MISSISSIPPI RIVER GEOMORPHOLOGY & WEST BAY DIVERSION

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Abstract. A detailed geomorphic assessment was conducted for the lower Mississippi River from Belle Chase (RM 75 AHP) to East Jetty at the gulf outlet of Southwest Pass. The geomorphic assessment was part of a multi-task study of the effects of West Bay Diversion on induced shoaling within the Pilottown Anchorage Area conducted by ERDC Coastal & Hydraulics Laboratory for USACE, New Orleans District. The overall objectives of the geomorphic assessment were to document the historic trends and changes in hydrology, sedimentation, and channel geometry for the lower Mississippi River, to summarize the local changes observed in the Pilottown anchorage since the opening of the West Bay diversion, and to evaluate the changes at Pilottown with regard to the documented historic trends. Tasks performed as part of the geomorphic assessment include a geometric data analysis, gage and discharge data analysis, review of dredge records, and development of a historic events time line. Results from the various tasks conducted as part of the geomorphic assessment were integrated in order to formulate conclusions that best describe and explain the cause and effect of the overall morphological trends observed in the study area. The integration process takes the results from a given analysis and interprets the results in relation to the results of all analyses using best engineering judgment. In doing so, definitive trends can be established and areas of conflicting results can be identified. Results of the geomorphic assessment are presented.

INTRODUCTION

The dominant morphological processes that drive the observed changes in the lower Mississippi River and delta system can operate over very large spatial and temporal scales. There are many factors, both natural and man induced, that can contribute to these processes. The effects of large floods and storms, changing sediment loads and characteristics, channel maintenance activities, dredging practices, diversions (natural and man-made), subsidence and relative sea level rise are just a few such factors, but are not a comprehensive list. In terms of temporal scales that are typically associated with river morphology, the diversion at West Bay has been operating for a very short time period. The question must be asked to what degree the observed shoaling at the Pilottown anchorage is a result of large-scale, long-term river morphology, or a direct result of the impacts of the West Bay diversion. It is therefore important to establish the long-term morphological trends that are occurring in this reach of the river and to evaluate the observed shoaling at the Pilottown anchorage with regard to these trends. These morphological trends are determined by means of a geomorphic assessment.

The geomorphic assessment brings together all the known information and data about the river reach, and provides a description and understanding of if/how the lower Mississippi River has changed in a historical perspective. Methods and tools used in the geomorphic assessment include analysis of channel geometry data, stage and discharge data, dredging records, sediment data, and natural events and anthropogenic influences. Each section of the geomorphic assessment provides an incremental contribution to the overall understanding of the dominant processes that have shaped and formed the system.

The results of the analyses were integrated with the overall objectives of documenting the historic trends and changes in hydrology, sedimentation, and channel geometry for the lower Mississippi River, summarizing the local changes observed in the Pilottown anchorage since construction of West Bay diversion, and evaluating the impacts of the diversion with regard to the historic trends.

Often times the results of a particular analysis may conflict with the results of other analyses. Therefore, it is important to interpret results of all analyses in an integrated manner in order to achieve the most accurate description of the dominant processes that have influenced channel development in the study area. It is also important to remember that a geometric analysis of this nature focuses on observed data which gives a description of specific channel conditions representative of a given point in time. Any observed change from one time period to another is a cumulative response resulting from all influencing forces acting on the system during that span of time. Careful engineering judgment must be exercised when attributing an observed system response to a specific cause or event.

STUDY AREA

The detailed geomorphic assessment was conducted for the lower Mississippi River from Belle Chase (RM 75.0 Above Head of Passes (AHP)) to East Jetty at the gulf outlet of Southwest Pass (RM 18.5 Below Head of Passes (BHP)). The assessment focused on the time period from 1960 to the present. The main area of focus was the reach of the Mississippi River in the vicinity of West Bay Diversion and the Pilottown Anchorage Area as shown in Figure 1.

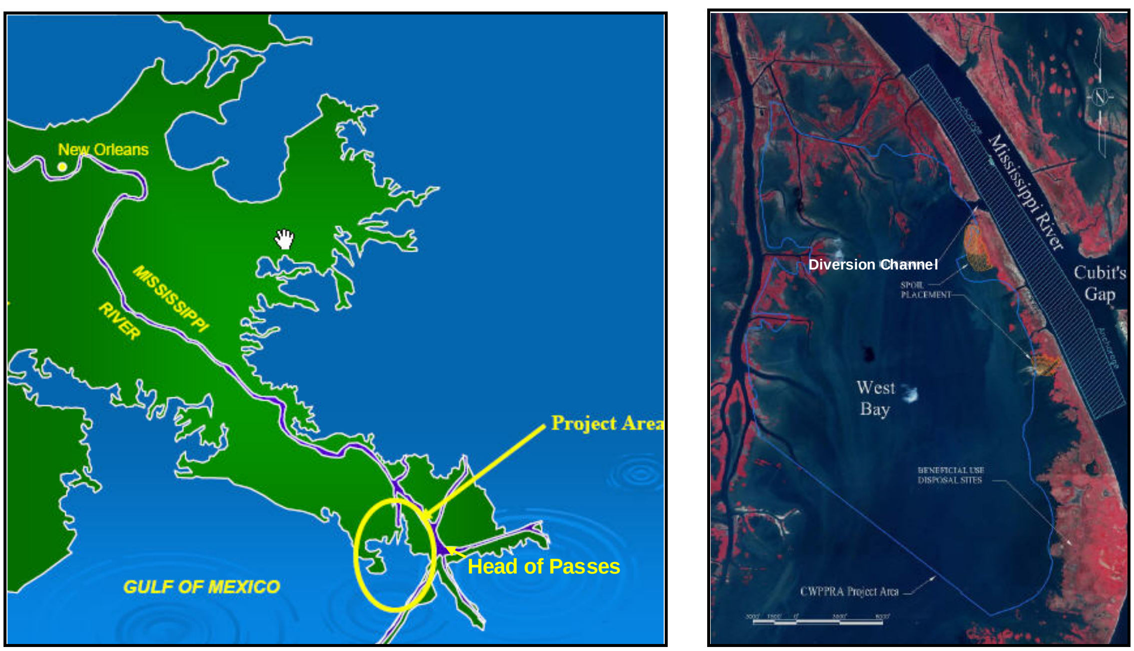

Figure 1. West Bay Diversion Geomorphic Assessment Study Area

GEOMORPHIC ASSESSMENT METHODS

The specific tasks of the geomorphic assessment include a geometric data analysis, gage/discharge/sediment data analysis, assessment of dredge records, and development of a historic events time line.

Geometric Data Analysis. The purpose of the geometric data analysis was to document the changes in channel dimension, pattern and profile of the lower Mississippi River within the study reach. A comprehensive database of channel geometry data was compiled from historic comprehensive hydrographic surveys of the lower Mississippi River. Tasks of the analysis include cross section comparisons, volumetric computations, and channel pattern comparisons.

Gage/Discharge/Sediment Data Analysis. The purpose of the gage, discharge and sediment data analysis was to evaluate existing data to determine how the distribution of flow in the outlets within the study area has changed over time, and how these trends have impacted the morphology of the lower Mississippi River. Historic published discharge data and non-published post-construction discharge data at the West Bay diversion collected by USACE New Orleans were obtained to form a discharge database for this analysis.

Dredge Data Assessment. Dredge records were obtained from USACE New Orleans and analyzed to determine trends in dredging requirements in the lower Mississippi River and Southwest Pass. Total dredge volumes were available by year, and are representative of the total dredging requirements for the reach from Venice, LA to the outlet of Southwest Pass. Daily dredge records for each dredge contract could not be obtained; therefore no information on the location, amount and time of specific dredge quantities could be determined. In addition to the dredge records, grain size analyses of dredge material grab samples were available for many of the dredge contracts.

Historic Events Time Line. A tabulation of historic events pertaining to the lower Mississippi River was compiled by USACE New Orleans and provided as part of the geomorphic assessment. The document provided information on river engineering activities that have occurred in the study area since 1960, including changes to navigation channel maintenance, enlargement of passes and diversion construction. This information, along with information on significant flood and storm events, was used to improve the interpretation of results of the other analyses and to gain a better understanding of the geomorphology of the lower Mississippi River.

Integration of Results and Conclusions. Integration of the results from all of the analyses conducted as part of the geomorphic assessment was the basis for formulating study conclusions. The results from each analysis were evaluated with respect to the results of the other analyses to establish the trends in river morphology and sedimentation from a historic perspective. The integrated results were evaluated to determine if observed shoaling trends in the Pilottown anchorage area were within the influence of large-scale, long-term morphological changes occurring within the study reach, or a specific result of the impact of West Bay diversion. Since conflicting results are always a possibility, all results were evaluated in an integrated manner to arrive at the most accurate and complete assessment.

GEOMETRIC DATA ANALYSIS AND RESULTS

The geometric data analyses were conducted with the comprehensive and channel condition hydrographic survey data adjusted to horizontal NAD83 State Plane Louisiana South and vertical NAVD88. The comprehensive hydrographic surveys are full river surveys collected on a decadal scale, whereas the channel condition hydrographic surveys are collected on a monthly timeframe but over a smaller area for determination of maintenance dredging needs in the Mississippi River navigation channel. Channel condition surveys used for the geometric data analysis were the October time-frame surveys.

<u>Cross Section Analysis</u>. Cross sections were generated in the GIS system at regular intervals in the study reach and used to extract the bathymetry data for each hydrographic survey. The cross sections are orientated from left to right looking downstream. The location for the cross sections within the extent of the anchorage area is shown in Figure 2. The extracted bathymetric data for all surveys available at each cross section were plotted for comparison and to determine any trends in channel dimension change. A comprehensive presentation of the cross section data for the study is not possible in the scope of this paper; therefore selected comparisons will be shown to illustrate the overall findings of the analysis.

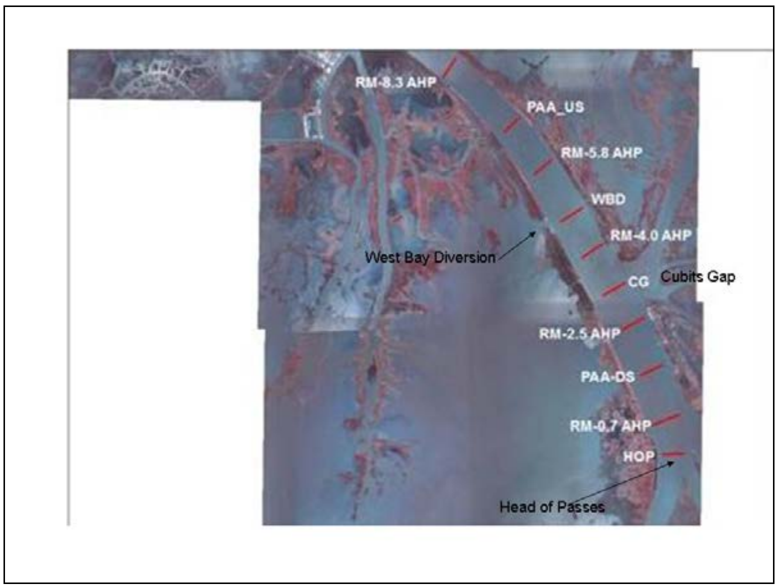

Figure 2. Cross section locations within Pilottown Anchorage Area

In general, the cross section data indicates that the Mississippi River profile above Venice (RM 10.3 AHP) has experienced little change to a slight lowering over the study period. Cross sections indicate that some channel adjustment in dimension and profile has occurred, primarily in response to construction of revetments, but no system-wide trends of adjustment were noted. The cross section comparison for RM 75.0 AHP is shown as a representative example in Figure 3.

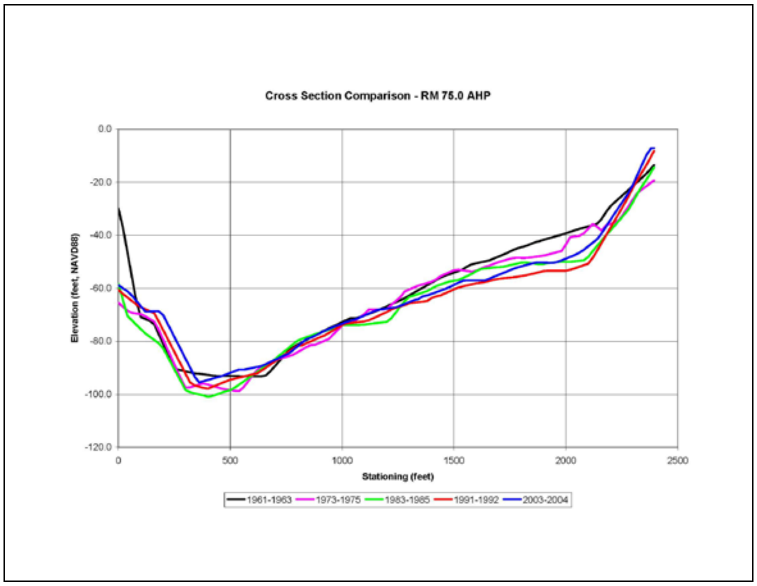

Figure 3. Cross section comparison for RM 75.0 AHP, Mississippi River

The cross section comparisons indicated that a change in channel depth trend occurs downstream of Venice, where diversion of river flow via Baptiste Collette Bayou and Grand Pass occurs. The comparisons show that river depths have decreased by as much as 20 feet since the 1990s. Figure 4 shows the depth changes that have occurred at RM 6.7 AHP, which is the upstream extent of the anchorage area. In addition to the change in depth, the plot illustrates a shift in the thalweg channel location towards the right descending bank. The vertical line in the plot represents the boundary of the anchorage area.

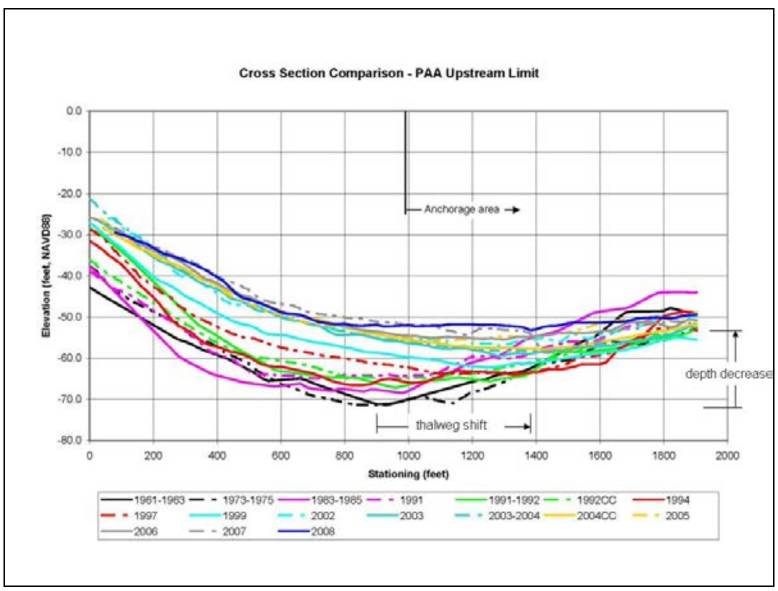

Figure 4. Cross section comparison at upstream extent of anchorage area, RM 6.7 AHP

The cross section comparison for RM 2.5 AHP shown in Figure 5 indicates changes in dimension that have occurred in the downstream extent of the anchorage area in the vicinity of Cubits Gap, another significant diversion point of river flow. The plot also shows the impact of regular maintenance dredging for the Mississippi River navigation channel that is required from this point to the gulf outlet. As can be seen in the plot, a significant lateral bar has developed along the right descending bank within the anchorage area. This lateral bar development was occurring well before the construction of the West Bay diversion in 2003, and correlates with the deepening of the Mississippi River navigation project that transpired in 1987. One possible explanation for this morphological adjustment is that the lateral bar is building as the river compensates for the increase in channel flow area due to the deepening of the navigation project.

Cross section comparisons were also made for locations within Southwest Pass. Since this is the primary navigation outlet to the gulf, the channel dimension is totally dominated by the effects of maintenance dredging, and no trends were identified. In general, the cross section comparison results indicate that the river channel upstream of Venice is stable to slightly lower, but a trend shift to decreasing depths occurs downstream of Venice. Downstream of Cubits Gap the influence of navigation channel maintenance dredging is observed, as well as the development of a large lateral accretion along the right descending bank. The comparisons indicate that the later bar was developing prior to the construction of West Bay diversion.

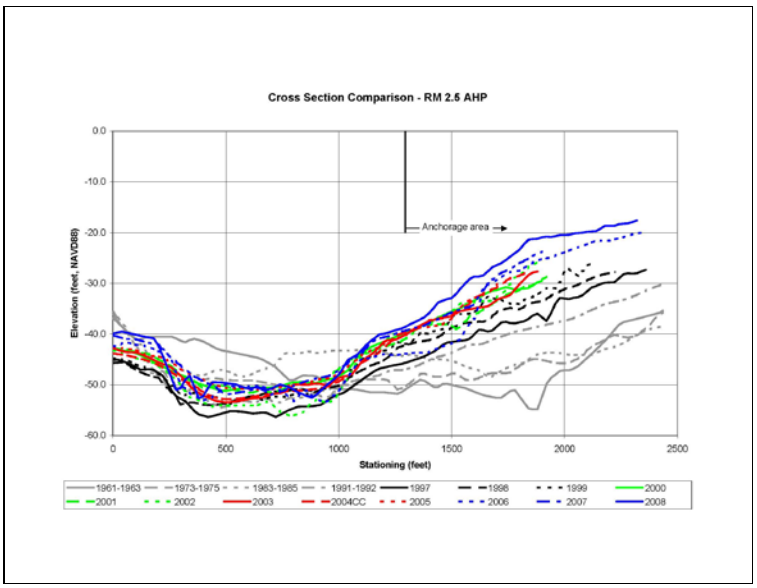

Figure 5. Cross section comparison for RM 2.5 AHP in downstream vicinity of anchorage area

Volumetric Analysis. Polygons representing the area between each cross section within the anchorage area and a 500 foot width from the anchorage area line towards the right descending bank were constructed in the GIS. The volume for each hydrographic survey was computed for each polygon, and the difference for each successive survey was used to determine a temporal change in volume representative of sediment accretion or erosion within the polygon area. In addition, the incremental volume changes were converted to an average bed elevation change by dividing by the surface area of each polygon. This was performed for both the decadal hydrographic surveys and the yearly channel condition surveys. The volumetric analysis was also conducted for polygons constructed for the other river reaches in the study area outside of the anchorage area, but are not presented in this paper.

The computed average bed elevation change from the channel condition hydrographic surveys for the anchorage area polygons is shown in Figure 6, along with the location of the polygons. In general, the overall trend has been an increase in average channel bed elevation over time, with a deeper channel observed in the upstream portion of the anchorage area than in the downstream anchorage area. Average depths in the upstream portion of the anchorage area (PAA1a) range from 50 to 60 feet and from 45 to 30 feet in the downstream portion of the anchorage area (PAA3b). The average bed elevation plots for the polygons immediately upstream and downstream of the diversion (PAA1b and PAA2a) seem to indicate a noticeable decrease in average depths immediately after the diversion was constructed, but the variability in the data makes it difficult to formulate definitive conclusions. Plots for polygons in the downstream extent of the anchorage area below Cubits Gap (PAA3a and PAA3b) indicate no trend change due to diversion construction, as well as indicate that the channel bed was accreting prior to diversion construction.

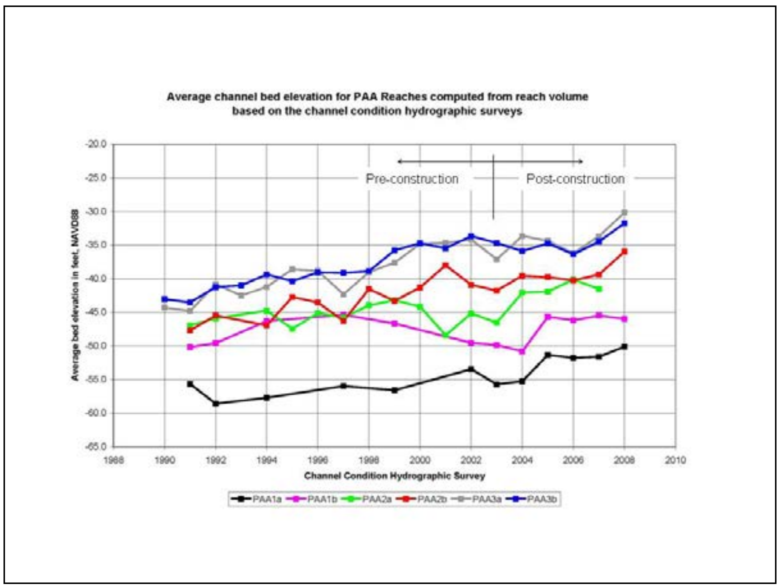

Figure 6. Average bed elevation change for volumetric polygons in the anchorage area

Channel Pattern Analysis. The hydrographic surveys were contoured and the -45 foot depth contour was traced to determine the position of the river channel, and a qualitative channel pattern analysis was conducted. The -45 foot contour corresponds to the authorized channel depth for the Mississippi River deep draft navigation project, and the location of this contour over time gives some sense of the historic stability of the thalweg channel. No major meander shifts of the main river bank line have occurred over the study period.

The -45 foot contours for the channel condition surveys are shown in Figure 7, with the focus on the lower Mississippi River downstream of Venice. Upstream of Venice the width of the -45 foot channel averages 80 percent or more of the total top bank width of the river. Immediately downstream of Venice and the distributaries of Baptiste Collette and Grand Pass a alternate lateral bar sequence is observed. Below Venice a lateral bar is formed along the left descending bank, and the -45 foot channel occupies approximately 50 percent of the total top bank width. A crossing occurs near the upstream limit of the anchorage area, with the thalweg channel shifting from the right to the left descending bank. The thalweg channel has crossed to the left descending bank at the latitude of the West Bay diversion, and is fully entrenched along the right descending bank from Cubits Gap to Head of Passes. A very large lateral bar has developed along the right descending bank in this reach. Downstream of Cubits Gap the channel-ward extent of the bar is such that the -4 foot channel occupies only 25 to 30 percent of the total top bank width of the river. This large lateral bar is almost entirely located within the anchorage area limits.

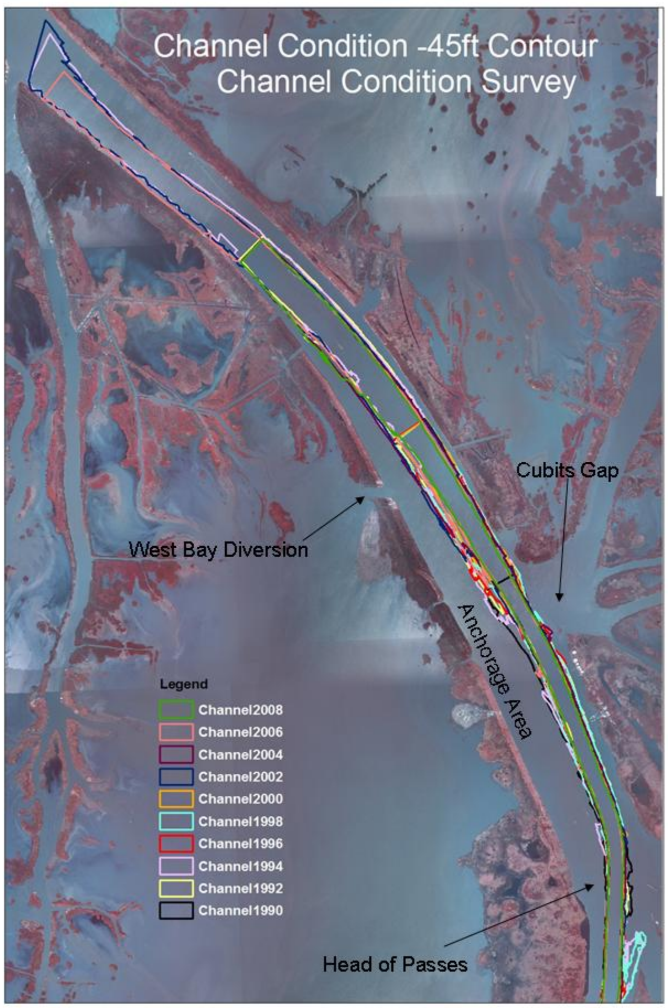

Figure 7. Contour tracings for -45 foot channel for the channel condition surveys

The effects of regular channel maintenance dredging between Cubits Gap and Head of Passes can be seen from the contour tracings as well as the cross section comparisons for this area (Figure 5), and the channel location is very consistent in this reach. Between Cubits Gap and West Bay diversion there is evidence of greater variability in the channel location and width.

Although difficult to definitively determine, there appears to be some narrowing of the channel width since the opening of the diversion. The channel from the most recent hydrographic survey in 2008 indicates this most narrow channel of all survey tracings.

GAGE/DISCHARGE/SEDIMENT DATA ANALYSIS

Published discharge measurements for the Mississippi River and the distributaries and passes within the study area were used to compute the flow distribution of each outlet as a percentage of Mississippi River discharge. These flow distribution percentages were plotted versus time to investigate changes in the flow distribution patterns during the study period. Over the study period, the combined flow distribution from Baptiste Collete Bayou and Grand Pass has increased from 6-8 percent of river discharge at Venice in the early 1960s to 16-20 percent currently. The flow distribution for the West Bay diversion has increased as the diversion channel has developed. At the time of construction West Bay diversion was carrying approximately 2 percent of river discharge at Venice to 7-8 percent currently. Conversely, the percentage of Venice discharge carried by Cubits Gap has decreased since construction of West Bay from approximately 15 percent to 12 percent. The plot of flow diversion as a percentage of river flow at Venice for West Bay diversion and Cubits Gap is shown in Figure 8.

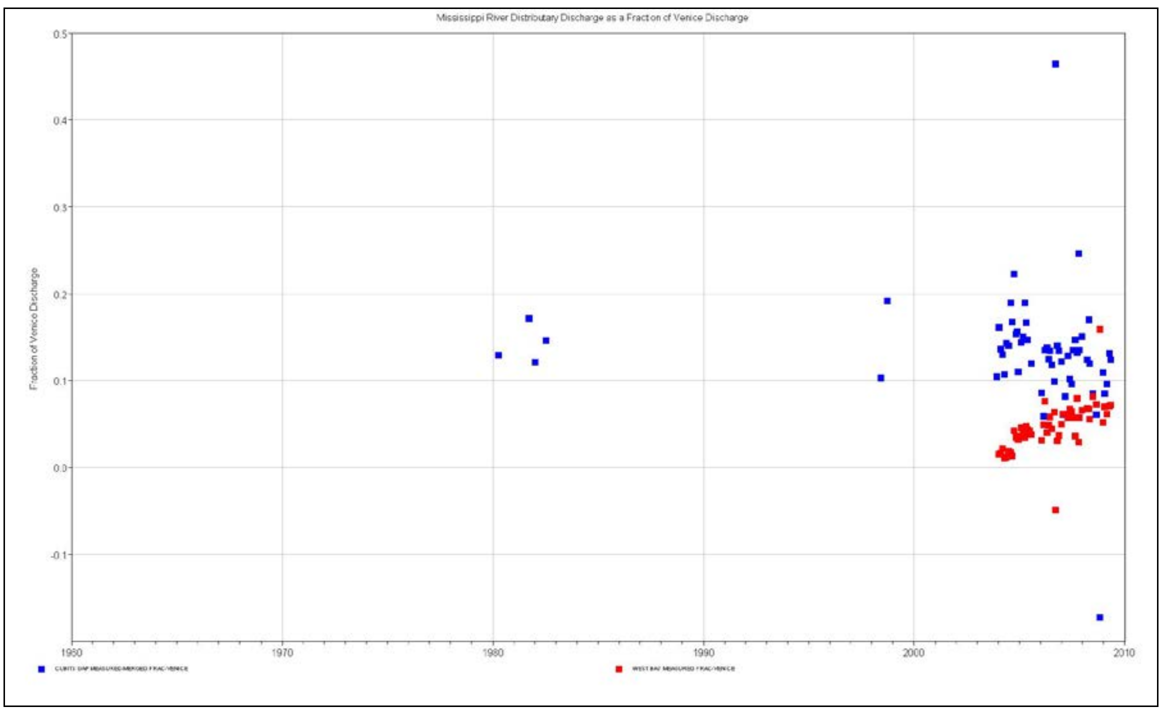

Figure 8. Flow distribution for West Bay diversion and Cubits Gap as a percentage of Mississippi River discharge at Venice, LA.

The current combined flow distribution for all distributaries and passes on the Mississippi River from Venice to Head of Passes as a percentage of Venice discharge is approximately 40 to 45 percent. This loss of river water likewise results in a loss of sediment transport capacity within this reach, which contributes to the development of the alternate lateral bars found downstream of Venice. As the flow distribution in the area changes the river continually adjusts its dimensions to convey the sediment load.

Previous analyses of long-term suspended sediment data for the Mississippi River at Tarbert Landing indicate there has been a reduction in suspended sediment load for the lower river. Demas and Allison (2009) report a significant trend in reduced suspended sediment load at Tarbert Landing for the period 1976-2006 (Figure 9). This reduction in suspended sediment load suggests that observed shoaling increases in the lower river and the anchorage area are a result of reductions in transport capacity due to an altered hydraulic regime rather than an increase in sediment supply.

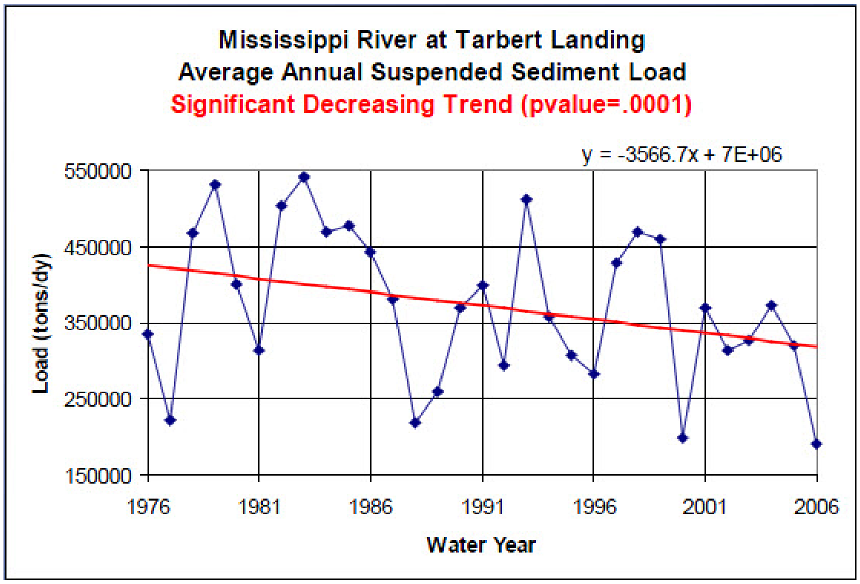

Figure 9. Annual suspended sediment load for Mississippi River at Tarbert Landing (after Demas and Allison 2009)

DREDGE DATA ANALYSIS

Dredge records were collected and analyzed to determine trends in required maintenance dredging for the Mississippi River deep draft navigation project. These dredge records report the total annual dredge volume for the Head of Passes reach as well as Southwest Pass, the primary gulf outlet channel. No site-specific information was available from these records, and the annual totals are presented to illustrate the trend in general dredging activity in the study area. The annual dredge volumes since 2000 have been less than the long-term average, but identification of a long-term trend for the study period is uncertain. The reduction in annual dredge volumes does seem to correlate with the long-term reductions in suspended sediment load for the lower Mississippi River. The plot of annual dredge volumes for Southwest Pass, including the Mississippi River channel above Head of Passes, is shown in Figure 10.

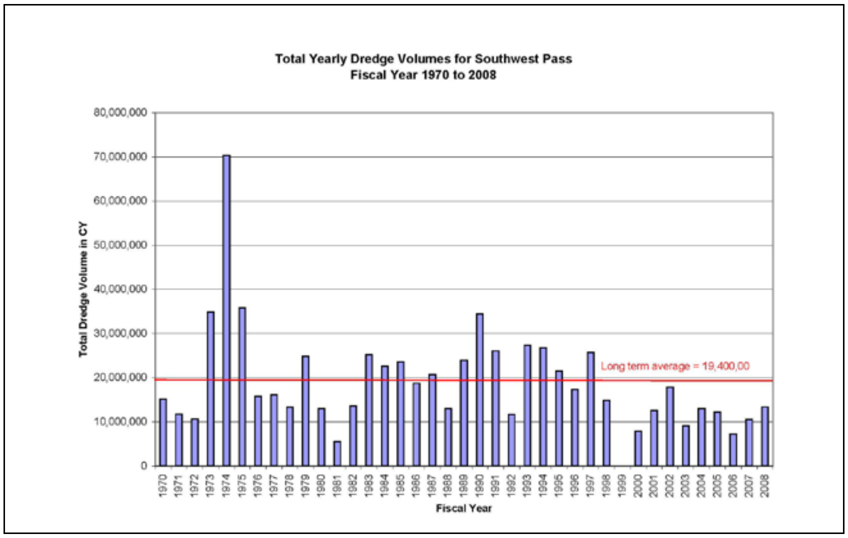

Figure 10. Total annual dredge volumes for Southwest Pass & Mississippi River Head of Passes

HISTORIC EVENTS TIME LINE

A comprehensive report of the events that have transpired in terms of river engineering, channel maintenance and other man-induced activities for the study area was compiled. The information provides background information that is essential for an accurate interpretation of the results of the various analyses conducted in the geomorphic assessment. The report covers the principle river engineering activities that have occurred from 1960 to the present. Four significant events are detailed that are believed to at least contribute in some degree to the river channel morphology observed over the study period: 1) deepening of the navigation project from -40 feet MLG to -45 feet MLG, 2) enlargement projects on Baptiste Collette Bayou and Grand Pass, 3) river bank line restoration projects and 4) construction of West Bay diversion.

INTEGRATION OF RESULTS AND CONCLUSIONS

The results of the various analyses of the geomorphic assessment were integrated and evaluated using best engineering judgment with regard to long-term morphological trends in the study area, construction of West Bay diversion, and the potential impacts of the diversion on induced shoaling in the Pilottown anchorage area. The following conclusions are presented:

- The lower Mississippi River and delta region is a dynamic system that has experienced significant morphologic adjustment over the study period.
- The river channel upstream of Venice has been generally stable in dimension and pattern over the study period, with essentially no change to a slight increase in channel depth.
- A definitive change in channel trends occurs at Venice. In general, channel depths from Venice to Cubits Gap decrease consistently over the study period. Downstream of Cubits Gap and throughout Southwest Pass the channel is heavily influenced by navigation maintenance dredging. Depth change trends are basically indistinguishable except for increases due to deepening of the navigation project.

- The lateral bar along the right descending bank that extends throughout the anchorage area was developing prior to the construction of West Bay diversion, and would have continued to develop to some degree without construction of the diversion. Development of the lateral bar downstream of Cubits Gap appears to correspond to deepening of the navigation project.
- Construction of West Bay diversion has likely contributed to increases in deposition rates in the anchorage area mainly between the diversion and Cubits Gap. Deposition rates in the anchorage area downstream of Cubits Gap indicate little influence due to construction of the diversion.
- The distribution of Mississippi River flow via outlets in the study area is believed to be a major factor in observed channel morphology and deposition trends between Venice and Head of Passes.
- Identifying and quantifying impacts that are specific to West Bay diversion is difficult using these types of assessments. Observed changes in the geometric data are a cumulative result of all processes and influences such as river hydrology, floods, storms, dredging activities and river engineering projects. Impacts specifically attributable to construction of West Bay diversion are best determined through numerical modeling. Modeling results should be evaluated along with the geomorphic assessment results to achieve the most comprehensive and accurate interpretation of diversion impacts on anchorage area shoaling.

REFERENCES

Demas, C. and Allison, M.A. (2009) "Overview of Sediment Processes and Data Availability for the Lower River", presentation at Louisiana Coastal Area (LCA) Science & Technology Program Diversion Summit.