MORPHODYNAMICS OF THE MISSISSIPPI RIVER

Final Report

Principal Investigator: Colin R Thorne
Research Associates: Oliver P Harmar and Nicholas Wallerstein

School of Geography,
University of Nottingham
University Park
Nottingham, U.K.
NG7 2RD

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CONVERSION OF SI TO CUSTOMARY UNITS

The following units are used in this report and may be converted as indicated:

Distance	1 km = 0.625 miles	Mass	1 tonne = 1.1 U.S. tons
Discharge	1 m^3s^{-1} = 35.32 ft^3s^{-1}		

1. INTRODUCTION

1.2 Background

The Lower Mississippi River, extending from Cairo, Illinois to the Gulf of Mexico, annually transports approximately 170 million tonnes of sediment. Historically, the quantity and calibre of sediment derived from catchment erosion have been affected by changes in land-use and management. For example, soil erosion increased during the 19th and early 20th centuries due to settlement by Europeans and this may have elevated catchment sediment supply to the Mississippi River, while more recently the supply of sediment from tributaries is known to have decreased markedly as a result of river engineering and management. Specifically, the construction of large dams as part of the Mississippi River and Tributaries (MR&T) Project has trapped sediment that would otherwise have been supplied to the Mississippi, particularly by the Missouri River. Marked changes have also occurred in the extent of eroding bankline along the Mississippi and these must have reduced the input of sediment derived from this source. For example, during the last three decades, a sustained construction program of bank revetments and dikes has produced a stable alignment.

Given these trends in sediment supply from catchment, tributary and bank sources, it is not surprising that most studies of sediment movement report a large decrease in measured sediment loads at selected monitoring stations along the Mississippi River over the last 50 years (Kesel, 1988; Dardeau and Causey, 1990). However, a case can be made that the bed material load must have increased since the 1940s. This argument is based on analysis of morphological changes observed along the river that have led to an overall increase in slope and available stream power, coupled with the fact that bed material sizes along the river have remained almost constant (Biedenharn et al., 2000). It is possible that the overall decrease in total measured loads in the Lower Mississippi River masks an increase in the amount of bed material load carried by the river. If proven, this would have strong implications for the future morphological evolution of the channel as it responds to flow events and past engineering interventions.

1.2 Aims and Objectives

To investigate the recent history of sediment transport in the Lower Mississippi, a project was initiated with the aims of:

1. compiling a comprehensive computer database containing all available data on measured sediment loads and bed gradations for the Lower Mississippi River;

2. performing quality control procedures to validate the data;
3. undertaking an initial analysis on the data to identify and evaluate trends in space and time.

To achieve these aims, the following specific objectives were identified:

1. Locate and collect historical records of suspended load concentration, discharge and bed material size gradation measurements from US Army Corps of Engineers and US Geological Survey archives for the Lower Mississippi Valley;
2. Gather supplementary information including temperature, type of instrumentation, measurement technique, special circumstances etc. pertaining to the sediment transport measurements;
3. Compile all data into a spreadsheet database and write computer macros to perform a range of quality control checks for errors and inconsistencies;
4. Perform selected initial evaluation of spatial and temporal trends in sediment loads for fine and coarse fractions over the period of record.

1.3 Administrative Actions

A technical contract for a project titled 'Sediment Transport in the Lower Mississippi River' was negotiated between the University of Nottingham and the contracting office and a final version was agreed. The project was awarded by the contracting office to the University of Nottingham, Geography Department and initiated on 16th November 1999. Dr N P Wallerstein was appointed as a research associate for the project. Mr Oliver Harmar was recruited as a postgraduate hourly student to work on data entry and compilation. On July 17th, 2000 a parallel project 'Morphodynamics of the Mississippi River' was contracted and initiated to expand the scope of this study, specifically dealing with initial data analysis using the database compiled in the sediment transport study. This is the Final Report for the initial analysis study.

1.4 Logistics

The Principal Investigator made a week long visit to the Engineering Research and Design Center (formerly the Waterways Experiment Station) in late 1999. This meeting was used to initiate the research and collect sample data for evaluation at the University of Nottingham. The Principal Investigator travelled to Vicksburg again in Spring, 2000. The purpose of this second meeting was to discuss the framework and format of the database in detail and explore possibilities of extending the scope of the work. In July, 2000 the student hourly employee travelled to Vicksburg and worked full-time on the project for 8 weeks. The RA worked on the project part-time in Nottingham.

1.5 Report Content

This report deals with initial analysis of the sediment transport database compiled in an earlier project titled 'Sediment Transport in the Lower Mississippi River'. It cannot be read and understood without first reading about how the data were collected, compiled and quality checked. For this reason, and to ensure that this report is viable as a stand-alone document, the contents of the Final Report for the earlier transport study are included here in the first four sections and 3 appendices. Also, the database itself is also included on a CD-ROM attached to the back cover.

2. SEDIMENT DATA COLLECTION

This section describes the sources of data, the variability in the types of data available, and the sampling procedures used to collect the data. However, first it is important to address and resolve terminology problems encountered in compiling and discussing sediment data.

2.1 Definition of Sediment Transport Terms

To clarify the database and analysis and so avoid confusion, it is necessary to list the definitions of different types of sediment load referred to in this report. The definitions are summarised in Table 1.

Bed Load

Component of total sediment load made up of particles moving in frequent, successive contact with the bed. Transport occurs at or near the bed, with the submerged weight of particles supported by the bed. Bed load movement takes place by processes of rolling, sliding or saltation.

Suspended Load

Component of the total sediment load made up of sediment particles moving in continuous suspension within the water column. Transport occurs above the bed, with the submerged weight of particles supported by anisotropic turbulence within the body of the flowing water.

Bed Material Load

Portion of the total sediment load composed of grain sizes found in appreciable quantities in the stream bed. The bed material is the bed load plus the portion of the suspended load composed of particles of a size that are found in significant quantity in the bed.

Coarse Load

Portion of the total sediment load composed of grains coarser than 0.063 mm. The coarse load of the Mississippi River consists of sand.

Wash Load

Portion of the total sediment load composed of grain sizes finer than those found in appreciable quantities in the stream bed.

Fine Load

Portion of the total sediment load composed of grains finer than 0.063 mm. The fine load of the Mississippi River consists of silt and clay.

Measured Load

Portion of the total sediment load measured by conventional suspended load samplers. Includes a large proportion of the suspended load but excludes that portion of the suspended load moving very near the bed (that is, below the sample nozzle) and all of the bed load.

Unmeasured Load

That portion of the total sediment load that passes beneath the nozzle of a conventional suspended load sampler, by near-bed suspension and as bed load.

Total Sediment Load

The total mass of sediment transported by the stream. It can be broken down by source, transport mechanism or, measurement status (Table 1).

Table 1. Classification of the sediment load

Measurement Method	Transport Mechanism	Sediment Source
Unmeasured Load	***Bed Load***	***Bed Material Load***
	Suspended Load	
Measured Load		
		Wash Load

2.2 Data Sources

This project involved the assimilation and collation of data on four principal rivers. These are the Mississippi River, Atchafalaya River, Red River and the Old River (which connects the Mississippi River to the Atchafalaya). Measured sediment data was collated for *all* locations within the study area where records are available. Table 2 lists the sampling stations on each of the rivers described above. Appendix A lists the source organisation associated with data collection, the time period of available data, and a brief description of each data set for each sample station.

The major sources of data were the U.S. Army Corps of Engineers and the U.S. Geological Survey.

The data from the U.S. Army Corps of Engineers archives is collected by two regional District Offices: Vicksburg District and New Orleans District. Within the Vicksburg District, near-continuous data records extend back to 1979. However, several problems existed with this data. Firstly, the data existed in only a hardcopy paper format between 1979 and 1983 and in a text file format between 1984 and 1998. The latter period of data had to be obtained from Vicksburg District Offices and could not be simply imported into Excel. Therefore, the first priority was the conversion of this data into a workable spreadsheet format. Secondly, the records included detailed information for each vertical in the cross-section where sediment concentrations and bed material was sampled. The data had not been composited to produce fine, coarse and total sediment loads or average bed gradation data for the entire cross-section for each survey date. Therefore, to use this data in the preliminary analysis a suitable compositing routine needed to be applied to each data set.

Table 2. – Sediment Transport Gaging Stations included in Study

River	Station Name	River Mile (above Head of Passes, LA)
Mississippi River	St. Louis, MO	179.8[c]
	Chester, IL	110 [c]
	Thebes, IL	43.8 [c]
	Memphis, TN	735
	Arkansas City, AK	554
	Vicksburg, MS	436
	Natchez, MS	363
	Coochie, LA	317
	Tarbert Landing, LA	306
	Red River Landing	302
	St. Francisville, LA	266
Red River	Alexandria, LA	105[a]
	Madame Lee Revetment, LA	35[a]
Atchafalaya River	Simmesport	6[b]
	Melville	30[b]
	Morgan City	115 [b]
Old River	Knox Landing	314
	Low Sill Outflow	

[a] Above confluence of Red and Atchafalaya Rivers
[b] Below confluence of Red and Atchafalaya Rivers
[c] Above the confluence of the Mississippi and Ohio Rivers

Within the New Orleans District Data, near continuous records extend back to 1967 for Coochie and 1974 for Tarbert Landing on the Mississippi River. The majority of the available data had already been compiled at the Waterways Experiment Station. However, the New Orleans District Offices supplied the more recently available data, from 1995 to 1998, and assisted in either confirming the existence of prolonged temporal gaps within the data records or forwarding the missing data. Unlike the data reported for the Vicksburg District, compositing routines had already been applied to the New Orleans District data. The records report mean coarse, fine and total concentration data, mean suspended sediment gradation data and mean bed material gradation data.

The second major source of data was U.S. Geological Survey (USGS) archives. These records include only coarse, fine and total suspended sediment concentration and load data. Further, the sampling frequency is considerably coarser than either the USACE Vicksburg or New Orleans Districts so the analysis of long-term temporal trends is subject to greater uncertainty. However, despite these problems, the USGS data records are still valuable for two reasons. First, at locations where USACE records are absent, USGS records provide alternative long-term sediment series. Secondly, and perhaps more importantly, at locations, such as Vicksburg on the Mississippi River, where USGS data is available in conjunction with USACE data, comparisons of the temporal record provide an indication of data accuracy and introduce the possibility of data calibration.

The majority of the available USGS data collated for this study was obtained from the Waterways Experiment Station. However, additional suspended sediment data has also been downloaded from the USGS Sediment database website and incorporated within this study. This data is available for locations such as St. Louis, Thebes and Chester on the Mississippi River and provides the only long-term record for these locations. However, caution must be used when incorporating this data into the preliminary analysis because it represents daily total concentration and total sediment load data that has been computed from a sediment rating curve of total suspended sediment concentration against discharge. These time-weighted daily mean concentration values differ significantly from all other measured sediment records and may contain interpolation errors of an unknown magnitude.

The earliest recorded sediment data used within the study was obtained from the report by Robbins (1977). This data is available for Vicksburg and Arkansas City on the Mississippi River for study periods extending from 1929 to 1932 and 1967 to 1974. The earlier period of the record is particularly important because it provides data on the sediment transport characteristics of the river prior to the reported decrease in sediment loads associated with the wide-scale engineering and management actions performed under the Mississippi River and Tribituaries (MR&T) Project.

Data from Arkansas City, Vicksburg, and Natchez on the Mississippi River is also included in this study for the period 1969 to 1979. However, this data has two limitations that must be recognised. First, it is of unknown origin and therefore the data collection, analysis, and processing procedures are unknown. Second, no survey dates are attached to the coarse and total concentration data and so temporal trends cannot be evaluated.

These initial considerations highlight the very large volume of data potentially available to this study, but also reveal some of the problems and limitations inherent to the data.

2.3 Sampling Procedures

Ideally, to support analysis of spatial and temporal trends within sediment transport data, it is desirable that the sampling methodology and sampling frequency are consistent between sites and through time. However, there is considerable variability within the dataset in these respects because of the variety of practices adopted by different agencies collecting the data and because of technological advances during the long time period over which the data were collected. This section addresses these issues by documenting the current sampling procedures used by each data collection agency and considering the consistency of each sampling procedure through time.

2.3.1 U.S. Army Corps of Engineer Sampling Procedures

2.3.1a Vicksburg District

The Vicksburg District sampling procedure has remained consistent since the earliest data was collected. This procedure is documented in the following discussion. Suspended-sediment and bed material samples are taken at the end of each discharge measurement. Samples are routinely taken at six vertical locations, the location being determined by increments of equal discharge (Figure 1).

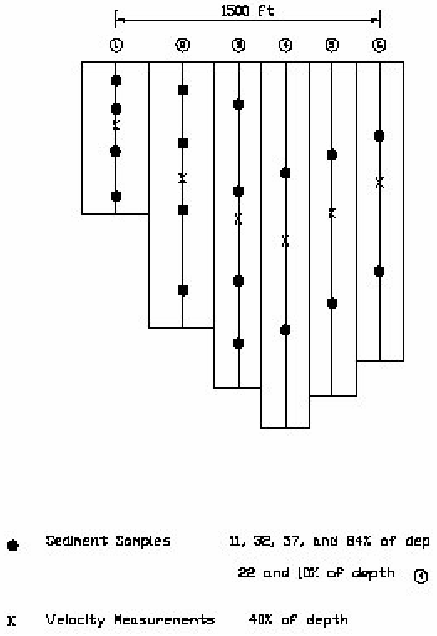


Figure 1. The USACE Vicksburg District Sampling Routine

These locations correspond to 8, 25, 42, 58, 75 and 92 percent of the total width. Suspended sediment samples are taken using U.S. P-61 or U.S. P-63 point-integrated suspended sampler. At Arkansas City and Natchez, a total of 24 samples were collected for each discharge event. Point samples were taken at each of the six verticals, at 10.7, 32.3, 57.0 and 84.0 percent depths of each vertical. At Vicksburg, a total of 18 samples were collected for each discharge event. The discharge range is located at a bend where the channel adjacent to the right descending bank consists of a point bar and the channel next to the left descending bank consists of a deep pool. Measurements were taken at six verticals, with four measurements in the right three verticals and two measurements in the left three verticals at 22 and 70 percent depths. The total sediment concentrations and coarse and fine percentages were determined in the laboratory for each of the eighteen samples.

Mississippi River bed-material samples were taken with a BM-54 bed material sampler at the base of each vertical. The bed material gradation data is reported in a ‘weight retained’ format for each sieve size.

Since 1994, a Doppler sensing system has been used to calculate discharge, replacing conventional stream gaging techniques.

2.3.1b New Orleans District

The sampling procedure adopted by the New Orleans District differs significantly to that used by the Vicksburg District. Also, the sampling procedure has undergone several modifications since 1983. For example, Appendix B documents the modifications in procedure at Tarbert Landing gaging station between 1974 and 1993.

Since the mid-1990s, the New Orleans District has continued to use conventional discharge measurements alongside the introduction of the Doppler technique. The U.S. Geological Survey is responsible for all of the laboratory analysis of the sediment samples collected by the New Orleans District. Total sediment loads are determined by multiplying the water discharge, in cubic feet per second (cfs), by the concentration of suspended sediment, in milligrams per litre or parts per million, and a coefficient (0.0027) to convert to US Customary units. The processing of bed material data differs from that in the Vicksburg District because different sieve sizes are used in the analysis. Further, both the suspended and bed material gradation data are reported in a cumulative ‘percent finer’ format.

2.3.2 U.S. Geological Survey Sampling Procedure

The U.S. Geological Survey laboratory analysis and data processing procedures follow those adopted by the USACE New Orleans District.

2.3.3 Other Sampling Procedures: Robbins (1977)

Suspended sediment samples taken at Arkansas City and Vicksburg from 1929 to 1931 were obtained using the Vicksburg sediment trap. Samples were collected at eight verticals spaced equally across the river, at the surface, mid-depth and near the bottom. The sediment concentration of each was multiplied by the percent of total discharge carried in the respective vertical divisions. The sum of these weighted concentrations was taken as the mean concentration of sediment through the cross-section.

From 1967 onwards, the P-61 sampler was used. The sampling procedure mirrored that adopted by the USACE Vicksburg District, as described in sub-section 2.3.1a.

2.3.4 Summary

The preceding discussion has highlighted the difficulties in comparing data from several different sources because of the differences in sampling, data processing, and data reporting procedures. These potential sources or variability and uncertainty must be borne in mind when analysing the data for any purpose.

3. DATA COMPILATION AND VALIDATION

This section addresses the techniques used to compile the data into a consistent format for the database. It also documents the series of macros and procedures used to validate the data.

3.1 New Standard Data Format

A standardised format in Microsoft Excel was devised and all data were transferred by using the *Macro* programming tool within Excel. This new format was designed to both preserve all existing data and expedite future analysis. The selected format was based upon that used by the USACE New Orleans District as this was the most extensive and detailed data set available. The database itself is fully described in Appendix C and may be found on the CD-ROM that accompanies this document.

3.2 METHODS USED FOR COMPILATION AND VALIDATION

3.2.1 U.S. Army Corps of Engineers data

3.2.1a Vicksburg District Data

This first priority for this data was to transfer it into a workable spreadsheet format. The 1979 to 1983 data which was only available in paper hardcopy format was manually entered into the computer in an Excel format. However, this option was considered too labour intensive for the 1984 to 1998 text file format data. Therefore, a computer program was written to extract the relevant data from the text files and import it into an Excel format. However, due to the inconsistencies within these text files, it was necessary to manually verify the Excel generated data against the original text file format. During the process, any inconsistencies were highlighted and corrected.

Once the data was in an Excel spreadsheet format, a series of macros were required to transfer into the desired standard format. However, at this stage, it was first necessary to undertake initial data analysis by calculating mean suspended coarse, fine and total concentrations and mean bed material gradation data for each cross-sectional survey. This compositing routine also enabled key sediment loads to be determined. Prior to the calculation of mean bed material data, it was necessary to convert the gradation data from a ‘weight retained’ format into a cumulative ‘percent finer’ format. This removed the tendency for bias based on the total weights of sample extracted.

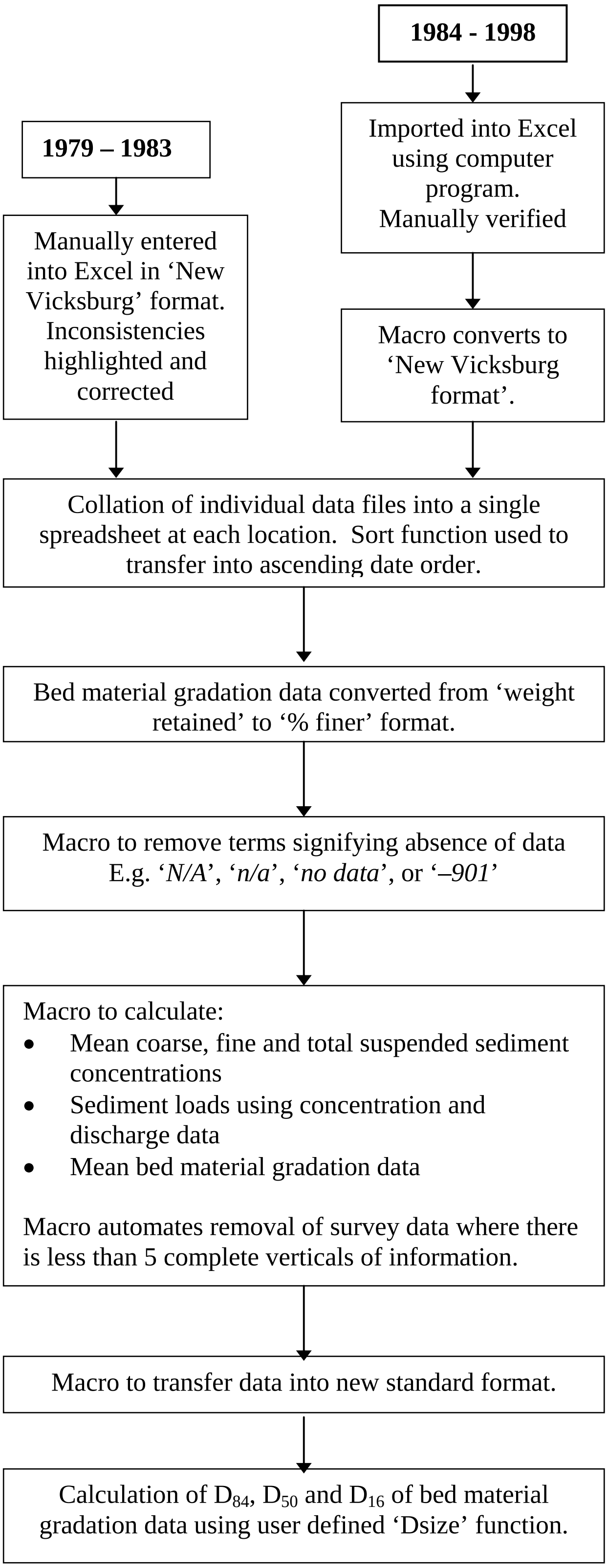
The calculation methodology adopted followed the U.S. Geological Survey standard procedure; this had also been used in the initial analysis of the USACE New Orleans District data so was considered most appropriate. Total sediment load was acquired by multiplying total water discharge, in cubic feet per second (cfs), by the concentration of suspended sediment, in parts per million, and by a coefficient of 0.0027 to convert it to US Customary units.

At the same time as undertaking these calculations, it was considered necessary to remove incomplete survey entries, thereby, improving the reliability of the mean computed suspended and bed material data. Therefore, a macro was written to automate the removal of survey records where less than 5 complete verticals of data were available. In order to 'prepare' the data for this automated data removal process, it was necessary to remove error entries within the spreadsheets such as '*N/A*', '*n/a*', '*no data*', or '*–901*'.

The next stage of the compilation process was to transfer the computed data into the new standard format using a further macro. By importing the 'user defined' *Dsize* function into Excel, the D_{16}, D_{50} and D_{84} for the bed material data was then calculated.

The series of compilation and validation procedures which were applied to the Vicksburg District data are summarised in Figure 2.

Figure 2. Compilation and validation procedures for Vicksburg District Data



Imported into Excel using computer program. Manually verified

Manually entered into Excel in 'New Vicksburg' format. Inconsistencies highlighted and corrected

Macro converts to 'New Vicksburg format'.

Collation of individual data files into a single spreadsheet at each location. Sort function used to transfer into ascending date order.

Bed material gradation data converted from 'weight retained' to '% finer' format.

Macro to remove terms signifying absence of data E.g. '*N/A*', '*n/a*', '*no data*', or '*–901*'

Macro to calculate:

- Mean coarse, fine and total suspended sediment concentrations
- Sediment loads using concentration and discharge data
- Mean bed material gradation data

Macro automates removal of survey data where there is less than 5 complete verticals of information.

Macro to transfer data into new standard format.

Calculation of D_{84}, D_{50} and D_{16} of bed material gradation data using user defined 'Dsize' function.

3.2.1b New Orleans District Data

The compilation procedure for the New Orleans District data was less complicated than that for the Vicksburg District data because a compositing routine had already been applied. However, the additional data files obtained from the New Orleans District Offices were in a 3-page text file format. These files were manually entered directly into the new standard. The original files were transferred into the standard format using Excel based macro programs. The final stage of this compilation routine was the collation of individual data spreadsheets, representing short-time periods, into a single spreadsheet for each location. Errors signifying the absence of data were then removed from the collated spreadsheets.

Once in the standard format, it was necessary to perform a series of data validation procedures because, unlike the Vicksburg District data, no data validation had been initially performed. The validation steps undertaken on each of the data types are as follows:

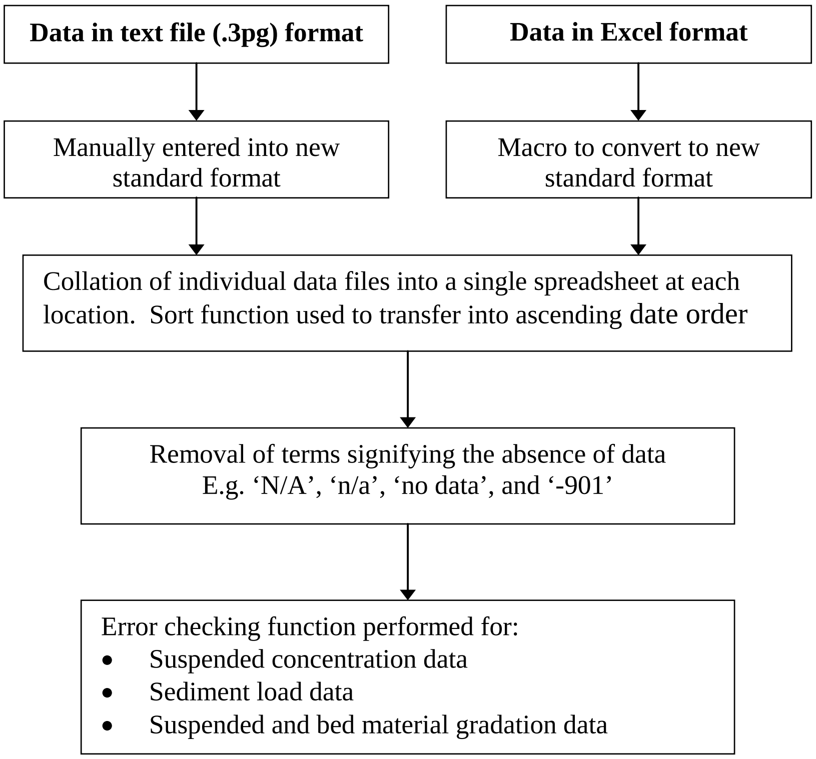
a) **Suspended concentration data**. Error checking functions were used to ensure that the sum of the reported coarse and fine concentration data was within a 5% error band of the reported total concentration data. Where errors were highlighted, the data was adjusted according to the most realistic combination of concentration values.

b) **Suspended load data**. Once the reliability of the suspended concentration data had been verified, similar error checking procedures were applied to the suspended load data. The first check ensured that the reported coarse and fine load data was within a 5% error band of those calculated using the relevant concentration and discharge data and the appropriate correction factor. Based on the identification of numerous errors, it was decided to re-compute all of the coarse and fine suspended load data to ensure consistency with data processing procedures. The total sediment load data was adjusted to the sum of the fine and coarse load data.

c) **Suspended and bed material gradation data**. An error checking function was used to ensure the percent finer values increased as the sieve size increased. All highlighted errors were corrected prior to preliminary analysis.

The series of compilation and validation procedures which were applied to the New Orleans District data are summarised in Figure 3.

Figure 3. Compilation and validation procedures for New Orleans District Data



3.2.1c USGS Data

The USGS data files obtained from the Waterways Experiment Station were transferred to the standard format using a macro. The error checking procedures for suspended concentration and suspended load data, as outlined in the USACE New Orleans District section, were applied in order to validate the data series.

The USGS data files downloaded from the USGS Sediment website were manually transferred into the standard data format.

3.2.1d Other Data

The 1929 to 1931 and 1967 to 1974 data from the report by Robbins (1977) spreadsheets were transferred to the standard format and collated into single sheets based on the separate time periods.

The 1969 to 1979 coarse and total suspended sediment concentration data for Arkansas City, Vicksburg and Natchez was transferred to the standard format using a further macro. Coarse, fine and total load data was computed using the standard U.S. Geological Survey method.

4. PRELIMINARY DATA ANALYSIS

This section aims to explain the preliminary analysis undertaken on the sediment transport data once all records had been compiled into a standard format and quality assurance measures had been adopted. The main stations used in the analysis are:

- Memphis, RM 735 (USGS)
- Arkansas City, RM 554 (USACE, Vicksburg District)
- Vicksburg, RM 436 (USACE, Vicksburg District)
- Natchez, RM 363 (USACE, Vicksburg District)
- Coochie, RM 317 (USACE, New Orleans District)
- Tarbert Landing, RM 306 (USACE, New Orleans District)
- St. Francisville, RM 266 (USGS)

However, reference will also be made to Simmesport on the Atchafalaya River due to its long near-continuous temporal record (1950 to 1998).

4.1. COMPARISON OF USACE AND USGS RECORDS

At sampling stations where USGS data had been collected in conjunction with USACE data, it was possible to compare the records directly. This comparison was performed at two stations on the Mississippi River:

a) Vicksburg (RM 436) where USGS data could be compared to USACE Vicksburg District data in the period 1979 - 1993
b) St. Francisville (RM 266) where USGS data could be compared to USACE New Orleans District data at Tarbert Landing (RM 306) in the period 1978 to 1997.

The USACE and USGS data for total suspended sediment concentration at Vicksburg are shown in Figure 4. The equivalent data for coarse suspended sediment concentration are shown in Figure 5. Both USACE and USGS data show a wide degree of scatter and the two data clouds plot on top of one another. Any apparent difference in the appearance of the two data clouds may be explained by relative abundance of USACE data compared to USGS data due to the higher sampling frequency employed by the USACE.

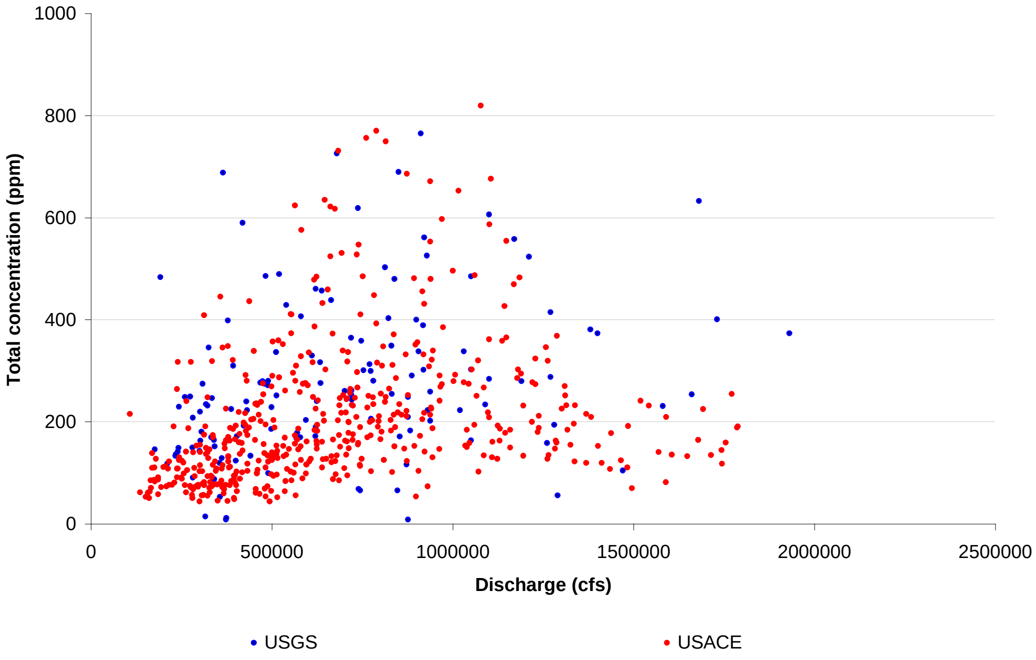


Figure 4. Total Suspended Sediment Concentration against Discharge at Vicksburg

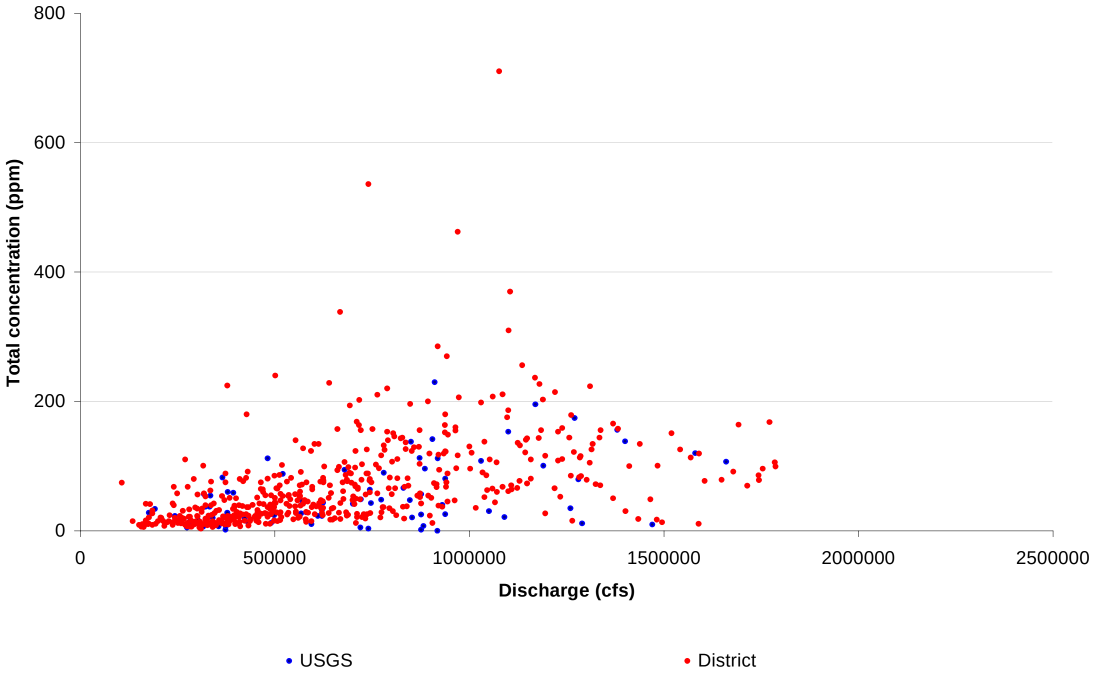


Figure 5. Coarse Suspended Sediment Concentration against Discharge at Vicksburg

A plot of coarse suspended sediment concentration against discharge using data from the St. Francisville (USGS) and Tarbert Landing (USACE) stations is shown in Figure 6. The data again show strong scatter with the data clouds coinciding.

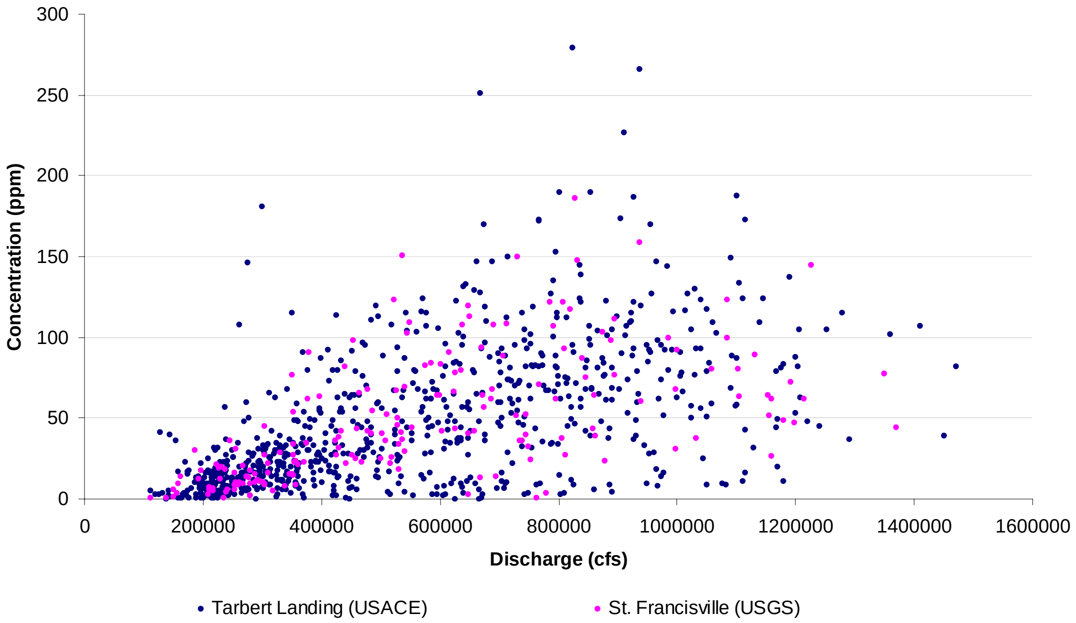


Figure 6. Coarse Suspended Sediment Concentration against Discharge using USACE data from Tarbert Landing (1974 - 1999) and USGS data from St. Francisville (1978 – 1997).

The records of coarse sediment load measurements at St. Francisville and Tarbert Landing reveals a marked decrease in coarse suspended sediment concentration at Tarbert Landing during the period 1986 to 1990 that is not reflected in the coarse sediment record for St. Francisville (Figure 7).

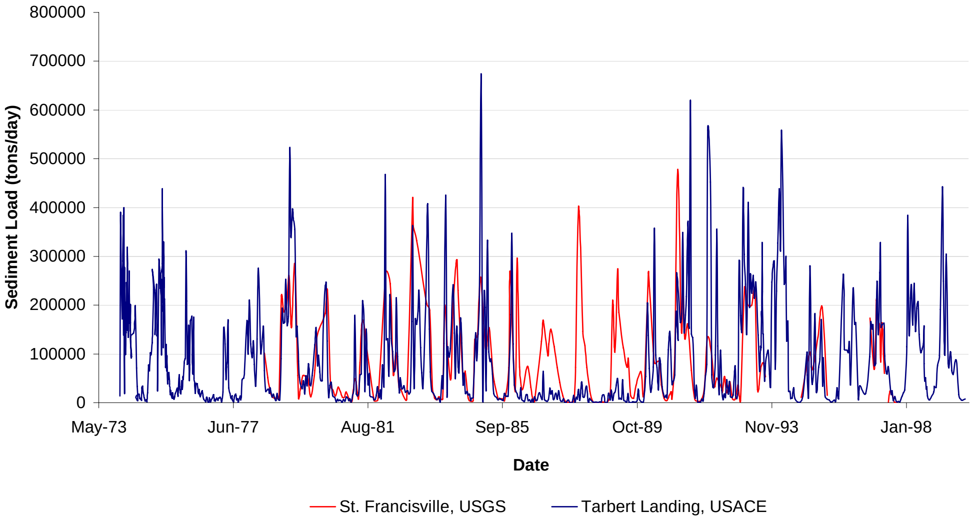


Figure 7. Records of Coarse Load measurement for USACE data at Tarbert Landing and USGS data at St. Francisville

Cross-referencing this reduction with temporal changes in the sampling procedure at Tarbert Landing, it is apparent that the reduction in measured coarse load coincides with a reduction in deep water sampling at Tarbert Landing (Appendix B). On this basis, it is reasonable to attribute the difference in the measured coarse loads for the period 1986 to 1990 to the change in USACE sampling procedure.

It may be concluded that comparison of records from USACE and USGS data collection campaigns suggests that there are generally no apparent differences between the data sets. This is important because it means that the sediment records collected by the two agencies can be combined and used conjunctively.

4.2 COMPARISON OF COARSE AND BED MATERIAL LOADS

4.2.1 Context

The relationship between coarse load and bed material load is particularly important when trying to determine the geomorphic response of the Mississippi River to engineering and management actions that occurred throughout the 1930s, 1940s and 1950s. Studies by Biedenharn (1995) indicate that the river presently has a significantly greater stream power than prior to the cutoffs. Investigations by Nordin and Queen (1992) indicate no coarsening of the bed material since 1932. Therefore, as the Lower Mississippi is not a sediment starved system, according to the equation by Lane (1957), an increase in stream power would be expected to be offset by an increase in the bed material load as the river adjusts to equilibrium. However, several investigators have reported a large reduction in the sediment load of the Lower Mississippi River this century (Robbins, 1977, Keown et al., 1981, Kesel, 1988). This apparent paradox may be explained by the fact that these investigations were based on measured suspended sediment data that includes both suspended bed material load and wash load, but is predominantly wash load. This study aims to examine to what extent it is possible to use the coarse component of the suspended sediment load as a proxy for the suspended component of the bed material load.

According to previous studies performed at the Waterways Experiment Station, records from Coochie and Tarbert Landing sampling stations indicate that the percentage of 0.125 mm material in the bed is actually less than 6% on average. This suggests that sediment in the Mississippi River that is finer than 0.125 mm constitutes wash load and should be classified as such. Therefore, for the purpose of this investigation, sediment coarser than 0.125 mm in the suspended gradation data was classified as bed material load. The percentage of material coarser than 0.125 mm was then multiplied by the total load and the resulting values for bed material load were plotted against the corresponding values for coarse load. This analysis was only possible at Coochie and Tarbert Landing on the Mississippi River due to the limited availability of suspended gradation data. However, the same analysis was also applied to Simmesport on the Atchafalaya River where a more extensive data set is available.

4.2.2 Results

Plots of coarse load against bed material load for Coochie and Tarbert Landing stations on the Mississippi River are shown in Figures 8 and 9, respectively.

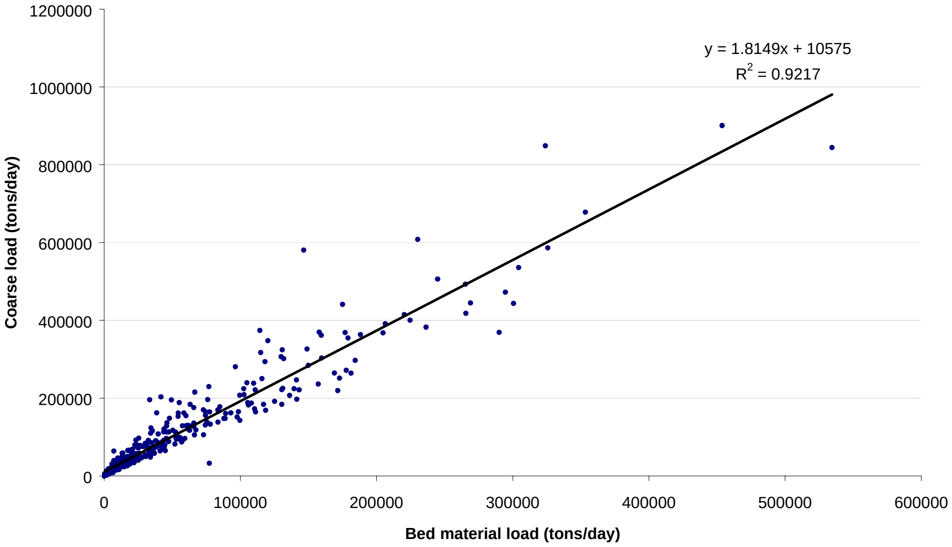


Figure 8. Comparison of Coarse Load and Bed Material Load at Coochie

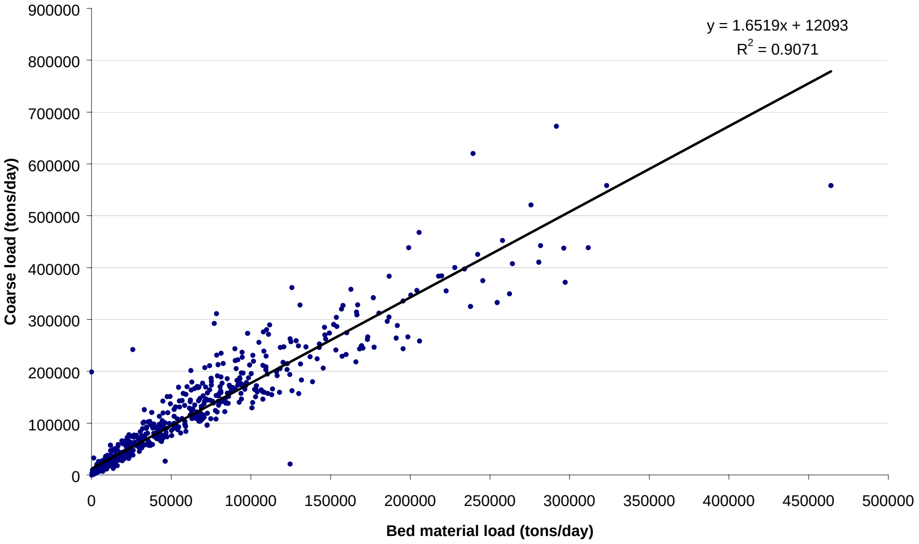


Figure 9. Comparison of Coarse Load and Bed Material Load at Tarbert Landing

Each graph shows a strong and statistically significant relationship between the two parameters. Consideration of the gradient of the regression lines for stations on the Mississippi River indicates that the coarse load is larger than the suspended component of bed material load by a factor in the range of

1.65 to 1.8. This suggests that using the coarse load to represent the bed material load of the Mississippi River would result in a considerable over-estimate of the transport rate.

The equivalent data for Simmesport (Figure 10) display a weaker correlation, although this is still significant statistically. This perhaps indicates that it is not ideal to use of 0.125 mm as the cut-off for bed material load on the Atchafalaya River. The abundant data from Simmesport is nonetheless useful because the gradient of the regression line emphasises that use of the coarse load to represent the bed material load could overestimate the sediment flux by a factor of two or more. It may be concluded that the quantity of bed material load transported by the river is lower than the coarse load.

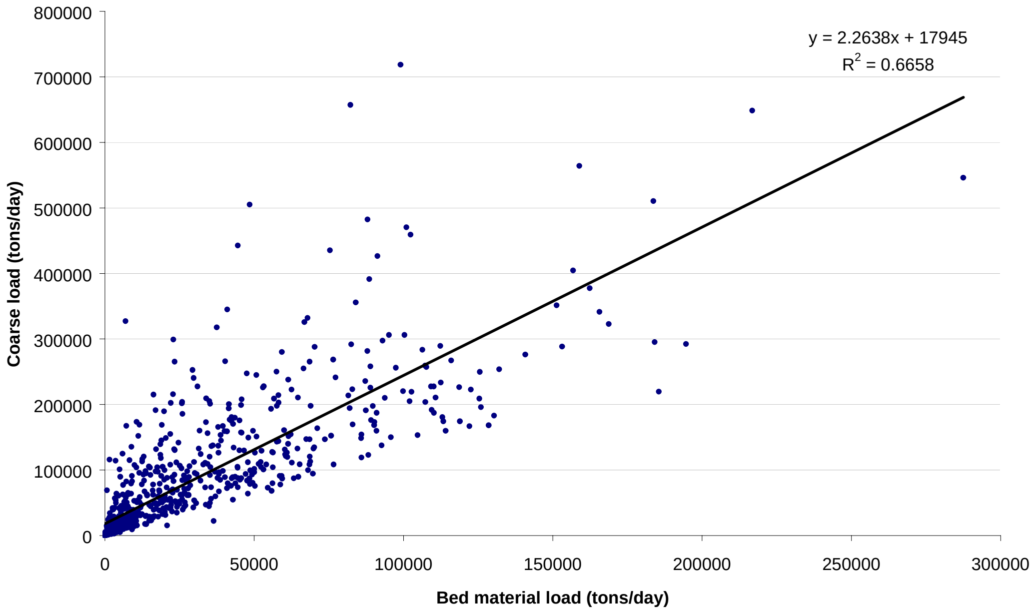


Figure 10. Relationship between Coarse Load and Bed Material Load at Simmesport

The fact that bed material load constitutes a relatively small proportion of the total measured suspended sediment load is emphasised in Figure 11. This figure, based on data for Simmesport, illustrates that in over 50% of samples the bed material load constituted less than 5 % of the total measured suspended load. Also, in only about 10% of samples did bed material load make up more than 15% of the total measured suspended load.

Consideration of the relationship between bed material load and the coarse load is important because it demonstrates that the division between coarse and fine load may not properly represent the division between bed material and wash loads. If fine sand is in fact part of the wash load, then calculations of bed material load based on measured coarse loads may over-estimate the amount of bed material load moving in suspension. It appears from the data for Simmesport that the proportion of bed material load moving as suspended load is usually less than 5% and nearly always less than 15%. This focuses interest on the unmeasured load, because it suggests that the majority of bed material load may move as bed load and near bed load, passing beneath suspended load samplers. As bed material load is accepted to be most important in channel-forming processes, this emphasises the need to measure bed load in order to better gage the flux of bed material load in the Mississippi River.

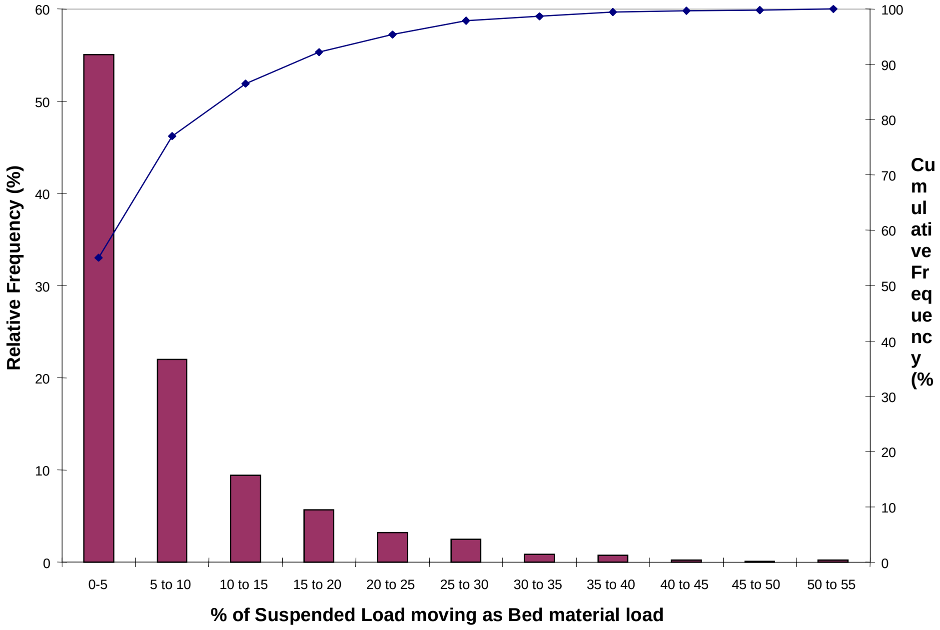


Figure 11. Frequency distribution of the percentage of Total Suspended Load classified as Bed Material Load at Simmesport

4.3 EFFECT OF TEMPERATURE ON SEDIMENT CONCENTRATION

4.3.1 Context

This analysis examined the hypothesis that water temperature has a significant effect on the ability of a river to entrain and transport sediment. If this is true then the river will exhibit higher suspended sediment concentrations during cold weather. This hypothesis follows from the principle that as temperature decreases, viscosity increases and therefore the ability to entrain and carry sediment in suspension increases. In the context of the Mississippi River, a significant temperature effect would result in marked seasonal variations in sediment concentration for a given discharge.

To identify whether there is a discernible temperature effect, suspended sediment concentrations were plotted against discharge with the concentration data classified into several temperature bands. This analysis was performed for records from Coochie on the Mississippi River and Simmesport on the Atchafalya River.

4.3.2 Results

The data for Simmesport are plotted in Figure 12 and the results for Coochie are shown in Figure 13.

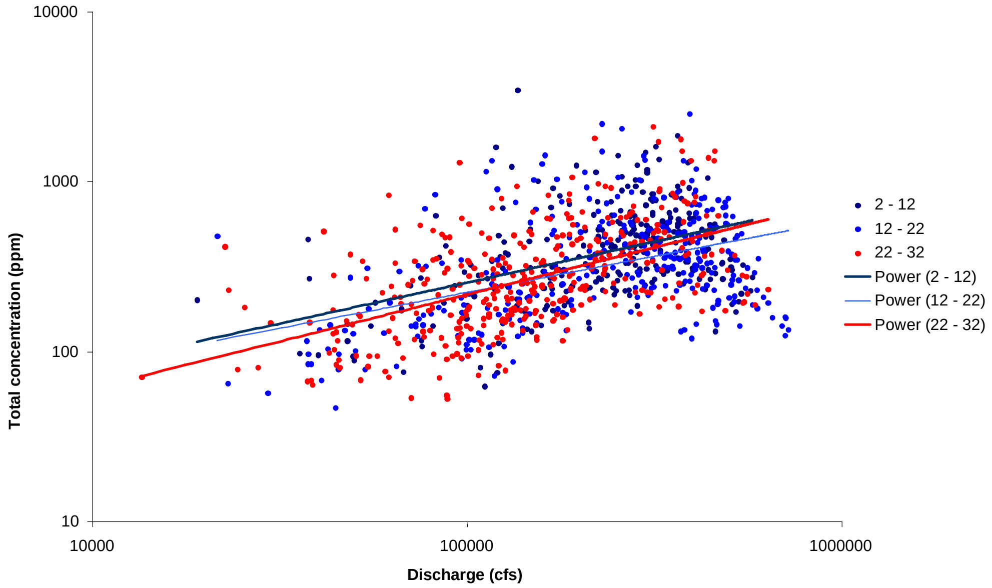


Figure 12. Effect of Temperature (^{0}C) on the relationship between total Suspended Sediment Concentration and Discharge at Simmesport on the Atchafalaya River

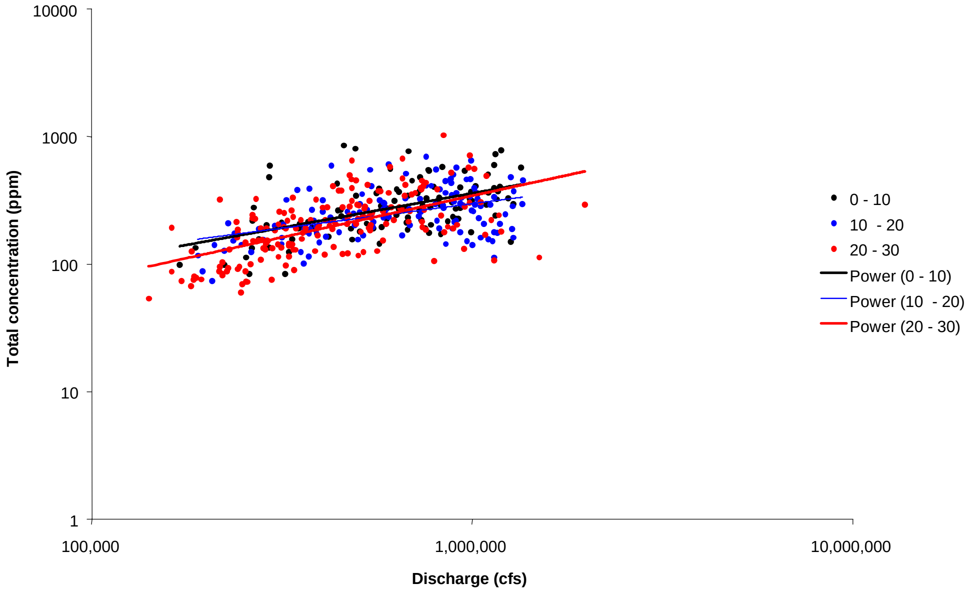


Figure 13. Effect of Temperature (^{0}C) on the relationship between total Suspended Sediment Concentration and Discharge at Coochie on the Mississippi River

In Figures 12 and 13 the sediment concentrations for different temperature classes plot on top of each other and here is no discernible banding in the data clouds. Regression analysis was used to fit trend lines for the relationship between discharge and concentration for each to temperature class. The gradients and intercepts of the regression lines are such that the lines plot on top of one another and given the wide scatter in the data there is no possibility of there being a statistically significant difference between them.

It can be concluded from this preliminary investigation that the data do not support the existence of any marked temperature effects on suspended sediment concentrations in the Mississippi and Atchafalaya Rivers. On the basis of available data, it may be concluded that no significant seasonality in the processes of sediment transport driving geomorphic evolution would be expected.

4.4 DISCHARGE AND SEDIMENT CONCENTRATION

To understand and explain the geomorphic significance of the sediment regime of the Mississippi River, it is crucial to understand the relationship between sediment concentration and discharge.

Plots of coarse and fine suspended sediment concentration against discharge are shown in Figures 14 and 15 for Coochie and Tarbert Landing, respectively.

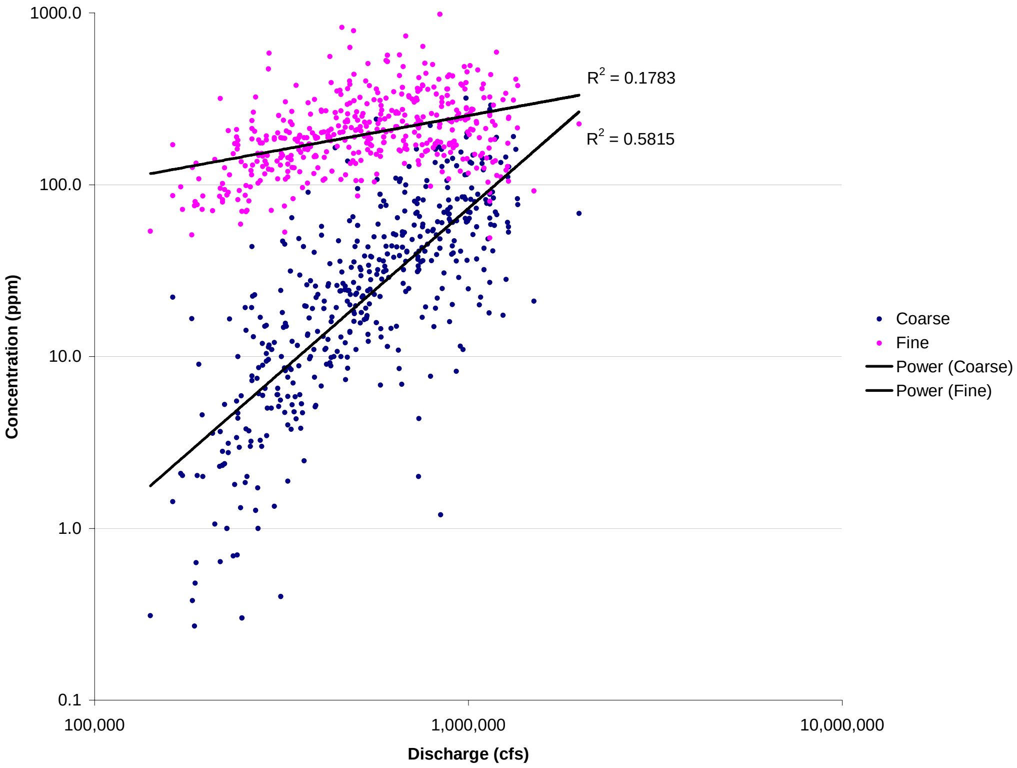


Figure 14. Fine and Coarse Suspended Sediment Concentrations as functions of Discharge at Coochie on the Mississippi River

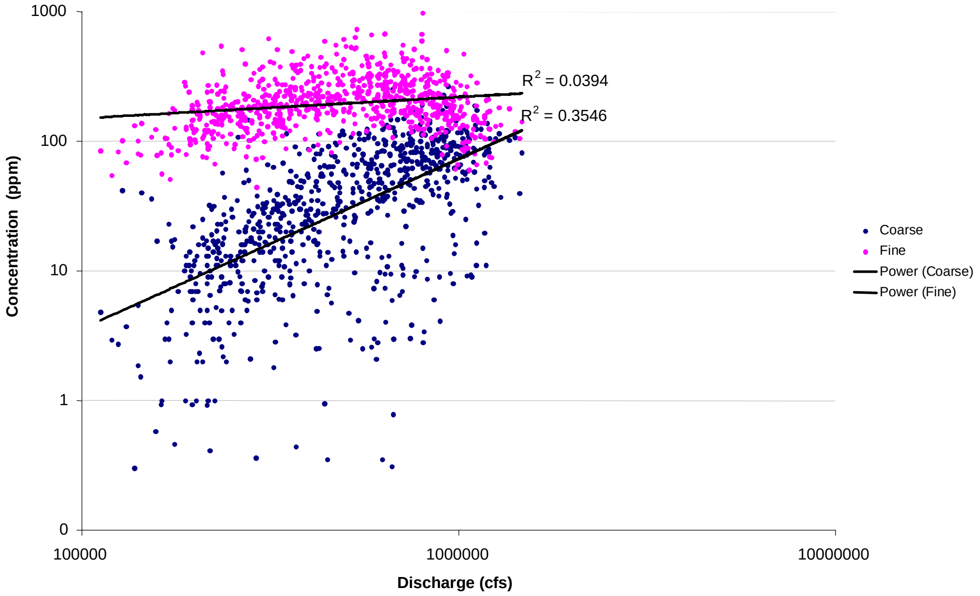


Figure 15. Fine and Coarse Suspended Sediment Concentrations as functions of Discharge at Tarbert Landing on the Mississippi River

Inspection of these graphs demonstrates the very different ways that the fine and coarse material concentrations vary with discharge. In the case of fine material, which approximates to wash load, there is only a very weak relationship between discharge and concentration. The data scatter over a log-cycle and a regression line fitted to them has no statistical significance. These results are as expected for wash load. This is the case because wash load is primarily derived from watershed erosion. The quantity carried by the river is usually supply rather than transport limited and so is unrelated to fluvial hydraulics. As the load is supply-limited, the concentration is smaller at low discharges (when there is little runoff and sediment yield from the watershed) and also at high discharges (due to dilution effects in the very large volume of water). With this in mind, the data for Coochie and Tarbert suggest that the concentration of fine sediment in the Mississippi River has a maximum of the order of 1,000 ppm.

Transport of bed material load in a river is generally believed to be limited by the ability of the flow to entrain and carry the relatively coarse sediment. Coarse load concentration in the Mississippi River is consistent with this general rule in that it shows a marked positive trend in Figures 14 and 15. The coefficients of determination are quite low due to the very wide scatter in the data, but the regression lines are significant. There is no evidence of supply-limited conditions at very high discharges. These results are typical of the sample sites along the Mississippi River, as can be seen by inspection of the coefficients of determination listed in Table 3.

Table 3. Correlation coefficients between discharge and suspended sediment concentration at sampling stations on the Mississippi River

Sampling station	Coarse Sediment	Fine Sediment	All Sediment
Memphis	0.58	0.20	0.42
Arkansas City	0.27		0.13
Vicksburg	0.47		0.29
Natchez	0.45		0.22
Coochie	0.60	0.27	0.42
Tarbert Landing	0.57	0.05	0.25
St. Francisville	0.58	0.03	0.19
Means	**0.50**	**0.14**	**0.27**

To further explore the relationship between coarse suspended sediment concentration and discharge, the record for the Coochie station was plotted. This is shown in Figure 16.

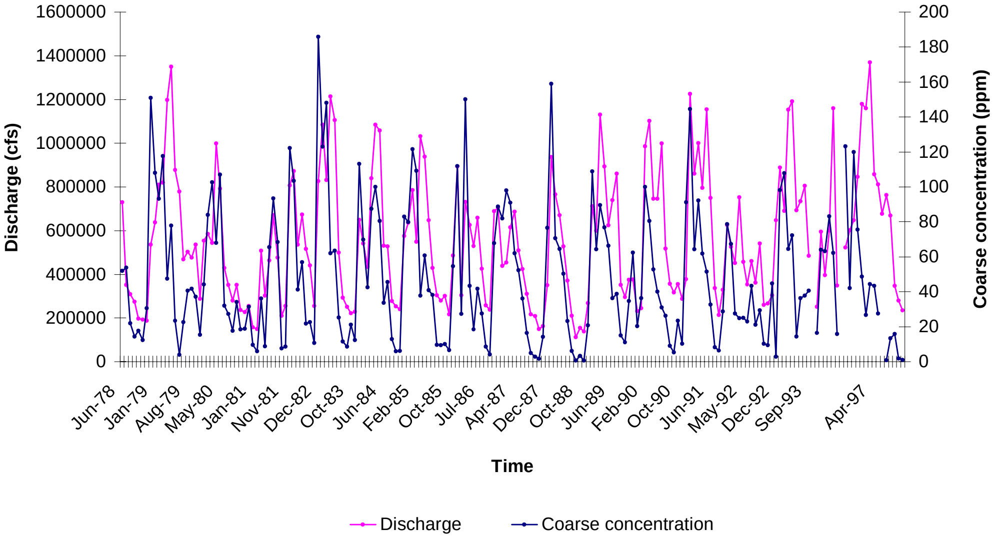


Figure 16. Records of Discharge and Coarse Suspended Sediment Concentration measured at St. Francisville on the Mississippi River

Close examination of Figure 16 illustrates that coarse load concentration peaks on the rising limb of the flood hydrograph, prior to the peak in discharge, and decreases rapidly during the falling limb. This trend can be explained by the widely observed hysterisis loop in the relationship between coarse sediment concentration and discharge, caused by the dynamics of the floodwave in the fluvial system. Knighton (1998) presents a detailed explanation of this mechanism, which centres on the fact that, for a given discharge, the energy slope is steeper on the rising limb of the hydrograph than it is during the falling stage. Further statistical analysis of the discharge and coarse suspended sediment concentration data series using a cross-correlation technique would allow this lag time to be quantified and it is recommended that this analysis be performed in future.

In conclusion, this section has demonstrated complexities in the relationship between sediment transport and discharge. Clearly, the movement of fine material (as wash load) is controlled by non-hydraulic factors related to sediment yield from the watershed and supply-limited dilution at very high discharges. The dilution effect may limit sediment concentrations in the Mississippi River to less than 1,000 ppm. The transport of the coarse suspended load, shows a positive relationship with discharge, indicating that the concentration is transport-limited. It is suspected that the relationship between bed material load (material coarser than 0.125 mm) would show a yet stronger positive correlation with discharge if data were available to explore this. While in general high sediment concentrations are associated with high discharges the data show a wide scatter of points. Partially, this may be explained by hysterisis between sediment concentration and discharge. For similar discharges, concentrations are higher on the rising limb of the hydrograph and to better explain the relationship between coarse sediment load and discharge the records should be disaggregated into rising, steady and falling limb conditions. This would require some definition of the magnitude of stage change required to constitute a significant alteration in discharge and a decision regarding the time period over which a trend in stage change would have to be maintained for it to constitute a rising or falling limb. Selection of the magnitude and duration thresholds is a major task beyond the scope of this initial data analysis, but it should be addressed in future research.

4.5 TEMPORAL AND SPATIAL DISTRIBUTIONS OF SUSPENDED SEDIMENT LOAD

This analysis examines the distributions of sediment load in time and space, with a view to commenting on the decreases in sediment loads reported in the Mississippi River over the last 50 years reported by, for example, Kesel (1988), and Dardeau and Causey (1990).

4.5.1 Temporal analysis

The records of coarse and total sediment load measured at Vicksburg and Tarbert Landing on the Mississippi River are shown in Figures 17 and 18. All data are shown with no smoothing or averaging, to emphasise the highly variable nature of the record. Generally, peaks in coarse load correspond with peaks in total load although the coarse load is much smaller than the total load. Despite this, it should be remembered that it is the coarse load, and more specifically the bed material load, which has most geomorphic significance.

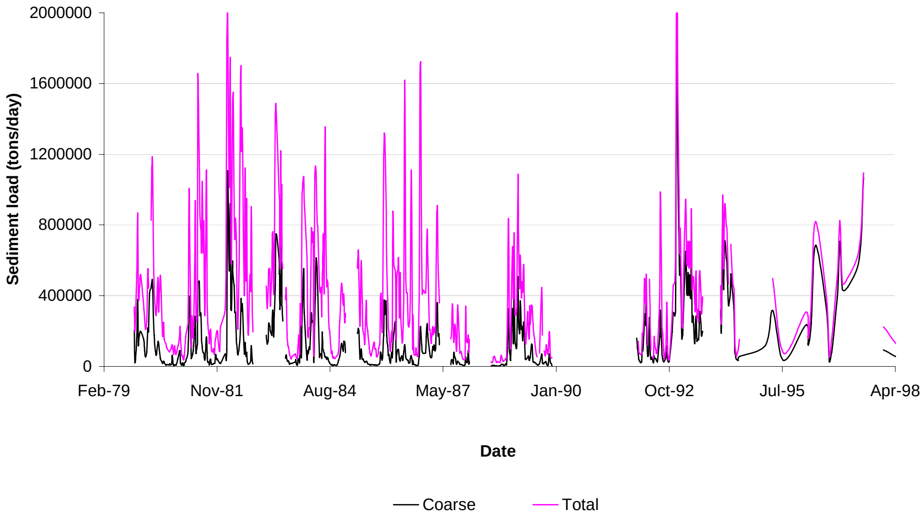


Figure 17. Record of Total and Coarse Suspended Sediment Concentrations at Vicksburg on the Mississippi River

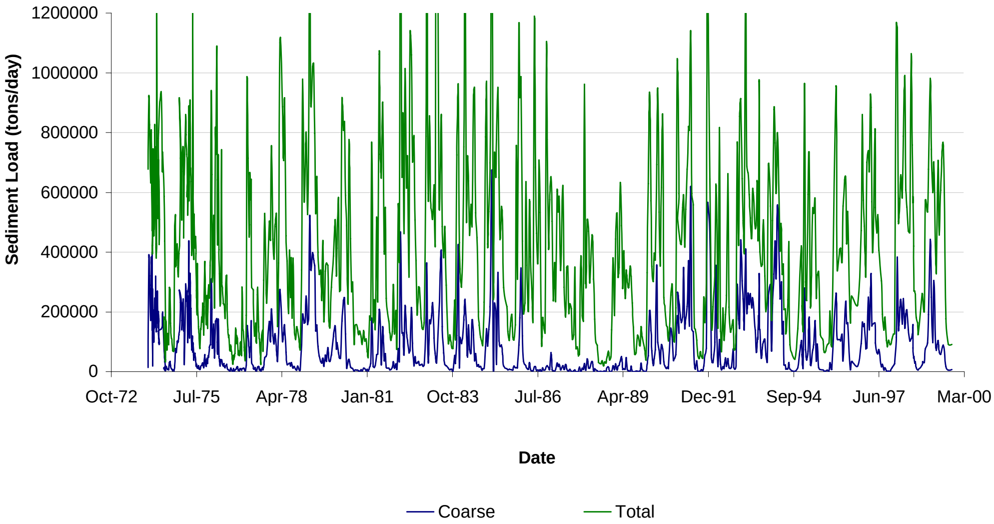


Figure 18. Record of Total and Coarse Suspended Sediment Concentrations at Tarbert Landing on the Mississippi River

At this timescale of analysis it is apparent that short duration, high magnitude and low frequency sediment load events dominate the movement of sediment by the Mississippi River. The data for Vicksburg illustrates that there are marked gaps in the record, while that for Tarbert Landing demonstrates that there are step changes that require close and careful examination. For example, the decrease in measured coarse material load between 1986 and 1990 at Tarbert Landing (Figure 18) might be taken to indicate some change in the transport regime, but cross-referencing it to the record of measurement techniques in Appendix B suggests that it may result from a reduction in near bed sampling.

4.5.2 Spatial analysis

The records of coarse and total loads have the potential to reveal spatial variations in the movement of sediment through the Mississippi River. In view of the coincidence between USGS and USACE measurements established in section 4.2, data from both sources may be combined to support spatial analysis. The sediment load records for consecutive stations along the river, from upstream to downstream are shown in Figures 19 to 25.

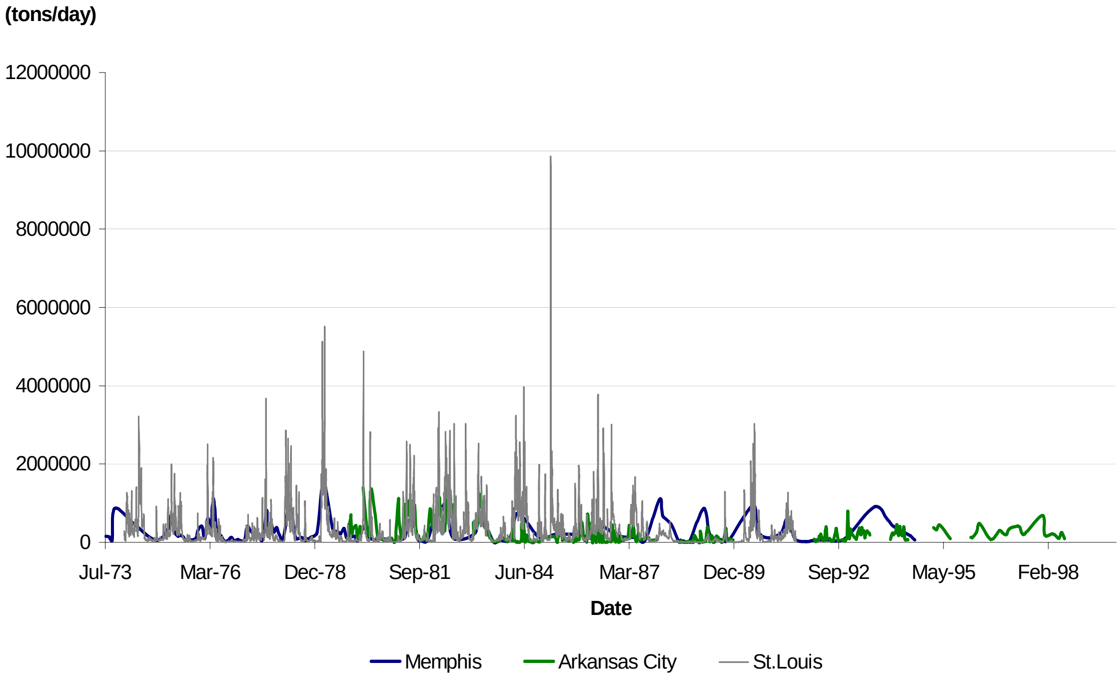


Figure 19. Temporal trends in Total Load at St. Louis, Memphis and Arkansas City

Consideration of Figure 19 immediately demonstrates that it is difficult to compare the records for consecutive stations directly. Problems arise due to different sampling frequencies, different periods of record and varying techniques used to generate the data at the various stations. For example, periods of time covered by the records for Memphis and Arkansas City do not overlap very much. Also, the appearance of the record for St Louis is obviously quite different to those for Memphis and Arkansas City. This occurs because of the different ways that the records have been generated at each station: daily computed data for USGS measurements at St Louis, directly measured USGS data for Memphis and measured USACE data at Arkansas City. The record for St Louis has been generated by combining the continuous record of water discharge with a sediment rating curve to generate what appears to be a complete daily record of sediment load. In fact, the sediment measurement frequency was probably no greater than those at the other stations and the apparent existence of a continuous record is in this sense misleading. It would in theory be possible to calculate total sediment fluxes for each station based on the available records these fluxes. However, use of differences in fluxes between stations to infer changes in sediment storage in the intervening reaches would be unwarranted by the base data. The fact is that sediment transport is highly episodic and a routine sampling programme (such as that at Memphis and Arkansas City) is unlikely to capture the short duration, high magnitude peaks in the temporal distribution. Hence, estimates of annual flux based on routine measurements will almost certainly under-estimate the true load transported by the river. Conversely, a synthesised record, like that for St Louis, better represents the true sequence of transporting events, but its accuracy is limited by the validity of the sediment rating curve used to estimate the unmeasured sediment loads that occurred during peak flows. It is obvious from the Q versus Qs relationships (for example, plotted in Figures 14 and 15) that these rating curves have low correlation coefficients and incorporate approximately one log cycle of uncertainty. While spatial comparison of records is informative in terms of demonstrating general trends and tendencies, it must be undertaken with great care to be reliable.

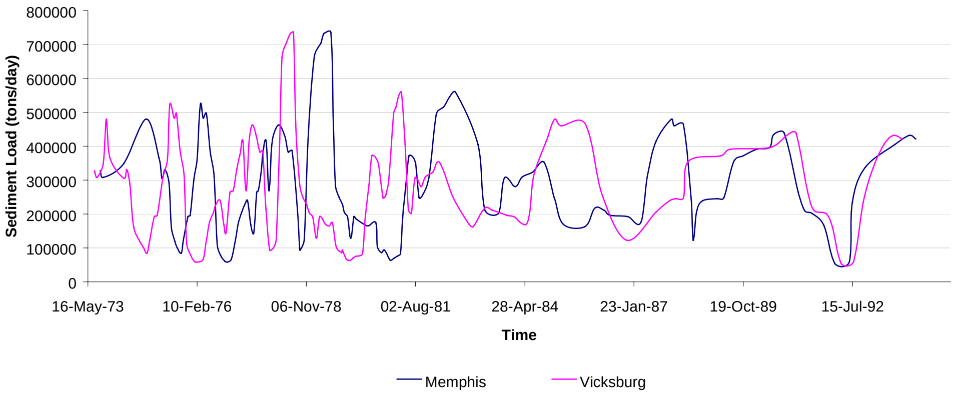


Figure 20. Temporal trends in Coarse Load for USGS records at Memphis and Vicksburg

A further issues is raised when the records for Memphis and Vicksburg (Figure 20) are plotted together. Close examination of Figure 20 reveals that while the measured load records at Memphis and Vicksburg are comparable, between 1974 and 1980, the record at Memphis is *identical* in form to that at Vicksburg, but lagged by approximately one year. This finding casts doubt on the validity of the USGS data for these stations and suggests that there may have been a transposition error during manipulation of the data that resulted in part of the record for one station being written over the record of the other. Further examination of the original data would be required to resolve this issue. The more general point raised by these records is that users must at all times be vigilant in inspecting the data for oddities or inconsistencies that may reveal hidden problems.

Comparisons of the records for Vicksburg with those for the stations immediately upstream (Arkansas City) and downstream (Natchez) are shown in Figures 21 and 22.

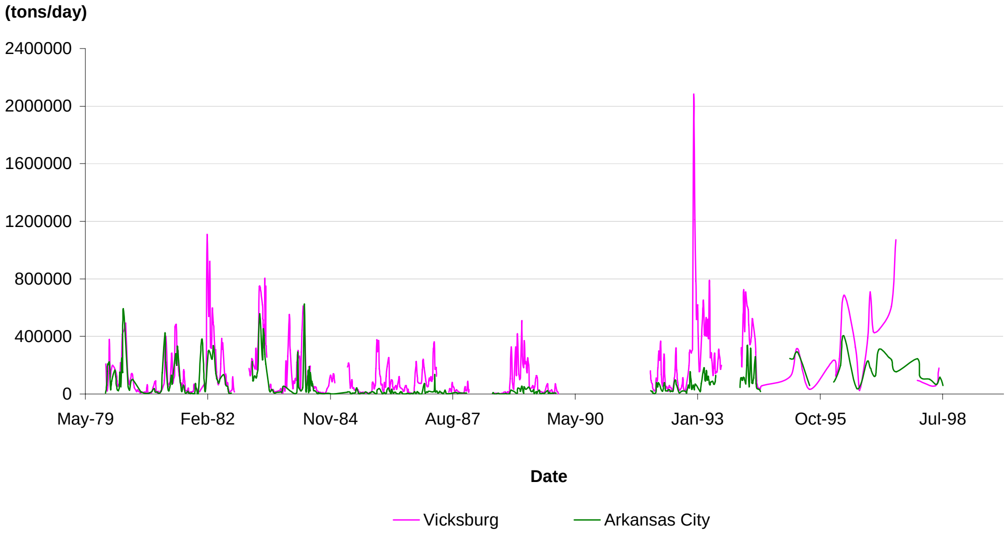


Figure 21. Temporal trends in Coarse Load at Arkansas City and Vicksburg

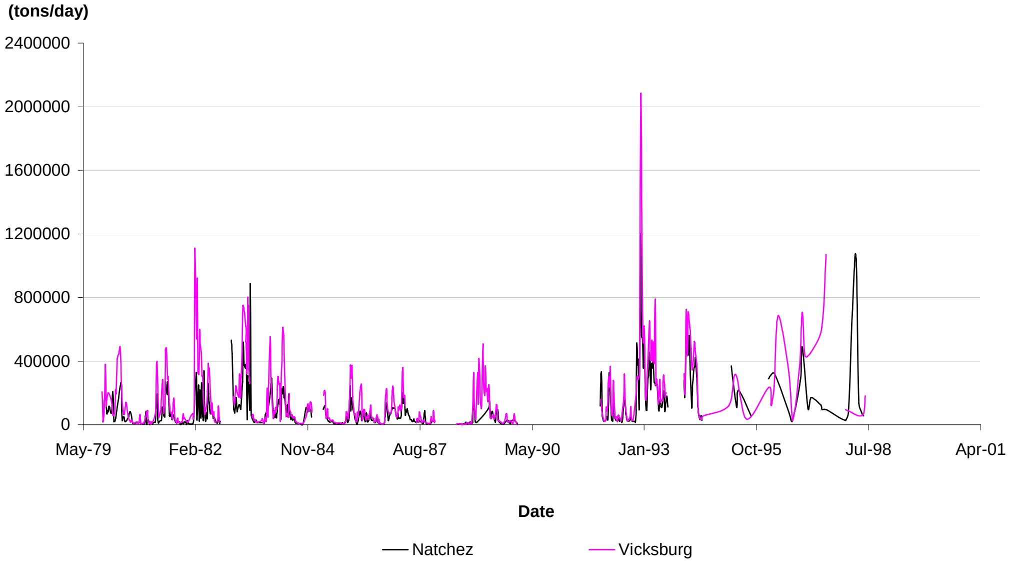


Figure 22. Temporal trends in Coarse Load at Vicksburg and Natchez

Differences in both the sampling periods and sampling frequencies again limit the confidence that can be placed on spatial analysis. Nevertheless, the records seem to indicate that coarse loads at

Vicksburg are higher than those at both Arkansas City and Natchez. The difference is most marked between Vicksburg and Arkansas City. If confirmed, these differences could indicate morphological adjustment in the reaches around Vicksburg. However, before such a conclusion could be supported other possible explanation for the higher measured coarse loads at Vicksburg would have to be eliminated. For example, a possible local explanation could be hypothesised. The Vicksburg measurement range is located near a bend and just downstream of the I-20 Interstate and Highway 80 bridges. Possibly, a combination bend scour coupled with constriction scour at the bridge during high flows generates additional bed material load that elevates the measured coarse loads at the station approximately 0.3 miles downstream. This speculative explanation should be investigated by checking if scour upstream of the Vicksburg measuring range is consistent with or exceeds general scour observed elsewhere in the Mississippi River during high in-bank discharges.

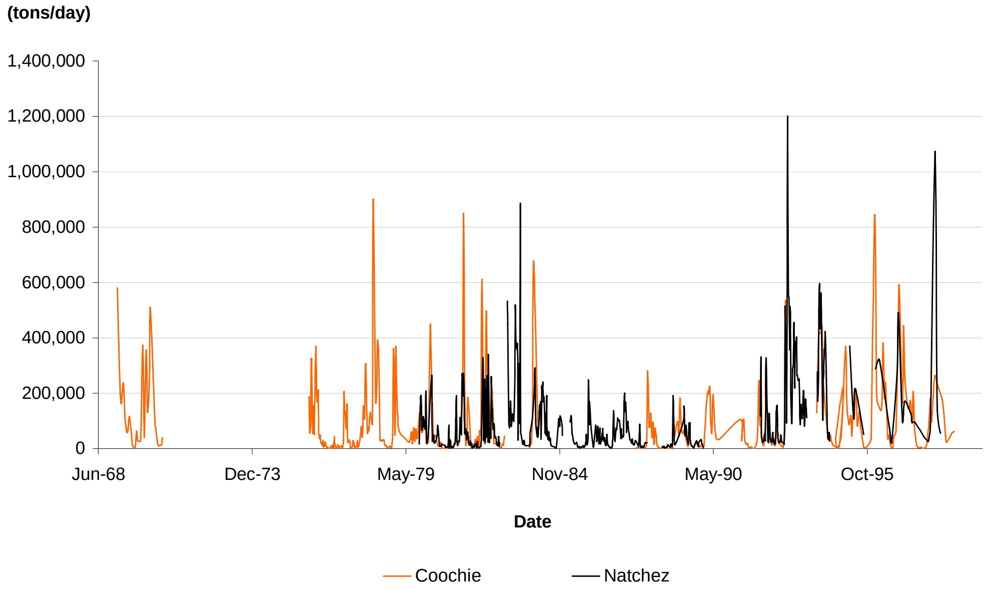


Figure 23. Temporal trends in Coarse Load at Natchez and Coochie

Comparison of the records for Natchez and Coochie (Figure 23) and Coochie and Tarbert Landing (Figure 24) show general consistency, although the short period of record at Natchez limits the usefulness of any comparison. It could not be concluded from these records of coarse load that morphological adjustment has been occurring in the reach between Natchez and Coochie. Inspection of the record for Tarbert Landing (in Figure 24) shows that the marked reduction in measured coarse loads between 1984 and 1990 was not observed at Coochie. This again suggests that the apparent reduction in coarse load was not real, but occurred due to reduced deep water sampling at Tarbert Landing.

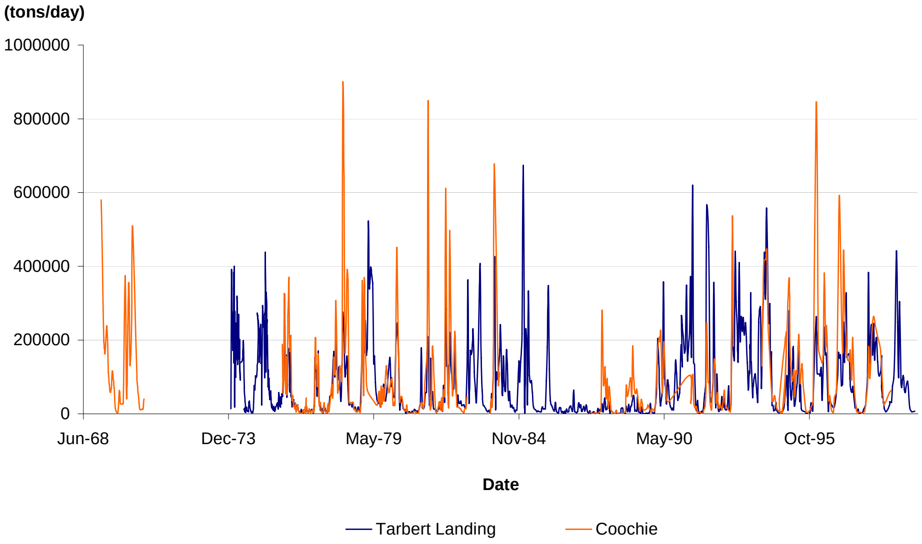


Figure 24. Temporal trends in Coarse Load at Coochie and Tarbert Landing

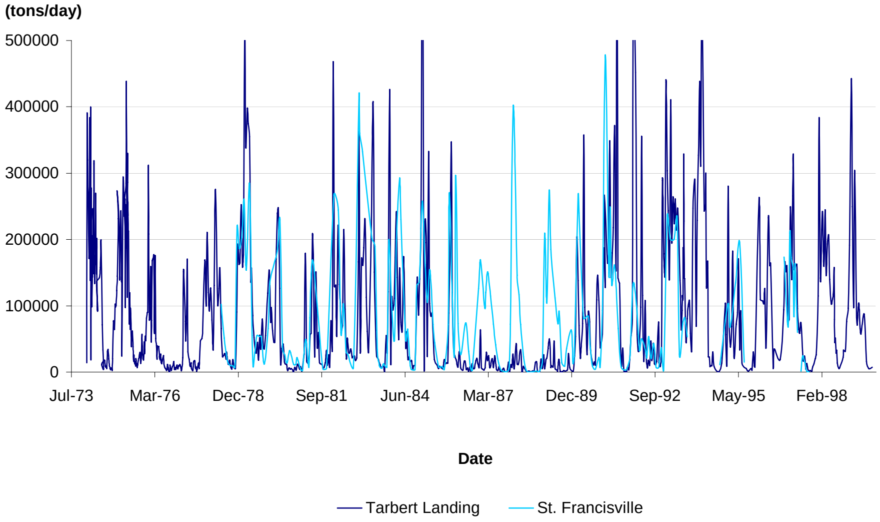


Figure 25. Temporal trends in Coarse Load at Tarbert Landing and St. Francisville

Comparison of Tarbert Landing and St Francisville (Figure 25) indicates that measured coarse loads are closely comparable with the exception of the period 1984 to 1990. This finding had been noted previously in section 4.1 and Figure 7.

It can be concluded from this section that the records of coarse sediment load at the decadal timescale are dominated by seasonal variation due to the bulk of transport occurring during high water periods, with loads reducing to very low levels during low water conditions. Based on the USACE and USGS data collected using methods and techniques that are known and believed to comparable, it is not possible to comment on the reduction in sediment load reported by previous researchers. This is the case because identification of a reduction depends on using data that predate the availability of measurements using current techniques. While the spatial analysis indicates broad agreement between the records at consecutive sampling stations over the period of record, there is some evidence for morphological adjustment in the reaches around Vicksburg involving a tendency toward bed scour between Arkansas City and Vicksburg and aggradation between Vicksburg and Natchez. However, analysis is limited by differences in both the sampling periods and sampling frequencies at different stations.

4.6 TEMPORAL AND SPATIAL VARIATIONS IN SUSPENDED SEDIMENT AND BED MATERIAL GRADATION

The Mississippi River cut-off program represented the greatest single engineering or naturally induced perturbations to the Lower Mississippi River in the past several hundred years (U.S. Army Corps of Engineers, 1982). Consideration of specific gage records for eleven morphological reaches on the Mississippi River by Biedenharn (1995) allowed a model of channel response to be developed. This response model was used to assign aggradation and degradation tendencies to morphological reaches. The model proposed that Arkansas City is at a hinge point in a channel system that is currently experiencing degradation upstream to New Madrid and aggradation downstream towards Coochie and Tarbert Landing. These latter locations form a second hinge point where aggradation upstream gives way to dynamic equilibrium downstream.

This section of the study examines the extent to which trends within the suspended and bed material gradation data support the proposed pattern of morphological response.

4.6.1 Bed material gradation data analysis

Bed material gradation data was available from the USACE records at five locations along the Mississippi: Arkansas City, Vicksburg, Natchez, Coochie and Tarbert Landing. Preliminary analysis involved investigating temporal changes in the D_{84}, D_{50} and D_{16} grain sizes, which may be taken to represent the entire grain size distribution. The results are plotted in Figures 26 to 32.

At Arkansas City, there are clearly no time trends in the D_{84}, D_{50}, or D_{16} records between 1979 and 1998 (Figure 26). This is also the case for the D_{50} and D_{16} sizes at Vicksburg over the same time period. However, a regression line fitted to the D_{84} data suggests on first inspection that pronounced fining has taken place in the coarser fraction of the bed material (Figure 27). Closer inspection of the scatter of the D_{84} data in Figure 27 reveals that the apparent fining trend may be explained by a marked reduction in scatter after 1992. In fact, there is no D_{84} coarser than 1 mm after that date, perhaps suggesting that samples have been truncated in some way. If all D_{84} values coarser than 1 mm were to be excluded from analysis then the apparent fining trend would disappear. This finding demonstrates that the fitting of regression lines to raw data is probably inappropriate for these data records.

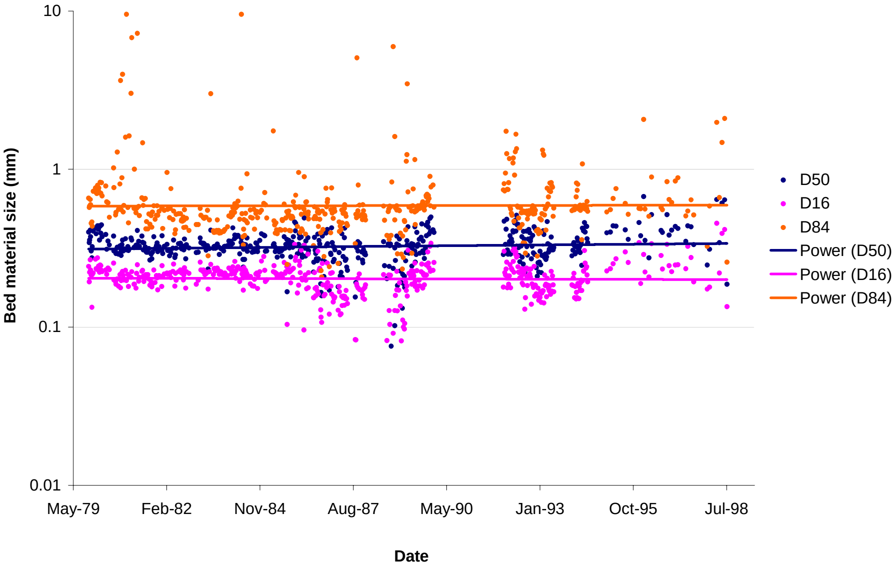


Figure 26. Temporal trends in the D_{84}, D_{50} and D_{16} of Bed Material at Arkansas City

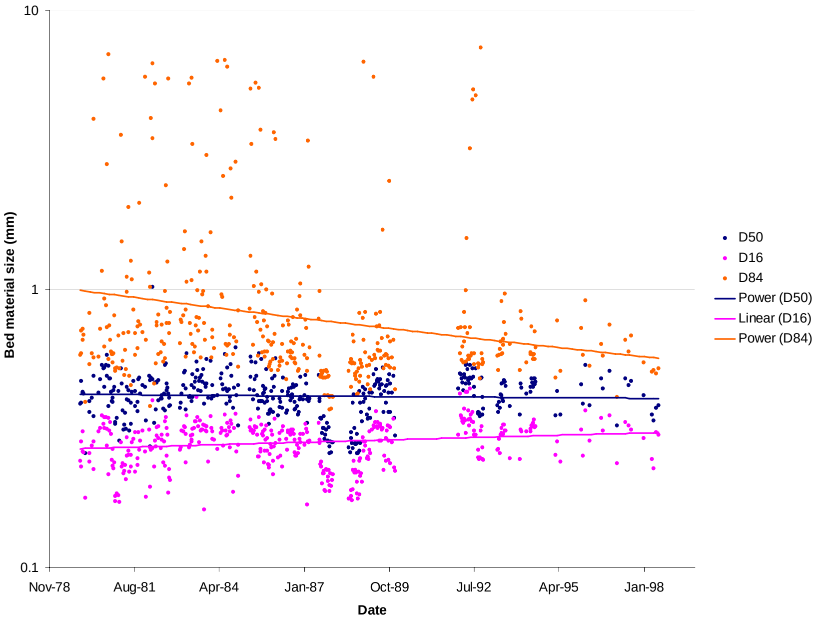


Figure 27. Temporal trends in the D_{84}, D_{50} and D_{16} of Bed Material at Vicksburg

The records for Natchez are shown in Figure 28. There may be a tendency for the D_{50} and D_{16} sizes to coarsen very slightly over the period of record, but this trend is not apparent in the D_{84} because it is obscured by an apparent fining trend, again due to the absence of coarse sizes after 1992.

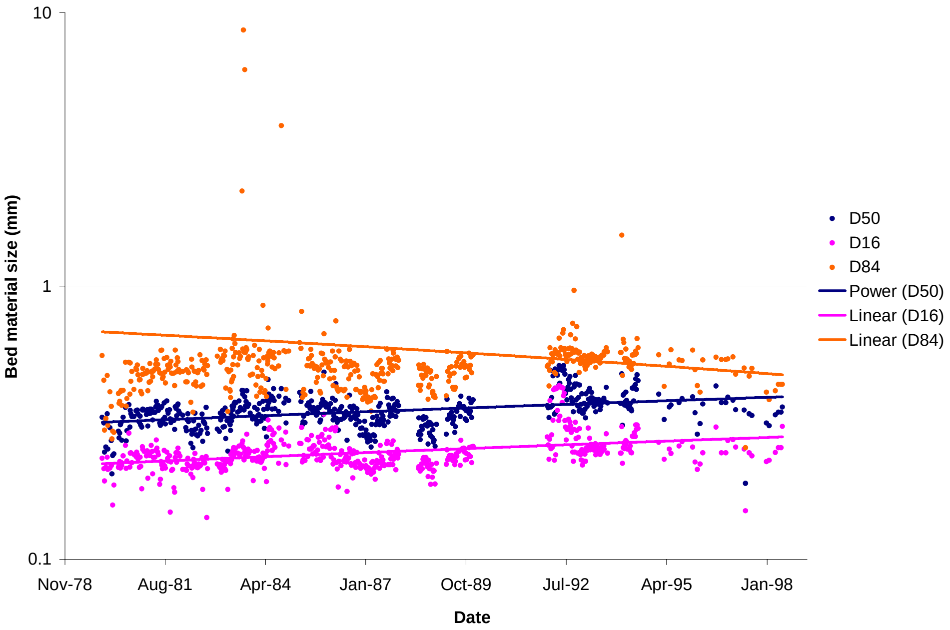


Figure 28. Temporal trends in the D_{84}, D_{50} and D_{16} of Bed Material Gradation Data at Natchez

Coochie and Tarbert Landing are only 11 river miles apart and the bed material size records are consistent with one another. The record for Tarbert landing is shown in Figure 29 and that for Coochie in Figure 30.

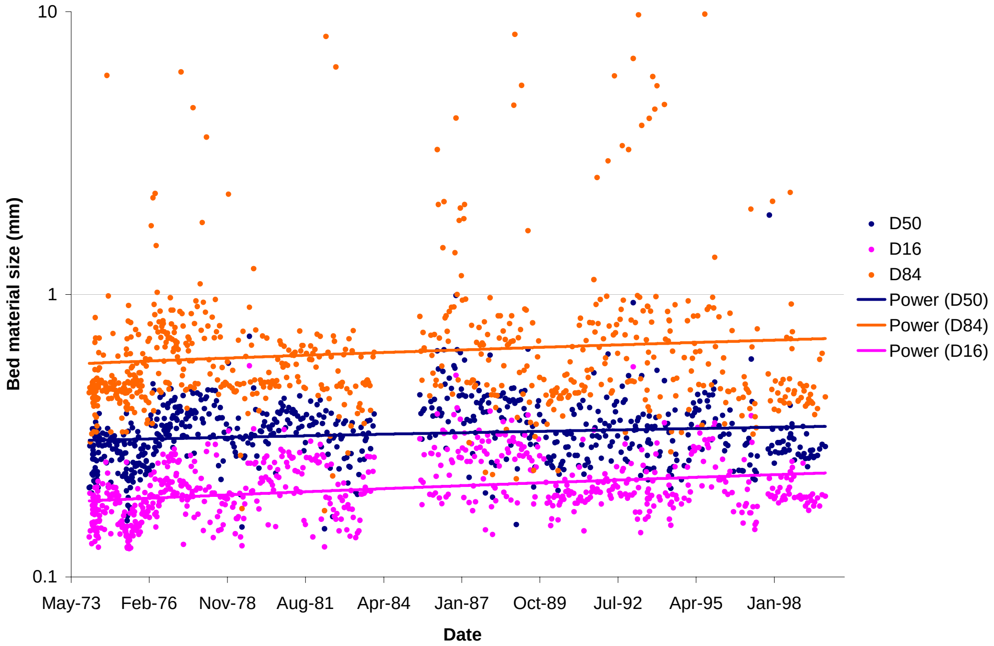


Figure 29. Temporal trends in the D_{84}, D_{50} and D_{16} of Bed Material at Tarbert Landing

There is no evidence of truncation of the coarse end of the distribution in these records and fitting regression lines to the data suggests a slight coarsening trend through increases in the D_{84}, D_{50} and D_{16}

between 1967 and 1998. However, the shape of data clouds does little to support the existence of a consistent trend and, if anything, sizes at Tarbert Landing have decreased somewhat in the late 1990s.

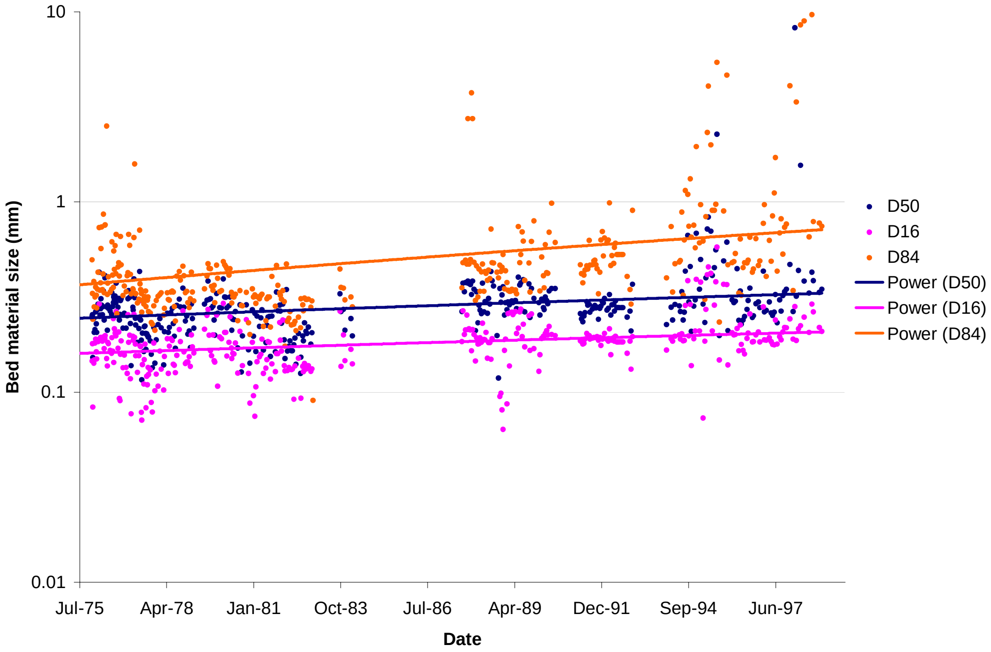


Figure 30. Temporal trends in the D_{84}, D_{50} and D_{16} of Bed Material Gradation at Coochie

Although there is an absence of firm temporal trends within the bed material records, it is possible to investigate spatial variations in bed material size percentile classifications. The average bed material diameters for a range of percentiles at key sampling stations are presented in Table 4.

Table 4 Bed material diameters (mm) at sampling stations (1979 – 1998)

Reach	**D_{84}**	**D_{50}**	**D_{16}**	**D_{10}**	**D_5**
Arkansas City	0.72	0.34	0.21	0.19	0.15
Vicksburg	0.95	0.42	0.28	0.25	0.21
Natchez	0.55	0.35	0.24	0.22	0.19
Coochie	0.44	0.27	0.18	0.16	0.13
Knox Landing	0.62	0.38	0.27	0.24	0.20
Tarbert	0.91	0.34	0.22	0.19	0.17

As can be seen in Table 4 and Figures 37 to 41, the gradation along the Lower Mississippi River from Arkansas City to Tarbert Landing presents a pattern with the coarsest bed material in Vicksburg and the finest in Coochie. The average D_{10} varies from 0.16 mm to 0.25 mm with a mean value of about 0.2 mm. This basically means that there are no appreciable quantities of material finer than about 0.2 mm, from Arkansas City to Tarbert Landing, found in the bed. Therefore, the bed material at these locations is composed of materials coarser than about 0.2 mm, while material finer than this should be considered wash load.

It may be concluded that initial analysis of the bed material gradation data reveals no firm trends of bed material coarsening or fining. The wide scatter and gaps in the records, coupled with doubts about possible truncation of the coarse fraction at some sites, make inapplicable techniques such as simple regression. In fact, further processing and filtering of the data would be required before any statistical analysis could produce meaningful results. Despite this, it is possible to conclude that the bed material at all sampling stations is composed of materials coarser than about 0.2 mm.

4.6.2 Suspended sediment gradation data analysis

Suspended sediment gradation data was only available from USACE New Orleans District records at Coochie and Tarbert Landing on the Mississippi River. Because the coarser fractions of the suspended sediment loads constitute the bed material load, which is important geomorphologically, preliminary analysis investigated temporal changes in the D_{84} and D_{95} sizes of the measured coarse load. The results are plotted in Figures 31 and 32.

Regression lines fitted to the data suggest that if anything D_{84} and D_{95} may posses a slight coarsening trend, despite a reduction in the coarsest D_{84} values observed at Coochie since the 1970s. However, at both locations, the data clouds exhibit wide scatter and gaps in the record that effectively preclude simple statistical treatment on the grounds that data are non-normally distributed and would generate non-random residuals. Taken together with the records of bed material size at these stations, the time trend indicates that sediment sizes have either stayed about constant or increased slightly in this reach of the Mississippi River.

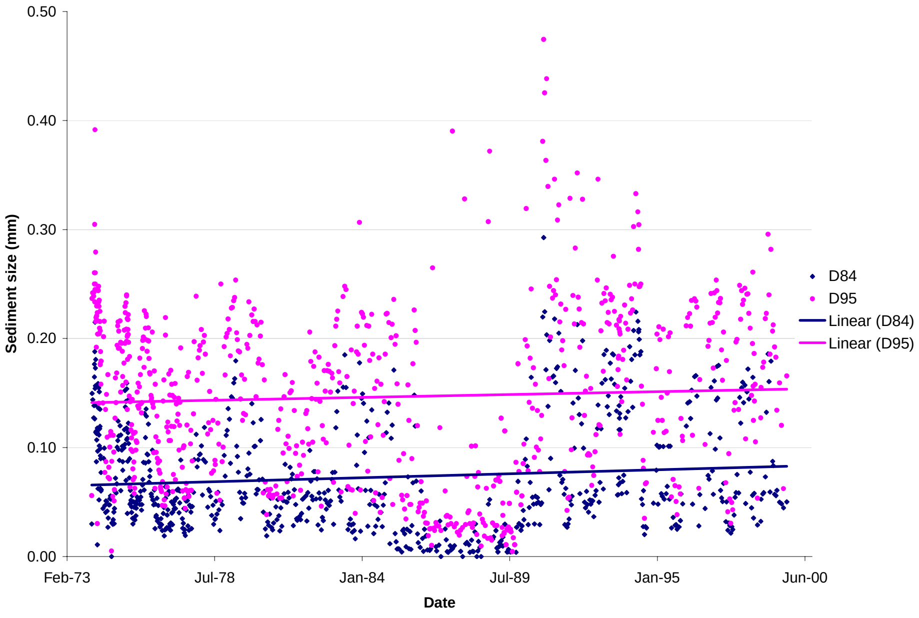


Figure 31. Temporal trends in the D_{84} and D_{95} of Suspended Sediment at Tarbert Landing

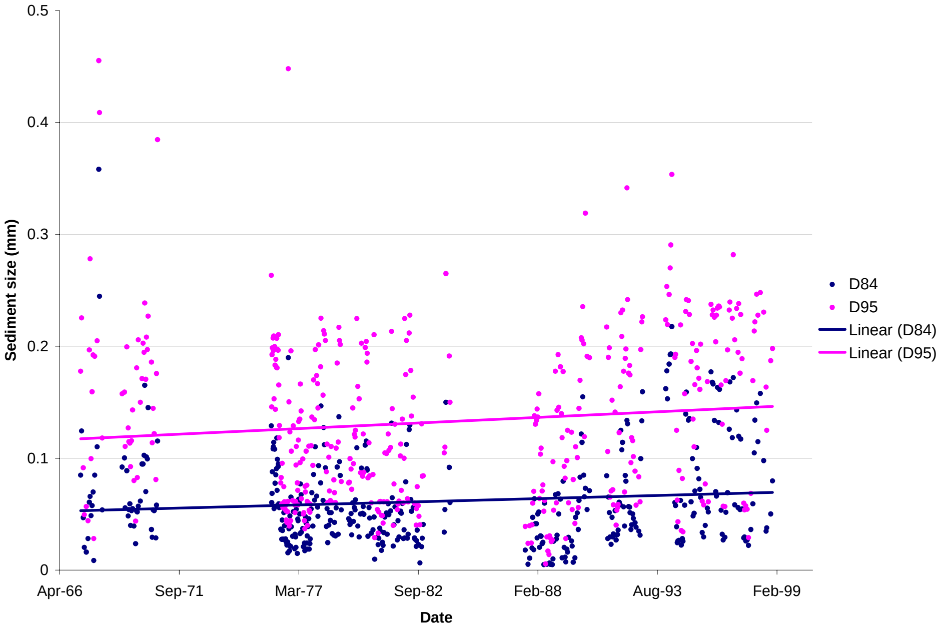


Figure 32. Temporal trends in the D_{84} and D_{95} of Suspended Sediment at Coochie

4.6.3 System Context

The records of bed material and coarse suspended load grain sizes are not inconsistent with the proposed pattern of morphological response in the river. Absence of any pronounced trend in grain size at Arkansas City is consistent with the concept that the reach is in dynamic equilibrium and represents a hinge point separating reaches of degradation upstream and aggradation downstream. Coochie and Tarbert Landing are located at a proposed hinge point between aggradation upstream and dynamic equilibrium downstream. Absence of any marked coarsening or fining of both suspended and bed material sizes is consistent with this proposal.

The records available for the Mississippi River must be treated with caution because temporal changes in suspended sediment and bed material gradations may relate to temporal changes in discharge. For example, in alluvial rivers suspended samples tend to coarsen and bed material samples tend to fine during wetter periods with above average runoff. Before any change in bed material or suspended sediment size in the Mississippi River can be attributed to morphological change, the possibility that it is in fact a response to a change in the runoff regime must first be eliminated. Also, it is important to stress that it is very difficult to at this spatial scale to link changes in suspended and bed material directly to channel stability. For example, Gomez et al. (1989) report the migration of coherent bed load pulses downstream through time in a dynamically stable system. If bed load in the Mississippi River also moves in pulses this could help in explaining spatial and temporal bed material trends in the data records. These records, therefore, provide huge research potential for identifying pulses and trends, but sustained and detailed analysis will be required to unlock the information the records contain.

Bearing in mind the complexity of the fluvial system, further research is recommended in order to explore the relationships between sediment size, flow regime, sediment transport dynamics and morphological adjustments in the Mississippi River.

5. SUMMARY AND RECOMMENDATIONS

This study has conducted preliminary analysis of a database of measured suspended sediment transport data for the Lower Mississippi River compiled for the US Army Corps of Engineers. This analysis yielded useful insights into the nature of the data, its strengths and its limitations. It also provides the basis from which to make several important recommendations for further sediment transport measurement and research on the Lower Mississippi River. This section summarises the conclusions and presents those recommendations.

5.1 SUMMARY

1) There is good agreement between USACE and USGS data sources. This suggests reliable sampling and data processing procedures have been adopted.
2) If bed material load is defined as being coarser than 0.125 mm to 0.2 mm, then Coarse Load overestimates the suspended component of Bed Material Load by a factor of 1.65 to 1.8 in the Mississippi River. Although the suspended component of Bed Material Load constitutes only a small percentage of Total Suspended Load, this percentage increases with discharge. These findings have important implications for morphological analysis of the Mississippi River.
3) Temperature is known, potentially, to influence suspended sediment concentrations. However, the data available in this study revealed no relationship between temperature and sediment concentration.
4) Coarse suspended sediment concentration has a stronger positive relationship with discharge than fine suspended sediment concentration. This finding reinforces the geomorphological significance of material moved by Bed Material Load.
5) No temporal trends are evident over the period of observation based on initial analysis of sediment load records. Spatial analysis reveals that it is difficult to compare the records for consecutive stations due to differences in sampling period and frequency. While general associations exist between adjacent sampling stations, it would be unwarranted to draw firm conclusions at this time.
6) Temporal and spatial trends within the suspended sediment and bed material gradation data are partially consistent with the model of morphological response proposed Biedenharn (1995). However, further analysis is required in order to fully investigate the relationship between flow regime, sediment transport and morphological change.

5.2 Recommendations

1. Collection of bed material and sediment transport data on the Lower Mississippi River is vital to our understanding of the morphology and morphological response of the system. It is erosion, sediment transfer between reaches and deposition that threatens the sustainability of river improvement works on the river and it is siltation that drives the on-going requirement for dredging. The only way to develop and improve the engineering capability to manage the system is through sound understanding of sediment processes and morphological adjustments. Measured suspended and bed material sampling are two components in developing this understanding. However, the collection program should be modified to make the data more usable in terms of interpreting morphological change and response. *It is therefore, imperative that data collection continues for the foreseeable future to support analysis and prediction of the morphological evolution of the river over periods of 50 to 100 years.*
2. The issues raised in 1) focus attention on the actual uses of sediment transport data. *These uses should be identified by bringing together data gatherers and end-users. In light of the end users, any changes to the collection procedure must ensure that the data collected are suitable for the purposes for which the programme is designed.*
3. Regional applications of the sediment transport data are severely limited by inconsistencies in the records for different gaging stations. It would be advantageous in this regard if sampling strategies, frequencies and dates were co-ordinated between gaging stations. *Data collection should be organised to optimise the usefulness of the product and this infers regional co-ordination of sampling programs across the USACE Districts and USGS offices responsible for field measurements.*
4. The existing records result from routine sampling of the river and consequently contain abundant data on average and intermediate discharges. However, rarely does a routinely scheduled measurement coincide with a high flow event. In fact, records based on routine measurements almost certainly under-estimate the true transport of sediment, especially in the coarser size fractions responsible for driving morphological changes. The limitations of using rating curves based on routine sampling to estimate sediment fluxes have long been recognised and theoretically based sampling strategy for the measurement of sediment loads exist (Walling, 1977). They involve combining a reduced program of routine (background) sampling with event sampling to capture sediment loads on those few days each year when the majority of sediment movement takes place. It is recommended that serious consideration be given to development of an advanced, strategic sampling program for the Lower Mississippi River to replace the present routine sampling program.
5. The analyses presented here have demonstrated that the use of coarse load to represent bed material load may lead to over-estimation of the quantity of bed material load moving in suspension. It appears that the portion of the coarse load finer than 0.125 to 0.2 mm should properly be considered wash load in the Mississippi River. This is potentially significant as it is

the bed material load that drives morphological adjustment and response in the system. *It is recommended that in future the size gradations of all measured suspended sediment load samples be determined. It is further recommended that sediment transport and bed material sampling records are re-examined to determine if gradation data for suspended load can be synthesised from bed material gradations. If this were to be possible, the historical bed material gradation records for the Vicksburg District should be used to generate suspended load gradations.*

6. The finding that the proportion of total load that constitutes bed material load is markedly smaller than the coarse load focuses attention more closely on the unmeasured load. If little bed material load moves in suspension, then it becomes even more important that some knowledge is gained of the sediment moving as bed load and near-bed load as this may be responsible for significant transport of bed material load. In the past, measuring bed load was hampered by lack of a reliable and repeatable measurement technique. This is no longer the case and it is technically feasible to measure bed load using relatively new technologies such as Acoustic Doppler Current Profilers (ADCPs). The ADCP has a ‘bottom tracking’ function which could be used to measure the speed of movement of the bed relative to a fixed point such as a bridge. A measure of the speed of downstream movement of the bed, coupled with an estimate of the thickness of the active layer, could be used to compute bed load. This technique has been used successfully on both gravel-bed and sand-bed reaches of the Frazer River in British Columbia. While the Frazer is much smaller than the Mississippi, it is nonetheless a large alluvial river and in principle the technique should be transferable. *It is strongly recommended that consideration be given to a trial or pilot program to measure bed material load in the Lower Mississippi River in order to ascertain the contribution of bed load to bed material transport responsible for driving morphological evolution and response of the fluvial system.*

6. REFERENCES

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APPENDICES

APPENDIX A: Sources, Periods of Record, Sampling Frequencies and Types of Data included in the Database and Initial Analysis

Source, period, frequency and type of data included within the project

Gaging Station	Data Source	Period	Frequency	Data type
St Louis	USGS Sediment website	1948-1991	Daily	Computed data for total concentration/load only
Chester	USGS Sediment website	1980-1994	Daily	Computed data for total concentration/load only
Thebes	USGS Sediment website	1980-1994	Daily	Computed data for total concentration/load only
Memphis	LHS CD (USGS data)	1973-1994	Mostly 4 weeks	Coarse, fine and total load/concentration data only
Arkansas City	Robbins	1929-1931	Weekly	Total load concentration data only
	Robbins	1967-1974	1-4 weeks	Coarse, fine and total load/concentration data only
	Unknown source	1969-1979	No dates attached	Coarse, fine and total load/concentration data only
	LHS CD (Vicksburg District data)	1979-1983	1-2 weeks	Coarse and fine suspended sediment concentration data and bed material gradation data for each vertical on the cross-section.
	Vicksburg District text file	1984-1998	1-4 weeks	Coarse and fine suspended sediment concentration data and bed material gradation data for each vertical on the cross-section.
Vicksburg	Robbins	1929-1931	Weekly	Total load concentration data only
	Robbins	1968-1974	1-4 weeks	Coarse, fine and total load/concentration data only
	Unknown source	1969-1979	No dates attached	Coarse, fine and total load/concentration data only
	LHS CD (USGS data)	1973-1994	4 weeks	Coarse, fine and total load/concentration data only
	LHS CD (Vicksburg District data)	1979-1983	Weekly	Coarse and fine suspended sediment concentration data and bed material gradation data for each vertical on the cross-section.
	Vicksburg District text file	1984-1998	1-4 weeks	Coarse and fine suspended sediment concentration data and bed material gradation data for each vertical on the cross-section.
Natchez	Unknown source	1969-1979	No dates attached	Coarse, fine and total load/concentration data only
	LHS CD	1970-1974	1-4 weeks	
	LHS CD (Vicksburg District data)	1979-1983	Weekly	Coarse and fine suspended sediment concentration data and bed material gradation data for each vertical on the cross-section.
	Vicksburg District text file	1984-1998	1-4 weeks	Coarse and fine suspended sediment concentration data and bed material gradation data for each vertical on the cross-section.

Coochie	LHS CD (New Orleans District data)	1967-1970	2 weeks	Coarse and fine suspended sediment concentration data and both suspended and bed material gradation data
	LHS CD (New Orleans District data)	1975-1984	2 weeks	Coarse and fine suspended sediment concentration data and both suspended and bed material gradation data
	LHS CD (New Orleans District data)	1987-1998	2 weeks	Coarse and fine suspended sediment concentration data and both suspended and bed material gradation data
Tarbet Landing	New Orleans	1974-1999	2 weeks	Coarse and fine suspended sediment concentration data and both suspended and bed material gradation data
	USGS Sediment Database	1974 - 1986	Daily	Computed data for total concentration/load only
St Francisville	LHS CD (USGS data)	1978-1997	2-4 weeks	Coarse, fine and total load/concentration data only

APPENDIX B: Temporal changes in the USACE New Orleans District sampling procedure at Tarbert Landing (supplied by Waterways Experiment Station)

Date	Verticals	Samples per Vertical	Sample Depths	Samples
1974	8	5	0.15, 0.3, 0.5, 0.7 and 0.9	40
1975	8	5	0.15, 0.3, 0.5, 0.7 and 0.9	40
1976	8	5	0.15, 0.3, 0.5, 0.7 and 0.9	40
1977	8	5	0.15, 0.3, 0.5, 0.7 and 0.9	40
1978	8	5	0.15, 0.3, 0.5, 0.7 and 0.9	40
1979	8	5	0.15, 0.3, 0.5, 0.7 and 0.9	40
1980	8	5	0.15, 0.3, 0.5, 0.7 and 0.9	40
1981	8	5	0.15, 0.3, 0.5, 0.7 and 0.9	40
1982	8	5	0.15, 0.3, 0.5, 0.7 and 0.9	40
1/13/83	8	5	0.15, 0.3, 0.5, 0.7 and 0.9	40
1/27/83	8	5	0.15, 0.3, 0.5, 0.7 and 0.9	40
02/10/83	8	5	0.15, 0.3, 0.5, 0.7 and 0.9	40
2/23/83	8	5	0.15, 0.3, 0.5, 0.7 and 0.9	40
03/10/83	8	5	0.15, 0.3, 0.5, 0.7 and 0.9	40
3/24/83	8	5	0.15, 0.3, 0.5, 0.7 and 0.9	40
04/07/83	8	5	0.15, 0.3, 0.5, 0.7 and 0.9	40
05/06/83	8	5	0.15, 0.3, 0.5, 0.7 and 0.9	40
5/30/83	4	2	0.5 and 0.7	8
6/15/83	4	2	0.5 and 0.7	8
6/29/83	4	2	0.5 and 0.7	8
7/13/73	4	2	0.5 and 0.7	8
7/27/83	4	2	0.5 and 0.7	8
08/10/83	4	2	0.5 and 0.7	8
8/24/83	4	2	0.5 and 0.7	8
09/08/83	4	2	0.5 and 0.7	8
9/22/83	4	2	0.5 and 0.7	8
10/04/83	4	2	0.5 and 0.7	8
10/18/83	4	2	0.5 and 0.7	8
11/04/83	4	2	0.5 and 0.7	8
11/15/83	4	2	0.5 and 0.7	8
11/29/83	4	2	0.5 and 0.7	8
12/16/83	4	2	0.5 and 0.7	8
12/30/83	4	2	0.5 and 0.7	8
1984	4	2	0.5 and 0.7	8
1985	4	2	0.5 and 0.7	8
1986	4	2	0.5 and 0.7	8
1987	4	2	0.5 and 0.7	8
1988	4	2	0.5 and 0.7	8
1989	4	2	0.5 and 0.7	8
01/09/90	4	2	0.5 and 0.7	8
1/22/90	4	2	0.5 and 0.7	8
02/08/90	4	2	0.5 and 0.7	8
2/22/90	4	2	0.5 and 0.7	8
03/05/90	4	2	0.5 and 0.7	8

3/19/90	4	2	0.5 and 0.7	8
04/02/90	4	2	0.5 and 0.7	8
4/16/90	4	2	0.5 and 0.7	8
4/30/90	4	3	0.5, 0.7 and 0.95	12
5/14/90	8	5	0.15, 0.3, 0.5, 0.7 and 0.95	40
5/29/90	4	3	0.5, 0.7 and 0.95	12
06/11/90	8	5	0.15, 0.3, 0.5, 0.7 and 0.95	40
6/25/90	4	3	0.5, 0.7 and 0.95	12
07/09/90	8	5	0.15, 0.3, 0.5, 0.7 and 0.95	40
7/23/90	4	3	0.5, 0.7 and 0.95	12
08/06/90	8	5	0.15, 0.3, 0.5, 0.7 and 0.95	40
8/22/90	4	3	0.5, 0.7 and 0.95	12
09/04/90	8	5	0.15, 0.3, 0.5, 0.7 and 0.95	40
9/17/90	4	3	0.5, 0.7 and 0.95	12
10/03/90	8	5	0.15, 0.3, 0.5, 0.7 and 0.95	40
10/15/90	4	3	0.5, 0.7 and 0.95	12
10/29/90	8	5	0.15, 0.3, 0.5, 0.7 and 0.95	40
11/13/90	4	3	0.5, 0.7 and 0.95	12
11/26/90	8	5	0.15, 0.3, 0.5, 0.7 and 0.95	40
12/10/90	4	3	0.5, 0.7 and 0.95	12
12/27/90	8	5	0.15, 0.3, 0.5, 0.7 and 0.95	40
1/16/91	4	3	0.5, 0.7 and 0.95	12
1/28/91	8	5	0.15, 0.3, 0.5, 0.7 and 0.95	40
02/11/91	4	3	0.5, 0.7 and 0.95	12
2/27/91	8	5	0.15, 0.3, 0.5, 0.7 and 0.95	40
03/11/91	4	3	0.5, 0.7 and 0.95	12
3/25/91	8	5	0.15, 0.3, 0.5, 0.7 and 0.95	40
04/08/91	4	3	0.5, 0.7 and 0.95	12
4/22/91	8	5	0.15, 0.3, 0.5, 0.7 and 0.95	40
05/08/91	4	3	0.5, 0.7 and 0.95	12
5/20/91	8	5	0.15, 0.3, 0.5, 0.7 and 0.95	40
06/03/91	4	3	0.5, 0.7 and 0.95	12
6/17/91	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
07/01/91	4	3	0.5, 0.7, and 0.95	12
7/17/91	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
7/29/91	4	3	0.5, 0.7, and 0.95	12
08/12/91	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
8/26/91	4	3	0.5, 0.7, and 0.95	12
09/11/91	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
9/24/91	4	3	0.5, 0.7, and 0.95	12
10/07/91	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
10/23/91	4	3	0.5, 0.7, and 0.95	12
11/04/91	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
11/18/91	4	3	0.5, 0.7, and 0.95	12
12/02/91	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
12/16/91	4	3	0.5, 0.7, and 0.95	12
1/13/92	4	3	0.5, 0.7, and 0.95	12
1/29/92	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
02/10/92	4	3	0.5, 0.7, and 0.95	12
2/20/92	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
03/11/92	4	3	0.5, 0.7, and 0.95	12
3/23/92	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40

04/06/92	4	3	0.5, 0.7, and 0.95	12
4/20/92	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
05/04/92	4	3	0.5, 0.7, and 0.95	12
5/19/92	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
06/01/92	4	3	0.5, 0.7, and 0.95	12
6/15/92	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
6/29/92	4	3	0.5, 0.7, and 0.95	12
7/13/92	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
7/27/92	4	3	0.5, 0.7, and 0.95	12
08/12/92	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
8/24/92	4	3	0.5, 0.7, and 0.95	12
09/10/92	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
9/23/92	4	3	0.5, 0.7, and 0.95	12
10/13/92	4	3	0.5, 0.7, and 0.95	12
10/19/92	4	3	0.5, 0.7, and 0.95	12
11/02/92	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
11/16/92	4	3	0.5, 0.7, and 0.95	12
11/30/92	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
12/14/92	4	3	0.5, 0.7, and 0.95	12
12/30/92	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
01/11/93	4	3	0.5, 0.7, and 0.95	12
1/25/93	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
02/08/93	4	3	0.5, 0.7, and 0.95	12
2/22/93	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
03/08/93	4	3	0.5, 0.7, and 0.95	12
3/22/93	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
04/05/93	4	3	0.5, 0.7, and 0.95	12
4/19/93	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
05/03/93	4	3	0.5, 0.7, and 0.95	12
5/17/93	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
06/01/93	4	3	0.5, 0.7, and 0.95	12
6/28/93	4	3	0.5, 0.7, and 0.95	12
07/12/93	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
7/21/93	4	3	0.5, 0.7, and 0.95	12
7/26/93	4	3	0.5, 0.7, and 0.95	12
7/28/93	4	3	0.5, 0.7, and 0.95	12
08/02/93	4	3	0.5, 0.7, and 0.95	12
08/04/93	4	3	0.5, 0.7, and 0.95	12
08/09/93	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
08/12/93	4	3	0.5, 0.7, and 0.95	12
8/16/93	4	3	0.5, 0.7, and 0.95	12
8/18/93	4	3	0.5, 0.7, and 0.95	12
8/23/93	4	3	0.5, 0.7, and 0.95	12
09/07/93	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
9/20/93	4	3	0.5, 0.7, and 0.95	12
10/04/93	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
10/18/93	4	3	0.5, 0.7, and 0.95	12
11/01/93	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
11/15/93	4	3	0.5, 0.7, and 0.95	12
11/29/93	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
12/23/93	4	3	0.5, 0.7, and 0.95	12
01/06/94	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40

1/20/94	4	3	0.5, 0.7, and 0.95	12
02/03/94	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
2/17/94	4	3	0.5, 0.7, and 0.95	12
03/03/94	8	5	0.15, 0.3, 0.5, 0.7, and 0.95	40
3/17/94	4	3	0.5, 0.7, and 0.95	12
4/14/94	4	3	0.5, 0.7, and 0.95	12
4/21/94	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
4/28/94	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
05/04/94	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
05/12/94	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
5/25/94	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
06/02/94	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
6/16/94	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
6/23/94	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
6/29/94	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
7/14/94	4	3	0.5, 0.7 and 0.9	12
7/27/94	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
08/10/94	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
10/06/94	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
11/10/94	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
12/22/94	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
12/29/94	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
01/11/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
1/26/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
02/09/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
2/23/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
03/09/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
3/22/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
04/06/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
05/04/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
5/17/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
06/01/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
6/15/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
6/29/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
07/12/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
08/03/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
8/31/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
9/14/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
9/26/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
10/26/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
11/09/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
11/22/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
12/06/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
12/14/95	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
02/01/96	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
2/15/96	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
3/14/96	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
3/28/96	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
04/11/96	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
4/25/96	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
5/22/96	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
06/06/96	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20

6/19/96	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
7/18/96	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20
08/01/96	4	5	0.15, 0.3, 0.5, 0.7 and 0.9	20

APPENDIX C: Data files on the Compact Disc

Accessing the Data Files

The Compact Disc includes copies of all the data files as well as copies of the analysis tools used within the study. The file named *'Maplink'* in directory *\Other* provides a series of hyperlinks from which all the data and preliminary analysis graphics can be easily accessed. Alternatively, data and analysis files can be manually accessed by browsing the directory structure. Data is stored in the following order of directory structure:

1) Data processing stage (original, intermediate, or final)
2) River Name
3) Sampling station location

For example, the final Arkansas City collated data file, named *'ArkDistrict.xls'* can be accessed through the directory structure *\Data\Final\Mississippi River\Arkansas City*

A comprehensive sediment inventory named *'Inventory.xls'*, listing the source of each original data file, the beginning and end dates, the sampling frequency and the type of data available can be found in directory *\Analysis tools.* Where short time period files have been collated into a larger file for a specific location, the shorter files have been included as extra spreadsheets within the larger file. The collated data sheet is named 'All Data'. Where several macros have been used to perform calculations or change the layout of files, the data at each stage of compilation is included on the compact disk. The final data sheet for each source at each location is coloured yellow. Validation procedures which have been applied to the data are also colour coded

Accessing the analysis files

All the analysis files can be directly accessed by opening the file *'Maplink.xls'* in directory *\Other* and following the appropriate hyperlinks. Alternatively, they can be accessed by browsing in directory *\Analysis.*

Accessing the report

This report and the accompanying figures can be viewed in directory *\Report.*

Other files

The Macro programming text files and the standard data formats can be viewed in directory *\Other.*