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Special Study on Sediment Discharge and Its Consequences (SedSS)

Technical Report Number 12

ANALYSIS AND RESULTS OF DISCHARGE AND SEDIMENT MONITORING ACTIVITIES IN THE SOUTHERN LAKE TANGANYIKA BASIN, ZAMBIA - ANNEX REPORT

by
H M Sichingabula
2000

Pollution Control and Other Measures to Protect Biodiversity in Lake Tanganyika (RAF/92/G32)
Lutte contre la pollution et autres mesures visant à protéger la biodiversité du Lac Tanganyika (RAF/92/G32)

Le Projet sur la diversité biologique du lac Tanganyika a été formulé pour aider les quatre Etats riverains (Burundi, Congo, Tanzanie et Zambie) à élaborer un système efficace et durable pour gérer et conserver la diversité biologique du lac Tanganyika dans un avenir prévisible. Il est financé par le GEF (Fonds pour l'environnement mondial) par le biais du Programme des Nations Unies pour le développement (PNUD)"	The Lake Tanganyika Biodiversity Project has been formulated to help the four riparian states (Burundi, Congo, Tanzania and Zambia) produce an effective and sustainable system for managing and conserving the biodiversity of Lake Tanganyika into the foreseeable future. It is funded by the Global Environmental Facility through the United Nations Development Programme.

Burundi: Institut National pour Environnement et Conservation de la Nature
D R Congo: Ministrie Environnement et Conservation de la Nature
Tanzania: Vice President's Office, Division of Environment
Zambia: Environmental Council of Zambia

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June 2000 Lusaka

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Many thanks also go gauge readers whose efforts made the smooth conclusion of this study possible and include, Messrs Edward Chifunda, Abraham Mbao, Alfred Mpondela, John Kapembwa, Daniel Matebele and Miss Prisca Chakumanda; Drs. Graeme Patterson, Andy Menz, Kelly West are specifically thanked for their trust in me to get the work done and for all the support given to the Study Team; Messrs Olivier Drieu, Clement Mwela, O. C. Mwansa, Sunday Ng'ambi, Happy Sikazwe, James Siakavuba, Lucy Muwowo, John Chama, John Chipasha, Robert Sinyinza, L. Mwape, for their friendship and assistance in the field and office; Ms Irene Mubanga and Mr. John Chalo for typing most of the Annex data.

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Henry M. Sichingabula

INTRODUCTION

1.1 Introduction

This report documents the data collected by the Zambia Special Sediment Study Group for the Lake Tanganyika Biodiversity Project in the period September 1998 to December 1999 as an annex to the Final Report (Sichingabula, 1999a). It also updates in summary form measured cross-sectional water levels (gauge heights), discharge and suspended and total dissolved sediment concentrations and sediment load plus rating curves for discharge and sediment loads on account of increased data collected between June and December 1999. Locations of studied stations are repeated in order that they are not forgotten as one reads this Annex Report. These are shown in Figure 1 while site characteristics are given in Table 1.

Methodological matters of the study are not included herein because they were adequately covered in the Final Report plus numerous Quarterly Reports prepared during the course of the project. However, in cases where updating of data not previously presented the approaches used in the generation and compilation of the data are briefly discussed. In conclusion the reports makes a number of recommendations aimed at ensuring that the efforts of the project participants do not go to waste and the investments made by the project continue to be utilised not only to the benefit of the Zambian people but many others too. The most important updates made are those of discharge and sediment rating curves and estimated values.

1.2 Terms of Reference

The Terms of Reference for the extension of the project activities from July to December, 1999 were varied. In rephrased form they included the following:

1. To conduct low level intensive measurement of discharge during the dry season;

2. To find ways of having the project stations operational after termination of project activities;

3. To compile and document all water level, discharge, sediment and other related data into the annex report; and

4. To come up with project proposals for possible funding by international agencies in later phases of the project.

Figure 1. Location map of sediment monitoring stations in South Lake Tanganyika basin, Zambia

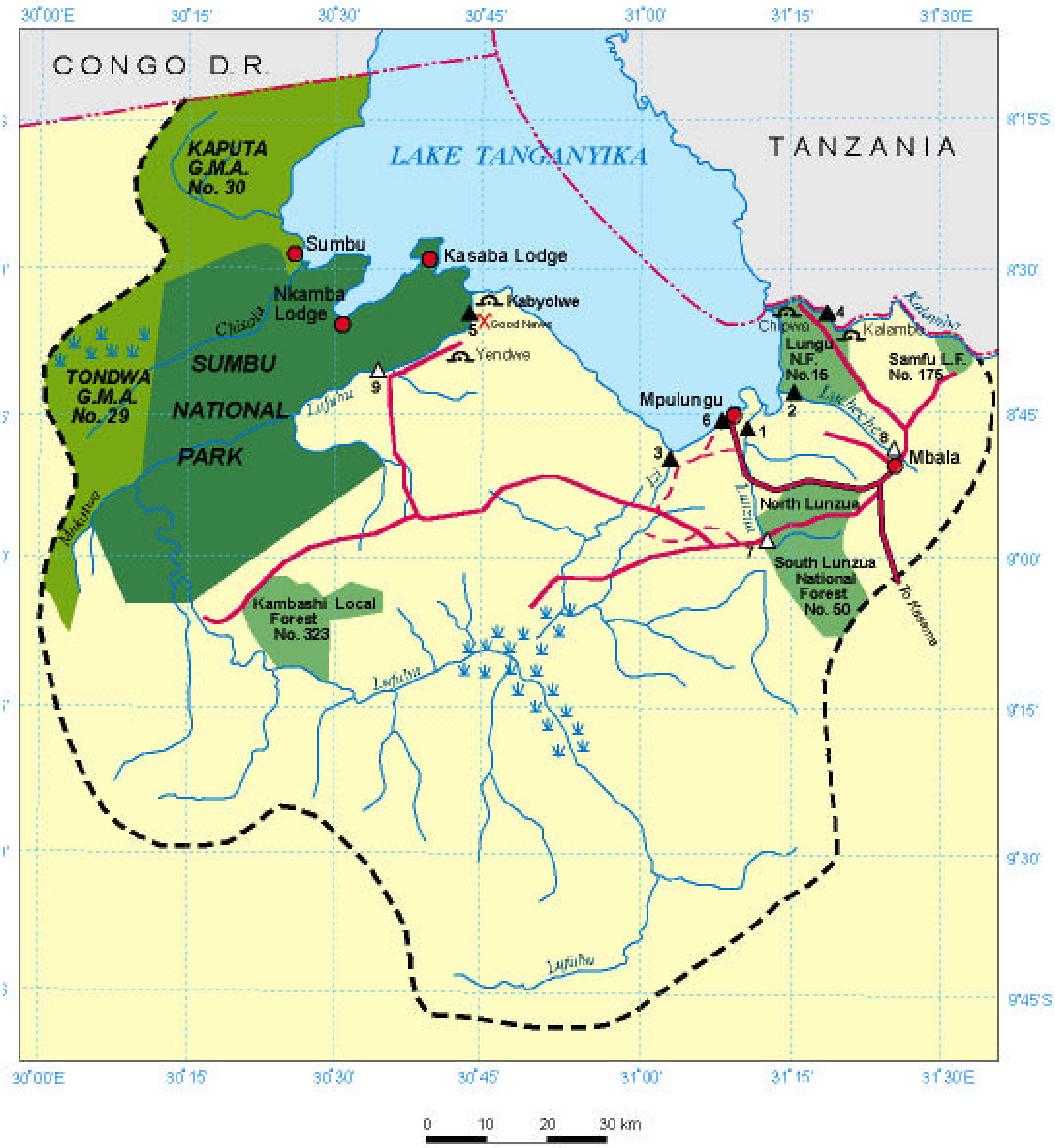


Table 1. Locations and sizes of studied catchments in the southern Lake Tanganyika basin, Zambia.

No.	Station No.	River and Station	Location Latitude	Longitude	Elevation** (masl)	Area (km^2)
A. LTBP STATIONS						
1.	7-022	Lucheche R. near Kawe Village	08º 48' 50"	31º 08' 49"	830	312.0
2.	7-030	Kalambo R. at Kalambo Village	08º 35' 55"	31º 15' 22"	1171	2,575.0*
3.	7-015	Izi R. at Mbete Village	08º 48' 51"	31º 02' 29"	830	54.4
4.	7-008	Lunzua R. at Simumbele Village	08º 46' 23"	31º 08' 49"	905	686.0
5.	7-775	Lufubu R. near Kabyolwe Village	08º 35' 51"	30o 44' 09"	758	7,047.0
B. WATER AFFAIRS STATIONS						
6.	7-750	Lufubu R. at Keso Falls	08º 46' 23"	31º 08' 49"	905	686.0
7.	7-005	Lunzua R. at Kambole R/B	08º 46' 23"	31º 08' 49"	905	686.0
8.	7-010	Lake Tanganyika at Mpulungu Fisheries	08º 45' 49"	31º 06' 34"	795	-

* Area determined by GIS mapping by A. Mills at NRI, University of Greenwich, UK.
** Elevations determined by GPS surveys.

2.0 DISCHARGE AND SEDIMENT RATING CURVES UPDATE

The discharge and sediment rating curves used for estimating daily discharge and daily suspended sediment loads in the Final Report were updated and applied to the observed water level and estimated discharge data for the period June to December, 1999.

Discharge rating curves constructed included simple linear, second degree polynomials and log-log power functions. Graphical presentation of these models are illustrated together with some statistics. The statistics given include r^2, the coefficient of determination, n, the number of observed values, SE, standard error of estimate in the units of the dependent variable and p as the level at which the regression equations were significant.

For sediment rating curves it was found that the relationship between discharge and sediment load was stronger than that of discharge and sediment concentration. Consequently, only the discharge-sediment load relationships were discussed. The updated and now new rating equations for the southern Lake Tanganyika streams, applied only to the water level and discharge data for the period June to December 1999, are discussed below for each river in the order given in the Final Report (Sichingabula, 1999a).

2.1. Lucheche River

For Lucheche River the discharge rating curve changed from simple linear to polynomial with a reduction in the r^2 value as indicated in Equation 1 below and illustrated in Figure 2a.

$$Q(m^3\,s^{-1}) = 16.271 - 49.32Gh + 37.477Gh^2 \quad r^2 = 0.971 \quad n = 25 \quad (1)$$

The suspended sediment load (SSL) rating equation remained unchanged as polynomial again with a slight decrease in the r^2 value owing to increased low flow values in the dry season between May and October. The updated sediment rating equation given as Equation 2 below is also illustrated in Figure 2b.

$$SSL\ (td^{-1}) = 0.23 - 0.179Q + 0.415Q^2 \quad r^2 = 0.838 \quad n = 25 \quad (2)$$

2.2 Kalambo River

The updated discharge rating curve for Kalambo River changed from a second degree polynomial to a power function with a lowered r^2 value as shown in Equation 3 and illustrated in Figure 3a.

$$Q(m^3\,s^{-1}) = 14.354\,Gh^{4.144} \quad r^2 = 0.945 \quad n = 25 \quad (3)$$

For suspended sediment load, the rating curve remained unchanged as a power function, Equation (4) illustrated in Figure 3b.

$$SSL\ (td^{-1}) = 0.45079Q^{1.3126} \quad r^2 = 0.928 \quad n = 25 \quad (4)$$

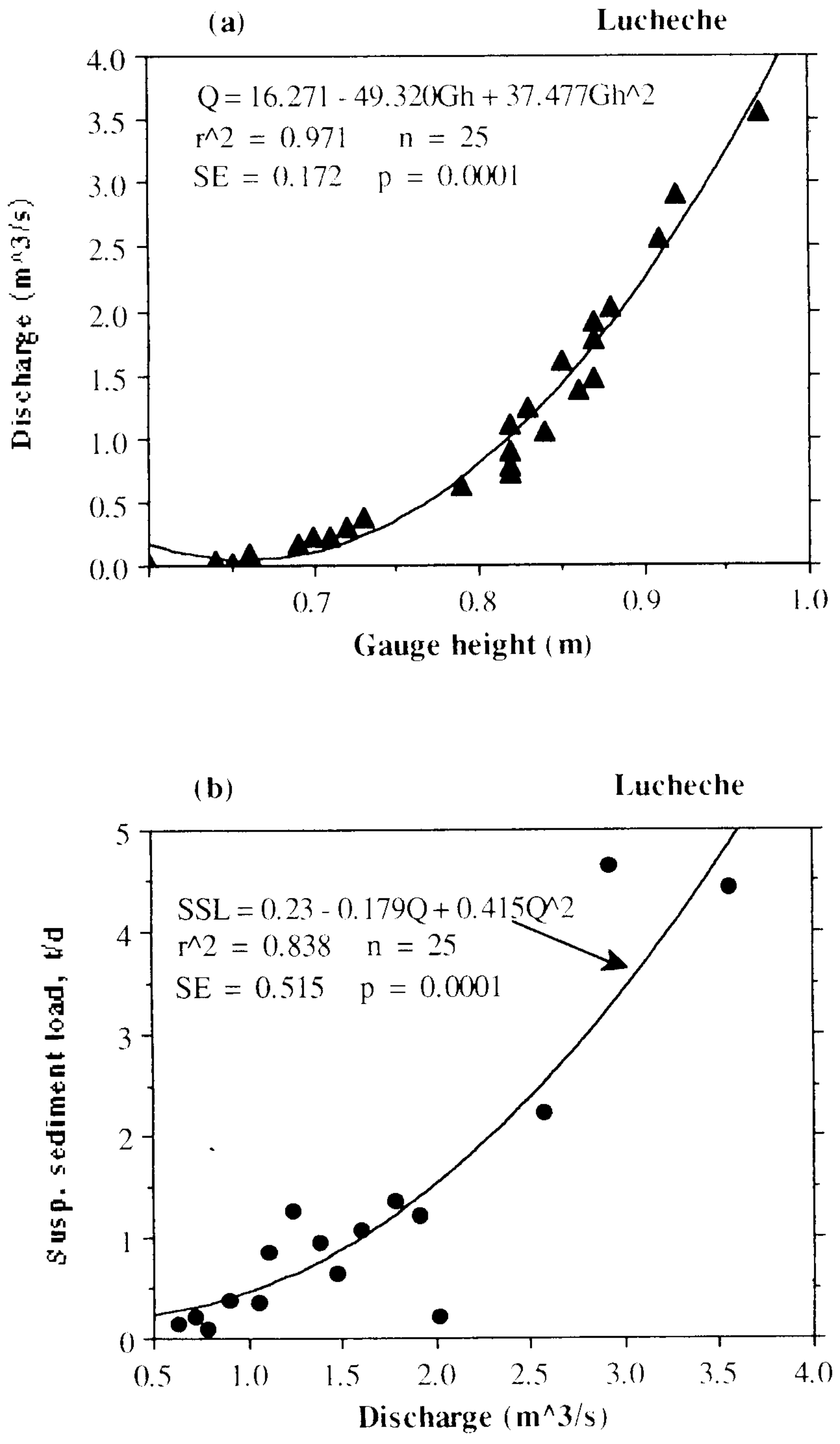


Figure 2. Rating curves for Lucheche River at Kawe Village (a) discharge, (b) sediment load, September 1998 - December, 1999.

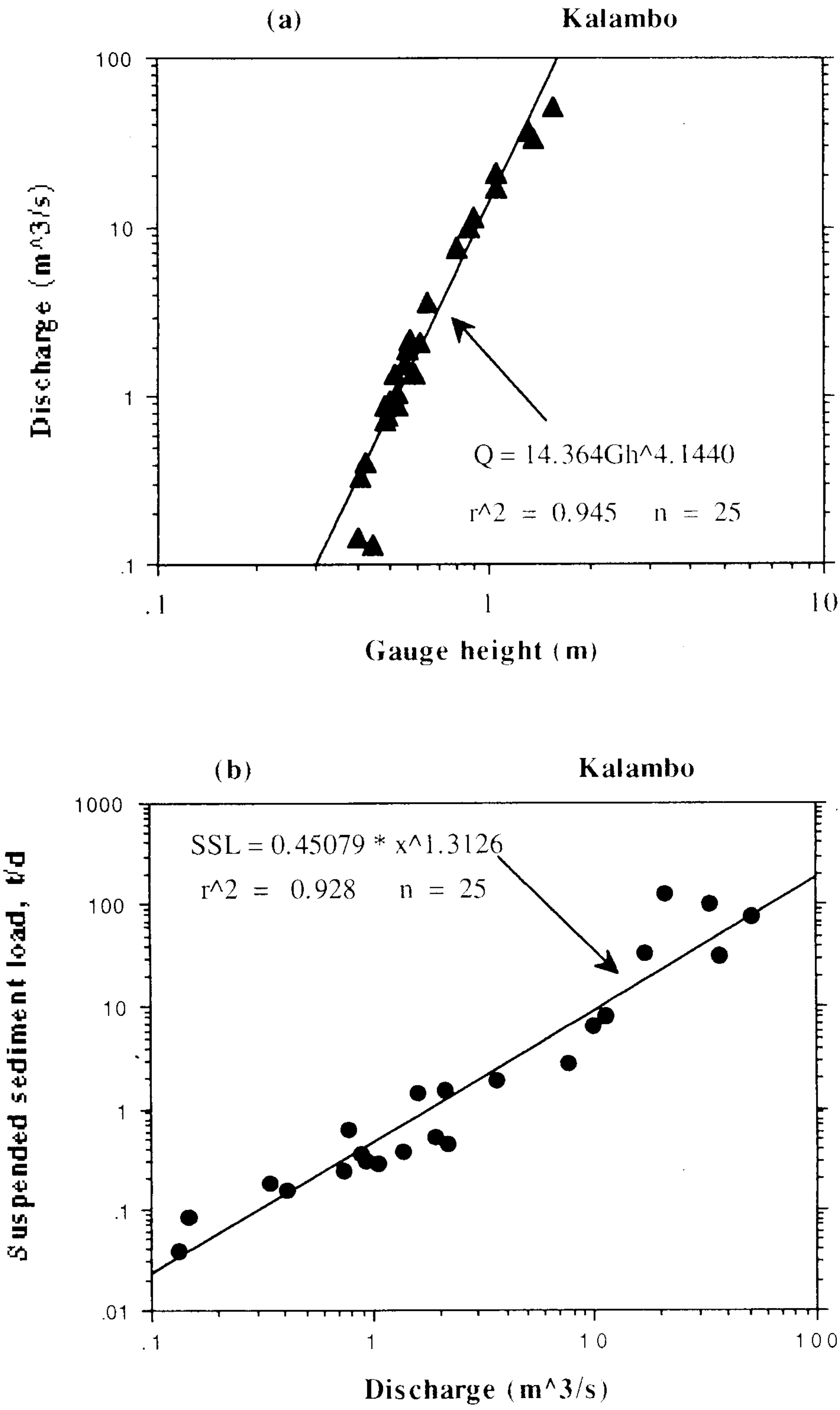


Figure 3. Rating curves for Kalambo River at Kalambo Village (a) discharge, (b) sediment load, September 1998 - December, 1999.

2.3 Izi River

The discharge rating curve for Izi River did not change with increased low flow measurements such that the second degree polynomial (Equation 4) still best described the relationship between water level or gauge height and discharge as illustrated in Figure 4a.

$Q(m^3 s^{-1}) = 2.423 - 6.413Gh + 5.435Gh^2$ $\quad r^2 = 0.969 \quad n = 26 \quad (5)$

Similarly, the sediment rating curve remained unchanged as a simple linear equation (Equation 6), graphically demonstrated in Figure 4b.

$SSL\ (td^{-1}) = 1.126Q - 0.384 \quad r^2 = 0.928 \quad n = 26 \quad (6)$

2.4 Lunzua River

The updated discharge rating curve for Lunzua River applied to the period June to December 2000 is a simple regression equation as was used in the earlier period. It is given in Equation (7) below and illustrated in Figure 5a.

$Q(m^3 s^{-1}) = 33.52\ Gh^2 - 19.101 \quad r^2 = 0.98 \quad n = 26 \quad (7)$

But the sediment rating equation changed from simple linear to second degree polynomial shown as Equation 8 and illustrated in Figure 5b.

$SSL(td^{-1}) = -1.7 + 0.295Q + 0.179Q2 \quad r^2 = 0.451 \quad n = 26 \quad (8)$

2.5 Lufubu River

For the largest river in the Lake Tanganyika basin, Lufubu, the discharge rating curve after inclusion of more low flow measurements remained a second degree polynomial (Equation 9) and illustrated in Figure 6a. But there was an increase in the r^2 value indicating that scatter around the regression line decreased.

$Q(m^3 s^{-1}) = 7006.178 - 2939.657Gh + 308.812Gh^2 \quad r^2 = 0.904 \ n = 41 \quad (9)$

Similarly the updated sediment rating curve was also a polynomial (Equation 10) as illustrated in Figure 6b.

$SSL(td^{-1}) = -2.508 + 0.206Q + 0.012Q^2 \quad r^2 = 0.95 \quad n = 41 \quad (10)$

In future, as more field data become available the above discharge and sediment rating equations will be revised so that they become more representative of mass flux conditions on these rivers. If these data are applied to the observed water level (Gh) values for the entire period up to December 1999, it will be noticed that the estimated values up to May 1999 will be lower than those given in the Annexes 1a.1 to 3e.2. The figures up to May 1999 were not revised largely not to cause confusion when comparing it to or using the data given in the Appendices of the Final Report (Sichingabula, 1999a). Those interested in updating all the data generated by the project should be free to apply the new rating equations, but note the differences in calculated summary values of different variables discussed below.

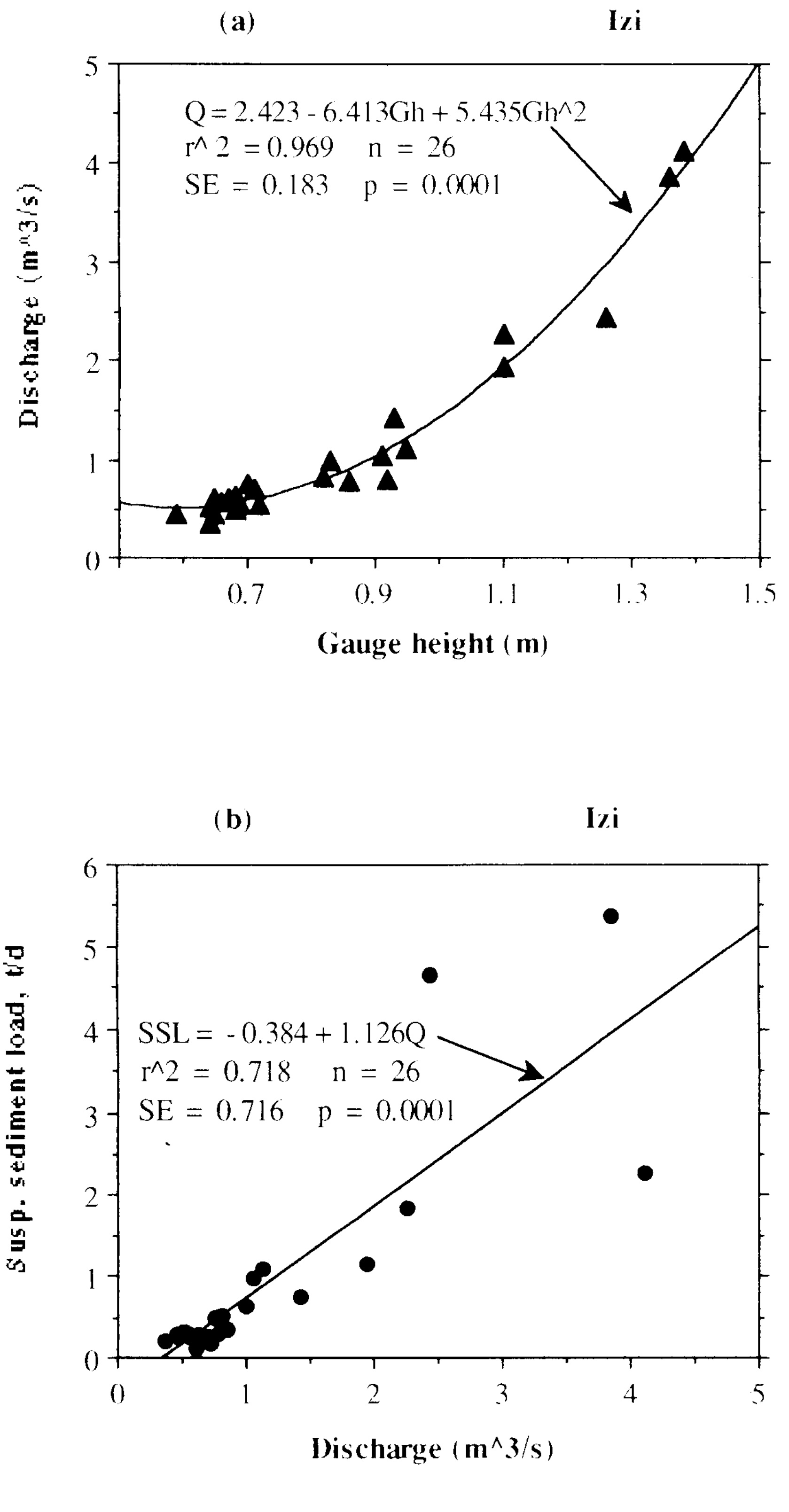
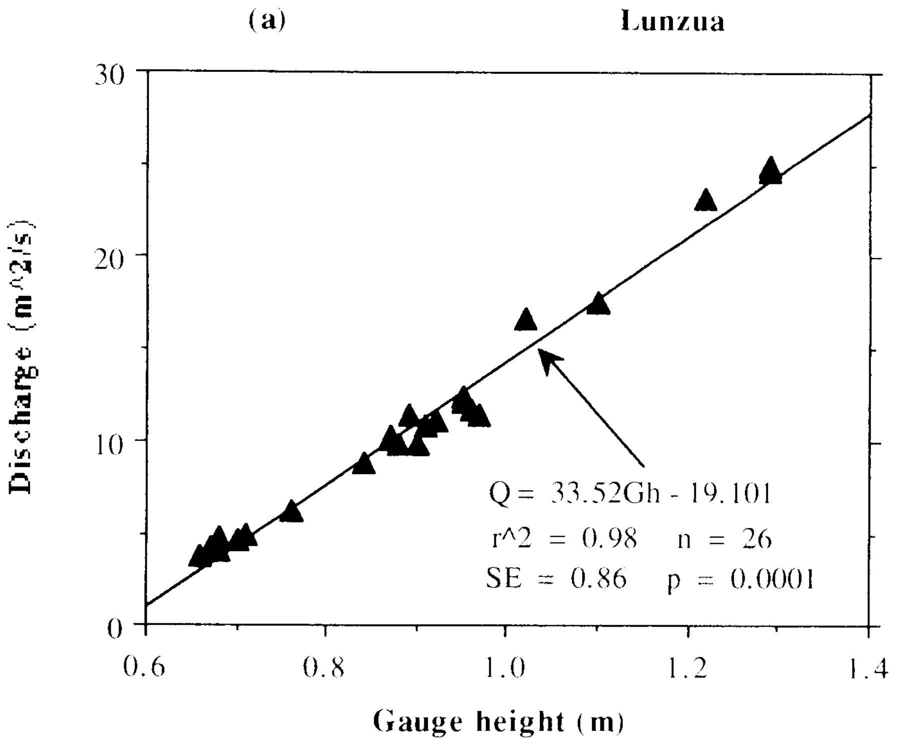


Figure 4. Rating curves for Izi River at Mbete Village (a) discharge, (b) sediment load, September 1998 - December, 1999.



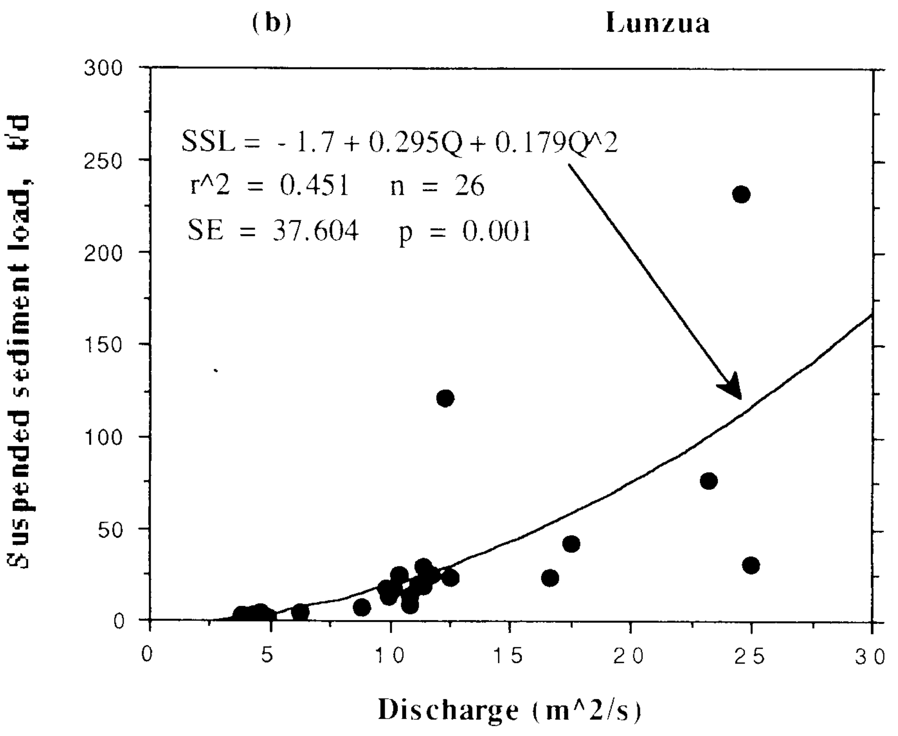
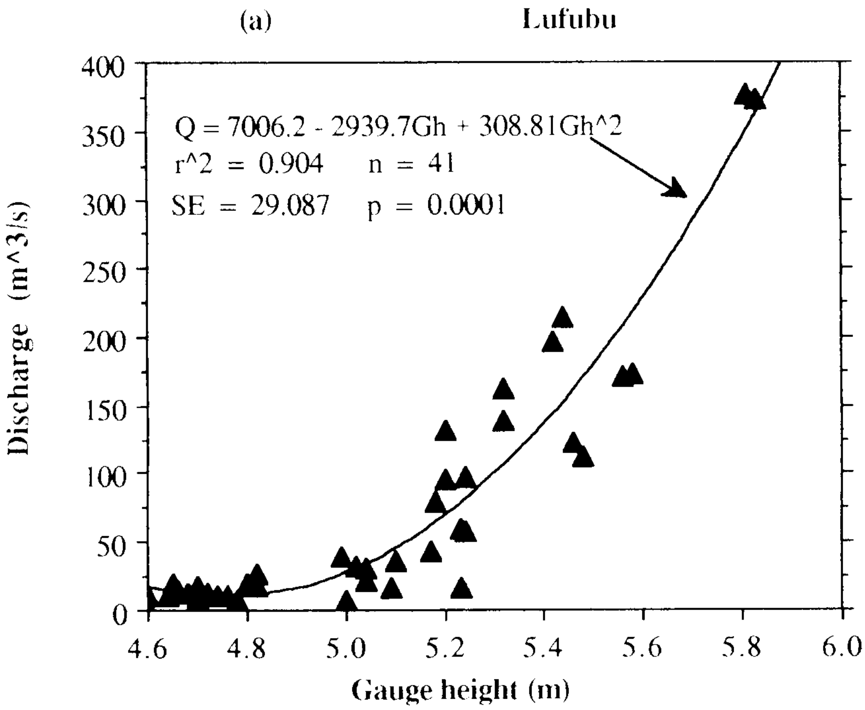


Figure 5. Rating curves for Lunzua River at Simumbele Village (a) discharge, (b) sediment load, September 1998 - December, 1999.



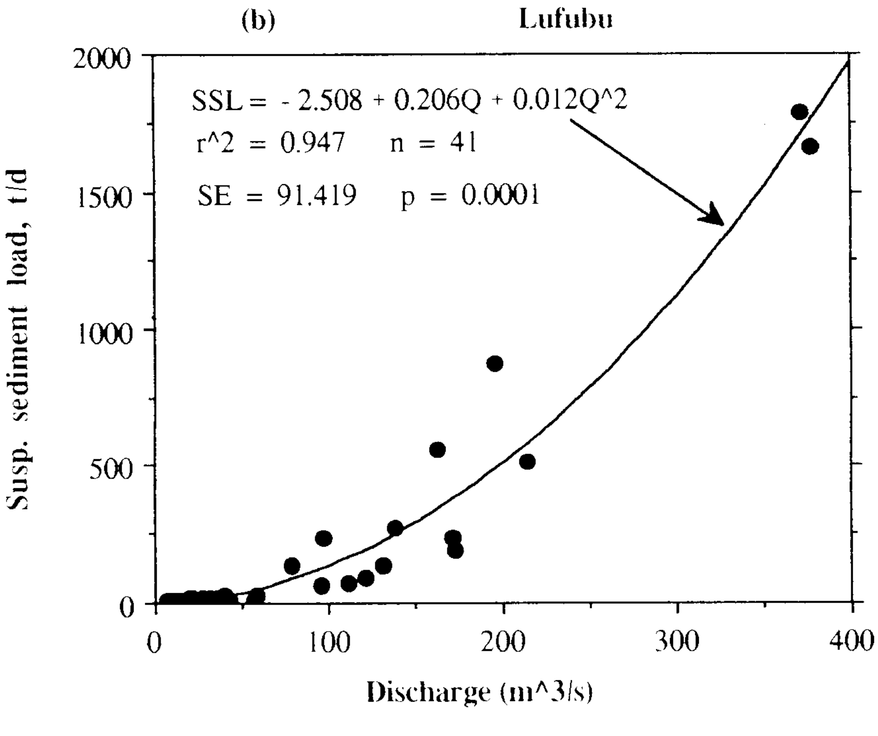


Figure 6. Rating curves for Lufubu River near Kabyolwe Village (a) discharge, (b) sediment load, September 1998 - December, 1999.

The new equations tend to produce low estimates of sediment loads because they are more representative of average annual estimates of sediment transport than the equations in the Final Report which were largely based on more moderate and high flows. The low estimates of sediment transport may be consistent with results of workers in the whole Lake Tanganyika basin covering all the five riparian countries.

2.6 Lake Tanganyika at Mpulungu

Lake Tanganyika water levels monitored at Mpulungu Fisheries Department harbour (7-010) in the period October 1998 to December 1999 are given in Annexes 1f.1 and 1f.2. Variations of lake water levels at Mpulungu were however not re-assessed.

3.0 RE-ANALYSIS OF COMPILED DATA AND RESULTS

Summary statistics of all the data sets given (Annexes 1a.1 to 3a.2) were determined and tabulated. Tables 2 and 3 show that generally there were minor variations in the summaries given as min, mean and max values. This was attributed to the fact that in the period June to November the rivers are at low stages such that discharge and sediment fluxes are also very low. In some years the small rivers could even be dry. However, in the month of December once the rainy season has set in earnest, the discharge and especially sediment load increase dramatically for some isolated events. For instance on 15th December 1999 the water level on Lunzua River reached 1.96 m giving an estimated discharge value of 46.595 $m^3 s^{-1}$ which yielded the highest recorded sediment load of 400 tonnes on that day.

3.1 Variations in Lake Water Levels

Water levels of Lake Tanganyika in Mpulungu were not re-analysed to include the data for the dry season in 1999. Instead a long supplemental data record for the whole lake supplied by NASA at Goddard Centre through Dr. Charon Birkett, were used to illustrate variations in water level changes in the period September 1993 to September, 1999 (Figure 7). More of this type of data, though its supply is usually late by about four months, will continue to be received from NASA in coming months.

3.2 Magnitude-Frequency Analysis of Suspended Sediment Transport

The other type of analysis conducted to the overall data set is the determination of the effective discharge (Q_{eff}) for suspended sediment transport. The effective discharge is the flow which transports the most load in a given period of time (Wolman and Miller, 1960; Pickup and Warner, 1976). This is a useful concept which has application to scheduling of sediment dredging programmes where sedimentation is a problem and helps in the utilisation of resources in the most economical and efficient manner.

Sichingabula (1999a) determined the class-based effective discharges for the southern Lake Tanganyika basin streams for the period from September 1998 to May 1999. In the current report similar analyses were conducted in order to update the record owing to increased discharge measurements up to December 1999. The results of analysis based on twelve discharge classes used in the Final Report, are given in Table 4. The findings were that in a majority of cases the (Q_{eff}) did not change much.

Further to the above analysis, it was decided to determine the event-based effective discharge (Event-based Q_{eff}) (Sichingabula, 1999a), determined as the individual discharge values multiplied by their frequency of occurrence (duration) to assess which transports the most load in a given period of time. This analysis was necessitated by the criticisms levelled against the class-based approach (Sichingabula, 1993; 1999b).

Table 2. Summary data of water levels, discharge and sediment loads on rivers in southern Lake Tanganyika basin, Zambia.

					Water Level (m)			Discharge ($m^3\ s^{-1}$)			Susp. Sed. Load (td^{-1})		
No.	Station No.	River	Period	Days	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
1.	7-022	Lucheche	18.09.98-31.12.99	471	0.60	0.79	1.18	0.045	0.976	7.335	0.149	0.866	22.472
2.	7-030	Kalambo	01.10.98-31.12.99	457	0.38	0.74	2.14	0.251	10.477	114.219	0.074	21.155	384.896
3.	7.015	Izi	18.09.98-31.12.99	470	0.57	0.83	1.48	0.531	1.091	4.930	0.147	0.819	5.235
4.	7.008	Lunzua	20.09.98-31.12.99	468	0.64	0.88	1.96	2.353	10.382	46.598	0.250	19.072	400.726
5.	7.775	Lufubu	16.09.98-31.12.99	472	4.59	5.07	5.81	10.349	64.855	346.680	0.909	121.635	1539.634

Table 3. Specific sediment yields by rivers in the southern Lake Tanganyika basin, Zambia.

No.	Station No.	River	Period of study	No. of Days	Drainage area (km^2)	Total Discharge (million m^3)	Total sed. load (t)	Sed. load (t/km^2)
1.	7-022	Lucheche	18.09.98 - 31.12.99	471	312.0	39.7	408.0	1.3
2.	7-030	Kalambo	01.10.98 - 31.12.99	457	2,575.0†	413.7	9,668.0	3.8
3.	7.015	Izi	18.09.98 - 31.12.99	470	54.4	44.3	384.8	7.1
4.	7.008	Lunzua	20.09.98 - 31.12.99	468	686.0	419.8	8,925.6	13.0
5.	7.775	Lufubu	16.09.98 - 31.12.99	472	7,047.0	2.6 billion	57,411.7	8.1

† Estimate based on GIS mapping of the catchment by A. Mills at NRI, University of Greenwich, UK.

Table 4. Magnitude and frequency characteristics of class-based and event-based effective discharges for suspended sediment transport on rivers in the southern Lake Tanganyika basin, Zambia.

No.	Station No.	River	Drainage Area (km^2)	Period of record	Class-based Qeff (m^3s^{-1})	(% Freq)	Event-based Qeff (m^3s^{-1})
1.	7-022	Lucheche	312.0	18.09.98-31.12.99	1.57	1.6	10.26
2.	7-030	Kalambo	2,575.0*	01.10.98-31.12.99	109.50	1.1	114.25
3.	7-015	Izi	54.4	18.09.98-31.12.99	0.71	6.3	4.93
4.	7-008	Lunzua	686.0	20.09.98-31.12.99	16.70	3.1	46.55
5.	7-775	Lufubu	7,047.0	16.09.98-31.12.99	248.00	2.3	346.00

* Estimate based on GIS mapping of the catchment by A. Mills at NRI, University of Greenwich, UK.

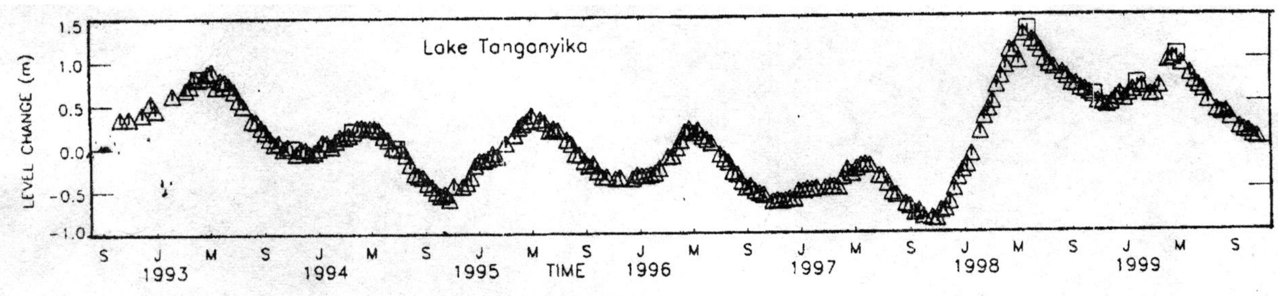


Figure 7. TOPEX/POISEDON altimetrically derived variations in mean water level change on Lake Tanganyika, September 1993 to September 1999 (NASA, Goddard Center).

The results of the event-based Qeff analysis are also given in Table 4 and illustrated in Figures 7.1 and 7.2. This analysis revealed major changes in the effective discharge values on three out of five rivers. These were cases in which the Qeff changed from being a low flow event of high frequency to the highest flow event of low frequency. This was observed to be the case on the small rivers, namely, Lucheche, Izi and Lunzua. On these rivers the highest recorded discharges were the event-based effective discharges showing that they transported the most load compared to all other discharge events in the period of study. On large rivers, the class-based and event-based effective discharges are usually coincident or are not very different from each other.

This could be said to be the case on the two large rivers studied in northern Zambia, Kalambo and Lufubu (Table 4), where both effective discharges were high flow events. This observations is consistent with findings made on Canadian rivers in the Fraser River basin by Sichingabula (1993) which later led him to suggest that that the class-based Qeff approach should be discarded (Sichingabula, 1999b). But the results of this study suggest that perhaps more research is required on the usefulness and applicability of the event-based effective discharge concept in different physiographic settings and on a variety of catchment scales before completely doing away with the Wolman and Miller's (1960) approach.

3.3 Retrodiction of Suspended Sediment Load

It is generally the case almost every where that discharge records on most rivers in the world are much longer than those for sediment. This is because discharge is much easier to determine than suspended or dissolved load. Consequently, many countries including Zambia, started monitoring water levels and discharges long before monitoring sediment transport. In northern Zambia, long water level and discharge data are available on Lufubu River at Keso Falls and on Lunzua River at Kambole Road Bridge stations (Figure 1). In the Final Report (Sichingabula, 1999a: Appendices 4 and 5), historical discharge data for these rivers were provided but without any sediment data. In the Annex Report herein, an attempt was made for the first time, to estimate the sediment load transported by these two rivers based on archival discharge record and physical understanding of sediment transport processes. These considerations are discussed below.

3.3.1 Lufubu River at Keso Falls Station

Lufubu River at Keso Falls station (7-750) is located upstream of Kabyolwe station and Yendwe Village (Figure 1). After cascading down the rocky escarpment, at Keso Falls, Lufubu River flows on bed rock and is armoured in places due to lag deposits such that only minimal sediment is recruited in the reach. In Yendwe Village area and downstream reaches the character of the river changes owing to variations in bed and bank materials. Here the river flows on sandy alluvium and moderately meanders due to moderate gradient. It is believed that Yendwe area is a major zone of sediment recruitment by Lufubu River evidenced by bank caving and collapse observed in 1997 near Yendwe (Sichingabula,1999a: 22, Figure 7a).

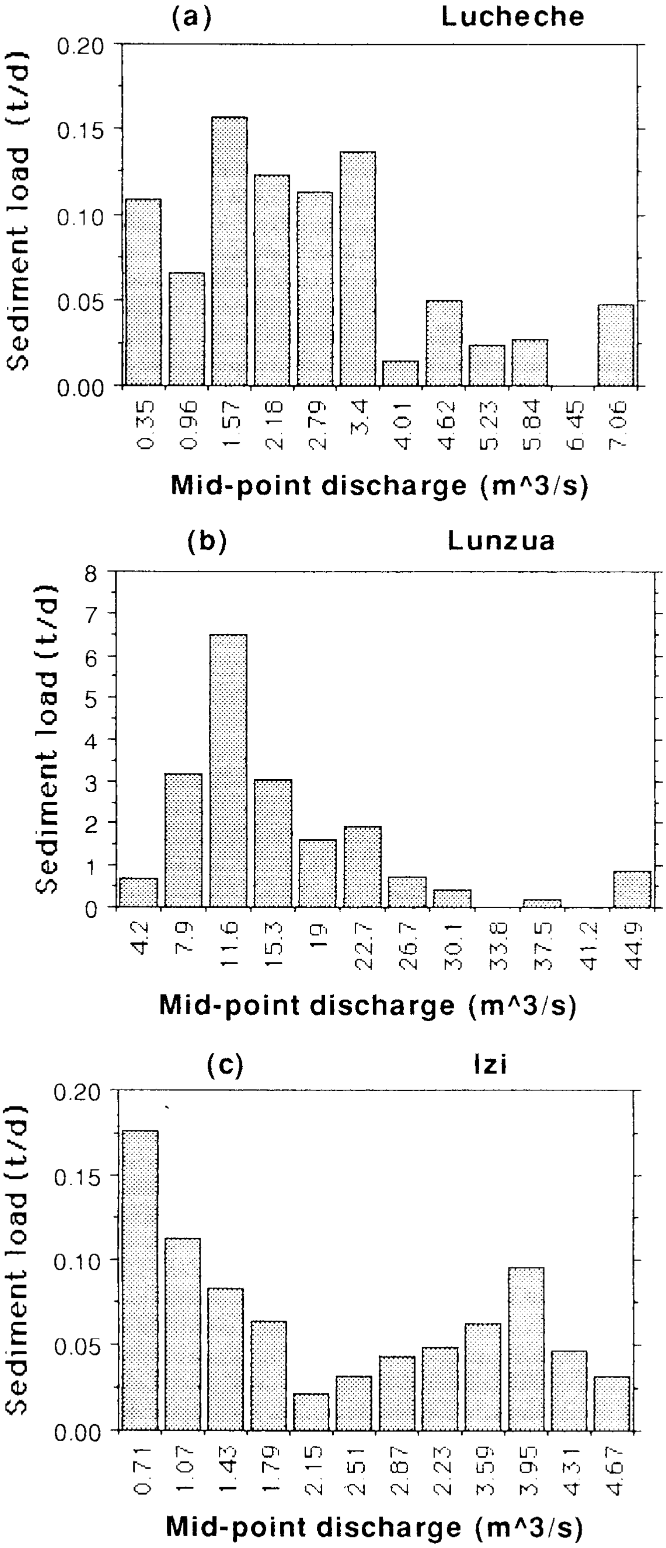


Figure 7.1. Sediment-discharge regimes for (a) Lucheche River at Kawe Village, (b) Lunzua River at Simumbele Village and (c) Izi River at Mbete Village, September 1998 - December, 1999.

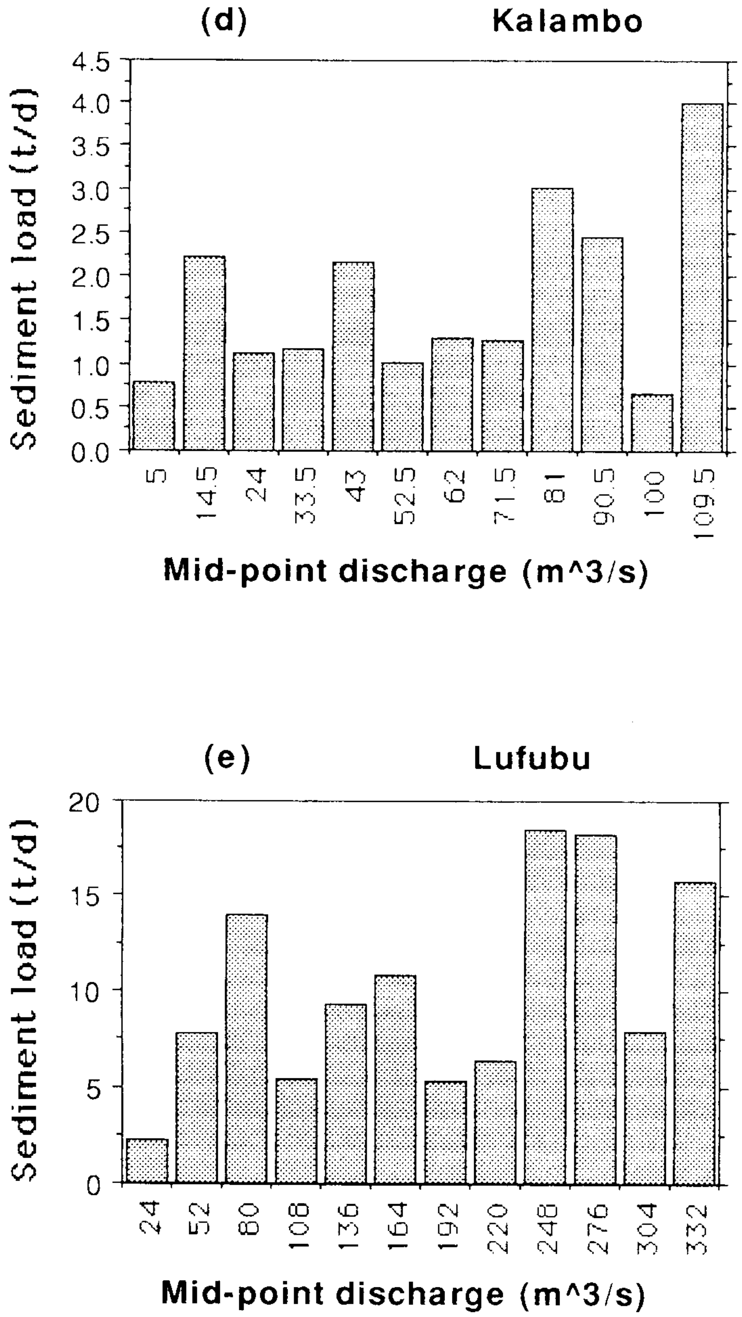


Figure 7.2. Sediment-discharge regimes for (d) Kalambo River at Kalambo Village, (e) Lufubu River near Kabyolwe Village, September 1998 - December, 1999.

At Keso Falls, clay, silt and fine sand compose 11.4% while the medium-and-sand coarse fraction makes 98.4% of bed material load (Sichingabula, 1999a: 54; Figure 8a). At Yendwe below Keso Falls (Figure 8b), bed material composition was found to be 65.3% for clay-silt-fine sand fraction and 87.5% for medium-coarse sand component. Below Yendwe Village the composition of finer grain sizes decreased slightly, clay-silt-fine sand content was found to be 44.9% while the medium-to-coarse sand fraction reduced from 98.4% at Keso Falls to 54.7% (Sichingabula, 1999b: Table 6). This indicates that large quantities of sediment are recruited in the reach below Keso Falls and also that a considerable amount is lost by deposition. Above Keso Falls most of the sediment comes from the plateau above the escarpment where chitemene cultivation is widespread largely because this area is far from towns where chemical fertilisers are easily accessible (Figure 8c). Further downstream of Yendwe Village the character of the river does not change much except near the Kabyolwe Village station where the banks are more stable due to increased clay and silt content.

On the basis of the above understanding, an appropriate approach to estimate sediment load for Lufubu River at Keso Falls, using historical discharge record shown in Annex 4a, was devised. This is because there were neither discharge nor sediment concentration data for Keso Falls station in the period of project measurement on Lufubu River at Kabyolwe station between September 1998 and December 1999. The basic assumption of the approach used to estimate sediment load at Keso Falls station based on Kabyolwe station was that, sediment load like discharge increases proportionately with drainage area provided the two stations are located within a climatically homogeneous region.

The estimation of suspended sediment load for Lufubu River at Keso Falls was and can be done in three steps: (i) apply the sediment rating equation for Kabyolwe station (Equation (10)) to the historical discharge data at Keso Falls shown in Annex 4a; (ii) multiply the obtained sediment load by 0.181; and (iii) subtract value in (ii) from (i). The 0.181 is the correction factor for variation in catchment areas between the two stations combined with 20% estimated loss of sediment load between Yendwe and Kabyolwe Village station. This is evidenced by the high medium-coarse sand component making 98.8% of the bed material load and 37.9% for clay-fine sand fraction at Kabyolwe station (Sichingabula, 1998: 13). Medium-coarse sand component of sediment by its size for most part moves as bed load implying that large quantities of it are deposited during below moderate flows. It is only very high flows which are capable of flushing it out of the system onto the lake, but this happens in a just a few days per year. For most of time, the medium-coarse load remain resident on the bed. Conversely, most of the clay-silt-fine-sand component, which is not capacity load, composes only 0.9% of the bed material load as it is transported through the system onto the lake where it settles to the bottom from suspension in the still waters. The results of this approach for estimating suspended sediment load are given in Annex 4b.

By any standard, the estimated sediment load of Lufubu River at Keso Falls are believed to be within acceptable limits considering the physical factors taken into account for their estimation. However, empirical data are required to validate the generated data and this assertion.

3.3.2 Lunzua River at Kambole Road Bridge Station

This station is located on the plateau above the escarpment before the river issues into the Mwanzandolo Falls once exploited by the Zambia Electricity Corporation (ZESCO) for hydroelectric power generation on Lunzua River downstream of the Falls. The catchment area at Kambole station (7-005) is 362.7 km^2, but within a distance of 15 km going down to Simumbele

Village station the catchment area increases by more than two times to 686 km^2 because of the Mwambezi River which joins on the right bank immediately upstream of Simumbele Village station. There is neither discharge nor sediment data on this tributary. Its discharge and sediment inputs into Lake Tanganyika are incorporated in the measurements of Lunzua River at Simumbele Village.

To estimate the sediment load of Lunzua River at Kambole Road Bridge station, when there is no overlap in the data records at both stations, the approach of proportion of areas between Kambole Road Bridge and Simumbele Village stations was used on assumption that in a climatically homogeneous region, discharge increases proportionately with area, and that most of the sediment is derived from catchment slopes. Therefore sediment load at Kambole Road Bridge could be determined, using sediment data at Simumbele Village station, as a proportional percentage of the area at Simumbele Village station adjusted for storage and minimal recruitment (<5%) of sediment between the two stations.

Unfortunately, this approach produced negative values, attributed to the very large catchment area at Simumbele Village caused by the joining of the Mwambezi tributary whose discharge and sediment contributions were unknown and therefore could not be subtracted to get realistic values of the contributions of Lunzua River main channel monitored at Kambole Road Bridge. Consequently, no estimates of sediment loads associated with historical discharge data given in Annex 5 were calculated. Estimation of sediment loads will only be possible if simultaneous measurements of discharge and sediment concentrations are made at Kambole Road Bridge and Simumbele Village stations. Measuring of discharge and sediment concentration on Mwambezi River could greatly assist in assessment of major sediment sources in the Lunzua catchment. This is something to be considered by future investigations.

3.4 Summaries of Measured Cross-sectional Data

Campaigns of field data measurements conducted by the Water Affairs staff based at Kasama, Northern Province, on a weekly basis in the rainy season and bi-weekly basis in the dry season, ranged from 26 on Lunzua at Simumbele to 41 on Lufubu River at Kabyolwe station. Occasionally intensive measurements of high and low flows were also conducted by a combined team of the Team Leader, Water Affairs staff from Lusaka and Kasama were also made in 1999. A compilation of these data is given in Annexes 6a to 6e. These summary data were used in the determination of discharge and sediment load rating equations for each of the five stations. Some cross-sectional variables data were not utilised in the analyses conducted for the Final and Annex reports.

The other type of data not analysed is the total dissolved solids (TDS), and water temperature at time of analysis, monitored by the study team at all the five discharge and sediment stations in the southern Lake Tanganyika basin. These data are given together with summaries of cross-sectional discharge measurements in Annexes 6a to 6e. These data were not analysed largely because sampling for TDS concentrations commenced late in the study period. In future, with increased measurements TDS measurements will be combined with SS loads to obtain the total suspended sediment load (TSS) transported by the studied rivers onto Lake Tanganyika. Thus, the assessment of the importance of chemical or solute load to the total sediment load transported by different rivers in Tanganyika basin is left for future investigations.

3.5 Miscellaneous Data

Short duration intensive cross-sectional data for Lunzua River at Simumbele Village are available from field work campaigns conducted by Mr. Ian Donohue working in one of the sedimentation study groups. The data were collected in a period of one week with measurements taken an regular intervals on each day (Annex 7). These data were not incorporated in the data compilation by the Zambia Special Sediment Study Group. Their inclusion here is to allow others conduct independent analysis and interpretation of this data set. Generally, these data indicate that sediment concentrations on Lunzua River are highly variable within a matter of hours on any given day. This suggests the need for calculation of daily mean SS concentrations to be based on more than one sample observation per day, especially during rainy season.

4.0 CONCLUSION

By and large, the objectives of the Lake Tanganyika Biodiversity Project Zambia Special Sediment Study were achieved as evidenced by the reported results. Almost all the Terms of Reference for the last quarter of this study were achieved. Firstly, intensive measurement of discharge were made in and as reported in the October 1999 Report to Dr. Graeme Patterson. Secondly, a letter was written together with Olivier Drieu to the Director of Water Affairs requesting for continuation of monitoring activities in the southern Lake Tanganyika basin. There seems not to be a decision made on this request by the Zambian Government through Water Affairs. Thirdly, compilation of all data collected by the Zambia Special Sediment Study Group has been done in this Annex Report. Lastly, the preparation of research project proposal(s) for future investigation under the project is still underway.

Finally, it is concluded that more investigations in future should help to affirm the finding reported in the Final and Annex reports, which were based on limited discharge and sediment data. Consideration should also be given to the need for continued monitoring of the studied parameters in order to build a long-term database necessary for future development and management planning of Lake Tanganyika.

5.0 RECOMMENDATIONS

The Zambia Special Sediment Study came to an end with termination of monitoring activities on 31 December, 1999 and the closing of the LTBP Mpulungu office in May, 2000. It is wished that other projects will commence in order not to lose the international collaboration enjoyed by all who participated in the project and so that what has been gained in this short time is not lost. Therefore, the following recommendations and proposals are made for consideration and implementation by project managers, regional and Zambian government, as well as the international community, in particular NGOs and funding agencies.

1. Monitoring of daily water levels at project stations in the southern Lake Tanganyika basin, upon which estimates of discharge and sediment loads are based, should commence as soon as possible, to permit long-term assessment of pollution, discharge and sediment flux into Lake Tanganyika.

2. A local study team supported by outside technocrats should be put in place for the purposes of smooth continuation of some research and monitoring activities initiated by the project. This would help to lay a good foundation for any future projects designed along the lines of LTBP. This would require involvement of institutions which participated in this project.

3. The project, to a certain extent, provided some measure of development to the area by way of employment to local people. It would be good if the project stations were kept open so that the gauge readers continue earning an income albeit small. The Government of the Republic of Zambia through Water Affairs should source funding in order to keep the stations operational. This would ensure that the long-term record of discharge and sediment data, required for water resources development in the region, is maintained.

4. The Department of Fisheries Department in Mpulungu which plays a major role in the protection of resources in the lake should be supported materially and financially so that it continues to perform its mandated functions. Without the presence of this office in the region the natural resources of the Lake Tanganyika would be greatly abused to the detriment of national and regional development.

6. The international community and funding agencies should continue to support scientific research and the building-up of databases for not only Lake Tanganyika, but other Great Lakes of Africa as whole, for the sake of common humanity and global nature of environmental problems experienced in Africa. This would partly help in the preservation and promotion of Lake Tanganyika's rich biodiversity.

6.0 REFERENCES

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