HEC-6T MODELING OF THE ATCHAFALAYA RIVER BASIN, LOUISIANA

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Abstract: HEC-6T modeling was part of the 2010 Atchafalaya Flow Line Study. The purpose of the overall study was to determine the design flood profile, 50 years in the future. This study effort included HEC-RAS modeling, 2D ADH modeling, and a Geomorphic Analysis in addition to the HEC-6T modeling. The HEC-6T model structure included several flow distributaries and return flows, three inflow boundaries, two outflow boundaries, several loops, and two historical dredging reaches. The model used 1997 cross section geometry for the base condition. The model was calibrated to flow and sediment measurements. The model was verified against 2006 cross section data and dredging records. The future conditions model was then simulated to 2059 to provide a future conditions cross section data set. The future conditions cross sections were inserted into the HEC-RAS model to assist in the computation of the future conditions Flow Line flood profile. Sediment volumes that were deposited into the Gulf in the HEC-6T model were used to modify the future conditions 2D ADH model.

INTRODUCTION

The Atchafalaya Basin Floodway System is a portion of the Mississippi River and Tributaries Project that was authorized by the Flood Control Act of 1928. A portion of Mississippi River flood flows are diverted to the Atchafalaya Basin at the Old River Control Structure and at the Morganza Control Structure. The Atchafalaya Basin needs to safely pass 1,500,000 cfs for the design flood. Periodically the design water surface profile (Flow Line) is reanalyzed for existing and future conditions. This current study is a reanalysis of the Atchafalaya Flow Line based on the current conditions and also based on conditions expected 50 years in the future. The future conditions for the channel were developed with the HEC-6T one-dimensional sediment transport model. The HEC-6T model is proprietary software published by Mobile Boundary Hydraulics, Inc.

COMPOSITION OF THE HEC-6T MODEL

Area of Study and Model Network: The HEC-6T model covers the Atchafalaya River Basin, Wax Lake Outlet, the Old River Control Channel, and the Red River upstream to the Acme Gage (Figure 1). The model consists of three inflow points, the Red River, the Old River, and the Morganza Spillway. There were two outflow points, the Lower Atchafalaya River and the Wax Lake Outlet. The model is comprised of 20 segments and 16 control points (Figure 2).

Data Sets: Three data sets make up the HEC-6T model input; geometric, sedimentary, and hydrologic. The HEC-6T geometric data set was built principally from the HEC-RAS model. The HEC-RAS model was developed from Light Detection and Ranging (LIDAR) overbank topography (1998), channel bathymetry for the Atchafalaya Basin and Wax Lake Outlet (1997-1998), and channel bathymetry for the Red River (2001 channel surveys).

The sedimentary record principally consists of sediment inflow rating curves and bed material particle curves. There are two inflow points in the HEC-6T model, Red River at Acme and the Old River Control Structure inflow. The sediment inflow rating curves came from the Lower Mississippi River Sediment Study and calibrated to the published record of sediment measurements at Simmesport. Bed material information came from the Nordin Study and the ROMA study. Other sediment parameters include sediment diversion coefficients (used at flow divides) and sediment function. If sediment diversion coefficients are not used, then the sediment will be divided at the same ratio as the water. Use of the sediment diversion coefficients allow for the division of sediment at a ratio different from the water.

Sediment diversion coefficients were used in two locations, Wax Lake Junction and Horseshoe Bend. The function selected for the analysis was the Toffaletti Sediment Transport Function. The Toffaletti function used sediment data from the Simmesport gage in its development, and therefore is calibrated to the Atchafalaya River. Additionally, EM 1110-2-1418 states that "Toffaletti is appropriate for large sand bed rivers".

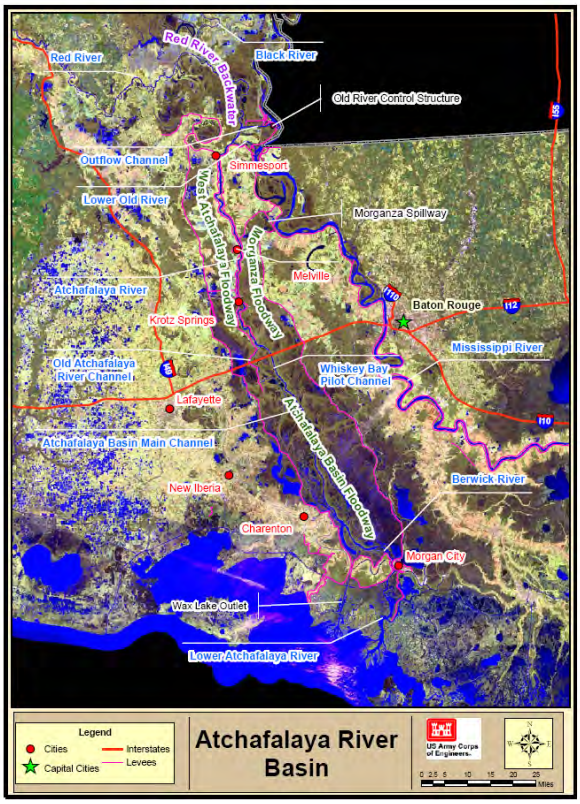

Figure 1 Map of Project Area

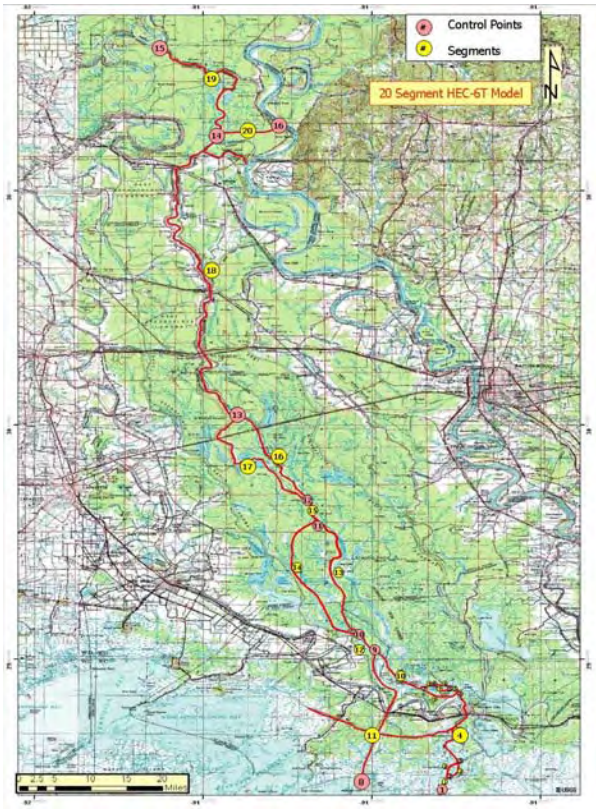

Figure 2 HEC-6T Model Network

The hydrologic record consists of inflows, tailwater stages, water temperature, and time step. The inflow record was developed from historical Old River and Red River inflows from 1973 and 1977-2007. Red River flows were computed by subtracting Old River flows from Simmesport flows. A lateral inflow was added to simulate Morganza Spillway inflow. Tailwater stages used came from the Eugene Island (Lower Atchafalaya River) gage record for the same time period. Two discharge points were used in the model – Lower Atchafalaya River and Wax Lake Outlet Channel. The nearest gage is Eugene Island on the LAR (RM -151.9). The tailwater boundary condition values for the future conditions modeling were adjusted for predicted mean sea level rise.

<u>Geologic Controls.</u> Revetments exist at many locations throughout the modeled area. These are of the form of either bank paving or rock dikes. With the exception of the Ten Mike Dike region, no allowances were made in the model to account for such features. Ten Mile Dikes, constructed in 1991, are located between River Miles 9 and 10 downstream of Simmesport. These were incorporated into the HEC-6T Model by restricting the allowable erosion width from the left bank toe to the toe of the dike at the right bank.

Three distinct areas were identified as having a non-erodible clay layer in the thalweg. This is important in designing HEC-6T model tests because this restricts the amount of sediment available to erode and

contribute to the sediment calculations. The bed sediment reservoir in the cross sections representing these areas were coded as having zero depth of available sediment.

The three areas coded as having a non-erodible layer were downstream of Simmesport (RM -13) upstream to the junction with the Old River Control Channel, Grand / Six Mile Lake (RM-108.3 to-101.0), and in the constructed reach of Wax Lake Outlet from RM-108.3 to the GIWW (RM-115). Historical thalweg data, geological mapping, or anecdotal information suggests these three areas consist of a hard clay layer in the thalweg and is resistant to further erosion.

Flow Withdrawals / Flow Returns: Multiple flow withdrawals and returns were used to match characteristics in the prototype. Defined channels such as the East and West Freshwater and Access Channels remove flow from the channel and return flow to the channel downstream. At higher flows, a significant portion of the flow enters the East and West Floodways. This flow enters the model at the downstream end of the basin. Figure 3 shows the flow withdrawals and returns used in the model.

The percent of sediment in the diverted flows can be controlled with coefficients. If not specified, the sediment is proportioned by the ratio of water. Of the sediment that leaves, the sediment returning can also be controlled. A single percentage, or a table of coefficients, can be used. The table allows the percent of sediment returning to the model to vary with water discharge and particle size class.

Dredging: There are two main dredging sites in the model network, Berwick Bay on the LAR (RM 121.4 to RM 120.1) and Horseshoe Bend on the LAR (RM 137.5 to RM 134.9). These were included in model simulations

MODEL CALIBRATION

Calibration demonstrates that results computed by the 1-Dimensional, Atchafalaya River model matches prototype behavior. The model consists of cross sections, reach lengths, n-values, bed gradation, sediment transport function, inflowing water-sediment mixture, computational time step and the sorting and armoring time step.

The parameters that demonstrate how well the model reproduces the prototype are water surface elevations, sediment concentrations, sediment delivery, bed gradations and aggradation/degradation of the channel cross section.

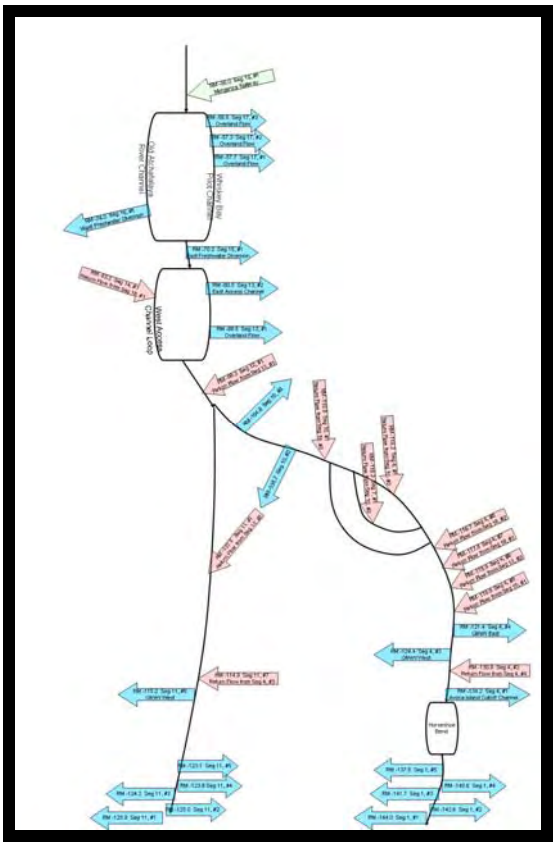

Figure 3 Model Flow Withdrawals and Returns

Fixed-Bed, Steady-State Hydraulics: The model was calibrated in three phases. Phase 1 was fixed-bed, steady-state hydraulics. Figure 4 shows results of fixed-bed, steady-state hydraulic calibration for basin inflows of 200,000, 400,000, and 600,000 cfs. The model shows good agreement with gage rating curves.

Movable-Bed, Steady-State Hydraulics: The test is also termed the "robustness test". This consisted of simulating bank-full conditions in the model for an extended period of time. If the model is constructed properly, equilibrium conditions should be reached. For this test, 83 of the 398 model cross sections changed by more than five feet. Of these 83 sections, 17 had not reached equilibrium. These 17 sections are in the Gulf area, which is depositional. The model therefore passes the robustness test.

Movable-Bed, Quasi-Unsteady Hydraulics and Sediment: The third test of calibration was movable-bed, quasi-unsteady hydraulics and sediment using the 1997 to 1998 mean daily flow record. This period of time was chosen because sediment and flow records are available for the West Grand Lake and Cypress Pass locations for that time period, in addition to the extended record at the Morgan City and Calumet gages. Gages used for calibration and verification are show in Figure 5.

Comparisons were made of prototype data to model results for flow, stage, and sediment transport at the Calumet and Morgan City gages, and flow and sediment transport for the West Grand Lake and Cypress Pass gages. The model showed good agreement with prototype data.

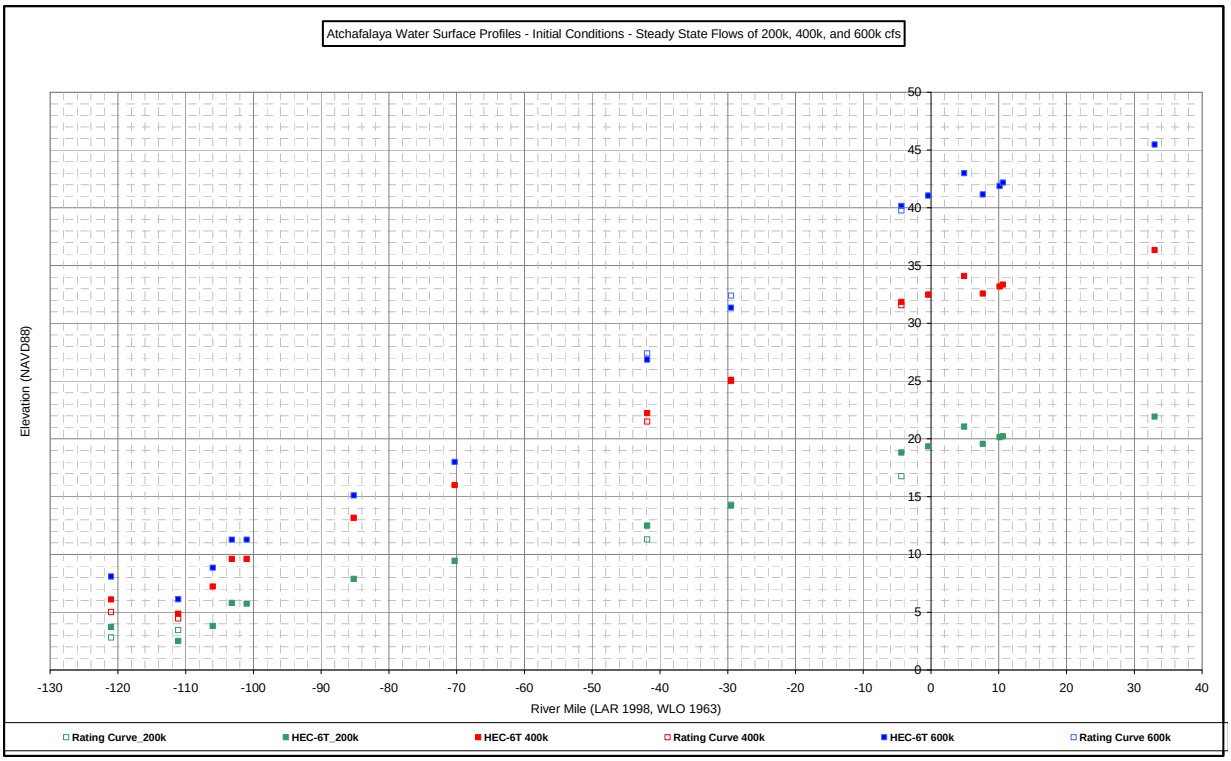

Figure 4 Water Surface Profiles, Model vs. Gage Rating Curves

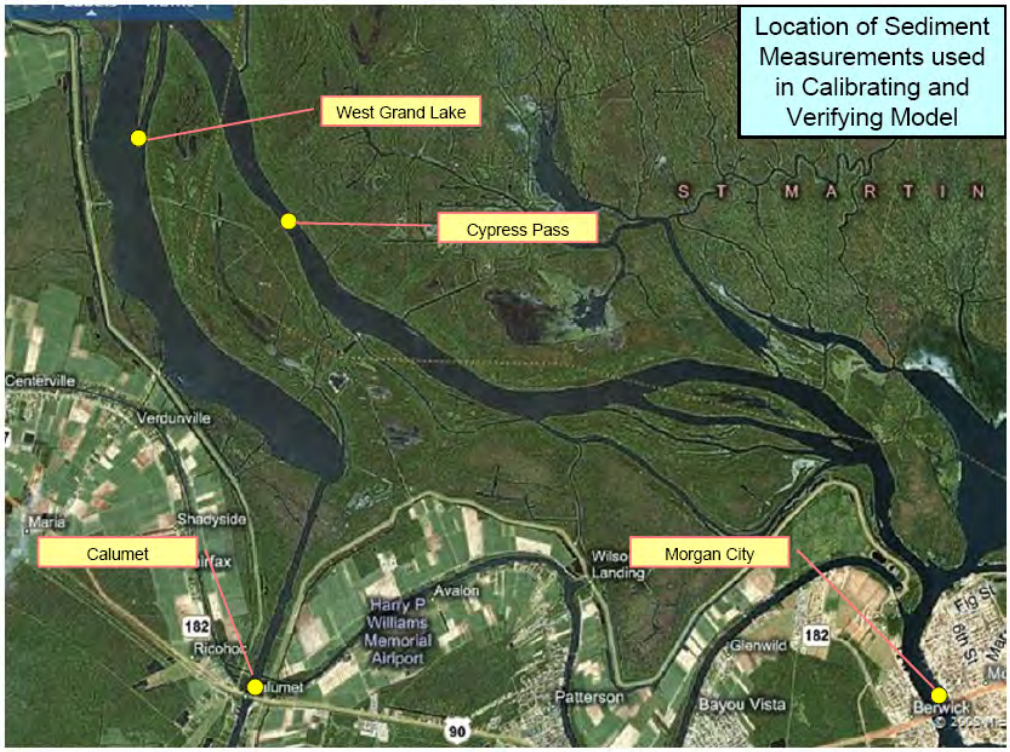

Figure 5 Location of the Calumet, Morgan City, West Grand Lake and Cypress Pass Gages.

MODEL VERIFICATION

The verification period chosen for the analysis was 1997-2006. This period was chosen for two reasons. One, the purpose of the study was to predict conditions 50 years in the future, therefore the model being calibrated and verified to 2006 conditions enables the model to progress on its 50-year future conditions simulation. Two, a channel hydrosurvey data set exists for 2006, enabling another parameter to verify the model against.

Simmesport Sediment Inflow: There is a published record of sediment measurements at Simmesport. Historical sediment yields from that record were one of the data sets used to verify the HEC-6T model. Sediment inflow rating curves were adjusted to match the Simmesport sediment record. Results are shown in Table 1.

Table 1. Comparison of Prototype to Model Simmesport Sediment Loads

	Average Annual Sediment Load (million Tons/year)		
	Total Load	Silts/Clays Load	Sand Load
Simmesport Measured (1997-2005)	57.6	41.8	15.8
Simmesport Measured (add 15% for Unmeasured)	60.0	41.8	18.2
Model Results (1997-2005)	58.5	45.4	18.4
Model Deviation from Measured (%)	-2.5	8.6	0.9

Morgan City and Calumet Gage Measurements: Gage values exist for flow, stage, sand transport, and silts/clays (fines) transport. Measurements of flow and sediment transport occur approximately once a month. On dates when measurements occurred, model values were extracted and data was plotted against model values along with a "line of perfect agreement" for reference. Hydrodynamic comparisons are shown in Figures 6-7, respectively.

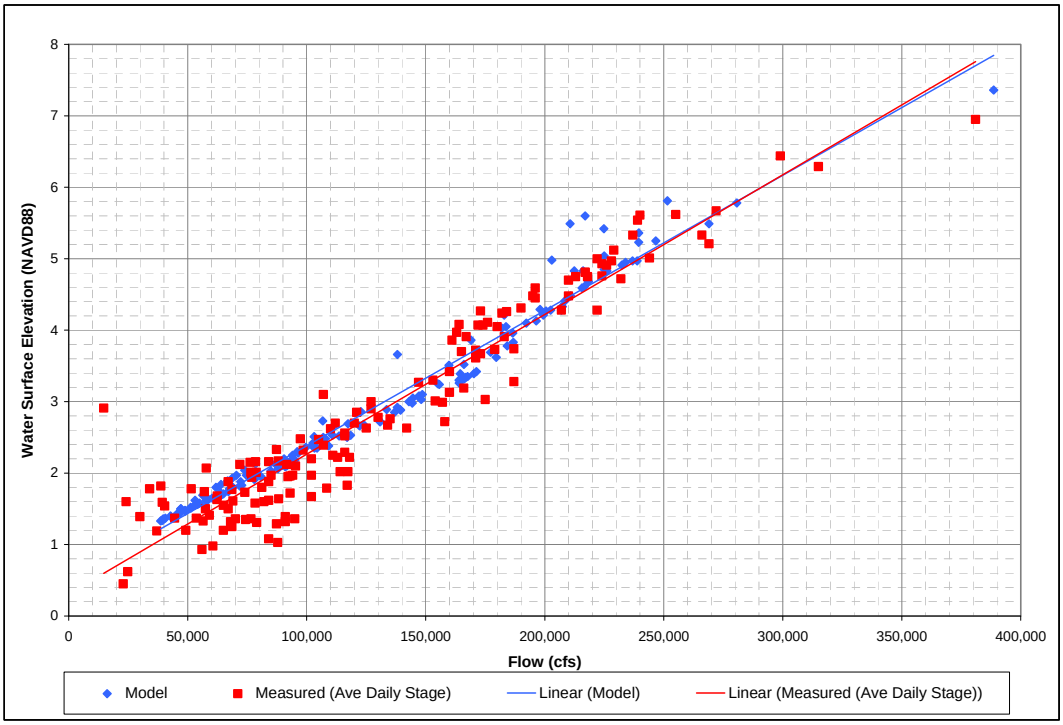

Figure 6 Morgan City Rating Curve, Model vs. Measured Values

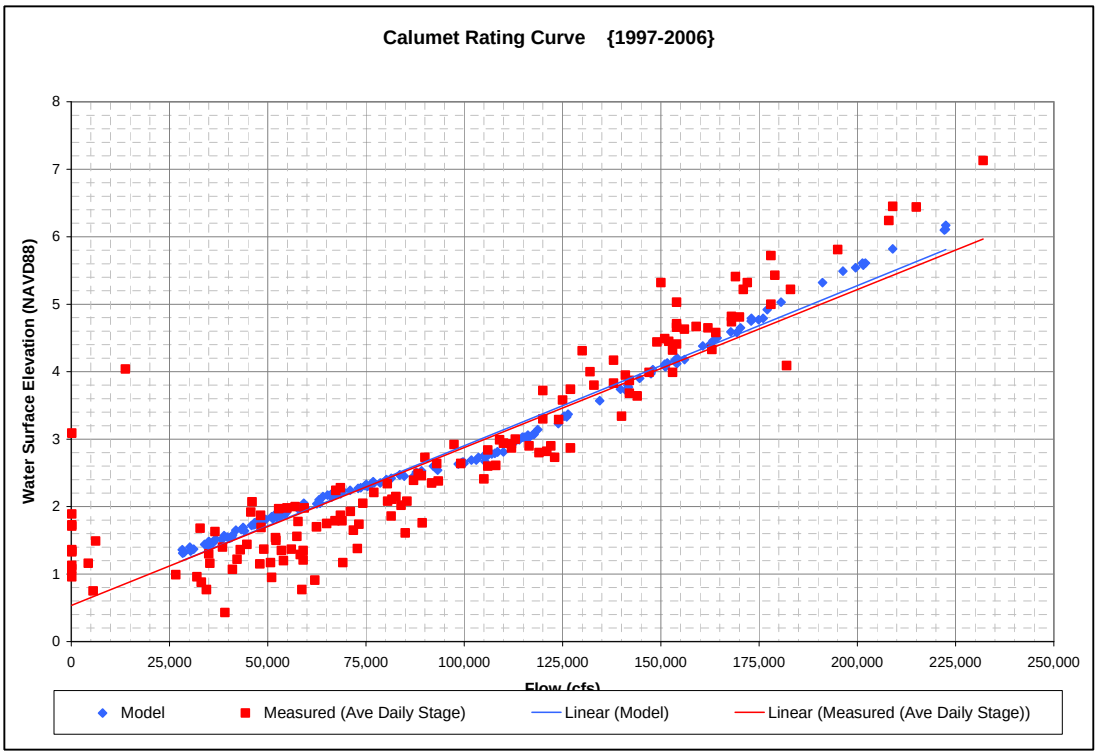

Figure 7 Calumet Rating Curve, Model vs. Measured Values

Upon examining the sand transport rating curves, it is evident that there is a threshold level for sand measurements that the measurements do not drop below. Even at relatively low flows, measured sand transport does not fall below this threshold. It has been theorized that some error might be introduced into the sand transport measurements, and perhaps during low flow periods sand concentrations might be inflated due to tides or wind and wave impacts.

Therefore, another set of rating curves were developed that removed the comparison when measured flows dropped below the "threshold level". Trend lines have been added to these plots. This shows model performance at higher flows, an important parameter for this study. Sand transport rating curve comparisons are shown in Figures 8 and 9.

Dredging Volumes: – A large amount of historical data is available regarding prototype dredging. There are two main dredge cuts in the area that the HEC-6T model covers, Berwick Bay and Horseshoe Bend. The Lower Atchafalaya River and Bayous Chene-Boeuf-Black Feasibility Study Sediment Analysis performed a thorough analysis of the dredging data and established a baseline average annual prototype dredging volume for the model to verify itself. The comparison between prototype and model values is shown below in Table 2.

Table 2. Comparison of Prototype vs. Model Dredging Volumes Verification Period 1997-2006

Dredging Site	Prototype Average Annual Dredging (yd^3)	HEC-6T Model Output – Average Annual Dredging (yd^3)	Model Deviation from Prototype (%)
Berwick Bay	1,300,000	1,196,000	-8.0
Horseshoe Bend	1,400,000	966,000	-31.0

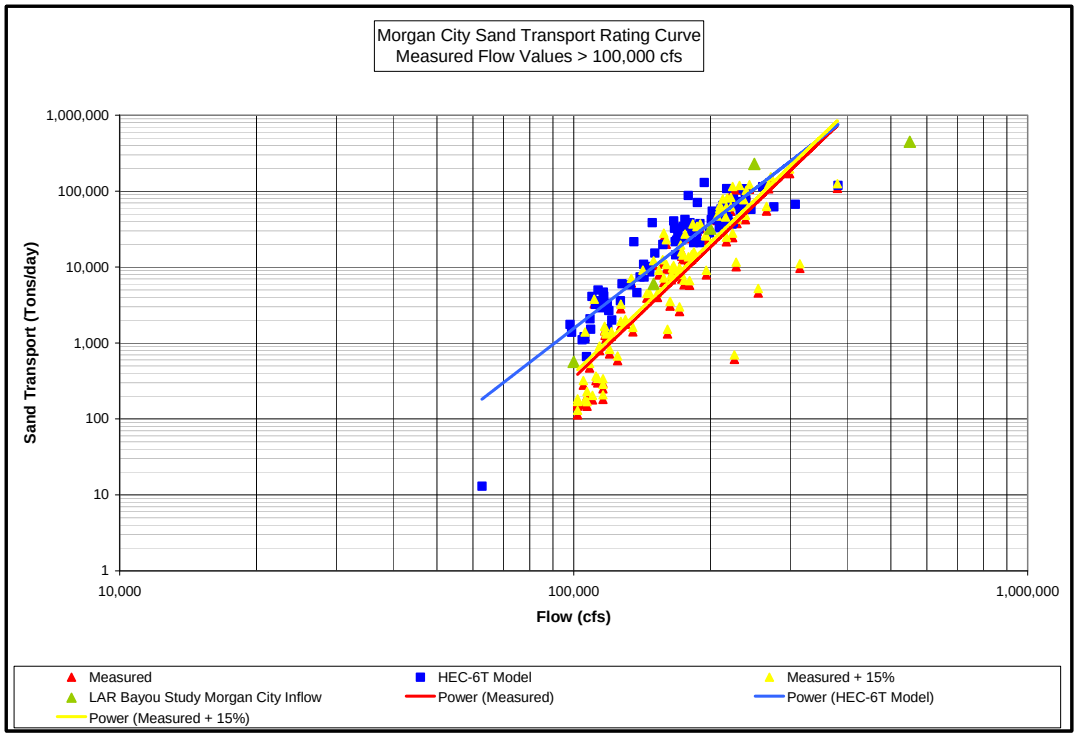

Figure 8 Morgan City Sand Transport Rating Curve, Model vs. Measured Values

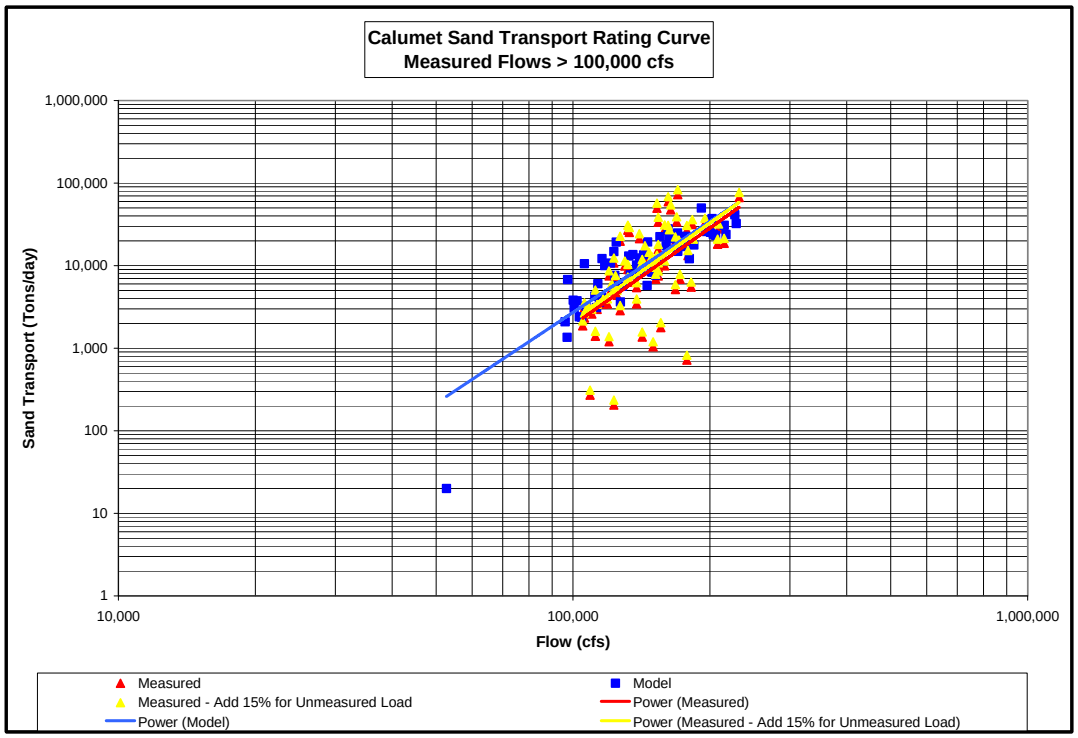

Figure 9 Calumet Sand Transport Rating Curve, Model vs. Measured Values

STUDY RESULTS

The results of the HEC-6T modeling were principally used in two ways. One, the future conditions cross sections were inserted into the future conditions HEC-RAS model. Second, the sediment volumes deposited into the Gulf were used to develop the future conditions Gulf geometry in the ADH model.

Specific Gage Analysis: These plots show gage trends over time in the form of stages for specific discharges. This information is extracted from the model over long-term simulations by periodically running a "trace discharge" through the model. For this analysis, trace discharges of 200,000 cfs, 400,000 cfs and 600,000 cfs were entered at the inflow boundary. Figure 10 shows the specific gage plot for the 400,000 cfs basin inflow runs.

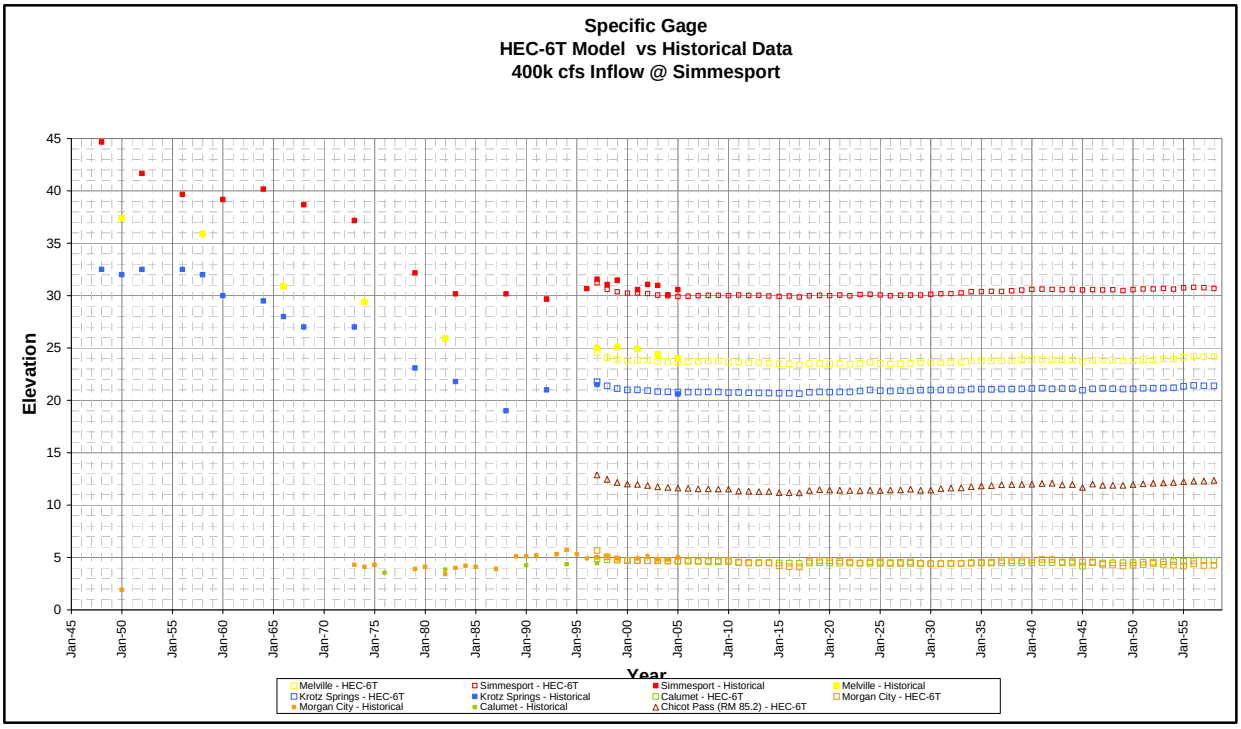

Figure 10 Historical and Model Prediction Specific Gage Plots for Atchafalaya Basin Gages

Sediment Delivery: Sediment delivery is defined as the amount of sediment (expressed in tons in this analysis) that passes a given cross section. Sediment delivery can increase in the downstream direction if local inflows put sediment into the system or bed erosion adds sediment to the flow. Sediment delivery will decrease if deposition is occurring or if outflows (distributaries) remove sediment from the system.

Figure 11 shows accumulated sediment delivery model values at selected landmarks for sands, silts and clays.

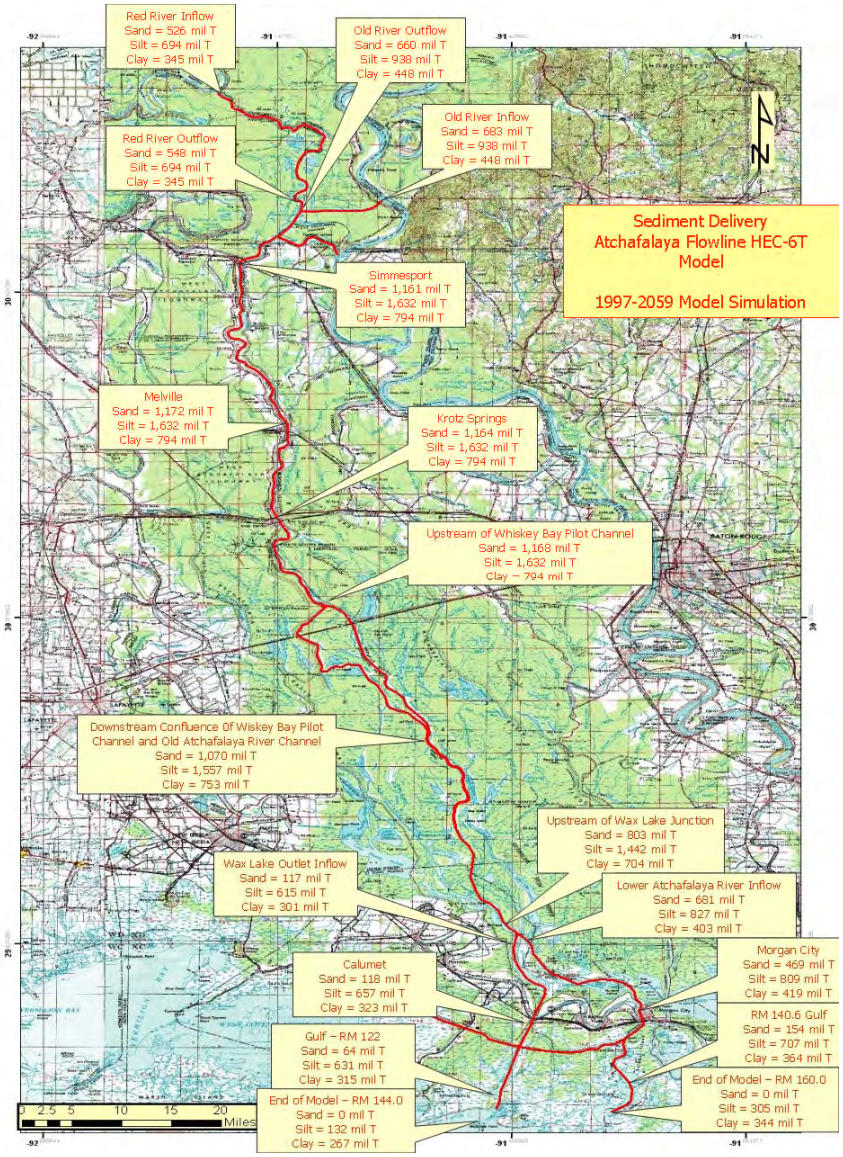

Figure 11 Accumulated Sediment Delivery Model Results for 63-Year Simulation

<u>Sediment to the Gulf:</u> Gulf boundary is defined as RM 140.6 on the LAR and RM 122.0 on the WLO. Sediment deposited in the Gulf over the life of the simulation is shown in Table 3.

Table 3 HEC-6T Model Results – Sediment Deposition in the Gulf

	Sediment Deposited in Gulf (million yd^3)		
	Sand	Silt	Clay
Lower Atchafalaya River	105.9	480.8	33.5
Wax Lake Outlet	46.0	461.6	52.8

<u>Cross Sections:</u> Future conditions cross sections from the HEC-6T model were provided electronically to the HEC-RAS model for use in the computation of the future conditions flow line.

SENSITIVITY

The method used to test parameter sensitivity was to compare water surface profiles while varying parameters. The base model was simulated with the recommended parameters. At the end of the 63-year simulation, Project Flow Line flow and tailwater stage were ran in a short burst. This provided an approximate future conditions Project Flowline profile. The following parameters were tested in the model to determine their impact upon the model profiles: increasing and decreasing sediment inflow by 10% and 20%, increasing and decreasing inflows by 10%, increasing and decreasing water temperature by 5 degrees, and changing the method of computing future sea level rise. Sensitivity analyses were performed throughout the model network. Sensitivity results for the middle and upper Atchafalaya Basin are shown in Figure 12. Cross sections which provided the highest and lowest flow line elevation were provided to the HEC-RAS model for computation of flow line sensitivity.

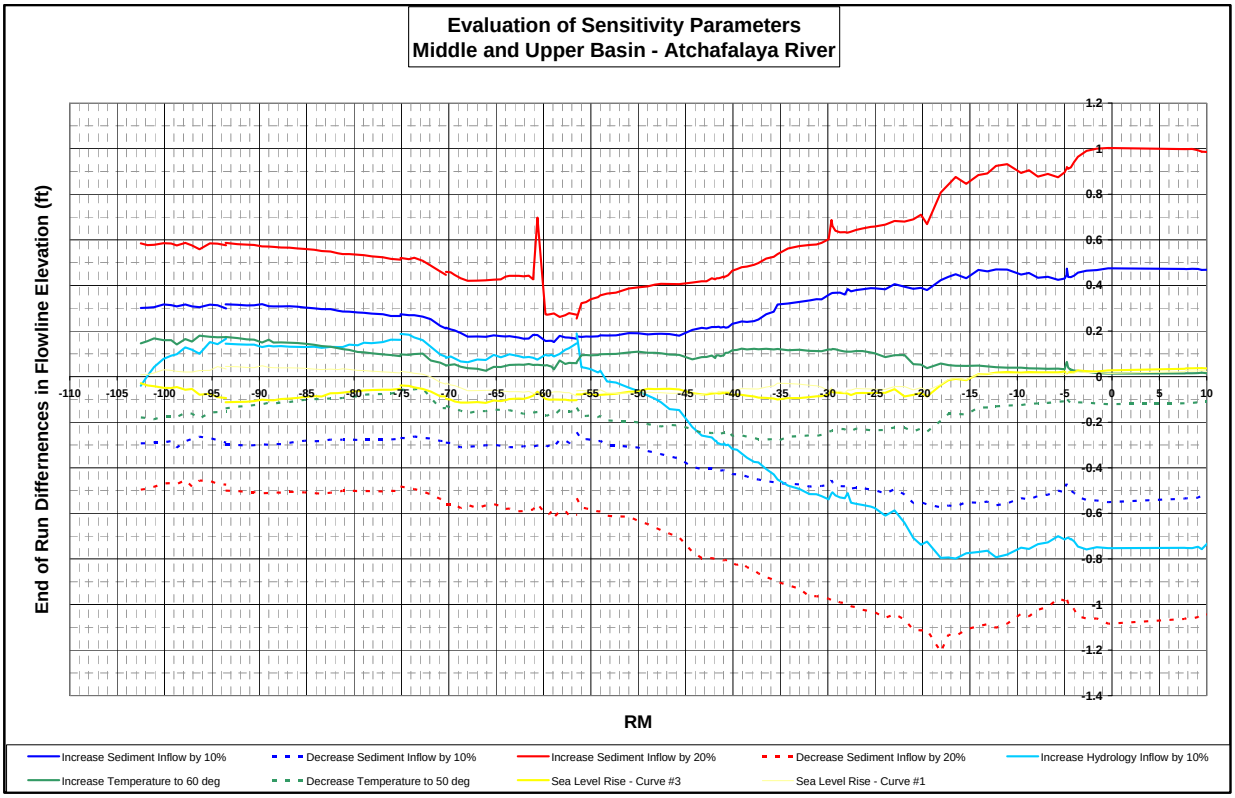

Figure 12 Sensitivity of Model Parameters in the Middle and Upper Atchafalaya River Basin

These results show that the major impact to the profiles is the change to the sediment inflow rating curves by $\pm$ 20%.

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