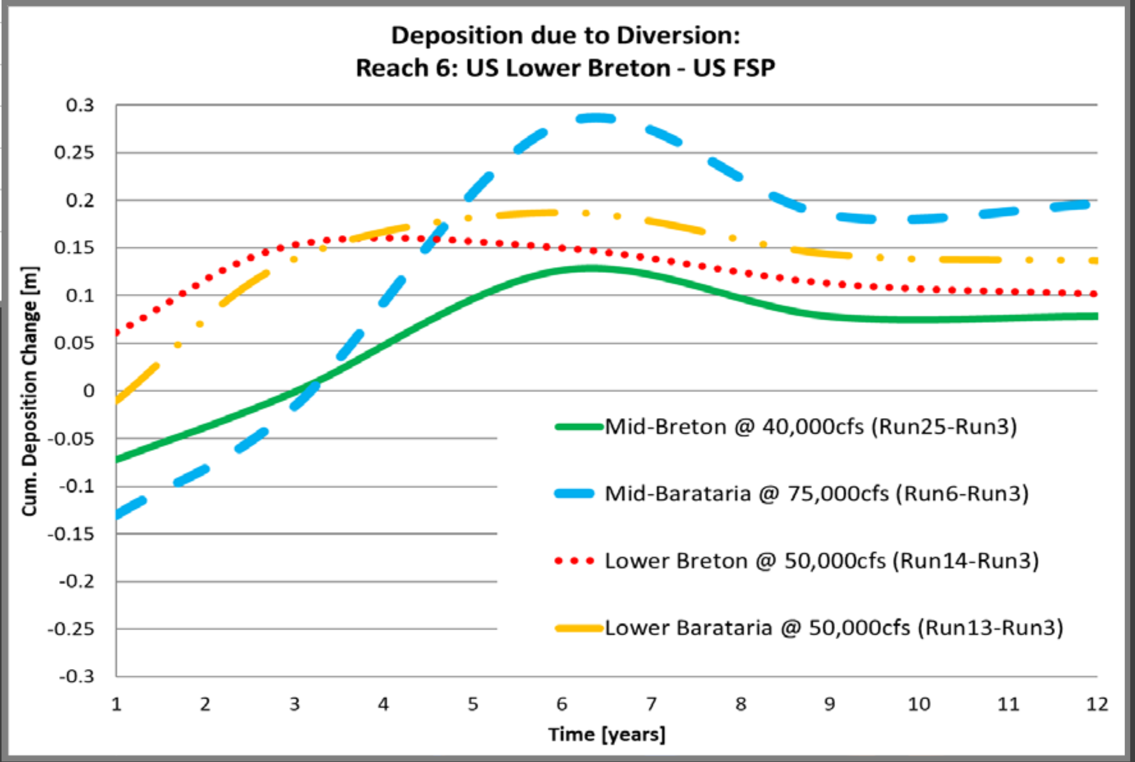
Analysis: Deposition by Reach



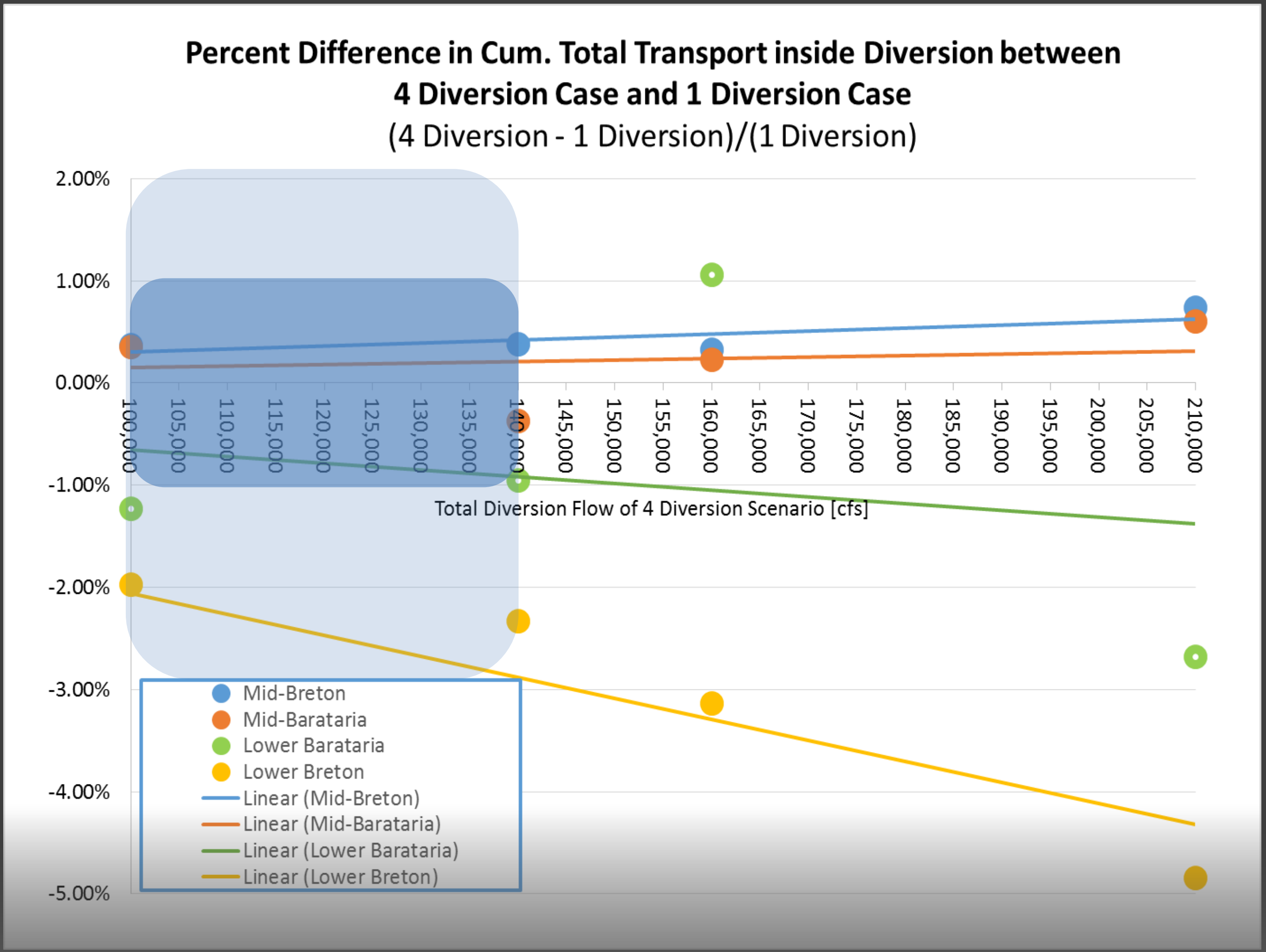
Dependencies increases with the total diverted flow by a single diversion.



For same discharge flows, the deposition increases the closer the diversions are located to HOP.

Each diversion does not function independent in terms of local and regional deposition within the Mississippi River.

Analysis: Sediment Diverted



For total diversion flow < 140,000 cfs, the difference in diverted sand between 1 and 4 diversion cases is

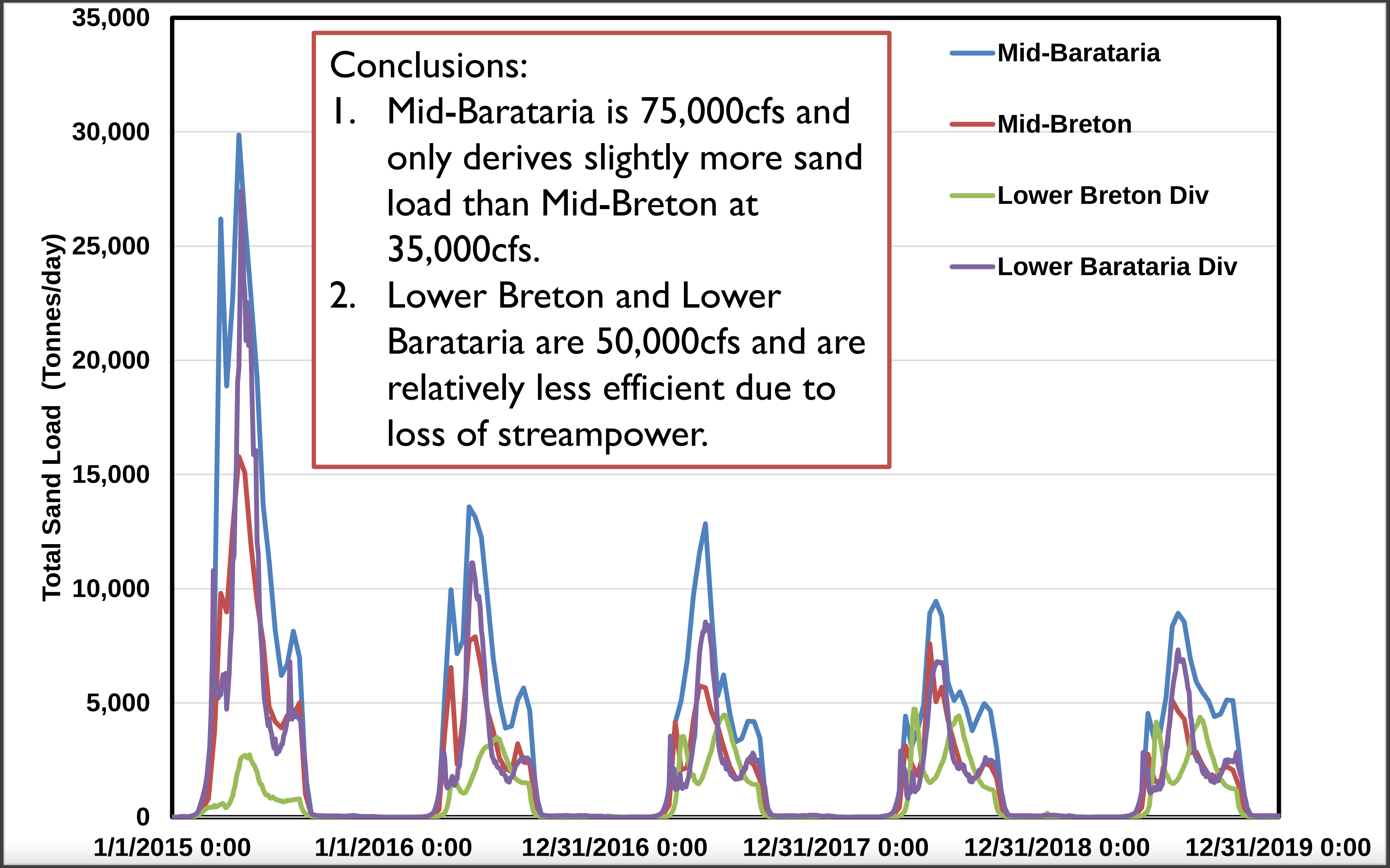
< 3%.

When excluding the Lower Breton Diversion, a total flow of less than 140,000cfs would only generate a difference of

< 1%.

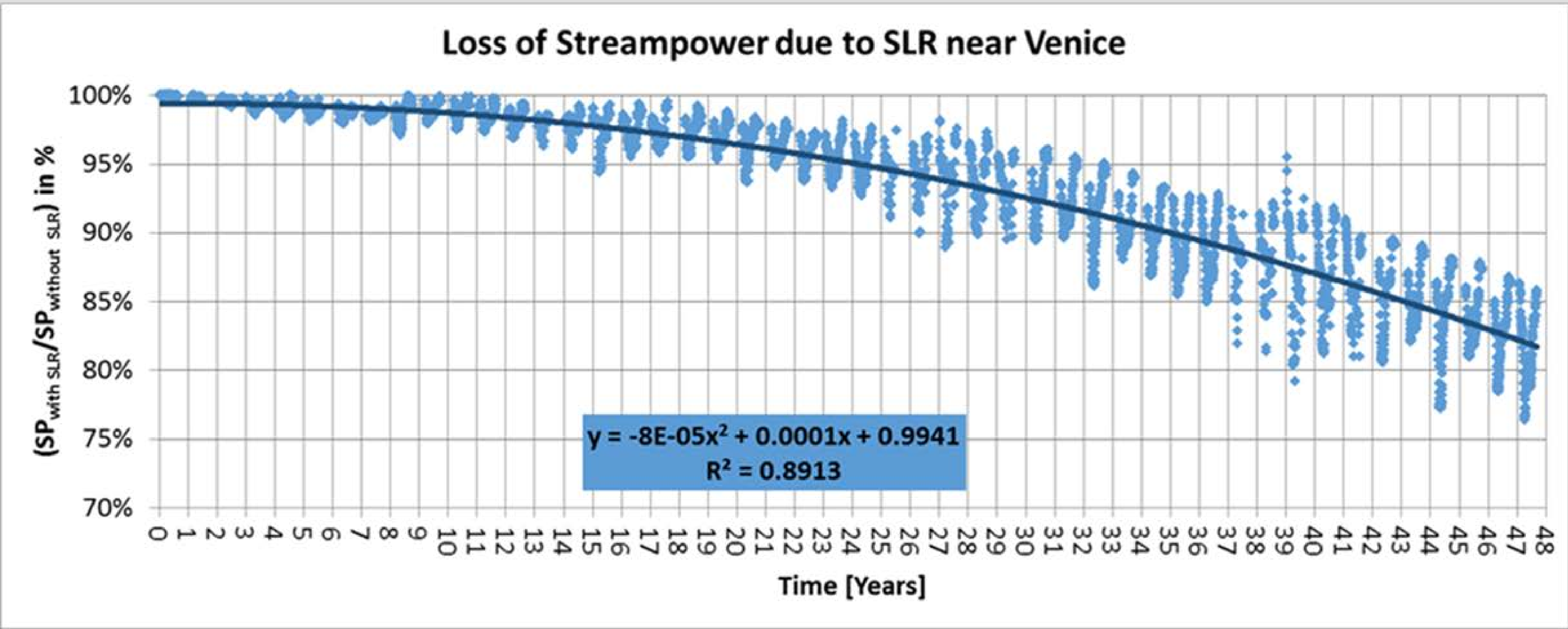
Total Diverted Flow should not exceed 140,000 cfs

Regional Model: Sediment Diverted



Diverted Sand Load (4 diversions at same time)

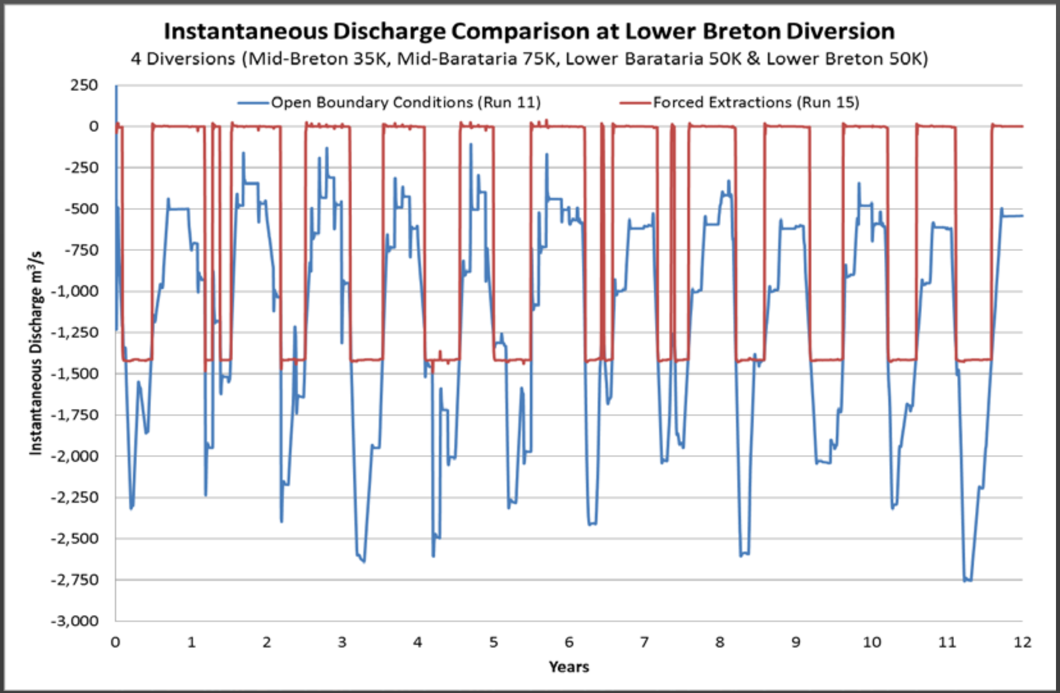
Analysis: System Response due to SLR



Average loss at year 48 is approx. 18%. (max. 24%)

Instantaneous discharge (> 8,000m^3/s) data were plotted for Venice (RM 11.2). The results show an accelerated loss of stream power with time, which contributes to accelerated deposition.

Analysis: Diversion Changes



Diversion (2012 Master Plan)	Qmax [cfs]	RM	Invert [ft]	Width [ft]	Remarks
Mid-Barataria	75,000	60.8	-40	330	Myrtle Grove
Mid-Breton	35,000	67	-40	165	White Ditch
Lower Barataria	50,000	42	-40	165	Empire
Lower Breton	50,000	39	-40	165	Black Bay

Does the river have sufficient energy to divert the targeted discharges for the 4 main diversion locations?

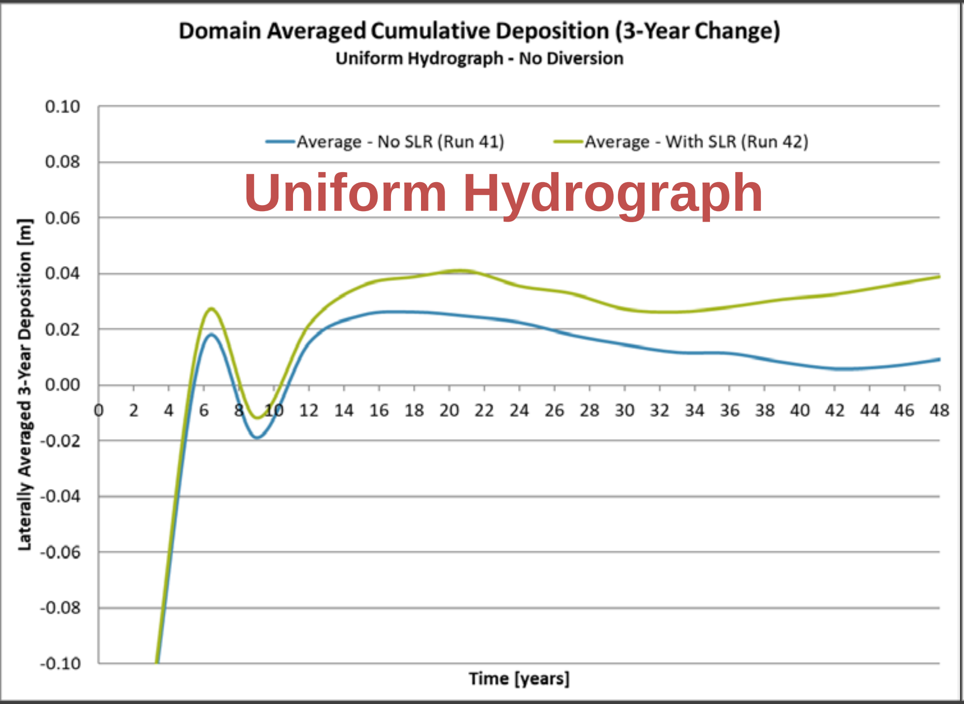
There is sufficient energy in the river to divert the desired flows to the established maximum of 210,000 cfs with an exit channel with 2 m/s velocity.
(2m/s is anticipated to prevent sand deposition in the delivery channel)

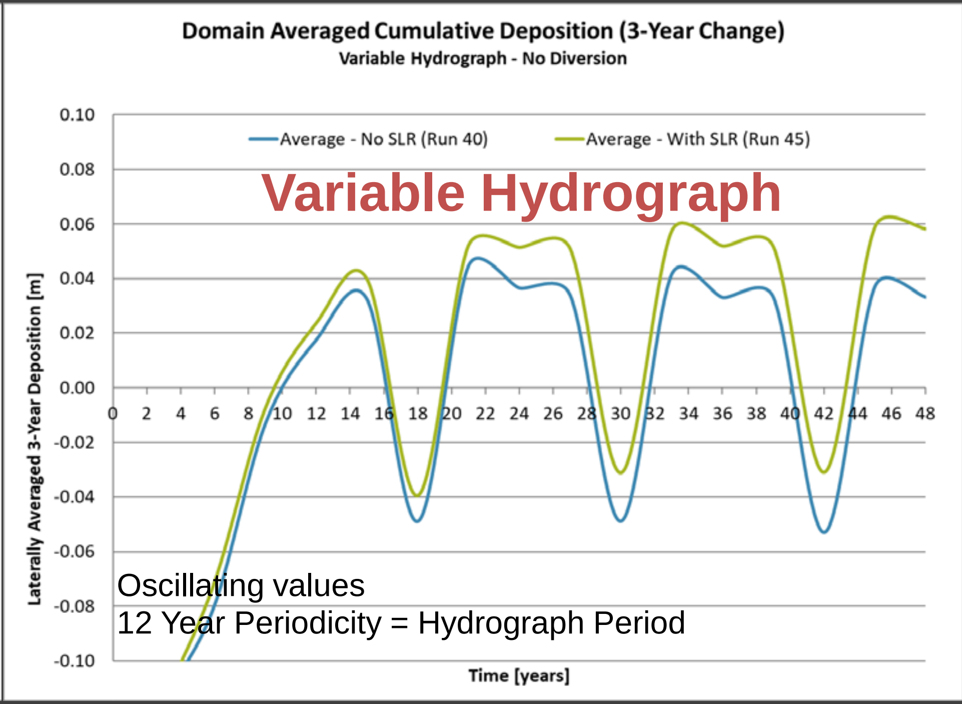
It is assumed that there are no energy losses due to the control structure, which implies a wide channel opening.

Changes in width will warrant revised analysis

There is **no absolute or dynamic equilibrium** in the 48-year simulation.

Analysis: Deposition Trends with SLR



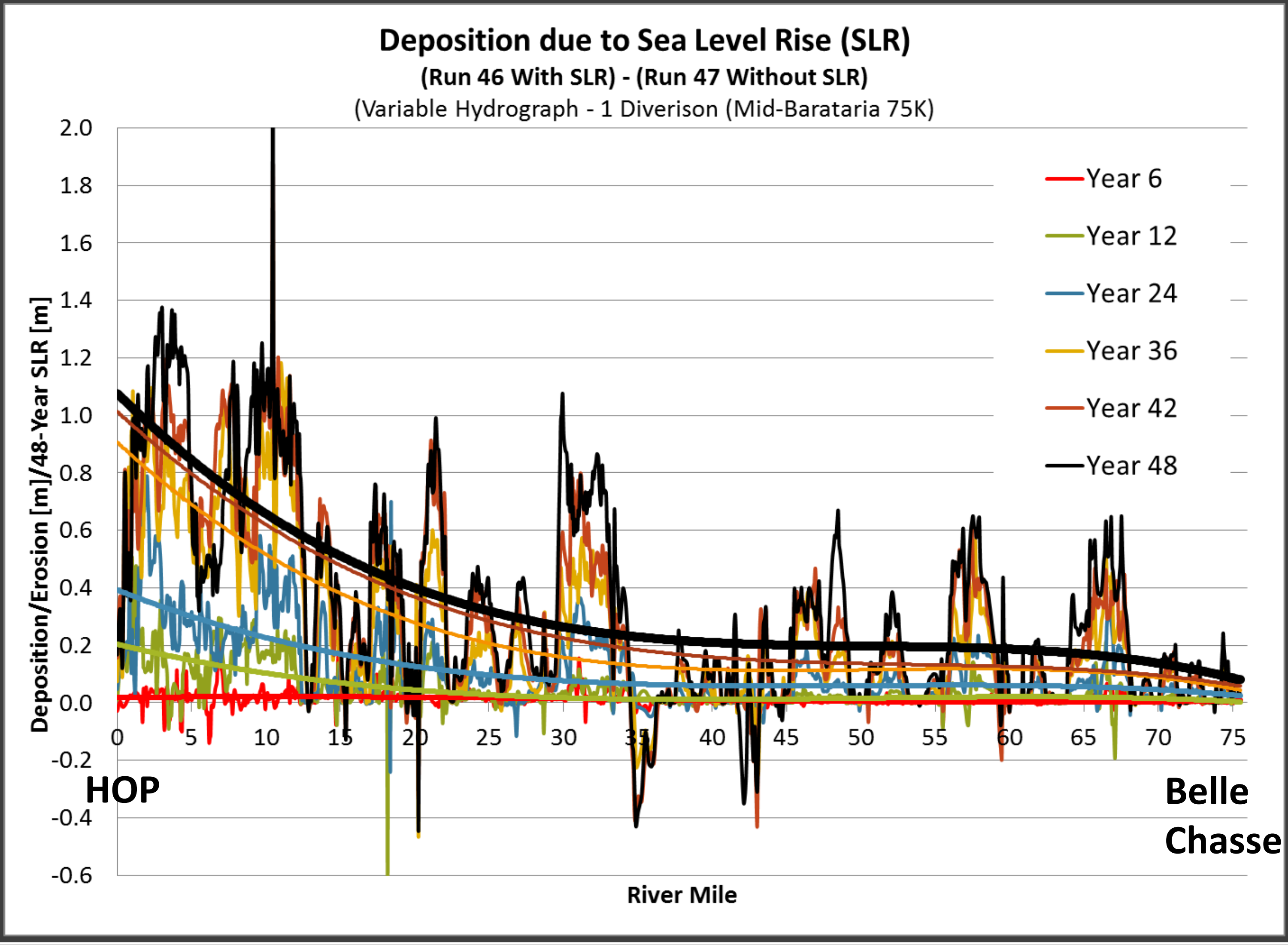


A true equilibrium was neither achieved for the without SLR nor the with SLR scenario evaluated by the 48 year model runs.

The depositional trends are accelerated with SLR

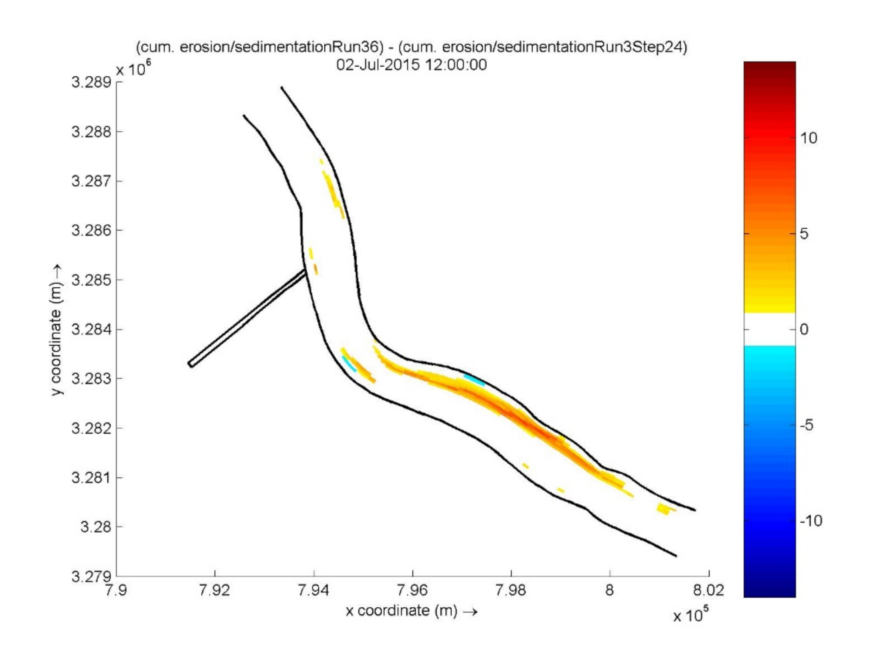
Analysis: Deposition due to SLR & Diversions

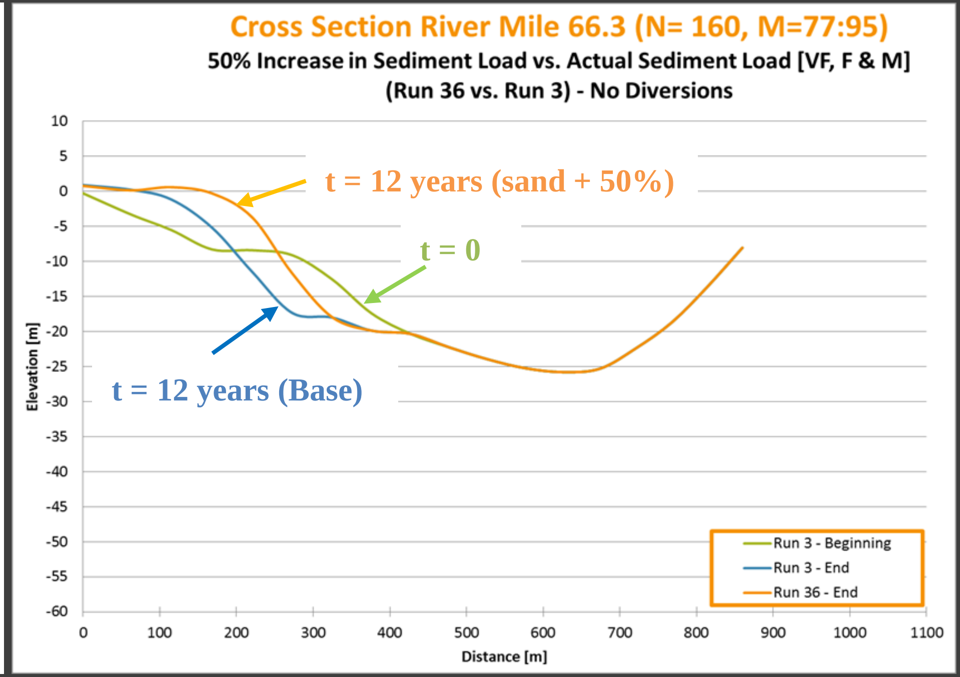
Normalized Deposition



Over 48 years the deposition at HOP approaches the 48-year SLR and decreases to approx. 10% of the 48-year SLR at Belle Chasse.

Analysis: How does change in sediment load impact morphologic changes?

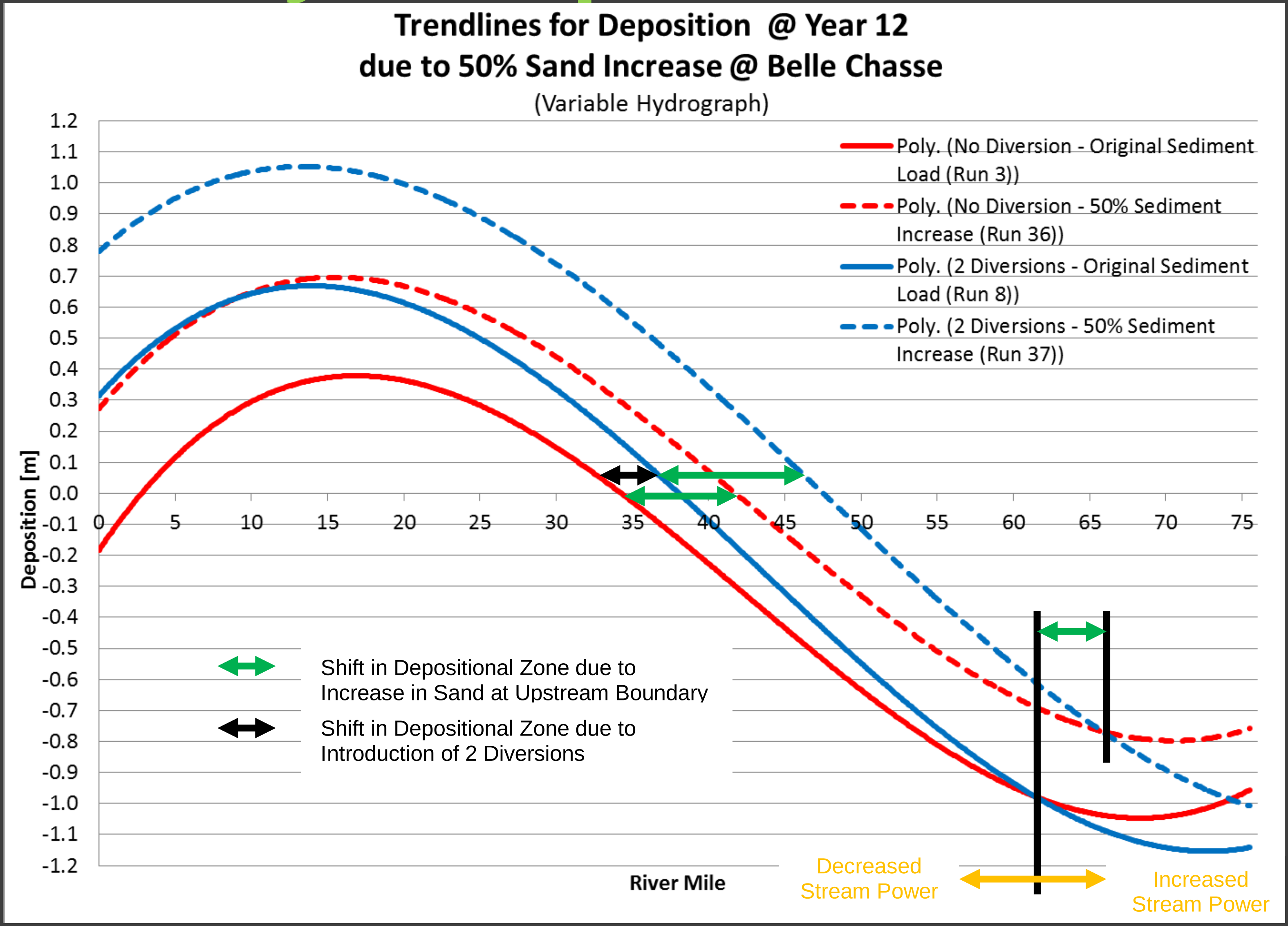




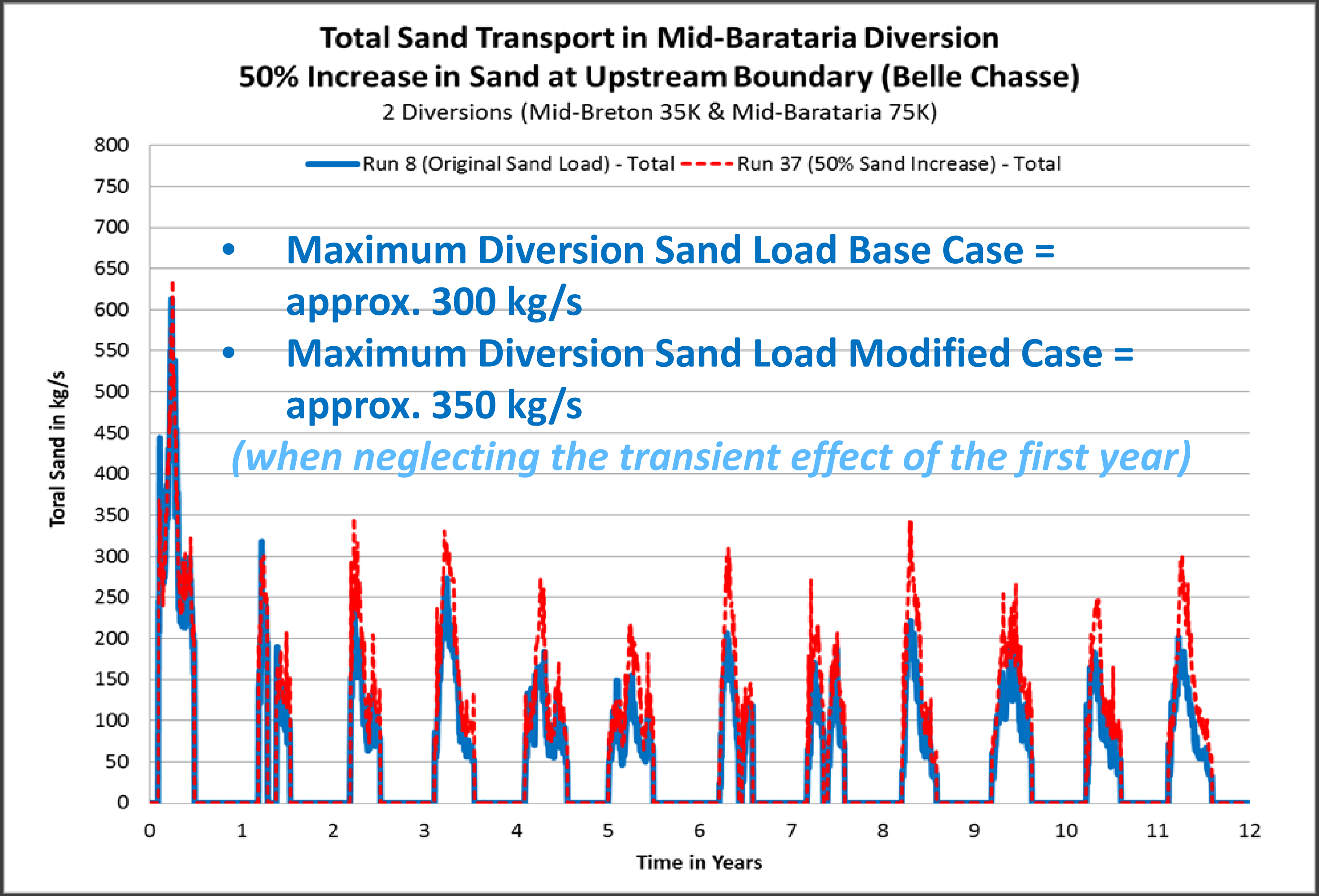
A 50% increase in sand load is representative of the uncertainty in the upstream sand concentration.

A 50% increase in sand load generates deposition within the river, especially within existing point bars.

Analysis: Depocenter Shifts



Analysis:
Sand Diverted due to variability in Sand Supply



50% sand increase at the upstream boundary results in a proportionally smaller increase of sand load in the diversion.

Key Conclusions

- *The absolute bathymetry equilibrium depends on the annual variability of the hydrograph, even if the flow duration curves are the same.*
- *A near bathymetric equilibrium is reached upstream of Fort St. Philip, whereas downstream of Fort St. Philip no equilibrium occurred within the 48 year period of the simulation, due to the effect of the distributaries and uncontrolled outflows.*
- *Loss of streampower generated by sea level rise and diverted flow results in increased deposition, especially below Fort St. Philip.*
- *Morphological changes are dependent on the number and location of multiple diversions. The largest interdependencies occur for the most downstream diversions, and increase with the total diverted flow.*
- *Sediment capture showed only minor interdependencies for multiple diversions if the total diverted flow remains below 140,000 cfs.*
- *The introduction of larger diversions, like the Mid-Barataria diversion, result in an upstream shift of the depocenter and an increase of cumulative impacts along the river system.*
- *A 50% increase in sand concentration had a greater impact on the growth of bars than on the capture efficiency of a diversion.*
- *Regional long term trends need to be considered when evaluating local effects due to individual projects.*

Recommendations

- *A* ***48-year variable hydrograph*** *should be developed to represent the actual periodicity of the historical record and include an adjustment for climate change and related discharge trends.*

- *Study a* ***combination of proposed diversions and beneficial dredging****.*

- *Analyze the impacts of* ***removal of upstream point bar*** *material to performance of diversion.*

- *Running the Shortmodel for the planned operational procedures as well as the adjusted location and geometry of the* ***Mid-Barataria and Mid-Breton Diversion*** *to identify cumulative impacts and capture rates.*

Nina J. Reins, PhD, PE, PMP

nina.reins@freese.com

900 Camp Street #3C3

New Orleans, Louisiana 70130

UNO Dissertation Research

Committee Chair: Dr. Alex McCorquodale, Co-Chair: Dr. Ioannis Georgiou