SEDIMENT INVESTIGATIONS IN THE VICINITY OF THE OLD RIVER COMPLEX, LOUISIANA: RED RIVER ABOVE OLD RIVER OUTFLOW CHANNEL

Nina J. Reins, MS, Shaw Coastal, New Orleans, Louisiana, nina.reins@gmx.de; Tonja L. Koob, PhD, PE, Gaea Consultants, LLC, New Orleans, Louisiana, tonja.koob@gaeaconsultants.com

Abstract: This research introduces the Old River Control Complex (ORCC) and defines the existing problem of disproportionate water versus sediment diversions. Because the ORCC is a water control complex built to keep the Atchafalaya River from taking over the Mississippi River and to generate power, it is crucial for the system to function properly to maintain a balanced sediment regime. The slightest changes in the sediment environment can be critical for the Mississippi, Atchafalaya, and Red Rivers, and for the Old River Outflow Channel itself. Scouring and deposition occur due to an existing imbalance of sediment concentrations. Therefore, analyzing the available sediment data for stations in the vicinity of the ORCC is important to understand the overall shifts of sediment occurring in this area. If the sources for the shifts of sediment can be defined, additional recommendations for future handling methods can be made, and excessive scouring and deposition can be prevented.

Focusing on the station *Red River above Old River Outflow Channel*, this research outlines a method of properly assembling, managing and interpreting the data available from a sediment sampling station in the vicinity of the ORCC. The spreadsheets developed in this study are easy to use for ongoing data management and make updating the analysis and future interpretations much easier. The introduced methods can now be easily implemented for the key stations to draw more detailed conclusions concerning sediment shifts.

INTRODUCTION

The Mississippi River is one of the world's major river systems in size, habitat diversity, and biological productivity. Under natural conditions, the Mississippi River might have switched its course to the Gulf of Mexico via the Atchafalaya distributary between 1965 and 1975. The river has been prevented from doing so by artificial levees and control structures at Old River. Natural diversion of Mississippi River flow to the Atchafalaya has been imminent because the Atchafalaya is both a steeper and shorter route to the Gulf of Mexico than is the Mississippi. The Atchafalaya now drains about 30% of the latitude flow of the Mississippi and the Red Rivers to the Gulf of Mexico.

The structures controlling this flow through the Old River Outflow Channel are referred to as the Old River Control Complex (ORCC), which is located on the west bank of the Mississippi River about 50 miles northwest of Baton Rouge, Louisiana, as shown in Figure 1. This complex is a vital part of the Mississippi River and Tributaries (MR&T) flood control plan.

The initial features were: two mechanically operated control structures, designated as the Low Sill Structure and the Overbank Structure; inflow and outflow channels; a lock for navigation, and other appurtenant works. Construction began in 1955 and was completed in 1963. An Auxiliary Structure was added to the complex in 1986 to provide greater flexibility and to reduce stress on the Low Sill Structure, which was damaged in the 1973 flood. Four years later a privately owned and operated hydropower plant was constructed in the immediate vicinity of the ORCC.

Sediment transport plays an important role in this complex. Accumulation of large grain sediment in some areas within the vicinity of the ORCC and significant accretion in others cause problems for facility operators as well as bank instabilities and failures. U.S. Army Corps of Engineers (USACE) hydraulic experts believe that a continued accumulation of large-grain sediment in the Mississippi River may lead to a deterioration of the MR&T system in the vicinity of the ORCC area, and could ultimately result in a need to increase the height of the Mississippi River levees to provide the required level of flood protection. The numerous bank failures and soil erosion in the lower Red River may require expensive levee setbacks if measures are not implemented to reduce the number of bank failures that are occurring at a progressive rate. There is also concern that the current ratio of large-grain sediment between the Mississippi River and Atchafalaya River is out of the targeted range and will eventually result in navigation problems and an increase in bank failures throughout the system, resulting in regional and national consequences.

There is no unanimity among experts of the cause or significance of the events that are being observed in the lower Red, Old, Mississippi, and Atchafalaya Rivers. This is a very complex river system that requires recognizing subtle changes that will lead to significant problems many years before the problem occurs. Constant vigilance and experience are necessary to understand and perceive minor changes that could ultimately alter the system in a negative way. Part of the difficulty is recognizing the subtle changes and determining if the changes are part of a natural cycle or if they are a detrimental pattern that will destabilize the system. The MR&T system is so important to the region and the nation that every anomaly with a potential to destabilize the system should be investigated thoroughly.

Sediment investigations have been made since the 1930's, but the most recent study, published in 1999, was the "Lower Mississippi Sediment Study" by the Louisiana Hydroelectric Limited Partnership, Vidalia, Louisiana. The study results were reviewed by sediment transport experts in the consulting and academic fields who recommended further and, if possible, more detailed monitoring and analysis, and updating of the reviews about every five years. Because of the broad agreement on this recommendation, especially within the USACE, a new comprehensive study within the vicinity of the Red, Old, Mississippi, and Atchafalaya Rivers (ROMA Study) is in preparation. A draft was established in 2004 to introduce the purpose and the tasks of this study. This research is the first approach towards fulfilling some of the goals established by the ROMA Study draft document. Collecting, processing and managing data is one of the tasks detailed in the draft. Existing data needs to be inventoried and updated, and appropriate databases have to be established for use during the study and in future reviews. Sediment concentration and grain size analyses are a substantial portion of the data to be processed and analyzed. To evaluate the trends in sediment transport within the ORCC and its vicinity, it is necessary to research and compare the stations above and below Old River Outflow Channel and the Outflow Channel itself. The stations 1) Red River above Old River Outflow Channel, 2) Coochie, 3) Simmesport, 4) Tarbert Landing and 5) Old River Outflow Channel fulfill this criterion, and are illustrated in Figure 2.

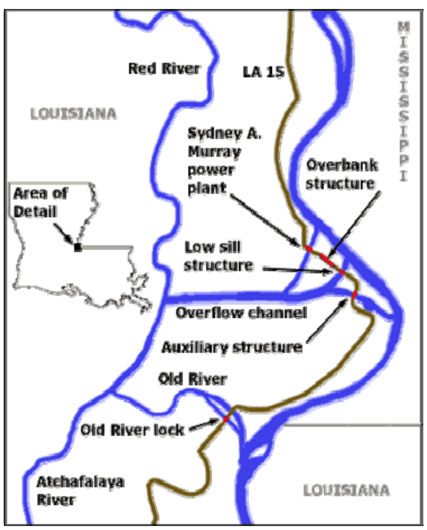

Figure 1 Old River Control Complex

Figure 2 Sediment Sampling Stations in the Vicinity of the ORCC

These sediment sampling stations have long data records, making it possible to evaluate changes over time in the hope of predicting future trends. Due to the overwhelming amount of data for each station, and the effort it takes to verify the data, this research focused on one station, and developed a template for the other stations.

METHODS

Data Collection: Sediment data at all five stations within the vicinity of the ORCC is available in an electronic 3pg format from the USACE from 1973 to 2003 for Tarbert Landing and Simmesport, from 1975 to 2003 for Coochie and Red River above Old River Outflow Channel, and from 1977 to 2003 for the Old River Outflow Channel. Some 3pg files have less information than others, depending on the sampling procedure or whether the soil tests were successful. Missing data was identified and old documents and handwritten data files, which were not available in electronic form, were researched for needed data. No additional data was found for the Red River above Old River Outflow Channel.

Because of the overwhelming amount of data, which has to be either reviewed closely or manually entered into the computer and analyzed for errors, only the station Red River above Old River Outflow Channel was picked to create all spreadsheets and documents needed for data interpretation because of (a) it experienced lack of sediment resulting in numerous bank failures and soil erosion in the lower Red River due to scouring and (b) because almost all collected data was available in electronic form.

Creation of One Data Summary: In cooperation with the USACE, the decision was made to use the information in the 3pg summaries to create one data summary including all the years of available data. It includes the date of the sampling, gage reading [ft], type of sampler used, number of verticals taken, discharge [cfs], coarse load [tons/day], Fine Load [tons/day], Total Load [tons/day], Coarse Concentration [ppm], Fine Concentration [ppm], Total concentration [ppm], suspended sediment sieve analysis, and bed material sieve analysis. The only year between 1973 and 2003 without any 3pg files is 1990. No sediment samples were taken at this station during that year. Some months are missing in other years, and every water year had a different number of sampling dates, making a comparison of the analyzed data more complicated and more prone to errors.

Creation of Grain Size Distribution Curves: In agreement with the USACE, the decision was made to establish a general spreadsheet for Grain Size Distribution Curves, but not to create a grain size distribution curve for every day measurements were taken. The detailed analysis of the Suspended Sediment and Bed Material, as well as its quality control, is a further, very extensive analysis which will not be covered in this research, but will have to be completed to fulfill the goals set in the Draft of the "Red, Old, Mississippi and Atchafalaya Rivers Comprehensive Study". To still use the provided information to view a trend in the change of bed and suspended material, the available data was divided into four periods of measurement (1973-1979, 1980-1989, 1991-1999, 2000-2003) and average grain size distribution curves for bed material and suspended sediment are shown in Figures 3 and 4.

Creation of Discharge Curves: The maximum, minimum and average daily discharge data from Simmesport and Old River Outflow Channel were combined and formatted in a spreadsheet and QA/QC measures were applied. To determine the daily discharge values for Red River above Old River Outflow Channel, the values of the Old River Outflow Channel had to be subtracted from the values from Simmesport. If either of the values for a specific day was not given, the cell to be calculated remained empty. If a negative value or a value below 4,000 cfs was calculated for Red River above Old River Outflow Channel, it was changed manually to 4,000 cfs, due to information from the USACE, which is based on their experience with the river. Additionally the daily average from water years 1972/1973 to 2003/2004 was calculated. Graphs presenting the calculated discharge values were created for every water year and supplemented with the actual measured values in the field and the average for the entire period of records. An example discharge graph is presented in Figure 5.

With this procedure, calculated values could be compared to actual measured discharge values. Typographical errors in the measured data were detected and resolved in agreement with the USACE. The average helps to define if the specific water year is a high water year, an average water year or a low water year. It also makes it easier to detect the time period of any particular flood. This information, together with the computed loads as introduced later, helps to find a correlation between load and discharge for any given water year.

CREATION OF POWER CURVES

Power Curves for Every Water Year: From the created data summary, power curves were obtained for every water year. The x-axis of the graph is discharge in cfs, and the y-axis is sand concentration in ppm. After all data points for the specific water year were added to the graph, a power curve trendline was generated. The equation and the R-squared value received from this trendline were placed next to each graph. For sampling dates where the sediment concentration equaled zero, the value was changed to one in order to establish the power curve trendline. With a value of one the calculated load for those days is still close to zero and does not appreciably change the outcome of the data analysis.

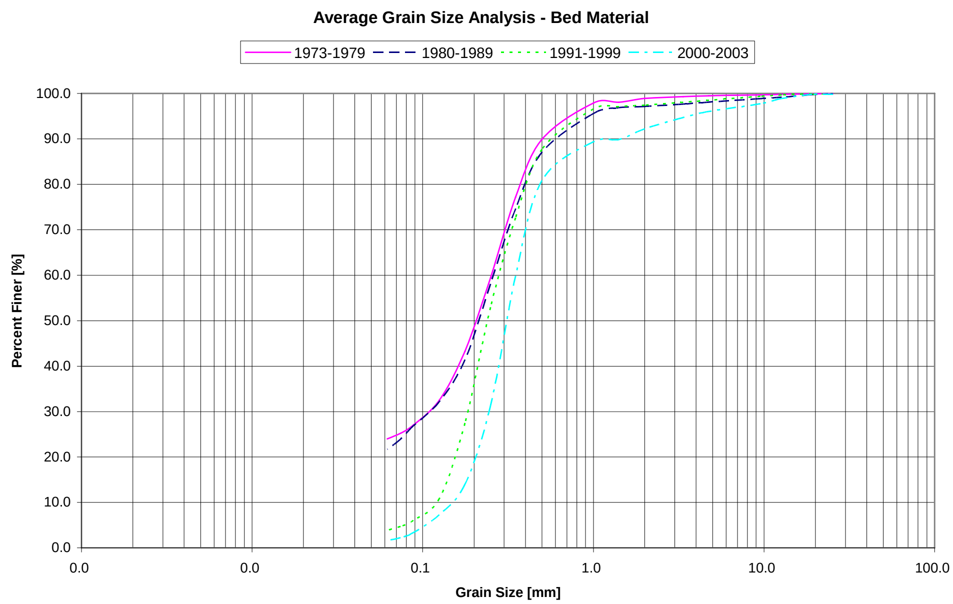

Figure 3 Average Grain Size Analysis for the Bed Material over Time (1973-2003)

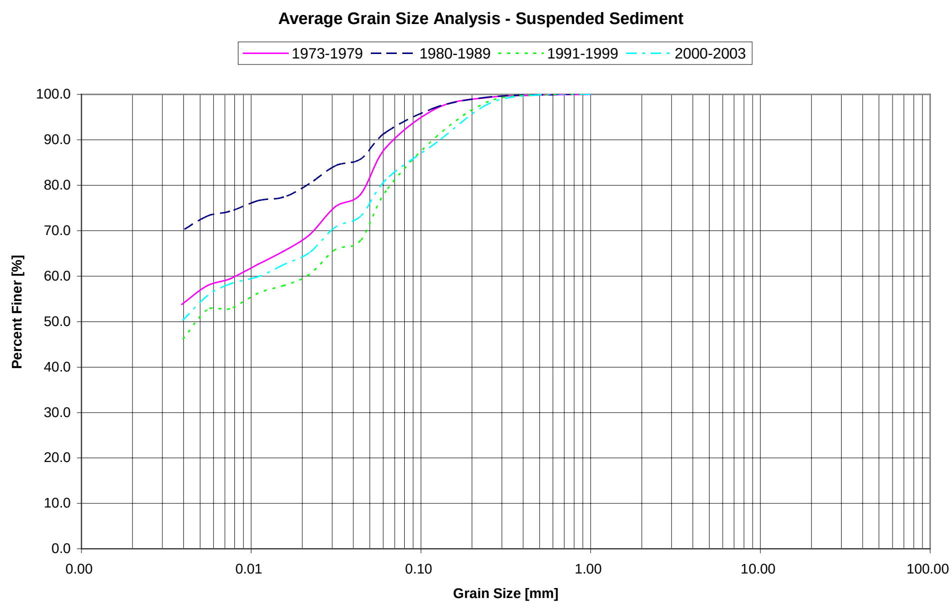

Figure 4 Average Grain Size Analysis for the Suspended Material over Time (1973-2003)

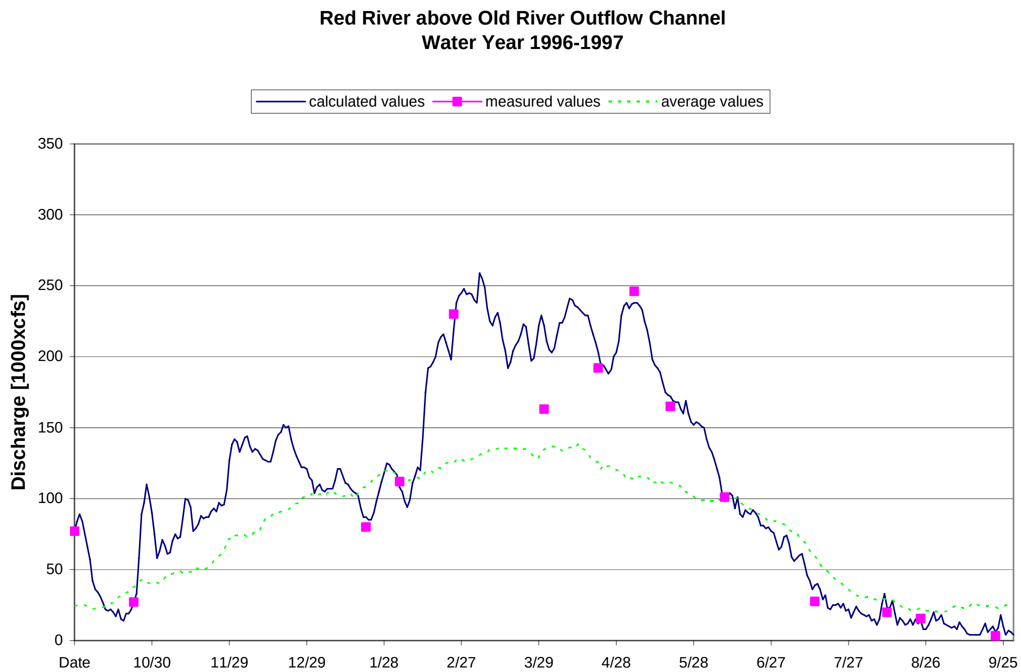

Figure 5 Discharge Graph for the Water Year 1996-1997 at Red River above Old River Outflow Channel, including Calculated and Measured Discharge Values

Combined Power Curves for a Period of Time: Similar to the procedure described above, power curves were established representing a longer period of time, instead of just one particular water year, and were combined in one graph. The periods chosen to be presented intended to cover a period of 10 years each, starting with 1970, 1980, 1990, and 2000. Due to the available period of record from 1973 - 2003, and the fact that no sampling occurred in 1990, the periods chosen were 1973 – 1979, 1980 – 1989, 1991 – 1999, 2000 – 2003. All data points used to create the trendlines were removed from the graph and only the four trendlines are shown in Figure 6 with their equations and R-squared values. These power curves are designed to find overall trends, and because each one is based on more data points than a single water year, the trendlines are more accurate than annual trendlines.

Load Calculation for Water Years 1972/1973 to 2002/2003: Daily discharge data and the power curve results were used to create a daily summary for every water year, including discharge, sand concentration, and coarse load. After calculating the load per day, the annual load for the water year was calculated. To calculate the coarse load in tons/day the following equation provided by the USACE was used:

$$\text{Coarse Load [tons/day]} = \text{Sand Concentration [ppm]} \times \text{Discharge [cfs]} \times 0.00269568 \quad (1)$$

In a final step, the annual load in tons was calculated. To visualize the calculated information, Figure 7 was created to show the Computed Annual Load per Water Year for the entire period of record. The graph was obtained by using all available information of this research.

CONCLUSIONS AND RECOMMENDATIONS

For the Red River above Old River Outflow Channel a correlation exists between annual sand loads and the discharge pattern. Post-1990 high water years produced more load than pre-1990, which is not the case for average or low flows. Because of the continuous high waters in the period 1991-1999, there might have been more sediment uptake upstream from the gage due to more powerful flow and loosened sediment from the lock constructions, which would explain the experienced increase of sand load. Furthermore, because of the scouring problem observed in the Lower Red River after the construction of locks and dams upstream,, high discharges might have accelerated this scouring process, and therefore, produced more annual load for high water years post-1990. This would also explain why the average and low water years do not show an increase in computed annual load. The water flow was not powerful enough to accelerate scouring in the way high water flows can during high water years and flooding times did.

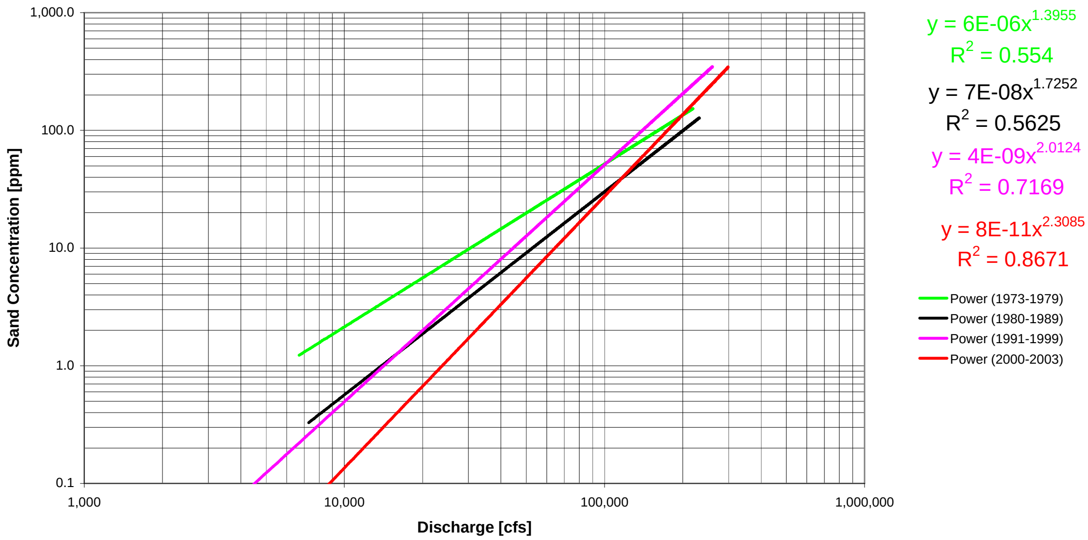

Figure 6 Combined Discharge-Sand Concentration Graph for Red River above Old River Outflow Channel

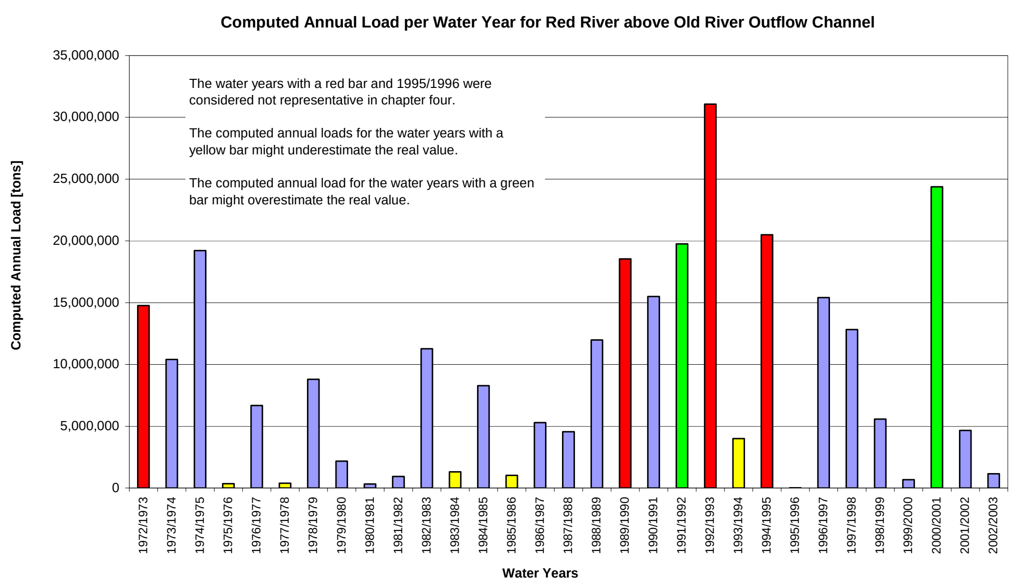

Figure 7 Computed Annual Load per Water Year for Red River above Old River Outflow Channel

To define more accurately how the locks and their operations correlate with the scour problems experienced in the Lower Red River, it is recommended, as a first step, for the ROMA Comprehensive Study to compare sediment sampling stations on the Red River below the locks and upstream of the sampling station Red River above Old River Outflow Channel with the observations from the sampling station Red River above Old River Outflow Channel. As a second step, if necessary, a more detailed study over the period of approximately a year, covering the stretch from the L.C. Boggs Lock to the Old River Outflow Channel, should be conducted. Sediment samples and discharges can be measured frequently throughout the year, especially after closures and openings of the L.C. Boggs Lock. This information, along with a geomorphologic assessment, would help to analyze more specifically the sediment source/impact relationship, and help to produce management options for more environmentally sustainable and functional lock operations.

From the average power curve trendlines a chronological downward trend in sand concentration for discharges below approximately 100,000 cfs can be seen. At least 2/3 of all flows within one water year are below 100,000 cfs, implying that for most flows a downward trend in sediment concentration can be observed. For discharges higher than approximately 100,000 cfs, no clear trend could be observed. This could be the result of the construction of locks and dams on the Red River. These locks close during low flow times, which offers an explanation for the sand deficit at Red River above Old River Outflow Channel for low flows, because sediment becomes trapped in the pools. Conversely during high water and flood periods the locks are open and the suspended sediment can pass without any barriers, which explains why no explicit trend can be observed. Further investigations will have to be made to verify this trend conclusion.

In comparing the average grain size distributions of the bed material over time, a continuous decline in fines can be observed. The main flushing out of fines, which results in an armoring of the bed, occurred in the 1990's, and continues to the present. This is a potential problem because the fines provide the habitat for benthic organisms, which are the lowest members of the food chain in this system and their loss would overtime affect the rest of the food chain. Also, the fine bed material is where fish and other organisms place their eggs. Without the fines, the eggs would be lost in the gaps between the coarser particles, resulting in lower species reproduction. One explanation for the armoring is the sediment loss of the stream during closure periods of the locks. Closing the locks during low flows results in a sediment deficit downstream of the locks and encourages the uptake of downstream particles in order for the stream to return to its sediment equilibrium. Because the flow beyond the locks is not very powerful, the uptake of fine material versus coarse material is more likely to happen, explaining the experienced loss of fines. Based on the available data, more uptake of fines occurred in the 1990's, which was attributed to the completion of the construction of the five locks on the Red River between Shreveport and the Old River Outflow Channel, and the fact that more high water years and high average water years occurred in this period resulting in a more powerful stream with more capacity for sediment uptake. More data pertaining to the verification of these findings should be collected and analyzed to confirm these introduced conclusions. If supplemental data verifies that the locks are causing the experienced sediment deficit, it is recommended to manage the locks on the lower Red River as a system, making the passage of sediment more organized, and if necessary, to dredge material from the pool to the downstream end of the locks during closure periods to decrease the sediment deficit downstream.

No definite trend was found for the suspended sediment. The lack of a trend could result from much of the suspended sediment being wash load generated from particle uptake in the watershed. Because wash load is that part of the total sediment load that is composed of particles smaller than 0.0625 mm, smaller than the particles present in appreciable quantities in the stream bed, it is only present as suspended sediment. Because the watershed characteristics and their contributions to the suspended load have not changed significantly since the 1970's and because the locks are flushed frequently, the settling suspended material is the first material which continues its downstream transport leading to no detectible change in suspended sediment.

It should be stated, that in the Draft of the ROMA Study, the reason given for the experienced scouring in the Red River is inaccurate. It has been stated by the USACE that a decrease in sand load is causing the problems, but a decrease in sand load has not been observed in this research. It has been found that the load correlates with the discharge and stayed similar for average and low water years over time. However, a decrease in sand concentration has been observed, which is the reason for the scouring, because the sand concentration, not the sand load, is the important variable to measure in a river experiencing bed and bank erosion.

The most time consuming parts of the introduced analysis involved manually entering and verifying data. Recognizing that fact, the introduced study will be very work- and labor-intensive. To make the quality control of the existing data more efficient for the other four key stations in the vicinity of the ORCC, it is recommended that a statistical analysis be done with the data once it is summarized in the database spreadsheet. Also, because in the future all the new data will be in a 3pg format, one recommended action is to write a program to copy the important information from the 3pg file into the summary spreadsheet, which would minimize the needed labor for updates.

To improve and expedite quality control for the future, it is recommended that the people sampling in the field indicate the measurements that seem odd. An engineer in the office, familiar with the river and the collection procedures, can check the data before it is entered into the data summary. This way no further verification of the data would be necessary after it had been entered to the summary spreadsheet.

The station Red River above Old River Outflow Channel was established in 1963, but there are only 3pg-files available from the USACE starting in 1973. Data from 1963 to 1972 would be very valuable for this research because that decade precedes the construction of the locks and dams on the lower Red River and because it would add another decade to strengthen the conclusions and trend analyses presented here.

Because the data available for the Red River was not always consistent over time, and because the amount of samples throughout a water year has declined drastically (from 26 to 6), the analysis is limited and a certain variability has to be accounted for. Specific values, like the computed annual load, cannot be taken as 100% accurate numbers, which should always be in mind for further conclusions. To be able to draw overall and more complex conclusions for the Old River Control Complex and its vicinity, the analysis introduced has to be finished for Tarbert Landing, Coochie, Old River Outflow Channel and Simmesport. Only with the same type of analysis for all these stations can the data be comparable and adequate recommendations made. It should also be noted, however, that even with the results from all five stations, a more comprehensive analysis of channel geometry and geomorphology is required to fully interpret the trends identified with this sediment study.

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