

Mid-Barataria Sediment Diversion (BA-0153)

Conveyance Channel Flushing Modeling

Flow, Sediment Transport and Morphology Modeling (Slides 2-7)

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Executive Summary

- Review from FTNOMLV-CONSOL Phase 1 Modeling: A maximum 5,000 cfs constant daily diversion flow during the base flow period (MR Daily Flow < 450,000 cfs) was found to result in deposition in the conveyance channel due to inadequate sediment transport capacity in the channel. Over several years, the successive depositions can reduce channel cross-section and therefore diversion capacity, which would then require channel maintenance dredging as early as within the first decade, much earlier than when basin dredging is predicted to be needed.
- This investigation answers the following questions:

- **Is the assumption of the continuous availability of a maximum of 5,000 cfs daily flow during the entire base period realistic?**

Ans: No. In a typical year, during the *base flow period (between Aug-Nov)*, it is found that the diversion can only divert flow to the basin for 40% of this period (48 days out of 120 days, mostly when MR>300,000 cfs), which indicates that diversion is likely to be kept closed remaining 60% (72 days) of the period. Note that large extremes of this averaged condition is possible, e.g, in a very wet year like 2018, base flow of 5,000 cfs is possible 100% of the Aug-Nov period, while say in a very dry year like 1980, less than 12% of the Aug-Nov period would have had a 5,000 cfs flow. Based on MR Flow, the following flow regimes can be established.

MR < 225,000 cfs: Full reverse flow from basin to river if diversion open. *Maximum flow not sufficient for flushing.*

225,000 < MR < 300,000 cfs: Intra-daily reverse flow from basin to river most days if diversion open. *Maximum flow not sufficient for flushing.*

300,000 < MR < 350,000 cfs: No reverse flow, 5,000 cfs or lower base flow possible from river to basin. *Maximum flow not sufficient for flushing.*

350,000 < MR < 450,000 cfs: No reverse flow, 5,000 cfs base flow possible from river to basin. *Maximum flow sufficient for flushing.*

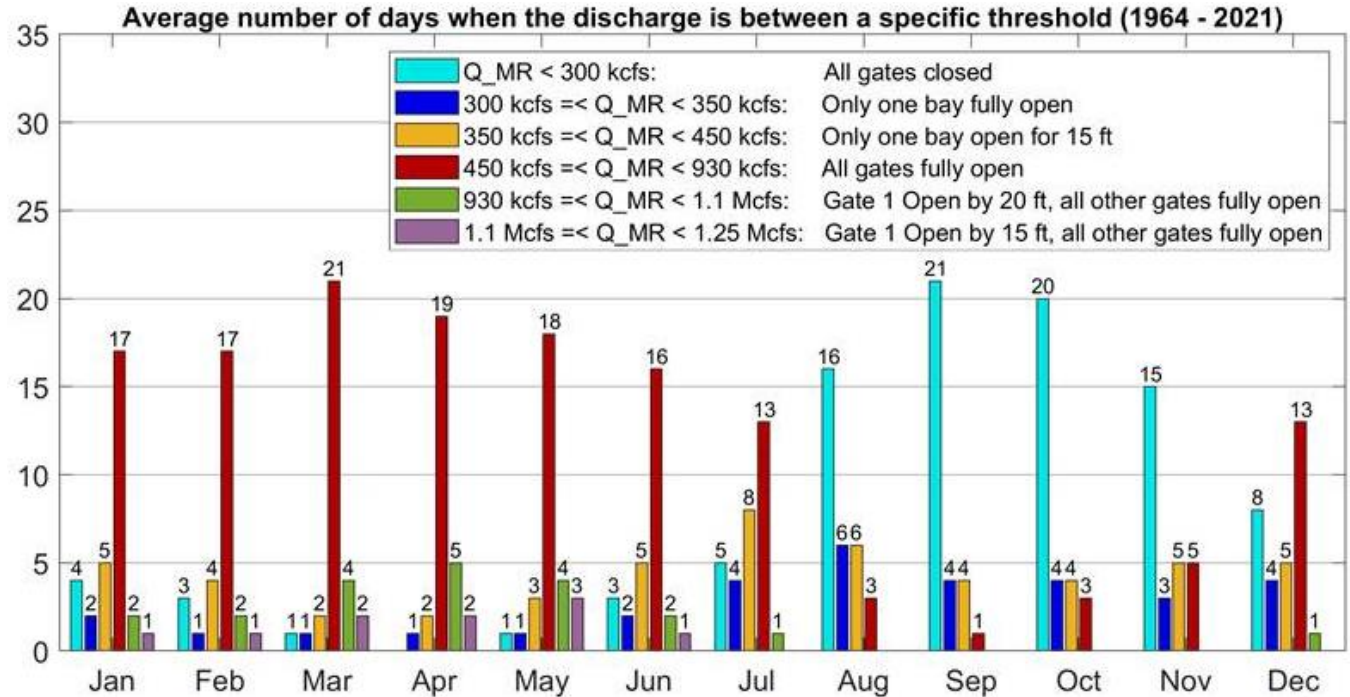
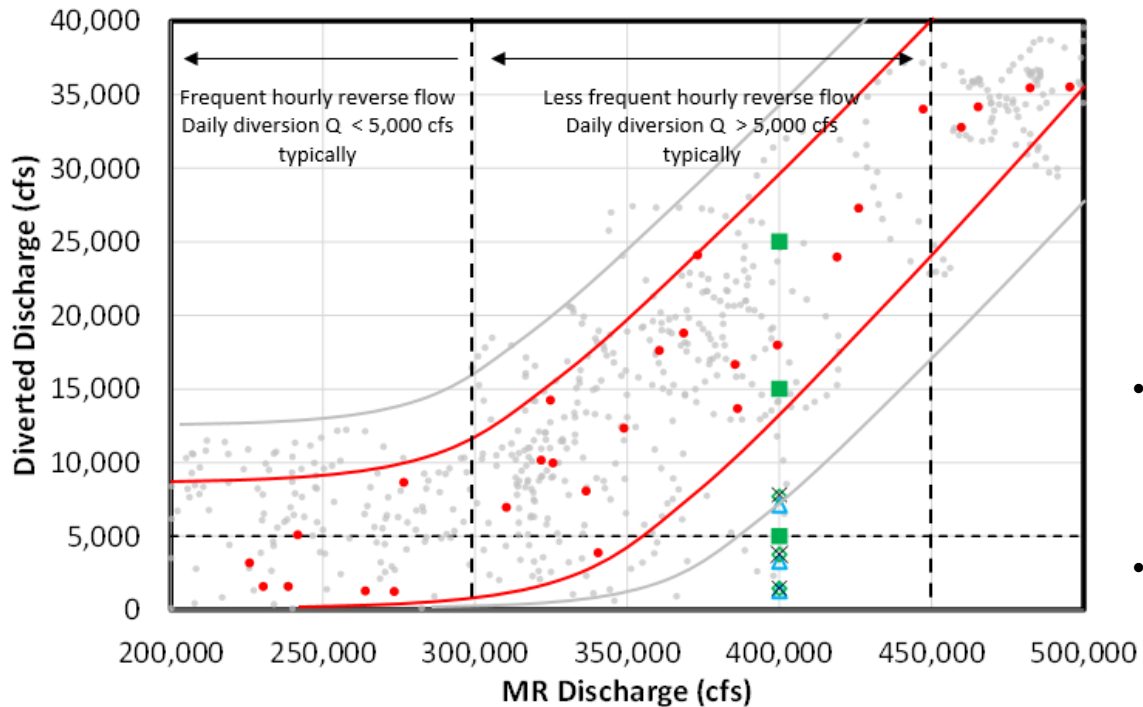
(RECOMMENDED Period)

- **Can flushing flow keep the diversion channel free of deposition? If so what is the desired flow and duration?**

Ans: In a given year, *if the diversion is mostly closed* during the base flow period, no deposition builds up in the channel and therefore ***no flushing is required***. Typically ***flushing is only required for those years when the diversion operates at 5,000 cfs or below flow for an extended period like 2-3 months*** consecutively. In those years, ***opening all the gates for at least a 7 day period when the diversion is expected to reach a peak daily flow of 10,000-15,000 cfs flow is found to be sufficient to flush the channel of the deposits***. Since availability of such periods may be rare (possibly 1 or 2 for such years), the operations manager need to be prepared whenever the river presents such opportunity, which is typically when the river flow oscillates between 350,000-450,000 cfs during the base flow period.

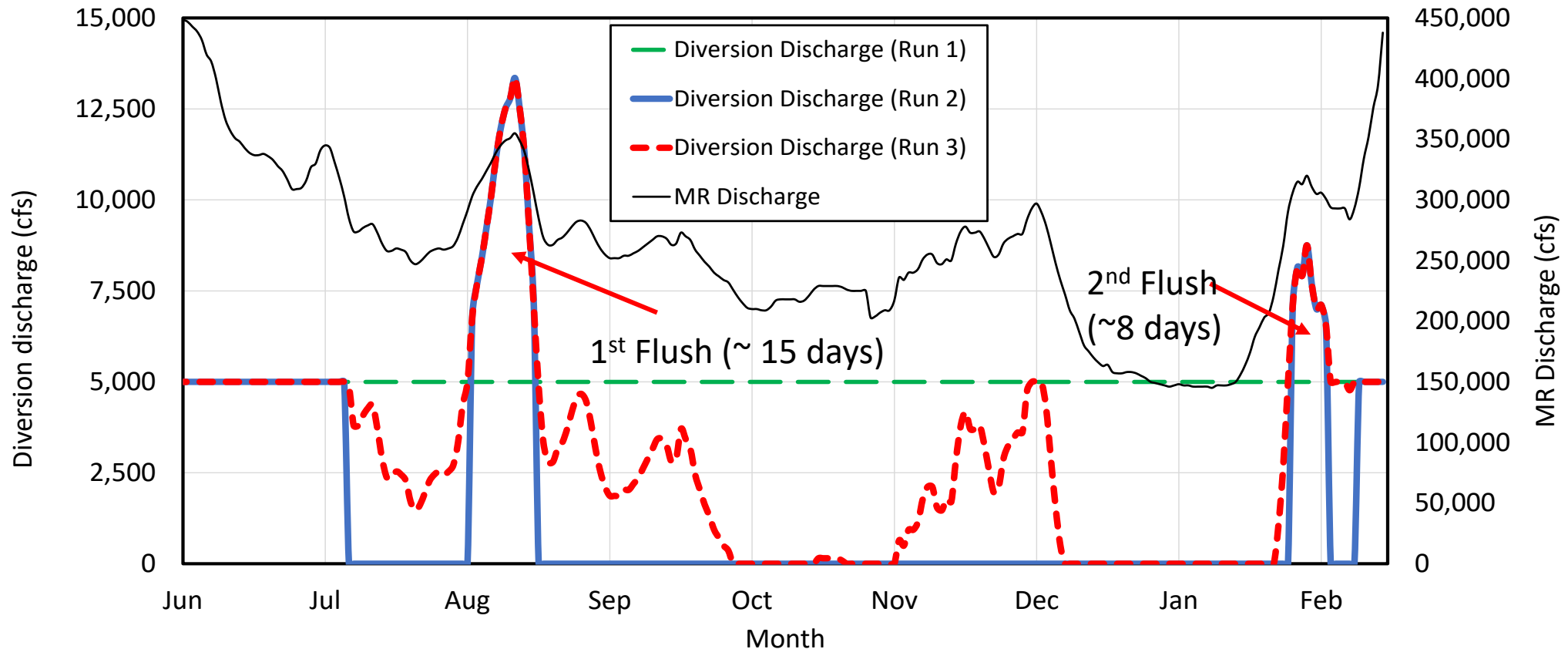
Diversion Base Flow Availability and Typical Duration when MR < 450,000 cfs

- All Bays Open: Hourly Discharge (Delft3D)
- All Bays Open: Daily Discharge (Delft3D)
- All Bays Open: Steady State Discharge (FLOW-3D)
- △ Bay 1 Open, Bay 2&3 Closed: Steady State Discharge (FLOW-3D)
- ◇ Bay 2 Open, Bay 1&3 Closed: Steady State Discharge (FLOW-3D)
- × Bay 3 Open, Bay 1&2 Closed: Steady State Discharge (FLOW-3D)



- Modeling indicates that a constant diversion base flow of 5,000 cfs is not guaranteed when MR < 450,000 cfs. Thus it may not be realistic to expect, neither the basin side benefits nor the channel deposition issues from such a hypothetical scenario.
- Statistically, in a typical year the diversion can divert 5,000 cfs only for about 48 days (40%) of the 120 days in the Aug-Nov period. The diversion may need to be kept closed the remaining 72 days on an average to prevent reverse flow. Even if reverse flow is allowed, there is no obvious basin side benefit to allowing such flow.
- Following slides explore two additional realistic scenarios instead.

Three Flushing Simulation Scenarios: 1980* MR Hydrograph Simulated



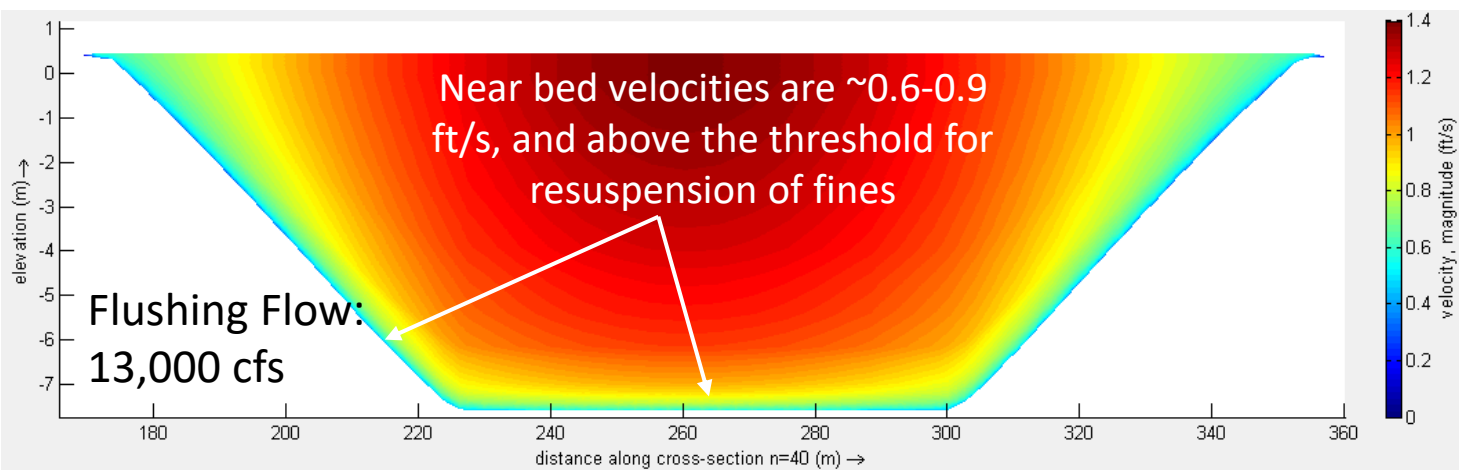
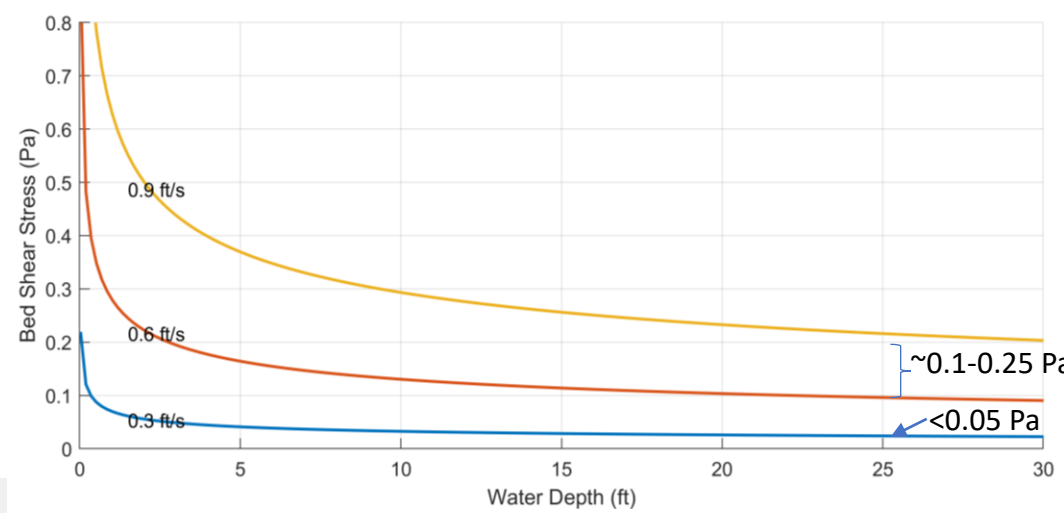
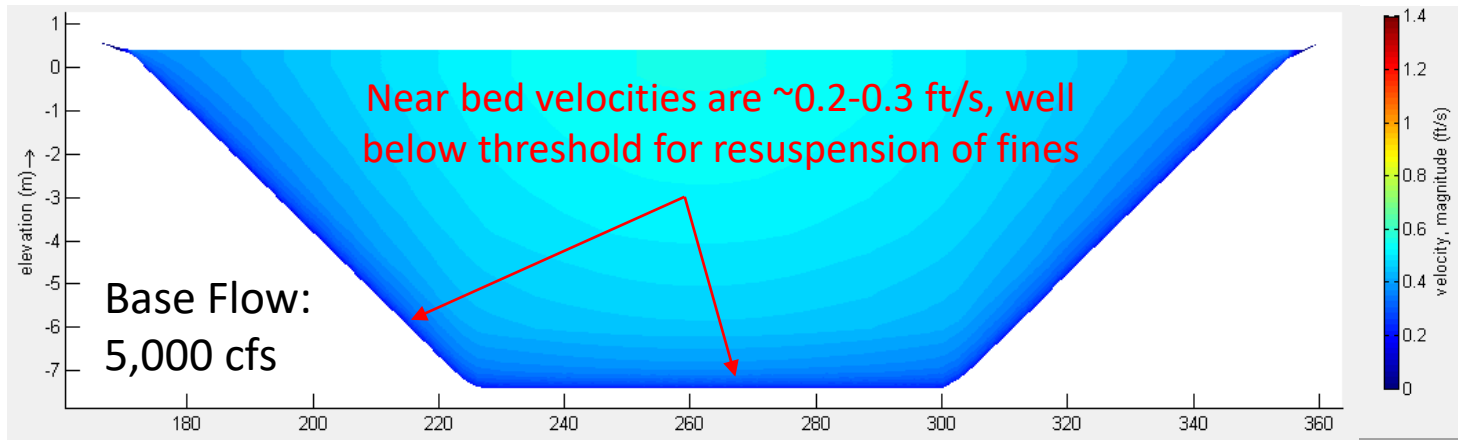
Run 1: No flushing simulated. 5,000 cfs constant diversion flow throughout base flow period, when MR flow < 450,000 cfs.

Run 2: With flushing simulated. 5,000 cfs for 300,000 < MR Flow < 450,000 cfs but diversion closed below 300,000 cfs.

Run 3: With flushing simulated. 5,000 cfs for 300,000 < MR Flow < 450,000 cfs but diversion kept open below 300,000 cfs, except for the period of complete flow reversal (mostly below MR < 225,000 cfs) when diversion is kept closed.

*1980 was one of the longest base flow period in record (June 1980-Feb 1981, ~7.5 months) and is chosen intentionally to examine the worst possible effects. Basin conditions are current (2020) which determines the tidally averaged daily diverted discharge conditions simulated. 3D Delft3D coupled flow and morphology FTN-CHANNEL model used.

Velocity Distribution within Channel: Flushing Flow > 10,000 cfs provides adequate shear stress and transport capacity for silt movement



Type of bed	Percentage sand (150-250 μm)	Wet and dry bulk density (kg/m³)	Critical bed-shear stress of particle/surface erosion (N/m²)	
			Natural beds of UK sites (intertidal and subtidal)	Artificial beds (homogeneously mixed)
Pure mud	0%	1200-1300 (350-450)	0.05-0.25	0.1-0.15 (HK-mud)
Light sandy mud	20%	1300-1400 (450-650)	0.15-0.25	0.15-0.2 (HK-mud)
Sandy mud	40%	1400-1600 (650-950)	0.2-1.0	0.2-0.4 (HK-mud)
Muddy sand	60%	1600-1700	0.4-1.5	0.4-0.8 (K,M,S-muds)
Muddy sand	80%	1700-1800	0.6-1.8	1-3 (K,M,S-muds)
Light muddy sand	90%	1800-1900	?	0.5-1.5 (K,M,S-muds)
Pure sand (150-250 μm)	100%	1900-2000	0.15-0.2	0.15-0.2 (K,M,S-muds)

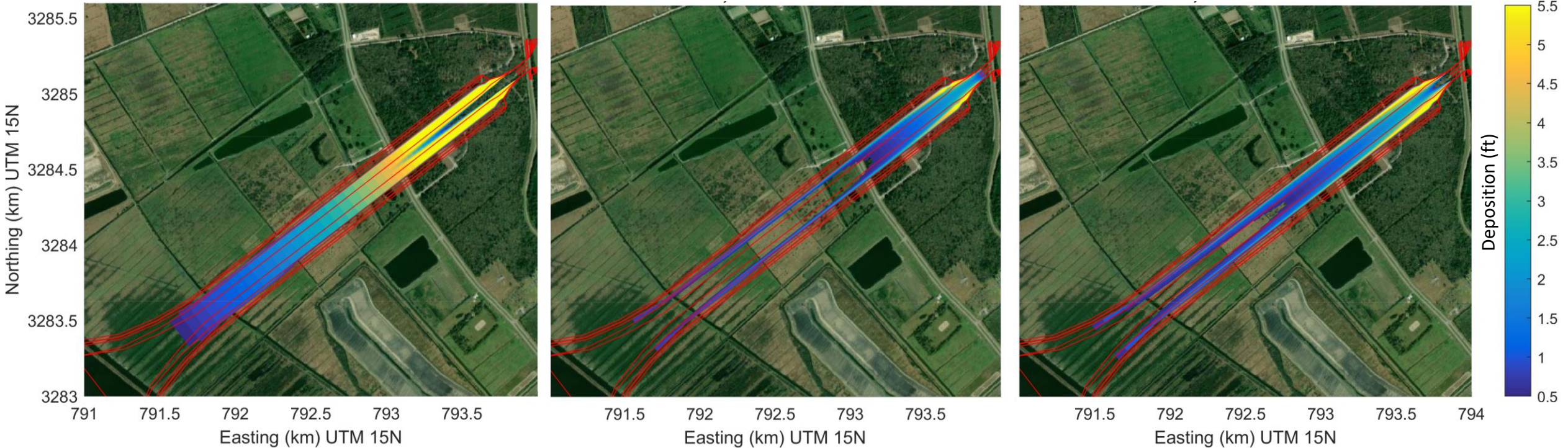
HK= Hong-Kong, S=Scheddt, K=Kaolinite, M=Montmorillonite
Table 2.3.2 Critical bed-shear stress of mud-sand mixtures (laboratory-field, Mixener and Torfs 1996)

Deposition at end of Base Flow period

Run 1: No flushing, Constant 5,000 cfs throughout Base Flow Period

Run 2: With flushing, Diversion closed when MR < 300,000 cfs (no reverse flow allowed)

Run 3: With flushing, Diversion closed only when MR < 225,000 cfs (partial reverse flow allowed)



- **Run 1 showed the highest deposition** in the channel due to the maximum sediment delivery to the channel and consistently low sediment transport capacity due to lack of flushing. Sediment buildup is more in the upstream half of the channel, over the years the entire channel is expected to deposit.
- **Run 2, showed the least deposition** in the channel among the three scenarios **due to reduced sediment delivery to the channel** (diversion mostly closed late Aug-Jan) **as well as the two flushing flow events**. This shows that even for the worst base flow year (longest period) chosen, it is possible that channel deposition may not be a real concern if the diversion is closed for most of the period and flushing is done at least once.

Conclusions and Recommendations

- Constant base flow of 5,000 cfs may not be available for the entire base flow period, every year. Modeling and statistical analysis of past 50 yrs of MR hydrograph reveals that on an average year, only 48 days during the Aug-Nov period may be available for base flow.
- It is recommended that the diversion be kept closed below 300,000 cfs MR flow to prevent reverse flow from the basin to the river. This can also help to reduce fine sediment influx into the channel during this very low flow period when adequate sediment transport capacity is not available in the channel, to prevent deposition of the fine sediment. There is also no obvious benefit of allowing reverse flow from a basin benefit perspective.
- When the MR flow is between 350,000 to 450,000 cfs, the diversion gates may be all opened to allow flushing flow for at least 7 days.
- A minimum of 10,000 cfs diversion flow is needed to flush the channel over 7 days, with a flow exceeding 15,000 cfs considered ideal following a long (2-3) months depositionary period.
- Salinity modeling is ongoing to understand basin side effects on salinity for the three scenarios explored here.
- The modeling here does not consider any consolidation of the fine sediment within the base flow period. Consolidated sediment critical shear stress of erosion can be as much as 5-6 times the critical shear stress of unconsolidated fine sediment, which may become harder to erode as was found in channel berm deposition modeling conducted before in 60% design. It is advised that during the initial years of operation, the channel be surveyed and sediment and geotechnical data collected from the bed, following the base flow period, to further understand whether consolidation is present and if it can be prevented by a more frequent flushing regime, provided the river allows the desired flushing frequency and capacity.

Additional Slides from Past Presentations (For Discussions Only)

Premise for 5,000 cfs Base Flow Recommendation by The Water Institute

- Messina, F. and Meselhe, F. (2017). *TO46: Mid-Barataria Optimization Plan: Base Flow Option*. Tech Memo submitted to CPRA. The Water Institute at the Gulf.
 - “The analyses considered a scenario without the diversion and five values of base flow (0 cfs, 1,000 cfs, 2,500 cfs, 5,000 cfs and 10,000 cfs) with a trigger discharge of 450,000 cfs in the Mississippi River...This study predicts that the diversion base flow would have small impacts on salinity, and the different diversion operations showed similar trends with respect to reference conditions without the diversion in both years modeled.”
- Meselhe, E., Sadid, K., Messina, F. and Jung, H. (2017). *TO46: Basin-wide Delft Evaluation of Diversion Operations (Production Runs 11-15)*. Tech Memo submitted to CPRA. The Water Institute at the Gulf.

Table 8: Predicted land gain, land sustained and land loss (in acres) for Future With Projects without Base Flow (PR13) referenced to Future Without Project (PR14).

Land change for Mid-Diversions (PR13) compare to PR2		Year 10 (2030)	Year 20 (2040)	Year 30 (2050)	Year 40 (2060)	Year 50 (2070)
Barataria	Land gain	2,025	5,943	9,765	12,493	14,179
	Land loss	338	1,311	3,220	4,537	3,707
	Land sustained	1,157	3,409	6,532	13,229	19,214
	Net change	2,844	8,041	13,077	21,185	29,686

Table 9: Predicted land gain, land sustained and land loss (in acres) for Future With Projects with Base Flow (PR15) referenced to Future Without Project (PR14).

Land change for Mid-Diversions (PR15) compare to PR2		Year 10 (2030)	Year 20 (2040)	Year 30 (2050)	Year 40 (2060)	Year 50 (2070)
Barataria	Land gain	3,012	7,300	11,842	30,381	16,306
	Land loss	370	1,375	3,334	14,590	3,609
	Land sustained	1,706	4,343	7,562	4,445	24,015
	Net change	4,348	10,268	16,070	15,790	36,713

PR 15 (with 5,000 cfs Base Flow when MR flow is below 450,000 cfs) predicted a ~24% increased land area built/sustained in the Barataria Basin over PR13 (with no base flow) over 50 yrs.

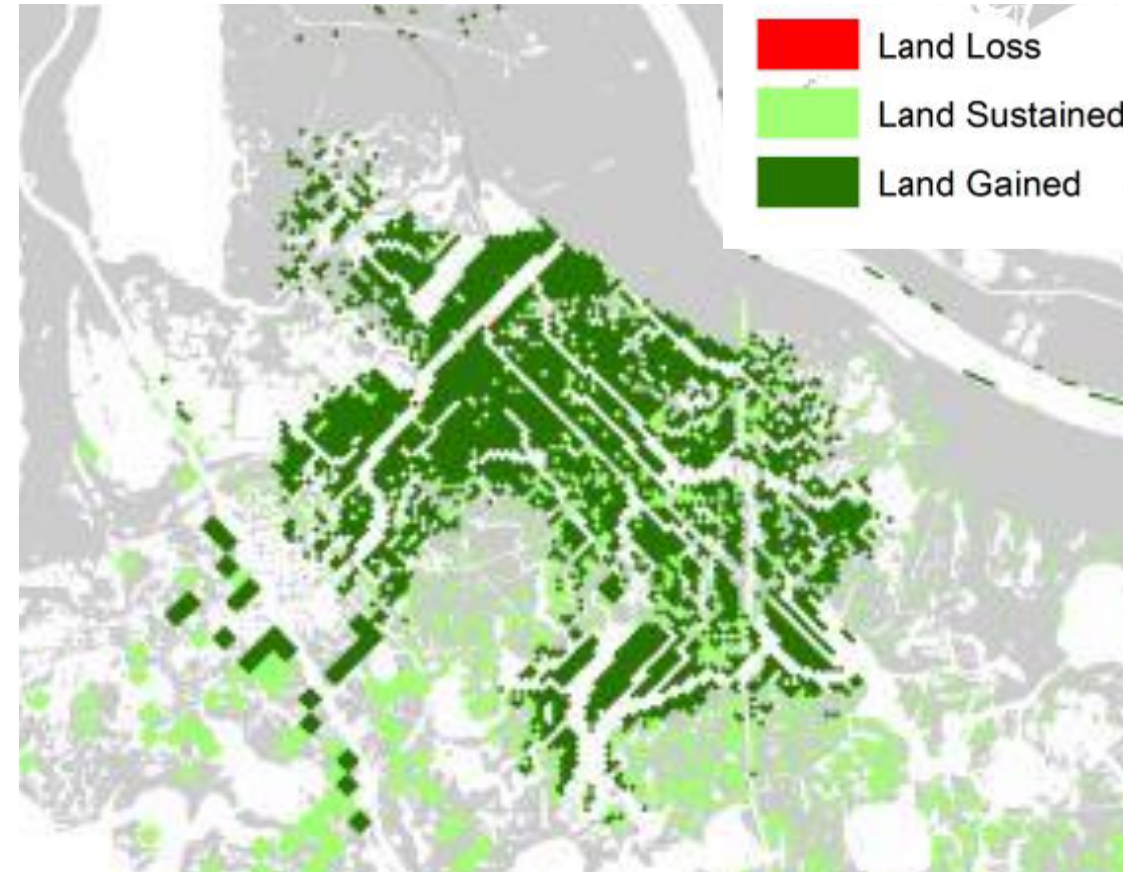
- FTNOMLV-CONSOL Phase 1 modeling considered 5,000 cfs constant base flow when MR <450,000 cfs according to CPRA/WI’s recommendation.

Land Change Near the MBSD Outfall: WI Modeling

PR 13 (No Base Flow) 2070



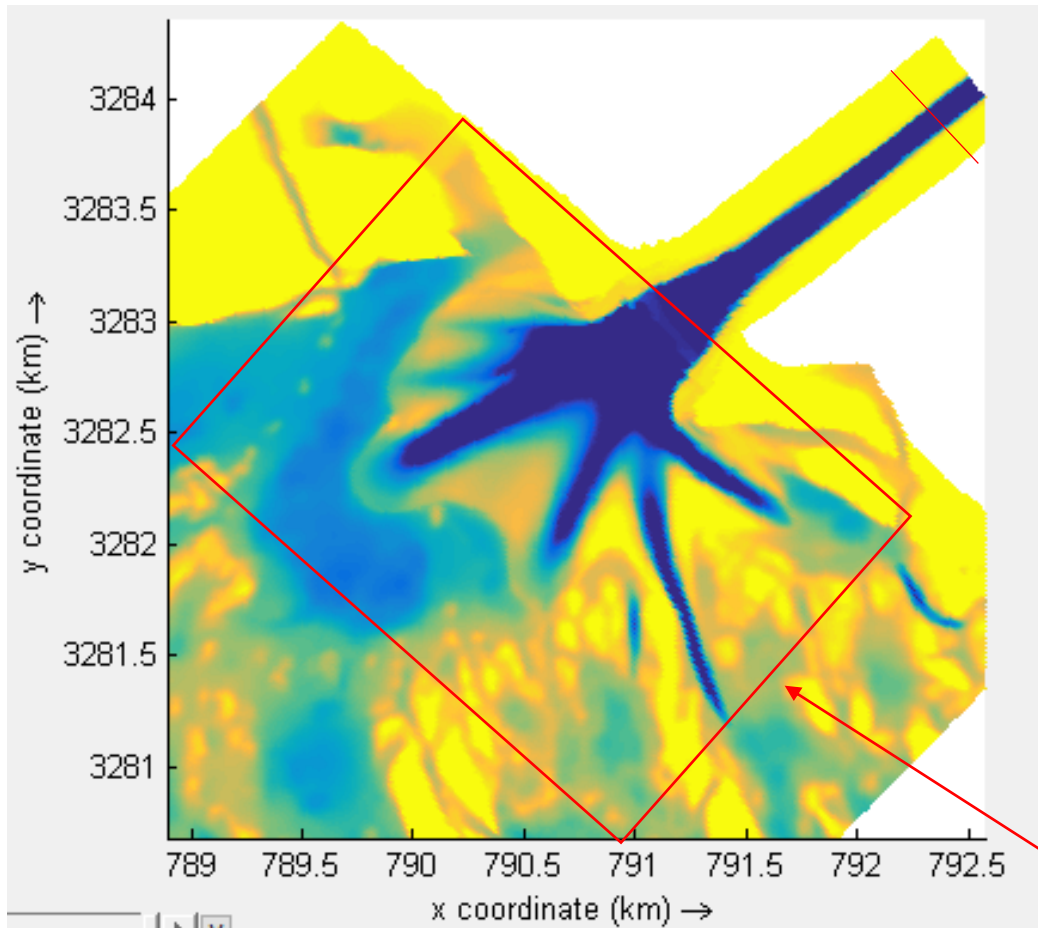
PR 15 (With 5,000 cfs Base Flow) 2070



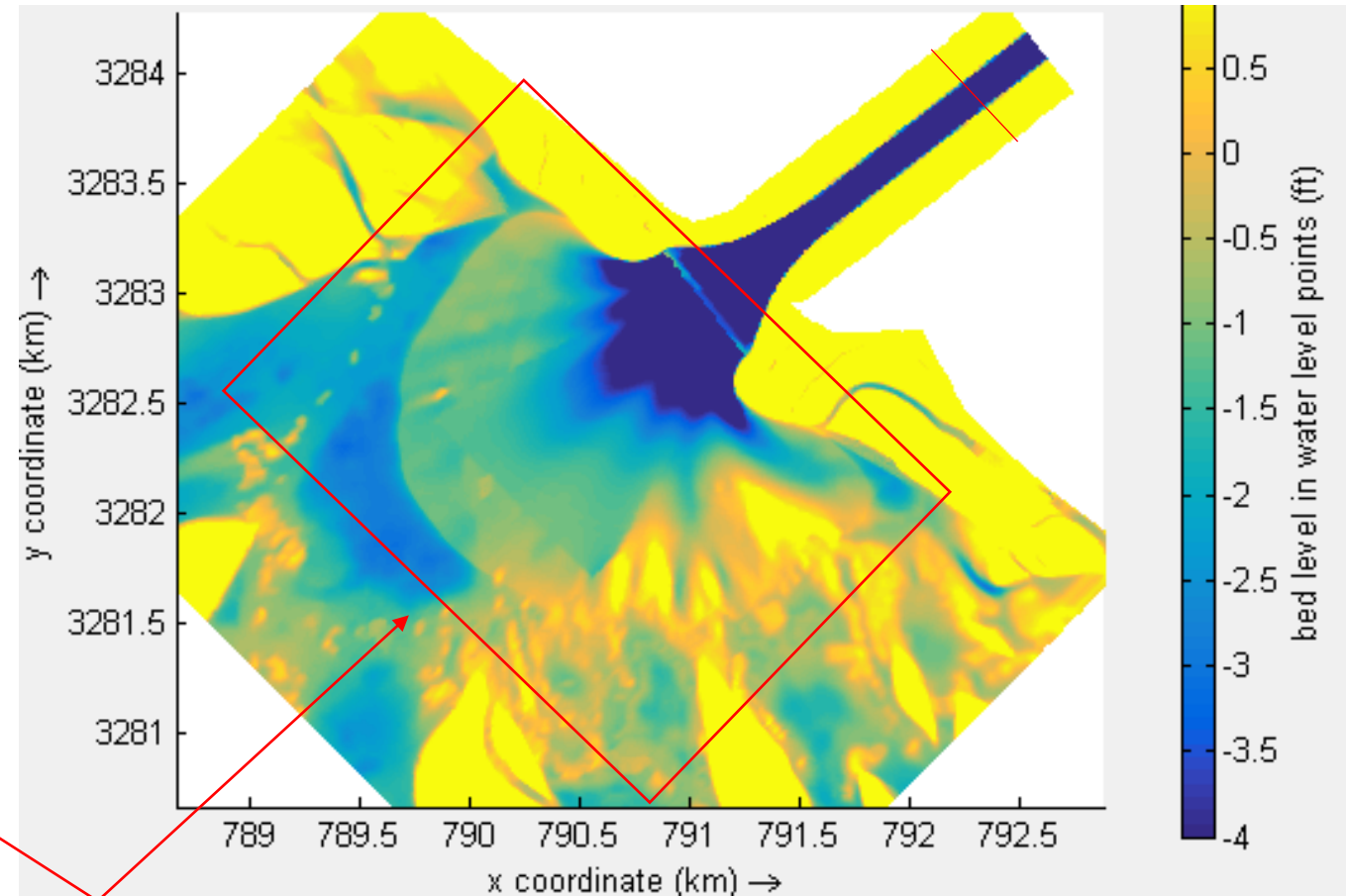
Insufficient Resolution Near the Diversion OTF to adequately capture near-field effects. Also not a head driven system.

Findings from FTNOM-LV-CONSOL Phase 1 Model: Increased deposition proximal to the OTF and constriction of the 2D flow spreading in the basin

With 5,000 cfs Base Flow (2025)

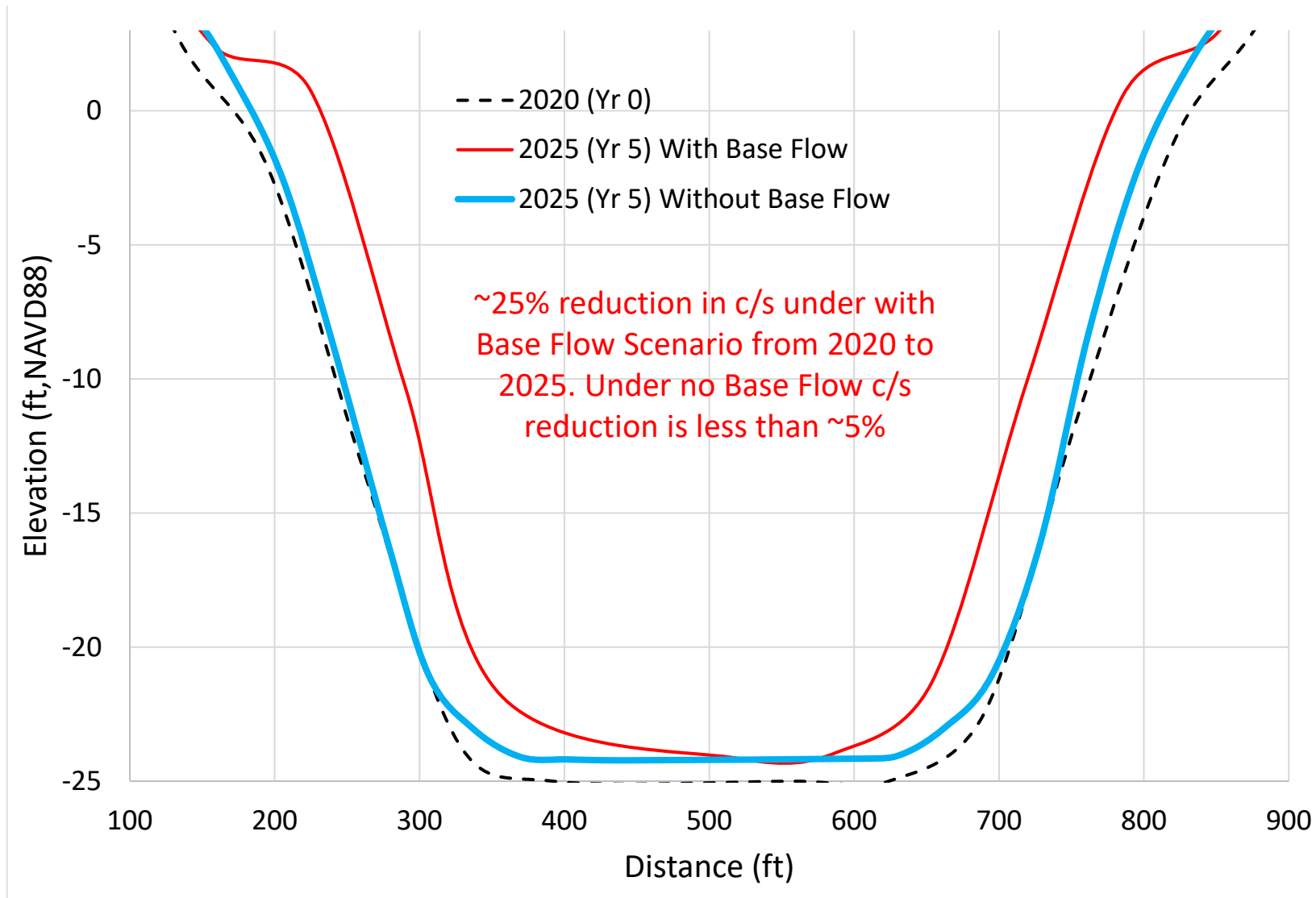


Without Base Flow (2025)



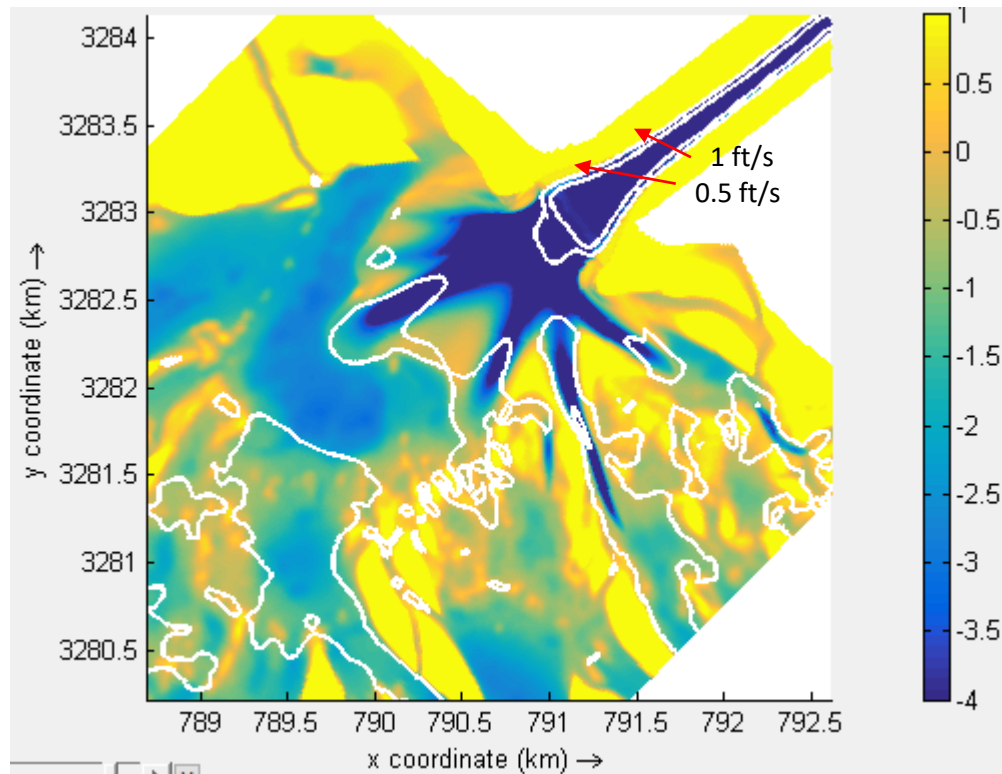
~0.4 ft of additional mean deposition with Base Flow from that without. Fingerlike projections of deltaic channels also start to form which decreases the c/s area of flow emanating from the OTF and causes increased flow resistance in base flow scenario.

Findings from FTNOM-LV-CONSOL Phase 1 Model: Deposition in Conveyance Channel Reduces Cross-section by about 25% in 5 years if not dredged



Flushing Flow Required with Base Flow of 5,000 cfs

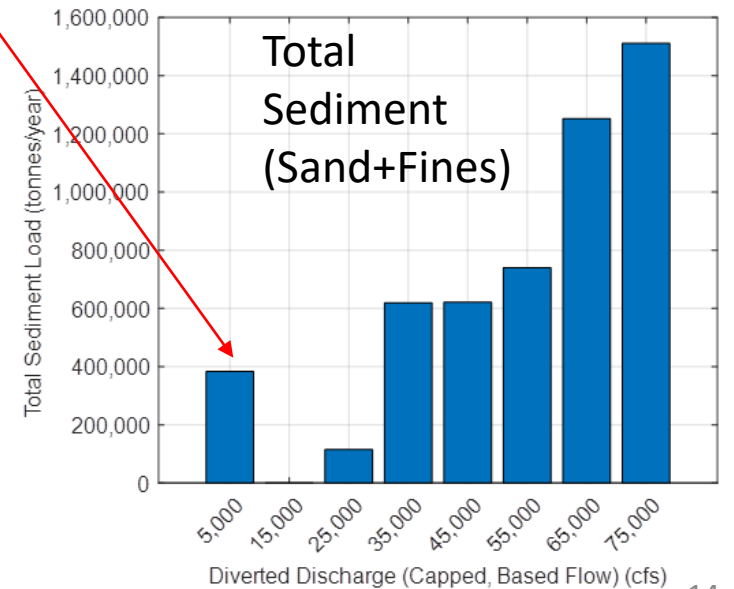
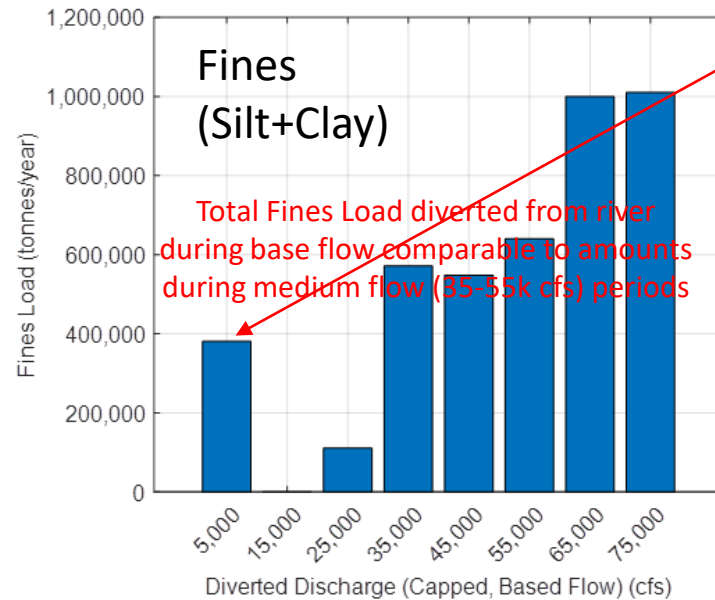
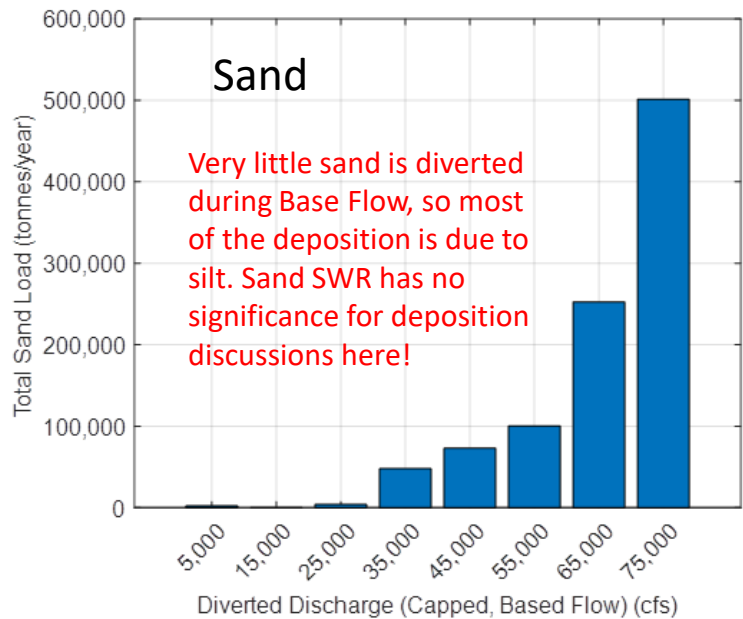
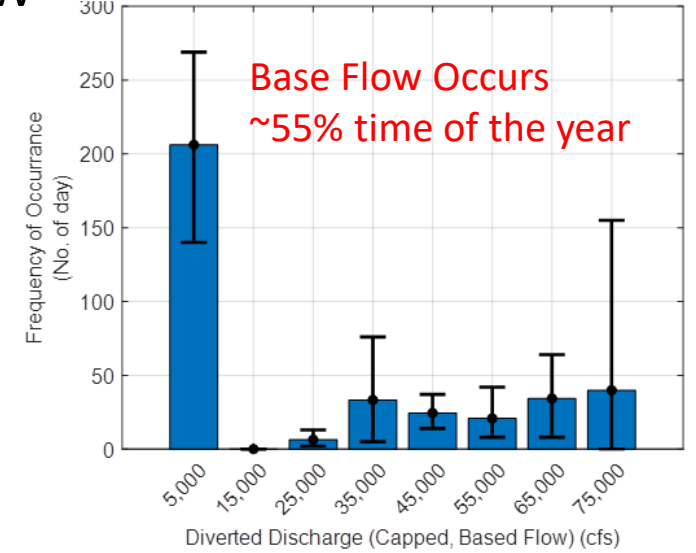
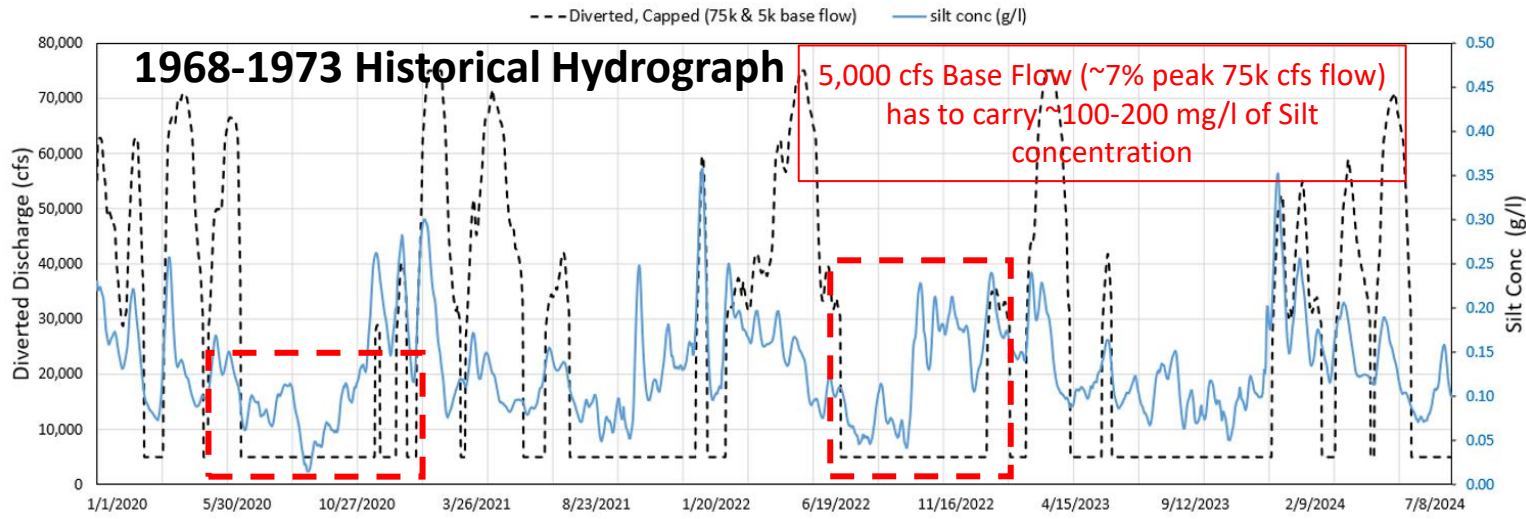
Base Flow Velocity Contours (white lines)
overlaid on Bathymetry (Colored Contours)



- Velocities in channel:
 - Peak Flow: ~ 7 ft/s
 - Base Flow: ~ 1 ft/s
- Velocities at Outfall:
 - Peak Flow: ~ 5 ft/s
 - Base Flow: $< \sim 0.5$ ft/s
- A minimum of ~ 2 ft/s velocity in channel and immediately downstream of the OTF is recommended to keep the zone relatively clear of silt deposition.
- This would indicate a minimum of 20,000-25,000 cfs diversion base flow may be needed, will need to be confirmed by modeling. If this is not possible, operational strategies at Low and Below Trigger flows need to be investigated, eg., flushing flows. Modeling is needed to confirm flows and durations, to be done in 90%.
- Silt also tends to consolidate and gain cohesive strength over time, which can cause faster deposition as it will be more difficult for the peak from to erode the sediment, which is not modeled here.

Why does the Channel and Outfall Show Deposition during Base Flow?

Investigations into Sediment Supply During Base Flow



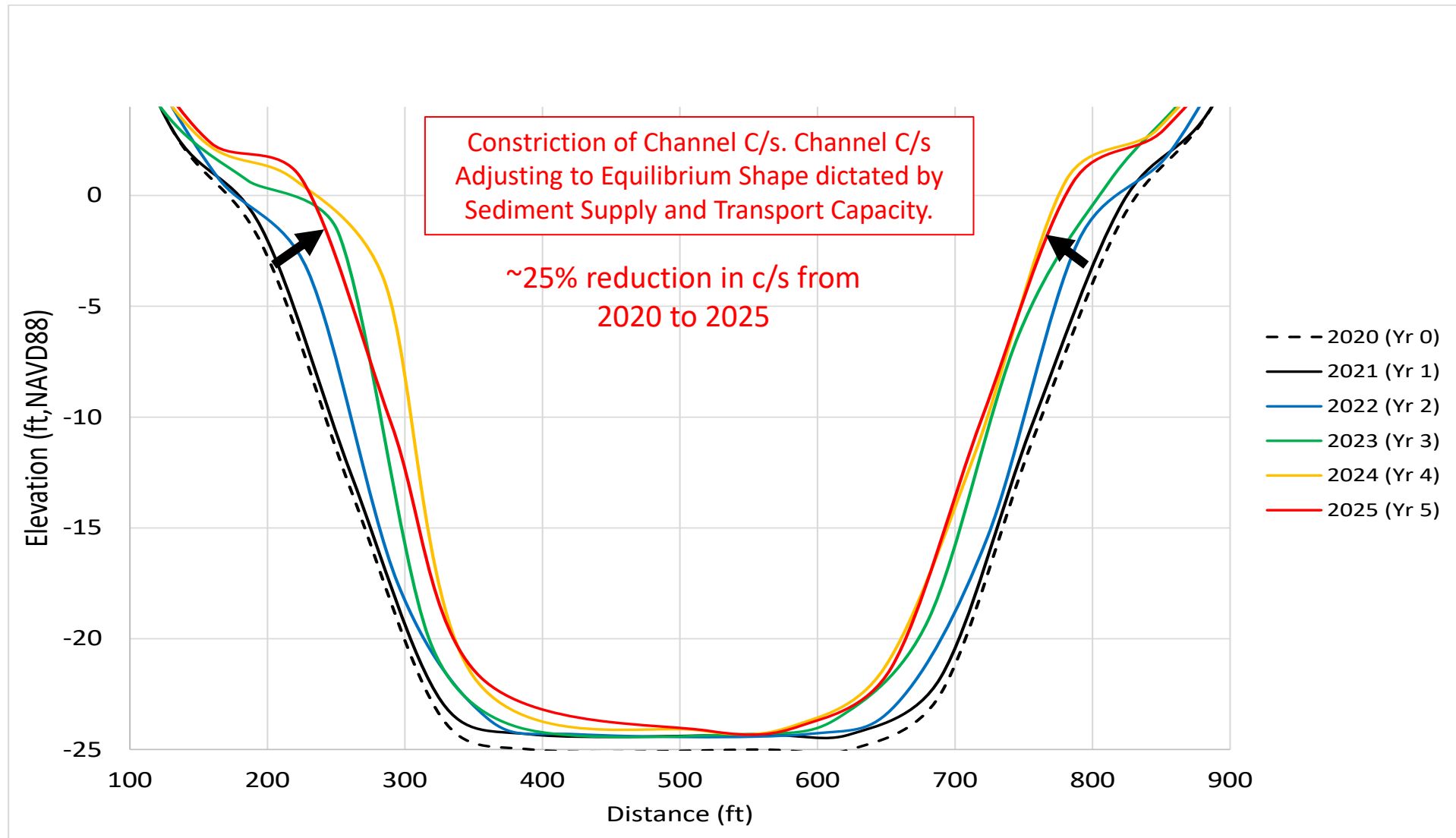
Reduction in Diversion Capacity in 5 Years Due to Base Flow Induced Deposition

Daily MR Discharge u/s MBSD	Daily Diversion Discharge			
	<u>No Deposition in Channel/Outfall</u>	<u>Without Base Flow: Deposition in Outfall and Minimal Deposition in Channel</u>	<u>With Base Flow: (Increased) Deposition in Outfall Only (Channel Dredged)</u>	<u>With Base Flow: (Increased) Deposition Both in Outfall and Channel</u>
(cfs)	(cfs)		(cfs)	(cfs)
450,000	28,500	25,000 (-25%)	24,000 (-16%)	19,000 (-33%)
600,000	45,600	41,700 (-9%)	41,100 (-10%)	31,100 (-32%)
750,000	64,700	58,100 (-10%)	57,300 (-11%)	44,400 (-31%)
900,000	73,700	71,800 (-3%)	70,500 (-4%)	55,000 (-25%)
1,000,000	79,800	77,200 (-3%)	75,600 (-5%)	59,000 (-26%)
1,250,000	94,900	92,900 (-2%)	91,100 (-4%)	69,100 (-27%)

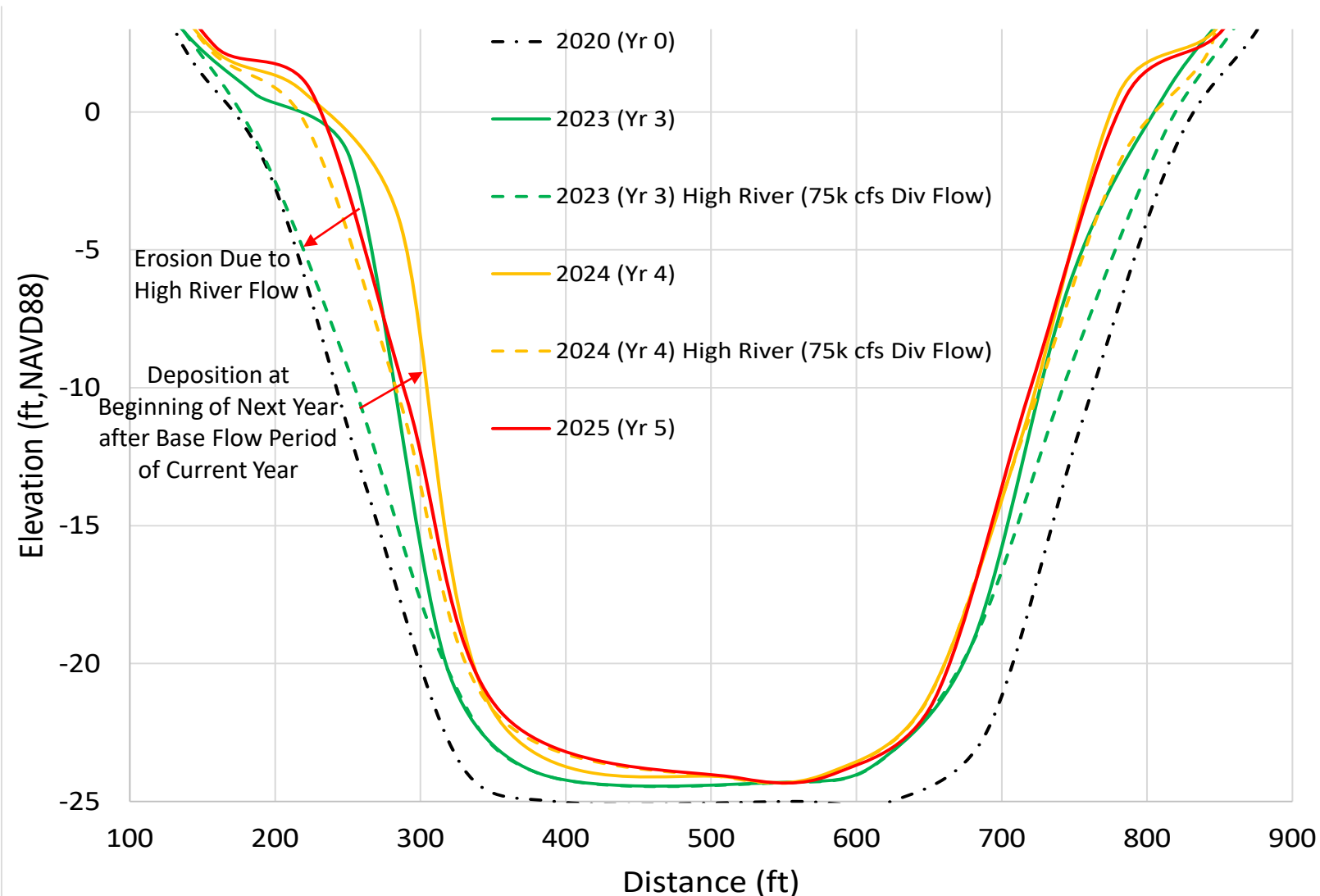
Percentages in parentheses with respect to no deposition in channel/outfall scenario

- Deposition in channel has a much greater influence in reduction of flow capacity (~20-25%) compared to deposition in Outfall only (~5-8%).
- Without Base flow the diversion capacity decrease is lesser than with base flow.

Inter-Annual Channel Cross-section Evolution (2020-2025) with Base Flow



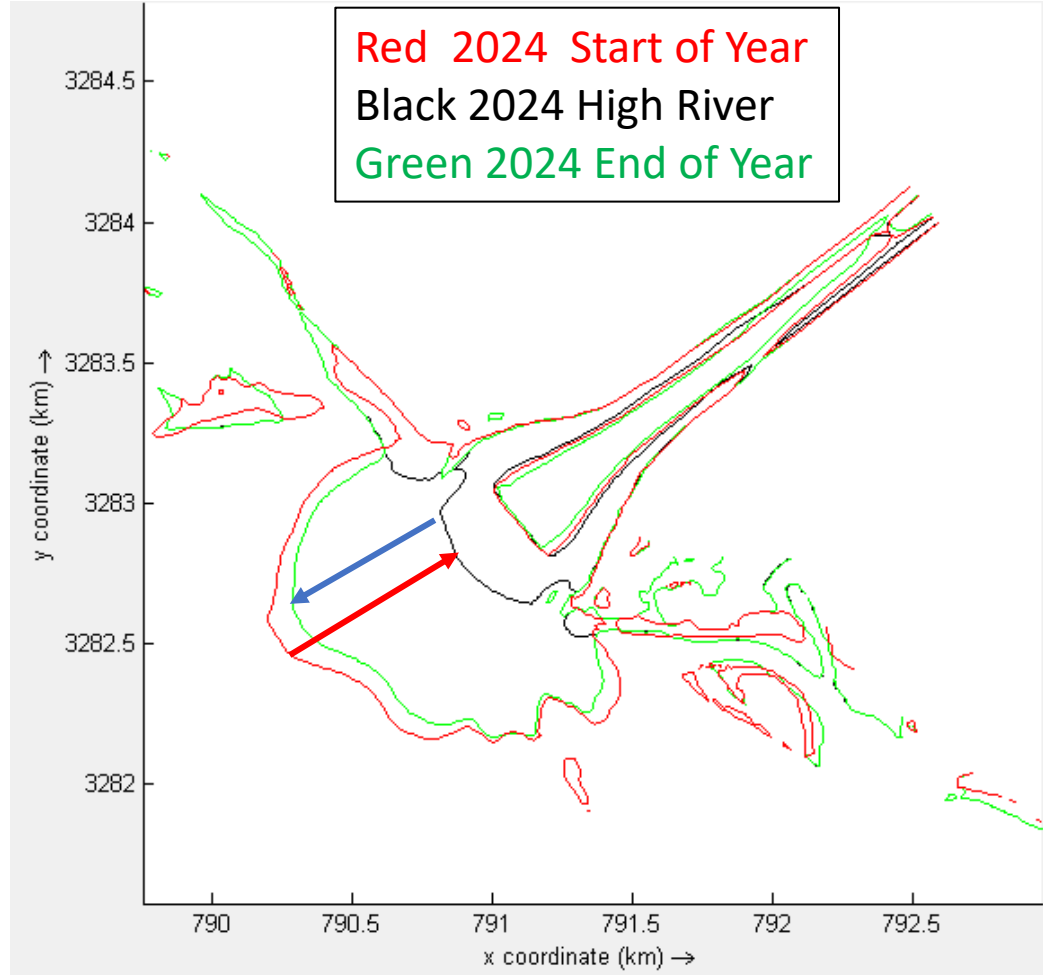
Intra-Annual Channel C/s Evolution: Does the Deposition During Base Flow of Previous Year Get Eroded at High Flow of Next Year?



Yes, at High River some of the deposition (from past base flow) clears itself but new sediment (primarily silt) re-deposits during base flow following the High River period. Over time the deposition (deposition during base flow) exceeds the erosion (during High Flow) in the channel leading to a overall aggradational channel c/s. There seems to be some equilibrium establishing though as rate of reduction in c/s is slowing down. However a 25-30% reduction in c/s maybe unavoidable if base flow is maintained. More investigation needed to see when equilibrium is reached.

Intra-Annual Outfall Sand/Silt Extents Evolution: How does the OTF sediment distribution change in top layer?

Silt



Sand

