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Technical Assessment of the Old, Mississippi, Atchafalaya, and Red (OMAR) Rivers: HEC-RAS BSTEM Analysis of the Atchafalaya River

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Technical Assessment of the Old, Mississippi, Atchafalaya, and Red (OMAR) Rivers

HEC-RAS BSTEM Analysis of the Atchafalaya River

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Abstract

This report documents the bank erosion modeling performed under Task 6 (HEC-RAS Sediment Modeling) of the Old, Mississippi, Atchafalaya, and Red (OMAR) Rivers System Technical Assessment. The objectives of the bank erosion modeling effort were to compare the relative impact various flow scenarios might have on bank retreat on a stretch of the Atchafalaya River between Simmesport, LA, and the Whiskey Bay Pilot Channel. The effort included compilation of field and soil boring data, selection of bank retreat sites, creation of representative soil profiles for the reach, calibration of soil parameters to measured retreat rates, and modeling bank retreat and volume of material eroded under various flow scenarios. This modeling effort was intended for scenario comparison and should not be used as a prediction of exact rates of bank erosion. The study found that varying the amount of flow entering the Atchafalaya River from the Mississippi River could increase dramatically or significantly reduce the extent of bank erosion, relative to the current management scenario.

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Preface

The investigation documented in this report was conducted for the US Army Corps of Engineers, Mississippi Valley Division (MVD), as part of the Mississippi River and Tributaries Project, under Project No. 478534, and published through the Mississippi River Geomorphology and Potamology (MRG&P) Program. At the time of publication of this report, the MRG&P Program director was Dr. James W. Lewis. The MVD commander was MG Diana M. Holland, and the MVD director of programs was Mr. Edward E. Belk.

The work was performed by the River and Estuarine Branch of the Flood and Storm Protection Division, US Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL). At the time of publication of this report, Mr. David P. May was chief of the River and Estuarine Branch, and Dr. Cary A. Talbot was chief of the Flood and Storm Protection Division. The deputy director of the Coastal and Hydraulics Laboratory was Mr. Keith W. Flowers, and Dr. Ty V. Wamsley was the director.

The commander of ERDC was COL Christian Patterson, and the director was Dr. David W. Pittman.

1 Introduction

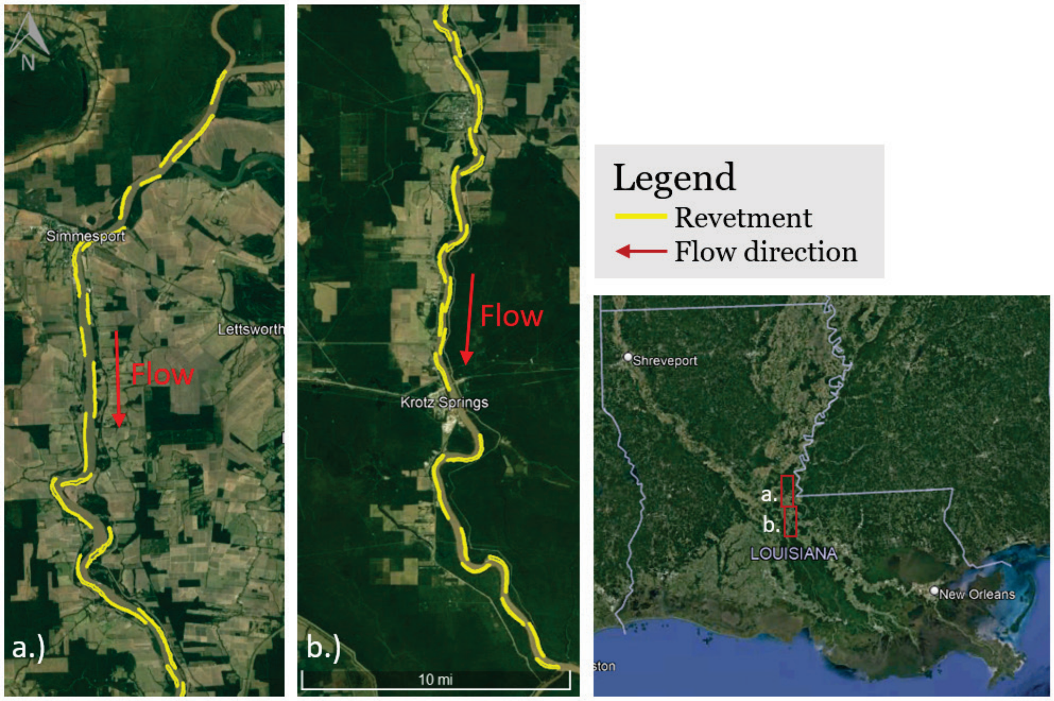
The Mississippi River Basin has changed dramatically over time due to man-made and natural causes since settlement of the basin. These adjustments have had cascading impacts that continue to act upon the river, its tributaries, and its distributaries. The focus of this report is the Atchafalaya River, a distributary of the Lower Mississippi River. The Atchafalaya River is composed of flows from the Red and Black Rivers plus a portion of the Mississippi River flow regulated by the Old River Control Structure (ORCS). The individual structures of the ORCS were built in various stages between 1959 and 1986. The ORCS maintains the Mississippi in its current alignment and controls flow releases into the Atchafalaya to prevent the Mississippi from shifting to the preferential path of the present Atchafalaya Floodway.

The Old, Mississippi, Atchafalaya, and Red (OMAR) Rivers System Technical Assessment, of which this report is a subset, is intended to provide a review of the historical behavior of this area, a critical assessment of the performance of the ORCS and surrounding systems, and a prediction of future performance and impacts. The OMAR Assessment consisted of data collection, modeling, and assessment to develop a comprehensive understanding and provide sound engineering recommendations. As part of the OMAR Assessment, this report documents efforts to look at potential impacts of Atchafalaya River flow regulation on bank erosion in the Atchafalaya River.

1.1 Background

Prior to the OMAR Assessment, there was assumed to be a system-wide problem with the Atchafalaya River widening due to toe scour and subsequent bank failure. The geomorphology task within the OMAR study found that while there was a period of dramatic widening in the early to mid-twentieth century, this behavior has tapered off in the recent decades (Lauth et al. 2022). The trends in width show very slight increases to no change from 1976 to 2019 and overall stability within the reach between Simmesport, LA, and the Whiskey Bay Pilot Channel with very slight periods of erosion and deposition over the aforementioned time period (Little and Biedenharn 2022). Additionally, the majority of the river within the study focus area, from the ORCS to Whiskey Bay Pilot Channel, is revetted on the outside bank of meander bends where erosion would be expected (Figure 1).

Figure 1. Aerial imagery of the study area with revetments shown in yellow. Study area is broken into two sections for ease of viewing with a.) being the upstream half and b.) being the downstream half.



Analysis of satellite imagery and survey data by the Task 2 team revealed that the recent reports of bank failure were localized occurrences rather than a symptom of a system-wide widening issue. However, for additional caution, this study was conducted to test the impact varying flow scenarios may have relative to the existing bank retreat at two representative sites on the Atchafalaya River.

1.2 Objective

The objective of this modeling effort was to compare the relative impact various flow scenarios could have on bank retreat in the upper portion of the Atchafalaya River.

1.3 Approach

This study started by modifying an existing Hydrologic Engineering Center River Analysis System (HEC-RAS) model to use the Bank Stability and Toe

Erosion Model (BSTEM). Once the hydraulic model was calibrated, two sites with measurable bank erosion were modeled using BSTEM within HEC-RAS. Representative soil profiles were developed using a combination of soil boring data and field observations. To account for uncertainty in the available data, two sets of BSTEM parameters were developed to give high and low estimates. The BSTEM model was then run for the various flow scenarios suggested by the OMAR Assessment. In the scenarios, only the flow hydrographs were varied, and the expected impact on sediment transport capacity and sediment load was not simulated.

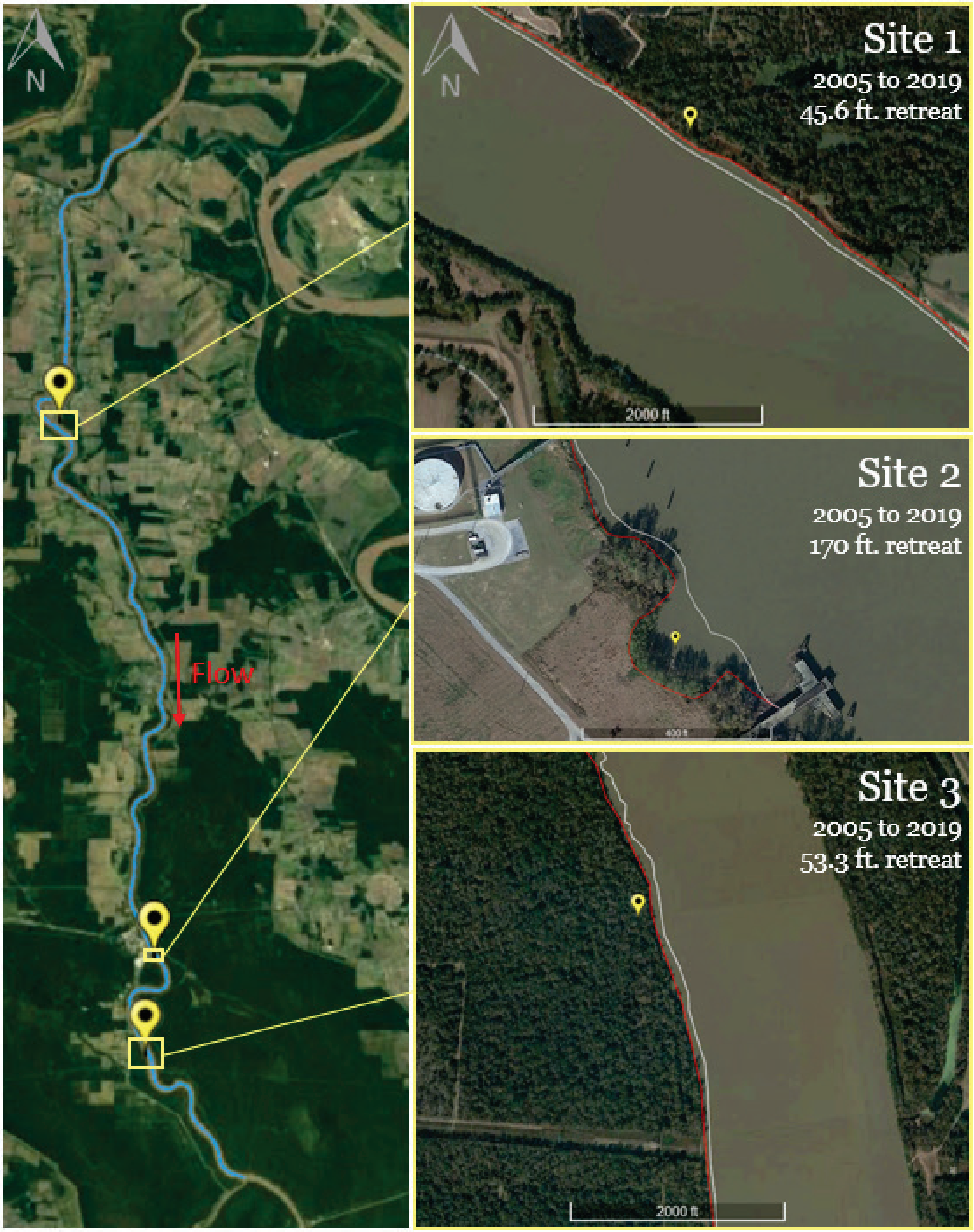
This modeling effort is intended for scenario comparison and not to be used as a prediction of bank erosion for flow scenarios.

2 Methodology

2.1 Site selection

The first step taken by the team was to use Google Earth to investigate the river reach of interest, the Atchafalaya River from Simmesport, LA (just downstream of the ORCS), to Whiskey Bay Pilot Channel. Potential bank erosion modeling sites were identified as locations that were not protected by revetment and where the banks had migrated back gradually, not due to a localized effect. In several locations, localized bank failure was observed just downstream from the end of revetments, likely due to the recirculation off the end of a revetment scouring the unprotected bank. Such cases were avoided in site selection as the BSTEM model simulates the dynamics from toe scour and not scour from secondary currents. Originally, three sites were chosen, but the second site was later disregarded because it was suspected that the failure was due to localized hydraulic effects (Figure 2). Localized scour sites were avoided because the scope of the study focuses on broad impacts of varied flow conditions rather than local impacts due to external drivers such as a structure causing scour. Additionally, the BSTEM model is a one-dimensional (1D) model calculating the factor of safety of the bank given the bank geotechnical components and the hydraulic forcings and is not intended to incorporate local scour from eddies, etc.

Figure 2. Map showing entire study area with the river centerline (blue) from the HEC-RAS model in the left panel and the three sites initially identified with polylines showing the 2005 (white) and 2019 (red) bank lines, with 2019 imagery as base map, in the right panels.



Once the sites were identified, the bank retreat rate was measured from imagery within Google Earth to give an estimate of retreat over a length of bank. Aerial imagery from 2005 and 2019 were compared, and bank lines were delineated by the extent of woody vegetation. Locations of roadways and other permanent features were compared to confirm that there were no issues with imagery georeferencing between imagery datasets for this relative comparison. These permanent features had minimal spatial variations between the aerial photography sets compared with the observed bankline movement. A line was drawn along the bank that extended the length between revetments. In the case of Site 1, the bank line began after the bend, on the point bar side, and then extended to the next revetment. To calculate overall bank retreat distances over the length of bank being measured, a polygon was drawn using the delineated bank locations. The area of the polygon was divided by the average length to get an average bank retreat distance over the 14 yr[1] period. The bank lines and polygons were delineated at a consistent scale (~4000 ft(2) eye altitude elevation in Google Earth) across the time periods and between sites for congruency.

2.2 Bank sample analysis and creation of representative bank profiles

The goal of the study was not to recreate existing conditions within the Atchafalaya River at specific sites but rather to test the flow scenarios on a representative bank soil profile. The Atchafalaya has historically been a very dynamic alluvial system, and there is significant spatial variability of materials because of this (Fisk 1952). Data were compiled from bore logs provided by the US Army Corps of Engineers (USACE), New Orleans District (MVN), and from several soil samples taken by the US Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), team during a site visit in October 2020 and analyzed by ERDC CHL Field Data Collection and Analysis Branch. Based on the observations and gradations, representative soil types and layers were identified and given elevations that aligned with the locations of the sites within the model. The bore logs recorded material at depths relative

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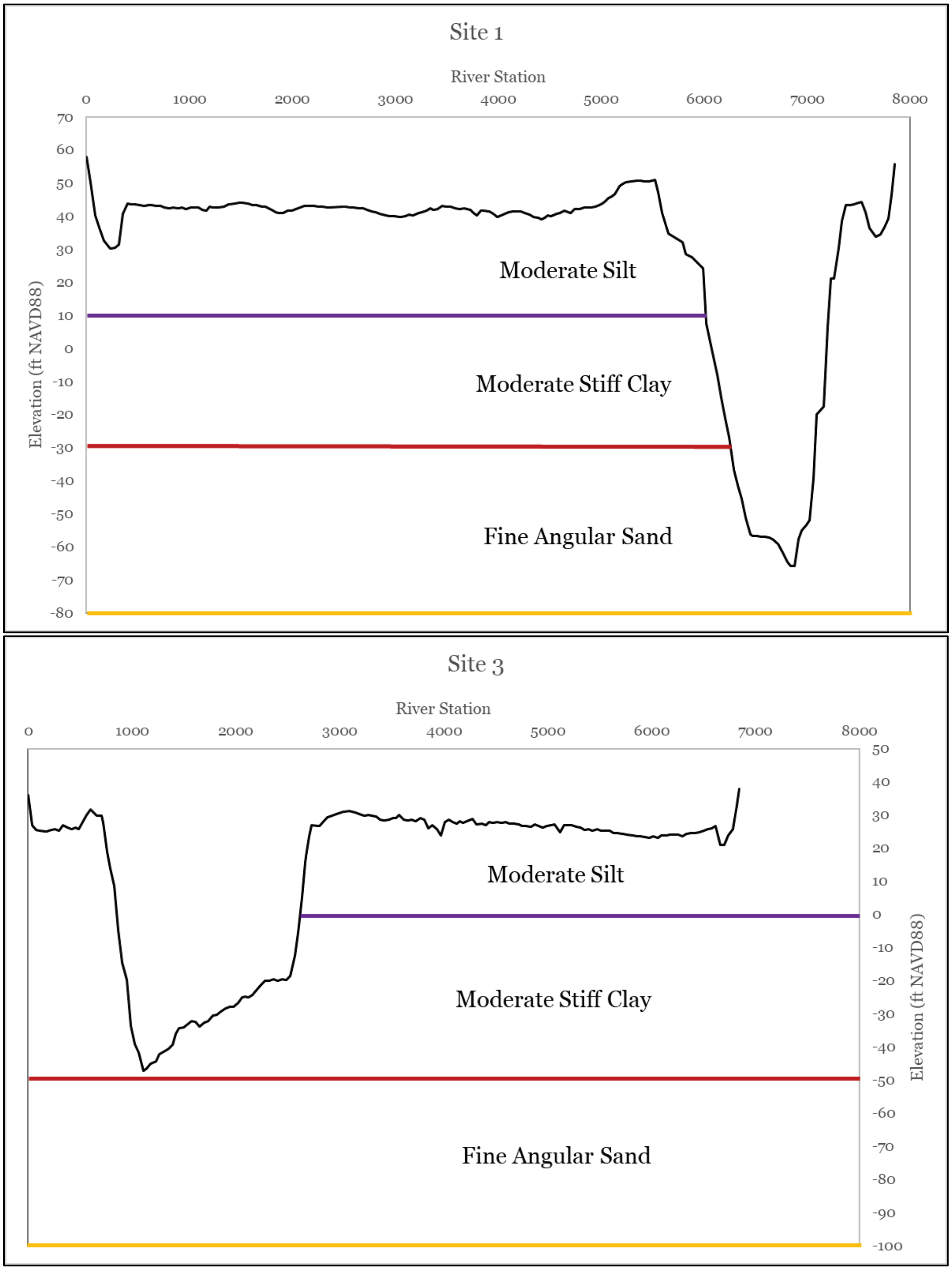
[1] For a full list of the spelled-out forms of the units of measure used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 248-52, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

(2) For a full list of the unit conversions used in this document, please refer to *US Government Publishing Office Style Manual*, 31st ed. (Washington, DC: US Government Publishing Office 2016), 345-7, https://www.govinfo.gov/content/pkg/GPO-STYLEMANUAL-2016/pdf/GPO-STYLEMANUAL-2016.pdf.

to the ground elevation where they were collected. To use these data to create a bank soil profile, the depths were first converted to elevations relative to NAVD88, and the descriptions given in the bore logs were considered as well as the soil description and gradation from bank samples collected from the site during the field visit. For Site 1, the four nearest bore logs (from approximately 3,000 to 4,000 ft from the site) plus the closest site from the same side of the river (approximately 7,000 ft away) were closely considered, plus bore logs from adjacent bends and the field visit bank samples, to determine a representative soil layering and depths for the reach. Site 3 followed a similar approach using the two nearest bore logs from the same side of the river (1,800 to 4,000 ft away from the site) and the next two nearest (1,400 to 1,800 ft away), plus bore logs from adjacent bends and the field visit bank samples, to determine a representative soil layering and depths for the reach. The resultant profiles consisted of three layers, with the top being a layer of silt, followed by a layer of clay, followed by a bottom layer of sand that extended beyond the depth impacted by the model (Figure 3).

Figure 3. Soil profile material types and elevations determined from the bore logs and field samples and used in the BSTEM model.

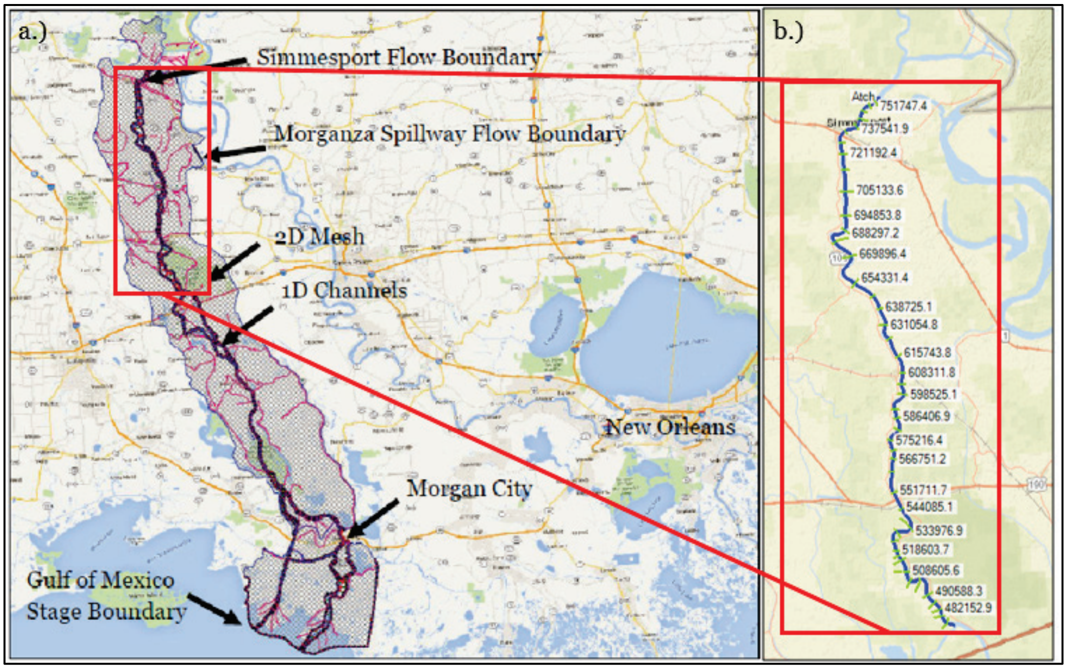


2.3 Hydrologic Engineering Center River Analysis System (HEC-RAS) model domain and inputs

The model of choice for this study was the BSTEM, a module within the HEC-RAS 1D sediment model. BSTEM was initially created by the United States Department of Agriculture, Agricultural Research Service, as an Excel-based model to calculate factors of safety based on bank material characteristics and hydraulic conditions (Simon et al. 2011; Langendoen and Simon 2008). The USACE integrated BSTEM into HEC-RAS to utilize the hydraulics within the HEC-RAS model, with the added option of placing failed material into the sediment load of the HEC-RAS 1D Sediment model (Gibson et al. 2015; USACE 2015). The results are highly dependent on the various soil parameters required as inputs. Idealized soil types with accompanying parameters and generalized gradations are available to the user within HEC-RAS, but calibration is needed to reflect actual conditions.

An existing HEC-RAS model of the Atchafalaya River was used as the basis for the BSTEM analysis. This model was built by MVN and documented in the Mississippi River and Tributaries Flowline Assessment Hydraulics Report (Lewis et al. 2018). It was built in HEC-RAS 5.0.3, and the original domain covered the entire Atchafalaya Floodway with the upstream boundary of ORCS and the downstream boundary of the Gulf of Mexico via the Atchafalaya River and the Wax Lake Outlet Channel. The channels were 1D cross sections connected to the two-dimensional (2D) overbanks via lateral structures (Figure 4a). For this study, the model was cut down to the 1D main channel to use BSTEM within the HEC-RAS 1D Sediment model. Additionally, the model was trimmed to the area of interest, Simmesport, LA, to the Whiskey Bay Pilot Channel, and converted to HEC-RAS Version 6.1, the most recent version at the time of this study (Figure 4b).

Figure 4. Model domain of a.) the source 1D/2D model provided by the USACE MVN and b.) the trimmed 1D portion used for the BSTEM analysis.



2.4 Hydraulic model calibration

The smaller, strictly 1D model was then recalibrated hydraulically for a range of six flows by adjusting the Manning's *n* roughness coefficients in the channel and overbank (Table 1) and varying roughness with flow (Table 2). The flow-varying roughness factors were selected to improve the hydraulic calibration results with the goal of keeping modeled stages within 5% of the observed. Increased roughness factors for flows from 250k cfs to 500k cfs produced better matches to gaged water levels. This is likely due to the substantial interaction with the floodplain that occurs at these flows.

Table 1. Final Manning's roughness values for each cross section after hydraulic calibration.

River Station	LOB	CH	ROB	River Station	LOB	CH	ROB
751747.4	0.075	0.035	0.075	590334.6	0.075	0.029	0.075
748763.5	0.075	0.035	0.075	586406.9	0.075	0.029	0.075
744971.8	0.075	0.035	0.075	580908.3	0.075	0.029	0.075
741341.1	0.075	0.035	0.075	575216.4	0.075	0.029	0.075
737541.9	0.075	0.035	0.075	570457	0.075	0.029	0.075
732010.6	0.075	0.035	0.075	566751.2	0.075	0.029	0.075

Table 1. (cont.) Final Manning's roughness values for each cross section after hydraulic calibration.

River Station	LOB	CH	ROB	River Station	LOB	CH	ROB
726305.1	0.075	0.035	0.075	561101.4	0.075	0.029	0.075
721192.4	0.075	0.035	0.075	551711.7	0.075	0.028	0.075
714391.8	0.075	0.035	0.075	544085.1	0.075	0.028	0.075
705133.6	0.075	0.034	0.075	533976.9	0.075	0.028	0.075
694853.8	0.075	0.032	0.075	527604.6	0.075	0.028	0.075
688297.2	0.075	0.03	0.075	523015.7	0.075	0.028	0.075
679364.6	0.075	0.03	0.075	518603.7	0.075	0.028	0.075
669896.4	0.075	0.03	0.075	516010.9	0.075	0.028	0.075
654331.4	0.075	0.03	0.075	513795.5	0.075	0.028	0.075
645018.3	0.075	0.03	0.075	508605.6	0.075	0.028	0.075
638725.1	0.075	0.03	0.075	503756	0.075	0.028	0.075
631054.8	0.075	0.03	0.075	499431	0.075	0.028	0.075
624356.1	0.075	0.03	0.075	490588.3	0.075	0.028	0.075
615743.8	0.075	0.03	0.075	486029.6	0.075	0.028	0.075
608311.8	0.075	0.03	0.075	482152.9	0.075	0.028	0.075
603054.6	0.075	0.029	0.075	479361.5	0.075	0.028	0.075
598525.1	0.075	0.029	0.075	475518.4	0.075	0.028	0.075

Table 2. Flow varying roughness factors assigned during hydraulic calibarion.

Flow (cfs)	Flow Varying Roughness Factor
0	1
100000	1
250000	1.2
500000	1.05
700000	1

The upstream boundary condition was a flow hydrograph from the USACE gage at Simmesport (USACE gage 03045Q), and the downstream boundary condition was a stage hydrograph at the USACE gage at Whiskey Bay Pilot Channel (USACE gage 03240). The calibration was checked by running steady-state flow and comparing the stage at three gages within the model domain: Simmesport (USACE gage 03045), Melville (USACE gage 03060), and Krotz Springs (USACE gage 03075). The gage locations and comparison of observed versus modeled data are shown in Table 3.

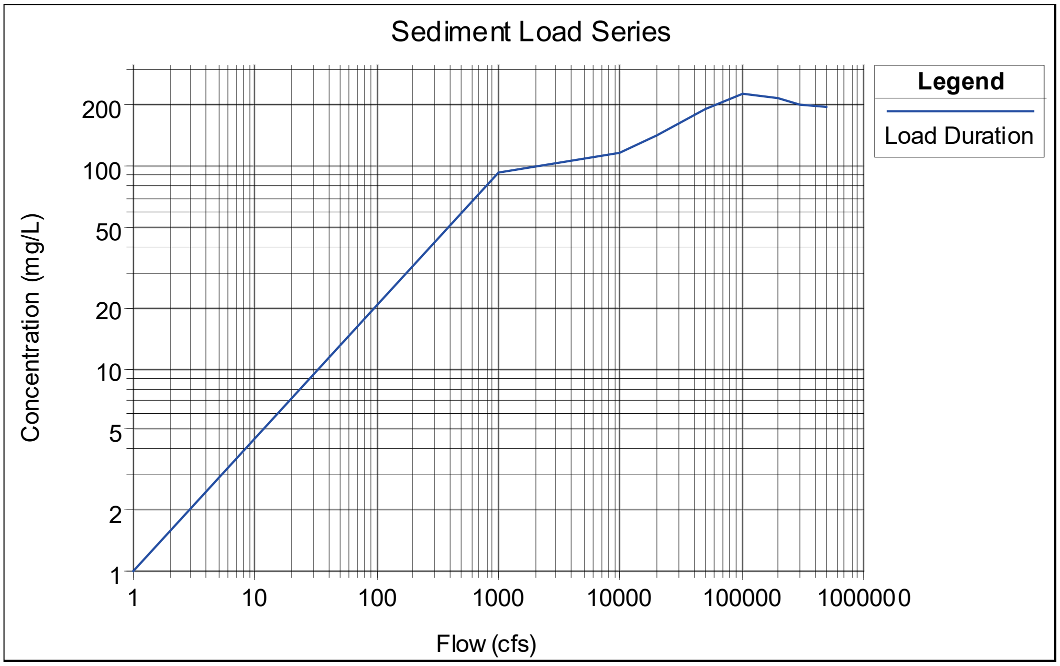
Table 3. Locations of model boundaries and gages used for data input and model calibration (left) and the comparison of results to modeled water surface elevation (WSE) after hydraulic calibration (right). The darker cells indicate a greater difference in water surface elevation with blue meaning the modeled stage is higher than observed and red indicating the opposite.

	Flow (cfs)	Simmesport - RS 714391.8			Melville - RS 608311.8		
		Observed	Modeled	Percentage Difference (%)	Observed	Modeled	Percentage Difference (%)
		WSE (ft)			WSE (ft)		
	694,000	44.82	44.63	-0.3	35.47	35.59	0.7
	581,000	39.82	39.66	-0.4	30.89	30.94	0.2
	495,000	36.46	35.62	-2.5	27.52	27.62	-0.1
	349,000	27.95	28.37	2.1	21.36	21.16	0.3
	207,000	16.45	16.80	5.0	11.68	11.38	3.5
	103,000	7.62	7.69	-3.0	5.30	5.55	-2.5
	Flow (cfs)	Krotz Springs - RS 561101.4			Whiskey Bay Pilot Channel - RS 475518.4		
		Observed	Modeled	Percentage Difference (%)			
		WSE (ft)			WSE (ft)		
	694,000	31.86	32	0.8	25.73		
	581,000	27.69	27.66	0.0	21.81		
	495,000	24.48	24.73	0.4	19.51		
	349,000	19.13	18.84	0.1	15.35		
	207,000	10.62	10.01	1.5	8.69		
	103,000	4.86	5.18	-1.4	4.22		

2.5 BSTEM calibration

As previously mentioned, BSTEM is equipped with default soil parameters for various soil types that can be found in the BSTEM User's Guide (USACE 2015). While these values are satisfactory estimates, the soil characteristics can vary greatly by site and spatially within a site, so calibration is needed. Once the model was calibrated hydraulically, sediment inputs were added to the model. This included the sediment rating curve at the upstream boundary. The curve used was consistent with the concurrent sediment modeling tasks within the OMAR Assessment (Figure 5) (Donohue et al. 2022).

Figure 5. Sediment rating curve provided at the upstream boundary of the model domain.



As previously mentioned in Section 2.2, bore log data, site visit observations, and field samples were used to create representative soil profiles of the river reaches being analyzed. The soil profiles were assigned to the cross sections nearest the selected sites: River Station 679364.6 for Site 1 and River Station 508605.6 for Site 3 (Figure 2; Figure 3).

The typical method for calibrating a HEC-RAS sediment and BSTEM model is to calibrate the sediment transport first before adding bank data. Then the bank processes are isolated by assigning the cross sections as *pass-through nodes* to effectively turn off the sediment transport. The BSTEM model is then calibrated to observed bank retreat rates. Finally, the combined HEC-RAS and BSTEM models, without pass-through nodes, are run in unison. Since the objective of this study was to identify bank stability and toe erosion in response to varying flow conditions, the sediment model was not calibrated or utilized in the simulations. Instead, the cross sections were assigned as pass-through nodes for the entirety of the study, effectively ignoring sediment transport in the main channel and isolating the bank processes. Additionally, since the gradation data are used in the sediment model when soil is eroded or fails and is added to the sediment load, gradations are not necessary for this study. The bed gradation input was taken from samples collected by MVN in 2020, and the bank soil was assigned the default gradations provided in the model. While these gradation data are likely realistic for the system, the model does not utilize them in the BSTEM analysis, and the values should not impact the results.

The flows used for the BSTEM model calibration are the measured flows at the Simmesport Gage (USACE gage 03045Q) from 2005 to 2019, as this is the time period that corresponds to the aerial imagery used to estimate bank retreat rates (Figure 6). The temperature data were compiled from measurements taken at four gages within the study reach (Old River Outflow Channel USACE 02600, Simmesport USACE 03045, Simmesport USGS 07381490, and Melville USGS 07381495) with any missing values interpolated temporally (Figure 7).

Figure 6. Streamflow recorded at Simmesport, LA (USACE Gage 03045Q), during the calibration period from 2005 to 2019.

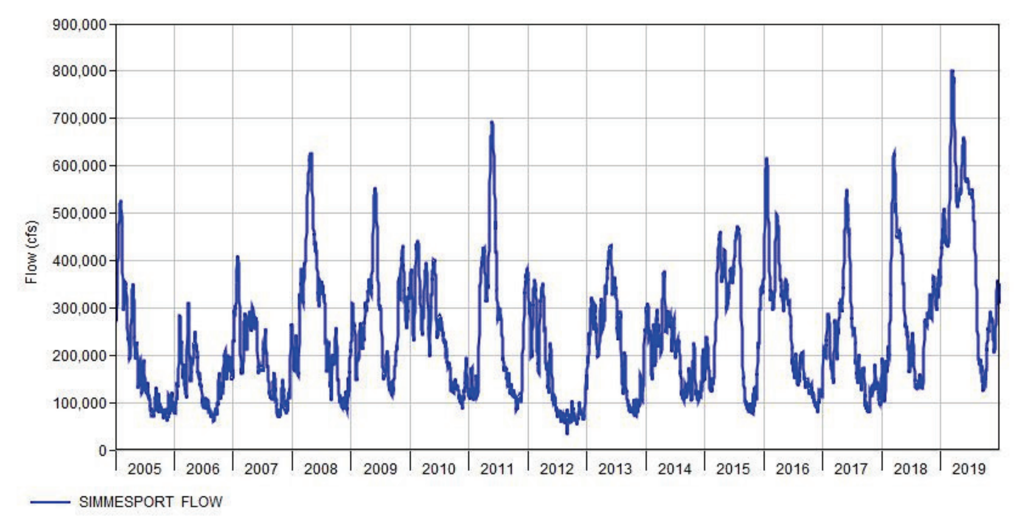
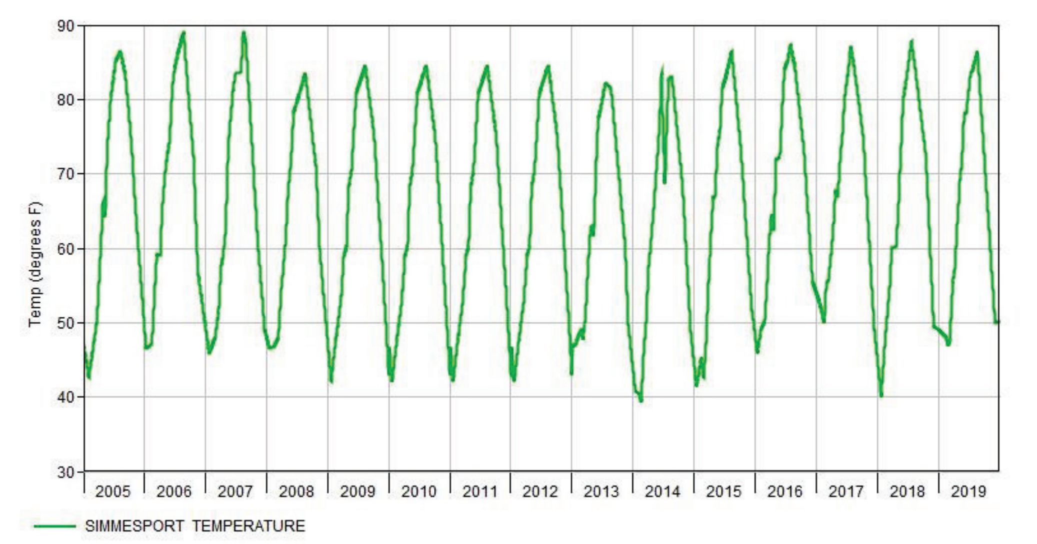


Figure 7. Water temperature assimilated from four nearby gages during the calibration period from 2005 to 2019.



Groundwater data were not available; therefore, several simulations were conducted to interpret the response of groundwater to saturated hydraulic connectivity and groundwater reservoir length to establish values that resulted in a realistic response (Figure 8). Assigned values are listed in Table 4.

Figure 8. Flow and groundwater lag that is due to the selection of values for hydraulic conductivity (k) and reservoir length.

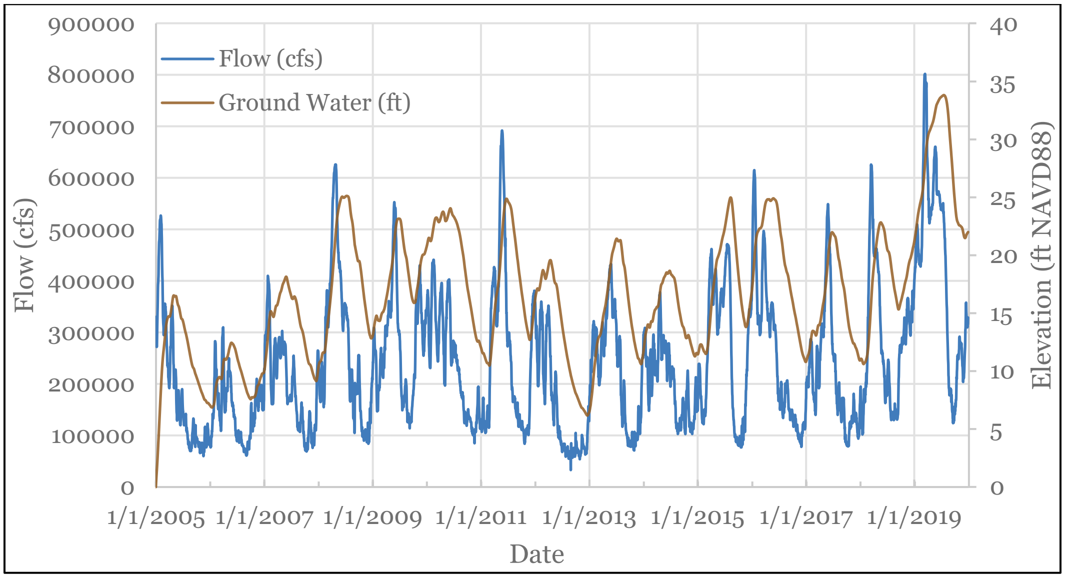


Table 4. Groundwater parameters determined by typical values and sensitivity runs.

Groundwater Parameters			
Site	Soil Layer Type	Saturated Hydraulic Conductivity (K) (ft/day)	Reservoir Length (L) (ft)
Site 1	Moderate Silt	1	100
	Moderate Stiff Clay	0.1	100
	Fine Angular Sand	1	100
Site 3	Moderate Silt	1	100
	Moderate Stiff Clay	0.1	100
	Fine Angular Sand	1	100

Next, the default values for the saturated unit weight, friction angle, cohesion, Φ_b (the angle representing the relationship between shear matrix suction and apparent cohesion), critical shear stress, and erodibility were initially used within the model to evaluate how these would perform in capturing the observed bank retreat. Each site was investigated independently, both because of the difference in observed behavior and the spatial heterogeneity of the bank materials. Bank retreat was severely overpredicted, so a sensitivity analysis was conducted to investigate the role the parameters played on toe erosion and bank failure. Initially, the cohesion and friction angle were altered resulting in little change to the bank retreat. Next, erodibility was varied, and the bank failure was dialed in to 50 to 100 ft from the observed bank erosion. However, the process was mainly toe scour with one large bank failure event. This was not deemed realistic for the system. Friction angle and cohesion were then decreased to simulate smaller, more frequent bank failures, and erodibility and critical shear were finally dialed back to reach a bank retreat close to the observed range. The sensitivity analysis revealed that the toe erosion was mainly driven by erodibility and critical shear and the bank failure was driven by cohesion and friction angle. Early on, to achieve close to the amount of observed bank retreat, the erodibility needed to be decreased from the default values. This resulted in solely toe erosion for the majority of the simulation with one bank failure event within the last several time steps. While this sudden failure is characteristic of bank failure, analysis of the aerial imagery showed that the banks underwent a few bank failures during the time period investigated, so the model was calibrated to reflect a more realistic response. Two sets of soil parameters were identified at each site that slightly over- and underpredicted the measured bank retreat, and these parameters were used for each flow scenario to get a resultant range of potential responses.

2.6 Model simulations

The model was run using observed flows from the Simmesport gage from January 1, 1990, to December 31, 2019, as the upstream boundary condition for the control scenario and hypothetical flow splits as the upstream boundary conditions for the modeling scenarios (Table 5).

Table 5. Flow scenarios and descriptions provided by the Task 4 sediment modeling team (Brown et al. 2022). Table was modified to add column that describes impact flow split change has on upstream model boundary near Simmesport.

Scenario ID	Brief Description	Full Description	Simplified Impact on Upstream Boundary
Scenario 3	Ratio 1	Ratio 1 as defined in Design Memorandum 17 (USACE 1980): This is a scenario where there is no hydropower, and a large amount of flow goes through the Auxiliary Structure.	Flows mostly the same as actual flows, with high flow peaks in 2016, 2018, and 2019 that exceed the observed by around 100,000 cfs, so hydrograph is slightly flashier during 2016–2019.
Scenario 4	Ratio 1 with Hydropower	Ratio 1 With Hydropower (as defined in Old River Control O&M Manual [USACE 1988]). Hydropower shares with Auxiliary. Low Sill is not used in this scenario. Anything that would go to Low Sill in the table of the O&M Manual will add to Auxiliary instead.	Flows same as Scenario 3.
Scenario 5	60/40 during high flow	60/40 latitude flow distribution during high flow, but 70/30 on a long-term basis through the use of a payback/tracking algorithm.	Higher flow peaks (>300k cfs) exceed actual flows by 50k to 200k cfs, but lower flow peaks (<300k cfs) are less than actual peaks by ~25k cfs. Scenario 5 flows are mostly higher and flashier than actual.

Table 5. (cont.) Flow scenarios and descriptions provided by the Task 4 sediment modeling team (Brown et al. 2022). Table was modified to add column that describes impact flow split change has on upstream model boundary near Simmesport.

Scenario ID	Brief Description	Full Description	Simplified Impact on Upstream Boundary
Scenario 6	80/20 during high flow	80/20 latitude flow distribution during high flow, but 70/30 on a long-term basis through the use of a payback/tracking algorithm.	Higher flow peaks (>400k cfs) are less than actual flows by ~200k cfs, but lower flow peaks (<400k cfs) exceed actual peaks by ~25k cfs. Scenario 6 flows are mostly lower and less flashy than actual.
Scenario 7	Cap Tarbert Flow at 1.25Mcfs	All flow over 1.25M cfs at Tarbert is diverted through ORCS (up to a limit of what the Atchafalaya can handle). 70/30 latitude flow distribution on long-term basis is maintained through the use of a payback/tracking algorithm.	Higher flow peaks (>550k cfs) exceed actual flows by 50k to 250k cfs, lower flow peaks (<500k cfs) vary from actual peaks by +/- ~25k cfs. Scenario 7 flows are mostly higher and flashier than actual.
Scenario 8a	Daily 80/20 no Low Sill constraint	Daily 80/20 latitude flow distribution; no safety constraints on Low Sill head differential	Lowest flows compared to actual flows and other flow scenarios. Scenario 8a is consistently (peaks and troughs) lower than the actual flow across the range of flows with peaks ranging from 10k to 300k cfs lower than corresponding actual flow peaks. Less flashy than actual.
Scenario 8b	Daily 80/20 with Low Sill constraint	Daily 80/20 latitude flow distribution; apply safety constraints on Low Sill head differential	Flows consistently (peaks and troughs) lower than the actual flow across the range of flows with peaks ranging from 10k to 200k cfs lower than corresponding actual flow peaks. Less flashy than actual.

Table 5. (cont.) Flow scenarios and descriptions provided by the Task 4 sediment modeling team (Brown et al. 2022). Table was modified to add column that describes impact flow split change has on upstream model boundary near Simmesport.

Scenario ID	Brief Description	Full Description	Simplified Impact on Upstream Boundary
Scenario 9	Daily 60/40	Daily 60/40 latitude flow distribution.	Flows consistently (peaks and troughs) higher than the actual flow across the range of flows with peaks ranging from 10k to 100k cfs higher than corresponding actual flow peaks. More flashy than actual.
Scenario 10	Maximize Auxiliary	Maintain 70/30 latitude flow distribution. Increase contribution to Auxiliary and decrease contribution to Hydropower (up to ~ 1/3 of diverted flow), based on conditions.	Flows consistently (peaks and troughs) lower than the actual flow across the range of flows with peaks ranging from 25k to 400k cfs lower than corresponding actual flow peaks. Much less flashy than actual.

The downstream boundary condition was a rating curve at Whiskey Bay Pilot Channel created from the gage data (Figure 9). Again, temperature data were compiled from measurements taken at the same gages within the study reach and any missing values were interpolated temporally (Figure 10).

Figure 9. Rating curve created from data gathered at the Whiskey Bay Pilot Channel Gage (USACE Gage 03250) and used as the downstream boundary condition.

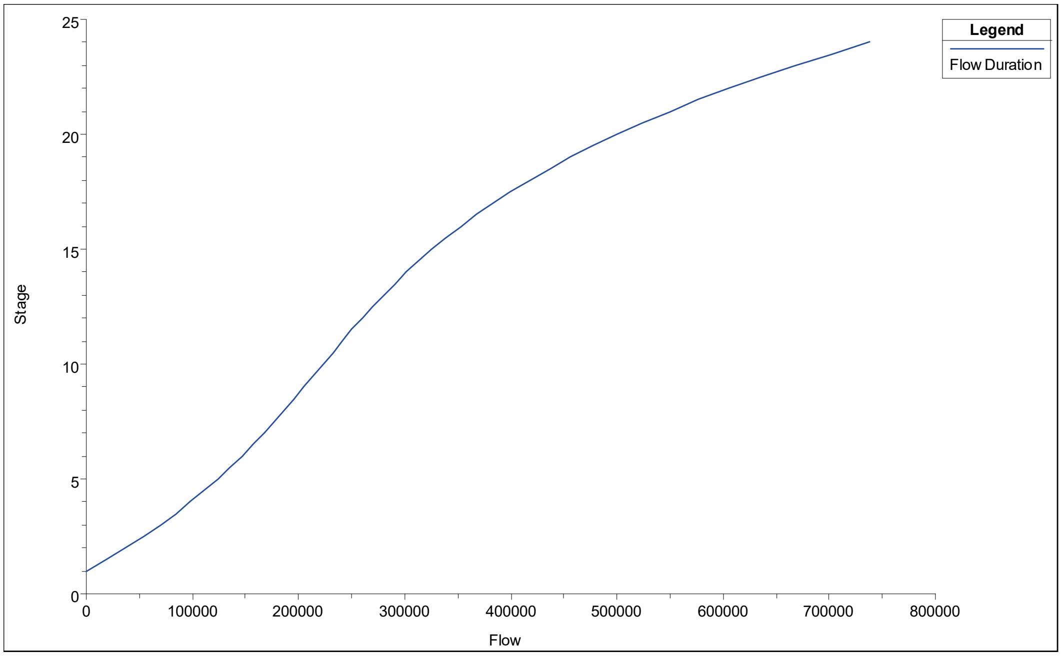
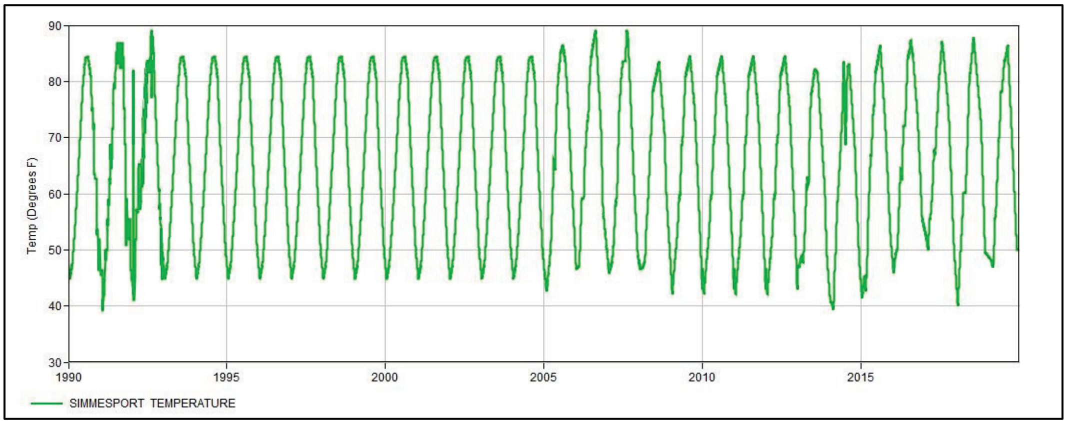


Figure 10. Water temperature assimilated from four nearby gages (USACE Gages 03045, 03060), and 03075) during the simulation period from 1990 to 2019.



Sites 1 and 3 were each run for the two sets of soil parameters identified as the closest over- and underestimates for the actual flows plus the nine flow scenarios.

3 Results

3.1 Calibration results

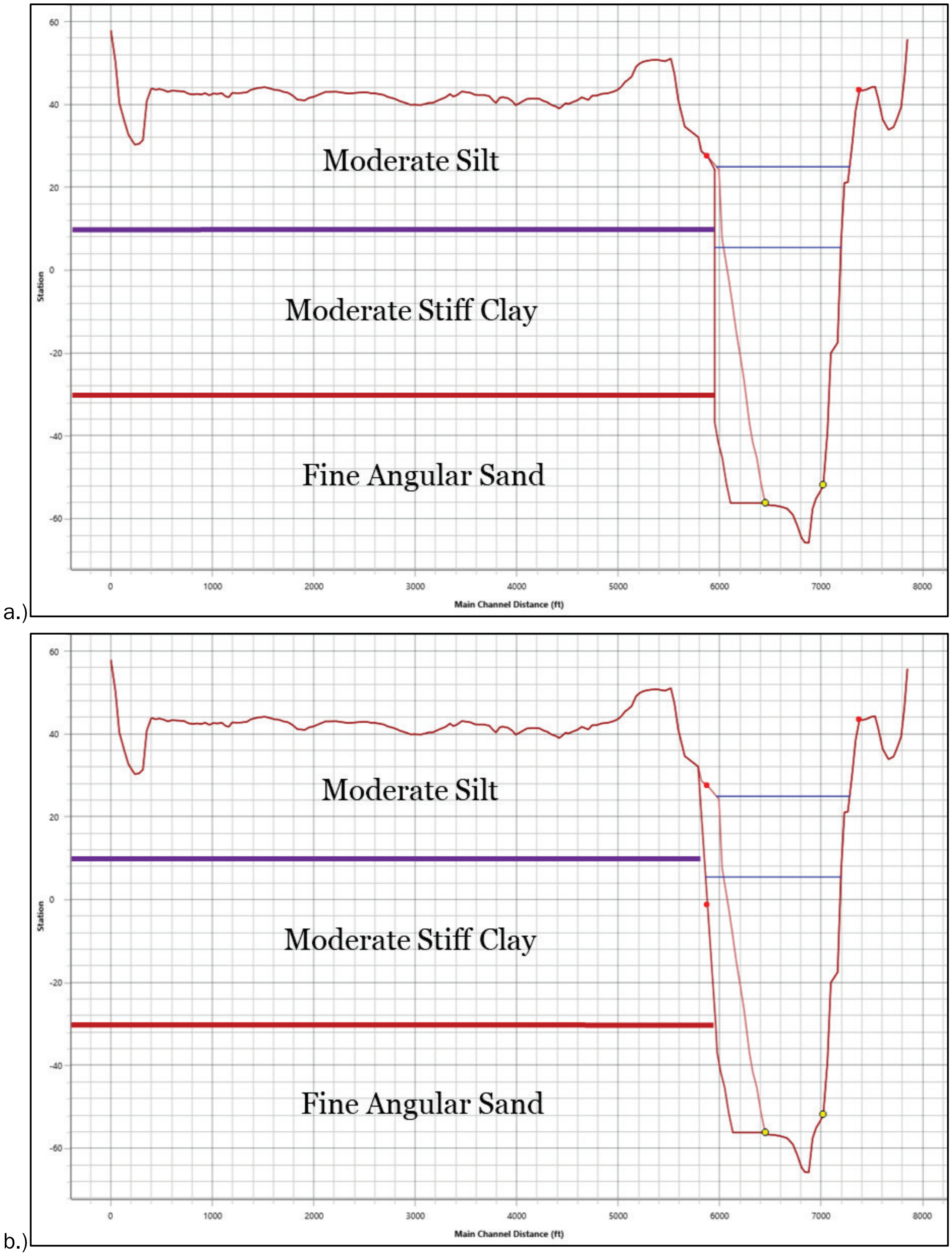
The sensitivity analysis of bank soil parameters yielded two sets of parameters per site that resulted in the closest overestimation and underestimation of bank retreat, respectively (Table 6).

Table 6. Parameters determined by calibration of bank retreat and then used in model simulations. For parameters where two values are given, the lower parameters correspond to the underestimate parameter case and the greater with the overestimated case.

	Layer	Saturated Unit Weight (lb/ft³)	Friction Angle (°)	Cohesion (lb/ft²)	Φ_b (°)	Critical Shear (lb/ft²)	Erodibility (ft³/lb-sec)	Modeled Top of Bank Erosion (ft)	Observed Top of Bank Erosion (ft)
Site 1	Silt	114.6	20 - 26.6	89.81	15	0.1044	1.00E-05 - 2.20E-05	0 - 93	46
	Clay	112.7	15 - 21.1	263.16	15	0.1044	1.00E-05 - 2.20E-05		
	Sand	117.8	25 - 32.3	8.354	15	0.00267	2.00E-05 - 2.20E-05		
Site 3	Silt	114.6	20 - 25	89.81	15	0.1044	3.00E-04	48 - 58	53
	Clay	112.7	15 - 20	263.16	15	0.1044	3.00E-04		
	Sand	117.8	25 - 31	8.354	15	0.00267	9.00E-04		

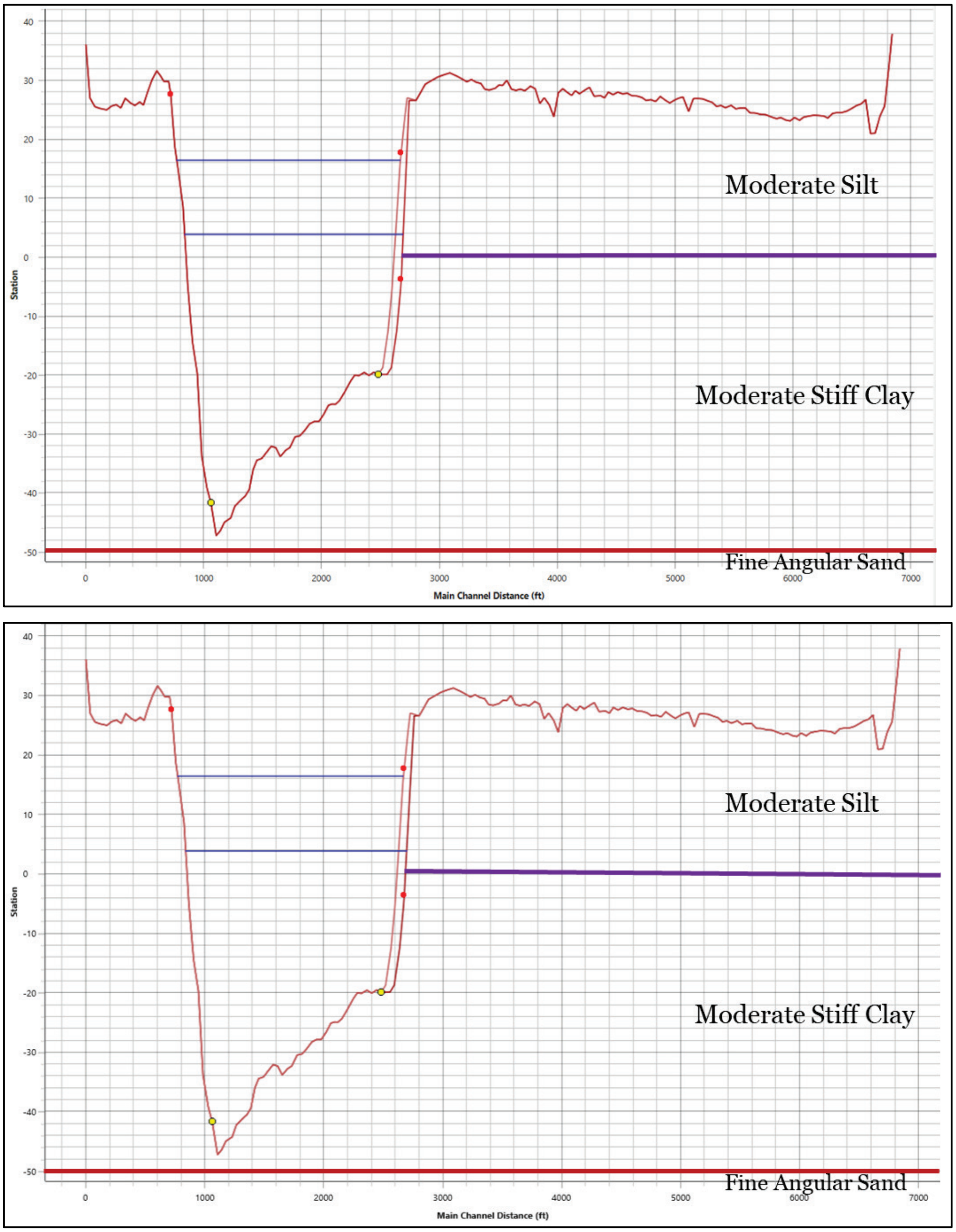
The default values were deemed most appropriate for the saturated unit weight, cohesion, basic friction angle, and critical shear, and a range of values were assigned for friction angle and erodibility. For Site 1, the observed bank erosion was 46 ft between 2005 and 2019. The parameter sets resulted in toe erosion and bank failure that did not reach the top of bank and therefore would not be visible above the water level to measure from aerial imagery (denoted as 0 ft of bank erosion) or 93 ft past the top of bank (or 47 ft more than the target top of bank location) (Figure 11). It was hypothesized that the geometry of the bank and stochastic nature of bank failure resulted in the inability to calibrate the bank retreat to a greater level of precision at Site 1. Since the objective of the study is a comparison of flow scenarios, not a prediction of exact bank retreat, it was deemed that the resultant range in bank retreat results was sufficient to capture the expected relative behavior.

Figure 11. Site 1 cross sections at first and last time-step for parameter sets that yield a.) underestimates and b.) overestimates of bank retreat.



For Site 3, the observed bank erosion was 53 ft between 2005 and 2019. The parameter sets resulted in toe erosion and bank failure 48 ft past the top of bank (or 5 ft shy of the target bank location) or 58 ft past the top of bank (or 5 ft past the target bank location) (Figure 12).

Figure 12. Site 3 cross sections at first and last time-step for parameter sets that yield a.) underestimates and b.) overestimates of bank erosion.



3.2 Flow scenario results

Once the range of soil parameters was selected, the observed data from 1990 to 2019 and the flow scenarios were run for each of the two parameter sets at the two final sites, and a resultant range of possible bank retreat distances and volumes of failed material were reported (Table 7).

The actual, recorded flows from 1990 to 2019 resulted in 230 to 240 ft of top of bank erosion modeled at Site 1 and 53 to 62 ft of top of bank erosion modeled at Site 3. This corresponded with the modeled erosion of approximately 280M cu ft of material at Site 1 and approximately 16M cu ft of material at Site 3. HEC-RAS calculates the volume of eroded material by multiplying the change in cross-sectional area by a length equal to half the distance to the upstream and downstream cross sections. Scenarios 3, 4, 5, 7, and 9 resulted in an increase in bank erosion and volume of failed material compared to the actual flows whereas Scenarios 6, 8a, 8b, and 10 resulted in a decrease. The increase in bank erosion (top of bank retreat) ranged from 0.9% to 553%, and the increase in volume eroded ranged from 0.4% to 475%. The greatest increases were observed for Scenarios 5 and 9, 60/40 at high flows and daily 60/40, respectively. Both scenarios included input hydrographs with higher high flows than the observed and overall flashier hydrographs that increase and decrease flow magnitude more rapidly than observed. The decrease in bank retreat ranged from -3.0% to -100%, and the decrease in volume eroded ranged from -1.8% to -100%. A change of -100% in bank erosion or volume denotes that there was erosion under actual flows, but no measurable erosion or bank failure in the scenario. In some cases, marked by a single asterisk in Table 6, zero ft of top of bank erosion is reported, but a volume of material still failed. This is due to toe scour and bank failure that does not reach the top of the bank, so a bank retreat is not measured. The cases marked by a double asterisk have no erosion modeled, so the top of bank erosion and the modeled volume eroded are both zero. Some cases, marked by a cross in Table 6, show a smaller amount of bank erosion corresponding to a larger amount of eroded volume and vice versa. This is a result of varying slopes of the failure plane. In these cases, the underestimated parameter set results in less erosion at the top of the bank, but more erosion at the toe (a steeper slope) for a greater volume of failed material, compared to the overestimated parameter where more top of bank erosion is simulated, but less volume overall is eroded (a shallower slope).

This is the result of the non-linear nature of the soil parameters since there are several soil parameters acting on each layer in the bank.

Comparing results in Table 7 to flow scenario descriptions in Table 5 points out that the flows that have higher high flow peaks and overall flashier hydrographs results in more bank erosion than the actual flow scenario. In the same way, less flashy flows predictably result in less bank erosion. This is to be expected considering the bank instability that is caused by rapid drawdown of water elevation and the lagging groundwater drawdown. Bank failure results from the reduction of a bank's factor of safety, with the gravity forces of the bank overcoming the hydrodynamic pressure forces exerted on the bank by the water in the channel. Additionally, the higher flows can exert greater sheer stresses on the toe of the bank resulting in more toe erosion and subsequent bank failure.

Table 7. BSTEM results for distance of top of bank erosion and volume eroded for actual flows and flow scenarios. The percent difference of the results for each flow scenario compared to the actual flows are also reported (comparing the under and overestimated parameter set results for actual flows discreetly with the corresponding result from the flow scenarios). In the table, "U" denotes the column of results from the set of parameters resulting in an underestimation of bank erosion in the calibration runs, and "O" denotes that of overestimation.

	Modeled Top of Bank Erosion (ft)			Percent Difference of Bank Erosion from Actual Flows (%)			Modeled Volume Eroded (million cu ft)			Percent Difference of Volume Eroded from Actual Flows (%)		
Actual Flows	U		O				U		O			
Site 1 †	230	-	240				285	-	280			
Site 3	53	-	62				15.5	-	16.3			
Scenario 3												
Site 1 †	232	-	243	0.9	-	1.3	286	-	281	0.4	-	0.5
Site 3	62	-	79	17.0	-	27.4	18.6	-	20.0	19.7	-	22.8
Scenario 4												
Site 1 †	232	-	243	0.9	-	1.3	286	-	281	0.5	-	0.5
Site 3	63	-	79	18.9	-	27.4	18.6	-	20.0	19.7	-	22.8
Scenario 5												
Site 1	238	-	273	3.5	-	13.8	292	-	298	2.4	-	6.5
Site 3	328	-	356	519	-	474	84.6	-	88.1	445	-	441
Scenario 6												
Site 1 †	223	-	230	-3.0	-	-4.2	280	-	271	-1.8	-	-3.1
Site 3	0*	-	0*	-100	-	-100	0.4	-	0.4	-97.5	-	-97.6

Table 7. (cont.) BSTEM results for distance of top of bank erosion and volume eroded for actual flows and flow scenarios. The percent difference of the results for each flow scenario compared to the actual flows are also reported (comparing the under and overestimated parameter set results for actual flows discreetly with the corresponding result from the flow scenarios). In the table, "U" denotes the column of results from the set of parameters resulting in an underestimation of bank erosion in the calibration runs, and "O" denotes that of overestimation.

	Modeled Top of Bank Erosion (ft)			Percent Difference of Bank Erosion from Actual Flows (%)			Modeled Volume Eroded (million cu ft)			Percent Difference of Volume Eroded from Actual Flows (%)		
Scenario 7												
Site 1 †	232	-	244	0.9	-	1.7	287	-	283	0.7	-	1.1
Site 3	191	-	200	260	-	223	48.0	-	49.0	209	-	201
Scenario 8a												
Site 1	0	-	80	-100	-	-66.7	130	-	165	-54.3	-	-41.0
Site 3	0**	-	0**	-100	-	-100	0	-	0	-100	-	-100
Scenario 8b												
Site 1 †	169	-	184	-26.5	-	-23.3	241	-	236	-15.3	-	-15.6
Site 3	0*	-	0*	-100	-	-100	0.4	-	0.4	-97.5	-	-97.6
Scenario 9												
Site 1	401	-	398	74.3	-	65.8	425	-	410	49.2	-	46.6
Site 3	346	-	374	553	-	503	89.3	-	93.0	475	-	471
Scenario 10												
Site 1	0*	-	0*	-100	-	-100	93	-	85	-67.3	-	-69.5
Site 3	0**	-	0**	-100	-	-100	0	-	0	-100	-	-100[1]

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[1] * Zero top of bank erosion, but a volume of material is eroded.

** No erosion occurred and neither bank erosion nor eroded material volume recorded.

† A greater volume of eroded material corresponds to less top of bank erosion and vice versa.

4 Conclusions and Recommendations

4.1 Conclusions

The objective of this study was to simulate a range of possible bank erosion responses to various flow scenarios in comparison to actual flows. Other OMAR Assessment tasks have concluded that the Atchafalaya River is in a state of relative equilibrium and not undergoing systemic widening (Lauth et al. 2022). The measured bank erosion used for calibration data is a result of natural processes of bank erosion and not seen as a symptom of a larger, systemic issue. Local scour effects resulting in notable bank failure are present throughout the system, but the extent of their impact is isolated, and such erosion is driven by local phenomena (e.g., piers, boat wakes) rather than changing inflows. This type of local effect is expected in many river systems and not a result of a systemic equilibrium problem; therefore, it is not addressed by this model study. According to the BSTEM model results, altering the flow distribution between the Mississippi and the Atchafalaya Rivers could increase the volume of bank erosion in the Atchafalaya by up to 475% or effectively eliminate it, depending on the scenario used. Bank retreat distance could increase by up to 553%. The scenarios that caused the greatest increases in erosion were those with flashier hydrographs compared to the current flow regime. As expected, more dramatic and rapid increases and decreases in flow introduce greater bank instability. This large range of impacts points out the stochastic and unpredictable nature of bank failure and the wide range of possible effects a change in flow scenarios could cause within the system.

4.2 Recommendations

This study created a bank stability and toe erosion model with limited soil parameters and made use of generalized site characteristics and a range of possible soil parameter values to get a range of possible solutions. While there is the option for the collection of more site-specific soil characteristics to add detail to the model, the study sufficiently answered the questions of the general trend in bank erosion expected from the various flow scenarios. Major flow alterations in the system, particularly increases, can cause large changes to bank stability and toe scour. Altering the flows could cause major and lasting impacts on the stability of the system throughout the study domain, and these impacts should be considered carefully.

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Abbreviations

1D	One-dimensional
2D	Two-dimensional
BSTEM	Bank Stability and Toe Erosion Model
CHL	Coastal and Hydraulics Laboratory
ERDC	US Army Engineer Research and Development Center
HEC-RAS	United States Department of Agriculture Agricultural Research Service
MVN	New Orleans District
OMAR	Old, Mississippi, Atchafalaya, and Red Rivers
ORCS	Old River Control Structure
USACE	US Army Corps of Engineers
WSE	Water surface elevation

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14. ABSTRACT

This report documents the bank erosion modeling performed under Task 6 (HEC-RAS Sediment Modeling) of the Old, Mississippi, Atchafalaya, and Red (OMAR) Rivers System Technical Assessment. The objectives of the bank erosion modeling effort were to compare the relative impact various flow scenarios might have on bank retreat on a stretch of the Atchafalaya River between Simmesport, LA, and the Whiskey Bay Pilot Channel. The effort included compilation of field and soil boring data, selection of bank retreat sites, creation of representative soil profiles for the reach, calibration of soil parameters to measured retreat rates, and modeling bank retreat and volume of material eroded under various flow scenarios. This modeling effort was intended for scenario comparison and should not be used as a prediction of exact rates of bank erosion. The study found that varying the amount of flow entering the Atchafalaya River from the Mississippi River could increase dramatically or significantly reduce the extent of bank erosion, relative to the current management scenario.

15. SUBJECT TERMS
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