A Sediment Budget for the Tombigbee River Basin and the Mobile River Basin

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December 2011

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Abstract

The purpose of this study is to develop a sediment budget for the Tombigbee River Basin and the Mobile River Basin. A two tier analysis was developed to determine the annual sediment changes along the Tombigbee River Basin (TRB) and the Mobile River Basin (MRB). Results indicate that important sedimentation processes are occurring on the impoundments distributed along the TRB and the Alabama River (ARB) which receives waters from the Cahaba River, Coosa River, and Tallapoosa River. Higher rates of sediment along the lower part of the TRB could be related to the occurrence of river bank instability processes between the Demopolis and the Coffeeville Dams on the Tenn-Tom Waterway. Total sediment loads at the entrance of the Mobile River ranged from 0.8 to 18.75 millions Mg yr^{-1}. Changes on morphological and hydrodynamic processes below the diversion of the Mobile River in two distributaries can be favoring sedimentation processes along the lower part of the basin and the Mobile Bay. Further analysis is expected to determine the accurate sediment behavior occurring along the lower MRB and its sediment contributions to the Mobile Bay and the Gulf of Mexico.

Introduction

A sediment budget is an accounting of the sources and disposition of sediment as it travels from its point of origin to its eventual exit from a drainage basin (Stream Systems Technology Center, 2004). Sediment budgets are important in defining the dynamic behavior of a river system (Sharp, 2007). Knowledge of stream and watershed characteristics is important for understanding natural processes and problems associated with watershed management and stream restoration. Sediment production and deposition have been linked to variations in fluvial sediment transport. In many lowland rivers, a major part of sediment is transported in suspension.

The Mobile River is the sixth largest river basin in the United States and the fourth largest in terms of flow (Figure 1). The water resources on the Mobile River Basin (MRB) are influenced by an array of natural and cultural factors, which impart unique and variable qualities to the streams, rivers, and aquifers and provide abundant habitat to sustain the diverse aquatic life in the basin (McPherson et al., 2003). Surface water in the Mobile River Basin generally meets Federal and State drinking water standards and guidelines for protection of aquatic life. However, water quality conditions are adversely affected by urban and agricultural activities, as indicated by elevated concentrations of nutrients, pesticides, and other organic compounds, and biological communities commonly exhibit signs of environmental stress (Atkins et al., 2004). Approximately 70% of the MRB is covered by forest and silviculture is the largest industry. Logging and other silviculture activities can significantly contribute high rates of sediment from erosion and runoff.

Assessment of a sediment budget in the MRB is important to increase the scientific understanding of sediment behavior and distribution within the basin as important factors that influence water quality trough the basin itself, the Mobile Bay and the Gulf of Mexico.

Purpose and Scope

The purpose of this report is to provide an estimate of sediment inflows, outflows and deposition along different sites within the Tombigbee River Basin (TRB) and the Mobile River Basin (MRB).

Description of the Study Area

The MRB encompasses 113,185 km^2 along the states of Mississippi, Alabama, Tennessee and Georgia (Figure 1). The western part of this basin, which is the sixth largest river basin in the United States, is comprised of the TRB (35,674 km^2) and the Black Warrior River (BWR - 16,280 km^2). The eastern MRB is drained by the Alabama River (ARB-58,726 km^2) which receives waters from the Cahaba River, Coosa River, and Tallapoosa River. The Mobile River is formed by the confluence of the Alabama and Tombigbee Rivers, near Vermont, AL. Downstream from the confluence, the Mobile River flows about 48 km to the south before splitting into several distributaries (Johnson et al., 2002). After flowing across a deltaic plain, these distributaries discharge into the Mobile Bay, which discharges into the Gulf of Mexico (Figure 2).

The mean annual flow in the MRB is about 1760 m^3 s^{-1}. The Alabama and Tombigbee Rivers contribute about 52 and 48% of the flow, respectively (Atkins et al., 2004). Mean annual runoff and precipitation generally are uniform throughout the MRB, with a highest precipitation amount typically occurring in the northeast part and southern area of the basin. Streamflow in the MRB is highly regulated by upstream impoundments. Around 1,020 km^2 of impoundments are extended along the entire basin, some of them constructed for hydroelectric generation and flood control purposes; other series of navigable impoundments were created by completion of the Tennessee Tombigbee Waterway to connect the MRB with the Tennessee River drainage in northeast Mississippi. As a result of this regulation, natural season flow patterns in these tributaries have been altered, with moderated peaks and low flows downstream from the impoundments. Water quality is affected by sediment and nutrients that are trapped in the impoundments and contribute to eutrophication, algal blooms, low oxygen levels and fish killing (Atkins et al., 2004).

Water quality agencies have identified numerous causes and sources of surface water impairment in the MRB. The complex combination of natural (e.g. physiography, geology, soils, climate, hydrology and ecology) and human factors (e.g. built impoundments, land use changes, mining) within the MRB are considered the principal influences on water quality (Johnson et al., 2002).

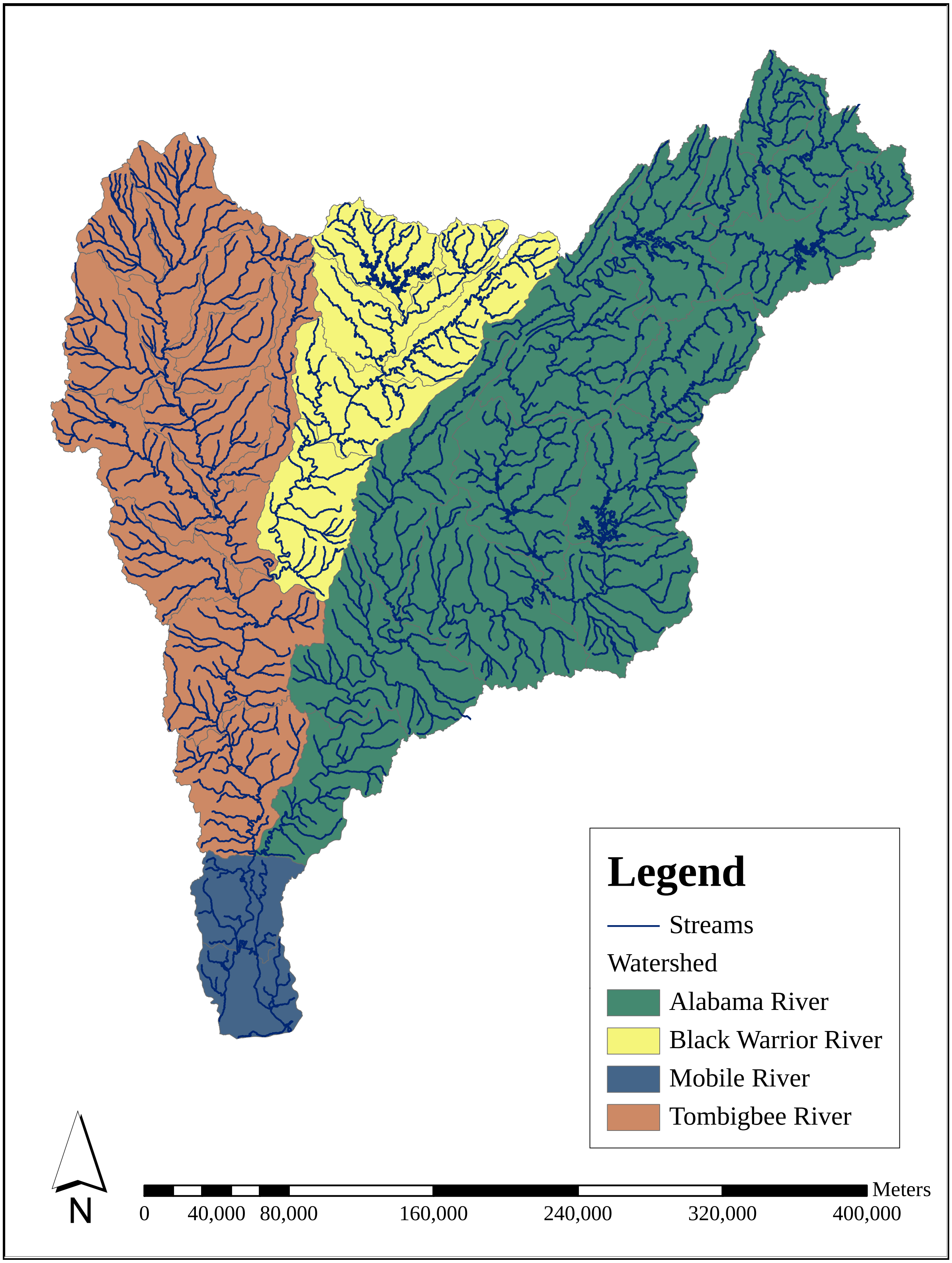


Figure 1. Mobile River Basin and principal Subbasins

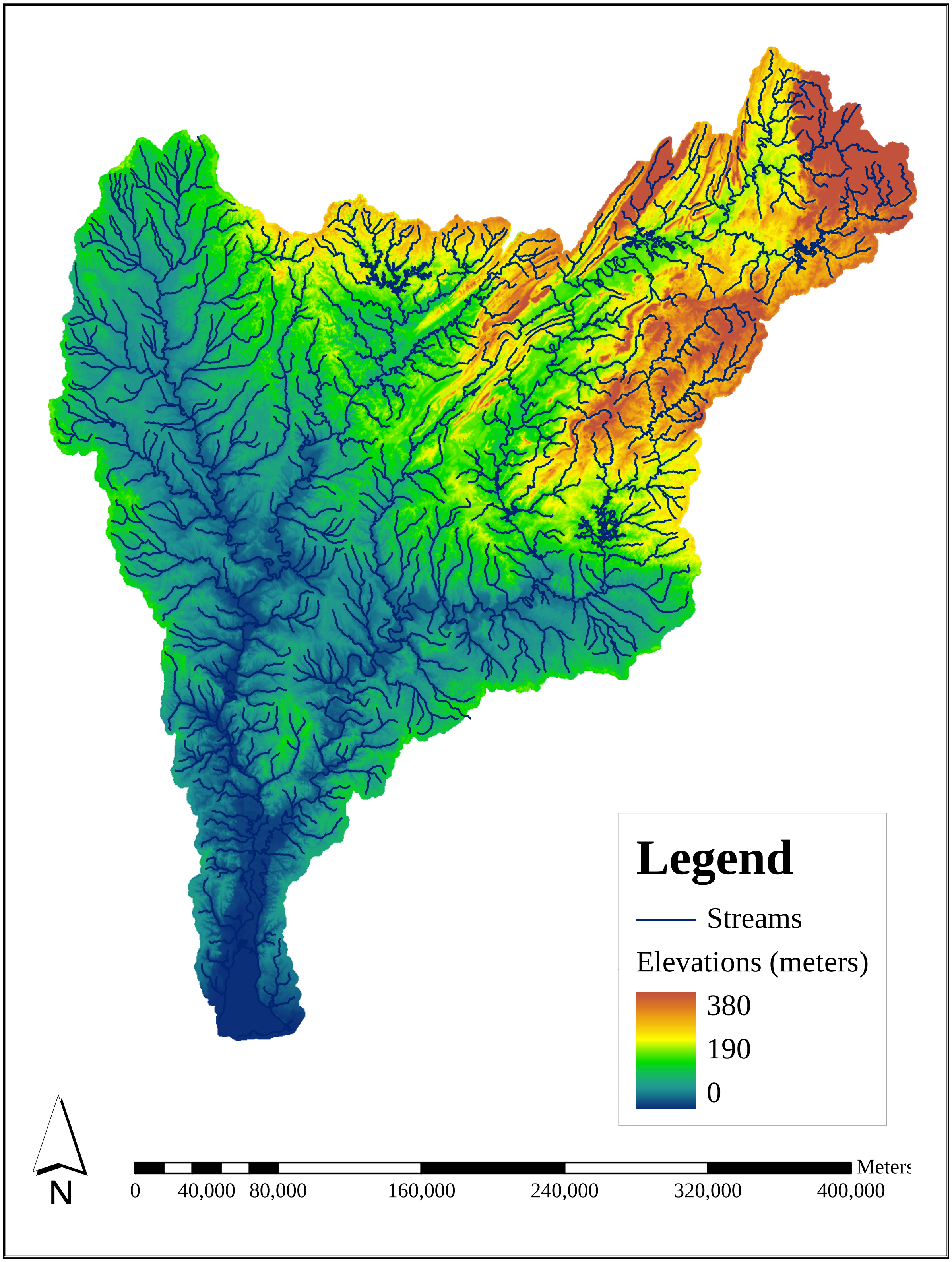


Figure 2. Topography in the Mobile River Basin.

Approach

The development of the sediment budget for the TRB and the MRB included the application of a two tiered analysis, based on the proposed sediment budget template developed by Sharp (2007). Initially, data from USGS stations within the MRB in the form of suspended sediment concentrations, suspended sediment loads, instantaneous flow, daily average flow and peak flow were collected. All available data from 1975 to 2010 for all the USGS gauging stations involved in the present study were used. Table 1 presents the USGS stations where data were collected and Figure 1 the location of these stations within the MRB.

All the USGS stations within the Upper Tombigbee River (HUC 03160101), the Middle Tombigbee River (HUC 03160106) and the Middle Tombigbee River-Chickasaw (HUC 03160201) subbasins were evaluated to provide an estimate of sediment inflows, outflows and deposition in the TRB (Figure 3). Results of the sediment budget developed by Sharp (2007) for the Aberdeen Pool were setup as the initial sediment load input for the upper subbasin (HUC 03160101). The sediment load at the outlet of each subbasin was considered as the total sediment load entering the next segment downstream. USGS stations within the same subbasin but not located on the Tombigbee River were used to determine the contribution of flow and sediment loads from tributary watersheds. The entire sediment load of a tributary watershed considered both, accounted and unaccounted areas. The upstream section within a watershed or subbasin contributing at the location of a USGS station was part of the accounted area. The section between the location of a USGS station and the mouth of the watershed, the outlet of a subbasin or a specific location within a subbasin (e.g. entrance of a lake) was considered as the unaccounted area. The sediment load of the accounted area of a watershed or subbasin was divided by its extension providing calculations of mean daily (Mg d^{-1} km^2) or mean annual (Mg yr^{-1} km^2) sediment yield for Tier 1 and Tier 2, respectively. The unaccounted area of a subbasin or a tributary watershed was considered to have similar sediment yield than the sediment yield observed at the upstream area contributing to a USGS station.

A sediment rating curve (expressed as Equation 1), which represents the relationship between suspended sediment discharges (Q_s) and the stream or river flow (Q), was developed for the entire dataset within a specific subbasin. The development of the sediment rating curves were the base of both of the tiered analyses, and were used to determine the sediment load generated by each tributary watershed, subbasin or upstream area contributing to a lake.

$$Q_s = aQ^b \qquad \text{Equation 1}$$

where

Q_s is the suspended sediment discharge (Mg d^{-1}), Q is the observed instantaneous flow (m^3 s^{-1}), and a and b are regression parameters.

The Tier 1 analysis implements basic principles to create an initial sediment budget by determining suspended sediment (SS) loads and yields at the magnitude of the effective discharge, also known as bankfull discharge ($Q_{1.5}$). A flow frequency distribution was generated from the annual maximum peak flow series at each USGS station by using the model PKFQWin (Version 5.2). The $Q_{1.5}$ was calculated from the generated flow frequency distribution (Figure 4, annual exceedance probability=0.6667).

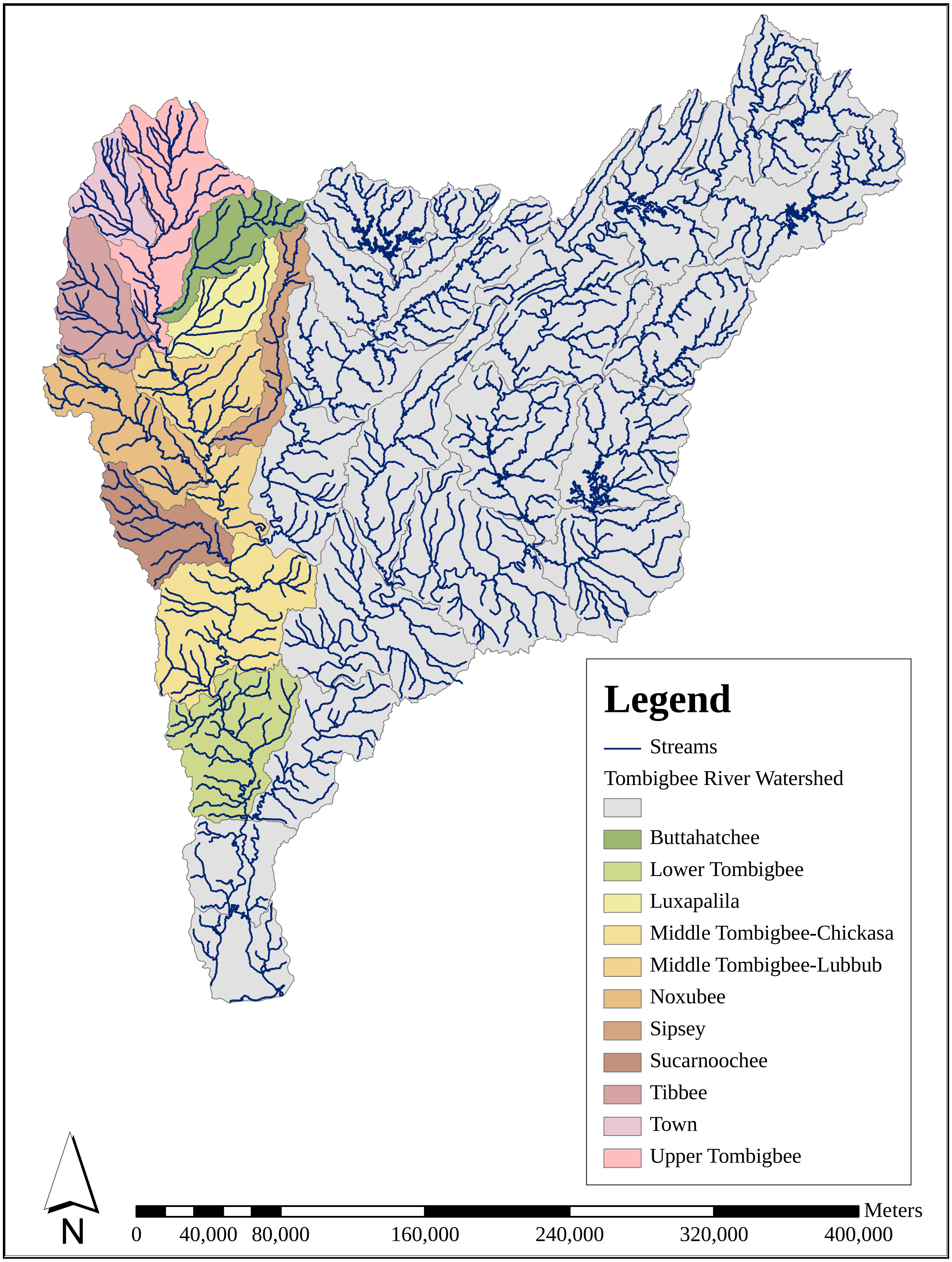
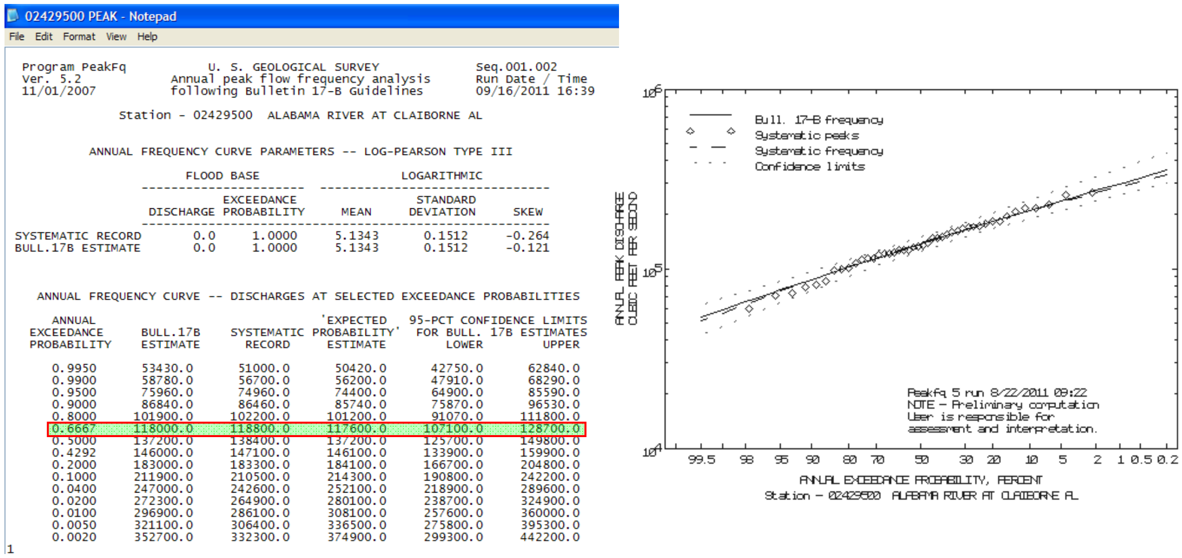


Figure 3. Tombigbee River Basin and subbasins

Table 1. USGS stations used to determine the sediment budget for the Tombigbee River Basin and the Mobile River Basin

River	Station	Type	Information
Tombigbee River	02437100 & 02437500	M	Tombigbee River at Aberdeen, MS
	02439400	T	Buttahatchee River nr Aberdeen, MS
	02441000	T	Tibbee Creek nr Tibbee, MS
	02443500	T	Luxapallila Creek nr Columbus, MS
	02444160 & 02444161	M	Tombigbee River below Bevil L&D nr Pickensville, AL.
	02444490	T	Bogue Chitto Creek near Memphis, AL
	02444500	M	Tombigbee River nr Cochrane, AL
	02446500	T	Sipsey River nr Elrod, AL
	02447025 & 02447026	M	Tombigbee River below Heflin L&D nr Gainesville, AL
	02448000	T	Noxubee River at Macon, MS
	02467000		Tombigbee River at Demopolis L&D nr Coatopa, AL
	02467500[1]	T	Sucarnoochee River at Livingston, AL
	02469525	M	Tombigbee River nr Nanafalia, AL
	02469761	M	Tombigbee River below Coffeeville L&D nr Coffeeville, AL
Black Warrior River	02462501	M	Black Warrior River below Bankhead L&D nr Bessemer, AL
	02465000	M	Black Warrior River at Northport, AL
	02466030 & 02466031	M	Black Warrior River at Selden L&D nr Eutaw, AL
Coosawattee River	02380500	T	Coosawattee River nr Ellijay, GA
	02383500	T	Coosawattee River nr Pine Chapel, GA
	02387500	M	Oostanaula River at Resaca, GA
Alabama River	02420000	M	Alabama River nr Montgomery, AL
	02423000	M	Alabama River at Selma, AL
	02428400, 02428401 & 02429500	M	Alabama River at Claiborne, AL
Mobile River	02470500[2]	M	Mobile River at Mt Vernon, AL
	02470629	D	Mobile River at River Mile 31.0 at Bucks, AL
	02471019	D	Tensaw River nr Mt Vernon, AL



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U. S. GEOLOGICAL SURVEY
Annual peak flow frequency analysis
following Bulletin 17-B Guidelines

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09/16/2011 16:39

Station - 02429500 ALABAMA RIVER AT CLAIBORNE AL

ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

	FLOOD BASE		LOGARITHMIC		
	DISCHARGE	EXCEEDANCE PROBABILITY	MEAN	STANDARD DEVIATION	SKEW
SYSTEMATIC RECORD	0.0	1.0000	5.1343	0.1512	-0.264
BULL.17B ESTIMATE	0.0	1.0000	5.1343	0.1512	-0.121

ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	'EXPECTED PROBABILITY' ESTIMATE	95-PCT CONFIDENCE LIMITS FOR BULL. 17B ESTIMATES LOWER	UPPER
0.9950	53430.0	51000.0	50420.0	42750.0	62840.0
0.9900	58780.0	56700.0	56200.0	47910.0	68290.0
0.9500	75960.0	74960.0	74400.0	64900.0	85590.0
0.9000	86840.0	86460.0	85740.0	75870.0	96530.0
0.8000	101900.0	102200.0	101200.0	91070.0	111800.0
0.6667	118000.0	118800.0	117600.0	107100.0	128700.0
0.5000	137200.0	138400.0	137200.0	125700.0	149800.0
0.4292	146000.0	147100.0	146100.0	133900.0	159900.0
0.2000	183000.0	183300.0	184100.0	166700.0	204800.0
0.1000	211900.0	210500.0	214300.0	190800.0	242200.0
0.0400	247000.0	242600.0	252100.0	218900.0	289600.0
0.0200	272300.0	264900.0	280100.0	238700.0	324900.0
0.0100	296900.0	286100.0	308100.0	257600.0	360000.0
0.0050	321100.0	306400.0	336500.0	275800.0	395300.0
0.0020	352700.0	332300.0	374900.0	299300.0	442200.0

1

Figure 4. Output file and plot of a flow frequency distribution generated by PKQWin (Ver. 5.2) for USGS stations

The SS load and daily SS yield at the $Q_{1.5}$ was obtained for each USGS station by using the sediment rating curve developed for each subbasin. Changes on sediment load (erosion or deposition) caused by the presence of an impoundment (e.g. lake) were evaluated by determining a sediment mass balance, which determines amounts of sediment entering the lake, dredging and sediment loadings from the lake.

Tier 2 analysis is a second stage where annual sediment discharges for each station are estimated using its mean daily flow data series. For this study, the used flow data series ranged from 1974 to 2010 when available. The sediment rating equation of each site was used to calculate mean daily SS load values (Mg d^{-1}) from the mean daily flow (m^3 s^{-1}). The mean daily SS loads were added for each complete calendar year to provide an annual SS load (Mg yr^{-1}). A mean annual SS load was generated by averaging annual sediment loads from 1974 to 2010. Once each station has a calculated annual SS load, a SS yield (Mg yr^{-1} km^2) was estimated for the contributing area where each station was located. Ungaged areas located downstream of a USGS station were considered to have similar sediment yield that gaged areas, when both areas were located within the same hydrologic unit (watershed) and flow was not routed through a downstream impoundment (dam).

The Tier 2 considers bed load as a percentage of the SS load. The bed load can be estimated as the 20% of the SS load for locations without the presence of an impoundment, or locations representing the influent of an impoundment. A lower value of 5% can be considered to calculate effluent flows from any impoundment in this study.

More extended and detailed information about the conceptualization and methodology used to develop a tiered sediment budget analysis is described by Sharp (2007) and Ramirez-Avila (2011).

Results

Annual sediment loads and yields were calculated based on a two tiered analysis for each USGS station within the TRB, the BWR and the lower Alabama-Coosa-Tallapoosa River Basin (ACT) with enough available sediment and flow dataset (Annex 1). The annual SS load estimations based on the Tier 1 and Tier 2 analyses for four subbasins within the TRB and for the outlets of the BWR and the lower ARB are presented in Tables 2 and 3.

Calculated deposition rates at the Columbus Lake were 10.2 and 3.4 millions Mg yr^{-1} of sediment using the Tier 1 and Tier 2, respectively. The Tier 1 deposition rate for the Aliceville Lake was 407,200 Mg yr^{-1} while the Tier 2 estimation described that the system is balanced when no dredging is performed. For the mass balance estimations reported dredging rates of 100,000 Mg yr^{-1} and 127,000 Mg yr^{-1} (McAnally et al., 2004) were considered for the Columbus and Aliceville Lake, respectively.

The sediment load from the BWR, a mixed land use basin, represented only 9% and 7% of the sediment load entering to the Mobile River. The relatively low sediment load from this area reflected the influence of impoundments upstream of the subbasin's outlet. Similar observations in the reduction of sediment loads from this subbasin were reported by McPherson et al. (2003).

For both methods of analysis, the Middle Tombigbee River-Chickasaw was the subbasin with the higher annual sediment yield (Mg km^{-2} yr^{-1}) within the TRB. Two important structures (Demopolis and Coffeeville Locks and Dams) are located within this subbasin, which could be the key to explain the significant increase in sediment loads occurred between the inlet and the outlet of this area. According to Bankhead et al., (2008) a considerable amount of widening (up to 85 m between 1974 and 2003) has occurred along the length of the Tombigbee River within this subbasin. During their research, areas of high bank erosion were more commonly observed in certain locations with a spatial trend being seen between the dams established in this subbasin. Downstream of Demopolis Dam bank erosion rates were low, but increased up to 3 m yr^{-1} along the following 48 km from the dam. Downstream of this length, trends of bank erosion decreased towards Coffeeville Dam, with bank erosion increasing again a few kilometers upstream of the dam. Below Coffeeville Dam, bank erosion rates were high, and then decreased downstream along the following 64 km.

The annual SS load entering the Mobile River after the junction of the Tombigbee/Warrior system with the Alabama River just north of the city of Mobile, AL was estimated as 34 million of Mg and 5.4 million of Mg for the Tier 1 analysis and Tier 2 analysis, respectively. Downstream from the confluence, the Mobile River flows about 48 km to the south before splitting into the Tensaw River and the Mobile River. A USGS station is located on each branch few kilometers after the diversion. The observed reduction in the cumulated magnitude of the SS load for both Tier analyses (Tables 2 and 3) was evidenced after estimating the individual load on each station. This reduction (deposition) can be caused by the individual occurrence or the combination of three factors: i) the changes on flow velocity caused by the diversion of the Mobile River; ii) the minimum change of channel slope and the meandering path of the branches from the diversion to their outlet into the Mobile Bay; and iii) the probable deposition on areas along the deltaic plain during high flow events.

The extension of the entire ACT represented the 53.1% of the total area contributing to the Mobile River; however, in both analyses the SS load contribution from this basin was 1.8 times smaller than the SS loaded by the Tombigbee/Warrior system. The observed lower sediment loads along the ACT could be attributed to the presence of a significant number of highly regulated impoundments constructed for hydroelectric generation and flood control processes.

For each tiered analysis, a linear relationship between the area of the watersheds and subbasins within the TRB and the BWR and the estimated SS load was determined (Figures 5 and 6). The best fitting observed when using the Tier 1 for estimations can be explained because the SS load variability depends only from the magnitude of the bankfull discharge ($Q_{1.5}$) after being determined a unique rating curve for each subbasin. For sediment load estimations based on the Tier 2 the change in the mean daily flow on each station along the different years the rating curve was routed (generally from 1974 to 2010) was the factor that affected the reduction in the linear fitting of the dataset.

Although the Tier 2 analysis used the same USGS flow gages that the Tier 1 analysis, the use of daily flow events provides a closer approximation to the natural flow conditions (Sharp, 2007). The occurrence of flows similar to or higher than the bankfull discharge is different for each watershed and subbasin. In the performance of an ongoing study, Avendaño et al. (2012) found that flows with magnitude similar to or above the bankfull discharge represented only the 15% of the entire flow records for the Buttahatchie River in Mississippi. This condition determines that the application of the Tier 1 generates a significant overprediction of the rate of sediment yield by a specific watershed and/or sediment deposited on specific locations (e.g. Columbus Lake on this study) and further analysis is necessary to perform a more accurate estimation of sediment loads when limited flow data is available.

Considering the application of the Tier 2 as the more accurate method to determine the sediment flux along the different watersheds and subbasins into the MRB, a total sediment load ranging from 0.8 to 18.75 million Mg yr^{-1} is expected to enter the Mobile River after the junction of the Alabama and the Tombigbee Rivers (Table 4). Further analysis is needed to determine the rate of reduction of the SS load and the total load of sediment along the distributaries below the Mobile River diversion. When comparing the similar range of dates (2004 to 2010) between the loads at the entrance of the Mobile River and the distributaries the trend to reduce the magnitude of the loads is consistent.

Table 2. Estimation of annual suspended sediment load for different subbasins within the Mobile River Basin based on Tier 1

Subbasin	**Drainage Area* (km^2)**	**Area Contribution (%)**	**Annual Suspended Sediment Load at $Q_{1.5}$ (Mg yr^{-1})**	**Suspended Sediment Load Contribution$^+$ (%)**
Upper Tombigbee River (03160101)	11,575	10.5	3,928,845	12
Middle Tombigbee River (03160106)	23,588	21.3	7,049,007	21
Lower Black Warrior River (03160113)	16,280	14.7	3,014,198	9
Middle Tombigbee River Chickasaw (03160201)	47,774	43.2	20,001,609	59
Lower Tombigbee River (03160203)	51,954	46.9	21,751,656	64
Lower Alabama River (03150204)	58,726	53.1	12,242,934	36
Suspended Sediment Load entering the Mobile River	110,680	100	33,994,591	100
Suspended Sediment load at distributaries			31,201,756	

* Including all upstream subbasin's area

$^+$ Ratio of total suspended sediment load entering to the Mobile River in AL.

Table 3. Estimation of annual suspended sediment load for different subbasins within the Mobile River Basin based on Tier 2

Subbasin	**Drainage Area* (km^2)**	**Area Contribution (%)**	**Mean Annual Suspended Sediment Load ($Mg\ yr^{-1}$)**	**Suspended Sediment Load Contribution⁺ (%)**	**Mean Annual Bed Load ($Mg\ yr^{-1}$)**	**Mean Annual Total Load ($Mg\ yr^{-1}$)**
Upper Tombigbee River (03160101)	11,575	10.5	732,223	14	146,445	878,668
Middle Tombigbee River (03160106)	23,588	21.3	3,701,669	69	740,334	4,442,002
Lower Black Warrior River (03160113)	16,280	14.7	348,827	7	69,765	418,593
Middle Tombigbee River Chickasaw (03160201)	47,774	43.2	3,168,627	59	633,725	3,802,353
Lower Tombigbee River (03160203)	51,954	46.9	3,445,867	64	689,173	4,135,041
Lower Alabama River (03150204)	58,726	53.1	1,915,331	36	383,066	2,298,398
Suspended Sediment Load entering the Mobile River	110,680	100	5,361,199	100	1,072,240	6,433,438
Suspended Sediment load at distributaries			3,098,150		619,630^	1,691,870

* Including all upstream subbasin's area

+ Ratio of total suspended sediment load entering to the Mobile River in AL

^Percentage of sediment load assumed as bed load could be different due to the change on morphological and hydraulic conditions after the diversion

Table 4. Range of sediment loads for the lower subbasins of the Mobile River Basin

Subbasin	Tombigbee River Output	Alabama River Output	Entering Mobile River	Distributaries*
Maximum SS Load ($Mg\ yr^{-1}$)	11,526,200	4,091,100	15,617,350 8,197,719*	5,831,500
Minimum Load ($Mg\ yr^{-1}$)	548,350	251,700	800,000	587,500
Maximum Bed Load ($Mg\ yr^{-1}$)	2,305,250	818,200	3,123,500 1,639,544*	1,166,200
Minimum Bed Load ($Mg\ yr^{-1}$)	109,650	50,300	16,000	117,500
Maximum Total Load ($Mg\ yr^{-1}$)	13,831,450	4,909,300	18,740,850 9,837,300*	6,997,700
Minimum Total Load ($Mg\ yr^{-1}$)	658,000	302,000	816,000	705,000

*Values determined only between 2004 and 2010 due to availability of data in one of the USGS stations.

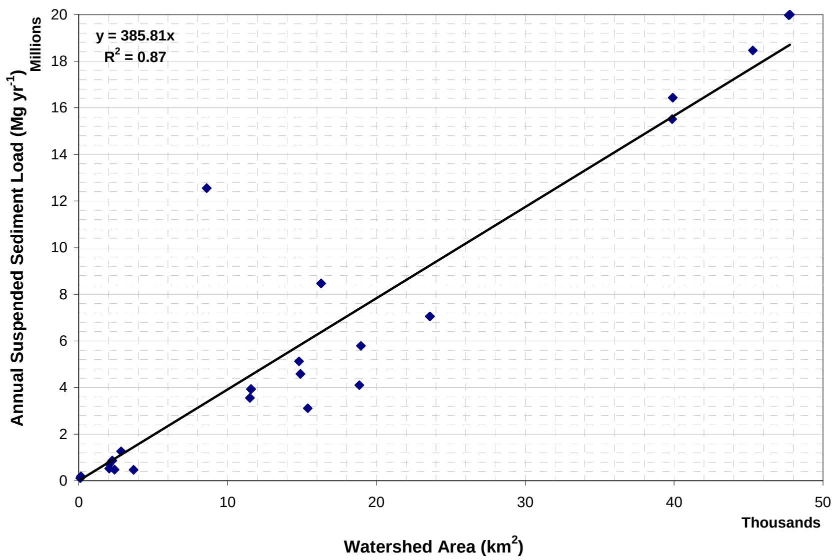

Figure 5. Relation between watershed area and Tier 1 estimated annual suspended sediment load.

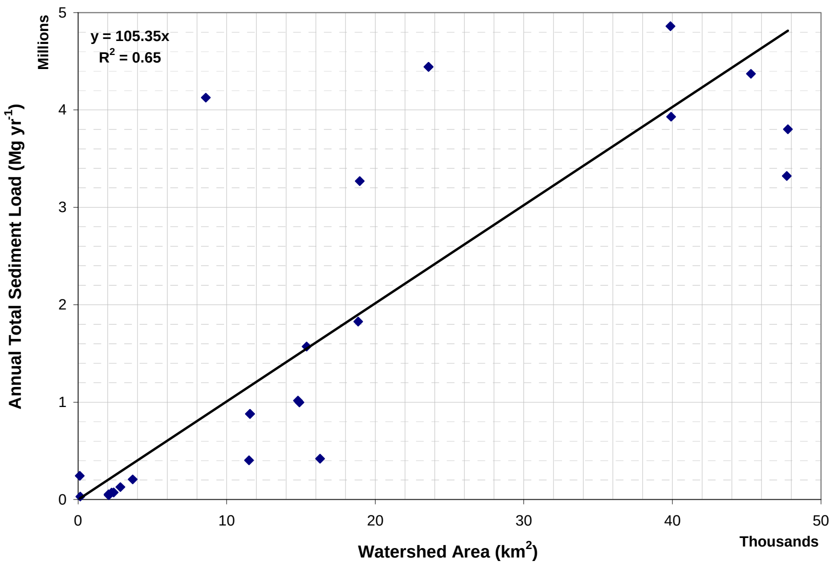

Figure 6. Relation between watershed area and Tier 2 estimated annual suspended sediment load.

Conclusion and Recommendation

From the sediment budget analysis of TRB and the MRB it has been determined that the system is contributing significant amounts of sediment to the impoundments. It was also observed that the system is experiencing an important process of sediment deposition along the lower part of the MRB. Based on sediment contributions from the upstream basin could range between 0.8 and 18.75 millions Mg yr^{-1}, the sediment deposition along the lower part of the MRB is on the order of 0.1 and 2.85 millions Mg yr^{-1}. Since the availability of data is limited for the lower part of the Basin and the Bay, where sediment concentration is different due to changes in morphological and hydrodynamic processes, further analysis is needed and the collection of data would be an initial step to facilitate the process. As discussed in the analysis of sediment trends along the upstream basins and the changes on sediments behavior below the Mobile River diversion, the Tier 2 appears to be a reasonable procedure to determine the loads and the trends of sediment processes along the entire watershed. The authors expect to develop a more detailed analysis along the Alabama River Basin to generate more important insights in the behavior of sedimentation processes along the Mobile River Basin.

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ANNEX

Annex 1.1. Estimation of the Tier 1 suspended sediment load at Q1.5 for USGS stations within the Upper Tombigbee River subbasin (03160101).

	Station	Type	Impound	Elevation (amsl)	Drainage Area (km^2)	$Q_{1.5}$ (cms)	$Qs_{1.5}$ (Mg/d)	SS. $Yield_{1.5}$ (Mg/d/km^2)	Total $Qs_{1.5}$ (Mg/yr)	Dredging (Mg/yr)	Lake Deposition (Mg/yr)
Upper Tombigbee River 03160101	02437100 & 02437500 (Sharp)	Input		47.2	5301.7	702.8	9292.2	1.8	10,173,983		
	MFS	Input				200.0	49.2		41,520		
	02437600 (James NSL Study)	Q,Qs		55.5	112.0	86.8	315.6	155.0	115,188		
	02439400 Buttahatchie River	Q,Qs		67.4	2,258.6	466.1	2178.3	1.1	868,876		
	Before Columbus Lake			49.4	8,600.0				12,553,753		
	02441000 Tibbee Creek	Q,Qs		47.0	2,849.3	598.3	2,902.7	1.2	1,258,712		
	-	Imp	Columbus Lake							100,000	10,153,218
	02441390	Q		30.5	11,500.0	1,717.1	9,751.4	0.9	3,559,247		
	MFS	Q				225.0	943.1		344,249		
	Upper Tombigbee OUTLET	Outlet			11,574.7		10,764.0		3,928,845		

Annex 1.2. Estimation of Tier 1 suspended sediment load at Q1.5 for USGS stations within the Middle Tombigbee River subbasin (03160106).

	Station	Type	Impound	Elevation (amsl)	Drainage Area (km^2)	$Q_{1.5}$ (cms)	$Qs_{1.5}$ (Mg/d)	SS. $Yield_{1.5}$ (Mg/d/km^2)	Total $Qs_{1.5}$ (Mg/yr)	Dredging (Mg/yr)	Lake Deposition (Mg/yr)
Middle Tombigbee River 3160106	Upper Tombigbee Outlet	Input			11,574.7		10,764.0		3,928,845		
	02443500 Luxapallila Creek	Q, Qs		43.4	2,058.6	340.7	1,781.3	0.9	715,489		
	Before Aliceville Lake				14,800.0				5,119,424		
	-	Imp	Aliceville Lake							127,000	407,212
	02444160 & 02444161	Q, Qs		30.5	1,4892.4	1859.0	12,562.2	0.8	4,585,212		
	02444490 Bogue Chito Creek	Q, Qs		47.0	150.0	110.0	484.8	3.2	193,198		
	02444500	Q,Qs		27.4	15,384.5	1328.9	8,536.0	0.6	3,115,640		
	02446500 Sipsey River	Q, Qs		60.3	2,046.5	200.7	968.9	0.7	529,248		
	Before Gainesville Lake				1,8850.0				4,101,360		
		Imp	Gainesville Lake								-1,687,011
	02447025 & 02447026	Q, Qs		19.8	18,958.7	2276.1	15,858.6	0.8	5,788,371		
	02448000 Noxubee River	Q, Qs		43.3	3,681.2	257.7	1,292.1	0.4	471,632		
	Middle Tombigbee OUTLET	Outlet			23,588.1		19,359.2		7,049,007		

Annex 1.3. Estimation of the Tier 1 suspended sediment load at Q1.5 for USGS stations within the Middle Tombigbee River-Chickasaw subbasin (03160106).

	Station	Type	Impound	Elevation (amsl)	Drainage Area (km^2)	$Q_{1.5}$ (cms)	$Qs_{1.5}$ (Mg/d)	SS. $Yield_{1.5}$ (Mg/d/km^2)	Total $Qs_{1.5}$ (Mg/yr)	Dredging (Mg/yr)	Lake Deposition (Mg/yr)
Middle Tombigbee River Chickasaw 03160201	Middle Tombigbee OUTLET	Input			23,588.1		19,359.2		7,049,007		
	02466030 & 02466031 BWR	Input		15.2	16,280.4	1715.4	21,430.3	1.4	3,014,198		
	02467000 (Before Demopolis Lake)				39,868.5				10,063,205		
			Demopolis Lake								-920,821
	02467000	Q, Qs			39,909.0	2953.4	45,020.9	1.1	16,432,614		
	02467500 Sucarnoochee Creek			27.4	2,405.2	161.2	846.5	0.5	472,722		
	2469525 (Before Coffeville Lake)			0.0	45,291.1				18,458,074		
			Coffeeville								-1,512,553
	02469761			0.0	47,700.0	3406.5	54,714.0	1.1	19,970,628		
	Middle Tombigbee-Chickasaw OUTLET	Outlet			47,774.0		54,798.9		20,001,609		

Annex 1.4. Estimation of the Tier 1 suspended sediment load at $Q_{1.5}$ for USGS stations within the Black Warrior River subbasin.

	Station	Elevation (amsl) (m)	Drainage Area (km^2)	$Q_{1.5}$ (cms)	$Qs_{1.5}$ (Mg/d)	SS. $Yield_{1.5}$ ($Mg/d/km^2$)	Total $Qs_{1.5}$ (Mg/yr)
Black Warrior River	02462501	52.9	10,310	1,756	2,349	0.2	857,439
	02465000	25.4	12,484	2,648	20,810	1.7	7,595,739
	02466030 & 02466031	15.2	15,048	1,715	21,430	1.4	7,822,062
	Outlet Lower Black Warrior River	-	16,280	1,715	21,430	1.4	8,642,785

Annex 1.5. Estimation of the Tier 1 suspended sediment load at $Q_{1.5}$ for USGS stations within the Coosawattee River subbasin.

	Station	Elevation (amsl)	Drainage Area (km^2)	$Q_{1.5}$ (cms)	$Qs_{1.5}$ (Mg/d)	SS. $Yield_{1.5}$ ($Mg/d/km^2$)	Total $Qs_{1.5}$ (Mg/yr)
Coosawattee River	02380500	370.6	14,874	132	2,038	0.1	744,005
	02383500	187.8	2,127	330	8,273	3.9	3,019,746
	02387500	184.1	4,101	490	4,358	1.1	1,590,836

Annex 1.6. Estimation of the Tier 1 suspended sediment load at $Q_{1.5}$ for USGS stations within the Alabama River subbasin

	Station	Elevation (amsl)	Drainage Area (km^2)	$Q_{1.5}$ (cms)	$Qs_{1.5}$ (Mg/d)	SS. $Yield_{1.5}$ ($Mg/d/km^2$)	Total $Qs_{1.5}$ (Mg/yr)
Alabama River	02420000	29.8	38,623	2,811	10,460	0.3	3,817,902
	02423000	18.8	43,763	2,990	18,693	0.4	6,822,996
	02428400, 02428401 & 02429500	0.1	56,750	3,341	31,398	0.6	11,831,024
	Outlet Lower Alabama River	0.1	58,726	3,341	31,398	0.6	12,242,934

Annex 1.7. Estimation of the Tier 1 suspended sediment load at $Q_{1.5}$ for the junction of the Tombigbee River and the Alabama River entering to the Mobile River.

	Station	Elevation (amsl)	Drainage Area (km^2)	$Q_{1.5}$ (cms)	$Qs_{1.5}$ (Mg/d)	SS. $Yield_{1.5}$ ($Mg/d/km^2$)	Total $Qs_{1.5}$ (Mg/yr)
Mobile River	Outlet Lower Tombigbee River	0.0	51,954	3,640	54,799	0.0	20,001,609
	2428400, 2428401 & 2429500 Alabama	0.1	58,726	3,341	31,398	0.6	12,242,934
	Entrance to Mobile River	0.0	110,680	-	88,341	0.8	32,244,544

Annex 1.8. Estimation of the Tier 2 annual suspended sediment load, bed load and total load for USGS stations within the Upper Tombigbee River subbasin (03160101).

	Input Station	Type	Impound	Lat	Long	Elevation (amsl)	Drainage Area (km^2)	Qs (Mg/yr)	SS. Yield ($Mg/yr/km^2$)	Total Qs (Mg/yr)	Bed Load (Mg/yr)	Total Load (Mg/yr)	Dredging (Mg/yr)	Lake Deposition (Mg/yr)
Upper Tombigbee River 03160101	02437100 & 02437500 (Sharp)	Input		33.82056	88.54639	47.2	5301.7	2,791,341	526	2,791,341	558,268	3,349,609		
	MFS	Input						14,771		14,771	2,954	17,725		
	02437600 (James NSL Study)	Q,Qs		33.81333	88.56639	55.5	112.0		1,808	202,536	40,507	243,043		
	02439400 Buttahatchie River	Q,Qs		33.79000	88.26528	67.4	2258.6	54,414	26	59,464	11,893	71,356		
	Before Columbus Lake			33.57600	88.49200	49.4	8600.0			3,439,089	687,818	4,126,907		
	02441000 Tibbee Creek	Q,Qs		33.53778	88.63333	47.0	2849.3	89,242	37	106,024	21,205	127,229		
	-	Imp	Columbus Lake										100,000	3,390,262
	2441390	Q		33.51694	88.48944	30.5	11500.0	383,249	63	383,249	19,162	402,412		
	MFS	Q						344,249		344,249	17,212	361,462		
	Upper Tombigbee OUTLET	Outlet					11574.7			732,223	146,445	878,668		

Annex 1.9. Estimation of the Tier 2 annual suspended sediment load, bed load and total load for USGS stations within within the Middle Tombigbee River subbasin (03160106).

	Input Station	Type	Impound	Lat	Long	Elev. (amsl)	Drainage Area (km^2)	Qs (Mg/yr)	SS. Yield (Mg/yr/km^2)	Total Qs (Mg/yr)	Bed Load (Mg/yr)	Total Load (Mg/yr)	Dredging (Mg/yr)	Lake Deposition (Mg/yr)
Middle Tombigbee River 03160106	Upper Tombigbee Outlet	Input					11574.7	10,764		732,223	146,445	878,668		
	02443500 Luxapallila Creek	Q, Qs		33.51417	88.39528	43.4	2058.6	32,470	18	36,096	7,219	43,315		
	Before Aliceville Lake						14800.0			846,914	169,383	1,016,297		
	-	Imp	Aliceville Lake										127,000	-108,421
	02444160 & 02444161	Q, Qs		33.21056	88.28861	30.5	14892.4	950,207	64	950,207	47,510	997,718		
	02444490 Bogue Chito Creek	Q, Qs		33.53778	88.63333	47.0	150.0	22,668	151	24,748	4,950	29,698		
	2444500	Q,Qs		33.08111	88.23722	27.4	15384.5	1,308,452	85	1,308,452	261,690	1,570,142		
	02446500 Sipsey River	Q, Qs		33.25694	88.77639	60.3	2046.5	29,994	22	44,886	8,977	53,863		
	Before Gainesville Lake						18850.0			1,522,825	304,565	1,827,390		
		Imp	Gainesville Lake											-1,443,127
	02447025 & 02447026	Q, Qs		33.85222	88.15417	19.8	18958.7	3,114,778	164	3,114,778	155,739	3,270,517		
	02448000 Noxubee River	Q, Qs		32.10194	88.56167	43.3	3681.2	118,218	32	172,558	34,512	207,070		
	Middle Tombigbee OUTLET	Outlet					23588.1	3,666,768		3,701,669	740,334	4,442,002		

Annex 1.10. Estimation of the Tier 2 annual suspended sediment load, bed load and total load for USGS stations within the Middle Tombigbee River-Chickasaw subbasin (03160201).

	Input Station	Type	Impound	Lat	Long	Elev. (amsl)	Drainage Area (km^2)	Qs (Mg/yr)	SS. Yield (Mg/yr/km^2)	Total Qs (Mg/yr)	Bed Load (Mg/yr)	Total Load (Mg/yr)	Dredging (Mg/yr)	Lake Deposition (Mg/yr)
Middle Tombigbee River Chickasaw 03160201	Middle Tombigbee OUTLET	Input					23588.1	3,666,768		3,701,669	740,334	4,442,002		
	02466030 & 02466031 BWR	Input		32.77778	87.84056	15.2	16280.4	322,418	21	348,827	69,765	418,593		
	Before Demopolis Lake						39868.5			4,050,496	810,099	4,860,595		
			Demopolis Lake											929,839
	2467000						39909.0	3,275,630		3,275,630	655,126	3,930,756		
	02467500 Sucarnoochee Creek			32.57361	88.19333	27.4	2405.2	39,543	25	60,498	12,100	72,597		
	2469525 (Before Coffeville Lake)			32.13000	88.04111	0.0	45291.1			3,642,548	728,510	4,371,057		
			Coffeeville											1,049,152
	02469761 & 02469761			31.75694	88.12500	0.0	47700.0	3,163,719	66	3,163,719	158,186	3,321,905		
	Middle Tombigbee-Chickasaw OUTLET	Outlet					47774.0	3,168,627		3,168,627	633,725	3,802,353		

Annex 1.11. Estimation of the Tier 2 annual suspended sediment load, bed load and total load for USGS stations within the Black Warrior River subbasin.

	Station	Elevation (amsl)	Drainage Area (km^2)	$Q_{1.5}$ (cms)	SS. $Yield_{1.5}$ ($Mg/d/km^2$)	Total Qs (Mg/yr)	Bed Load (Mg/yr)	Total Load (Mg/yr)
Black Warrior River	2462501	52.9	10,310	52,120	5	52,120	10,424	62,545
	2465000	25.4	12,484	291,811	23	291,811	58,362	350,173
	2466030 & 2466031	15.2	15,048	322,418	21	322,418	64,484	386,901

Annex 1.12. Estimation of the Tier 2 annual suspended sediment load, bed load and total load for USGS stations within the Coosawattee subbasin

	Station	Elevation (amsl)	Drainage Area (km^2)	$Q_{1.5}$ (cms)	SS. $Yield_{1.5}$ ($Mg/d/km^2$)	Total Qs (Mg/yr)	Bed Load (Mg/yr)	Total Load (Mg/yr)
Coosawattee River	2380500	370.6	14,874	16,335	1	16,335	3,267	19,602
	2383500	187.8	2,127	14,723	7	14,723	2,945	17,668
	2387500	184.1	4,101	28,543	7	28,543	5,709	34,252

Annex 1.13. Estimation of the Tier 2 annual suspended sediment load, bed load and total load for USGS stations within the Alabama River subbasin

	Station	Elevation (amsl)	Drainage Area (km^2)	$Q_{1.5}$ (cms)	SS. $Yield_{1.5}$ ($Mg/d/km^2$)	Total Qs (Mg/yr)	Bed Load (Mg/yr)	Total Load (Mg/yr)
Alabama River	2420000	29.8	38,623	607,969	16	607,969	121,594	729,562
	2423000	18.8	43,763	208,875	5	208,875	41,775	250,651
	2428400, 2428401 & 2429500	0.1	56,750	1,792,862	33	1,850,891	370,178	2,221,069

Annex 1.14. Estimation of the Tier 1 suspended sediment load at $Q_{1.5}$ for the junction of the Tombigbee River and the Alabama River entering to the Mobile River

	Station	Elevation (amsl)	Drainage Area (km^2)	$Q_{1.5}$ (cms)	SS. $Yield_{1.5}$ ($Mg/d/km^2$)	Total Qs (Mg/yr)	Bed Load (Mg/yr)	Total Load (Mg/yr)
Mobile River			51,954	3,168,627	66	3,168,627	633,725	3,802,353
	2428400, 2428401 & 2429500 Alabama	0.1	58,726	1,792,862	33	1,915,331	383,066	2,298,398
	02470500 Mobile River	0.0	110,680	13,929	0.1	5,083,959	1,016,792	6,100,750

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