

OVERSEAS DEVELOPMENT ADMINISTRATION



HYDROMETRY PROJECT-SOMALIA

Final Report-Stage 1

ARCHIVE

SIR M MACDONALD & PARTNERS LIMITED
Consulting Engineers
Demeter House, Cambridge CB1 2RS
United Kingdom

in association with

INSTITUTE OF HYDROLOGY
Wallingford, Oxon OX10 8BB
United Kingdom

FEBRUARY 1985

OVERSEAS DEVELOPMENT ADMINISTRATION

HYDROMETRY PROJECT-SOMALIA

Final Report-Stage 1

ARCHIVE

SIR M MACDONALD & PARTNERS LIMITED
Consulting Engineers
Demeter House, Cambridge CB1 2RS
United Kingdom

in association with

INSTITUTE OF HYDROLOGY
Wallingford, Oxon OX10 8BB
United Kingdom

FEBRUARY 1985

CONTENTS

	Page Nr
SUMMARY	S-1
CHAPTER 1 INTRODUCTION	
1.1 Background to Project	1-1
1.2 Scope of Project/Project Organisation	1-1
1.3 The Hydrological System in Southern Somalia	1-2
1.4 Historical Development of the Hydrometric Network in Somalia	1-3
1.5 The State of the Hydrometric System from 1982	1-6
1.6 Implementation of Progress Report Recommendations	1-7
1.7 Extension of the Project Period	1-8
1.8 State of River Flows in 1983/84	1-8
CHAPTER 2 PROJECT ACTIVITIES, GENERAL AND OFFICEWORK	
2.1 General Responsibilities	2-1
2.2 Staff Training and Attitudes	2-1
2.3 The Microcomputer System	2-2
2.3.1 Hardware	2-2
2.3.2 Software	2-2
2.4 Data Processing Procedures	2-4
2.4.1 The Revision of Current Data Handling Procedures	2-4
2.4.2 Determining Staff-gauge Zeros	2-5
2.4.3 Stage-discharge Rating Development	2-6
2.5 Availability and Quality of Records	2-10
CHAPTER 3 PROJECT ACTIVITIES, FIELDWORK	
3.1 General Approach to Fieldwork	3-1
3.2 The State of the Network - Rehabilitation and Maintenance	3-2
3.2.1 The River Shebelli Network	3-2
3.2.2 The River Juba Network	3-4
3.3 Inspection of Potential New Stations	3-6
3.4 Current-Meter Gauging Network	3-7
3.5 Performance of Other Field Equipment	3-8
CHAPTER 4 CONCLUSIONS AND FURTHER WORK	
4.1 Concluding Remarks	4-1
4.2 Proposed Project Extension	4-1

CONTENTS (cont.)

Page Nr

REFERENCES

APPENDIX I INSTITUTE OF HYDROLOGY REOPORTS

- 1 Hydrometry for Somalia. Report and Recommendations
- 2 Computer System and Hydrological Database Version MG1.1

APPENDIX II OPERATIONAL EXPERIENCE OF COMPUTER SOFTWARE

- | | | |
|------|-----------------------------|------|
| II.1 | Introduction | II-1 |
| II.2 | General Software Structure | II-1 |
| II.3 | Data Display During Editing | II-2 |
| II.4 | Use of CON Command | II-2 |
| II.5 | Discharge Measurement Lists | II-2 |

APPENDIX III NEW AUTOMATIC WATER-LEVEL RECORDING FACILITIES

- | | | |
|-------|---|-------|
| III.1 | Progress | III-1 |
| III.2 | Proposed Operation of New Automatic Recorders | III-2 |

APPENDIX IV STATION DETAILS - COMPUTER PRINTOUT

- | | | |
|----|---|-------|
| 1 | Surface Water Data Base - Station Summary | IV-1 |
| 2 | Station Details - Lugh Ganana | IV-2 |
| 3 | Station Details - Bardheere | IV-2 |
| 4 | Station Details - Jamamme | IV-3 |
| 5 | Station Details - Beled Weyn | IV-3 |
| 6 | Station Details - Bulu Burti | IV-4 |
| 7 | Station Details - Maheddey Weyn | IV-4 |
| 8 | Station Details - Balcad | IV-5 |
| 9 | Station Details - Afgoi | IV-5 |
| 10 | Station Details - Audegle | IV-6 |
| 11 | Station Details - Kurton Warey | IV-6 |
| 12 | Discharge Measurements - Lugh Ganana | IV-7 |
| 13 | Discharge Measurements - Bardheere | IV-10 |
| 14 | Discharge Measurements - Jamamme | IV-11 |
| 15 | Discharge Measurements - Beled Weyn | IV-12 |
| 16 | Discharge Measurements - Bulu Burti | IV-14 |
| 17 | Discharge Measurements - Maheddey Weyn | IV-16 |
| 18 | Discharge Measurements - Afgoi | IV-18 |
| 19 | Discharge Measurements - Audegle | IV-19 |
| 20 | Rating Equation - Lugh Ganana | IV-20 |
| 21 | Rating Equation - Bardheere | IV-24 |
| 22 | Rating Equation - Jamamme | IV-24 |
| 23 | Rating Equation - Beled Weyn | IV-24 |

CONTENTS (cont.)

		Page Nr	
APPENDIX IV (cont.)			
	24	Rating Equation - Bulo Burti	IV-25
	25	Rating Equation - Maheddey Weyn	IV-25
	26	Rating Equation - Afgoi	IV-25
	27	Rating Equation - Audegle	IV-25

LIST OF TABLES

Table Nr	Title	Page Nr
1.1	The Hydrometric Network of River Flow Gauging Stations	1-4
2.1	Discharge Measurements Taken During the Project	2-12

LIST OF FIGURES

Figure Nr		Following Page Nr
1.1	Location Map	1-2
1.2	Annual River Discharge Hydrographs (River Juba)	1-8
1.3	Annual River Discharge Hydrographs (Rivers Juba and Shebelli)	1-8
1.4	Annual River Discharge Hydrographs (River Shebelli)	1-8
1.5	Annual River Discharge Hydrographs (River Shebelli)	1-8
2.1	Example of Station Summary Sheet	2-3
2.2	Example of Monthly Summary of Daily River Stage and Flow Data Sheet	2-3
2.3	Example of Annual Summary of Flow Data Sheet	2-3
2.4	Example of Discharge Measurement Sheet	2-3
2.5	Example of Stage-Discharge Rating Sheet	2-3
2.6	Example of Current-Meter Discharge Computation Sheet	2-3
2.7	Data Returns for 1984	2-4
2.8	Data Returns for 1982/1983	2-4
2.9	Rating Curve - River Juba at Lugh Ganana	2-8
2.10	Rating Curve - River Juba at Bardheere	2-8
2.11	Rating Curve - River Juba at Jamamme	2-8
2.12	Rating Curve - River Shebelli at Belet Weyn	2-8
2.13	Rating Curve - River Shebelli at Bulo Burti	2-8
2.14	Rating Curve - River Shebelli at Mahaddei Weyn	2-8
2.15	Rating Curve - River Shebelli at Afgoi	2-8
2.16	Rating Curve - River Shebelli at Audegle	2-8
2.17	Availability of Stage and River Flow Data	2-10
4.1	Proposed Extension Programme of Work	4-1

SUMMARY

This report describes work carried out on the project in 1984, following the preliminary visit made by the MMP hydrologist in November/December 1983.

As a result of this initial trip, recommendations were made (MMP, 1984) for the programme of work during the project. Suggestions were made for the improvement of field and office practices and the purchase of new equipment. Particular emphasis was placed on the importance of improving automatic water-level recording facilities as a means of improving the quality of data collected.

In 1984 the project continues with four separate short period inputs by the MMP hydrologist from February to December, a total of eight months spent in Somalia, inclusive of the initial trip.

The hydrologist's main duty was the day-to-day running of the hydrology section. This included the supervision and training of staff in fieldwork and routine office practices, and the operation of the computer data processing system introduced into the section as part of the project.

Records of staff-gauge readings at eight currently operated flow gauging stations, some from as early as 1951, were entered into the computer and in total 194 station years of data were examined and stored on archive files on computer disk. New ratings were established for all these stations and the complete set of stage data was reprocessed to produce daily, monthly and annual flow statistics on formatted printouts.

Data collection practices by observers were improved and manual office procedures for handling incoming data revised to interact with the computer based system. Considerable fieldwork was carried out during the project, including many discharge measurements by current-meter and the rehabilitation of gauging station installations.

Most of the equipment supplied for the project performed satisfactorily, although failures of uninterruptible power supply units and flow gauging suspension cables did cause problems.

The IOH programmer was responsible for the development of the computer system, spending one month in the UK designing and writing programs for the Comart computer purchased for the project, followed by two months in Somalia completing the software and training counterpart staff in its use.

The original objectives of the project could not be fully achieved during the original time scale and, following a request made by the Somalia Government to the ODA, it is anticipated that the work will be continued into 1985/86 and the scope of the project activities expanded. During this extension period further development of the computer system will be undertaken and the recommended new automatic water-level recording facilities will be installed. Among the new topics to be introduced will be the analysis and modelling of hydrological systems on computer, including the applications of flood and drought forecasting techniques. An investigation into the water resources of the northern region of Somalia is also proposed.

CHAPTER 1

INTRODUCTION

1.1 Background to Project

The project was concerned with the operation of the hydrometric network of river level and flow gauging stations on the two main perennial watercourses of Southern Somalia, the Juba and Shebelle rivers. The project was initiated following a request by the Somali Government for assistance to bridge the gap between the end of a FAO funded project (FAO/TCP/SOM 8906 + 0104) in 1980/81 and the proposed establishment of the national 'Water Centre', part of a UNDP 'IPF' country programme originally scheduled for 1985. A joint proposal (April 1983) by Sir M. MacDonald & Partners (MMP), and the Institute of Hydrology (IOH) was accepted by the Overseas Development Administration (ODA), and the project commenced in November 1983.

1.2 Scope of Project/Project Organisation

The main objective in providing this bridging assistance was to ensure continuity of hydrological records in the future, and to achieve this, expert personnel and some new equipment were provided for the project. An MMP hydrologist was based in the Hydrology section, within the Department of Land and Water Resources of the Ministry of Agriculture in Mogadishu, spending 8 months in Somalia on four separate trips during 1983/84. These trips covered the following periods:

- | | | | |
|-----|---------------------------|---|----------|
| (1) | November/December, 1983 | - | 1 month |
| (2) | February to April, 1984 | - | 2 months |
| (3) | May to July, 1984 | - | 2 months |
| (4) | October to December, 1984 | - | 3 months |

The overall function of the MMP hydrologist was the management of the Hydrology section and the training of the counterpart staff provided.

An hydrologist/programmer from IOH was the other principal participant on the project, being responsible for developing a computer system to aid hydrological data processing in Somalia. After an initial one month input designing and developing software in the UK, the IOH programmer was based in Mogadishu for a further 2 months for the completion, implementation and full testing of the computer system; the initial training of counterpart staff in basic computer operation techniques was also undertaken.

Additional intermittent support was provided by:

- (i) The MMP Resident Representative in Mogadishu who provided local back-up and liaison, particularly during the MMP hydrologist's absences from Somalia.
- (ii) The MMP Associate Hydrologist who had overall responsibility for managing the project from MMP head office in Cambridge.
- (iii) An MMP draughtsman who assisted in the preparation of drawings and graphs for this and the Progress Report.

This report describes all the major activities and achievements of the project, but concentrates on the work of the MMP hydrologist. Full details of the computer hardware and software system have already been provided in IOH reports (IOH, 1984a and IOH 1984b) which are reproduced in Appendix I. The system is also briefly outlined in Chapter 2, and some operational experiences and suggested enhancements to the software are described in Appendix II.

The main work which occupied the Hydrology section during the project can be conveniently summarised under two distinct categories of activities, which are described in more detail in Chapters 2 and 3.

(i) Office Work

- The processing and quality control (validation) of all incoming field data.
- The operation of a microcomputer database system specially introduced for the project, and the training of staff in its use for the storage and processing of incoming field data.
- The examination and preparation of all historic data available for archiving on the database on computer disk.
- The establishment of stage/discharge rating curves for all stations for the entire period of records with particular emphasis placed on changing ratings due to shifting river bed profiles.
- The improvement of manual office data processing procedures to operate in parallel with the computerised system.
- The provision of information and data reports for internal management and external agencies, consulting engineers, etc.

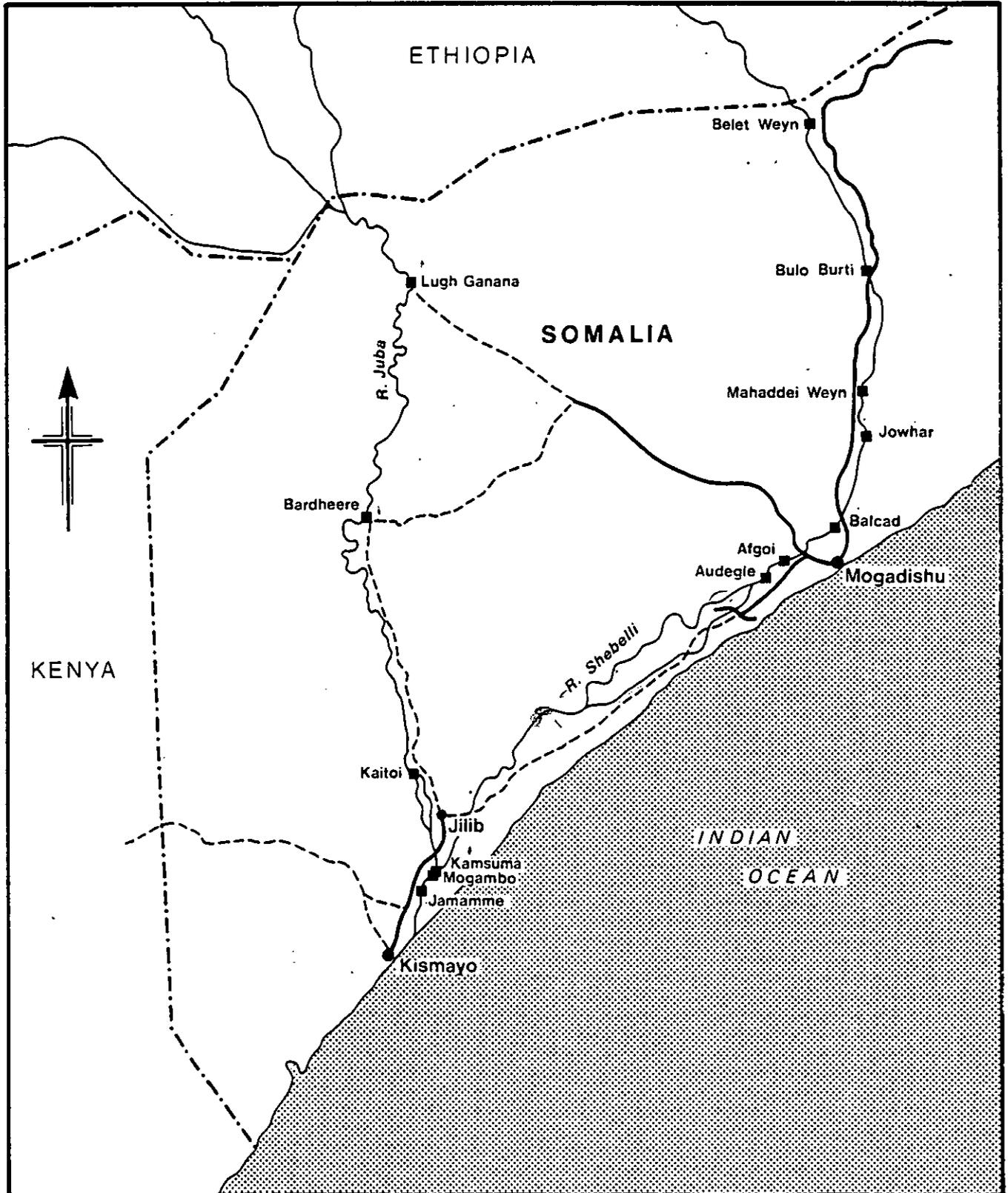
(ii) Fieldwork

- The rehabilitation and maintenance of the existing stations.
- The direct measurement of river flows by current meter gauging methods to check for possible shifting rating curves.
- Checking by levelling of staff-gauge zeros and datum points.
- Improving the quality and continuity of daily staff-gauge readings by full-time MOA observers.

1.3 The Hydrological System in Southern Somalia

The Juba and Shebelle rivers are the main perennial watercourses in the southern region of the country. Figure 1.1 is a location map of the area showing the rivers and their catchments. The climate is hot and semi-arid to arid, and within the rivers' catchment area in Somalia, the rainfall varies from 100 mm in the north to 500 mm in the southern coastal strip near Mogadishu. The temporal and spatial distribution of this rainfall is such that little of it reaches the river directly as a result of surface runoff in Somalia, the major component of runoff being generated from the Ethiopian highlands to the north, during the 'gu' and 'der' flood seasons.

Figure 1.1
Location Map



- Surfaced road
- - - Unsurfaced road
- Gauging station

0 100 200 km

The Shebelli is, in fact, a tributary of the Juba, although only major flood events ever reach the confluence of the two rivers downstream of Jilib. A large area of swamps in the lower Shebelli downstream of Kurten Warey, with enormous natural storage capacity, absorbs most of the runoff. Abstractions of river water take place throughout the length of the lower Shebelli, for water supply and irrigation. Other losses occur due to recharge through the river bed into the unconfined aquifer which supplies water to Mogadishu, and the combined effect causes a marked reduction in both flood and baseflows, even before natural storage in the swamps swallows the remaining flow. The flows of the river Juba are also under pressure due to increasing abstractions for water supply and irrigation during the critical minimum flow period in March and April before the gu flood arrives.

The accurate measurement of the river flows of the Juba and Shebelli is, therefore, of the greatest importance for the effective management of scarce water resources.

1.4 Historical Development of the Hydrometric Network in Somalia

River level stage readings have been taken since as early as 1925 at one location, Jowhar on the Shebelli river. The records are believed to be held in store in the SNAI offices at Jowhar, although access to them could not be arranged. Fairly regular observations of river stage have been recorded at two stations since 1951 :

- (i) Lugh Ganana in the north on the Juba river near the top of the Somali catchment of the river near the Ethiopian border.
- (ii) Belet Weyn on the Shebelli river in a similar location to the east.

Daily records are available for this period, although they are not the originals and there is unfortunately no register of any details of the station. In view of this, the quality of the data must be regarded as suspect. Most other stations have records available from 1963 onwards.

River level observations at these flow gauging stations have normally been facilitated with the use of staff-gauges covering the normal range of water level variation. The gauges were read by full-time observers generally 2 or 3 times per day and the readings received on monthly data sheets. Each staff-gauge consisted of a series of 1 m or 2 m long plates graduated in 1 or 2 cm divisions. These staff gauges are either secured in continuing series on a bridge pillar or abutment, or may also be mounted on RSJs set in concrete on the river bank, in which case the normal practice is to have a series of 1 or 2 m long staffs in level sequence up the river bank. The zero datum of the staff-gauge is known as the gauge-zero and should be the lowest level at which the river normally stops flowing. In practice, with shifting bed profiles, this 'no flow' stage of the river varies considerably from season to season.

Original staff-gauge readings are only available from early 1963, at the start of the FAO funded Lockwood study into the Water Resources of Somalia (Lockwood Survey Corporation Ltd., 1966). Some documentation of hydrometric work carried out during that project is still available, since proper records of station datums and local Bench Marks were kept. However, many of the original station details have been lost and none has been kept fully up to date over the years. During the Lockwood project automatic water level recording installations were

constructed on the river banks at many stations. These consisted of large diameter stilling wells lined by concrete ring pipes with two small diameter inlet pipes entering horizontally from the river at different levels. The datum points for measuring water levels within these wells have been designated MP points, and each MP has a datum value assigned to it, as metres above mean sea level (m AMSL) surveyed from local national bench marks. These bench marks have had different values assigned to them at various times, causing considerable confusion over values of station datum points when historical records have been examined or reprocessed. Datum points were also established on bridges, from which dippings of river levels were also taken in substitution for, or as a check on, staff gauge readings; these are designated MB datum points. Direct measurements of river discharge were taken using current meter by winch suspension from bridges where possible, or from boats or convenient ferries. The network of stations established by the Lockwood study has continued in operation, although not without interruption, to the present day with little change. The same stilling wells exist, the same MBs are still in use in many places and some of the original staff gauges are still being read. The current network of stations is listed in Table 1.1 and, except for Balcad which is not now operated, the original gauges set up are still regarded as the primary stations of the existing network, and are the ones on which efforts have been concentrated during this project. The location of each of these stations is indicated in Figure 1.1. All these primary stations have original records existing from early 1963 up to the present day.

TABLE 1.1

The Hydrometric Network of River Flow Gauging Stations

Primary Network (currently operated by MOA Hydrology section):

Location	Staff-gauge range (m)	Current datums (m AMSL)	
		Gauge zero	MB (bridge)
River Juba:			
Lugh Ganana	0-7	141.42	151.01
Bardheere	0-7	88.98	96.97
Jamamme (Arara Br)	none	0.00	11.04
River Shebelli:			
Belet Weyn	0-6	176.11	183.69
Bulo Burti	1-7	133.39	143.53
Mahaddei Weyn	0-6	104.57	112.09
Afgoi	0-6	77.42	84.89
Audegle	0-6	70.05	76.67

Secondary Network:

Location	Operating authority
Mareerey, river Juba	Juba Sugar Project
Mogambo, river Juba	Mogambo Irrigation Project (MMP)
Jowhar OSR, river Shebelli	MOA

Old stations (with useful records):

Kaitoi, river Juba
 Kamsuma, river Juba (to be rehabilitated)
 Balcad, river Shebelli

The Russian Selchozpromexport project carried out hydrological investigations on the Juba river in the 1963 to 1965 period, setting up a number of stations, including duplication of staff gauges at Lugh Ganana and Jamamme, but only brief details of that work are available from notes on file.

Further hydrological work on the Shebelli, particularly current water gauging checks, were carried out for 'The Water Control and Management of the Shabelli River Study' in the late 1960s (MMP, 1969). Some of the results of this work are contained in files but again many details of the hydrometry have not been documented, or have since been lost.

A Selchozpromexport team (Selchozpromexport, 1973) returned in the early 1970s to undertake hydrological studies on the lower Juba as part of the design of the Fanoole Irrigation and Hydroelectric Power project. The gauging stations at Lugh Ganana and Jamamme were rehabilitated, and also at Kaitoi which had operated briefly during 1963/64, yet Bardheere was virtually ignored; a new station was established at Kamsuma and temporary gauges set up elsewhere. Many of the data from this work are still available on the files in the Mogadishu section office. In addition there are important historical records for many of the stations at the Fanoole Project Office in Jilib. It has been recommended that these records be transferred to the Mogadishu office where they can be properly inspected, but this has not yet been authorised.

It is regrettable that many of the foreign-aided projects concerned with hydrometry have not maintained a proper record of their work, particularly regarding changes in staff-gauge zeros and other datum points or the log of maintenance of installations. Much of the work of this project has involved ploughing through poorly documented historical data files, trying to interpret inadequate or confusing information about station datum changes, so that available observations can be entered on to the computer database for reprocessing with some confidence. Because of this lack of an adequate station log-book system since the end of the FAO Lockwood study, the wrong staff-gauge zeros have frequently been applied to long periods of stage records with the result that previously computed flow records have contained many systematic errors. This was particularly the case in the 1970s when the hydrometric network gradually deteriorated and records became intermittent.

The decline was arrested in 1980 by a FAO funded hydrometry project over the 1980/81 period. The consultant hydrologist, B.A.P. Gemmell, reorganised the hydrological activities and started to investigate staff-gauge zeros, overlapping gauge plates, etc. His fieldwork was well written up (Gemmell, 1982) and he reintroduced the idea of a logsheet of station details. Particular emphasis was placed in Gemmell's project on establishing new stage-discharge rating curves, and this was achieved with a well trained team of field technicians who carried out over 180 discharge measurements by current meter during the two year project period. The range of discharge measurements obtained was large for every station, since the project period coincided with a severe drought at the beginning of 1981 when many low flow gaugings were taken by wading, followed immediately by a major flood event when several of the gaugings performed were the highest discharges ever measured at many of the stations.

Gemmell concentrated on the same stations that are listed in Table 1.1, but during the project it was decided to close down the Balcad station when it became clear that the new barrage operating just downstream of the station was causing an unstable stage-discharge relationship.

The current project aimed to build on the considerable achievements made by Gemmell, but with emphasis shifted from fieldwork to data processing in an attempt to integrate the historical records from all the stations on to a modern computerised data storage and processing system.

Prior to the start of this work, a similar project funded by the German Agency for Technical Co-operation (GTZ), had already been started in the Ministry of Juba Valley Development (MJVD) by Agrar-und Hydrotechnik GmbH (Agrar-und Hydrotechnik GmbH, 1984). The project was not only concerned with the hydrometry of the river, establishing a hydrological database computer system, but also with the management and development of the water resources of the Juba valley as a whole. The GTZ project work incorporated hydrological analysis of extreme river flows and also the modelling of hydrological systems in general. The project consultant, K. Jacobi, spent a considerable amount of time examining data from the primary stations, Lugh Ganana, Bardheere and Jamamme, as well as from other stations such as Kaitoi, Kamsuma, and also Mareerey, which is a secondary station operated by the Juba Sugar Project. Because of the common interests of the ODA and GTZ projects, close co-operation was maintained whenever possible and, indeed, some field trips were jointly undertaken.

Another current project with common interests in hydrometric work is being run by an Italian research team from Mogadishu University, whose primary objective is the study of salinity changes in the river Shebelli; but in order to obtain information about river flows, the project has set up a number of new automatic chart water-level recorders, two of which are at MOA primary stations. The existing recorder well and hut are being utilised at Belet Weyn, to little effect, due to siltation problems, but at Afgoi the recorder is installed in a purpose-built stilling pipe system attached to a bridge pillar, at the same location as the existing MOA station, which previously had no recording facilities. In addition similar new facilities have been established near Genale and Haway in the lower Shebelli, but these stations have no stage discharge rating and none is proposed in the foreseeable future. Better co-ordination of the hydrometric activities of the research team and the Hydrology section would obviously be mutually beneficial.

1.5 The State of the Hydrometric System from 1982

The FAO hydrometry project terminated at the end of 1981. No significant fieldwork, either flow gauging or station maintenance, had been carried out since the beginning of 1982 and no further assistance to the Hydrology section was available until the start of this ODA project in late November 1983. Details of the state in which the individual stations in the network were found at the start of the project are given in Chapter 3.

The section office and its staff were under the control of the Director of Land and Water Resources. The section had no professionally trained personnel and no manager. The sole member of the staff of the section was a Senior Hydrometric Recorder. Although unqualified in hydrology he had many years' experience as a technician and could undertake most of the normal basic field and office duties associated with hydrological work. Unfortunately the well trained team established by Gemmell in 1980/81 had been completely disbanded.

The filing system was inadequate and had to be reorganised. It was evident that the data processing system had not been updated for a number of years.

Pre-1980s stage discharge tables were still being used up to some unspecified time in 1983, when Gemmell's report was delivered and the new ratings established in 1980/81 were introduced. Up until then, incorrect gauge-zeros were still being used, gauge plate overlaps were being ignored and routine processing was introducing errors.

Monthly and yearly summaries of water level and discharge data were being compiled with some basic statistics, such as the mean, maximum and minimum monthly figures, worked out. However, long term records of total runoff, running monthly averages or annual maximum or minimum were not being extracted. There was no systematic procedure adopted for validating data and identifying observer error or obvious data fabrications. Routine plotting of hydrographs for validation of display was not being carried out. There were frequent gaps in data records with no techniques used to fill them. Internal demand for hydrological information was limited and management information reporting systems were not required. Most enquiries for data appeared to come from external aid organisations and consulting engineers.

The FAO project had re-established the hydrometric network, checked ratings, and resumed the flow of observer data which had almost dried up by the end of the 1970s, but very few improvements had been made in the data processing system applied in the office. Consequently the updating of manual office data processing procedures to work in parallel with the new computer system, was considered to be one of the first priorities of this ODA project. It was clear from a cursory inspection of all river flow statistics available, that the complete re-processing of all the station records should be tackled, using the original stage observations. This task was only feasible with the introduction of computerised data handling methods.

At the start of this project, two new trainees, both graduates in Agriculture, were assigned to the section. The day-to-day management of the activities of the section was assumed by the MMP hydrologist.

1.6 Implementation of Progress Report Recommendations

The general state of affairs described above became evident during the initial fact finding trip made by the MMP hydrologist in November/December 1983. A full report of the findings and recommendations was produced (MMP, 1984).

During that trip, fieldwork was carried out at all the stations on the river Shebelli, and the state of the installations at the flow gauging stations was then assessed. Insufficient time was available to visit stations on the Juba during this initial trip, but information about the state of that network was obtained from the MJVD consultant, K. Jacobi. It was clear that urgent rehabilitation of some stations was required, and many radical changes in the general data collection system were needed to improve the continuity and quality of incoming data. The following actions were taken following these recommendations.

- (a) New observer's record cards were designed, and issued to observers who were instructed to return the new cards on a weekly basis, reading to be taken at 6000, 1200 and 1800 hours. The new readings at midday was to be taken in addition to the long established practice of taking a reading in the morning and one in the late afternoon.

- (b) Readings were also to be taken from the bridge MB datum point using special water-level 'dipper' instruments. Two dippers were initially purchased for immediate use, although the type of instrument delivered proved to be unsatisfactory, with markings only at every metre.
- (c) Essential stationery and office supplies were purchased, including calculators, graph paper and pens, pencils, etc.
- (d) Equipment required for rehabilitating station installations was purchased and used at many stations, e.g. staff-gauge plates, an electric drill for fitting them to existing RSJs, and a petrol-engine powered water pump for cleaning out silted stilling wells and inlet pipes.
- (e) Computer system software requirements were outlined following the initial examination of the existing data systems, and many of these suggestions were later incorporated into the design of the system. In addition, a voltage stabiliser unit was purchased to combat the unreliable and unstable electricity supply.

The purchase of a new automatic water-level recording system recommended in the report could not be implemented immediately. Although new recorders and materials have since been ordered during the project, the construction of the new stations could not be carried out until the minimum flow period in February/March 1985 at the earliest. Further details of the proposed recording system are given in Appendix III.

1.7 Extension of the Project Period

It became clear during the project that the proposed objectives could not be achieved within the original project period. The calibre, experience and motivation of the counterpart staff was not sufficient to anticipate that the section would operate efficiently without further expert assistance. The planned re-organisation of water affairs in Somalia through the establishment of a UNDP sponsored national Water Centre, was not expected to occur in the foreseeable future. It was important, therefore, that the bridging assistance provided by this project should continue, and a proposal was submitted to the ODA for extending of the project for a further 18 months into 1985/86, following a request from the Somali Government. Details of the work proposed during the extension period are given in Chapter 4.

1.8 State of River Flows in 1983/84

The annual river discharge hydrographs for all primary flow gauging stations observed during the project period in 1984 are displayed in Figures 1.2 to 1.5. The pattern of runoff indicated from these annual hydrographs is not typical. Both the Juba and Shebelle rivers normally display a biannual, seasonal flood distribution, with major flood runoff events having extended peak discharges, occurring throughout each of the gu and der rainfall seasons. This is a response to seasonal rainfall over the Ethiopian Highlands catchment, and not to rains from within the catchments in Somalia.

Figure 1.2

Annual River Discharge Hydrographs (River Juba)

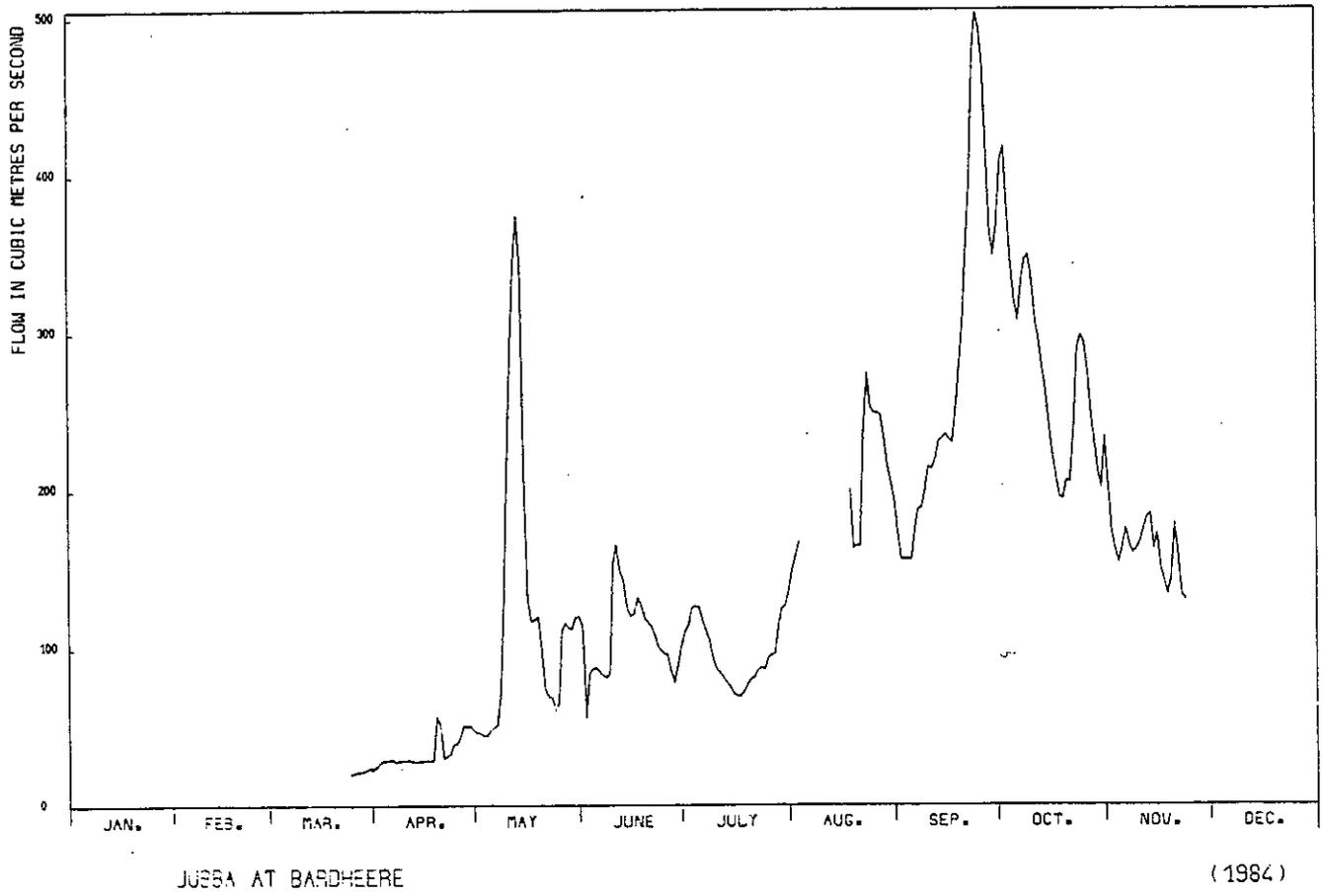
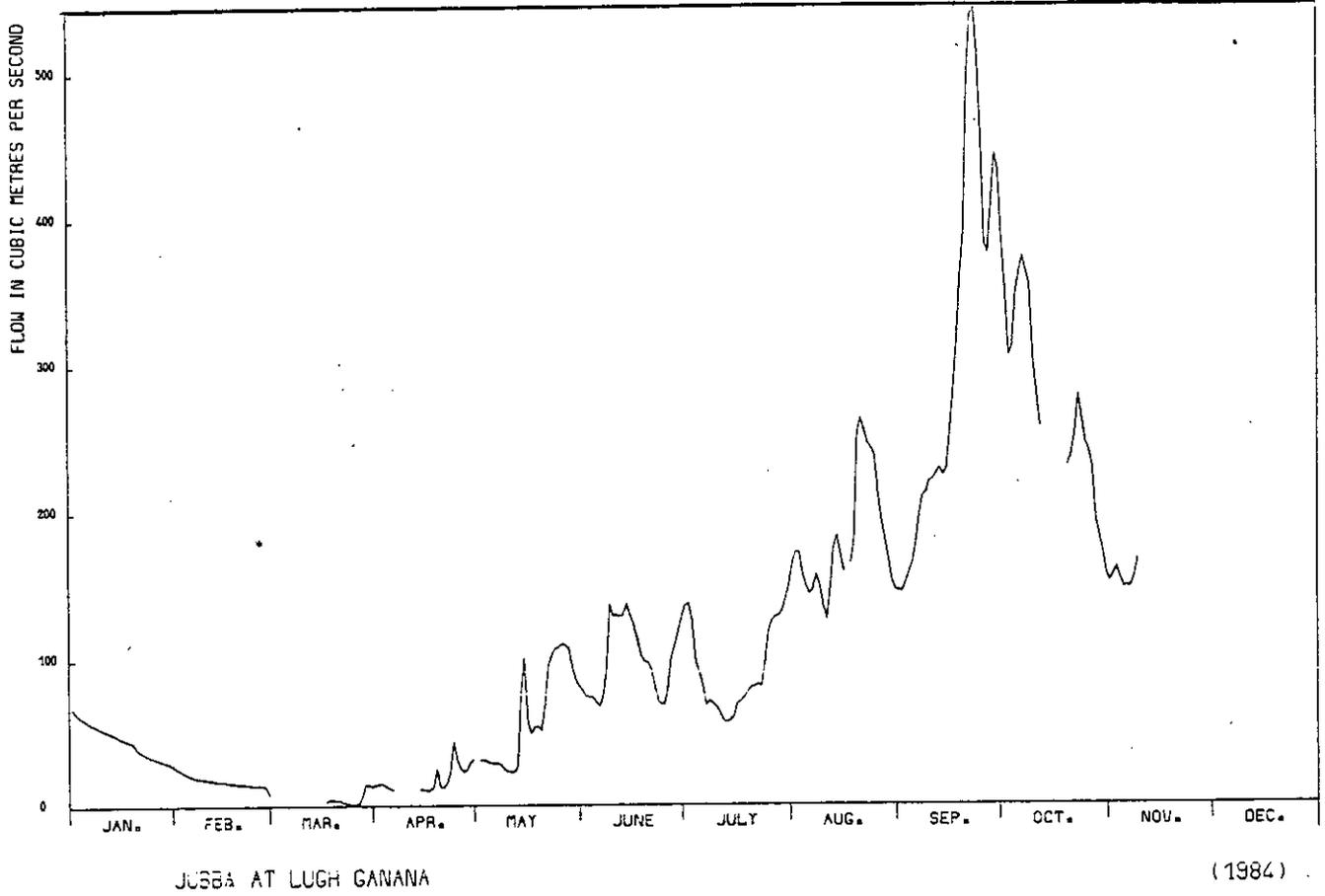


Figure 1.3

Annual River Discharge Hydrographs (Rivers Juba and Shebelli)

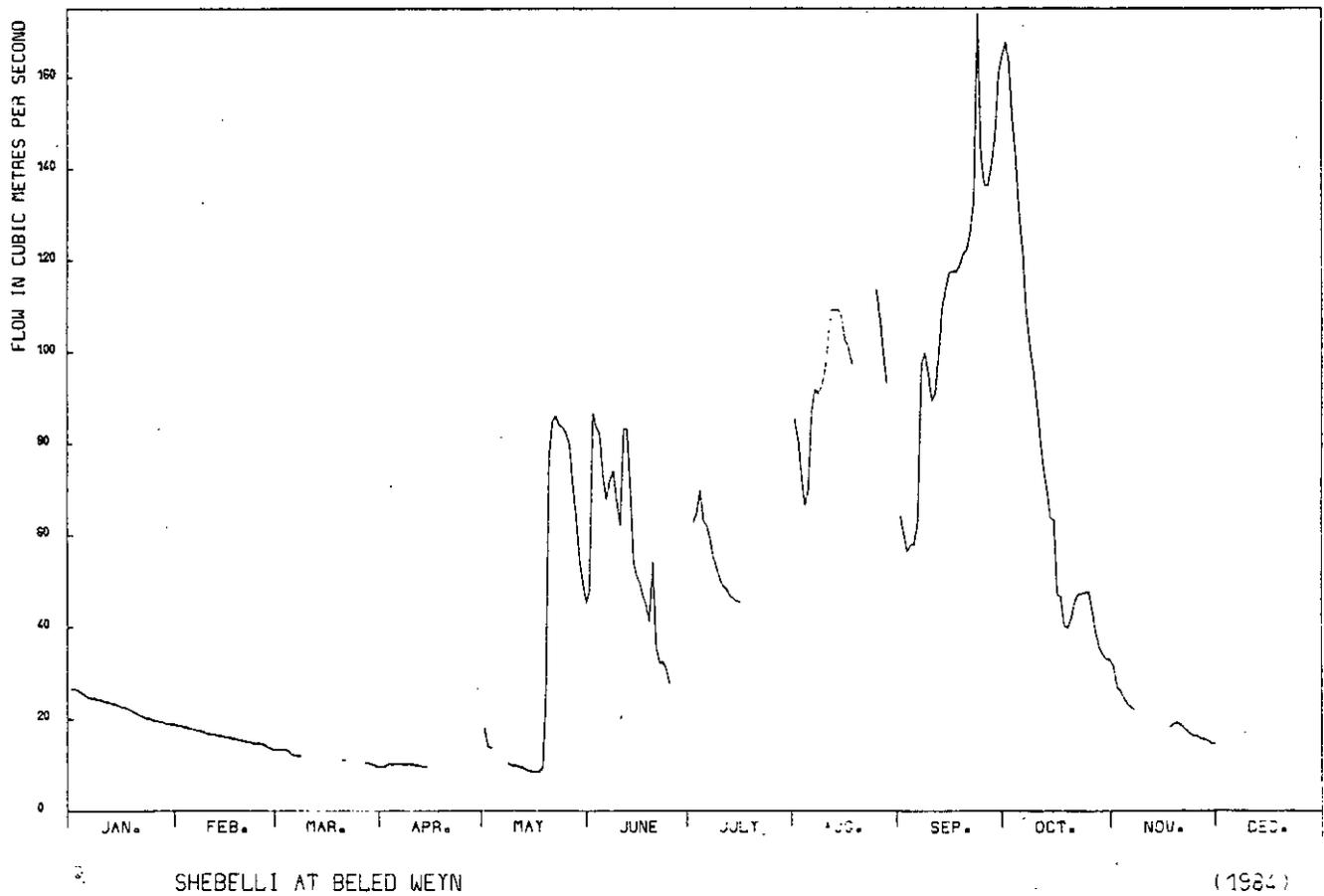
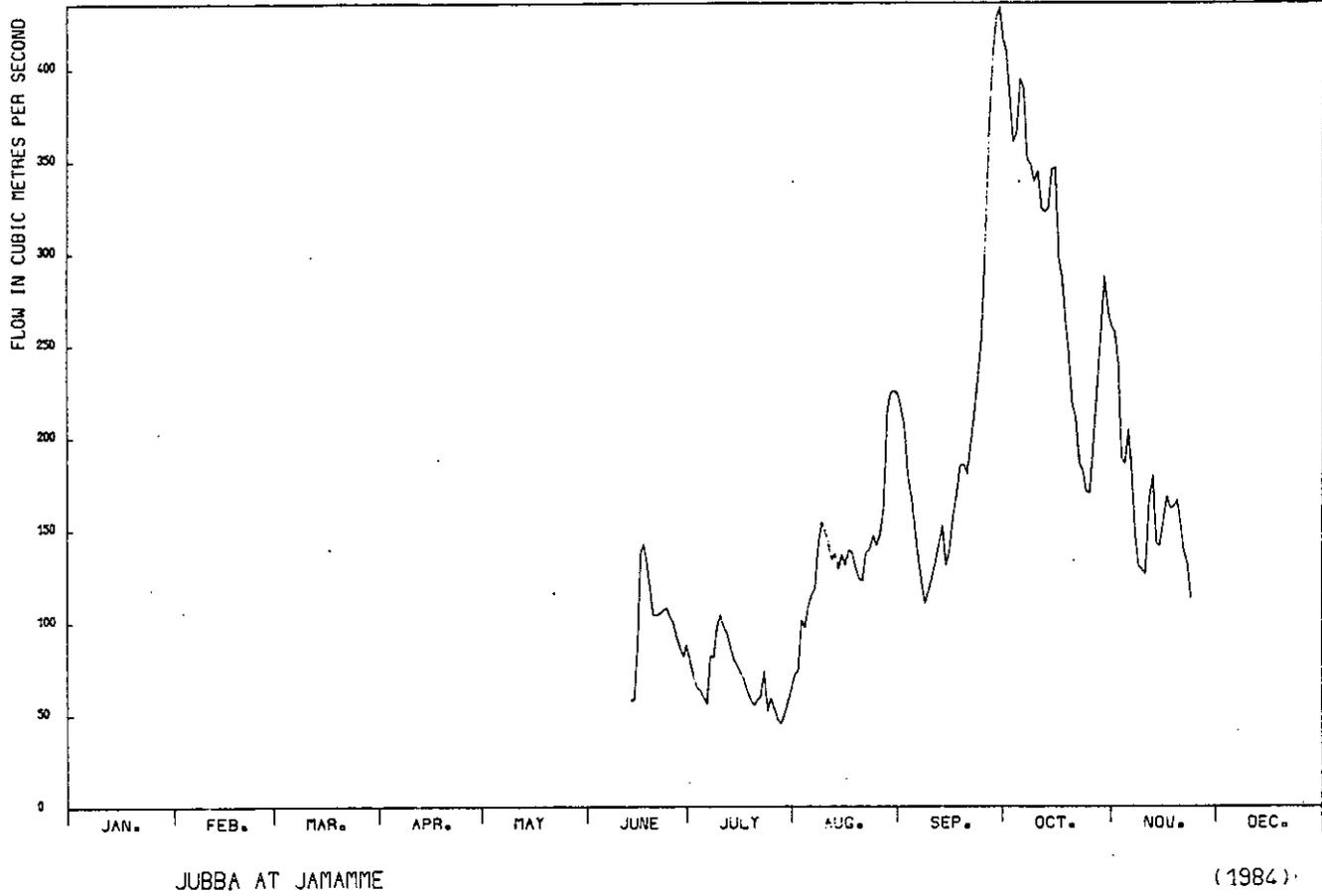


Figure 1.4

Annual River Discharge Hydrographs (River Shebelli)

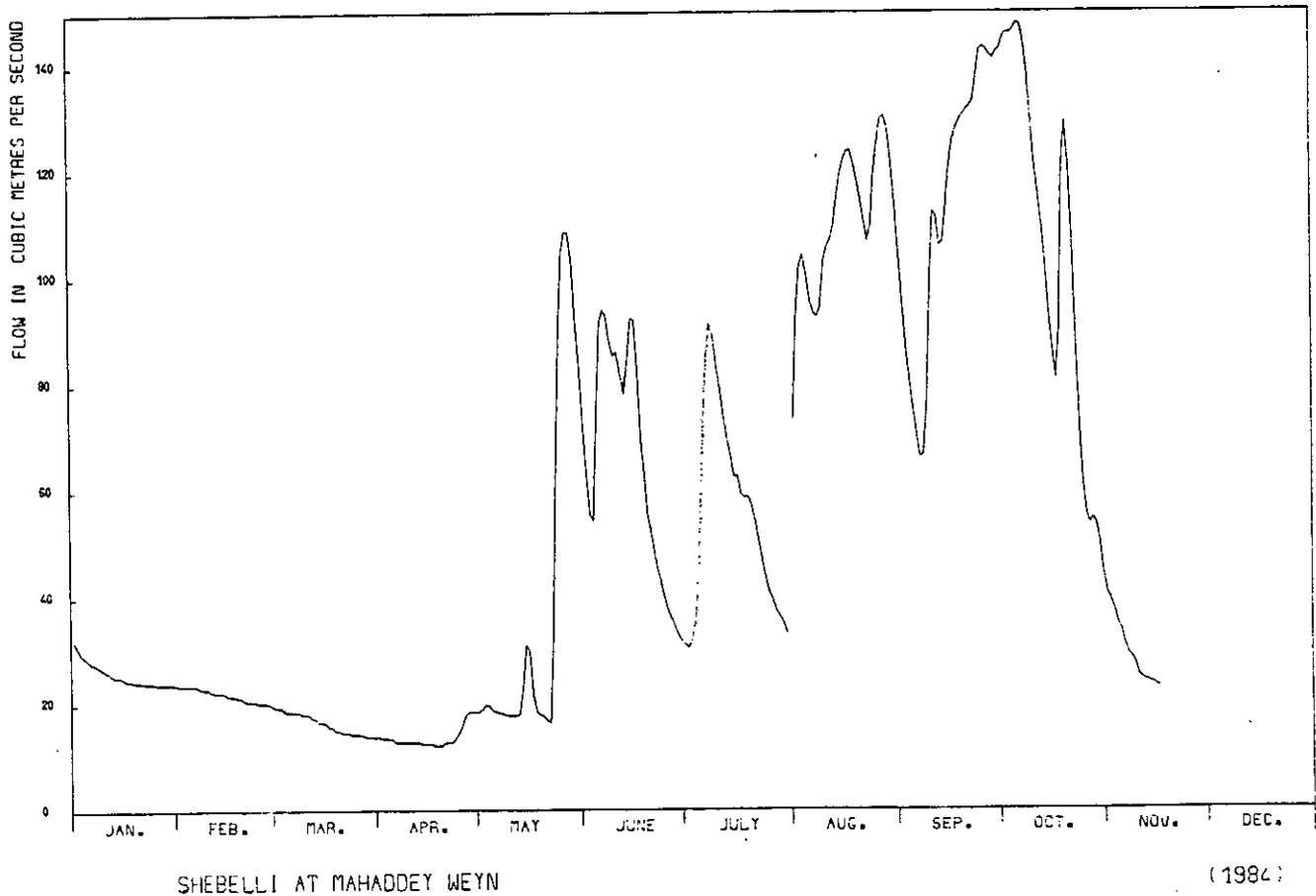
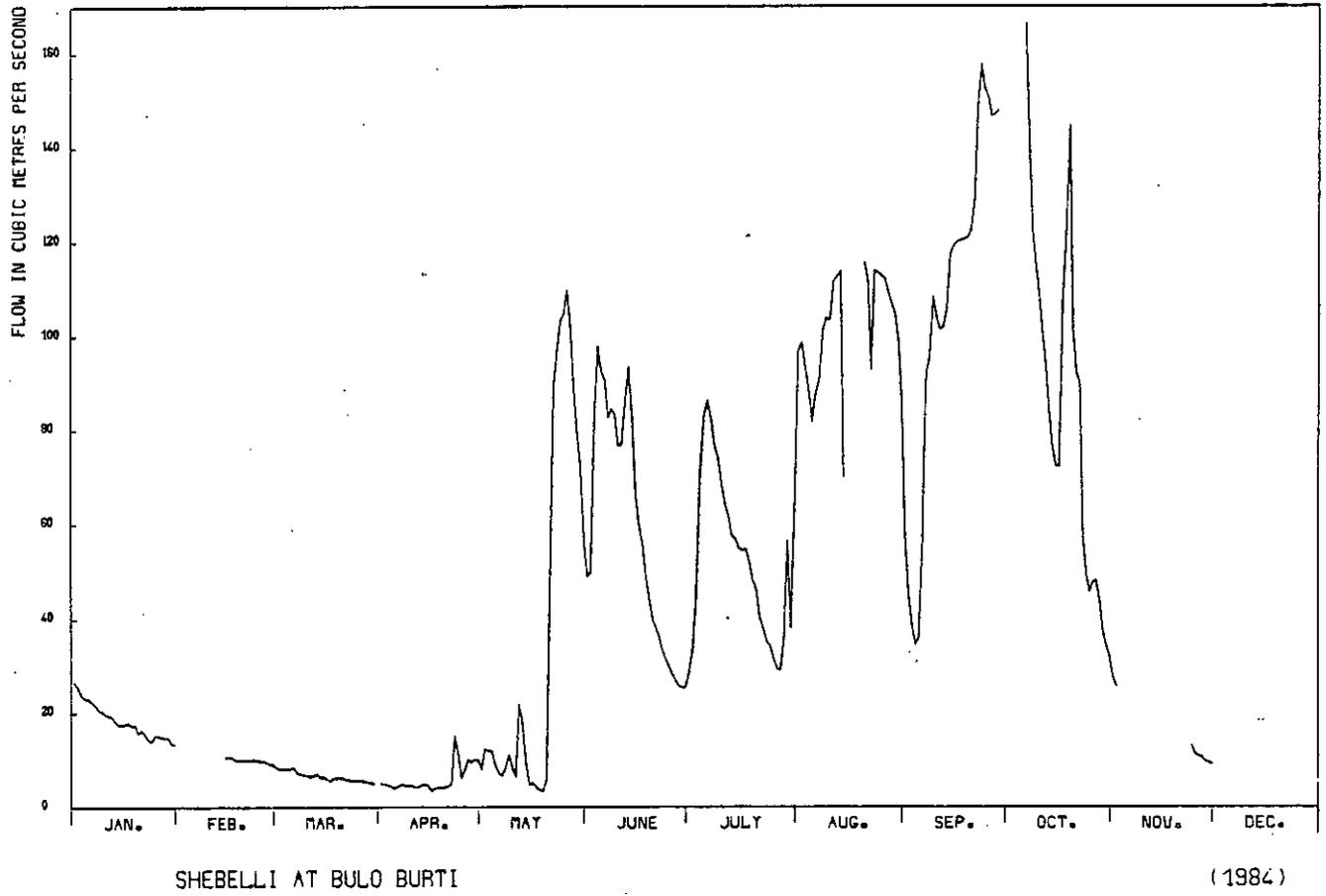
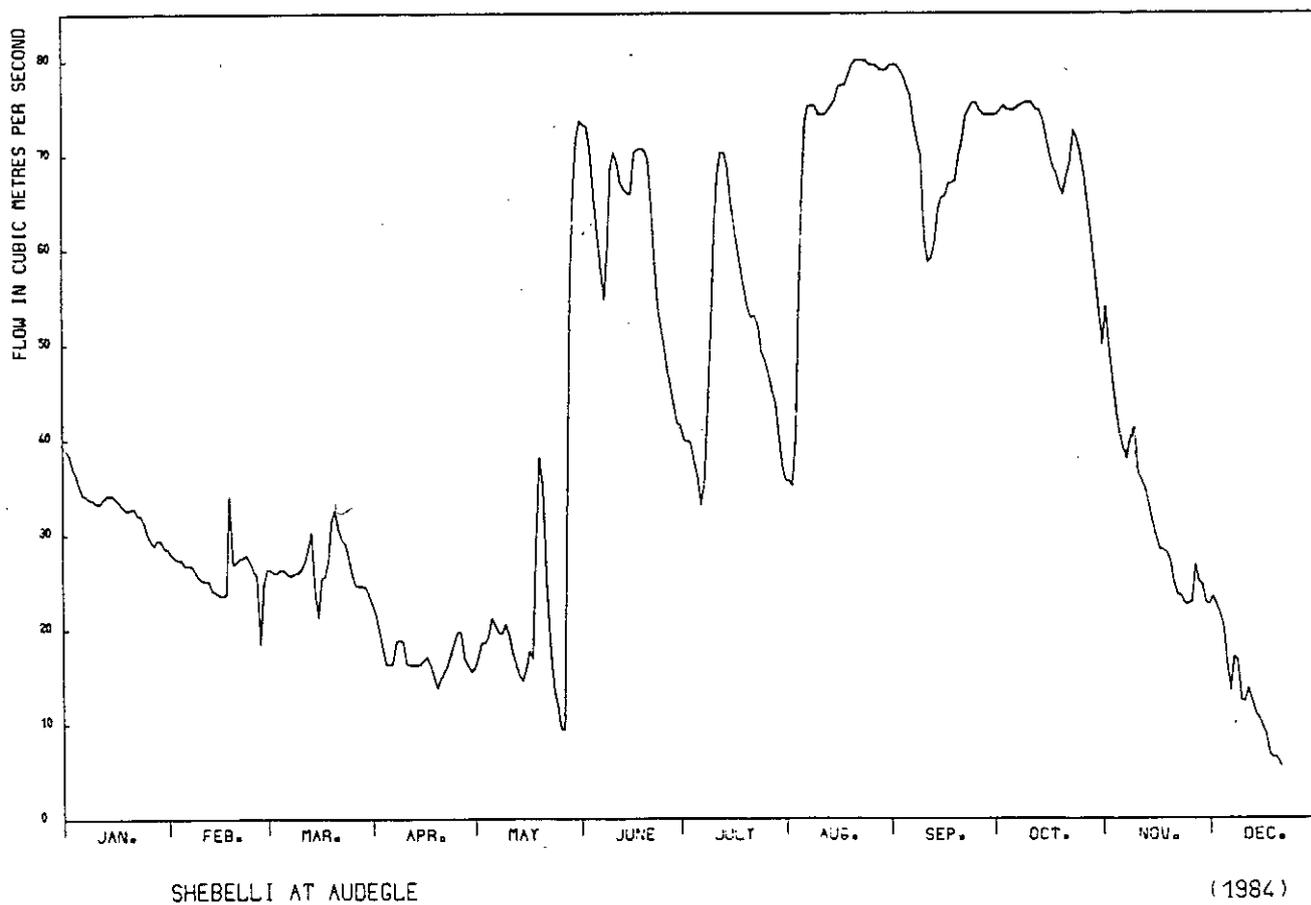
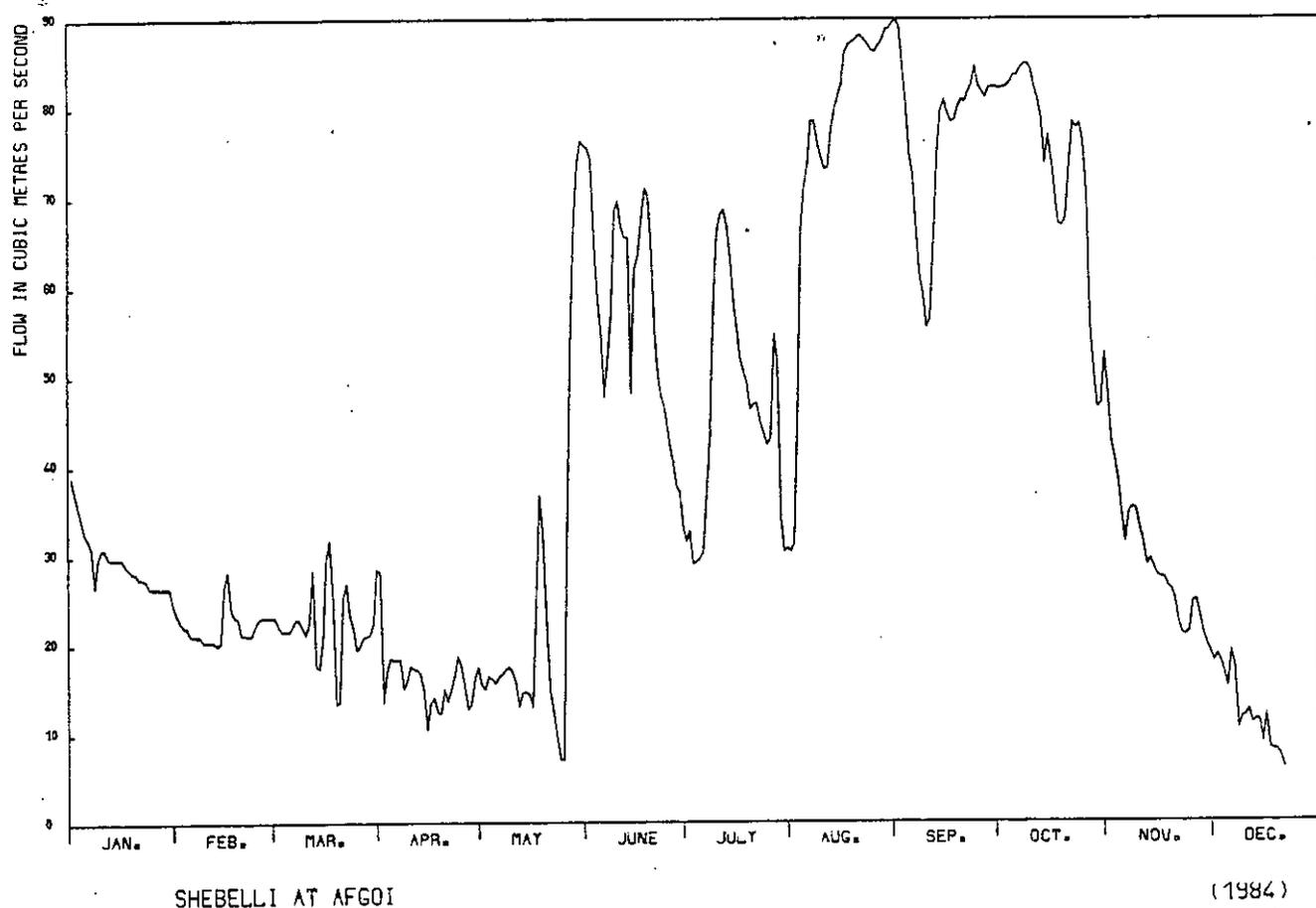


Figure 1.5

Annual River Discharge Hydrographs (River Shebelli)



The flood runoff in the antecedent der period up to the start of the project was fairly typical for both rivers, but the recession continued through March and into April as the gu rains in the Ethiopian catchments largely failed.

The gu flood hydrograph is normally expected to have started rising by the end of March and very often earlier. On the river Shebelli, no major hydrograph rise could be attributed to rainfall generated runoff until 21 April. On the Juba there are few reliable data prior to the rehabilitation of the Lugh and Bardheere staff gauges at the end of March, but it appears that no significant sustained increase in discharge occurred until 17 April. The minor hydrograph rises or oscillations on the Shebelli in February and March observed at Afgoi and Audegele, are attributed mainly to releases from the Jowhar Offstream Storage Reservoir (JOSR), with possibly some contributions coming from local surface runoff as a result of intense storms. Neither the Juba nor Shebelli exhibited the extended flood discharge hydrograph expected during the typical gu period from April to June. Major flood rises did not occur until the middle of May in either the Juba or the Shebelli rivers.

The der flood period from August to November was more typical in the Shebelli but on the Juba flood runoff was characterised by a series of isolated hydrograph peaks rather than sustained high discharge.

The total annual discharge volume was well below average for both the Juba and Shebelli rivers. Flow recession following the der flood was well established by the end of October in both rivers. The recession on the Shebelli was particularly rapid and by the end of December 1984, and the river was at a similar level as for the same time in 1980. The dry river beds experienced in the lower Shebelli at the beginning of 1981 are certain to recur in 1985 with inevitably disastrous consequences for irrigation fed agricultural developments adjacent to the river. The Juba recession flows are significantly higher than at the same stage in 1984, but irrigation requirements in the lower Juba during the critical months of March and April may not be fulfilled unless the gu flood arrives earlier than normal.

The absence of major flood peak discharges and the predominance of medium and low flows in the rivers greatly influenced the amount and nature of fieldwork attempted during the project and this is described in more detail in Chapter 3.

CHAPTER 2

PROJECT ACTIVITIES, GENERAL AND OFFICEWORK

2.1 General Responsibilities

The MMP hydrologist was solely responsible for managing the day-to-day activities of the Hydrology section, although the general areas of activities and programme of work were discussed and agreed jointly with the Director of the Department. The section itself was responsible for operating and maintaining the official MOA river flow gauging stations on the Juba and Shebelli rivers; the direct measurement of river flows for station calibration, liaison with observers based at the stations, the checking and filing of incoming stage data, and the calculation and maintenance of river flow records were all aspects of the work of the section. In addition the section is occasionally called upon to measure discharges in other river sections, in irrigation channels or in seasonal wadis. All other areas of hydrometry such as rainfall, climatological or groundwater data are organised by other departments of the MOA or in the case of groundwater by another Ministry. There is therefore no integrated approach to the monitoring of water resources in Somalia at the present time. The computer introduced into the section for the project is similarly dedicated to the processing and archiving of river flow data.

The project was therefore concerned with improving the quality and return of currently incoming river level/flow data, but also with the considerable quantity of historical data collected and largely processed manually for many years. It was the examination and sometimes interpretation of historic data from files, and the preparation of the data for the computer, that occupied the greatest amount of time during the project. Part of this process was the analysis on computer of current-meter discharge measurements for the derivation of stage-discharge relationships.

2.2 Staff Training and Attitudes

The training of the staff members of the hydrology section was one of the principal objectives of the project. Two new trainees, both with university degrees in Agriculture, were assigned to the section in the first few days of the project, joining the one existing hydrometric technician. Initially considerable time and effort was spent in explaining and demonstrating various basic hydrological principles and techniques both in the field and in preparation and processing of data in the office. The use of staff-gauges and automatic recorders in measuring river level, and the measurement of discharge with current-meters was outlined and exercises were performed in simple computations, hydrograph plotting and the conversion of stage to discharge using tables and curves.

In the absence of supervision by the MMP hydrologist productivity within the section was low. Staff turnover was a major problem in the middle of April 1984 - the experienced hydrometric technician left the section followed shortly after by one of the trainees. The other trainee spent 3 months in 1984 on a course in the USA. During the third visit to Somalia by the MMP hydrologist there were no counterpart staff available to assist with entering data on to the computer or routine data processing. However, a new trainee was assigned by the fourth visit, and by December 1984 two staff had gained a good appreciation of field and office practices in hydrometry and were familiar with the computer system.

2.3 The Microcomputer System

A microcomputer system was introduced into the section to assist with the processing and analysis of hydrometric data. Its application will ensure that a consistent and systematic approach is maintained in the future. It also allows the production of riverflow data reports to satisfy internal MOA requirements, or the needs of external agencies and consulting engineers, in a format suitable for a Yearbook type publication.

The system was designed specifically for this project, in conjunction with the IOH, who were directly responsible for detailed software development. A report on the work of the IOH hydrologist/programmer is reproduced as Appendix I, together with the System and Database manual which describes in detail the features and operation of the computer package. The principal elements of the system are briefly outlined below:

2.3.1 Hardware

The computer equipment purchased for the project was selected to cope with environmental conditions in Somalia, with particular emphasis on reasonable cost, reliability, robustness and upgradeability. A British made machine, the Comart Communicator was chosen for the heart of the system, to which a Cipher visual display terminal with keyboard and an Epson dot-matrix printer were attached. The Comart machine had an integral hard disk with a memory capacity of 5 megabytes, for storage of programs and data, offering a high degree of reliability.

An uninterruptible power supply unit was purchased to provide stabilised voltage plus a short period of emergency battery backup. Unfortunately the unit originally delivered never performed satisfactorily, and was replaced by a similar model which also proved incapable of handling the erratic and unreliable power supply in Mogadishu, failing completely after a few weeks operation. From May until October the computer was reluctantly used directly from the mains supply or sometimes with a portable generator. There was some risk of damaging the computer by using it in this way, but the only problem experienced was malfunctioning of the printer at very low voltages. This often occurred in the middle of long printouts of data, causing a great deal of frustration and time wasting. The problem was only solved when an alternative voltage regulator was delivered in mid-October and this performed satisfactorily for the rest of the project.

2.3.2 Software

An existing IOH database system, originally implemented on a mainframe computer, was adapted to run under the Comart machine's CP/M operating system. All the programs for accessing this database and for processing data were written in FORTRAN language. The menu-driven package was designed to be operated by personnel with little previous knowledge of computers using interactive question/answer prompts. The system processes and stores daily staff-gauge readings and computed mean-daily flows, together with lists of discharge measurements which are used to derive stage-discharge ratings for the stations. Sufficient capacity was created on the database for holding all data currently available in the MOA hydrometric files for the period 1951 to the present time and in the future up to 1990. The list of menu options available are given below as presented on the screen under three headings:

General

- (1) System summary
- (2) Change station parameters
- (3) Add new station or more years
- (4) Data backup onto diskettes
- (5) Error report
- (6) Finish

Gaugings and ratings

- (20) Add/delt/print gaugings
- (21) Plot/assign gaugings
- (22) Develop rating curve
- (23) Add/delt/print rating table
- (24) Enter/print gauging results

Stage and Flow Data

- (10) Add/edit staff-gauge data [Space available]
- (11) Convert stages to daily flows [for new options]
- (12) Add/edit daily flow data
- (13) Print stage and flow data

Options (21) and (22) incorporated screen graphics facilities for the display and derivation of rating curves.

Examples of the formatted printouts available from the system are shown as follows:

Figure 2.1 - System summary listing for which years of data space has been created on the database for a specified station.

Figure 2.2 - Monthly summary of daily river stage and flow data.

Figure 2.3 - Annual summary of flow data only.

Figure 2.4 - Discharge measurement listings.

Figure 2.5 - Stage-discharge rating table and equation.

Figure 2.6 - Current-meter discharge computations.

The system was developed to allow future expansion of the hydrometric network and to facilitate additional software developments, if required.

The main software package was completed by the IOH programmer in May and the system was immediately in operational use. An additional program (option 24) was later developed by the MMP hydrologist for calculating and printing current-meter measurement results (Figure 2.6).

The hardware and software generally worked well with no major breakdowns occurring or 'fatal' bugs identified. Minor problems were experienced with the keyboard; malfunction of some keys was found to be due to a build-up of dust on the key contacts, but this was easily removed with special cleaning fluid; also a small section of the keyboard not normally used in the data processing package failed completely, and although this did not adversely affect progress, the fault needs to be rectified at the next service. The inevitable minor bugs in the software were corrected without difficulty after consultation with the IOH programmer.

Example of Monthly Summary of Daily River Stage and Flow Data Sheet

 Ministry of Agriculture - Somali Democratic Republic
 Monthly summary of daily river flows

Jubba at Bardheere

Sep 1984

Station number 2

Catchment area 216730.0 Sq.km

Date	Stage readings			Mean daily stage (m)	Mean daily flow (cumecs)
	6hrs	12hrs	18hrs		
1	1.57	1.59	1.60	1.59	172.06
2	1.48	1.46	1.49	1.48	156.02
3	1.47	1.49	1.50	1.49	156.37
4	1.50	1.48	1.47	1.48	156.01
5	1.49	1.46	1.47	1.47	155.93
6	1.64	1.67	1.56	1.62	174.68
7	1.59	1.60	1.89	1.69	187.80
8	1.68	1.70	1.69	1.69	188.73
9	1.64	1.79	1.86	1.76	199.51
10	1.88	1.86	1.84	1.86	214.87
11	1.84	1.86	1.85	1.85	213.30
12	1.86	1.86	1.92	1.88	219.01
13	1.94	1.96	1.96	1.95	230.65
14	1.96	1.96	1.96	1.96	232.38
15	1.98	1.98	1.98	1.98	235.21
16	1.96	1.96	1.96	1.96	231.94
17	1.92	1.94	1.96	1.94	229.79
18	2.02	2.06	2.16	2.08	253.27
19	2.16	2.24	2.28	2.23	280.85
20	2.34	2.36	2.40	2.37	308.64
21	2.56	2.62	2.64	2.61	354.50
22	2.74	2.78	2.82	2.78	395.50
23	3.14	3.18	3.18	3.17	475.90
24	3.26	3.28	3.28	3.27	503.10
25	3.24	3.22	3.20	3.22	493.00
26	3.20	3.20	3.00	3.13	469.90
27	2.98	2.86	2.74	2.86	409.30
28	2.66	2.64	2.62	2.64	363.00
29	2.58	2.54	2.58	2.57	349.00
30	2.62	2.64	2.72	2.66	368.60
Monthly mean	.	.	.	2.17	279.29
Monthly maximum	.	.	.	3.27	503.10
Monthly minimum	.	.	.	1.47	155.93
Maximum recorded stage	3.28	m	-	equivalent flow	506.74 cumecs
Minimum recorded stage	1.46	m	-	equivalent flow	152.35 cumecs
Total discharge	723.93	Mcu.m		Runoff	3.3402 mm

Example of Annual Summary of Flow Data Sheet

 Ministry of Agriculture - Somali Democratic Republic
 Annual summary of daily river flows

Shebelli at Audegle

1981

Station number 15

Catchment area 280000.0 Sq.km

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.00?	0.00?	0.00?	75.60	84.60	85.97	44.19	38.59	83.85	80.60	81.65	32.81
2	0.00?	0.00?	0.00?	74.20	84.46	85.98	44.03	43.39	83.67	80.73	81.37	31.71
3	0.00?	0.00?	0.00?	74.03	87.09	86.22	44.68	46.33	83.53	81.37	80.82	27.88
4	0.00?	0.00?	0.00?	74.25	84.88	85.83	45.18	46.60	83.55	86.70	79.50	27.63
5	0.00?	0.00?	0.00?	74.23	84.63	85.12	46.16	46.31	83.79	87.19	77.37	29.53
6	0.00?	0.00?	0.00?	73.72	84.87	83.94	46.39	45.88	83.67	87.19	75.10	29.19
7	0.00?	0.00?	0.00?	73.20	84.88	84.07	46.01	49.83	83.53	87.19	74.21	28.91
8	0.00?	0.00?	0.00?	72.83	84.77	80.82	44.61	52.96	83.40	87.19	73.24	27.85
9	0.00?	0.00?	0.00?	72.68	84.46	78.39	42.85	53.61	82.99	86.92	72.39	25.78
10	0.00?	0.00?	0.00?	72.86	84.11	74.71	42.52	52.67	82.73	81.61	70.52	26.66
11	0.00?	0.00?	0.00?	73.64	84.58	72.10	40.34	52.26	82.73	81.12	66.78	26.56
12	0.00?	0.00?	0.00?	73.27	84.61	71.18	40.05	51.27	82.69	81.12	62.56	26.51
13	0.00?	0.00?	0.00?	73.90	84.61	69.26	42.07	54.77	82.22	80.98	60.10	25.68
14	0.00?	0.00?	0.00?	75.72	84.65	66.19	40.77	61.51	82.19	80.85	60.23	23.37
15	0.00?	0.00?	0.00?	77.04	85.17	65.17	39.83	70.46	82.19	80.85	64.91	21.85
16	0.00?	0.00?	0.00?	78.06	85.92	61.48	38.87	72.78	82.19	80.87	68.65	22.34
17	0.00?	0.00?	0.00?	77.93	86.09	59.01	38.28	83.04	85.15	81.10	68.10	21.32
18	0.00?	0.00?	0.00?	79.22	85.98	56.47	37.45	83.90	82.63	84.81	64.96	20.78
19	0.00?	0.00?	0.00?	78.75	85.97	54.39	36.01	84.60	82.78	87.19	60.79	20.92
20	0.00?	0.00?	0.00?	79.02	85.95	50.98	36.01	84.87	82.68	86.99	57.04	20.48
21	0.00?	0.00?	0.00?	80.18	85.71	48.66	36.00	84.88	88.54	82.64	52.46	19.85
22	0.00?	0.00?	0.00?	81.64	85.68	52.37	36.92	84.88	88.97	82.69	47.90	19.62
23	0.00?	0.00?	0.00?	82.59	85.43	43.43	40.18	84.88	88.97	82.73	46.03	20.51
24	0.00?	0.00?	0.00?	83.37	85.17	43.38	35.52	84.88	85.74	82.73	44.03	24.01
25	0.00?	0.00?	0.00?	83.80	85.17	51.62	33.86	84.87	81.22	82.73	40.79	27.40
26	0.00?	0.00?	43.94	84.07	85.39	50.34	32.20	84.63	81.12	82.73	39.09	26.72
27	0.00?	0.00?	66.52	84.07	85.19	45.07	34.38	84.61	80.97	82.59	38.23	24.88
28	0.00?	0.00?	73.00	84.07	85.43	43.74	33.92	84.61	80.62	82.46	36.78	23.28
29	0.00?		74.92	84.34	85.68	42.19	33.12	84.61	80.72	82.26?	35.84	23.70
30	0.00?		75.55	84.61	85.48	43.95	31.71	84.58	80.82	82.05?	34.02	24.09
31	0.00?		76.13		85.92		33.33	84.33		81.85?		23.99
Mean	0.00	0.00	13.23	77.90	85.24	64.07	39.28	67.98	83.33	83.23	60.52	25.03
Max	0.00	0.00	76.13	84.61	87.09	86.22	46.59	84.88	88.97	87.19	81.65	32.81
Min	0.00	0.00	0.00	72.68	84.11	42.19	31.71	38.59	80.62	80.60	34.02	19.62

Flows in cubic metres per second

 Annual statistics

Mean daily flow	50.16 cumecs	Total discharge	1581.78 Mcu.m
Max daily flow	88.97 cumecs	Runoff	5.6492 mm
Min daily flow	0.00 cumecs		

Example of Discharge Measurement Sheet

 Discharge measurements for station 11 : Shebelli at Bulo Burti

Order Number	Date	Rating Assigned	Stage m	Velocity m/s	Area sq m	Discharge cumecs
1	10 May 1963	a	5.93	1.045	200.11	209.120
2	16 Jun 1963	a	3.16	1.191	61.12	72.790
3	7 Jul 1963	a	2.67	0.653	65.44	42.730
4	8 Aug 1963	a	3.60	0.854	99.67	85.120
5	30 Aug 1963	a	4.37	1.008	128.67	129.700
6	9 Oct 1963	a	3.69	1.024	94.53	96.800
7	12 Nov 1963	a	2.45	0.665	47.11	31.330
8	8 Dec 1963	a	3.22	0.861	100.13	86.210
9	23 Dec 1963	a	3.24	0.822	99.17	81.520
10	5 Jan 1964	a	2.40	0.758	54.25	41.120
11	23 Jan 1964	a	2.32	0.727	48.86	35.520
12	8 Feb 1964	a	1.95	0.571	27.53	15.720
13	5 Mar 1964	a	1.90	0.489	17.12	8.370
14	20 Apr 1964	a	2.48	0.706	57.97	40.930
15	27 Apr 1964	a	1.94	0.548	43.18	23.660
16	26 May 1964	a	2.04	0.705	44.85	31.620
17	17 Jun 1964	a	2.05	0.701	40.86	28.640
18	3 Aug 1964	a	3.05	0.768	81.99	62.970
19	25 Aug 1964	a	4.57	1.013	147.70	149.620
20	4 Nov 1964	a	5.23	1.103	172.98	190.800
21	9 Mar 1965	a	1.58	0.528	13.11	6.920
22	27 Sep 1965	?	2.83	0.274	73.20	20.056
23	17 Nov 1965	a	3.33	0.745	92.51	68.920
24	19 Mar 1969	a	4.14	0.848	137.44	116.550
25	2 Nov 1969	a	2.53	0.802	59.99	48.110
26	26 Nov 1969	a	1.83	0.723	35.15	25.410
27	3 Mar 1971	a	1.23	0.480	13.75	6.600
28	26 Dec 1971	a	1.69	0.613	33.61	20.600
29	24 May 1972	a	4.28	1.064	120.00	127.680
30	29 Feb 1980	b	1.00	0.375	11.55	4.330
31	8 Mar 1980	b	0.97	0.334	17.60	5.880
32	18 Apr 1980	b	0.85	0.263	6.54	1.720
33	9 May 1980	b	4.04	1.024	130.22	133.350

Example of Stage-Discharge Rating Sheet

Rating table for station 1 : Jubba at Lugh Ganana

Rating A from 1 Jan 1951 $Q = 60.320 (h - 0.660)^{1.067}$ to 7.50 metres

Stage (a)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0										
0.1										
0.2										
0.3										
0.4										
0.5										
0.6								0.01	0.04	0.09
0.7	0.15	0.22	0.32	0.42	0.54	0.67	0.82	0.98	1.15	1.34
0.8	1.54	1.75	1.97	2.21	2.46	2.72	2.99	3.27	3.57	3.88
0.9	4.20	4.53	4.88	5.23	5.60	5.98	6.37	6.77	7.19	7.61
1.0	8.05	8.50	8.96	9.43	9.91	10.40	10.90	11.42	11.94	12.48
1.1	13.03	13.58	14.15	14.73	15.32	15.92	16.54	17.16	17.79	18.44
1.2	19.09	19.76	20.43	21.12	21.82	22.52	23.24	23.97	24.71	25.46
1.3	26.22	26.99	27.77	28.56	29.36	30.17	30.99	31.82	32.67	33.52
1.4	34.38	35.25	36.14	37.03	37.93	38.84	39.77	40.70	41.64	42.60
1.5	43.56	44.53	45.52	46.51	47.51	48.53	49.55	50.58	51.62	52.68
1.6	53.74	54.81	55.89	56.99	58.09	59.20	60.32	61.45	62.59	63.74
1.7	64.90	66.07	67.25	68.44	69.64	70.85	72.07	73.30	74.53	75.78
1.8	77.04	78.30	79.58	80.87	82.16	83.47	84.78	86.10	87.44	88.78
1.9	90.13	91.49	92.87	94.25	95.64	97.04	98.44	99.86	101.29	102.73

Flows in cubic metres per second

Example of Current - Meter Discharge Computation Sheet

CURRENT METER FLOW GAUGING RESULTS

STATION : R Jubba at Bardheera
 LOCATION : d/s face of bridge
 GAUGED BY : RJEH/Osman/Ali/Said
 DATE : 10/12/1984
 METER : Braystoke Model BFM.001 with series B011 prop
 METHOD : Bridge
 ORIGIN : Left Bank

CALCULATIONS ARE MADE USING THE MEAN SECTION METHOD
 MEASUREMENTS TAKEN AT : 0.2 & 0.8 of depth below water surface

TIME	START	FINISH					
:	15.15	17.30					
STAGE	0.78	0.77					
VERT NO	TAPE DIST M	DEPTH 'M	REVS / 50 SECS	VELOCITY M/SEC	MEAN VEL M/SEC	AREA SQ M	DISCHARGE CUMECS
1	0.000	0.000	0	0.00000			
			0	0.00000	-0.06223	2.80000	-0.17425
2	4.000	1.400	-14	-0.09334			
			-14	-0.09334	-0.02887	6.18000	-0.17840
3	8.000	1.690	5	0.03812			
			4	0.03310	0.13915	9.32000	1.29690
4	12.000	2.970	39	0.21603			
			49	0.26937	0.25470	14.16000	3.60652
5	16.000	4.110	56	0.30670			
			41	0.22669	0.20599	16.22000	3.34113
6	20.000	4.000	43	0.23736			
			8	0.05319	0.12684	15.46000	1.96095
7	24.000	3.730	32	0.17869			
			5	0.03812	0.13084	15.26000	1.99663
8	28.000	3.900	46	0.25336			
			8	0.05319	0.37401	16.50000	6.17115
9	32.000	4.350	105	0.56807			
			115	0.62141	0.56007	16.50000	9.24114
10	36.000	3.900	94	0.50940			
			100	0.54140	0.50540	15.20000	7.68201
11	40.000	3.700	91	0.49339			
			88	0.47739	0.45339	14.16000	6.41999
12	44.000	3.380	82	0.44539			
			73	0.39738	0.38405	13.06000	5.01565
13	48.000	3.150	67	0.36538			
			60	0.32804	0.30670	11.90000	3.64978
14	52.000	2.800	58	0.31737			
			39	0.21603	0.18975	10.30000	1.95446
15	56.000	2.350	28	0.15735			
			11	0.06826	0.08174	8.54000	0.69809
16	60.000	1.920	8	0.05319			
			7	0.04817	0.02985	6.08000	0.18146
17	64.000	1.120	1	0.01802			
			0	0.00000	-0.03465	4.74000	-0.16424
18	68.000	1.250	-14	-0.08334			
			-12	-0.07329	-0.07329	7.40000	-0.54233
19	72.000	2.450	-9	-0.05822			
			-13	-0.07831	-0.06324	10.40000	-0.65770
20	76.000	2.750	-6	-0.04314			
			-12	-0.07329	-0.07641	8.40000	-0.64184
21	80.000	1.450	-8	-0.05319			
			-24	-0.13602	-0.06307	2.90000	-0.18291
22	84.000	0.000	0	0.00000			
			0	0.00000			

 TOTAL DISCHARGE (CUMECS) = 50.67418
 TOTAL AREA (SQ. M.) = 225.47997
 MEAN VELOCITY (M/SEC) = 0.22474

A further account of some specific operational experiences with the computer system is given in Appendix II, in which some improvements to the software are suggested to allow greater flexibility in running certain programs.

Members of the hydrology section have been trained to operate most of the programs on the system, although further training and experience will be necessary, if new stage-discharge rating curves need to be derived without supervision.

2.4 Data Processing Procedures

The bulk of the work carried out in the hydrology section office during the project, comprised the processing of current and historic data returns from staff-gauge observers, plus several hundred discharge measurements taken by current-meter. The other major process was the derivation and analysis of stage-discharge rating tables and curves for the entire record available for each station. Systematic processing procedures were adopted, the principal steps of which are described in some detail below.

These procedures were used for all the currently operated primary river flow gauging stations in the network, listed in Table 1.1. There was insufficient time available to tackle the historical record of the abandoned Balcad station on the Shebelli, or the data from the Jowhar OSR staff gauges; the data from both these stations should also be examined in the future for inclusion on the computer database. In addition the results of the MJVD project should be incorporated into the system, where analysis of data from the secondary stations on the Juba has been undertaken in some depth.

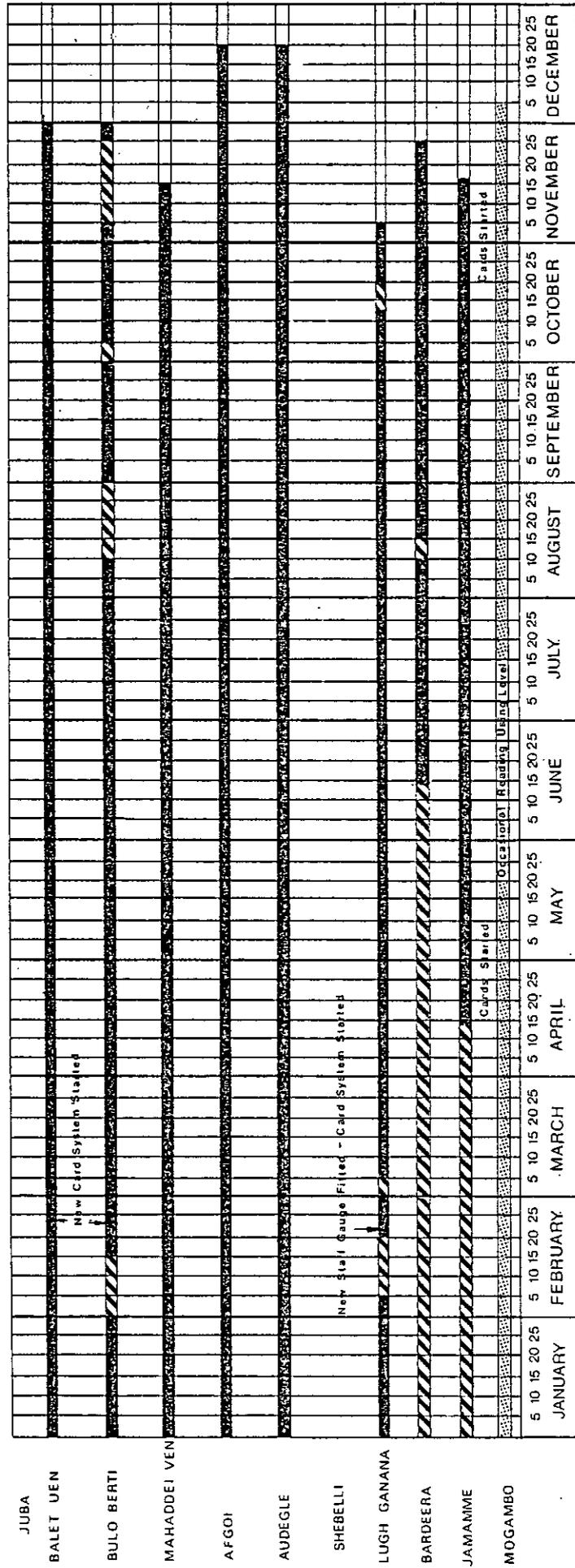
2.4.1 The Revision of Current Data Handling Procedures

It was necessary to revise general office procedures for handling incoming data from staff-gauge observers. The data collection and processing procedures in use up to 1984 were essentially the same as those introduced in 1963 by the Lockwood study. The monthly data sheets received from the staff-gauge observers were also used for calculating the mean-daily gauge-height and then with that value, the mean-daily flow was derived using 'look-up' stage-discharge tables. As gauge-zeros were adjusted occasionally and new ratings implemented, each sheet recorded several different computations of mean-daily flow for each day and therefore became rather confused over the years. In preparation for the introduction of the computerised data processing system, the method for returning data collected by field observers was revised to ensure a more regular return of data for computer entry on a weekly basis, thereby spreading the data processing workload more evenly over any month.

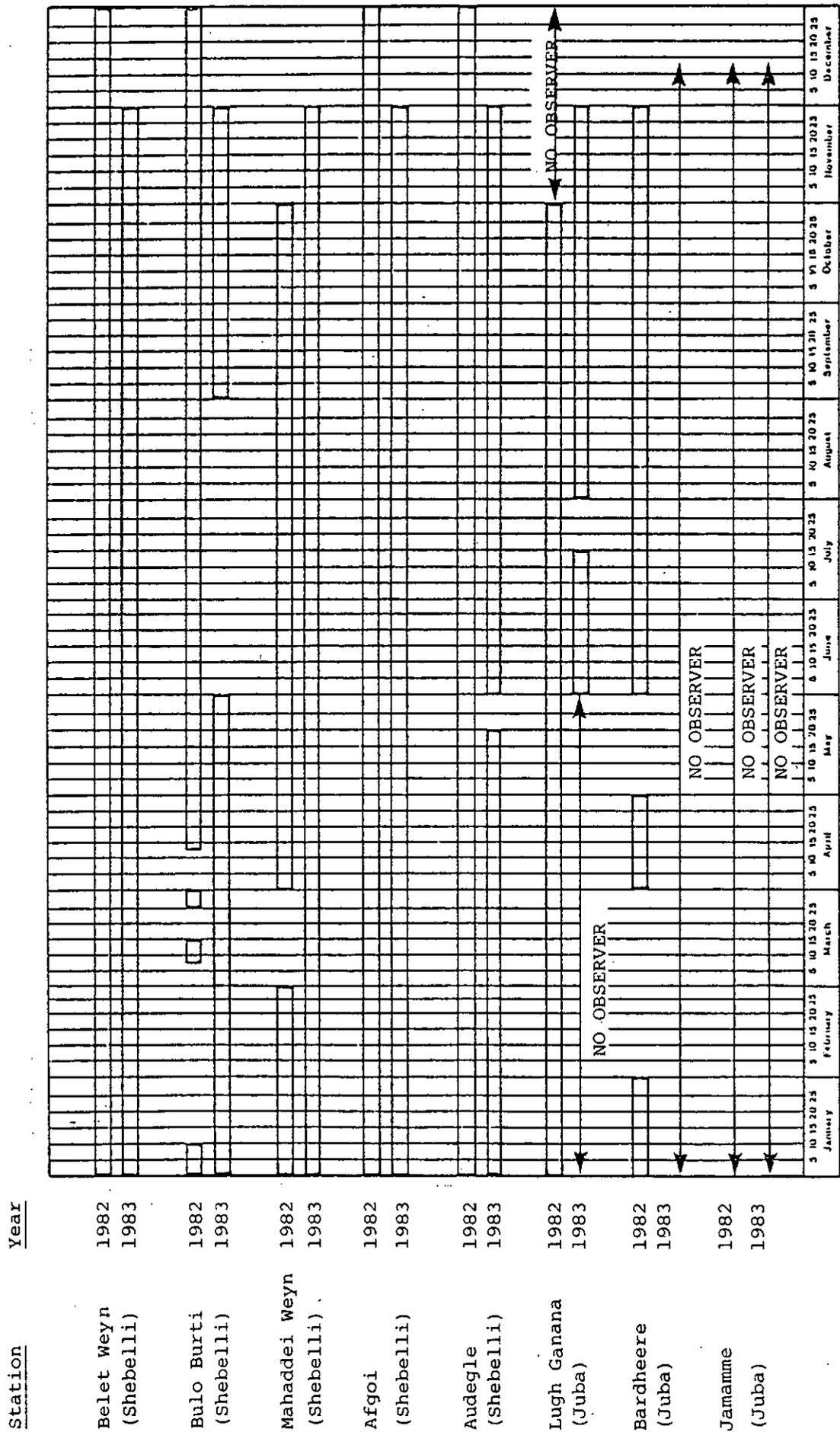
The new cards were introduced during the trip starting in February and all the observers were instructed to take three readings per day instead of two. Where possible bridge dippings were taken from MB datum points allowing a degree of cross-checking of data from staff-gauges. The new system worked reasonably well, although partly frustrated by an irregular postal system.

In the office the receipt of new cards from the observers was initially recorded on a bar chart which clearly showed the current state and continuity of the record. The general return of data during 1984 is illustrated by the chart of data cards received up to the end of December in Figure 2.7. This is a considerable improvement when compared with similar bar charts of data returns

Figure 2.7
Data Returns for 1984



Data Returns for 1982/1983



for 1982 and 1983, shown in Figure 2.8. Moreover, the general quality of data improved markedly at all the stations. The most dramatic improvements in the quality and return of data occurred at the river Juba stations of Lugh Ganana, Bardheere and Jamamme, due to the rehabilitation of staff-gauges and the on site retraining of observers.

Each new card received from observers was inspected for superficial validity of readings with obvious errors corrected. The data were then entered into the computer and adjustments made when necessary to take account of overlapping staff-gauge plates. During this stage, further validation of the time series of stage readings was made automatically by the computer program, checking for example, for changes in level outside pre-determined limits. The most recent data were then printed out and the mean-daily gauge heights plotted manually on calendar graph paper; these hydrographs were again examined for validity with corrections made if required using the editing features of the software. Simple stage correlation graphs between two stations were also used to check for gross errors in gauge-heights. Conversion of stage to discharge using unique rating equations would then normally be carried out using an option from the main menu. The new cards were also used for recording the completion of each step taken in the procedure, so that progress could be monitored.

Although efforts were concentrated on computerised methods of data processing for improving the efficiency of the handling and presentation of data, a parallel office filing system of maintaining flow records was continued as a back-up in the event of computer breakdown. This involved the production of monthly summaries of flow statistics, through the manual conversion of individual stage readings to discharge using tables or equations and the calculation of mean daily flows.

2.4.2 Determining Staff-gauge Zeros

Before any data could be processed either manually or by computer, it was necessary to establish the gauge-zero (GZ) datum of the staff-gauge set for each station. This GZ of the station is normally chosen as the approximate level of stage of the river at which flow normally ceases. Due to the shifting nature of the beds of the two rivers, this no flow stage is never a constant value and the GZ is therefore often set at a much lower position to ensure that stage does not become negative. Over the years, the GZ of a station is often changed, particularly when new staff-gauges are erected, but as long as a register is kept of dates and absolute values of these datums, adjustments can be made to ensure record continuity. In Somalia unfortunately good records of changes in GZ datums have not been kept, and a great deal of detective work was required on each station's record so that a detailed log of changes in GZ and other datums could be compiled. Only then was it possible to link various parts of the record together to establish a complete data set with a common GZ. The GZ selected for each station had ascribed to it a value in metres above mean sea level (m AMSL). This was generally the value most recently determined from surveying by B. Gemmell, and the zero of the existing staff-gauge set usually corresponded to the same level. The major exception to this was for Jamamme where the existing set of gauges was no longer in use, and it was necessary to revert to the GZ originally established by the Lockwood study in 1963. Once this absolute value of the GZ had been selected for each station, all stage data were processed and archived on computer in terms of a gauge-height above a common GZ for the entire record.

2.4.3 Stage-discharge Rating Development

New ratings were derived for all the primary stations in the network using a standardised procedure. This was a two part process involving:

- (i) analysis of discharge measurements, which was largely a time-consuming manual process;
- (ii) the derivation of rating equations, which was a computer assisted technique.

(i) Analysis of Discharge Measurements

All records of direct measurements of discharge made using current-meter velocity-area methods were extracted from station files. Some indirect measurements of flood peak discharge made by Gemmell using slope-area methods, can only be regarded as estimates and such results have not been included in the analysis. Each station had a set of discharge measurements (DM) which started in 1963 during the Lockwood project. The set of DMs for each station was initially inspected with the intention of establishing a unique rating for the entire stage record where possible. The data set was not evenly distributed over the period of record for any station, but was comprised of several distinct groupings of DMs. There were, for example, a major concentration of gaugings in the Lockwood period from 1963 to 1965 at all stations; another smaller group for the Shebelli stations around the time of the FAO Shebelle river study in 1968/69; a very large number of gaugings was carried out for the Fanoole Weir project by the Russian Selchozpromexport team from 1972 to 1977 - about 200 DMs were taken at Lugh Ganana, a few at Jamamme and many others at secondary stations on the lower Juba, which have recently been analysed in detail by the GTZ funded project in the MJVD, but none was taken at Bardheere. The FAO project led by Gemmell concentrated on re-rating all the stations in the network and made over 180 discharge measurements in 1980/81.

There is therefore considerable over-weighting in the distribution of data to specific periods, but the effect of this bias has not been considered in the rating analysis. It did in fact greatly help in assessing whether there were significant shifts in ratings over the long term.

All DM data available on the files in the Hydrology section office in Mogadishu were initially examined, and except at one station the entire data set was used for the rating analysis. For Lugh Ganana, more than 260 DM data sheets were on file, more than three-quarters of which relate to the Russian period. However, the maximum number that can be entered on to the computer database for gaugings is at present restricted to 166. To avoid undue bias in the distribution, only a selection of the Russian data was used in the rating analysis for Lugh Ganana. The main selection criterion was to ensure an even distribution of data points throughout the period 1972 to 1977, but annual high and low measurements were also included in the analysis.

The DMs carried out during 1983/84 are described in more detail in Chapter 3, but since gauging was (and still is) an on-going process, it was decided not to include them in the rating analysis for derivation purposes, but rather to use them as checks on the validity of the ratings derived during the current project. The same was true of the few measurements made by IOH experts during a visit in 1982, when the need for this project was first discussed.

The following steps were taken during the analysis of DMs:

- (a) Staff-gauge or MB readings noted on DM data sheets were converted to gauge-height above the current gauge-zero and checked against the staff-gauge record.
- (b) Some gaugings clearly of dubious quality were eliminated immediately from the analysis.
- (c) The computation of discharge from the original data was occasionally checked at random.
- (d) All initially valid DMs were plotted manually on both normal linear and semi-log stage-discharge graphs. This was done as a training exercise for the counterpart staff, as well as for inspection purposes.
- (e) Obvious outliers from the points comprising the main curve were examined in some detail, and further checks made of gauge-heights, calibration curves applied, etc., with corrections made where appropriate.
- (f) None of the outliers from the main band of data that still remained was eliminated at this stage; many of them could be explained by the use of one particular faulty meter which consistently produced velocities lower than expected; some had no obvious explanation.
- (g) The list of DMs was then entered on to the computer database for the next stage in the process.

The complete list of DMs for each station is given in Appendix IV.

(ii) Derivation of Rating Equations

Two programs were available in the software package to aid the development of rating curves. Option 21 facilitated the display on screen of the data points on a linear scale graph for inspection purposes; each point could then be assigned a group letter, which allowed separate analysis of the different data sets when checking for shifts in the rating. A particularly useful feature in this program is the ability to enlarge the scale of display of part of the screen, so that low flow data can be examined more closely when checking for rating shifts.

The analysis of these data was then archived and utilised in the second program which displayed the selected data set on a log-log scale. Linear regression techniques were then applied to produce a solution to the standard rating curve equation $Q = a (H + c)^b$ within predetermined limits for the coefficients a , b and c . A best-fit option could be accepted as the most suitable solution, or if preferred, a straight line fit through the scatter of points could be selected by eye. Attempts were made to break individual curves into a number of segments with different equations, since for some stations the data were not adequately represented by a single equation with the plot of extreme high and low DMs diverging from the optimum solution. However, the derivation program cannot cater for multi-segmented ratings at present and manual intervention into the computerised derivation process, in order to overcome this, was not successful.

The stage-discharge rating curves developed for each station, and data points used in the analysis, are plotted in Figures 2.9 to 2.16. The rating curves finally established were generally considered to be adequate. The most unsatisfactory rating curve produced was for Bardheere, where the instability evident in the rating was undoubtedly due to the poor velocity distributions frequently encountered at the bridge/old ferry site gauging section. An example of the flow reversals experienced during some gaugings at this site is shown in Figure 2.6. There is evidence that similar flow reversals, occurring during many measurements taken in the past, have not been properly accounted for in the computation of results; this undoubtedly accounts for much of the scatter on the plot. The Belet Weyn data plot would clearly benefit from the fitting of a multi-segment curve, and this may be possible during the project extension. Three of the stations - Bulo Burti, Mahaddei Weyn and Audegle had two separate rating curves, since there were clear indications that a rating shift had occurred over a long period in each case. The shifts evident at the latter two of these stations appeared to be due to construction of river control structures in the downstream reach, but at Bulo Burti major changes in river bed profiles due to flood erosion and deposition are suspected as the cause.

Some DMs which were omitted from the actual derivation process, because of doubts about the quality of the data, are indicated on the DM data plots. The main reasons for excluding them were, either errors in stage readings, or the use of a faulty meter. No DMs were excluded from the final equation derivation simply because they lay beyond a predetermined limit.

An example of the printout of a stage-discharge relationship in tabular form is given in Figure 2.5, whilst the full list of rating equations is included in Appendix IV.

(iii) Treatment of Historic Stage Records

Most of the original historical data were still available in files as the observers original handwritten returns on monthly sheets; some of the sheets were obviously fair copies of the returns. The same sheets were used for corrections and conversions, initially to stage as m AMSL and then to discharge using rating curves. Where possible these original data returns were entered into the computer, rather than someone else's interpretation or summary; the only records available from Lugh Ganana and Belet Weyn for the period 1951 to 1963 were mean-daily gauge-height annual summary sheets. The stage record of each station from 1963 was, however, critically examined in some detail.

Inspection of these old records and the preparation of the data for computer entry occupied the major proportion of project time. Many corrections, adjustments and interpretations were made but many of the inconsistencies in the data could not be fully resolved. Occasionally particularly suspect data were not entered on to the computer. Synthesized data were generally not entered onto the database. Some of the record quoted by others as being available, for example in the period 1951 to 1962, was in fact synthetic; only Lugh Ganana and Belet Weyn have observed records for this period. Nevertheless, data partially synthesized by Gemmeil for the 1980/81 period has been included, since it was done for relatively short periods of missing data and was based on additional spot readings available. Some examples of problems encountered with the data are listed below:

- Observers often misread staff-gauges typically giving 1 m errors; these were difficult to spot when stage was rapidly rising at the start of the flood.

Figure 2.9
Rating Curve-River Juba at
Lugh Ganana

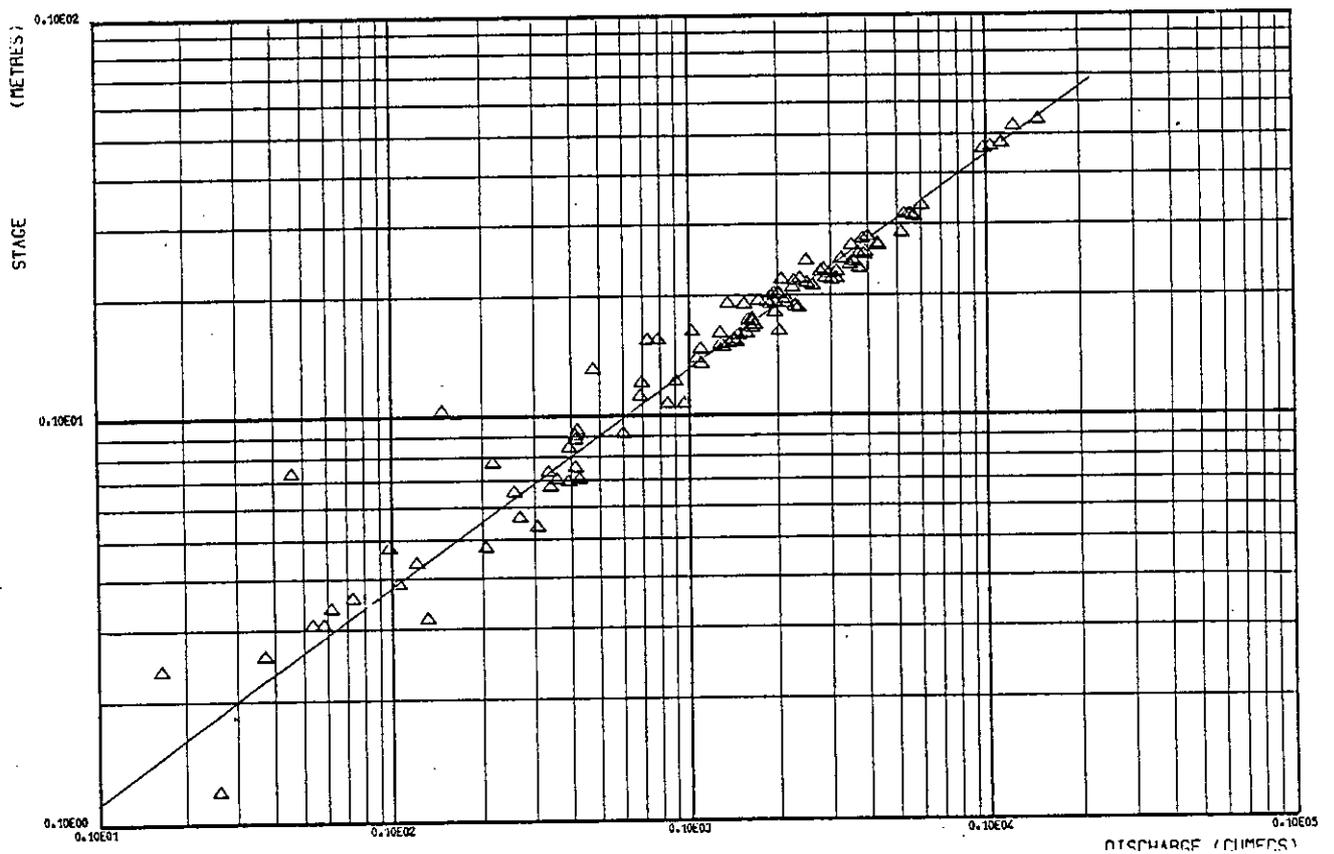
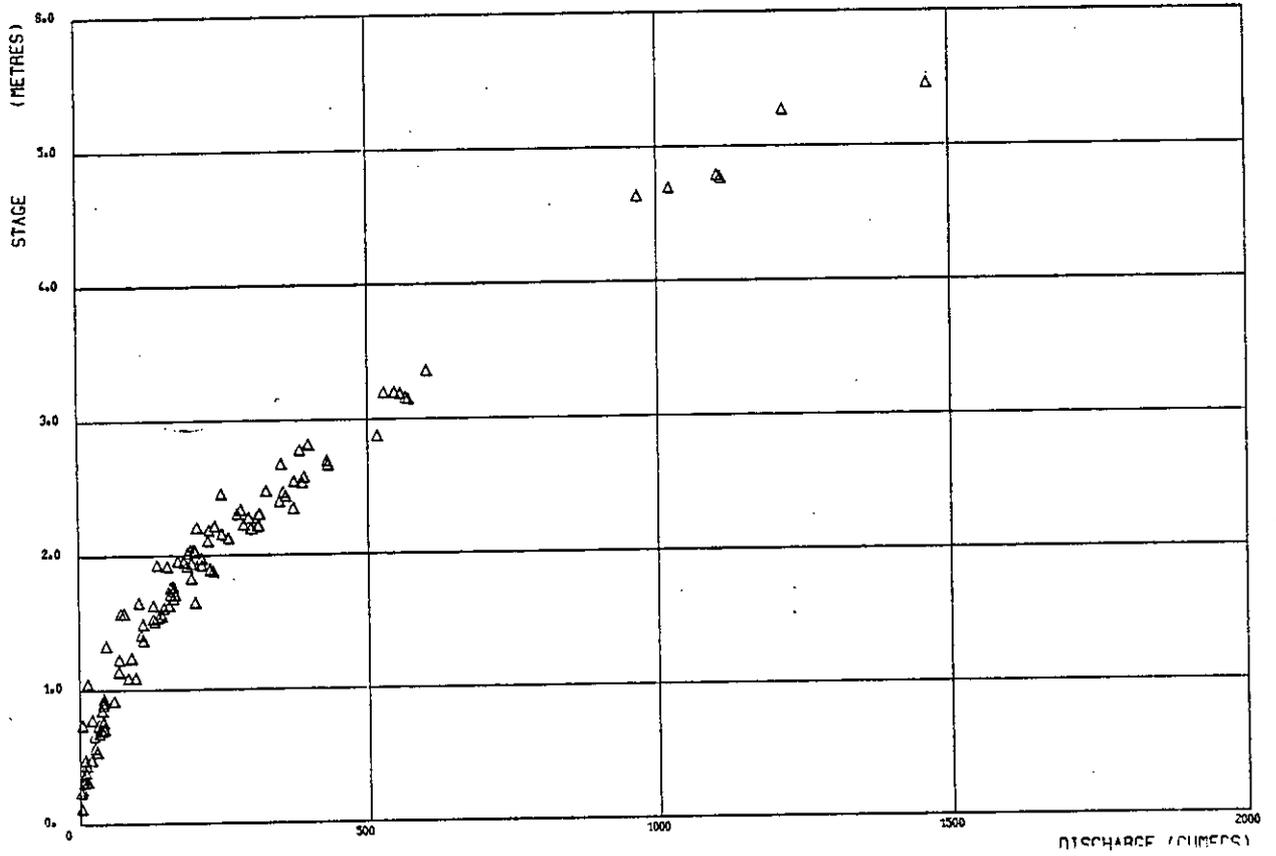


Figure 2.10

Rating Curve - River Juba at Bardheere

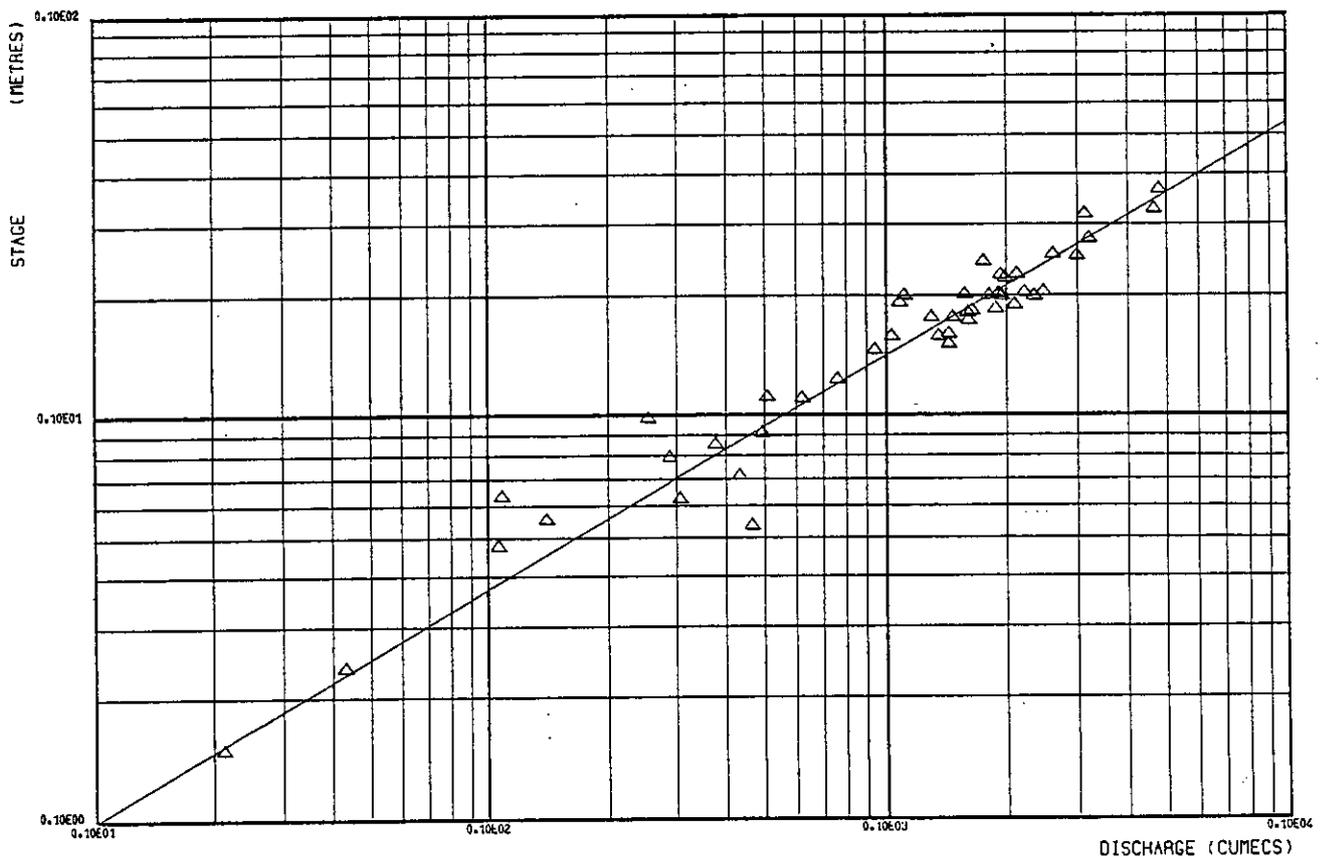
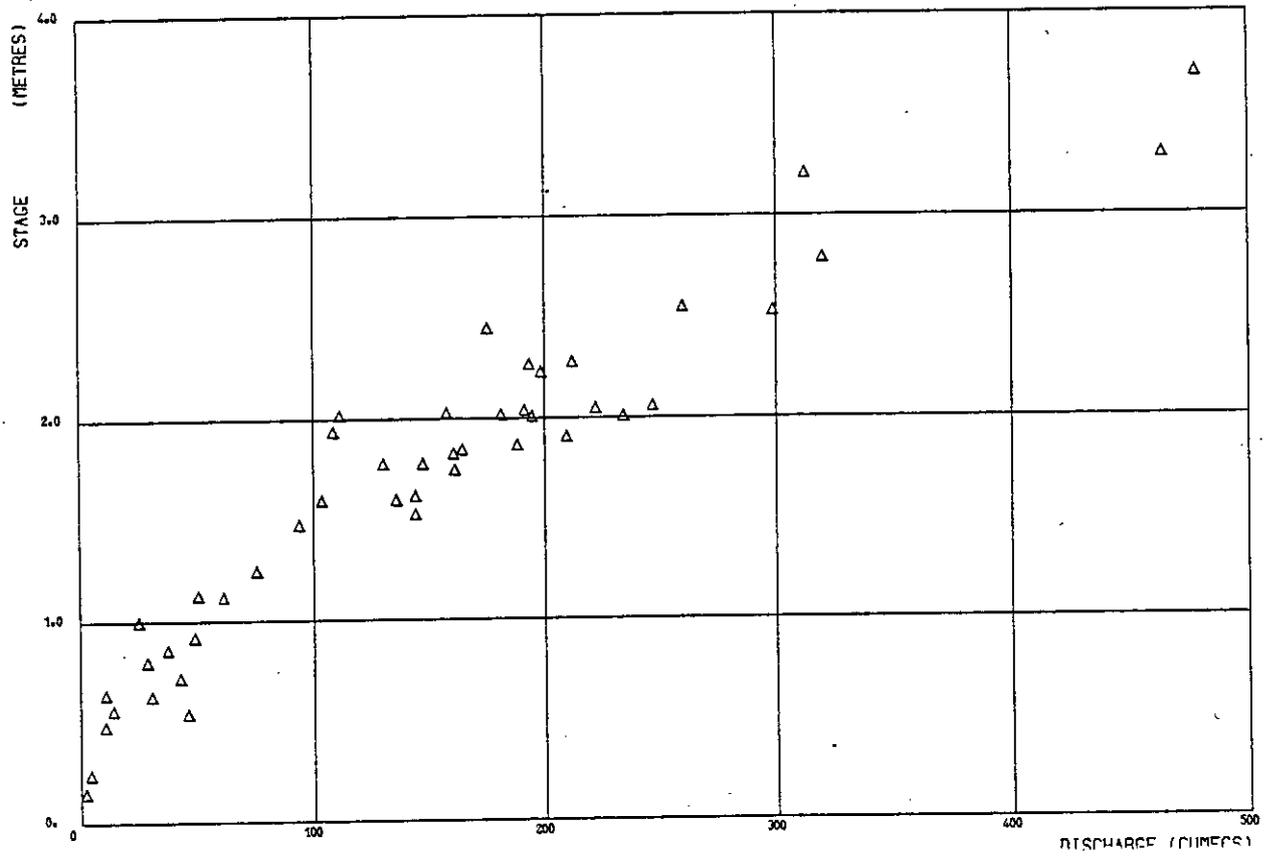


Figure 2.11

Rating Curve - River Juba at Jamamme

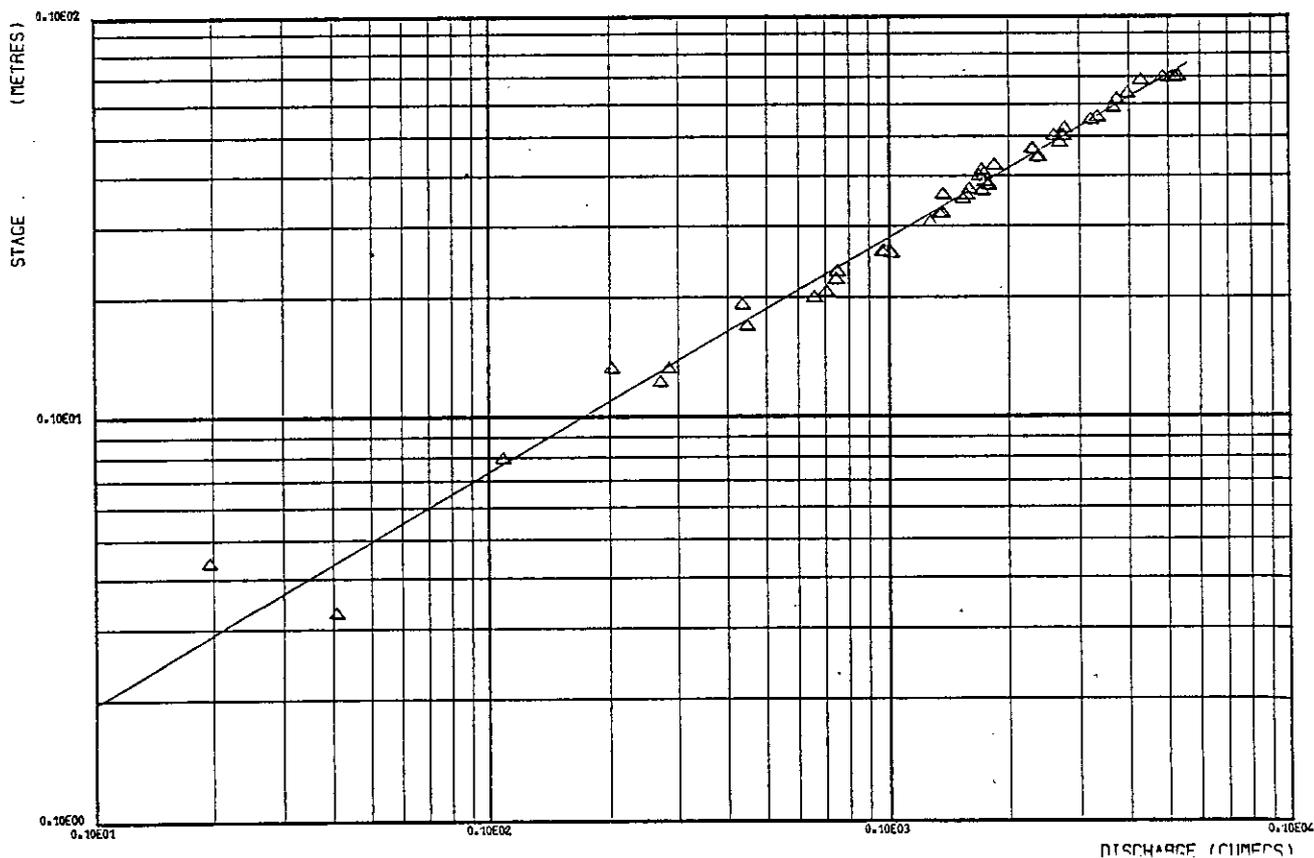
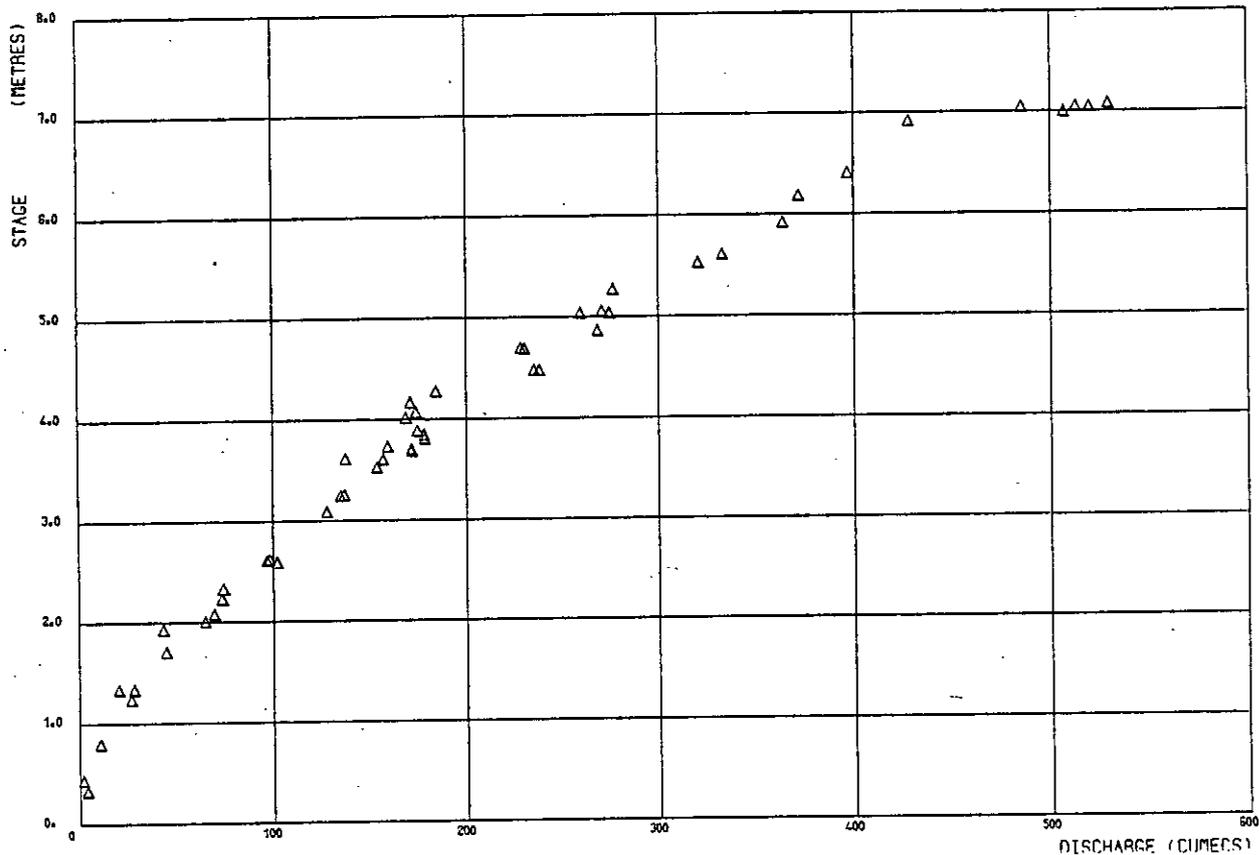


Figure 2.12

Rating Curve - River Shebelli at Belet Weyn

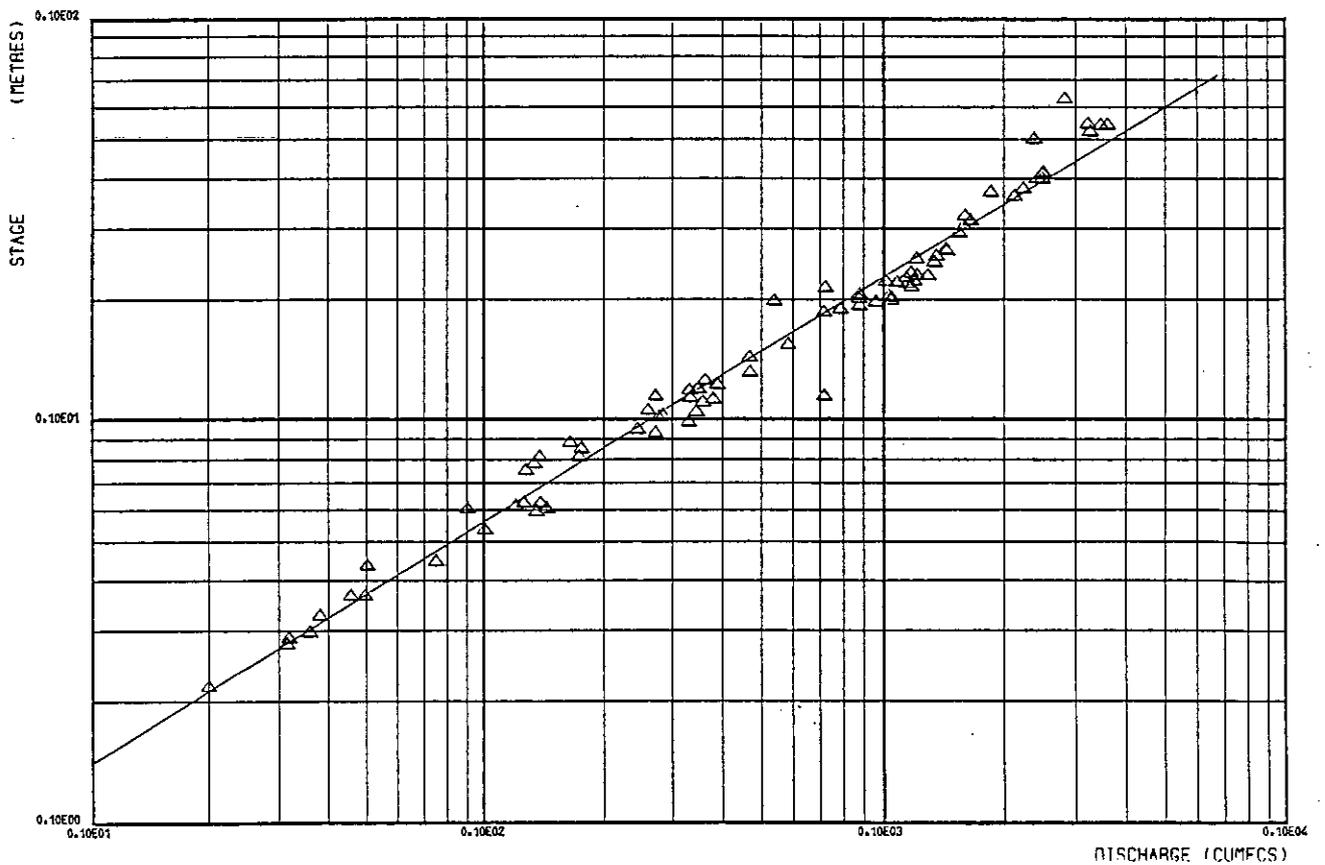
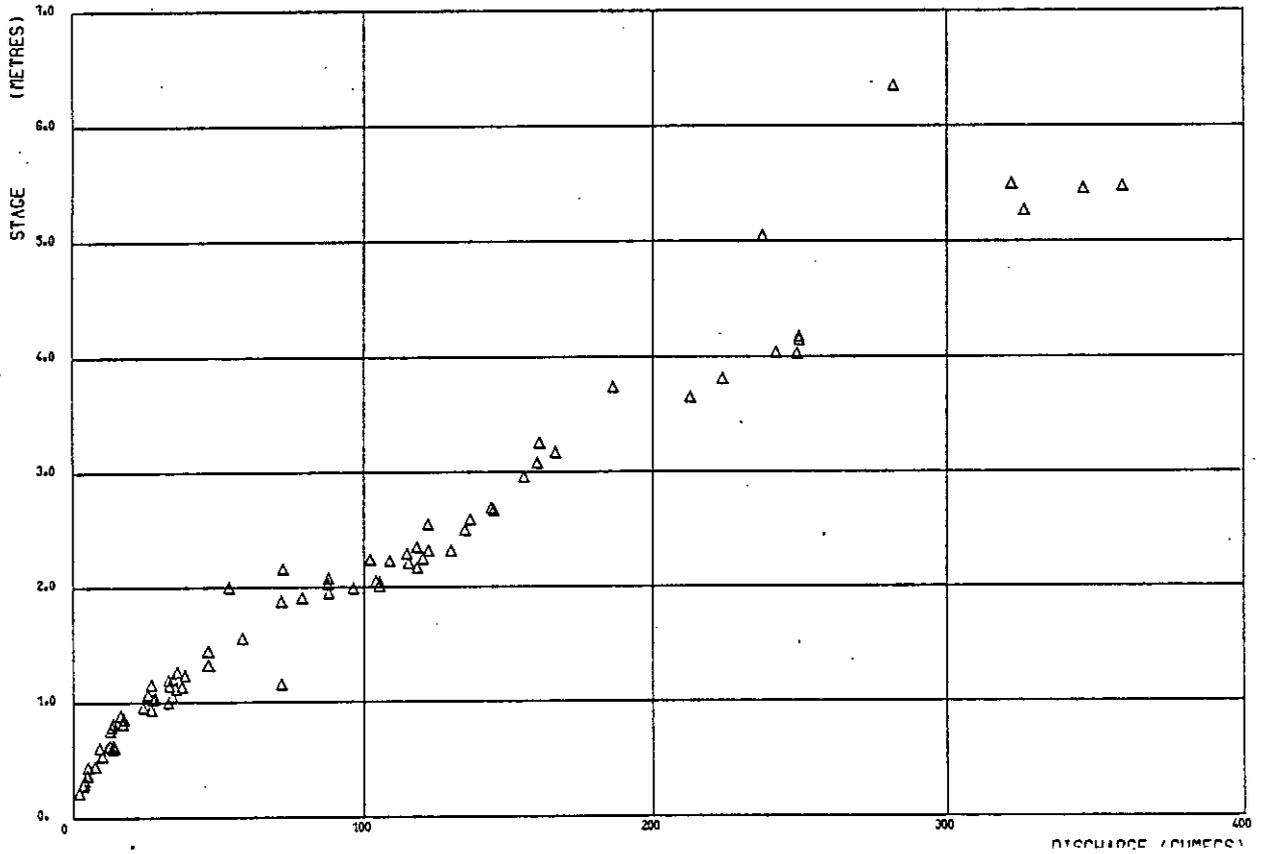


Figure 2.13

Rating Curve - River Shebelli at Bulo Burti

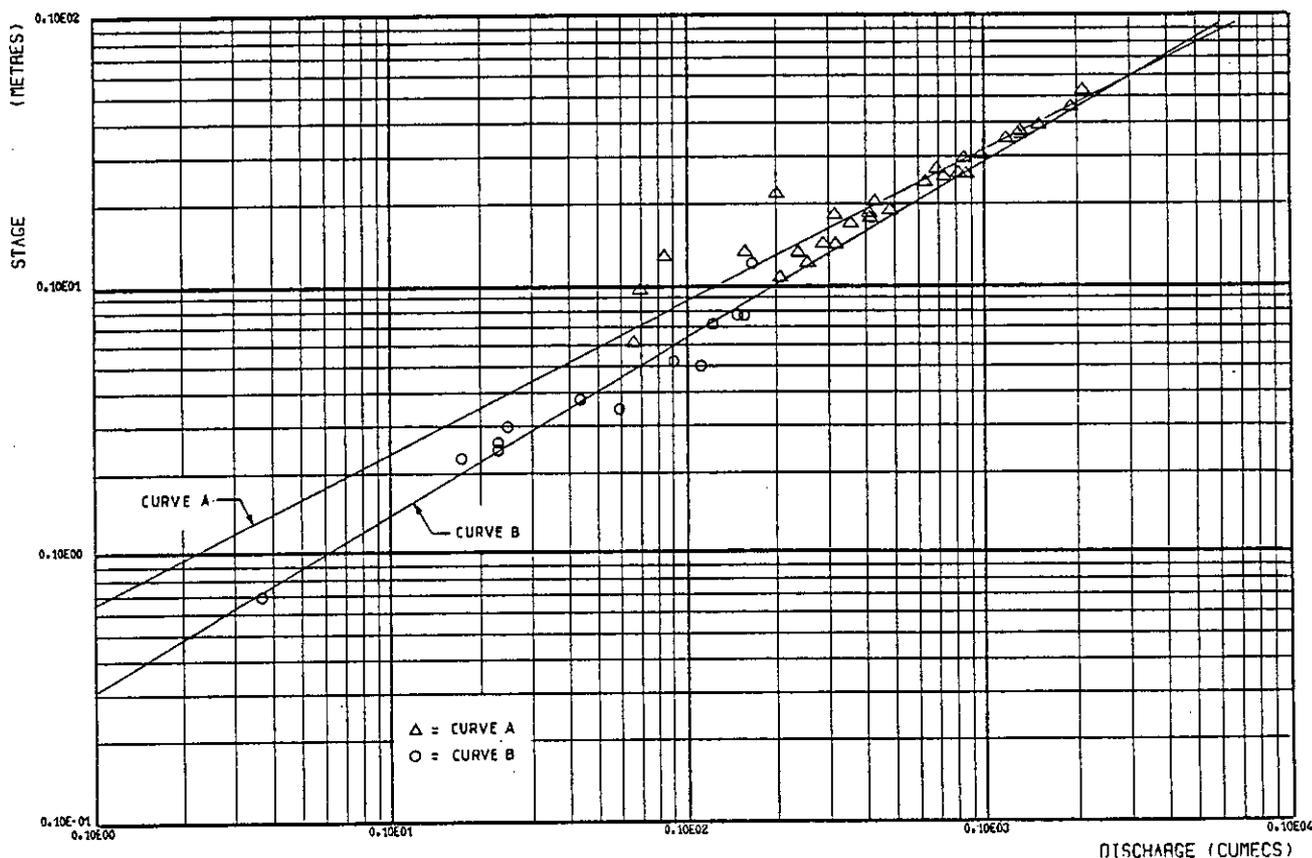
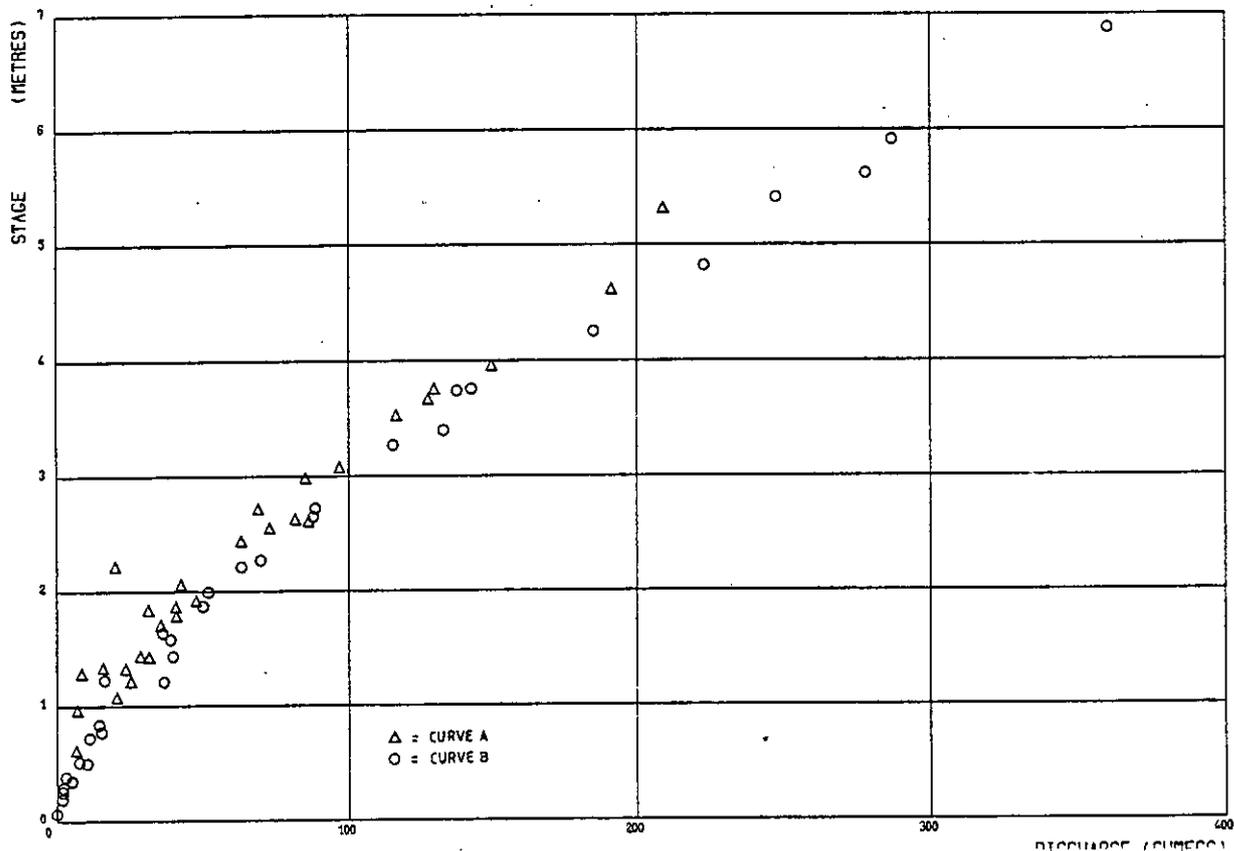


Figure 2.14

Rating Curve - River Shebelli at Mahaddei Weyn

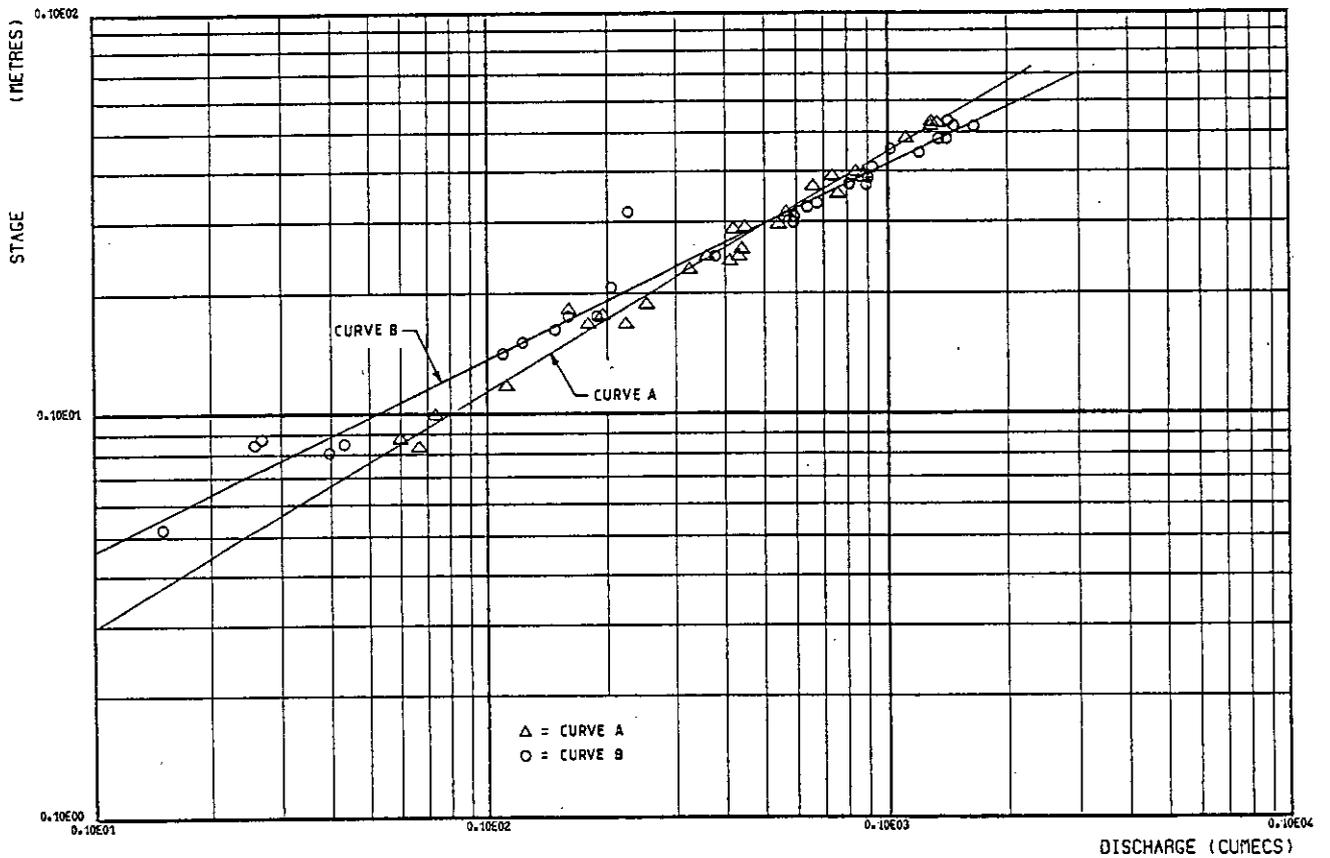
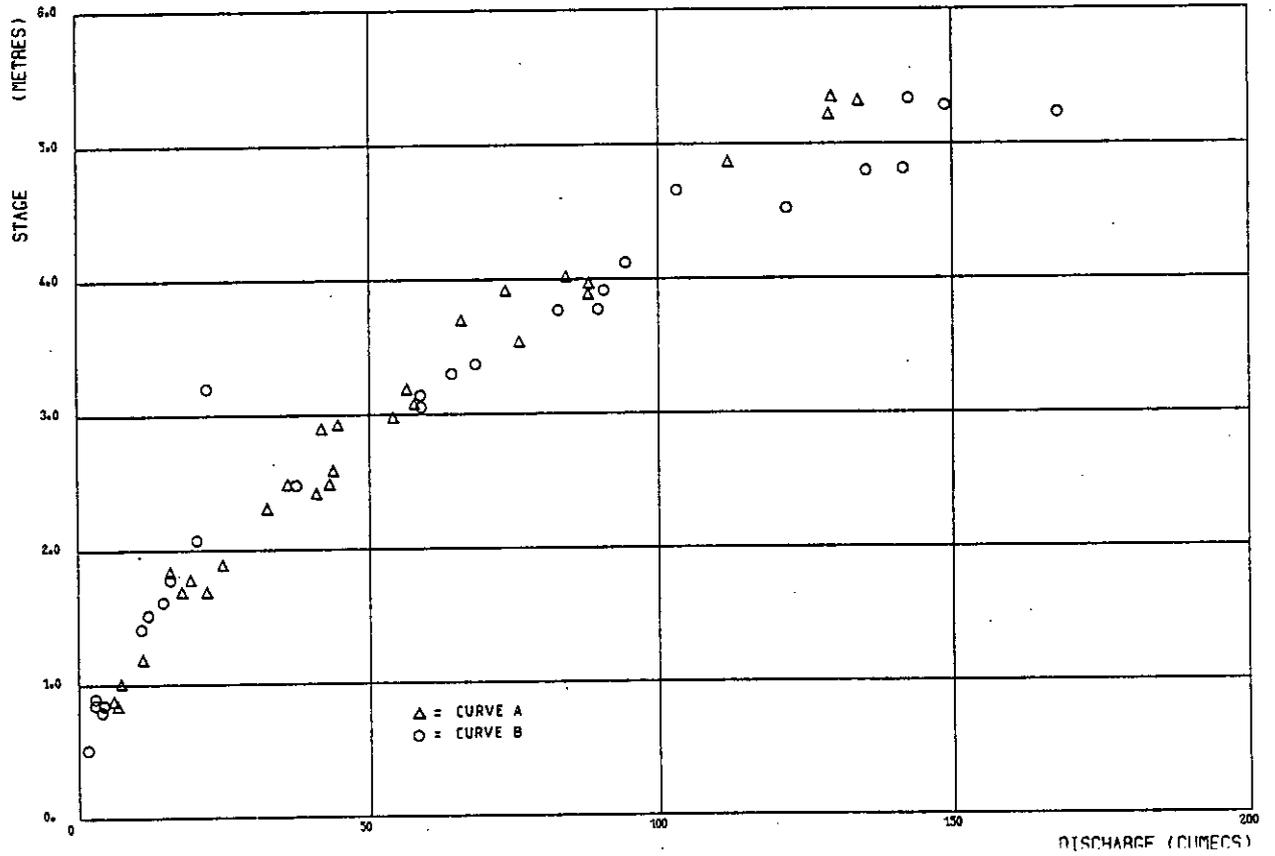


Figure 2.15

Rating Curve - River Shebelli at Afgoi

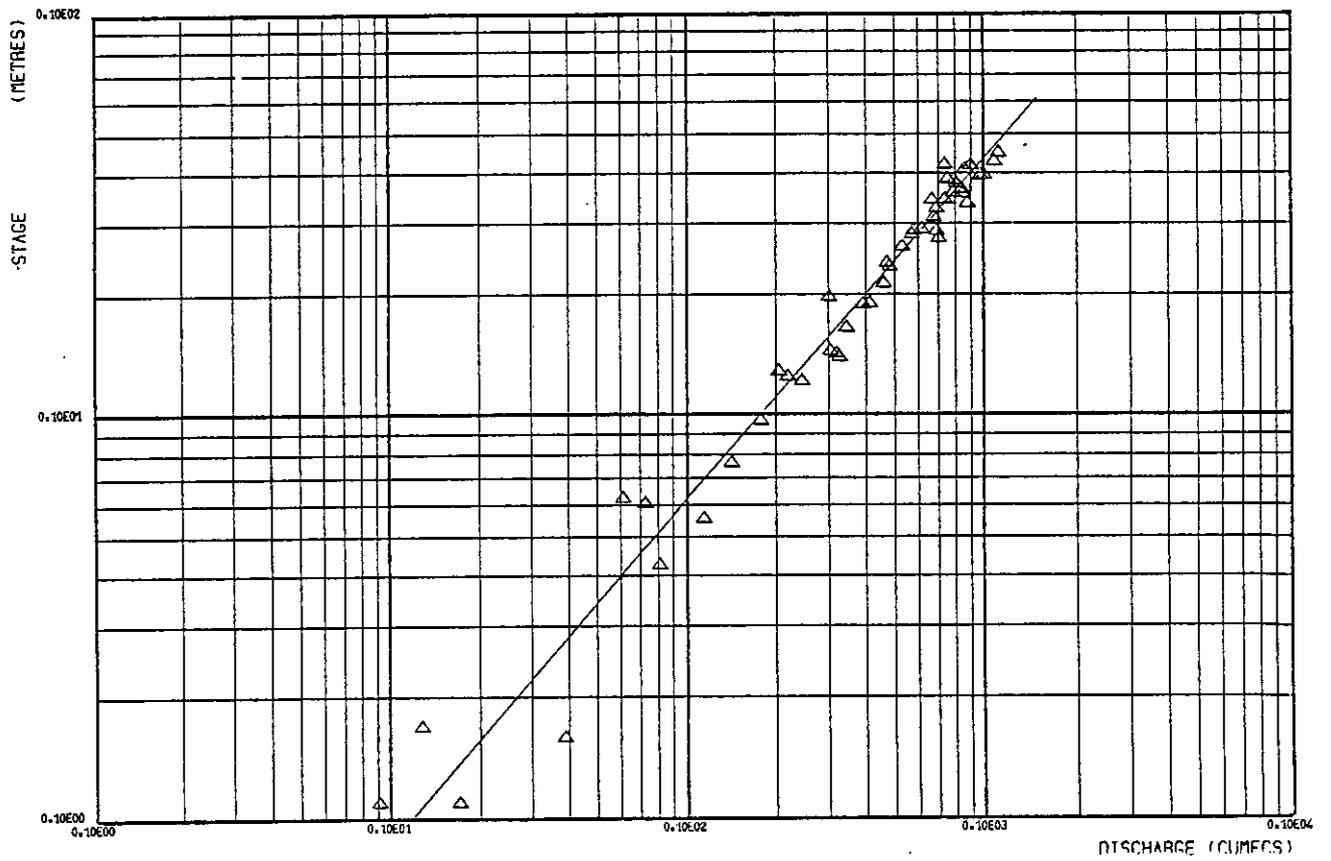
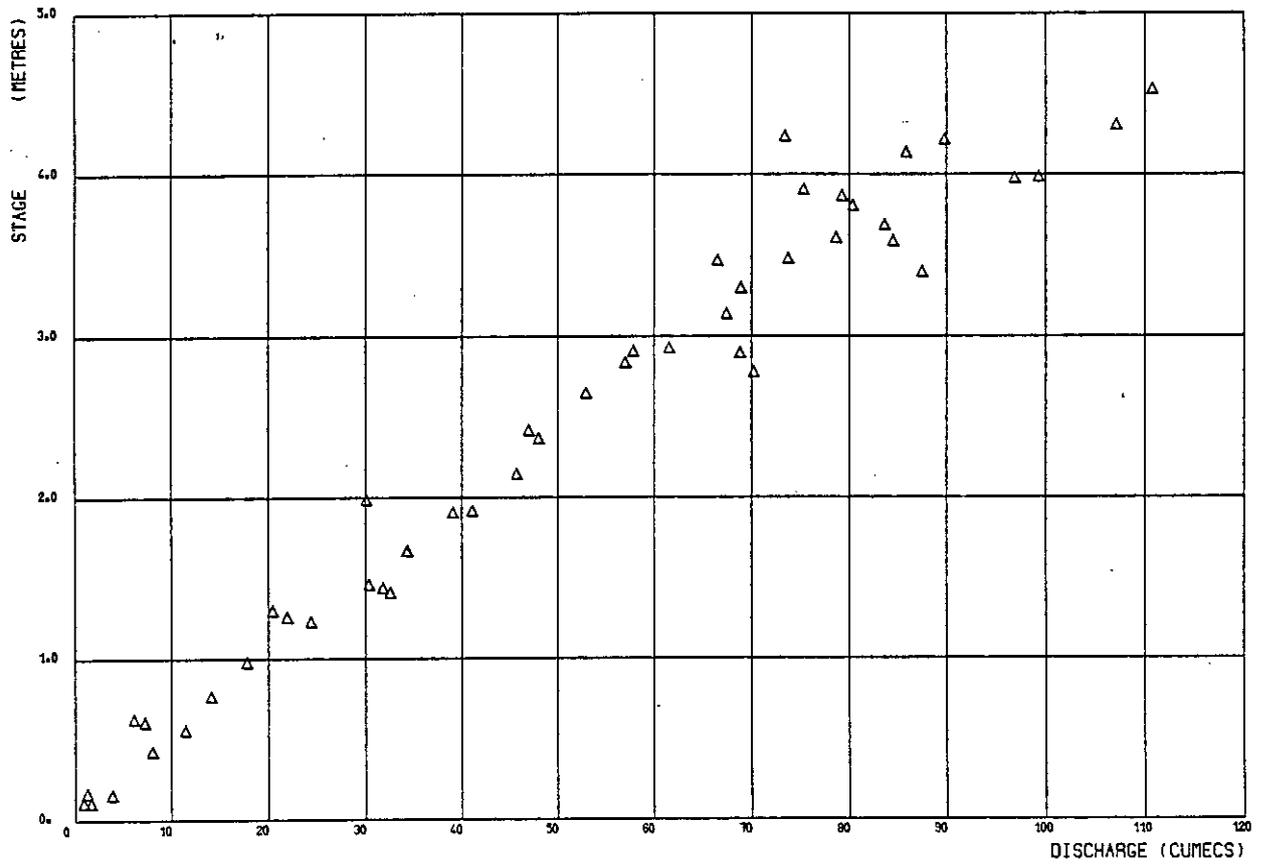
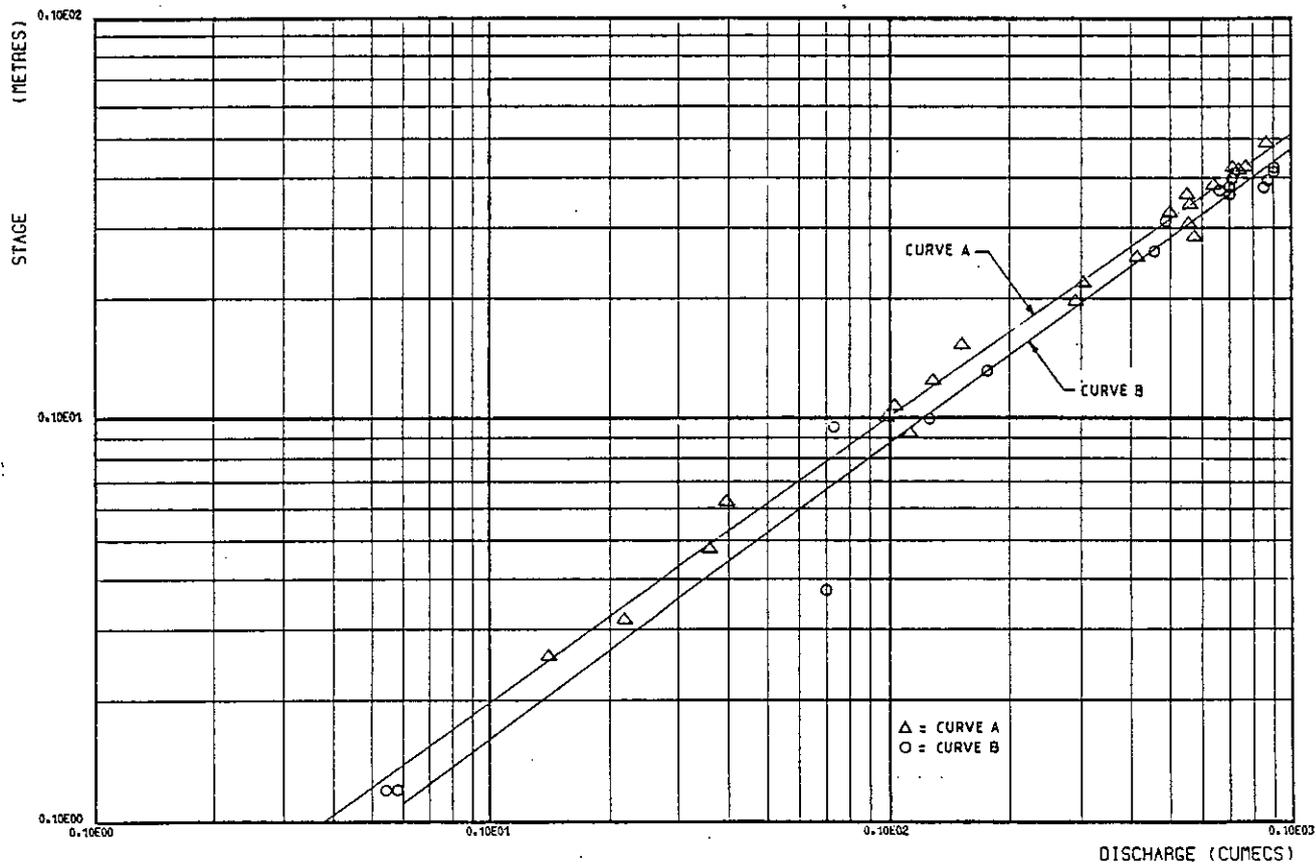
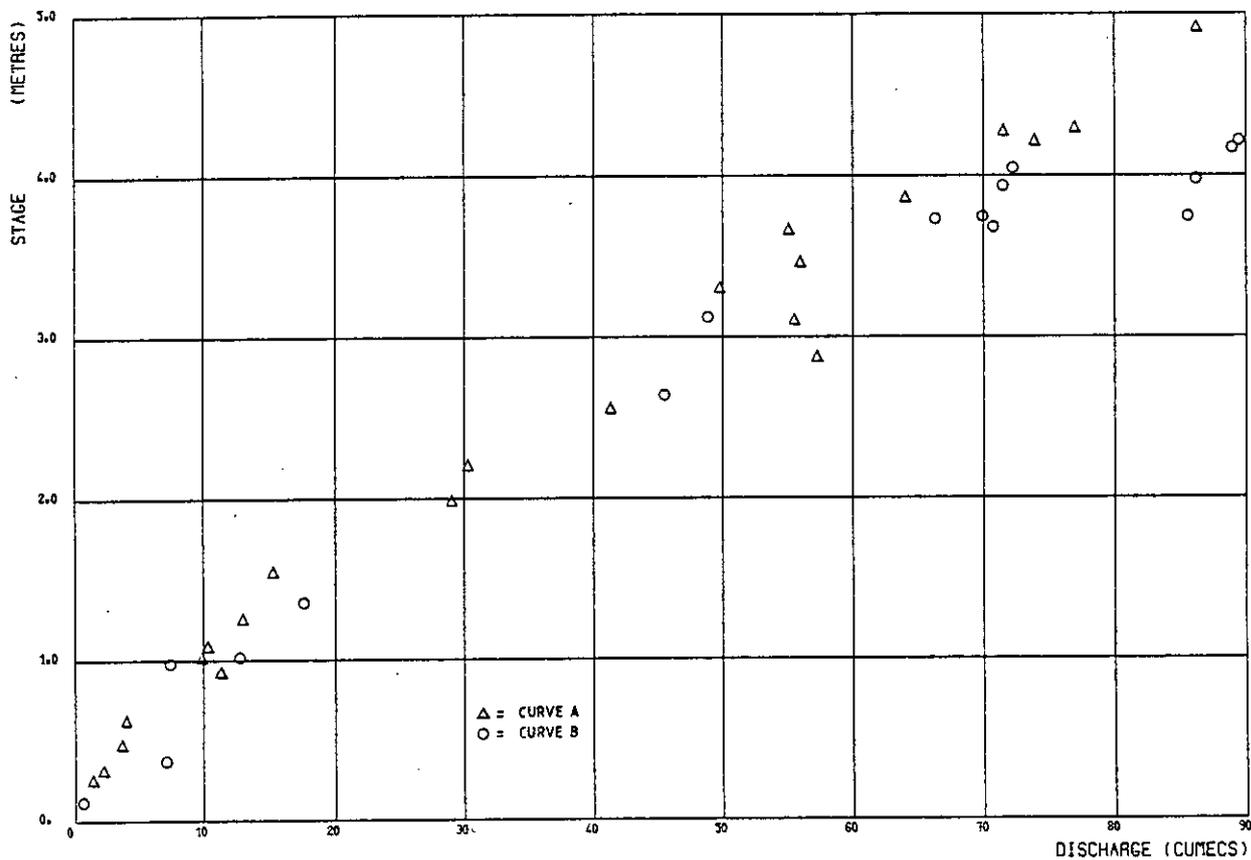


Figure 2.16

Rating Curve - River Shebelli at Audegle



- The gauge-zero in use was sometimes not indicated or altered and there were few logs kept of changes in gauge-zero when new staff-gauge plates or stands were installed.
- Overlaps of staff-gauge plates had to be accounted for.
- Inconsistencies occurred between staff-gauge readings and check dippings from MB datum points; staff-gauge readings were generally preferred to MB data; MB dippings were frequently taken using shortened tapes with the length of missing tape not noted on the observer's returns.
- Recorder or dip data in stilling-wells were used even when inlet pipes were blocked; no records were kept of when silt was last cleared.
- The end of one month's or year's data often failed to match the beginning of the following month indicating error or fabrication of data.
- Long periods of data were fabricated by observers; some cases were spotted and excluded from the database, others may have been missed and further checks will be required using cross-station correlation techniques.

Stage data entered on to the computer were subjected to various quality control tests before acceptance, and a constant could be added to each reading for correcting systematic errors or to adjust for changes in gauge-zero. At the end of each session of entering or editing data, the results were written to the computer disk for permanent storage using the 'save' command.

Further checking of the data is required before the data can be considered to have been fully validated. Some new errors will certainly have been introduced due to typing errors and these will only be identified when the original records are checked against the monthly summary printouts; this was not done during the project due to lack of time, mainly due to the fact that operating the printer tied up the computer for long periods, when it was also required for data entry.

Once the entire record available for a station had been entered on to the computer database, the conversion of stage to discharge was carried out using one of the menu options. The program enabled one year's data to be converted at a time, using the appropriate rating stored on the database; the computed mean-daily flows for that year were then 'saved' on to the computer disk for permanent storage.

It is at this stage in the procedure that the first complete summary of river stage and flow would be printed out. Following inspection of the printed results and comparison with original data, errors and gaps can be detected. The computed flow data can be edited or short gaps in the record filled; up to a five day gap can be filled using a logarithmic interpolation technique and individual flow values can be inserted if necessary. Any data infilled in this way are flagged with an 'f' on both the screen and the printouts.

Although there was insufficient time available to carry out the procedure just described, it was possible, however, to obtain annual summary printouts of all the data entered on to the computer. These data must be regarded as unvalidated until further checks have been made.

The long process of producing the full set of monthly summary printouts for each station had already begun as the project ended. This should be completed by the counterpart staff, but was expected to take at least two weeks.

2.5 Availability and Quality of Records

(i) Data Continuity

None of the stations in the hydrometric network has a continuous stage or flow record. Statistical analysis of data for flood or drought frequency would not therefore be valid unless the important gaps in the records, perhaps of several years' duration, are synthetically filled. This has not been attempted during this project but should be considered in the near future and is feasible using computerised modelling techniques.

A bar chart of all the stage and river flow data available for the primary stations in the hydrometric network is shown in Figure 2.17. The most complete record covers the period of the FAO/Lockwood study, when the present network was first established. Undoubtedly more resources were employed for that study than have since been available to the hydrology section in Somalia. The poorest part of the records is clearly the mid-seventies when there was little or no expert assistance based in the section, although the influence of the Fanoole project studies is reflected by reasonable returns for Lugh Ganana and Jamamme for some of the period. The loss of record is generally due to:

- (a) absences of the observer;
- (b) missing staff-gauge plates or loss of measuring tapes for MBs;
- (c) fabrication of data by the observer.

Copies of returns are always kept by the observer and data lost in the post can usually be recovered on the next visit.

The return of data improved in 1980/81 during the FAO Hydrometry project, but deteriorated again in 1982/83 when commitment to hydrological work reduced. However, the record entered on to the computer for 1980/81 does not represent a 100% return of data, since some of the record was synthesized using spot checks and station correlations. The 1984 log shows considerable improvements in data return (78%) compared with the two preceding years of 1982 (75%) and 1983 (60%), see Figures 2.7 and 2.8. This level of return will only be maintained, and hopefully improved further, if expert assistance to the section is continued in the foreseeable future.

(ii) Data Quality

The quality of data within the stage and flow records is as important as its continuity. The occasional fabrication of data has already been noted and where possible suspect records have been excluded from the database. The remaining stage data are not of consistently high quality, and although ratings are generally satisfactory, the computed mean daily discharges are only as good as the accuracy and time distribution of stage data. Some of the many problems associated with the staff-gauge/observer system of data collection have already been outlined and these only serve to compound the inherent human error of reading a graduated gauge from some distance away; this would typically be +/- 2 to 5 cm depending on the position, type and condition of gauge.

A more accurate measurement of stage can usually be made using proper water level dipper instruments from MB datum points on bridges, although high winds do sometimes make it impossible to take accurate readings. Many of the stage

records have been calculated from MB readings in the past using tape measures with weights tied on the end, but this method is error prone if corrections are not made for the attachments; in addition the tapes frequently broke and observers often failed to report this shortening of the tape.

The Progress Report suggested that immediate improvements in data quality could be obtained if MB dip measurements were taken by observers, as well as staff-gauge readings. Two instruments initially ordered for the project proved to be unsuitable, since they were only graduated at every metre and observers found it difficult to use short lengths of tape measure for determining readings in between metre markings.

The most significant improvements in data quality can be expected when the new automatic water level recorders are installed; the new shaft-encoder sensors ordered are capable of producing a measuring resolution of 1 mm, but will actually be set to record changes in level of 1 cm.

The accuracy of the computed discharge data is not only dependent on the quality of stage readings, but also on how good the channel rating is and on the frequency of sampling of points on the continuous time series of the discharge hydrograph.

It has already been noted that the stage-discharge ratings derived were considered to be satisfactory for medium to high flows, although multi-segment rating curves may improve the fit at some stations. Because of the relatively poor rating at Bardheere, the computed record of flows will not be of the same quality as at Lugh Ganana or Jamamme, which have much better ratings. This should be clearly recognised when Bardheere data are used for the design of the proposed dam on the middle Juba. Low flows are generally not accurately gauged since the continually shifting beds never allow stable ratings to become established. This is illustrated by studying the list of gaugings carried out during the project (see Table 2.1), in which the measured discharge is compared with that computed using the appropriate station rating. Some of the low flows measured, indicate that the ratings can be in error by more than 100% in the lower ranges. Given the conditions in Somalia, it is impossible to take DMs regularly enough to enable new low flow ratings to be derived for every season, and thus errors of this order of magnitude must be accepted and understood.

Further errors in the computation of mean-daily flows are introduced by inadequate sampling of the runoff hydrograph. Two or even three readings per day of stage is barely adequate for representing a continuous hydrograph, especially with an approaching flood wave when levels may rise more than 1 m in a few hours. Hourly measurements of stage would provide much improved sampling of the time-series, and this will be achievable when the new automatic water level recorders are installed.

TABLE 2.1

Discharge Measurements Taken During the Project

Date	Station	Method	Gauge height (m)	Velocity (m/s)	Area (m ²)	Q _m (measured flow) (m ³ /s)	Q _{sd} (stage/discharge curve flow) (m ³ /s)	% Error (100-Q _{sd} /Q _m)
14.03.84	Lugh Ganana	WA	1.10	0.41	29.24	11.99	13.03	8.70
11.12.84	Lugh Ganana	BR	1.60	0.30	140.44	41.81	53.74	28.50
12.03.84	Bardheere	WA	0.29	0.26	40.93	10.77	25.30	134.80
10.12.84	Bardheere	BR	0.78	0.23	225.48	50.67	67.53	33.30
08.02.84 *	Jamamme	BR	1.25	0.39	51.66	20.26	27.92	37.80
04.04.84	Jamamme	BR		No flow in river - Fanoole weir closed				
13.06.84	Jamamme	BR	1.92	0.67	98.68	65.76	56.23	-14.50
31.10.84	Jamamme	BR		Not completed - suspension cable failed				
04.04.84	Kamsuma	BR		No flow in river - Fanoole weir closed				
13.06.84	Kamsuma	BR	0.02**	0.44	148.00	65.63	-	-
30.10.84	Kamsuma	BR	5.62**	0.87	303.30	264.98	-	-
22.03.84	Belet Weyn	WA	0.41	0.58	20.45	11.95	11.73	-1.80
28.06.84	Belet Weyn	BR	0.85	0.66	52.25	34.45	28.46	-17.00
26.08.84 *	Belet Weyn	BR	2.14	1.36	86.84	118.16	106.13	-10.20
21.03.84	Bulo Burti	WA	1.13	0.46	24.33	11.25	7.00	-37.80
27.06.84	Bulo Burti	BR	1.85	0.86	43.35	37.31	26.63	-28.60
16.04.84	Mahaddei Weyn	BR	1.36	0.34	31.47	10.80	10.55	-2.30
05.07.84 *	Mahaddei Weyn	BR		Not completed - faulty meter				
18.07.84	Mahaddei Weyn	BR		Not completed - data lost in river				
12.12.83	Afgoi	BR	3.73	0.65	88.11	56.99	60.13	5.50
19.02.84 *	Afgoi	BR	2.15	0.62	35.49	21.92	23.12	5.50
18.06.84	Afgoi	BR	4.19	0.66	104.43	68.94	71.74	4.10
06.08.84 *	Afgoi	BR	4.36	0.62	108.63	67.11	76.11	13.40
20.12.84 **	Afgoi	BR	1.31	0.17	11.20	1.87	6.35	239.80
16.10.84 \$	Audegle	BO	4.88	0.66	100.98	66.18	71.13	7.50

Total number of gaugings attempted = 25

- Notes:
- * Gaugings carried out by counterparts without supervision.
 - + Water depths too small for accurate gauging from bridge.
 - \$ Single point measurement (normal practice two point).
 - ** MB dip reading not gauge height.
 - BR Winch suspension from bridge.
 - BO Winch suspension from boat.
 - WA Low flow wading.

CHAPTER 3

PROJECT ACTIVITIES, FIELDWORK

3.1 General Approach to Fieldwork

The geographical location of most of the stations, in relation to Mogadishu, is such that useful fieldwork can be achieved without overnight stays at only three of the stations, Audegle, Afgoi and Mahaddei Weyn, all about 2 hours drive away. Fieldwork was often carried out at these stations on an 'ad hoc' basis at short notice. Most of the other more remote stations had to be visited during well organised field trips, in which a number of different tasks were tackled at more than one site. A great deal of equipment had to be packed into the Land Rover, including petrol and spare wheels, to ensure that all eventualities were catered for. Much of the time spent away on field trips was unproductive driving time.

The work required during visits to stations in the network included one or more of the following activities.

- (a) Data Collection - Staff gauge and bridge dip (MB) check readings were taken and observer's completed data cards collected, with new cards supplied; observers were trained or given new instructions if required; charts on recorders were changed.
- (b) Station Maintenance - The conditions of staff-gauge plates and stands was inspected, with missing plates replaced if water-level conditions allowed; silt was removed from the base of staff-gauge stands whenever possible; accumulated silt in stilling wells and inlet pipes was cleared by flushing out with river water, or if necessary manually dug out; recorders were checked, their clocks wound and ink reservoirs topped up.
- (c) Flow Gauging - The measurement of river discharge using a current-meter with velocity-area methods was one of the main objectives of every trip; normally the gauging was from a bridge, but at very low flows, it was sometimes possible to wade across the river at a suitable section, using the current-meter on rods.
- (d) Check Levelling - Routine checks were made of gauge-zero levels, or MB datum points, especially when new plates were fitted or new datums established, using local bench marks.

A total of twelve field trips was undertaken, which involved staying one or more nights away from Mogadishu, equally divided between the most remote destinations of:

- (i) Belet Weyn on the upper Shebelli;
- (ii) Lugh Ganana and Bardheere on the upper Juba; and
- (iii) Jamamme and Kamsuma on the lower Juba;

other stations were visited en route. Numerous other one-day trips were made to the other stations on the network. Most of the fieldwork was supervised by the MMP hydrologist. The amount of fieldwork achieved was significantly less than

was originally intended, as various constraints forced the fieldwork element of the project to be curtailed. These include:

- Lack of continuity in staff availability and training meant that it was not possible to establish a team with sufficient experience to be able to undertake long field trips without supervision. It was considered more important for the MMP hydrologist to concentrate on the data processing workload.
- A petrol supply crisis developed in June, which got progressively worse until the end of December, when local petrol became virtually unobtainable.
- Problems with the gauging equipment reduced the opportunities for taking measurements during November and December.

3.2 The State of the Network - Rehabilitation and Maintenance

Many of the gauging stations had deteriorated due to lack of maintenance since 1981. Initial maintenance work concentrated on the Shebelli stations, where several problems had been identified during the first fact-finding trip in November/December 1983. The stations on the river Juba were first visited in early March 1984. The initial state of each station and the nature of maintenance work carried out, are described below with reference to each site.

3.2.1 The River Shebelli Network

(i) Belet Weyn

This station is at the top of the catchment close to the Ethiopian border and about six hours' drive from Mogadishu. It has a long record, dating back to 1951, and because of this and its location it is one of the two most important stations. The staff-gauges were in good condition, although silt had accumulated around the base of the lowest plate obscuring the markings. The observer did not consider that silt removal was part of his duties; the silt was easily cleared with a spade in a few minutes. A Leopold & Stevens A35 strip-chart recorder was in working order, but the stilling-well and inlet pipes were totally blocked up with silt. Most of the silt was removed manually, using local labour. The well was flushed clean successfully on a later trip, using the water pump purchased specifically for such a task. Early in 1984, the original Leopold & Stevens recorder was removed from the instrument hut by the Italian research team studying salinity levels, apparently with permission from someone in the Ministry of Agriculture. It was replaced with a more modern Siap chart recorder. Unfortunately, the provision of a new recorder for this station by the research team did not improve the quality of data, since the major problem of siltation was not tackled. A new stilling-pipe system, attached to one of the bridge abutments, is proposed for this station to overcome this problem.

A new MB datum point was established, since the previous one, established by Gemmell in 1980, could not be located. Check levelling of datums and gauge zeros was carried out for training purposes.

(ii) Bulo Burti

The staff-gauge was discovered to be in poor condition with plates missing in the 1 to 3 m range and 3 to 5 m range; these were replaced in March. Gemmell had altered the original 0 to 6 m range to 1 to 7 m, with the intention of installing a new staff-gauge to avoid negative gauge heights, but none has been installed in the lowest 0 to 1 m range, and river stage never dropped low enough to allow this during the project. Whilst these staff gauges were still missing a water-level dipper was provided so that readings could be continued from a newly established MB point on the bridge. Confusion by the observer over the limits of the range, frequently caused 1 m errors on data cards, but with the readings also available from the MB, these errors were easily spotted.

An old recorder house and stilling-well existed at the station, but had been abandoned by Gemmell following the flooding of May 1981, when the inlet pipes were completely covered by silt. No attempt has been made to locate them during this project.

Routine check levelling of datums and gauge zeros carried out for training purposes and to check replacement gauge-plate positions.

(iii) Mahaddei Weyn

Gauge plates were missing in the 0 to 2 m and 2 to 4 m ranges. New plates were fitted in the 2 to 4 m range, but unfortunately levels never came low enough to allow plates to be refitted in the lowest range. Missing data can however, be computed from correlation with stage readings collected at the Sabuun barrage at the offtake to the Jowhar OSR, offstream storage reservoir, which is just downstream of this gauging station. The 7 cm overlap between the 2 to 4 m and 4 to 6 m staff gauges still remains, and corrections are made when data are returned to the office. There are no recording facilities at this site. A new water-level dipper will be required at this station so that readings can be taken from the MB datum point which was re-established during this project.

(iv) Afgoi

The staff-gauge was in good condition but, due to its position on the support pillar of an old bridge, in an advanced state of collapse; it was difficult to read especially at low stages. Observer errors, mainly due to rounding, are common. In addition, the bridge pillars attract accumulations of debris which obscure staff-gauge plates. Keeping the gauge clear of debris is a hazardous task, since the observer has to climb down the supporting structure with crocodiles lurking below.

A new MB (MB1) was established above the staff gauges. The Italian research team constructed a new recorder installation with a Siap chart recorder and another MB (MB2) was established in the small access into the stilling-pipe below the instrument box. For a period, the observer was provided with a dipper to take MB readings, but this was not successful since the sum of the MB readings and the staff-gauge readings always equalled the same value, which conveniently approximated to the gauge-height of the MB above the staff-gauge zero. It was obviously calculated every time and one was never certain which of the readings was genuine.

(v) Audegle

This is the most downstream station on the Shebelli. The staff-gauge at this station was found in a good state of repair with no maintenance required. The observer proved to be the most diligent of any in the network and checks on the records showed that the accuracy was good, in spite of a confusing staff-gauge range. Unfortunately current-meter gauging from the old bridge was considered too dangerous, due to its collapsed state. The structure, which accumulated large amounts of debris, also caused undesirable velocity distribution around the bridge. A new bridge had recently been constructed a few hundred metres downstream of the old bridge, but due to its Bailey type construction it too was impossible to use for gauging purposes, and so the one gauging attempted was by boat. There is no recording facility at this site and due to the lack of suitable abutments close to the water's edge, there is little possibility of constructing a suitable installation.

3.2.2 The River Juba Network

The three existing stations on the Juba are all in excess of six hours drive away from Mogadishu, with road standards varying enormously. They therefore tend to be visited less often and have recently been the least well maintained. The hydrometric network of the Juba has also become of concern to the Ministry of Juba Valley Development (MJVD), in which a GTZ project was underway for 'Advisory Assistance' in all aspects of water resources development. The project hydrologist K. Jacobi, had surveyed the three stations in 1983. From the outset of this project close co-operation was maintained with Jacobi, particularly with regard to fieldwork.

(i) Lugh Ganana

This is the most inaccessible of all the stations in the network, partly due to a 20 km stretch of road near Lugh which is virtually impassable in the wet season. This station is near to the Ethiopian border at the top of the catchment, and because of its position and a long record, since 1951, it is considered to be one of the two most important stations, particularly for early warning of approaching floods.

The staff gauges were found to be in reasonable condition, although the observer's record had been poor since 1981, with no useful records at all in 1982. The MJVD project had purchased new staff-gauge plates for this station and these were fitted during a joint trip in March 1984. The 0 to 2 m range plates were fixed to a support pillar of the bridge and the original stand was used for the higher range above 2 m, with the maximum stage extended to 7 m using a hardwood extension to the stand. The observer was instructed how to read the new yellow and black gauges with 2 cm graduations. The longstanding 0.22 m overlap between the old staff gauges was thus eliminated. A new MB datum was established on the bridge, as the previous one was above a mud bank when the stage dropped to minimum levels.

The recorder stilling-well was found to be completely silted up and had to be bailed out with a bucket using locally hired labour. The inlet pipes were then flushed out by filling up the well from a hired water-tanker. On later trips the well was successfully cleaned out using the new water pump. However, the inlet pipes had originally been installed, in 1963, at far too high a level relative to gauge-zero and the minimum stage that can be recorded is 1.34 m. In 1984 the gauge-height was below this level for much of the time. A Leopold & Stevens

chart recorder had been reinstalled in March, but problems with the accuracy of the clock prevented any useful data from being extracted from the strip chart. A new stilling-pipe system is to be fixed to one of the pillars which protect the bridge from damage by debris.

(ii) Bardheere

This station is again remote from Mogadishu, taking a full working day to reach. Its strategic importance as a flow gauging station has increased recently due to the possibility that the Bardheere dam, could be constructed in the near future. The station was initially visited early in March 1984. The staff gauges were in poor condition with only the 4 to 6 m stand and plates still in position. The lower gauges were washed away in the flood of May 1981 and have never been replaced, consequently, little useful data had been collected since 1981. The replacment of the staff-gauge was considered by this and the MJVD project to be a priority, so new gauges were fitted to one of the central piers of the bridge during a return visit in March. The gauge-zero established by Gemmell was maintained by the range of the station extended to a maximum stage of 7.0 m. A new MB datum point was established on the upstream face of the bridge just adjacent to the new staff-gauges. Levelling was carried out to check the position of new staff-gauges and datum.

The recorder stilling-well system was silted up but cleared of silt in early March and again in July, using the same methods as at Lugh. However, the recorder was vandalised at some time after the July maintenance visit, and thrown into the stilling-well with the loss of all data. The bridge at this station is ideal for installing a new stilling-pipe system and this is proposed for 1985.

(iii) Jamamme (Arara Bridge)

This station proved to be the most problematic of any in the network. The staff-gauge system completed by Gemmell in 1981 had almost completely been destroyed, or covered with silt. The recorder well was competely silted up, with no trace of the inlet pipes, and had been abandoned by Gemmell in 1981; no attempt was made to rehabilitate it during this project. No useful water-level data had been collected since 1981, although with an MB datum available, bridge dippings could easily have been made to ensure continuity of the record. A dipper instrument was issued to the observer in April, but no useful data were recorded until June. One of the dippers purchased specially by the project for use from MB datum points proved to be totally unsuitable, since the only markings on the cable were at metre interals. In trying the measure the levels between metre markings the observer frequently made mistakes, and the resulting data were sometimes very difficult to interpret. An alternative instrument was supplied to the observer. Suspect data were later validated by correlation with a new station at Mogambo (see below), so that an adjusted record could be obtained for 1984.

Levelling was carried out at this site to establish a new MB and to attempt to confirm the relative levels of different gauge-zeros used since 1967. By using historical notes found on files, it was possible to identify bench marks used during different periods and to relate them to each other. Previously it had been thought that datums and gauge-zeros of old staff-gauges used in the Russian period of the 1970s, could not be related to those used by the FAO Lockwood study of the gauges levelled by Gemmell, which were only related to a TBM with no mean sea level value provided.

3.3 Inspection of Potential New Stations

The ever increasing demand for water abstraction from the rivers, particularly for irrigation schemes in the lower reaches of both the Shebelle and Juba rivers, has put severe pressures on the water resources at critical periods, mainly before the arrival of the gu floods at the beginning of the year. In view of this and the undoubted need for improved monitoring and control of water resources, extensions to the hydrometric network were considered desirable. During the project, potential sites for new primary flood level gauging stations have been visited at the following locations:

(a) Kamsuma, Lower Juba

This was the location of a station during the early 1970s when the Fanoole project was underway, but no data have been recorded since 1976. Due to the need for a recording station on the lower Juba to improve data quality, Kamsuma was selected as the most appropriate site. Arara bridge at Jamamme is not suitable for fixing stilling-pipes since there are no mid-channel bridge pillars, or abutments close to the water's edge. The Kamsuma station would be much better in this respect.

It is much easier to take gaugings by the bridge suspension method from Kamsuma than it is from Jamamme. Similarly, new staff-gauges can be more easily installed at this station. The data collected from Jamamme has traditionally been of lower quality than other stations.

A reasonable rating has already been derived from historical records by Jacobi, so that acceptable discharge results could be computed from stage data as soon as observation begins.

(b) Mogambo, Lower Juba

This station was actually established, with data cards being returned, during the project. The MMP staff supervising the construction of the Mogambo Irrigation Project, based some 18 km upstream of Arara bridge, has been taking occasional stage readings for some time using levelling equipment.

Because of the problems of obtaining good data from Jamamme, the MMP staff were requested in October, to start taking regular stage readings. Temporary staff-gauges were established in December 1984, prior to the construction of the scheme pumping station due for completion in the first half year of 1985, when permanent staff-gauge plates were to be installed.

(c) Bu'aale, Middle Juba

This site was visited with Jacobi in March, and is located some distance upstream of the Fanoole weir, well above any backwater influences. It is a good location for flood warning and for overall water resources management of the lower Juba. However, it is remote, with no all-weather roads leading to it. This would make regular visits for maintenance and current-meter gauging very difficult in the rainy seasons when the roads become impassable. The bridge at this site is

suitable for fixing a stilling-pipe, and if an automatic water-level recorder, capable of operating unattended for three months, was installed then reliable data collection would be feasible, and the maintenance requirements for staff-gauges less important.

(d) Kurten Warey, Lower Shebelli

This site is below most of the major water abstractions in the Shebelli, and upstream of the area of the swamp into which the river is absorbed. It would therefore be a good location for measuring the effect of water use and river bed recharge losses below Audegle. There is no bridge at this site, but a recently constructed barrage has a long stilling basin immediately downstream, at the end of which a support structure for a stilling pipe could be installed near the concrete revetment. The construction of this station is considered a priority and a new automatic recorder has been purchased in anticipation.

Other sites on the lower Shebelli, at Genale and Haway, are being used by the Italian salinity research team, but these are unrated sections and are not under the control of the MOA.

3.4 Current-Meter Gauging Network

The main activity during field trips was the measurement of river discharge by velocity-area methods using the two Braystoke meters purchased for the project. The gaugings were important for checking the validity and stability of stage-discharge relationships, but were also particularly useful exercises for providing general training in hydrological field practices.

Measurements were taken either by suspending the current-meter from a bridge and on one occasion a boat, or by wading across a suitable section. With the suspension method the new Braystoke meters had to be used with the existing Ott winch. However, the electrical connections between the meter and the winch cable were incompatible and for most of the time it was necessary to use two cables during each gauging, one for supporting the equipment and one for carrying the signal pulses. This system, although cumbersome to use, worked reasonably well until the Ott cable became damaged and unusable; temporary electrical connections were then made so that the Braystoke cable could be used by itself on the winch drum for supporting the equipment. This proved satisfactory for use with the smallest sinker weight available (10 kg), but when a 25 kg weight had to be used to maintain verticality during higher flow/velocity conditions at Jamamme in October, the cable stretched and failed. Luckily, the equipment was retrieved before the cable broke completely. The manufacturers had claimed that the breaking strain of the cable was in excess of 100 kg. A replacement cable was purchased from the UK, but this was of the same type that had failed and only usable with the smaller sinker weight. The gauging programme was therefore halted until December when flows had dropped sufficiently to allow the 10 kg sinker weight to be used again. The technique of measuring the angle of deflection of the suspension cable from the vertical and making corrections to the data was considered but was felt to be impracticable; the drag on the equipment with the 10 kg weight was too great to allow reasonable corrections to be made and staff would not have adopted the method easily.

Apart from the problems with the suspension cable, the performance of the new Braystoke current-meters was satisfactory, although one of the electronic pulse counter/timer units started to malfunction in December and was returned to the UK for repair.

A new suspension winch and rig for gauging work with the Braystoke meters were ordered in October, but had not arrived by the end of the 1984 project input.

The majority of the 25 gaugings performed during the project were from bridges. At Audegle, where the bridge suspension method was impossible, one measurement was carried out using an inflatable boat. This proved to be an extremely hazardous operation, since the craft was very difficult to control in the swift currents with hippopotami close by, and some counterparts were non-swimmers with no previous boat-handling experience; it was not attempted again. During the minimum flow period in March, gaugings were taken by wading with the current-meter on rods at Lugh Ganana, Bardheere, Belet Weyn and Bulo Burti. In all the gaugings, a standard two point velocity measurement (at 0.2 and 0.8 x depth) method was adopted.

A full list of the results from all the discharge measurements taken during the project is presented as Table 2.1. This list records a significant number of failed attempts owing to various misfortunes. The discharges measured cover only the low and medium flow ranges, since there were very few opportunities for measuring higher flows at any of the stations. The lack of major flood runoff events in both the gu and der seasons, the unavailability and inexperience of assistant staff at certain times throughout the project period, and also the failure of equipment during the der season were all important factors accounting for the absence of peak discharge measurements.

3.5 Performance of Other Field Equipment

The Land Rover station wagon provided for the project was totally reliable except for the inevitable punctures, and provided the ideal workhorse for carrying personnel and equipment on field trips.

Existing MOA hydrometric equipment available at the start of the project was generally not in good condition. Some useful old equipment such as current-meters, suspension winches, recorder, water-level dippers and levelling instruments existed, but much of it was unserviceable. Some items which were repairable, such as an Ott electronic current-meter counter and an automatic quick-set level base, were returned to the UK for repair.

The water pump proved very useful for flushing out silt from the old stilling-well installations.

The electric drill provided for maintenance work was used at several sites for fixing new staff-gauge plates, although drill bits tended to wear out very quickly through gauge stands made of 10 mm thick RSJs.

Two water-level dippers purchased for checking river levels from MB datum points were not suitable, due to inadequate graduations and markings.

Additional current-meter equipment, and a sediment sampling device, was purchased by the MJVD project and made available, on a permanent basis, to the Hydrology section of the MOA, although this equipment has not yet been used.

CHAPTER 4

CONCLUSIONS AND FURTHER WORK

4.1 Concluding Remarks

The first stage of the hydrometry project has successfully been completed within the originally proposed period, and it is hoped that a further extension of the project will enable the work to continue into 1985/86.

The main achievement of this project has been the establishment of a computer database, which now contains all the available river stage and discharge data for the eight gauging stations currently operated on the Juba and Shebelle rivers. Original and processed data can be retrieved from the database and either inspected on a VDU screen or printed out in summary report form. It has not been possible to fully check and validate the data now archived on computer during this stage of the project, so the record should be regarded as provisional for the time being.

Data collection practices in the field and manual office procedures have been revised to interact with the new computer based data processing system. Field-work activities included rehabilitation of flow gauging stations and regular current-meter measurements for checking new rating curves developed during the project. The general quality and return of data from staff-gauge observers improved considerably during 1984 compared with previous years, but further improvements are still required.

Some progress was made in training counterpart staff, although the project would benefit from the recruitment of more qualified staff.

4.2 Proposed Project Extension

Midway through the project it became clear that the original objectives would not be achieved in the time available and important new areas of work had also been identified, which required further attention. The Somali Government therefore formally requested that the project be continued. A programme of work for 1985/86 was submitted to ODA for consideration and the proposal for this extension to the project was being processed.

The first stage of the project, now completed, concentrated on the hydrometry of the Juba and Shebelle rivers, but the emphasis on the next phase of the project will be placed more on the hydrological analysis of the data together with improving the quality and reliability of the returns. The work of the Hydrology section will therefore be expanded in scope and the training and interest for the staff broadened.

The proposed extension period from January 1985 to July 1986 will be structured in a similar way to the thirteen month period just completed, with a series of short two to three months inputs in Somalia over an eighteen month period. The programme of work submitted (which is reproduced as Figure 4.1) comprises a total input of 21.5 man-months, most of which will again be undertaken by the MMP hydrologist and the IOH programmer. Some specific areas of work that should be incorporated into the new programme are listed below.

Figure 4.1

Proposed Extension Programme of Work

	1985												1986				MAN - MONTHS							
	MINIMUM FLOW						GU FLOODS						DER FLOODS				MINIMUM FLOW				GU FLOODS			
	J	F	M	A	M	J	J	J	A	S	O	N	D	J	F	M	A	M	J	SOM.	U.K.			
Resident Representative (MMPL)	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	4	0				
Hydrologist/Programmer (IH)	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	3.25	4				
Hydrologist (MMPL)	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	8	1.5				
Associate (MMPL)	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	0	.5				
Draughtsman (MMPL)	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█	0	.25				
																	15.25	6.25						

SOMALIA U.K.
 CONTINUOUS █
 INTERMITTENT - - -

TOTAL : 21.5

- (a) The new automatic water-level recording facilities should be installed as soon as is practicably possible. (See Appendix III for further details of these proposals.)
- (b) The entire record now on the computer database should be subjected to a rigorous error-checking procedure so that typing mistakes are corrected. Each station's record should then be validated using cross-station correlation techniques on computer, with suspect parts of the record identified for further examination.
- (c) The data for secondary flow gauging stations currently operated should also be entered on to the database, together with historic data from old stations not now in use. These stations are:

Secondary stations :

- (1) Several staff-gauges at the Jowhar OSR on the river Shebilli operated by MOA.
- (2) Mareerey on the river Juba operated by Juba Sugar Project.

Old stations :

- (1) Balcad, river Shebilli
- (2) Kaitoi, river Juba
- (3) Kamsuma, river Juba - to be rehabilitated as a primary station.

Most of the data available for secondary stations on the river Juba have already been examined and analysed in detail by K. Jacobi, the consultant hydrologist with the GTZ project in the MJVD. It would be cost effective if these data could be directly transferred from their computer on to the MAO database system, using a suitable interface. The adoption of stage-discharge rating curves, also developed by Jacobi for these stations, should be considered.

- (d) The existing hydrometric network should be extended to improve monitoring of resources in certain reaches of the two rivers. On the lower Juba the new staff-gauges at the Mogambo Irrigation scheme abstraction point should be incorporated into the network, in view of the problems associated with Jamamme, with both locations regarded perhaps as secondary stations. The proposed rehabilitation of the station at Kamsuma with the installation of automatic recording facilities would ensure that a high quality of record is produced and therefore this location should become the primary station for the lower Juba. On the middle Juba further consideration should be given to establishing a new flow gauging station at Bu'aale, perhaps with automatic recording facilities.

The lower reaches of the Shebilli river are not well monitored and the establishment of a new station with automatic recorder at Kurten Warey would greatly improve this situation. If the new logger/shaft-encoder system in stilling-pipes proves to be a success, then consideration should be given to equipping the stations at Bulo Burti, Mahaddei Weyn, Afgoi and Audegle with the same facilities.

- (e) Further development of the computer system is suggested involving upgrading the Comart machine, the provision of a graphics plotter and improvements to the software; new routines will be written to facilitate screen and plotter graphic displays, the derivation of multi-segment rating curves, and the processing of data from the new solid state loggers. The database will also be extended to include daily rainfall data.

New programs are also proposed to facilitate analysis of data on the computer, to include flood and drought frequency analysis and the development of a river flow forecasting model.

Before the start of the next stage of the project the Comart computer system should be shipped back to the UK so that it can be fully serviced and upgraded.

- (f) Further consideration should be given to providing an improved working environment for the computer and its operators, by the purchase and installation of an air-conditioner unit. This would increase the reliability of the computer system by the elimination of dust and heat problems.
- (g) A preliminary assessment of the water resources of the ephemeral rivers of the northern regions of Somalia, will be undertaken during a two week field survey trip in mid-1985.

REFERENCES

- | | | |
|--|-------|--|
| Agrar-und Hydro-
technik GmbH | 1984 | Advisory Assistance to the Ministry of Juba Valley Development, Hydrology of the Juba River. |
| Gemmell, B.A.P. | 1982 | Hydrological Data Collection and Upgrading of the National Hydrometric Network on the Juba and Shebelli rivers, also the in-service training of the field operational staff. |
| Institute of
Hydrology | 1984a | Hydrometry for Somalia, Report and Recommendations by C.S. Green, July. |
| Institute of
Hydrology | 1984b | Computer System and Hydrological Database, Version MG1.1, September. |
| Lockwood Survey
Corporation Ltd. | 1966 | Agricultural and Water Survey for the Somali Republic, Volume 2, Water Resources, June. |
| Sir M. MacDonald
& Partners | 1969 | Project for the Water Control and Management of the Shebelli River, Volume 4, Water Resources and Engineering, November. |
| Sir M. MacDonald
& Partners with
Institute of
Hydrology | 1984 | Progress Report on ODA Hydrometry Project, Somalia, February. |
| Selchozpromexport | 1973 | Headworks on the River Juba. |

APPENDIX I

INSTITUTE OF HYDROLOGY

REPORTS

1. Hydrometry for Somalia.
Report and Recommendations. C.S. Green, IOH, July, 1984.
2. Computer System and Hydrological Database Version MG1.1,
IOH, September, 1984.

Hydrometry for Somalia
Report and Recommendations

July 1984

Hydrometry for Somalia

Report and Recommendations

C.S. Green

Institute of Hydrology
WALLINGFORD
Oxon
UK.

July, 1984

Contents

1. Introduction
2. Work undertaken
 - 2.1 The computer and its installation
 - 2.2 Software developed
 - 2.3 Training of staff
3. Future work
4. Recommendations

1. Introduction

This report firstly summarizes the work carried out by the Institute of Hydrology for the Hydrometry Project in Somalia. Secondly, recommendations are presented which are considered necessary to ensure the benefits of this project to Somalia are not lost.

The part of the overall Hydrometry project in Somalia which involved the Institute of Hydrology was the provision of a micro-computer based hydrological data storage and processing system. The system was developed in the UK and installed in the offices of the Ministry of Agriculture in Mogadishu, Somalia.

The work was carried out by the Institute of Hydrology over the period December 1983 to May 1984 and allowed for 6 weeks software development time in the UK followed by 2 months installation, training and further software development in Somalia.

The system was designed to store basic river level data recorded in the field, apply quality control checks as data are entered into the computer data base and process this data to obtain mean daily flows and certain monthly and annual statistics.

The benefits of this work were seen as:

- (1) To ensure that all surface water data in Somalia are processed to a higher standard, both historic data and data yet to arrive. This will be of benefit to any future water related projects in Somalia.
- (2) To apply quality control checks to the data before being stored.
- (3) To avoid computational errors and tedium associated with manual processing of stage data to daily, monthly and annual flows.

- (4) To free local staff from the mundane data processing chores to enable them to concentrate on more important aspects of hydrological analyses.
- (5) To form a database upon which hydrological analysis might be undertaken at a later date by the Ministry staff.
- (6) To introduce Ministry of Agriculture staff to the idea of working with computers which will be of benefit to them and the Ministry in the years to come.

2. Work undertaken

2.1 The computer and its installation

The computer chosen for this project was a Comart Communicator CP500. The reasons for this were as follows:

- (1) It was a British made machine, sturdily constructed, government approved and tested for a number of years on the market.
- (2) An integral hard disc unit for storing of programs and data was standard on this machine. The hot and dusty conditions encountered overseas and especially in Somalia would severely test the reliability of a floppy disc system.
- (3) Service facilities are available in neighbouring Kenya by the Nairobi Comart agent.
- (4) The machine's modular construction and design philosophy permits upgrade at a later date without the need to purchase a new machine.
- (5) The machine operates under a well known operating system, CP/M.

Attached to the Comart CP500 is a Cifer 2841 terminal and Epson MX100 printer. The Cifer 2841 is a relatively inexpensive British made terminal, having the ability to display either text or graphic information. The Epson MX100 is a low cost printer sold worldwide.

The three items of computer equipment were connected to the Power Bank 500 Uninterruptible power supply. This item of equipment was purchased to provide a steady voltage to the computer and provide a few minutes battery back up in the event of failure of the local supply. This uninterruptible power supply and a subsequent replacement failed to perform satisfactorily in Mogadishu. At the moment the Institute of Hydrology is trying to reclaim the cost of this equipment and purchase another power supply from an alternative manufacturer.

The computer equipment was installed in the offices of the Ministry of Agriculture in Mogadishu. Although a specially portioned area had been constructed the room was considered to be too dusty to secure the satisfactory long term operation of the computer. It is strongly recommended that either the existing room be fitted with an air conditioning unit or the computer moved to a room with an air conditioner. There are two important reasons for this.

- (1) The very dusty environment in Mogadishu means that the computer equipment becomes covered with dust. Over a period of time this will cause failure of the computer. The computer could, however, be isolated from the dust if it were installed in an air conditioned room so that the door and windows could be kept shut.
- (2) The ambient temperature in Mogadishu can be quite high. This causes the equipment to operate at a high temperature. Any problems which might develop as a result of overheating would be reduced by having an air conditioned room.

2.2 Software developed

An existing mainframe database system developed at the Institute of Hydrology was scaled down and installed on the Comart CP500. Interactive facilities were added to assist the operators with entry and validation of data. Interactive graphical facilities were developed to assist in rating curve development. Printed output was designed to be copyable onto A4 or quarto sized paper for report production.

The system installed assumes no detailed knowledge of the workings of the computer, the computer operating system, or the storage of data on computer files. As such it will hopefully allow the user to concentrate on the task in hand and not have to worry about the complexities of the computer in order to carry out his or her job.

A full description of the software and its operation is given in the report 'Institute of Hydrology Hydrological Data Base' which is currently being written.

2.3 Training of staff

During the 2 months in Somalia a considerable amount of time was spent training local staff in the care and use of the computer. The importance of keeping the equipment clean was stressed. Instruction was given on all aspects of the operation of the data base system.

Data entry for one of the nine gauging stations operated by the Ministry of Agriculture was completed by local counterpart staff, a rating curve developed and the entire staff gauge records from 1951 to 1983 converted to daily flows. The complete processing of this one station under supervision, both tested the software and also enabled local staff to gain an understanding of the full system.

The remaining historic data should be on the system by the end of the project and assistance can be provided in the event of a query or problem by the member of the project remaining in Somalia.

The one unfortunate aspect of the training was that only one of the local staff received instruction in depth on the use of the computer. An obvious danger is that if she were to leave without anyone else being trained on the use of the computer, there would be no one left with sufficient knowledge to run the computer satisfactorily.

There are two reasons why only one counterpart was trained. Firstly there was insufficient time allocated in the project for software development, which meant that this had to be done at the same time as training of staff. The amount of time available for training was therefore not as large as originally intended. Secondly, the poor attendance of local staff meant that they were often unavailable for training.

It is strongly recommended that other members of the Hydrology Section at the Ministry of Agriculture be given training in the use of the computer before the project finishes at the end of the year. This training should be carried out both by the remaining project member in Somalia and the member of staff already trained.

3. Future work

The current hydrometry project for Somalia was intended as a stop gap measure to ensure continuity of hydrological data collection and processing until the proposed UNDP 'Water Centre' project. The UNDP project is designed to coordinate all water resource investigations in Somalia under one umbrella organisation. This project, originally due for 1984/85 has yet to get off the ground.

Previous projects, such as the FAO funded hydrometry project, (1980-1981) have done an excellent job. However at the end of the project an inevitable slow deterioration in hydrometry takes place. Stilling wells become blocked, staff gauge boards lost, gauging equipment and chart records break and trained staff leave for other jobs. This is not entirely the fault of the Ministry of Agriculture. Wages are poor in government service and are insufficient to keep bright, motivated staff when private organisations pay so much more. Obtaining spare parts for the large number of different pieces of hydrological equipment is a virtual impossibility. Equipment remains broken and useless.

The current project is due to finish at the end of this year. If no continuity is provided until the UNDP project starts the same thing will happen again. Equipment, already purchased at considerable expense by ODA, will break and remain unrepaired. Trained staff will leave and the all important continuity of hydrological data upon which Somalia's development is based, will be broken. The Ministry of Agriculture will be left with another set of equipment which cannot be repaired and a slow depletion of trained staff.

If the current project is to be viewed as a success there must be continuation in 1985 and even 1986 if necessary to ensure support until the UNDP 'Water Centre' can get started. Assistance should continue in both the field work and data processing aspects of the current project.

The programme for data processing in 1985 falls into three stages. Firstly a period of program development in the UK. Secondly a short period in Nairobi to service, upgrade the computer and attach the pen plotter. Finally a period of time in Somalia to allow for installation of new programs and further training of local staff.

In order to save subsistence costs it is proposed to develop the new programs in the UK on our home based Comart computer. This work will be undertaken in less time in the UK because of better working conditions and a more reliable power supply. In order that the programs developed will be fully compatible

between both machines an upgrade of the Somali Comart to 16-bit operation is proposed. This will then make both machines effectively the same, thus allowing us to support the machine in Somalia more effectively.

One additional item of equipment is proposed and this is a pen plotter. This is considered essential for both the presentation and viewing of data and data validation purposes. We propose to use the same model of pen plotter as already attached to our UK based Comart. This will again ensure complete compatibility between the two systems and enable programs to be developed in the UK beforehand.

The proposed new software (programs) falls into two categories. The first is improvements to the existing data base system and the second is a set of analysis programs.

The improvements to the existing data base system are listed below:

- (1) To increase the number of discharge measurements per station from 166 to 332. Some stations in Somalia have more than 166, the current limit which adversely affects rating curve development.
- (2) Ability to develop a 3 segment rating curve. At present only a single segment curve can be developed which is not always satisfactory.
- (3) On screen plotting of flow data. (At present it is not possible to plot data in any form - an obvious disadvantage when trying to validate data).
- (4) Plotting programs for the proposed plotter. These are essential for report production, validating data and looking at gaugings and rating curves.
- (5) To allow daily rainfall data to be stored on the system as well as flow data.

(6) To be able to enter data from the proposed new electronic data loggers directly onto the database system.

(7) Program to off load existing data from the database for analysis work or transfer on IBM compatible floppy disc to another computer.

The development time required for this software estimated at 3 months provided the proposed upgrade to the Comart is undertaken.

The second group of programs concern hydrological analysis. It is anticipated that these will be modified versions of existing programs already developed at the Institute of Hydrology. At this stage it is envisaged that they will cover flood analysis and possibly low flow analysis also. Development time for this software is estimated at 1 month.

The upgrade of the Somali Comart , connection of the plotter and full service of the Computer would be undertaken by the local Comart agents in Nairobi. It is estimated that this would be completed in one week under supervision of a project member in Nairobi. The project member will be required not only to supervise this work but also to handle customs clearance of equipment into and out of Nairobi airport.

Six weeks should be allowed for installation of the programs in Mogadishu and for the training of local staff.

The work on program development should start at the beginning of the project (hopefully 1st January 1985) and the visit to Mogadishu timed to coordinate with a return from Mogadishu of the field hydrologist. The field hydrologist would then be able to bring the computer from Mogadishu to Nairobi as accompanied baggage, making customs clearance easier. The computer could then be collected from Nairobi airport by the hydrologist/programmer, ready for the service and upgrade in Nairobi. After this work was complete all the equipment could be taken as accompanied baggage by the hydrologist/programmer to Mogadishu for installation.

Table 1 Estimated cost of project extension

Staff

5 days	PSO project supervision (UK)	712
4 months	SSO program development (UK-5 days/week)	8,164
1 week	SSO travel + computer upgrade (Nairobi)	758
6 weeks	SSO installation + training (Mogadishu)	4,652
		<hr/>
		14,286

Subsistence

1 week	SSO Nairobi (646 K/- per day)	238
6 weeks	SSO Mogadish (998 S/- per day) (see note (3))	914
		<hr/>
		1,152

Travel⁽⁴⁾

1 x Economy return air fare London-Mogadishu	1,126
Excess baggage/Air cargo (Shipment of computer from Mogadishu to Nairobi for upgrade/service and pen plotter to Nairobi and computer paper to Mogadishu)	600
UK travel (to/from airport with equipment)	100
	<hr/>
	1,826

Equipment

Comart upgrade (CP500 to CP1502)	1,045
Service etc. by Nairobi Comart agent	250
Gould DS10 plotter (with pens + paper)	2,235
Fresh supply of consumables for computer (Paper, print ribbons etc.)	200
	<hr/>
	3,730

Contingency

Covering local travel in Nairobi. UK computing + minor recurrent spending	1,000
	<hr/>
Total	21,994

Notes:

(1) All costs are 83/84 figures. Costs prevailing during project execution will be charged. All cost exclusive of VAT.

(2) Staff costs include overseas honorarium.

(3) Mogadishu subsistence calculated at half rate. Double this figure will be charged if MacDonald's mess unavailable.

(4) It is assumed that the project Land Rover in Mogadishu will again be available, with fuel, for the use of the IH hydrologist. If not cost of local hire will be added.

(5) If the project commences 1st January 1985 the costs in the two financial years would be as follows:

	<u>1984/85</u>	<u>1985/86</u>
Staff	8,300	5,986
Subsistence	-	1,152
Travel	-	1,826
Equipment	2,435	1,295
Contingency	500	500
	<hr/>	<hr/>
Total	11,235	10,759
	<hr/>	<hr/>

4. Recommendations

Recommendations regarding both the present project and the proposed extension are given here.

- (1) An air conditioned room should be provided by the Ministry of Agriculture for the computer equipment (see section 2.1). This is essential to ensure the long term operation of the computer.
- (2) At least one more of the local staff should be trained to use the computer before the end of the present project (see section 2.3).
- (3) The project be extended until the UNDP 'Water Centre' project takes over. Assistance should continue both on the field work side and the data processing and analysis side.
- (4) The programme of work for 1985 proposed herein should be undertaken to ensure the data processing procedures are maintained or improved upon.
- (5) The Ministry of Agriculture undertake to supply three competent and motivated counterparts for training during the project extension.

COMPUTER SYSTEM
&
HYDROLOGICAL DATABASE

Version MG1.1

Ministry of Agriculture - Somali Democratic Republic

INSTITUTE OF HYDROLOGY HYDROLOGICAL DATA BASE

Guide

Version MG1.1

Wallingford, 20th September, 1984

Institute of Hydrology
Wallingford
Oxfordshire
United Kingdom

with

Sir M MacDonald & Partners
Consulting Engineers
Cambridge
United Kingdom

Notice

All programs are the joint property of the Institute of Hydrology and the Ministry of Agriculture, Somalia and may not be copied without prior permission of both parties.

Contents

<u>Section</u>	<u>Page</u>
1. Introduction	1
2. Overview of the database	2
2.1 System limits, units and accuracy	4
3. Overview of the equipment	6
4. Setting up the computer	7
5. Moving the computer	8
6. Using the database system	9
6.1 Switching on the computer	9
6.2 Use of the keyboard	9
6.3 Data flags explained	10
6.4 Adding stations to the system	11
6.5 General operation	11
6.6 Security copies of data and programs	13
7. General programs	15
7.1 Option (1) System summary	16
7.2 Option (2) Change station parameters	17
7.3 Option (3) Add new station or more years	19
7.4 Option (4) Data backup onto diskettes	21
7.5 Option (5) Error report	23
7.6 Option (6) Finish (& CP/M)	24
8. Stage and flow data	25
8.1 Option (10) Add/edit staff gauge data	26
8.2 Option (11) Convert stages to daily flows	31
8.3 Option (12) Add/edit daily flow data	35
8.4 Option (13) Print stage & flow data	39
9. Gaugings and ratings	41
9.1 Option (20) Add/delt/print gaugings	42
9.2 Option (21) Plot/assign gaugings	46
9.3 Option (22) Develop rating curve	50
9.4 Option (23) Add/edit/print rating & table	54

Annex

A. More about the equipment	58
A.1 The Comart CP500 computer	58
A.2 The Cifer 2841 terminal	59
A.3 The Epson MX100 III printer	61

1. Introduction

This guide describes the setting up and operation of the Comart CP500 computer system installed in the offices of the Ministry of Agriculture, Mogadishu, Somalia.

A Hydrological Database system, developed at the Institute of Hydrology is installed on the computer. This is a set of menu driven programs for entering and storing basic hydrological data (daily flows and rainfall). This system is self contained and is entered automatically when the computer is switched on. The user does not have to understand the computer operating system, storage of data on files or the running of individual programs.

All software has been already installed on the 5MB hard disc of the Comart CP500 8bit microcomputer on provided for this project. The following notes are a guide both to the computer itself and the programs provided.

The general operation of the computer and the Hydrological Database is described in Sections 2 to 10 of this guide. Further information regarding the equipment is supplied in Annex A.

2. Overview of the data base system

The Institute of Hydrology Hydrological Data Base is a simple to use, microcomputer based, storage and analysis system for river stage, daily flow and daily rainfall data. No detailed knowledge of the workings of the computer are required, nor is an understanding of the computer operating system or the storage of data on computer files.

There is one type of station which is currently allowed by the system; daily flow. A daily flow station allows the entry and storage of staff gauge data (up to 3 readings per day), and the conversion to daily, monthly and annual discharges. Discharge measurement data are also stored and rating equations may be developed and stored on the system for the conversion of daily stage to flows.

Printed summaries of data are available and as such the system may therefore be considered to process raw hydrological data up to year book standard.

When the computer is first switched on the user first enters a password. A 'menu' or selection of various options is then presented to the user under four main headings:

- (1) General
- (2) Stage and flow data
- (3) Gaugings and ratings

For example under 'General' the user may select a summary of the system or perhaps change a station's parameters such as catchment area. All the options under these three groups are considered later. With one or two exceptions the user will always be transferred back to this initial menu when a particular task has been completed. A new selection may then be made from the menu. At every stage the response given to the computer is checked and the question repeated if an unacceptable reply has been given.

The conventional approach to programming; preparation of input data, running of program and output of results has not been used. Instead the system has been designed so that the user can see what is happening all the time. This is achieved by using screen editing facilities where the data can be 'moved' up or down the screen for checking or alteration. The graphics programs used in rating curve development have also been designed with interactive facilities to examine data in different ways rather than have a single graph displayed on the screen.

The following types of data may be stored on the system :

Flow stations

1. One, two or three staff gauge readings per day
2. Mean daily flows
3. Flag on each stage data (present/missing)
4. Flag on each flow data (good/substituted/missing)
5. A one line comment on the data every month
6. 166 discharge measurements (date, stage, velocity & flow)
(Space is allocated for 332 but lack of time prevented programs being changed to use it)
7. 20 date dependent rating curves. (Three parameter and up to three segments)

For a flow station the system will store one, two or three staff gauge readings per day, the actual number and their measurement time being specified on an annual basis. Data are stored in yearly blocks and operations take place on one year's data at a time. Thus if staff gauge data are to be entered into the system, the user has immediate access to one year of data and can move freely within that year, adding or changing data at will.

Data are stored efficiently by the system. For example the following information is stored in the same amount of space required to hold a four letter word (eg 'this'):

1. One daily flow value
2. One 'flag' or indicator showing whether the data is good substituted or missing
3. One staff gauge reading
4. One 'flag' showing whether the reading is present or missing

With this packing of data it is possible to hold up to four times as much data on the system than without.

As the user undertakes each job the computer monitors the progress. If a serious error were to occur (ie not just a typing error) the user enters an error report program. If the error is spotted by the computer the user will be taken to the program automatically. If not, the user can select the program from the menu. Both the user and the computer are then able to give certain information which are transferred to the printer. This output may then be sent to Wallingford where it could help us sort out the problem. Of course this type of error should not occur but if it did there is some method of attempting to solve it.

Many micro-computers programs use the computer language BASIC. This is very good for developing programs quickly and is used extensively. However the language is slow as each instruction has to be translated every time the program is run. Furthermore each computer seems to have its own version of BASIC which would make it difficult to transfer programs from one machine to another. The

system here uses FORTRAN. The time taken to develop programs is greater under FORTRAN but the final program is faster and more readily transportable from one computer to another.

2.1 System limits, units and accuracy

Overall limits apply to the system concerning the period over which data may be stored. This period must be between the years 1900 and 2000 and be specified at the beginning of the project. For the Ministry of Agriculture the period 1950 to 1990 has been defined as the project period.

There may be up to 50 stations on the system. Station numbers may be from 1 to 50. A station number, once installed cannot be changed at a later date. However the 32 characters reserved for the station name may be changed later if required.

Limits apply to all types of data held on the system. Table 1 lists these limits together with the units of measurement and the accuracy applicable to each type of data.

Any data entering the system must be within the limits given in this table. Certain of these limits may be defined on a station by station basis according to the column 'Station limit'. The purpose of this is to provide a quality check on the data entering the system.

Thus staff gauge data must not only be within the system limits before being accepted, but also inside the preset maximum and minimum for that station. Staff gauge data are also checked for unreal jumps by the 'Max staff change' parameter. Staff readings are not accepted if the value to be entered differs by more than this amount from the preceding value.

If required station limits may be changed at a later date, whereas system limits, defined by Table 1, cannot.

Station type	Data type	Units	Min value	Max value	Accuracy	Station limit
Flow	Staff gauge	m	-25.00	25.00	0.01	Yes
"	Max staff change	m	0.00	5.00	7 digit	Yes
"	Daily flow	³ m s ⁻¹	0.00	3200.0	0.01 to 320 0.1 over 320	No
"	Catchment area	² km	0.00	900000.	7 digit	Yes
"	Gauging stage	m	- defined by staff gauge above-			
"	Gauging flow	³ m s ⁻¹	0.0001	999999.	7 digit	No
"	Gauging velocity	⁻¹ m.s	0.00	20.00	0.01	No
"	Gauging area	² m	0.001	2000.0	not stored/ derived from flow & velocity	No

Table 1 : Station types, data types, units, system limits & accuracy

3. Overview of the equipment

The system is installed on a Comart CP500 micro-computer which has an industry standard operating system (CP/M 80) and a well proven processor (Z80). Many micro-computers use either cassette tapes or flexible diskettes to store programs and data. Although very reliable under ordinary conditions, the dusty conditions often encountered overseas make them unsuitable for everyday use. This is because both these types of storage are exposed to the atmosphere. The Comart has a sealed hard disc which, while being more expensive than the alternatives mentioned, was considered more suitable for use overseas. Hard disks also hold much more data and programs than either cassettes or flexible diskettes. The whole system of programs and data files fits comfortably on the Comart's hard disk. The Comart also has a flexible diskette facility which is used for making security copies of data and programs.

The screen or terminal connected to the Comart computer is a Cifer 2841. This was chosen because of its ability to display either text or graphical information at a reasonable cost.

The printer is an Epson MX100 III, which is a very well known printer and is used extensively worldwide.

Service facilities are available for the Comart at Nairobi, Kenya with the local Comart agent:

Rohde & Schwarz
Engineering & Sales C. Ltd.
ABC Building 2
Waiyaki Way
Nairobi
KENYA (PO Box 46658 - Telex 22030,22961 - Cab engsales)

4. Setting up the system

The computer should be installed in a clean, dry and dust free room. If the temperature or the humidity is high, the room should be air-conditioned. The units should not be covered during use nor should they be stacked on top of one another during operation. This is to prevent heat build up and to allow as much free ventilation as possible. If the environment is dusty the equipment should be covered with a cloth after use.

The room originally provided at the Ministry of Agriculture for the computer was too hot and dusty to guarantee the long term operation of the computer. It is recommended that either an air conditioner be fitted to this room so that the door and windows may be kept shut or the computer moved to another air conditioned office.

Before connecting the computer to the local power supply, the suitability of the supply to support the equipment should be ascertained. A multimeter is provided to test the voltage which should be in the range 220-240 volts (at MacDonalds Office). The AC frequency should be 50Hz. If the voltage is doubtful then a good stabiliser should be purchased and used to protect the equipment. The running current of all the equipment is about 1.5amps so a 500VA stabiliser would be suitable. If other micro-computers are being used locally try and determine what power regulation is being used by them. If in doubt contact IH for advice.

The computer, terminal and power supply are connected as shown in Figure 1. The ends of the connecting leads between the computer and terminal are marked A & B. The ends of the connecting leads between the computer and printer are marked C & D. The sockets into which these plug have been marked similarly. The keyboard plugs into the rear of the terminal and the lead should be clamped in the clips provided under the screen.

The three power supply leads are identical and are used to connect the three items of computer equipment to the junction box (four sockets, one unused). The single lead from the junction box plugs into the stabiliser or local power supply.

Remember to remove the protective cardboard diskette from the floppy disc drive of the Comart before switching the machine on. Store the cardboard diskette safely as it will be required again when the computer is moved.

5. Moving the computer

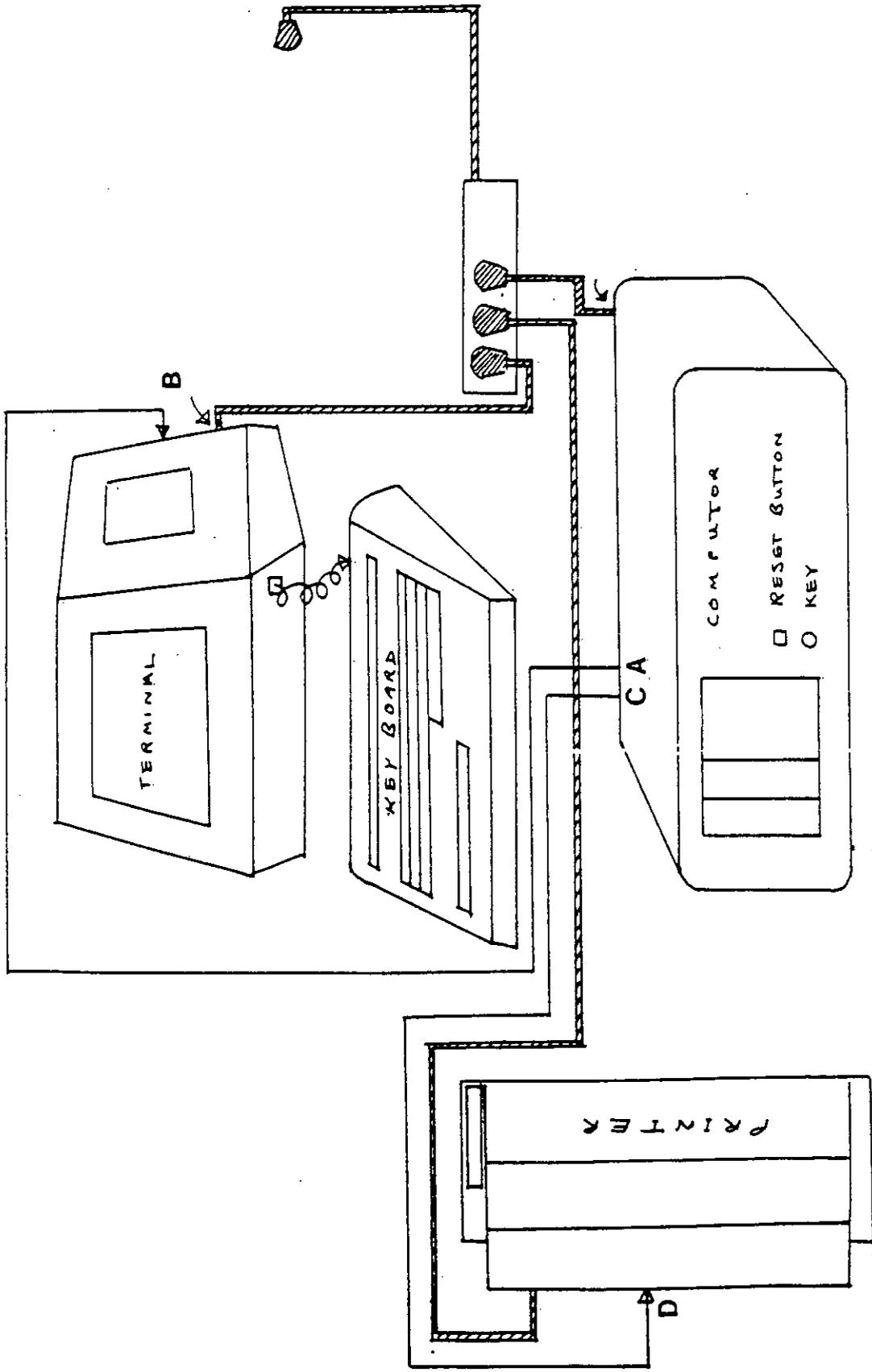
If the computer is to be moved, remember it is a delicate piece of equipment. If it dropped or shaken damage may occur.

Firstly remove all the connecting and supply leads and disconnect the keyboard from the screen. Insert the cardboard diskette into the flexible disk drive on the left hand side of the computer.

Insert a single sheet of paper into the printer as described on page 1.2 of the printer booklet (item (1.3)). Replace the two shipping screws on the underside of the printer as described on page 6 of the printer booklet. The two shipping screws are kept in the box of spare fuses in the drawer beneath the computer.

When the computer is set up for working again the cardboard disc must be removed from the floppy disc drive BEFORE turning on the computer, as must the two shipping screws under the printer.

If the computer is going to Nairobi for repair be sure to include the three manuals: one each for the Comart computer, Cifer terminal, and Epson printer.



6. Using the database system

6.1 Switching on the computer

To switch on the computer follow these instructions:

- (1) Switch on the local power supply
- (2) Switch on the Cifer 2841 terminal (switch at back)
- (3) Wait for display to come on. The green box in the left-hand corner should say 'L DCDOFF'. If it says 'LOCAL' refer to section A.2.
- (4) Switch on the computer at the back (left side)
- (5) Turn on computer with key (vertical position)
- (6) The screen should first say 'LINE rdy' in the lower left corner. Title information should then appear with a request for a password.

Having entered your password and pressed the [RETURN] key you will be presented with a selection or 'menu' of jobs which can be done on the system. This menu will re-appear whenever a particular job has been finished. To make your choice type the appropriate number followed by [RETURN].

6.2 Use of the keyboard

Throughout this manual square brackets [] are used to denote individual, non alpha-numeric, keys on the keyboard. For example [RETURN] implies the return key. The shift key is denoted by [SHIFT] and will always be followed by another key. For example [SHIFT] + a has the same meaning as on a type writer; the shift key is held down while 'a' is pressed. Another key, which is used in exactly the same way [SHIFT] is the control key [CTRL]. Thus [CTRL] + x means press 'x' whilst the [CTRL] key is held down.

Note that it is always necessary to press the [RETURN] key after you have finished your reply to indicate your command is complete. If you are typing in numbers it may be more convenient to use the [ENTER] key as it is in the numeric key pad. [RETURN] and [ENTER], however, do the same thing. The only exceptions to the rule of always pressing return are when the 'special keys' described below are used.

For any command you may use small or LARGE letters or a mixture - it does not matter. If you are entering a comment or a name make sure that the [CAPS LOCK] key is off and you will be able to make a neat

entry with capital letters where necessary.

If you make a mistake before pressing the [RETURN] key you may clear the whole of the line and start again by using the [CLEAR LINE] key. If you want to delete single characters use the [BACK SPACE] key. Note that sometimes the [BACK SPACE] key has an unusual effect - it deletes several lines from the screen! Why this happens is not certain so it may be best just to use [CLEAR LINE].

Certain additional or special keys are provided for database operation in addition to the normal alph-numeric range. The availability of special keys depends on the terminal connected to the computer :

Action	Terminal special key		Alternative Alpha key sequence
	Cifer 2841	Cifer T4	
Delete last character	[BACKSPACE]	[BACKSPACE]	[CTRL] + H
Clear line typed	[CLEAR LINE]	[CLEAR LINE]	[CTRL] + X
Top of data or 1st plot	[HOME]	[HOME]or[TOP]	T [RETURN]
End of data	[SHFT]+[HOME]	[END]	E [RETURN]
Move down a line	[v]	[v]	D [RETURN]
Move up a line	[^]	[^]	U [RETURN]
Move left	[<]	[<]	L [RETURN]
Move right	[>]	[>]	R [RETURN]
Save edits on file	(no key)	[SAVE]	S A V E [RETURN]
Abandon edits	(no key)	[ABANDON]	E X I T [RETURN]
Interrupt	(no key)	[INTRPT]	(no keys)
Print	(no key)	[PRINT]	P R I N T [RETURN]

If the terminal has no special key to perform the desired action, the 'Alternative alpha key sequence' must be used. Thus on the Cifer 2841, the letters S A V E followed by [RETURN] must be typed, whereas all that is necessary on the T4 is to press the [SAVE] key.

6.3 Data flags explained

Certain types of data stored on the system have flags associated with each entry. A flag is simply an indicator to tell us something more about the data. The flags are sometimes shown differently on the screen than on the printer, but have the same meaning. The flags on the printer were chosen for presentation purposes while the flags on the screen were chosen to make it quite clear what flag is associated with each item of data even if the result is a little untidy. The data types and flags are:

<u>Data type</u>	<u>Screen flag</u>	<u>Printer flag</u>
Staff gauge data missing	m	-
Daily flow missing	m	-
Daily flow good	g	(unflagged)
Daily flow data infilled	f	?
Gauging unassigned to a rating	?	?
Gauging assigned to a rating	a,b,c ...t	a,b,c ...t (- is minus sign)

6.4 Adding stations to the system

When setting up the system from scratch spend some time sorting out your station numbering system. A station number may be in the range 1 to 50. Once a station is numbered its number cannot be changed and it cannot be deleted. Also it is important to have some idea of the period of record for each station before entering that station on the system. This is because much less disc space is used if stations are added one at a time and the years for that station are entered chronologically. The notes on Option (3) consider this point further. It should be remembered that allocating space for a particular station or station year is different to adding staff gauge. When a station year is added the data are initially set missing. At a later date this missing data may be added or edited at will. It is the first part of this process, allocating disc space, which requires careful use.

The system has been already been installed with space for all stations operated by the Ministry of Agriculture. Space has been allocated for all historic data up to and including the year 1990. The new station at Kurtun Warey on the Shebelli has already been added to the system with space from 1984 to 1990. There should therefore be no problem with 'running out of disc space'. Furthermore there is currently sufficient space to allow for addition of a few more stations at a later date if required.

6.5 General operation

The list of currently available options on the system is given below :

General

- (1) System summary
- (2) Change station parameters
- (3) Add new station or more years
- (4) Data backup onto diskettes
- (5) Error report
- (6) Finish (& CP/M)

Stage & Flow data

- (10) Add/edit staff gauge data
- (11) Convert stages to daily flows
- (12) Add/edit daily flow data
- (13) Print stage & flow data

Gaugings & ratings

- (20) Add/delt/print gaugings
- (21) Plot/assign gaugings
- (22) Develop rating curve
- (23) Add/delt/print rating & table

This section considers some of the general aspects common to all these options.

Operation of the system proceeds on a question and answer basis. Every reply by you is checked by the computer to see whether it is reasonable or not. If it is unreasonable, the original reply is rejected and the question repeated. Sometimes an indication of the error is given, sometimes it is not.

Year numbers must always be entered in full. For example 1984 must be entered as 1894 not 84.

The [HOME] or [TOP] key takes you to the start of the block of data being edited or to the first point or line of a graphics program. The [SHIFT]+[HOME] or [END] key takes you to the end of the current block of data. The arrow keys allow movement within block of data in the direction of the arrow.

In many of the programs the message: Hit [RETURN] appears. This is simply a way of stopping the computer while you read certain information from the screen. Press the [RETURN] key when you are ready to continue.

In some programs you will be asked a question which expects a yes or no answer (eg Is the printer ready y/n >). The computer will always assume NO unless you enter YES, Y or y followed by [RETURN].

The question 'Is the printer ready y/n >' is always asked before any output is directed to the printer. This is an indication that you

should check that the printer is switched on, the paper fold is just above the print head and that three green lights (power, ready and on-line) are illuminated. If the printer is not ready and on-line the computer will wait indefinitely, without a warning to you, for the printer to be made ready.

The [SAVE] key or typing S A V E [RETURN] saves your edits while the [ABANDON] key has the same effect as typing E X I T [RETURN]; ie the edits are not saved.

Never leave the computer, terminal, or printer on when you leave the room. The local power supply may fail when you are away.

Do not place anything on top of the computer, terminal or printer while in use. These units become quite hot in a non air-conditioned room and need as much free ventilation as possible.

When you have finished using the computer select option 6 from the menu and you will be given instructions on how to turn off the equipment. If the environment is dusty cover the equipment with a cloth to keep off the dust.

6.6 Security copies of data and programs

It is a very good idea to make frequent copies of data which has been entered onto the computer system. If a fault develops in the computer which makes the original data unreadable, the data last copied onto the flexible diskettes will be needed to restart the system. The more frequently the data are copied the less work will have to be repeated in the event of a problem. Option (4) of the main menu will guide you step by step through this copying or 'backup' procedure.

All your data should easily be stored on three diskettes. These diskettes are labelled DATA BACKUP1, DATA BACKUP2 etc and have been prepared specially for this purpose. It is important that these diskettes are kept very very clean. The diskettes must be held only by the cardboard sleeve. Never touch the magnetic disc inside the sleeve.

Instructions for copying the data back from the diskette onto the computer are not given here. The situation under which this would be needed would be one where a serious problem had developed on the system. The problem could be made worse by trying to copy back data without a detailed knowledge of the system. It is essential that the problem be solved by someone having a thorough understanding of the computer, operating system and programs.

In the event of a total failure of the computer, these diskettes are the only means of transferring programs and data to a new machine. Looking after the diskettes and keeping them regularly updated (once per month) is your only security of data apart from the

printed summaries produced by the system.

7. General programs

Programs in this group are not specific to any one type of station or data. Instead they apply to the system as a whole and cover the following aspects of operation:

- (1) Summary of stations & their period of data on the system
- (2) Change of station parameters (eg name, catchment area)
- (3) Addition of a new station to the system or increase of the record length of an existing station
- (4) Copy the datafiles from hard disc to floppy disc for backup purposes
- (5) Report of serious errors
- (6) Finish database work and/or enter the operating system CP/M

The following sections consider the operation of all these options in more detail.

7.1 Option (1) Summary of system

Description

This option provides a summary of the stations on the system, including their parameters such as catchment area and shows the disc space (yearly blocks) assigned to each station.

A printed summary is available, giving full details of all stations.

Questions, Answers & Commands

Q. Details of station(s), to screen, printer or terminate s/p/t >

A. s, p or t. Terminate returns you to the main menu

Q. Is the printer ready >

A. y or Y for yes, anything else for no.

Q. Enter station number from above or A for all >

A. Any one of the station numbers given or A to look at all one by one.

Q. Hit [RETURN]

A. Press [RETURN] when ready.

7.2 Option (2) Change station parameters

Description

This option allows the following station parameters to be changed for any station already on the system:

Flow station

(1) The first set of station parameters which may be changed are :

- Name
- Maximum stage
- Minimum stage
- Maximum change between stage readings
- Catchment area

(2) Secondly the number of staff gauge readings per day and/or their time may be reset for any of the years on the system. (If the original number of staff gauge readings for the year to be changed was one this program will not allow an increase to two or three readings per day. This is because more file space is required. Option (3) from the main menu must be used if this particular change is required. But if you wish to reduce the number of staff readings per day or if you want to increase the number of readings per day from two to three you may use this option. If you want to change the time of any staff gauge readings you may also use this option.)

Questions, Answers & Commands

Q. Enter station number

A. Any station number of the requested type known to the system

Q. Enter option here >

A. <FLOW STATION>

1,2,3,4,5,6 or 7 as defined on the screen. Note options 1-5 concern changes in group (1) above while options 6 & 7 pass the user onto group (2) as defined above in 'Description'.

Q. Enter revision below or * to abort

>

A. <FLOW STATION>

Option(1) ... Up to 32 characters for station name

Option(2) ... 0 to 900000 (sq km)

Option(3) ... Minimum stage to 25.00 (m)

Option(4) ... -24 to Maximum stage (m)

Option(5) ... 0 to 5 (m)

or * as the first character on a line to abort entry

Q. Change no. staff gauge readings per day or their time ? y/n >

A. y or Y for yes anything else for no (no terminates the program)

Q. Which year >

A. Any year already on the system for the station. (eg 1984)

Q. Requested year not found try again y/n >

A. y or Y for yes anything else for no. (The year that you originally asked for was not on the system. You have now been given the chance to re-enter a year number.)

Q. New no. readings/day >

A. 1,2 or 3 (Note if the original number of readings per day was one you cannot increase this using this program; you must use option(3) from the main menu. You may however change its time.)

Q. Time 1 (0 to 23hrs) >

A. 0 - 23 (hrs)

Q. Time 2 (Time1 to 23hrs)

A. Time 1 specified above - 23 (hrs)

Q. Time 3 (Time2 to 23hrs)

A. Time 2 specified above - 23 (hrs)

Q. Edit another year >

A. y or Y for yes anything else for no

Q. Save revised data >

A. y or Y for yes anything else for no

7.3 Option (3) Add new station or more years

Description

This option allows either a new station to be added to the system or the number of years of data held by the system for an existing station to be increased. The number of staff gauge readings per day for a flow station may also be changed by this option. The actions of this program are irreversible regarding the amount of disc space used. Use this program only after reading the notes below and you are sure you know what you are doing.

When a flow station is first added to the system, space is automatically allocated for 166 discharge measurements and 20 rating curves.

Special note

This is the only program which will use up more of the available disc space on the computer. Use it according to the rules below and much wasted space will be avoided. Note that once you have allocated the space using this program it cannot then be released. There is no delete facility on the system (for reasons of security).

(1) Know in advance of running this program the length of period you wish to store data and know how many staff gauge readings per day in each of those years (for a flow station). Although specifying 1 staff gauge reading per day uses half the disc space as 2 or 3, if in doubt specify 2 or 3 and reduce later (using option(2) from the main menu).

(2) You can only add 10 years to the system at one time. Always start with the first year on record and work forward. If more than 10 years are to be added, the program must be re-run the required number of times.

(3) If the station is to be operated in the future add a reasonable number of years now (say to 1990). Putting these years on to begin with makes much better use of space than adding them later.

(4) Complete adding space for one station before adding the next.

All data are initially set to missing when this program is used. If by chance you should try and add data that already exists the original data will not be overwritten. There is one exception to this rule; for a flow station the number of readings per day and their time are changed according to your new specification. However if you should accidentally reduce the original number of staff readings per day, the original data may be retrieved by re-running this program with the correct number of readings per day.

Questions, Answers & Commands

Q. Please enter station number between 1 and 50

A. Any number between 1 and 50. (If the station already exists its name and parameters will be found from file.)

Q. New station - Enter name (or * to abort)

A. Up to 32 characters for station name. If * is the first character on the line the program terminates here.

Q. Enter catchment area in sq km >

A. From 0.0 to 999999.0 (sq km)

Q. Enter maximum possible staff gauge reading (>-24m,<25m) >

A. From -24.0 to 24.99 (m) (This parameter is used in quality control. No stage data will be accepted for this station unless it is below this limit)

Q. Enter minimum possible staff gauge reading (<max,>-25m) >

A. From -25.0 to the maximum specified above (m) (This parameter is used in quality control. No stage data will be accepted for this station unless it is above this limit)

Q. Enter max possible absolute change between staff readings (<5m,>0m) >

A. From 0.0 to 5.0 (This parameter is used in quality control to prevent unreal jumps in the data).

Q. Enter first year of block to be added (>1901,<1986)

A. From 1901 to 1986

Q. End year (no more than 10 years to 1986)

A. From start year to 1986 providing no more than 10 years are being asked for. (If you want more than 10 years see note above).

Q. Year 19xx No. readings/day >

A. 1, 2 or 3

Q. Time 1 >

A. From 0 to 24 (as an integer)

Q. Time 2 >

A. From Time 1 to 24

Q. Time 3 >

A. From Time 2 to 24

7.4 Option (4) Data backup onto diskettes

Description

This option enables copies of the data stored on the computer's hard disc to be made floppy disc. In case of failure of the hard disc or corruption of the primary data files, the last copy onto floppy disc will be used to restart the system after repair. The more frequently data are copied onto floppy disc the less work that is likely to have to be repeated once the system is restarted. It is recommended that this procedure be used once per month. If the backup procedure fails at any stage or you make a mistake the whole sequence must be repeated.

The backup procedure is undertaken in two stages. The first stage involves cleaning the diskette drive, the second entails the copying procedure.

The backup sequence is initiated by entering option (4) from the main menu for both stages of the backup procedure and proceeds on a question and answer basis. Explanation is presented on the screen about the correct sequence of entering diskettes.

Questions, Answers & Commands

Q. Have you cleaned the disc drive yet ?

A. y or Y for yes. Anything else for no

Q. When you have done this answer yes >

A. y or Y for yes. Anything else for no

Q. After about 30 seconds press the red button on computer and select option 4 again

A. Wait approximately 30 seconds after this message before pressing the red button on the front of the computer next to the key. Having done this wait for a few seconds and re-enter your password. Now select option (4) again from the main menu. The disc drive has now been cleaned.

Q. (3) Type BACKUP when you see A> below

A. Wait a few seconds for A> to appear then type BACKUP

Q. Remove cleaning diskette. Press [RETURN] when ready

A. Press the [RETURN] key when you are ready

Q. Insert diskette with green label "DATA BACKUP 1" into disk drive with arrow pointing inside and label facing the key.

Close door on disk drive
Press [RETURN] when ready >

A. Do as asked then press the [RETURN] key.

Q. Wrong disc

Press red button on front of computer and start again

A. A special note here. BEFORE starting the backup procedure, do the following:

- (1) Press red button
- (2) Wait a few seconds and re-enter password
- (3) Select option (6) - Finish.
- (4) Immediately hold down the down arrow key (above the 8 key on the numeric keypad). Hold this key down until the screen shows a series of A> line after line.
- (5) Press the red button and start the backup again from the start. You will, of course, have already cleaned the disc drive.

Q. Remove diskette "DATA BACKUP 1". Press [RETURN] when ready

A. Press the [RETURN] key when you are ready

Q. Insert diskette with green label "DATA BACKUP 2" into disk drive with arrow pointing inside and label facing the key.

Close door on disk drive

Press [RETURN] when ready >

A. Do as asked then press the [RETURN] key.

Q. Remove diskette "DATA BACKUP 2". Press [RETURN] when ready

A. Press the [RETURN] key when you are ready

Q. Insert diskette with green label "DATA BACKUP 3" into disk drive with arrow pointing inside and label facing the key.

Close door on disk drive

Press [RETURN] when ready >

A. Do as asked then press the [RETURN] key.

7.5 Option (5) Error report

Description

This option enables a serious error in the system to be reported to the Institute of Hydrology. Both the operator and the computer are able to print information which may help in tracing and solving the error. If this error is noticed by the user this program may be entered from the main menu as option 5. If the error is spotted by the computer during the course of your work you will be taken to this program without question.

Questions, Answers & Commands

Q. Is the printer in working order and ready y/n ?

A. y or Y for yes. Anything else for no

Q. Please describe the problem below. Your typing will be transferred line by line to the printer. Terminate your report by a * as the 1st character on a line.

A. Describe in detail what you were trying to do when the problem occurred and what the problem was and its effect. Anything you type will be transferred line by line to the printer as if you were writing a letter. Finish each line with [RETURN] and finish your report with an * as the first character on a line.

Q. When you are ready hit [RETURN] >

A. Press [RETURN] when you have found pen and paper

Q. More to come hit [RETURN] when ready >

A. [RETURN]

Note

When this program has finished you are not returned to the main menu but into the computer operating system. This is a precaution to ensure all files have been closed. When you see A> type MENU to resume work. (If, of course, your error is not serious enough to prevent this).

7.6 Option (6) Finish & CP/M

Description

This option should be selected when you have finished using the system. Instructions are given on stopping the computer equipment and all files are closed. This option is also used to enter the operating system (CP/M). If you wish to re-enter the database system from CP/M type MENU.

8. Stage and flow data

This group of programs is only concerned with flow stations and in particular their staff gauge and flow data. The programs appear in the main menu list in the order which they are normally required :

Order	Option	Description
1	(10)	Add or edit daily staff gauge data
2	(11)	Convert staff gauge data to daily flows
3	(12)	Edit or add daily flows
4	(13)	Print copy of stored data with summaries

Each of the above options operates on one station year block of data at a time. It must be remembered, however, that that block must have already been added to the system using Option 3 from the main menu. It is no good, for example, trying to add staff gauge data for station 1234 in 1984, if 1984 has not already been assigned to that station. If you are not sure what years have been assigned to a station, Option (1) from the main menu will tell you.

8.1 Option (10) Add/edit staff gauge data

Description

This option enables new staff gauge data to be added to the system or existing staff gauge data to be edited for any one station year. When the year is initially allocated to the station using Option (3) from the main menu, data are set missing. This is indicated by a flag on the screen 'm'.

Comments may be added to the data on a monthly basis as required.

Staff gauge data being added to the system are subjected to a quality check before acceptance. In all cases the staff reading must be above the station minimum, below the station maximum and must not differ more than a specified amount from its preceding value.

A further quality check is optional if a bridge dip reading is available at the same site as the staff gauge. In this case the readings must agree within a specified amount before acceptance. This is explained in the V command below.

A constant may be added to all data before entry. This has several applications which are described below under the command CON.

Questions, Answers & Commands

Q. Enter station number >

A. Any station number known to the system

Q. Enter year >

A. Any year for that station which has already been set up

Q. Command >

A. Any one of the following :

- Stage value to be entered at current position (eg 2.43)
- Jan, Feb, ... Dec
- [RETURN]
- Arrow key
- [HOME] or [TOP] key
- [SHIFT]+[HOME] or [END] key
- CON
- V
- COMM
- HELP
- S
- M
- SAVE
- EXIT

These commands are considered in more detail below

Commands

Stage data to be entered

Any numeric data above -24.0 and below 25.0 entered as a command will be treated as an attempt to enter staff gauge data at the current position in the record. A quality control procedure checks that each stage reading complies with the following :

- (1) The minimum stage limit set for the station
- (2) The maximum stage limit set for the station
- (3) The difference in staff gauge reading between the current and the preceeding value is below the limit set

If the constant facility is being used, the constant is applied before the above tests are undertaken (see command CON below).

If the verify facility is being used, two readings must be entered, separated by commas. The first reading is the normal staff gauge reading and the second is the bridge dip. Data are only accepted if the two readings are within the specified tolerance. The staff gauge reading is assumed to be the primary source of data and it is this value which is stored by the system, subject to the three tests above. (see command V below)

Jan, Feb, ... Dec

Entering the first three letters of the month name moves the current position within the annual record to the first day of the month specified.

[RETURN]

Pressing the [RETURN] or [ENTER] key alone causes the current position within the annual record to be advanced by one. Holding the [ENTER] key down causes continuous movement through the record.

Arrow keys

Pressing the arrow keys moves the current position in the direction of the arrow. Do not hold the arrow key down (on Somali Comart) but wait for the screen to finish scrolling before repeating an arrow key. On the UK and Thailand Comarts the arrow key may be held down to obtain continuous movement in the direction of the arrow.

[HOME] or [TOP]

Pressing the [HOME] or [TOP] key sets the current position to 1st January.

[SHIFT]+[HOME] or [END]

Pressing the [HOME] key while having the [SHIFT] key already depressed sets the current position to 31st December. The [END] key, if available, has the same effect.

CON

This command sets the constant which is added to staff gauge data immediately it is entered by the operator and before it is checked by the quality control procedure.

This command asks one question:

Q. Enter constant to be added to stage on input >
A. From -1000.0 to 1000.0

The constant may be removed once set by issuing the command CON once again and pressing the [RETURN] key to the above question.

The constant is useful in several ways, three of which are given here:

- (1) To apply a correction to staff gauge data on entry. For example incorrect metre readings by the observer.
- (2) To adjust readings above sea level to station datum.
- (3) To enter bridge dip readings when staff gauge readings are unavailable. Here the constant is the difference in datum between the staff gauge and the bridge rail. Bridge dip data are then entered as negative values, so that the following calculation takes place before the quality control :

$$\text{Staff reading} = \text{Datum difference} - \text{Bridge dip}$$

V (Verify)

This command allows each staff gauge value to be checked against a bridge dipping during the input procedure. The first time this command is used during each run of the program two questions are asked :

Q. Enter difference in datum (m) between bridge and staff gauge >
A. From -100.0 to 100.0 (m)

Q. Tolerance (m) (<1) to be allowed between readings >
A. From 0.0 to 1.0 (m). This is the difference between the staff reading and the bridge reading (converted to the equivalent stage) which is to be permitted. If this tolerance is exceeded, the staff gauge reading will not be accepted by the system.

To enter data with the verify mode set, two readings must be entered, separated by commas. The first reading is the normal staff gauge reading and the second is the bridge dip. Data are only accepted if the two readings are within the specified tolerance. The staff gauge reading is assumed to be the primary source of data and it is this value which is stored by the system, subject to the quality control tests.

Verify mode is turned off simply by issuing the command V once again. If verify is entered again after that the following question is asked:

Q. Reset verify parameters y/n ?
A. y or Y if you want to change those previously set. Anything else results in the most recent verify parameters being used again.

COMM

One line of comment (68 characters) can be stored for each month of data. This command allows the comment to be entered initially or revised later. One question is asked :

Q. Enter revised monthly comment or * to abort
A. Up to 68 characters. If * is the first character this command is aborted and the original comment is preserved.

HELP

A list of all commands is displayed on the screen when help is typed.

Typing HELP again removes this list.

S (Scroll)

Normally ten days of data are displayed on the screen. The current position being in the centre of the screen. Five preceeding days and the four following days are on the screen for inspection. This may be changed to a total of five lines by typing S (for Scroll) and to three lines by typing S once more. The next entry of S resets the number of lines on display to ten.

Reducing the number of lines on display increases the speed of scrolling and hence the speed with which data may be entered by the operator. However fewer lines are visible at any one time.

M (Missing)

To set the current data item missing issue the command M.

SAVE

Data which appear on the screen are held in the memory of the computer. Changes and additions which you make during any one run of this program are not stored on the system until you give the command SAVE. The command SAVE also causes the program to terminate and return control to the main menu.

EXIT

The command EXIT causes the program to terminate without saving any changes or additions you might have made. This command is used if you are just looking at the data or wish to abort an unsuccessful edit.

8.2 Option (11) Convert stages to daily flows

Description

This option allows staff gauge data to be converted to mean daily flows. The rating equation used to convert to mean daily flows will be taken from the rating curve file as set up under option (23).

It is possible either to convert the whole year in one operation or individual days using this program. The whole year is converted using the command ALL. Individual days may be converted by moving to the desired position within the annual record and giving the command CONV. Conversion then takes place at this and any subsequent position visited in the annual record until the command CONV is given again. Alternate CONV commands turn the conversion procedure on and off.

The algorithm used for conversion of stage to flow is currently as follows :

(1) If no staff gauge readings are present on the current day no conversion takes place.

(2) There are assumed to be 4 possible staff gauge readings per day at 6:00, 12:00, 18:00 and 24:00hrs.

(3) The actual times which have been assigned to each staff reading are not used by this algorithm, instead the staff gauge readings actually stored are transferred according to the following table :

Assumed time	Number of staff readings per day		
	1	2	3
6:00	m	1st	1st
12:00	1st	m	2nd
18:00	m	2nd	3rd
24:00	m	m	m

where 'm' is a missing value

(4) Any missing values in the above table are filled by linear interpolation, using the preceding and following day's data if necessary. If no data is available for interpolation the stage is assumed constant.

(5) The staff gauge readings at the assumed times are converted, using the appropriate rating, to instantaneous flows for the day in question, including the the midnight reading of the day before.

(6) Mean daily flow is estimated from the five instantaneous discharges by the trapezium rule.

It can be seen from this algorithm that changing a staff gauge reading on one day will change the estimate of flow on adjacent days

if that staff reading is used for interpolation in step (4) above. Therefore if a alteration is made to a staff gauge reading and the mean daily flow re-calculated, it is prudent to re-calculate the preceeding and subsequent daily flow as well.

Questions, Answers & Commands

Q. Enter station number >

A. Any station number known to the system

Q. Enter year >

A. Any year for that station which has already been set up.

Q. Command >

A. Any one of the following :

- Jan, Feb, ... Dec
- [RETURN]
- Arrow key
- [HOME] or [TOP] key
- [SHIFT]+[HOME] or [END] key
- COMM
- S
- CONV
- ALL
- SAVE
- EXIT

These commands are considered in more detail below

Commands

Jan, Feb, ... Dec

Entering the first three letters of the month name moves the current position within the annual record to the first day of the month specified.

[RETURN]

Pressing the [RETURN] or [ENTER] key alone causes the current position within the annual record to be advanced by one. Holding the [ENTER] key down causes continuous movement through the record.

Arrow keys

Pressing the arrow keys moves the current position in the direction of the arrow. Do not hold the arrow key down (on Somali Comart) but wait for the screen to finish scrolling before repeating an arrow key. On the UK and Thailand Comarts the arrow key may be held down to obtain continuous movement in the direction of the arrow.

[HOME] or [TOP] key

Pressing the [HOME] or [TOP] key sets the current position to 1st January.

[SHIFT]+[HOME] or [END]

Pressing the [HOME] key while having the [SHIFT] key already depressed sets the current position to 31st December. The [END] key, if available, has the same effect.

COMM

One line of comment (68 characters) can be stored for each month of data. This command allows this information to be entered initially or changed later. One question is asked :

- Q. Enter revised monthly comment or * to abort
- A. Up to 68 characters. If * is the first character this command is aborted and the original comment is preserved.

The comment may only be set with CONVersion OFF.

S (Scroll)

Normally ten days of data are displayed on the screen. The current position being in the centre of the screen. Five preceding days and the four following days are on the screen for inspection. This may be changed to a total of five lines by typing S (for Scroll) and to three lines by typing S once more. The next entry of S

resets the number of lines on display to ten.

Reducing the number of lines on display increases the speed of scrolling and hence the speed with which data may be entered by the operator. However fewer lines are visible at any one time.

CONV

When the program is first entered the conversion mode is OFF. In this mode it is possible to move through the data at will without converting stages to daily flow. To initiate conversion of stages to flow enter this command. The rating equation code letter used for conversion of each daily flow is displayed. Conversion takes place on a daily basis wherever the current position in the data is. Conversion can be turned OFF by re-entering the command

ALL

Conversion of the whole year's worth of data takes place in one operation when this command is issued. Conversion is automatically turned ON at the start and turned OFF at the end. Monthly comments, if any are displayed as conversion progresses as are the rating equations used daily. The display of daily data is not updated for reasons of speed. The display is set to 31st December when conversion finishes.

SAVE

Data which appear on the screen are held in the memory of the computer. Changes and additions which you make during any one run of this program are not stored on the system until you give the command SAVE. The command SAVE also causes the program to terminate and return control to the main menu.

EXIT

The command EXIT causes the program to terminate without saving any changes or additions you might have made. This command is used if you are just looking at the data or wish to abort an unsuccessful edit.

8.3 Option (12) Add/edit daily flow data

Description

This option allows either daily flow data to be added to the system or existing daily flow data to be edited.

When a year is first added to the system, using Option (3), the data are initially set missing. This is shown on the screen by the flag 'm'.

Daily flow data entered in by this program are flagged as being infilled (flag 'f'). This is because they do not come from the primary source of staff gauge readings converted by rating equation to mean daily flows.

Comments may be added to the data on a monthly basis as required.

The command INT, described fully below, allows infilling of data by log-log interpolation. These data are flagged as infilled.

Questions, Answers & Commands

Q. Enter station number >

A. Any station number known to the system

Q. Enter year >

A. Any year for that station which has already been set up

Q. Command >

A. Any one of the following :

- Mean daily flow to be entered at the current position
- Jan, Feb, ... Dec
- [RETURN]
- Arrow key
- [HOME] or [TOP] key
- [SHIFT]+[HOME] or [END] keys
- INT
- COMM
- HELP
- S
- M
- SAVE
- EXIT

These commands are considered in more detail below :

Commands

Mean daily flow to be entered

Any value between 0 and 3200.00 will be treated as a mean daily flow to be entered at the current position in the current annual record. These data will be flagged as infilled (flag on screen 'f', flag on printer '?'). This is because the mean daily flow is not being derived from the primary source of staff gauge readings converted by an appropriate rating to mean daily flow.

Jan, Feb, ... Dec

Entering the first three letters of the month name moves the current position within the annual record to the first day of the month specified.

[RETURN]

Pressing the [RETURN] or [ENTER] key alone causes the current position within the annual record to be advanced by one. Holding the [ENTER] key down causes continuous movement through the record.

Arrow keys

Pressing the arrow keys moves the current position in the direction of the arrow. Do not hold the arrow key down (on Somali Comart) but wait for the screen to finish scrolling before repeating an arrow key. On the UK and Thailand Comarts the arrow key may be held down to obtain continuous movement in the direction of the arrow.

[HOME] or [TOP]

Pressing the [HOME] or [TOP] key sets the current position to 1st January.

[SHIFT]+[HOME] or [END]

Pressing the [HOME] key while having the [SHIFT] key already depressed sets the current position to 31st December. The [END] key, if available, has the same effect.

INT

This command provides logarithmic interpolation between two 'good' (ie not 'infilled') mean daily flows. The command is effective only if the gap between days to be infilled is less than or equal to five days. If the gap is larger than this or there is no good data to interpolate on, interpolation is not attempted and a warning issued. If one or more of the flows being used for interpolation is zero, again no interpolation is attempted since it is not possible to take the logarithm of zero.

COMM

One line of comment (68 characters) can be stored for each month of data. This command allows the comment to be entered initially or revised later. One question is asked :

Q. Enter revised monthly comment or * to abort
A. Up to 68 characters. If * is the first character this command is aborted and the original comment is preserved.

HELP

A list of all commands is displayed on the screen when help is typed.

Typing HELP again removes this list.

S (Scroll)

Normally ten days of data are displayed on the screen. The current position being in the centre of the screen. Five preceding days and the four following days are on the screen for inspection. This may be changed to a total of five lines by typing S (for Scroll) and to three lines by typing S once more. The next entry of S resets the number of lines on display to ten.

Reducing the number of lines on display increases the speed of scrolling and hence the speed with which data may be entered by the operator. However fewer lines are visible at any one time.

M (Missing)

To set the current data item missing issue the command M.

SAVE

Data which appear on the screen are held in the memory of the computer. Changes and additions which you make during any one run of this program are not stored on the system until you give the command SAVE. The command SAVE also causes the program to terminate and return control to the main menu.

EXIT

The command EXIT causes the program to terminate without saving any changes or additions you might have made. This command is used if you are just looking at the data or wish to abort an unsuccessful edit.

8.4 Option (13) Print stage & flow data

Description

This option produces a printed summary of staff gauge data and mean daily flows.

A detailed printout, including all staff gauge data is available by typing the month of the year for which the print is required or by the command ALL which gives the entire staff gauge and flow data for the requested year.

A one page annual summary of the mean daily flows is provided by the command ANNUAL.

Printed output is produced which may be photocopied onto A4 or quarto size paper.

Questions, Answers & Commands

- Q. Enter station number >
A. Any station number known to the system
- Q. Enter year >
A. Any year already assigned to that station
- Q. Command >
A. Any one of the following :
- Jan, Feb, ... Dec
- ANNUAL
- ALL
- EXIT

These commands are considered in more detail below

Commands

Jan, Feb, ... Dec

Print the monthly staff gauge data and mean daily flow data for the month requested. Monthly statistics are calculated if no days in the month are flagged as missing. If a rating equation exists on the system for the requested station year, instantaneous monthly peak and minimum discharges are also calculated and printed. Data for each month are printed on one page.

ANNUAL

Print the mean daily staff gauge data for the whole of the requested year. Monthly statistics are calculated if no in a month are missing. Annual statistics are calculated if it was possible to calculate all monthly statistics. The annual summary is printed on one page. The summary is preceded by a dated title page.

ALL

Print a dated title page followed by each of the 12 possible monthly summaries as defined above. Finally an annual summary of mean daily flows is produced. A total of 14 pages is produced.

EXIT

The command exit terminates the program and returns control to the main menu.

9. Gaugings and ratings

This group of programs is only applicable to flow stations and in particular their discharge measurements (gaugings) and rating equations. The programs have been designed to allow the development of a rating curve on the computer in the same manner as it might be done attempted by hand.

The following stages of rating equation development have been identified and translated into four options in this group :

- (1) Preparation of a table of discharge measurements in chronological order. This is achieved under main menu Option (20).
- (2) Plotting of discharge measurements on a linear scale. This shows up outliers and reveals jumps or changes in the rating. These rating changes are time dependent and are due to changes in the control section as a result of flood deposition or scour or maybe movement of the stage board. This process of sorting out discharge measurements in various ratings is undertaken in Option (21).
- (3) A rating equation is fitted to each of the previously defined sets of discharge measurements. This is done on a logarithmic scale, where ratings can often be approximated to by straight lines. Option (22) reproduces this process.
- (4) A set of time dependent rating curves for each station is stored for converting stage readings to mean daily flows. Option (23) allows rating equations developed to be stored on the system and permits rating tables to be printed if required.

Each of the four options is described below in more detail.

9.1 Add/delete/print gaugings (discharge measurements)

Description

This option allows the addition of discharge measurements to the system for any known flow station. Discharge measurements may also be deleted or listed to the printer using this program.

When a flow station is first introduced to the system space is allocated for up to 332 discharge measurements automatically. At the moment, however, use is restricted to 166 discharge measurements. Information stored about each gauging is as follows:

- Date
- Stage
- Discharge
- Velocity
- Area (this is by inference from discharge & velocity)
- The rating curve (if any) the gauging is assigned to

When discharge measurements are first added to the system using this program, the operator must specify the date, stage, discharge and area. The velocity is calculated internally from the discharge and area. Gauging velocity and area are not used elsewhere in the system; only stage and discharge are used in rating development.

Assignment of any particular gauging to a rating takes place in the next stage of rating curve development, option (21) on the main menu.

Questions, Answers & Commands

Q. Enter station number

A. Any station number known to the system

Q. Command >

A. Any one of the following :

- Discharge measurement order number
- [RETURN]
- Arrow keys
- [HOME] or [TOP] key
- [SHIFT]+[HOME] or [END] key
- DELT
- ADD
- S
- PRINT
- SAVE
- EXIT

These commands are considered in more detail below:

Discharge measurement order number

Discharge measurement are automatically stored in chronological order. The current position within this list of gaugings may be set by entering the order number of the discharge measurement. For example the 25th gauging is displayed by entering the command 25.

[RETURN]

Pressing the [RETURN] or [ENTER] key alone causes the current position within the discharge measurement list to be advanced by one. Holding the [ENTER] key down causes continuous movement through the list.

Arrow keys

Pressing the arrow keys moves the current position in the direction of the arrow. Do not hold the arrow key down (on Somali Comart) but wait for the screen to finish scrolling before repeating an arrow key. On the UK and Thailand Comarts the arrow key may be held down to obtain continuous movement in the direction of the arrow.

[HOME] or [TOP]

Pressing the [HOME] or [TOP] key sets the current position to the first discharge measurement on the list.

[SHIFT]+[HOME] or [END]

Pressing the [HOME] key while having the [SHIFT] key already depressed sets the current position to last discharge measurement. The [END] key, if available, has the same effect.

DELT

The current discharge measurement is deleted from the list.

ADD

This command is used to add a new discharge measurement to the list. Firstly the date of the discharge measurement is requested with the question :

Q. Enter date of dm (eg 21,4,1984) >

A. The date of discharge measurement must be entered as three integer numbers, separated by commas, in the order day, month, year. The year must be within the project limits (1950-1990 Somalia), (1901-1986 Thailand).

The correct chronological location of the new discharge measurement is then found within the current list and the location is displayed on the screen. (Note that it is possible to have more than one gauging on each day). Finally this question is asked :

Q. Enter stage(m), area(sq m), flow(cumecs) eg 2.2,9.1,5.2 >

A. Enter three numbers specified by commas in the order specified by the question. The flow must be non zero and no greater than 99999 cubic metres per second. The area must be non zero and no greater than 2000 square metres. The stage must be within the station limits specified for that station. The velocity calculated from the discharge and area given must not exceed 20 metres per second.

There are a great many checks applied to the above answer. If any check fails the question is repeated. Check each of your three parameters carefully if you find your response rejected. You may use the [INTRPT] key to abort at this stage (on Cifer T4) or answer with * as the first character on a line (Cifer T4 & Cifer 2841).

S (Scroll)

Normally ten gaugings are displayed on the screen. The current position being in the centre of the screen. Five preceding gaugings and the four subsequent gaugings are on the screen for inspection. This may be changed to a total of five gaugings by typing S (for Scroll) and to three gaugings by typing S once more. The next entry of S resets the number of gaugings on display to ten.

Reducing the number of lines on display increases the speed of scrolling and hence the speed with which data may be entered or viewed by the operator. However fewer gaugings are visible at any one time.

PRINT

A printed list of all discharge measurements for the station is produced by this command. One question is asked :

Q. Is the printer ready y/n
A. Y or y for yes, anything else for no

SAVE

Data which appear on the screen are held in the memory of the computer. Changes and additions which you make during any one run of this program are not stored on the system until you give the command SAVE. The command SAVE also causes the program to terminate and return control to the main menu.

EXIT

The command EXIT causes the program to terminate without saving any changes or additions you might have made. This command is used if you are just looking at the data or wish to abort an unsuccessful edit.

9.2 Option (21) Plot/Assign gaugings

Description

This option allows discharge measurements to be plotted on the screen for inspection purposes and to allow individual discharge measurements to be assigned to a particular rating for rating curve development in Option (22).

Gaugings added to the system are initially not assigned to any rating and this is indicated on the screen by the flag '?'. This plotting program allows this assignment to be changed. Individual gaugings may be assigned any one of the letters a,b,c ... t. Groups of gaugings assigned to the same letter rating are accepted for rating equation development under Option (22).

Gaugings may be plotted on the screen with their current rating assignment letter by the command LETTER.

Normally the scale chosen for the graph allows for all points to be displayed. The scale may be changed by the SCALE command to look more closely at low flow discharge measurements. This may be useful when looking for shifts in the rating.

The assignment of gaugings can be changed at any time by re-running this program. Gaugings may even be 'de-assigned', if found unsuitable for any rating by the -? command.

Questions, Answers & Commands

Q. Station number ?

A. Any flow station known to the system having one or more gauging stored on the system

Q. Command >

A. Any one of the following :

- [RETURN]
- B (Back plot)
- [HOME] or [TOP]
- CLEAR
- ALL
- LETTER
- -a, -b, -c ... -t
- -?
- SCALE
- SAVE
- EXIT

These commands are considered in more detail below :

Commands

[RETURN]

Pressing the [RETURN] or [ENTER] key causes the next discharge measurement to be plotted on the screen. Continuous plotting may be achieved by holding the [ENTER] key down.

B (Back plot or point removal)

The command B causes the last point plotted to be removed from the screen. If there is just one point on the screen this command has no effect. The command is useful if it unclear where the last point had been plotted; pressing the three keys B [RETURN] [RETURN] in sequence causes the point to be displayed and removed again, thus making its location more noticeable.

[HOME]

Pressing the [HOME] key or [TOP] key causes all points to be removed except the first discharge measurement on the list. The previous effect of a [CLEAR] command to redefine the plotting starting point is cancelled.

CLEAR

The command clear clears all points on display except the current point. This now becomes the basis of any further plotting. The B command cannot gain access to points before the newly defined starting position. The effect of this command is cancelled by the [HOME] command which redefines the first point as the basis of plotting.

The purpose of this command is to clear from the screen many early discharge measurements which may be confusing when trying to allocate later discharge measurements to a rating.

ALL

All discharge measurements are plotted on the screen in one operation by issuing the command ALL.

LETTER

Normally points are plotted on the screen as dots. If the command LETTER is given, all subsequent points are plotted as dots with a single character above and to the right indicating to which rating the point is currently assigned. The command LETTER given again removes this annotation feature. It should be noted that this command is only effective from the current position, any points already displayed on the screen remain as they were until replotted.

-a, -b, -c ... -t

A minus sign preceding any letter between a and t assigns the current discharge measurement to a rating specified by the letter given in the command. Thus the command -q assigns the current discharge measurement as displayed above the plotting area to rating Q. When discharge measurements are first entered onto the system they are unassigned to any rating and this is represented by the character ?.

Normally plotting of discharge measurements in chronological order reveals any change in datum due to flood scour or deposition or maybe movement of the staff gauge. This program automates the plotting procedure and this command allows up to 20 ratings, from letter a to letter t, to be defined as a result of any shifts in station datum or control.

-?
--

A discharge measurement may be de-assigned from a rating by the command -?. The question mark indicates an un-assigned gauging.

SCALE

Often shifts in a station datum or control is more noticeable at low flows than flood flows, furthermore there tend to be more low flow discharge measurements at low flows than high flows. For these reasons it is sometimes desirable to look more closely at low flow gaugings. This may be achieved by the command SCALE which causes cross hairs to appear on the screen. The arrow keys may then be used to move these cross hairs to define the upper right corner of a rescaled graph. The original graph origin again forms the lower left corner of the new graph. Having redefined the the new graph boundaries, press the [SPACE] bar to initiate the redrawing process. Note that the new axes are chosen to give sensible annotation units and because of this may not correspond exactly with those specified by the cross hairs. Note also that only the discharge measurements which appear within the newly specified boundary will be visible.

The original axes and scaling may be recovered by giving the command SCALE again and using the cross hairs to define a new upper right corner OUTSIDE the plotting area.

SAVE

Data which appear on the graph are held in the memory of the computer. Any changes and additions which you make to the rating assignments during any one run of this program are not stored on the system until you give the command SAVE. The command SAVE also causes the program to terminate and return control to the main menu.

EXIT

The command EXIT causes the program to terminate without saving any changes or additions you might have made to the gauging assignments. This command is used if you are just looking at the gaugings or if you want to ignore any assignments made.

9.3 Develop rating curve (Option 22)

Description

This option allows a rating curve to be developed from a particular set of discharge measurements.

The set of discharge measurements must be a block of at least 10 gaugings assigned to a single rating (a,b, ... t) using Option (21) described above.

The rating equation takes the form :

$$Q = a (h + c)^b$$

where,

Q = Discharge
h = Stage
a = Rating multiplier parameter
b = Rating exponent parameter
c = Rating constant parameter

The parameters a and b are determined by this program using a least squares approach. The parameter c may be determined by manual trial and error or by an optimisation procedure using the BEST command.

The first value of parameter c is obtained from the lowest gauge height in the discharge measurement list. The parameter c is increased by 0.1 by command [RETURN] and decremented by 0.1 by the command B. In every case the percentage change in error between successive fits is displayed on the screen.

The SETB and SETC commands allow the range over which the parameters b and c may be chosen, to be re-defined. The b parameter range is a useful feature which prevents unreal exponents in the rating curve.

Questions, Answers & Commands

Q. Station number ?

A. Any flow station number with at least 10 discharge measurements assigned to one rating.

Q. Choose rating from below >

A. Any one of the available ratings displayed on the screen below the question.

Q. Command >

A. Any one of the following commands:

- [RETURN]
- B (Back)
- SETC
- SETB
- [HOME] or [TOP]
- BEST
- SAVE
- EXIT

These commands are considered in more detail below:

Commands

[RETURN]

Pressing the [RETURN] key increases the current value of the parameter c by 0.1 providing that the current maximum value of parameter c is not exceeded. A fresh set of optimum parameters a and b are recalculated and the new graph and data points are displayed on the screen. The change in error between the previous graph displayed and the new value of screen is shown on the top right of the screen. A negative sign on this error indicates a reduction of error, hence an improvement in fit. An increase in the percentage error implies a statistically poorer fit.

It should be noted that the value of parameter b will always be within the limits currently displayed on the bottom right of the screen. The purpose of these limits is to ensure 'sensible' exponents are chosen for the rating.

B (Back)

The command B decrements the current value of the parameter c by 0.1 provided that the current minimum value of c is not exceeded. The B command has the reverse effect of the [RETURN] command. If issued after a [RETURN] command the graph displayed returns back to the original. The recalculation of parameters a and b and the percentage change in error is as described above for [RETURN].

SETC

The command SETC redefines the currently set maximum and minimum values of the parameter c as displayed on the lower right of the screen. Initially the minimum c is set 0.02 above the lowest stage reading in the set of discharge measurements. The maximum c is initially set 2.0 above the minimum. Any rating developed will have

its c parameter from within that range. The range can be changed by the SETC command. One question is asked:

Q. Min c,max c (eg 0.2,1.2) >

A. Two numbers separated by commas defining the new minimum c and new maximum c. The minimum c must be greater or equal to the initial value as defined above. The maximum must be greater than or equal to the minimum and less than 10.0.

Note that this command may be used to specify a single value of the parameter c by setting both the maximum and minimum to the desired value.

SETB

This command has exactly the same effect as SETC command except the maximum and minimum values for parameter b are reset. The initial value of the minimum is 1.3 and the maximum 2.8. As with the SETC command, specifying the minimum and maximum as the same value causes a single value to be adopted for the exponent. This might be useful if, for example, an exponent of 1.5 was demanded for a rectangular weir. One question is asked:

Q. Min b, max b (eg 1.2,2.2) >

A. Two numbers separated by commas giving the new maximum and minimum values of the parameter b. The minimum must be greater than 0.5 and the maximum greater or equal to the minimum but less than 4.

[HOME] or [TOP]

The [HOME] or [TOP] key resets both the c and b parameter limits to the original set. The graph displayed also returns to the original.

BEST

This command obtains the 'best' value of the parameter c within the currently defined limits of the parameters b and c. The 'best' value of 'c' is determined to an accuracy of 0.01 by an optimisation procedure and is the one where minimum fitting error is achieved.

Care should be taken when using the BEST command. The user should check whether one or more parameter is on its limits and that the result produced is sensible.

SAVE

The save command provides the facility to transfer directly to the rating curve installation program. A pause is provided to enable the user to make a note of the three rating parameters, the rating code letter and the date of the first discharge measurement. One question is asked:

Q. Transfer to the rating curve editor now y/n >

A. Y or y for yes, anything else terminates the program and returns control to the main menu.

EXIT

The program terminates and control returns to the main menu.

Note

To avoid a scale change on the plotting of the graph on the screen, one or more points at the lower stage range are not displayed when the current value of parameter c is at the minimum possible. This condition occurs on the first graph displayed and after the [HOME] or [TOP] command is given.

9.4 Add, delete or print a rating equation or print a rating table

Description

This option permits a rating equation to be installed in the system or a rating equation to be removed from the system.

Installed rating equation may be listed or rating tables printed from any installed rating equation.

The rating equation takes the form :

$$\begin{aligned} Q &= a_1 (h + c_1)^{b_1} && \text{to } h_1 \text{ metres} \\ Q &= a_2 (h + c_2)^{b_2} && \text{to } h_2 \text{ metres} \\ Q &= a_3 (h + c_3)^{b_3} && \text{to } h_3 \text{ metres} \end{aligned}$$

where,

Q = Discharge
h = Stage
a₁, a₂, a₃ = Rating multiplier parameters
b₁, b₂, b₃ = Rating exponent parameters
c₁, c₂, c₃ = Rating constant parameters
h₁, h₂, h₃ = Stage limit for rating segment

Although a three segment rating curve is permitted, single or double segment ratings are also allowed. If multiple segment ratings are to be added to the system, there must be continuity at the segment stage limits h₁ and h₂.

During installation a date of operation is specified for each rating which defines the date that the rating becomes operative. Installed ratings are used for the conversion of staff gauge readings to daily flows in Option (11). The rating used in conversion of each day of data depends on this 'date of operation'.

Questions, Answers & Commands

- Q. Enter station number
A. Any flow station number known to the system

- Q. Enter command (Rat no,ADD,DELT,PRINT,SAVE,EXIT) >
A. Any one of the following commands
- Any one of the rating code letters shown on the screen
- ADD
- DELT
- PRINT
- SAVE
- EXIT

These commands are considered in more detail below:

Rating code letter

Entering any one of the rating code letters shown on the screen causes the parameters associated with that rating to be displayed.

If no rating equations have been installed, this command is, of course, meaningless.

ADD

This command is used to add a new rating equation to the system. A new rating can be added subject to the maximum number per station of 20. The possible questions and answers associated with this command are given below:

- Q. File full (20 rats). Hit [RETURN]
A. Press [RETURN] to continue. There are already 20 ratings installed for the station. No more may be added until at least one is deleted (use DELT command).
- Q. Enter date from which rating is to apply (eg 22,4,1984) >
A. Three numbers separated by commas in the order day,month,year. The date specified must be within the overall project limits and must not have been used by any other rating for the station.
- Q. Rating exists for this date.DELT first to replace.Hit [RETURN]
A. Press [RETURN] to continue. A rating already exists for the date specified. If you wish to replace the original rating it must be deleted first using the DELT command.
- Q. Enter rating code letter (a-t) >
A. Any letter from a (or A) to t (or T) inclusive not already in use.
- Q. Code in use already. Re-enter >
A. Any letter from a to t inclusive which has not already been used as a rating code letter.

Q. Part 1 parameters >

A. Four numbers separated by commas giving the parameters for the first segment of the rating curve. The four parameters are in the order a1,b1,c1,h1 as defined above and must be within these limits:

a1 from 0.0001 to 10000.0
b1 from 0.5 to 3.5
c1 from -10.0 to 10.0
h1 from -20.0 to 25.0

Alternatively if * is the first character of the answer, the command ADD is aborted.

Q. Part 2 parameters >

A. If the rating is single segment, press the [RETURN] key in reply to this question, if not enter four numbers separated by commas giving the parameters for the second segment of the rating. The four parameters are in the order a2,b2,c2,h2 as defined above and must be within the limits given above for the Part 1 parameters. Additionally h2 must be above the value of h1 specified in the Part 1 parameters.

Alternatively * as the first character in the reply aborts the ADD command.

Q. Error >5%.Hit [RETURN] & re-enter >

A. Press [RETURN] to continue. A continuity check at the stage h1 between the first and second segments of the rating has produced an error in discharges of greater than 5%. The two discharges calculated from the two segments at stage h1 are given on the screen as Q1 and Q2. You must look again at the parameters for your rating to ensure this check is satisfied. If you wish to abort this ADD command press [RETURN] here and give * as the first character to the next question.

Q. Part 3 parameters >

A. If the rating is double segment, press the [RETURN] key in reply to this question, if not enter four numbers separated by commas giving the parameters for the third segment of the rating. The four parameters are in the order a3,b3,c3,h3 as defined above and must be within the limits given above for the Part 1 parameters. Additionally h2 must be above the value of h2 specified in the Part 2 parameters.

Alternatively * as the first character in the reply aborts the ADD command.

Q. Error >5%.Hit [RETURN] & re-enter >

A. Press [RETURN] to continue. A continuity check at the stage h2 between the second and third segments of the rating has produced an error in discharges of greater than 5%. The two discharges calculated from the two segments at stage h2 are given on the screen as Q1 and Q2. You must look again at the parameters for your rating to ensure this check is satisfied. If you wish to abort this ADD command press [RETURN] here and give * as the first character to the next question.

DELT

The DELT command deletes the rating currently displayed on the screen. The command has no effect if there are no ratings for the station. The possible questions and answers generated by this command are:

Q. Delete which rating >

A. Enter a valid rating code letter from the list given on the screen

Q. Delete rating shown y/n >

A. Y or y for yes, anything else for no.

Q. No dm's to delete. Hit [RETURN]

A. Press [RETURN]. There are no ratings installed for the station so it is impossible to delete any. (Note for dm's read ratings).

PRINT

The PRINT command enables either all the rating equations for a station to be listed on the printer or a rating table to be printed for any of the installed ratings for the station. The possible questions and answers of this option are:

Q. Is the printer ready y/n ?

A. Y or y for yes, anything else for no

Q. List rating curves (1) or print rating table (2) 1 or 2 >

A. 1 or 2. (Option (1) is assumed unless (2) is specified explicitly)

Q. Enter rating code letter >

A. Any rating code letter displayed on the screen

SAVE

The SAVE command saves any changes made to the ratings during the present run of this program. The program then terminates and control returns to the main menu.

EXIT

The EXIT command terminates the program and returns control to the main menu. Any changes made during the current run of the program are not saved. This option may be used to abort an unsuccessful edit or to terminate the program after just looking at or printing the ratings.

A. More about the equipment

A.1 The Comart CP500 computer

The Comart computer should be kept clean and the filter at the rear of the unit replaced once per month. If the store of filters has run out, wash the old filter and allow to dry before replacing. The flexible disk drive should be cleaned using the cleaning diskette before data are copied. Full details of the cleaning operation are given under option (4) in the main menu.

Whenever the computer is moved the cardboard insert should be placed in the flexible disk drive (see '3. Moving the computer' above). Before using the computer again this insert must be removed.

If the computer fails to work (red light on front not on or no response to terminal) first check that all the leads are correctly inserted (Figure 1). Should the computer still fail to work check the fuses behind the computer in the rear panel one by one and replace them as necessary. There is a stock of spare fuses in the drawer beneath the computer. Make sure that the correct rating fuse is used to replace the old.

Technical specifications of the CP500 are:

Processor	- Z80 (@ 4MHz)
Hard disc	- 5.3 Megabyte
Operating system	- CP/M
Memory	- 64k
Flexible disk drive	- 790 Kilobyte (Dysan 207/2D) (2 sided double density diskettes)
Terminal line	- 9600 baud, Parity mark, 1 stop bit, DTR flw ctr
Printer line (Prmry)	- Serial DC1/DC3 support 9600 baud
Printer line (2ndry)	- Parallel (not used)

A.2 The Cifer 2841 terminal

The Cifer 2841 terminal should be kept clean and the filter changed once a month (as for the Comart computer). The keyboard should be kept as clean as possible and covered when not in use. The keyboard is a sensitive piece of equipment and care should be taken that it does not get too dusty.

The Cifer 2841 has an intelligence all of its own and remembers what type of connection to make to the computer. If the terminal is left unused a long time (several weeks) it is possible that the rechargeable batteries inside will become low and the terminal 'forget' that it is connected to a Comart CP500. This condition will first be noticed when you start up the computer after a long while. There will probably be nothing on the screen when you are expecting the familiar box, titles and request for password. Or, perhaps, there will be rubbish on the screen with curious symbols or perhaps a message such as !! Non volatile store error !!. In any case turn off all the equipment including the terminal but leave the power supply on. Now turn the terminal back on leaving the computer and printer off for the time being. If the problem is the one being described here the green box in the bottom left hand corner of the screen will say 'LOCAL'. We must now tell the terminal what connections to make to the computer and ask it to remember them. With the terminal on only follow these instructions:

Press key	Action
-----	-----
(1) LOCAL	(to change display to L DCDOFF)
(2) SETUP	(re-program CIFER terminal)
(3) 1	(select Line)
(4) 2	(for parity)
(5) 3	(for mark)
(6) [RETURN]	
(7) [RETURN]	
(8) 4	(for screen)
(9) 5	(for other)
(10) 3	(for cursor)
(11) 2	(for block)
(12) [RETURN]	
(13) [RETURN]	
(14) [RETURN]	
(15) 6	(for save)
(16) 2841	(for password)
(17) Any key	(save complete)
(18) [RETURN]	

Now turn the computer on and the normal display should occur. If not try and repeat the process.

If the terminal is completely dead (no display and red light next to Cifer name plate off) first check all the connections. If these

are OK look at the fuse at the back of the terminal and relace if broken using the correct rating of fuse from the stock kept in the drawer beneath the computer.

Technical specifications of the Cifer 2841:

- Text display - 32 rows of 128 columns or
25 rows of 80 columns
Essentially DEC VT100 emulation
- Graphics display - 1024 x 256 resolution
Tektronix 4010 emulation
- Keyboard - Software programable

A.3 The Epson MX100 III printer

Keep the printer clean and covered with a cloth when not in use. The printer booklet will remind you how to change the paper (page 11 onwards). Several spare ribbons have been supplied and are kept in the drawer beneath the computer. Changing these is a fiddly, messy job but has been done successfully by local staff (instructions are with each ribbon). Two complete new ribbon cartridges have also been supplied but these should only be used when the old cartridge breaks or all the spare ribbons are used.

If the printer is moved follow the instructions given above '3. Moving the computer'. In particular the transportation screws should be used and one sheet of paper inserted in the printer.

Before you turn on the printer make sure the paper join (ie where it folds) is just above the print head mechanism. This will ensure all the output starts properly at the top of a page.

If the paper becomes torn or stuck inside the printer, turn the printer OFF immediately. Clear the blockage and replace the paper. Make sure the box of paper is directly beneath the printer and that the lever marked 'release' on the left side is towards the front (ie in the direction of the arrow).

Your Epson printer is fitted with a special 'memory' which means that the printer itself can store 4 or 5 pages of data without holding up the computer. Thus you may find that you are able to continue working on the computer while at the same time the printer finishes your last printout.

Technical specifications:

Type	- Dot Matrix
Speed	- 100 characters/second
Resolution	- 9 x 9 matrix
Chars./line	- Normal 136, Large 68, Small 233
Interface 1	- RS232 with 16k buffer
Interface 2	- Centronics 8-bit parallel (Do not use)

APPENDIX II

OPERATIONAL EXPERIENCE OF COMPUTER SOFTWARE

II.1 Introduction

The software developed for the computer generally performed satisfactorily but experience of day-to-day use of the system revealed a number of areas where the usability or friendliness of the software could be improved. There was little opportunity to incorporate the type of refinements suggested into the original software due to lack of time.

II.2 General Software Structure

The major drawback in all the stage/flow data handling programs was the inability to access more than one station-year of data at a time and the lack of interaction between program functions. For instance, when editing stage data using option 10, having specified the station ID number and the year of the data required, it is not possible to access and inspect data from any other year without returning to the menu and specifying the station ID and new year again. It is not possible to inspect on the screen the time-series from say December through to January of the next year to check on continuity. Access to any year of data within the same program module without returning to the menu would be a great advantage.

When printing stage/flow data or when converting stage data to river flow, the system at present will again only allow access to one year's data at a time. A great deal of computer operating time is therefore required to convert (say) 20 years of data, since option 11 has to be initiated 20 times through the menu specifying ID number and a new year on each occasion. This may not be a very frequent operation but the problem becomes more exasperating when printouts of data are required. In order to obtain a complete set of annual summary flow data sheets for Lugh Ganana (1951 to 1984), the operator must initiate option 13 from the menu 34 times, waiting several minutes for the printer buffer to become clear in between printing successive years, before details of the next printout are specified. Therefore, the operator must sit in front of the computer for several hours at a time to obtain these printouts to satisfy the frequent requests for complete sets of station flow data summaries from consulting engineers or aid organisations. A modification to the program to allow any number of years of data to be accessed at one time would be a significant improvement.

Similarly it would be very useful when working on a particular station's data to be able to edit, convert and print data within one program without having to save any changes, exit and call up each of the other modules in turn. It would then be possible to inspect adjustments to data (perhaps graphically) to determine whether the changes made are acceptable, before finally saving the edited data.

Interaction between programs which handle discharge measurement data, would enable DMs displayed graphically in option 21 to be edited if required, an action only possible at the moment by returning to the menu and calling option 20.

The above examples illustrate how the flexibility and user-friendliness of the system could be improved, although the limited computer RAM and the structure of the database may make some of the suggested changes difficult to implement. Further comments and suggestions are made below with respect to specific features or options of the existing software.

II.3 Data Display During Editing

In options 10 and 12 stage and flow data are initially entered or edited at the current position of the cursor, which always stays on the same line of the screen display, and each new day's data is scrolled into the cursor line. This scrolling technique causes a small delay before the new screen display is formatted and because of this it is very easy when entering a continuous series of new data, for the operator to type in figures faster than the computer is capable of receiving them. Consequently the data being entered becomes truncated as the first few digits typed are not read, with the result that either the data is rejected by the validation routine or an incorrect value is entered into the computer; frequently this error is not spotted and is identified (hopefully) during subsequent checking and validation procedures. Many errors in the data could therefore be avoided if this method of data entry could be amended or speeded up.

II.4 Use of CON Command

This command is an essential feature of the software when adjustments to data are required to take account of overlapping gauge plates and changes in gauge-zero or when bridge dip readings from an MB are used. It can only be used within option 10 when editing or entering individual stage readings. It would be very useful to be able to edit long periods of data in which there is a systematic error using the CON command, by specifying the exact dates over which the constant should be applied, and then instructing the computer to automatically correct those data.

Occasionally stage data are required in terms of a level above Mean Sea Level. The CON command can be used to allow stage to be stored in this form, but normally the gauge-height above a gauge-zero is preferred. However, it would be convenient to be able to display and print stage data as metres above MSL when required, and the use of the command could be expanded in this way. The gauge-zero, as metres above MSL, could be an additional piece of data held in the system index of station parameters, and options could be incorporated in program modules to add this constant to all gauge-heights when retrieved from the database prior to display on screen or printout.

II.5 Discharge Measurement Lists

In Table 2.1, a column of data has been included which compares the measured discharge with the value calculated from the observed gauge-height using the relevant stage-discharge rating curve. This error difference is a very useful guide to the validity of the relevant rating or conversely to the accuracy of the gauging. It would be very useful to have such information presented on screen, perhaps when a new gauging is added to the database using option 20, and to include the error column in the printout.

APPENDIX III

NEW AUTOMATIC WATER-LEVEL RECORDING FACILITIES

III.1 Progress

It was not possible to implement, in the first stage of the project, the recommendation of the Progress Report relating to the purchase of new automatic water-level recorders.

The reconstruction of recording facilities at key stations was seen as essential if further significant improvements in the quality and return of data were to be obtained.

The existing recorder installations consisted of Leopold & Stevens strip-chart recorders operating in large diameter stilling-wells with narrow inlet pipes. These instruments are now obsolete and are difficult to operate and service with spare parts no longer available. Ever since initial construction in 1963 this type of stilling-well installation has proved totally unsuitable, due to the high sediment load of both rivers. The duration of a typical flood season is 2 to 3 months, in which time wells become totally clogged by silt. In order to prevent siltation in such conditions, the system needs pumping out regularly, but this is only possible during low flow periods when there is sufficient head difference available to flush out silt. Thus it is impossible to maintain the present system adequately.

The stations to be equipped with new recording facilities are:

- Lugh Ganana, river Juba
- Bardheere, river Juba
- Kamsuma, river Juba
- Belet Weyn, river Shebelle
- Kurten Warey, river Shebelle

The proposed new recording station would involve the installation of an open-ended stilling-pipe arrangement. Attached to bridge support piers or possibly to RSJ stands set in concrete. A small instrument box with locking facilities would be attached to the top of the stilling-pipe at bridge deck level. Two reports were produced during the project recommending that solid-state technology recorders be purchased. These can operate unattended for long periods and have extremely low maintenance requirements.

A report was prepared in April, detailing general requirements, type of instruments available and possible suppliers, as well as probable costs of equipment and installation, for five new stations plus one spare recorder unit. Out of the total budget cost of £13 420.00, 25% was to be paid by the Somali Government.

A further report submitted in September, recommended the purchase of six solid-state water-level recorders with shaft-encoder sensors manufactured by Technolog Ltd., together with a field data retriever unit, at a total cost of £6 759.00

without carriage and insurance. These were ordered in October but had not arrived in Mogadishu by the end of December 1984.

It would be most convenient if the recording facilities could be installed during the minimum flow period of February/March before the arrival of the gu flood. If this is not possible, the pipes would have to be fitted in sections, as allowed by river level changes during the flood season and subsequent recession period.

III.2 Proposed Operation of New Automatic Recorders

The total reliance on local field observers, in the absence of an effective automatic monitoring system, was seen as the cause of the poor quality and continuity of the record from gauging stations in the past. In the future the new water level recorders should be regarded as the primary source of data and the observers' record need only be used if the automatic recorder fails. This will yield dramatic improvements in the quality of the record, due to both the greater reliability and accuracy of data returns, and the more frequent sampling of the continuous hydrograph. The solid state data loggers will be capable of operating from batteries for in excess of three months at a time recording, on to memory chips, the stage readings every hour, or more frequently if required, with hydrograph flood peaks accurately traced. The data need only be retrieved every three months from the more remote stations thereby reducing the frequency of data collection field trips. The data can then be transferred on to computer disk files for display, perhaps graphically on screen, and analysis and permanent storage. The observers' record from cards should already have been entered on to computer at this stage, and direct comparison of the two records could then be made. Software should be incorporated into the data processing system so that the automatically recorded data would then replace the less accurate observers' data.

Maintenance of instruments and stilling pipes will be minimal. Occasional flushing out of the pipes would be recommended, using the water pump already provided by the project. Batteries for the recorders should be changed on every visit.

APPENDIX IV

STATION DETAILS - COMPUTER PRINTOUT

Surface water data base - Station summary

Stations on the system : 10

Station number	Station name
1 ...	Jubba at Lugh Ganana
2 ...	Jubba at Bardheere
3 ...	Jubba at Jamamme
10 ...	Shebelli at Beled Weyn
11 ...	Shebelli at Bulo Burti
12 ...	Shebelli at Mahaddey Weyn
13 ...	Shebelli at Balcad
14 ...	Shebelli at Afgoi
15 ...	Shebelli at Audegle
16 ...	Shebelli at Kurtun Warey

Station number 1 Station name : Jubba at Lugh Ganana

Catchment area 179000.0 sq km
Maximum staff gauge reading 7.50 m
Minimum staff gauge reading -1.00 m
Maximum change between staff readings 3.00 m

Space has been allocated on the system for the following years.
Brackets [] indicate number of staff readings per day.

1951 [1]	1952 [1]	1953 [1]	1954 [1]	1955 [1]	1956 [1]	1957 [1]	1958 [1]
1959 [1]	1960 [1]	1961 [1]	1962 [1]	1963 [2]	1964 [2]	1965 [2]	1966 [2]
1967 [2]	1968 [2]	1969 [2]	1970 [2]	1971 [2]	1972 [2]	1973 [2]	1974 [2]
1975 [2]	1976 [2]	1977 [2]	1978 [2]	1979 [2]	1980 [2]	1981 [2]	1982 [2]
1983 [2]	1984 [3]	1985 [2]	1986 [2]	1987 [2]	1988 [2]	1989 [2]	1990 [2]

-----ih

Station number 2 Station name : Jubba at Bardheere

Catchment area 216730.0 sq km
Maximum staff gauge reading 7.00 m
Minimum staff gauge reading -1.00 m
Maximum change between staff readings 2.00 m

Space has been allocated on the system for the following years.
Brackets [] indicate number of staff readings per day.

1963 [3]	1964 [2]	1965 [2]	1966 [2]	1967 [2]	1968 [2]	1969 [2]	1970 [2]
1971 [2]	1972 [2]	1973 [2]	1974 [2]	1975 [2]	1976 [2]	1977 [2]	1978 [2]
1979 [2]	1980 [2]	1981 [2]	1982 [2]	1983 [2]	1984 [3]	1985 [3]	1986 [3]
1987 [3]	1988 [3]	1989 [3]	1990 [3]				

-----ih

Station number 3 Station name : Jubba at Jamamme

Catchment area 268800.0 sq. km
Maximum staff gauge reading 7.50 m
Minimum staff gauge reading -2.00 m
Maximum change between staff readings 1.50 m

Space has been allocated on the system for the following years.
Brackets [] indicate number of staff readings per day.

1963 [2]	1964 [2]	1965 [2]	1966 [2]	1967 [2]	1968 [2]	1969 [2]	1970 [2]
1971 [2]	1972 [2]	1973 [2]	1974 [2]	1975 [2]	1976 [2]	1977 [2]	1978 [2]
1979 [2]	1980 [2]	1981 [2]	1982 [2]	1983 [2]	1984 [3]	1985 [3]	1986 [3]
1987 [3]	1988 [3]	1989 [3]	1990 [3]				

ih

Station number 10 Station name : Shebelli at Beled Weyn

Catchment area 211800.0 sq km
Maximum staff gauge reading 7.00 m
Minimum staff gauge reading -1.00 m
Maximum change between staff readings 2.50 m

Space has been allocated on the system for the following years.
Brackets [] indicate number of staff readings per day.

1951 [1]	1952 [1]	1953 [1]	1954 [1]	1955 [1]	1956 [1]	1957 [1]	1958 [1]
1959 [1]	1960 [1]	1961 [1]	1962 [1]	1963 [2]	1964 [2]	1965 [2]	1966 [2]
1967 [2]	1968 [2]	1969 [2]	1970 [2]	1971 [2]	1972 [2]	1973 [2]	1974 [2]
1975 [2]	1976 [2]	1977 [2]	1978 [2]	1979 [2]	1980 [2]	1981 [2]	1982 [2]
1983 [2]	1984 [3]	1985 [3]	1986 [3]	1987 [3]	1988 [3]	1989 [3]	1990 [3]

ih

Station number 11 Station name : Shebelli at Bulo Burti

Catchment area 231000.0 sq km
Maximum staff gauge reading 10.00 m
Minimum staff gauge reading -1.00 m
Maximum change between staff readings 2.00 m

Space has been allocated on the system for the following years.
Brackets [] indicate number of staff readings per day.

1963 [3]	1964 [2]	1965 [2]	1966 [2]	1967 [2]	1968 [2]	1969 [2]	1970 [2]
1971 [2]	1972 [2]	1973 [2]	1974 [2]	1975 [2]	1976 [2]	1977 [2]	1978 [2]
1979 [2]	1980 [2]	1981 [2]	1982 [2]	1983 [2]	1984 [3]	1985 [3]	1986 [3]
1987 [3]	1988 [3]	1989 [3]	1990 [3]				

-----ih

Station number 12 Station name : Shebelli at Mahaddey Weyn

Catchment area 255300.0 sq km
Maximum staff gauge reading 7.00 m
Minimum staff gauge reading -1.00 m
Maximum change between staff readings 2.00 m

Space has been allocated on the system for the following years.
Brackets [] indicate number of staff readings per day.

1963 [2]	1964 [2]	1965 [2]	1966 [2]	1967 [2]	1968 [2]	1969 [2]	1970 [2]
1971 [2]	1972 [2]	1973 [2]	1974 [2]	1975 [2]	1976 [2]	1977 [2]	1978 [2]
1979 [2]	1980 [2]	1981 [2]	1982 [2]	1983 [2]	1984 [3]	1985 [3]	1986 [3]
1987 [3]	1988 [3]	1989 [3]	1990 [3]				

-----ih

Station number 13 Station name : Shebelli at Balcad

Catchment area 272700.0 sq km
Maximum staff gauge reading 12.00 m
Minimum staff gauge reading 0.00 m
Maximum change between staff readings 1.00 m

Space has been allocated on the system for the following years.
Brackets [] indicate number of staff readings per day.

1963 [2] 1964 [2] 1965 [2] 1966 [2] 1967 [2] 1968 [2] 1969 [2] 1970 [2]
1971 [2] 1972 [2] 1973 [2] 1974 [2] 1975 [2] 1976 [2] 1977 [2] 1978 [2]
1979 [2] 1980 [2]

ih

Station number 14 Station name : Shebelli at Afgoi

Catchment area 278000.0 sq km
Maximum staff gauge reading 7.00 m
Minimum staff gauge reading -1.00 m
Maximum change between staff readings 3.00 m

Space has been allocated on the system for the following years.
Brackets [] indicate number of staff readings per day.

1951 [1] 1952 [1] 1953 [1] 1954 [1] 1955 [1] 1956 [1] 1957 [1] 1958 [1]
1959 [1] 1960 [2] 1961 [2] 1962 [2] 1963 [2] 1964 [2] 1965 [2] 1966 [2]
1967 [2] 1968 [2] 1969 [2] 1970 [2] 1971 [2] 1972 [2] 1973 [2] 1974 [2]
1975 [2] 1976 [2] 1977 [2] 1978 [2] 1979 [2] 1980 [2] 1981 [2] 1982 [2]
1983 [2] 1984 [3] 1985 [3] 1986 [3] 1987 [3] 1988 [3] 1989 [3] 1990 [3]

ih

Station number 15 Station name : Shebelli at Audegle

Catchment area 280000.0 sq km
Maximum staff gauge reading 6.45 m
Minimum staff gauge reading -2.00 m
Maximum change between staff readings 2.50 m

Space has been allocated on the system for the following years.
Brackets [] indicate number of staff readings per day.

1963 [2] 1964 [2] 1965 [2] 1966 [2] 1967 [2] 1968 [2] 1969 [2] 1970 [2]
1971 [2] 1972 [2] 1973 [2] 1974 [2] 1975 [2] 1976 [2] 1977 [2] 1978 [2]
1979 [2] 1980 [2] 1981 [2] 1982 [2] 1983 [2] 1984 [3] 1985 [3] 1986 [3]
1987 [3] 1988 [3] 1989 [3] 1990 [3]

-----ih

Station number 16 Station name : Shebelli at Kurtun Warey

Catchment area 300000.0 sq km
Maximum staff gauge reading 5.00 m
Minimum staff gauge reading 0.00 m
Maximum change between staff readings 1.00 m

Space has been allocated on the system for the following years.
Brackets [] indicate number of staff readings per day.

1984 [3] 1985 [3] 1986 [3] 1987 [3] 1988 [3] 1989 [3] 1990 [3]

-----ih

 Discharge measurements for station 1 : Jubba at Lugh Ganana

Order Number	Date	Rating Assigned	Stage m	Velocity m/s	Area sq m	Discharge cumecs
1	30 May 1963	a	2.87	0.659	312.63	206.020
2	21 Jun 1963	?	2.58	0.560	276.23	154.690
3	4 Jul 1963	?	2.62	0.693	249.99	173.240
4	12 Sep 1963	?	2.64	0.793	268.75	213.120
5	19 Oct 1963	a	2.85	0.877	258.44	226.650
6	20 Nov 1963	a	3.44	1.089	352.25	383.600
7	10 Dec 1963	?	3.24	0.970	403.54	391.430
8	26 Dec 1963	?	2.59	0.664	205.45	136.420
9	17 Jan 1964	?	2.23	0.511	153.76	78.570
10	31 Jan 1964	?	1.99	0.287	165.51	47.500
11	11 Mar 1964	?	1.71	0.151	97.35	14.700
12	2 Apr 1964	?	1.40	0.057	80.53	4.590
13	22 Apr 1964	?	2.23	0.486	149.38	72.600
14	25 Apr 1964	a	2.69	0.794	255.10	202.550
15	1 Aug 1964	?	2.31	0.652	158.87	103.580
16	2 Nov 1964	a	3.48	1.032	386.37	398.730
17	14 Nov 1964	a	2.58	0.631	299.89	189.230
18	18 Mar 1965	a	0.98	0.159	81.95	13.030
19	17 Sep 1965	a	2.15	0.661	167.69	110.840
20	15 Dec 1965	a	2.03	0.464	239.66	111.200
21	7 Jun 1967	a	2.23	0.623	228.75	142.510
22	2 Oct 1969	a	2.70	0.622	313.63	195.080
23	8 Jan 1970	a	1.20	0.355	86.23	30.610
24	26 Jun 1971	a	2.29	0.561	280.86	157.560
25	27 Jun 1971	?	2.31	0.662	305.41	202.180
26	16 Mar 1972	a	1.37	0.221	192.53	42.550
27	11 Jun 1972	a	2.86	0.797	378.61	301.750
28	8 Sep 1972	a	2.88	0.698	340.13	237.410
29	10 Sep 1972	a	2.97	0.782	355.35	277.880
30	17 Sep 1972	a	2.77	0.661	339.52	224.420
31	23 Sep 1972	a	2.61	0.597	307.42	183.530
32	14 Oct 1972	a	3.12	0.614	406.76	249.750

 Discharge measurements for station 1 : Jubba at Lugh Ganana

Order Number	Date	Rating Assigned	Stage m	Velocity m/s	Area sq m	Discharge cumecs
33	23 Oct 1972	a	3.00	0.659	431.67	284.470
34	6 Dec 1972	a	2.60	0.539	364.88	196.670
35	4 Feb 1973	a	1.36	0.184	212.28	39.060
36	2 May 1973	a	2.68	0.621	305.93	189.980
37	2 Jul 1973	a	2.17	0.587	224.74	131.920
38	2 Jun 1974	a	3.01	0.991	376.00	372.620
39	4 Jul 1974	a	2.21	0.580	251.09	145.630
40	15 Aug 1974	a	2.97	0.834	376.99	314.410
41	4 Sep 1974	a	3.10	0.912	394.84	360.090
42	9 Sep 1974	a	3.85	1.180	472.32	557.340
43	3 Oct 1974	a	3.06	0.819	425.82	348.750
44	2 Nov 1974	a	2.54	0.738	317.37	234.220
45	3 Dec 1974	a	1.75	0.447	189.64	84.770
46	15 Jan 1975	a	1.14	0.106	91.42	9.690
47	2 Feb 1975	a	1.02	0.051	143.14	7.300
48	10 Mar 1975	a	0.90	0.025	66.00	1.650
49	5 May 1975	a	2.89	0.947	305.11	288.940
50	7 Jun 1975	a	2.55	0.733	310.87	227.870
51	3 Jul 1975	a	2.56	0.739	309.36	228.620
52	30 Aug 1975	a	3.20	0.926	418.53	387.560
53	6 Sep 1975	a	3.13	0.878	404.76	355.380
54	11 Oct 1975	a	3.82	1.086	521.56	566.410
55	10 Nov 1975	a	2.88	0.806	388.77	313.350
56	7 Dec 1975	a	1.89	0.282	246.35	69.470
57	13 Jan 1976	a	1.32	0.141	181.63	25.610
58	16 Feb 1976	a	1.05	0.080	130.13	10.410
59	4 Mar 1976	a	1.00	0.048	128.54	6.170
60	29 Mar 1976	a	0.92	0.027	138.15	3.730
61	7 Aug 1976	a	2.94	0.769	387.06	297.650
62	8 Sep 1976	a	2.82	0.699	358.38	250.510
63	5 Oct 1976	a	2.70	0.669	299.52	200.380
64	2 Nov 1976	a	3.36	0.982	438.33	430.440
65	11 Nov 1976	a	3.54	1.017	508.16	516.800
66	9 Dec 1976	a	2.07	0.350	308.03	107.810
67	7 Jan 1977	a	1.58	0.249	240.52	59.890

Discharge measurements for station 1 : Jubba at Lugh Ganana

Order Number	Date	Rating Assigned	Stage m	Velocity m/s	Area sq m	Discharge cumecs
68	8 Feb 1977	a	1.75	0.359	270.36	97.060
69	10 Mar 1977	a	1.23	0.164	162.87	26.710
70	20 Mar 1977	a	1.14	0.137	149.78	20.520
71	6 Apr 1977	a	3.33	0.968	446.46	432.170
72	9 May 1977	a	5.30	1.242	778.71	967.160
73	30 May 1977	a	3.21	0.810	461.67	373.950
74	12 Jun 1977	a	3.34	0.685	513.74	351.910
75	18 Mar 1980	a	0.97	0.193	30.10	5.810
76	19 Mar 1980	a	0.97	0.071	75.35	5.350
77	1 May 1980	a	1.37	0.336	106.25	35.700
78	2 May 1980	a	1.34	0.326	104.23	33.980
79	3 May 1980	a	1.42	0.357	115.57	41.260
80	21 May 1980	a	2.37	0.697	241.08	168.030
81	22 May 1980	a	2.34	0.698	235.96	164.700
82	4 Jun 1980	a	1.90	0.573	157.77	90.400
83	7 Jul 1980	a	2.29	0.600	215.03	129.020
84	15 Aug 1980	a	2.27	0.719	206.12	148.200
85	16 Aug 1980	a	2.40	0.737	224.29	165.300
86	8 Oct 1980	a	2.59	0.749	285.31	213.700
87	9 Oct 1980	a	2.49	0.769	254.82	195.960
88	28 Oct 1980	a	2.20	0.662	208.74	138.183
89	7 Dec 1980	a	1.55	0.417	99.16	41.350
90	8 Dec 1980	a	1.57	0.424	97.50	41.340
91	12 Dec 1980	a	1.51	0.357	110.00	39.270
92	14 Dec 1980	a	1.40	0.356	94.16	33.520
93	22 Feb 1981	a	0.78	0.112	23.12	2.590
94	22 Mar 1981	a	1.80	0.413	166.27	68.670
95	24 Mar 1981	a	2.19	0.601	215.22	129.350
96	24 Mar 1981	a	2.42	0.673	237.25	159.670
97	25 Mar 1981	a	2.37	0.660	241.12	159.140
98	26 Mar 1981	a	4.02	1.258	479.27	602.920
99	27 Mar 1981	a	3.86	1.020	518.06	528.420
100	21 Apr 1981	a	5.36	1.192	858.31	1023.100
101	22 Apr 1981	a	5.45	1.244	889.84	1106.960
102	23 Apr 1981	a	5.43	1.241	896.78	1112.910
103	1 May 1981	a	6.12	1.347	1086.58	1463.630
104	2 May 1981	a	5.93	1.156	1053.65	1218.020
105	16 Aug 1981	a	2.79	0.759	345.43	262.184
106	25 Sep 1981	a	3.86	1.005	544.55	547.273
107	26 Sep 1981	a	3.81	1.078	529.61	570.918
108	22 Jan 1982	a	1.44	0.489	44.38	21.702
109	3 May 1982	a	2.43	0.592	277.67	164.378
110	7 May 1982	a	3.14	0.854	381.83	326.086
111	14 Mar 1984	b	1.10	0.410	29.24	11.989
112	11 Dec 1984	b	1.60	0.298	140.31	41.813

Total number of gaugings available = 112

ih

Discharge measurements for station 2 : Jubba at Bardheere

Order Number	Date	Rating Assigned	Stage m	Velocity m/s	Area sq m	Discharge cumecs
1	29 May 1963	a	2.18	0.776	384.79	298.600
2	20 Jun 1963	a	1.67	0.580	312.53	181.270
3	4 Jul 1963	a	1.52	0.598	314.82	188.260
4	4 Sep 1963	a	1.88	0.782	253.80	198.470
5	19 Oct 1963	?	2.10	0.707	248.19	175.470
6	20 Nov 1963	a	2.20	1.052	247.31	260.170
7	10 Dec 1963	a	2.44	1.067	299.85	319.940
8	26 Dec 1963	a	1.68	0.643	245.38	157.780
9	17 Jan 1964	a	1.13	0.455	206.90	94.140
10	1 Feb 1964	a	0.77	0.309	200.16	61.850
11	11 Mar 1964	a	0.28	0.198	154.55	30.600
12	29 Mar 1964	a	0.13	0.079	133.80	10.570
13	19 May 1964	a	1.92	0.783	246.91	193.330
14	1 Aug 1964	a	1.25	0.600	172.88	103.730
15	2 Nov 1964	a	2.86	0.992	315.02	312.498
16	18 Mar 1965	a	0.21	0.116	120.60	13.990
17	14 Dec 1965	a	1.43	0.522	282.09	147.250
18	8 Jun 1967	a	1.18	0.607	237.22	143.990
19	5 Oct 1969	a	1.69	0.715	267.43	191.210
20	5 Oct 1969	a	1.66	0.865	270.52	234.000
21	10 Jan 1970	a	0.19	0.320	144.81	46.340
22	29 Jun 1971	a	1.43	0.448	290.79	130.273
23	20 Mar 1972	a	0.37	0.207	208.74	43.210
24	22 Mar 1980	a	-0.11	0.165	26.12	4.310
25	30 Apr 1980	a	0.57	0.278	176.87	49.170
26	24 May 1980	a	1.50	0.484	339.81	164.466
27	25 May 1980	?	1.48	0.478	335.82	160.521
28	3 Jun 1980	a	0.90	0.287	264.29	75.850
29	8 Jul 1980	a	1.40	0.545	295.66	161.133
30	17 Aug 1980	a	1.27	0.577	249.57	144.000
31	10 Oct 1980	a	1.71	0.809	304.78	246.569
32	29 Oct 1980	a	1.25	0.606	224.16	135.840
33	16 Dec 1980	a	0.51	0.251	149.92	37.629
34	25 Feb 1981	a	-0.20	0.186	11.45	2.130
35	11 Jun 1981	?	1.67	0.303	367.79	111.440
36	13 Jun 1981	?	1.59	0.318	341.47	108.589
37	18 Aug 1981	a	1.93	0.514	412.55	212.050
38	19 Aug 1981	a	1.66	0.427	455.63	194.555
39	28 Sep 1981	a	3.35	1.018	469.72	478.171
40	29 Sep 1981	a	2.95	1.053	440.53	463.882
41	15 Nov 1981	a	1.70	0.613	361.98	221.894
42	16 Nov 1981	a	1.56	0.598	350.42	209.550
43	31 Dec 1981	a	0.65	0.119	212.29	25.263
44	24 Jan 1982	a	0.45	0.479	60.01	28.747
45	12 Mar 1984	b	0.29	0.263	40.97	10.774
46	10 Dec 1984	b	0.78	0.225	225.22	50.674

Total number of gaugings available = 46

ih

 Discharge measurements for station 3 : Jubba at Jamamme

Order Number	Date	Rating Assigned	Stage m	Velocity m/s	Area sq m	Discharge cumecs
1	21 Apr 1963	a	6.10	1.030	361.17	372.000
2	30 May 1963	a	6.32	1.067	372.07	397.000
3	1 Jun 1963	a	5.83	1.034	352.03	364.000
4	2 Jun 1963	a	5.52	1.000	333.00	333.000
5	4 Jun 1963	a	4.95	0.893	290.03	259.000
6	4 Jun 1963	a	4.95	0.949	288.97	274.230
7	15 Jun 1963	a	3.60	0.785	219.11	172.000
8	18 Jun 1963	a	3.80	0.783	223.36	174.890
9	25 Jun 1963	a	3.62	0.811	212.08	172.000
10	4 Jul 1963	a	3.00	0.696	183.91	128.000
11	6 Jul 1963	a	3.17	0.778	176.09	137.000
12	11 Jul 1963	a	3.72	0.894	199.82	178.640
13	14 Jul 1963	a	3.44	0.824	186.89	154.000
14	5 Aug 1963	a	3.53	0.777	177.03	137.550
15	23 Oct 1963	a	4.60	0.954	241.27	230.170
16	4 Dec 1963	a	4.97	1.000	270.27	270.270
17	2 Jan 1964	a	3.52	0.797	197.33	157.270
18	19 Jan 1964	a	2.52	0.687	141.06	96.910
19	21 Feb 1964	a	1.15	0.443	60.77	26.920
20	7 Apr 1965	a	0.35	0.074	26.49	1.960
21	8 Oct 1969	a	4.08	0.774	221.24	171.240
22	19 Nov 1969	a	4.39	0.976	243.61	237.760
23	19 Nov 1969	a	4.39	0.938	250.65	235.110
24	16 Jul 1971	a	4.19	0.784	235.27	184.450
25	17 Jul 1971	a	3.98	0.777	224.03	174.070
26	12 Apr 1972	a	1.62	0.589	76.10	44.820
27	19 Sep 1972	a	4.78	0.985	272.08	268.000
28	5 Oct 1972	a	3.93	0.828	204.11	169.000
29	18 Nov 1972	a	6.82	1.084	394.83	428.000
30	10 Mar 1973	a	0.71	0.348	31.03	10.800
31	14 Apr 1973	a	0.24	0.573	7.12	4.080
32	17 May 1973	a	1.84	0.562	77.40	43.500
33	21 May 1973	a	1.25	0.567	49.91	28.300
34	7 Jun 1973	a	3.16	0.839	160.91	135.000
35	18 Jun 1973	a	2.24	0.676	110.95	75.000
36	11 Jun 1980	a	1.99	0.652	108.10	70.480
37	12 Jun 1980	a	2.14	0.615	121.14	74.500
38	9 Jul 1980	a	2.50	0.652	156.61	102.110
39	11 Aug 1980	a	2.53	0.728	134.97	98.260
40	7 Nov 1980	a	3.65	0.870	183.44	159.590
41	8 Nov 1980	a	3.76	0.848	210.31	178.340
42	19 May 1981	a	6.96	1.242	418.66	519.970
43	20 May 1981	a	6.96	1.168	415.63	485.450
44	21 May 1981	a	6.99	1.276	415.13	529.700
45	22 May 1981	a	6.96	1.245	412.14	513.120
46	24 May 1981	a	6.91	1.181	429.31	507.020
47	11 Sep 1981	a	4.61	0.917	248.92	228.262
48	8 Nov 1981	a	5.44	0.964	332.61	320.633
49	9 Nov 1981	a	5.16	0.915	301.64	275.999
50	8 Feb 1984	?	1.25	0.392	51.68	20.259
51	13 Jun 1984	b	1.92	0.666	98.74	65.759

Total number of gaugings available = 51

 Discharge measurements for station 10 : Shebelli at Beled Weyn

Order Number	Date	Rating Assigned	Stage m	Velocity m/s	Area sq m	Discharge cumecs
1	11 May 1963	?	4.84	1.116	212.68	237.355
2	16 Jun 1963	?	1.79	0.611	87.86	53.680
3	7 Jul 1963	a	1.24	0.586	79.62	46.660
4	8 Aug 1963	a	1.82	0.865	101.10	87.450
5	30 Aug 1963	a	2.29	1.030	130.92	134.850
6	9 Oct 1963	a	2.03	0.900	113.57	102.210
7	12 Nov 1963	a	1.00	0.491	70.81	34.770
8	8 Dec 1963	a	1.70	0.770	102.12	78.630
9	23 Dec 1963	a	1.67	0.762	93.77	71.450
10	6 Jan 1964	a	1.06	0.503	71.97	36.200
11	22 Jan 1964	a	0.99	0.448	73.86	33.090
12	7 Feb 1964	a	0.65	0.287	61.08	17.530
13	4 Mar 1964	a	0.40	0.169	53.37	9.020
14	20 Apr 1964	a	0.93	0.511	74.17	37.900
15	28 Apr 1964	a	1.12	0.580	80.62	46.760
16	25 May 1964	a	0.79	0.504	65.44	32.980
17	18 Jun 1964	a	0.73	0.405	66.74	27.030
18	4 Aug 1964	a	1.35	0.703	82.92	58.290
19	26 Aug 1964	a	3.05	1.127	142.40	160.490
20	4 Nov 1964	a	3.53	1.140	162.90	185.710
21	9 Mar 1965	a	0.23	0.100	50.10	5.010
22	19 Oct 1965	a	1.87	0.901	97.36	87.720
23	14 May 1967	a	2.02	1.011	107.73	108.910
24	19 May 1968	a	5.06	1.370	237.83	325.830
25	11 Sep 1968	a	2.96	1.138	145.71	165.820
26	12 Sep 1968	a	2.87	1.106	144.46	159.770
27	13 Sep 1968	a	2.75	1.174	132.14	155.130
28	16 Sep 1968	a	2.38	1.048	130.39	136.650
29	23 Sep 1968	a	2.08	0.981	117.01	114.790
30	17 Nov 1968	a	0.94	0.434	76.66	33.270
31	26 Dec 1968	a	0.83	0.393	72.04	28.310
32	27 Dec 1968	a	0.82	0.382	72.09	27.540
33	31 Dec 1968	a	0.75	0.357	68.07	24.300
34	4 Feb 1969	a	0.58	0.226	58.85	13.300

 Discharge measurements for station 10 : Shebelli, at Beled Weyn

Order Number	Date	Rating Assigned	Stage m	Velocity m/s	Area sq m	Discharge cumecs
35	5 Feb 1969	a	0.61	0.215	63.86	13.730
36	18 Mar 1969	a	2.34	0.933	130.73	121.970
37	2 Nov 1969	a	1.03	0.503	77.28	38.870
38	2 Mar 1971	a	0.24	0.170	44.18	7.510
39	25 Dec 1971	a	0.61	0.289	59.97	17.330
40	23 May 1972	a	1.95	0.933	77.27	72.090
41	8 May 1974	a	0.86	0.463	55.75	25.810
42	27 Feb 1980	a	0.16	0.180	25.28	4.550
43	27 Feb 1980	a	0.16	0.160	30.94	4.950
44	7 Mar 1980	a	0.12	0.160	23.75	3.800
45	15 Apr 1980	a	0.01	0.100	20.00	2.000
46	18 Apr 1980	a	0.33	0.188	53.10	9.983
47	9 May 1980	a	1.80	1.200	87.83	105.400
48	10 May 1980	a	1.96	1.260	93.83	118.230
49	10 May 1980	a	2.04	1.260	95.48	120.310
50	11 May 1980	a	2.11	1.310	99.22	129.980
51	14 May 1980	a	2.11	1.300	94.08	122.300
52	24 Jun 1980	a	0.42	0.310	40.52	12.560
53	26 Jun 1980	a	0.39	0.320	42.13	13.480
54	30 Jul 1980	a	0.91	0.660	54.14	35.730
55	29 Aug 1980	a	1.74	1.080	81.32	87.830
56	30 Aug 1980	a	2.00	1.240	93.03	115.360
57	17 Sep 1980	a	1.84	1.170	89.00	104.130
58	18 Sep 1980	a	1.83	1.190	88.65	105.490
59	19 Sep 1980	a	1.78	1.160	83.10	96.400
60	18 Nov 1980	a	0.42	0.340	40.59	13.800
61	19 Nov 1980	a	0.40	0.340	42.12	14.320
62	1 Jan 1981	a	0.09	0.190	18.84	3.580
63	2 Jan 1981	a	0.07	0.170	18.53	3.150
64	9 Mar 1981	a	0.08	0.150	21.20	3.180
65	31 Mar 1981	a	3.82	1.560	159.61	248.990
66	1 Apr 1981	a	3.94	1.520	164.28	249.710
67	13 Apr 1981	a	5.29	1.410	228.10	321.620
68	14 Apr 1981	a	5.25	1.520	227.51	345.820
69	15 Apr 1981	a	5.27	1.540	233.14	359.030
70	12 May 1981	?	6.14	1.079	261.35	281.996
71	19 Jun 1981	?	0.95	0.810	88.33	71.551
72	10 Jul 1981	a	0.68	0.340	48.29	16.420
73	28 Aug 1981	a	2.46	1.330	108.77	144.660
74	29 Aug 1981	a	2.48	1.320	108.94	143.800
75	13 Oct 1981	a	3.97	1.380	180.88	249.620
76	14 Oct 1981	a	3.83	1.430	169.20	241.950
77	16 Oct 1981	a	3.60	1.396	160.13	223.540
78	17 Oct 1981	a	3.44	1.397	152.18	212.590
79	22 Nov 1981	a	0.95	0.608	44.41	27.000
80	14 Dec 1981	a	0.55	0.316	40.12	12.679
81	22 Mar 1984	b	0.41	0.584	20.46	11.950
82	28 Jun 1984	b	0.85	0.659	52.28	34.452
83	26 Aug 1984	b	2.14	1.361	86.82	118.160

Total number of gaugings available = 83

-----ih

 Discharge measurements for station 11 : Shebelli at Bulo Burti

Order Number	Date	Rating Assigned	Stage m	Velocity m/s	Area sq m	Discharge cumecs
1	10 May 1963	a	5.93	1.045	200.11	209.120
2	16 Jun 1963	a	3.16	1.191	61.12	72.790
3	7 Jul 1963	a	2.67	0.653	65.44	42.730
4	8 Aug 1963	a	3.60	0.854	99.67	85.120
5	30 Aug 1963	a	4.37	1.008	128.67	129.700
6	9 Oct 1963	a	3.69	1.024	94.53	96.800
7	12 Nov 1963	a	2.45	0.665	47.11	31.330
8	8 Dec 1963	a	3.22	0.861	100.13	86.210
9	23 Dec 1963	a	3.24	0.822	99.17	81.520
10	5 Jan 1964	a	2.40	0.758	54.25	41.120
11	23 Jan 1964	a	2.32	0.727	48.86	35.520
12	8 Feb 1964	a	1.95	0.571	27.53	15.720
13	5 Mar 1964	a	1.90	0.489	17.12	8.370
14	20 Apr 1964	a	2.48	0.706	57.97	40.930
15	27 Apr 1964	a	1.94	0.548	43.18	23.660
16	26 May 1964	a	2.04	0.705	44.85	31.620
17	17 Jun 1964	a	2.05	0.701	40.86	28.640
18	3 Aug 1964	a	3.05	0.768	81.99	62.970
19	25 Aug 1964	a	4.57	1.013	147.70	149.620
20	4 Nov 1964	a	5.23	1.103	172.98	190.800
21	9 Mar 1965	a	1.58	0.528	13.11	6.920
22	27 Sep 1965	?	2.83	0.274	73.20	20.056
23	17 Nov 1965	a	3.33	0.745	92.51	68.920
24	19 Mar 1969	a	4.14	0.848	137.44	116.550
25	2 Nov 1969	a	2.53	0.802	59.99	48.110
26	26 Nov 1969	a	1.83	0.723	35.15	25.410
27	3 Mar 1971	a	1.23	0.480	13.75	6.600
28	26 Dec 1971	a	1.69	0.613	33.61	20.600
29	24 May 1972	a	4.28	1.064	120.00	127.680
30	29 Feb 1980	b	1.00	0.375	11.55	4.330
31	8 Mar 1980	b	0.97	0.334	17.60	5.880
32	18 Apr 1980	b	0.85	0.263	6.54	1.720
33	9 May 1980	b	4.04	1.024	130.22	133.350

 Discharge measurements for station 11 : Shebelli at Bulo Burti

Order Number	Date	Rating Assigned	Stage m	Velocity m/s	Area sq m	Discharge cumecs
34	29 May 1980	b	2.90	0.901	78.00	70.280
35	29 May 1980	b	2.84	0.917	69.20	63.460
36	23 Jun 1980	b	1.42	0.758	20.59	15.610
37	29 Jul 1980	b	2.21	0.775	51.17	39.660
38	28 Aug 1980	b	3.34	0.951	93.47	88.890
39	1 Sep 1980	b	3.90	0.970	119.34	115.760
40	17 Sep 1980	b	3.29	0.956	91.90	87.860
41	15 Oct 1980	b	2.62	0.798	65.78	52.490
42	18 Nov 1980	b	1.41	0.666	22.85	15.220
43	20 Nov 1980	b	1.35	0.603	20.63	12.440
44	1 Jan 1981	b	0.92	0.189	13.12	2.480
45	3 Jan 1981	b	0.88	0.164	14.09	2.310
46	8 Mar 1981	b	0.69	0.242	1.49	0.360
47	10 Mar 1981	b	0.87	0.420	5.48	2.300
48	29 Mar 1981	b	4.90	1.090	170.05	185.350
49	1 Apr 1981	b	5.46	1.152	194.00	223.490
50	12 Apr 1981	b	6.05	1.167	212.19	247.620
51	15 Apr 1981	b	6.26	1.238	224.67	278.140
52	8 May 1981	b	7.51	1.244	289.34	359.940
53	17 Jun 1981	b	2.50	0.811	62.85	50.970
54	20 Jun 1981	b	2.26	0.535	69.18	37.010
55	9 Jul 1981	b	1.86	0.339	49.76	16.868
56	28 Aug 1981	b	4.38	0.975	141.64	138.100
57	30 Aug 1981	b	4.40	0.987	144.54	142.660
58	13 Oct 1981	b	6.55	1.115	258.06	287.737
59	23 Nov 1981	b	2.07	0.841	47.94	40.320
60	16 Dec 1981	b	1.47	0.458	33.32	15.260
61	15 Feb 1982	b	1.14	0.451	20.28	9.146
62	21 Mar 1984	c	1.13	0.462	24.35	11.249
63	27 Jun 1984	c	1.85	0.861	43.34	37.314

Total number of gaugings available = 63

-----ih

 Discharge measurements for station 12 : Shebelli at Mahaddey Weyn

Order Number	Date	Rating Assigned	Stage m	Velocity m/s	Area sq m	Discharge cumecs
1	9 May 1963	a	4.94	0.942	136.92	128.980
2	17 Jun 1963	a	3.74	0.841	99.76	83.900
3	6 Jul 1963	a	2.65	0.702	63.60	44.650
4	7 Aug 1963	a	3.64	0.767	95.78	73.460
5	29 Aug 1963	a	4.59	0.910	123.03	111.960
6	8 Oct 1963	a	3.69	0.876	100.25	87.820
7	11 Nov 1963	a	2.31	0.710	61.73	43.830
8	7 Dec 1963	a	3.26	0.765	99.15	75.850
9	22 Dec 1963	a	3.61	0.776	112.98	87.670
10	7 Jan 1964	a	2.14	0.683	59.90	40.910
11	21 Jan 1964	a	2.21	0.670	64.48	43.200
12	6 Feb 1964	a	1.41	0.553	40.33	22.300
13	27 Feb 1964	a	0.91	0.402	27.59	11.090
14	22 Mar 1964	a	0.60	0.318	18.81	5.980
15	21 Apr 1964	a	2.21	0.669	53.86	36.030
16	29 Apr 1964	a	1.61	0.589	42.65	25.120
17	24 May 1964	a	1.50	0.555	35.03	19.440
18	23 Jun 1964	a	1.56	0.414	38.48	15.930
19	3 Aug 1964	a	2.91	0.702	80.51	56.520
20	5 Nov 1964	a	5.07	0.948	136.54	129.440
21	8 Mar 1965	a	0.56	0.331	20.15	6.670
22	29 May 1967	a	5.04	0.890	150.55	133.990
23	8 Aug 1967	a	3.42	0.680	96.81	65.830
24	3 Nov 1969	a	2.80	0.759	76.06	57.730
25	1 Feb 1970	a	0.73	0.349	21.00	7.330
26	15 Mar 1970	a	2.62	0.657	63.68	41.840
27	29 Feb 1972	a	2.70	0.674	80.30	54.120
28	11 May 1974	a	2.03	0.585	55.64	32.550
29	11 Nov 1975	a	1.41	0.320	55.94	17.900
30	16 Feb 1980	b	0.75	0.231	17.10	3.950

 Discharge measurements for station 12 : Shebelli at Mahaddey Weyn

Order Number	Date	Rating Assigned	Stage m	Velocity m/s	Area sq m	Discharge cumecs
31	1 Mar 1980	b	0.79	0.260	16.62	4.320
32	18 Apr 1980	b	0.46	0.174	8.68	1.510
33	8 May 1980	b	3.71	0.767	107.43	82.400
34	28 May 1980	b	4.47	0.776	156.86	121.720
35	30 May 1980	b	3.72	0.744	120.00	89.280
36	22 Jun 1980	b	1.70	0.389	48.79	18.980
37	27 Jun 1980	b	1.46	0.296	40.81	12.080
38	28 Jul 1980	b	2.42	0.564	66.22	37.350
39	27 Aug 1980	b	3.00	0.704	83.31	58.650
40	14 Sep 1980	b	3.31	0.705	96.62	68.120
41	16 Sep 1980	b	3.24	0.661	96.85	64.020
42	20 Sep 1980	b	4.06	0.782	119.95	93.800
43	15 Oct 1980	b	3.08	0.675	86.96	58.700
44	17 Nov 1980	b	1.71	0.371	42.99	15.950
45	20 Nov 1980	b	1.56	0.351	41.74	14.650
46	1 Jan 1981	b	0.82	0.145	18.69	2.710
47	3 Jan 1981	b	0.79	0.146	17.81	2.600
48	2 Apr 1981	b	5.23	0.850	174.65	148.450
49	12 Apr 1981	b	5.28	0.818	174.21	142.500
50	5 Jun 1981	b	4.60	0.698	147.74	103.120
51	20 Jun 1981	?	3.14	0.325	69.66	22.640
52	27 Aug 1981	b	4.75	0.883	153.04	135.130
53	30 Aug 1981	b	4.76	0.894	158.28	141.500
54	12 Oct 1981	b	5.18	0.959	174.75	167.590
55	17 Dec 1981	b	2.01	0.397	51.56	20.471
56	4 Oct 1982	c	3.86	0.834	108.24	90.270
57	16 Apr 1984	c	1.36	0.343	31.48	10.797

Total number of gaugings available = 57

-----ih

Discharge measurements for station 14 : Shebelli at Afgoi

Order Number	Date	Rating Assigned	Stage m	Velocity m/s	Area sq m	Discharge cumecs
1	16 Sep 1963	a	5.03	0.690	124.41	85.840
2	23 Sep 1963	a	5.11	0.720	124.72	89.800
3	18 Nov 1963	a	2.56	0.667	51.60	34.420
4	1 Dec 1963	a	3.79	0.727	94.73	68.870
5	21 Dec 1963	a	4.80	0.631	119.35	75.310
6	9 Jan 1964	a	2.56	0.620	55.34	34.310
7	20 Jan 1964	a	2.33	0.653	48.73	31.820
8	12 Feb 1964	a	1.66	0.447	31.83	14.230
9	26 Feb 1964	a	1.32	0.382	21.15	8.080
10	6 Apr 1964	a	1.00	0.084	10.83	0.910
11	22 Apr 1964	a	2.30	0.620	52.56	32.590
12	3 May 1964	a	2.12	0.546	44.65	24.380
13	10 May 1964	a	3.04	0.695	65.80	45.730
14	14 May 1964	a	2.80	0.661	59.15	39.100
15	15 Jun 1964	a	1.45	0.426	27.04	11.520
16	27 Jun 1964	a	2.35	0.603	50.35	30.360
17	20 Sep 1964	a	4.37	0.709	104.02	73.750
18	30 Jun 1965	a	1.05	0.292	13.25	3.870
19	21 Sep 1965	a	3.67	0.690	101.80	70.240
20	22 May 1967	a	4.70	0.648	124.00	80.350
21	13 Jun 1967	a	4.76	0.682	116.19	79.240
22	26 Aug 1967	a	5.13	0.553	132.73	73.400
23	22 Jun 1969	a	2.88	0.474	63.50	30.100
24	26 Jan 1970	a	1.00	0.260	6.54	1.700
25	16 Feb 1970	a	2.19	0.500	40.88	20.440
26	17 Mar 1970	a	2.81	0.670	61.37	41.120
27	4 Aug 1971	a	4.58	0.836	100.01	83.606
28	16 Sep 1971	a	5.42	0.780	142.01	110.767
29	9 Jan 1975	a	5.20	0.810	132.23	107.110
30	7 Feb 1980	a	1.06	0.180	7.06	1.270
31	4 May 1980	a	1.87	0.510	34.90	17.800
32	1 Jun 1980	a	3.54	0.660	80.14	52.890
33	20 Jul 1980	a	1.52	0.350	17.46	6.110
34	25 Aug 1980	a	3.26	0.710	67.62	48.010
35	13 Sep 1980	a	3.82	0.720	85.57	61.610
36	5 Oct 1980	a	3.31	0.700	67.11	46.980
37	22 Nov 1980	a	1.50	0.410	17.71	7.260
38	5 Apr 1981	a	4.29	0.770	113.61	87.480
39	19 Apr 1981	a	4.48	0.740	114.19	84.500
40	1 Jun 1981	a	4.87	0.730	132.70	96.870
41	8 Sep 1981	a	4.88	0.770	128.97	99.310
42	12 Nov 1981	a	3.80	0.690	83.74	57.780
43	25 Sep 1982	b	4.50	0.682	115.28	78.620
44	5 Oct 1982	b	4.03	0.695	97.12	67.500
45	12 Dec 1983	b	3.73	0.647	88.08	56.990
46	19 Feb 1984	b	2.15	0.618	35.47	21.922
47	18 Jun 1984	b	4.19	0.660	104.46	68.943
48	6 Aug 1984	b	4.36	0.613	108.54	66.537

Total number of gaugings available = 48

Discharge measurements for station 15 : Shebelli at Audegle

Order Number	Date	Rating Assigned	Stage m	Velocity m/s	Area sq m	Discharge cumecs
1	4 Dec 1962	a	1.61	0.548	18.05	9.890
2	28 Jan 1964	a	2.80	0.561	54.05	30.320
3	12 Feb 1964	a	1.85	0.487	26.51	12.910
4	19 Feb 1964	a	1.68	0.428	24.25	10.380
5	25 Mar 1964	a	1.07	0.364	9.86	3.590
6	8 Apr 1964	a	0.91	0.244	8.93	2.180
7	9 May 1964	a	3.47	0.698	82.03	57.260
8	14 May 1964	a	3.15	0.607	68.02	41.290
9	21 May 1964	a	2.58	0.543	53.50	29.050
10	16 Aug 1964	a	4.06	0.574	97.49	55.960
11	2 Sep 1964	a	4.81	0.630	117.27	73.860
12	18 Feb 1965	a	1.52	0.392	28.83	11.300
13	21 Apr 1965	a	0.85	0.296	4.73	1.400
14	21 Sep 1965	a	3.90	0.614	81.09	49.790
15	13 Jun 1967	a	5.51	0.658	131.09	86.260
16	13 Nov 1968	a	4.46	0.542	118.14	64.030
17	4 Dec 1968	a	4.26	0.492	111.93	55.070
18	30 Jan 1969	a	2.14	0.361	42.19	15.230
19	29 Mar 1969	a	4.89	0.582	132.22	76.950
20	14 Apr 1969	a	4.87	0.553	129.29	71.500
21	17 Jan 1970	a	1.22	0.383	10.31	3.950
22	14 Nov 1971	a	3.70	0.550	100.89	55.490
23	13 Feb 1980	b	1.26	0.168	3.45	0.580
24	13 Feb 1980	b	1.26	0.166	3.25	0.540
25	5 May 1980	b	2.50	0.468	37.48	17.540
26	31 May 1980	b	4.89	0.525	132.82	69.730
27	17 Jun 1980	b	2.16	0.380	33.08	12.570
28	19 Jul 1980	b	1.52	0.405	17.33	7.020
29	25 Aug 1980	b	3.79	0.539	84.36	45.470
30	11 Sep 1980	b	5.20	0.524	137.60	72.100
31	24 Sep 1980	b	5.09	0.520	137.21	71.350
32	25 Oct 1980	b	4.27	0.441	110.49	48.725
33	22 Nov 1980	b	2.11	0.408	17.78	7.256
34	7 Apr 1981	b	4.90	0.581	147.04	85.430
35	3 Sep 1981	b	5.36	0.523	170.87	89.365
36	28 Oct 1981	b	5.32	0.506	175.47	88.790
37	26 Sep 1982	c	5.12	0.506	170.28	86.160
38	6 Oct 1982	c	4.83	0.441	160.25	70.670
39	16 Oct 1984	c	4.88	0.655	101.04	66.181

Total number of gaugings available = 39

ih

Rating table for station 1 : Jubba at Lugh Ganana

Rating A from 1 Jan 1951 $Q = 60.320 (h - 0.660)^{1.867}$ to 7.50 metres

Stage (a)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0										
0.1										
0.2										
0.3										
0.4										
0.5										
0.6								0.01	0.04	0.09
0.7	0.15	0.22	0.32	0.42	0.54	0.67	0.82	0.98	1.15	1.34
0.8	1.54	1.75	1.97	2.21	2.46	2.72	2.99	3.27	3.57	3.85
0.9	4.20	4.53	4.88	5.23	5.60	5.98	6.37	6.77	7.19	7.61
1.0	8.05	8.50	8.96	9.43	9.91	10.40	10.90	11.42	11.94	12.48
1.1	13.03	13.58	14.15	14.73	15.32	15.92	16.54	17.16	17.79	18.44
1.2	19.09	19.76	20.43	21.12	21.82	22.52	23.24	23.97	24.71	25.46
1.3	26.22	26.99	27.77	28.54	29.34	30.17	30.99	31.82	32.67	33.52
1.4	34.38	35.25	36.14	37.03	37.93	38.84	39.77	40.70	41.64	42.60
1.5	43.54	44.53	45.52	46.51	47.51	48.53	49.55	50.58	51.62	52.68
1.6	53.74	54.81	55.89	56.99	58.09	59.20	60.32	61.45	62.59	63.74
1.7	64.90	66.07	67.25	68.44	69.64	70.85	72.07	73.30	74.53	75.76
1.8	77.04	78.30	79.58	80.87	82.16	83.47	84.78	86.10	87.44	88.78
1.9	90.13	91.49	92.87	94.25	95.64	97.04	98.44	99.86	101.29	102.73

Flows in cubic metres per second

Rating table for station 1 : Jubba at Lugh Ganana

Rating A from 1 Jan 1951 $Q = 60.320 (h - 0.660)^{1.667}$ to 7.50 metres

Stage (m)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
2.0	104.18	105.63	107.10	108.57	110.06	111.55	113.05	114.57	116.09	117.62
2.1	119.16	120.71	122.27	123.83	125.41	127.00	128.59	130.20	131.81	133.44
2.2	135.07	136.71	138.36	140.02	141.69	143.37	145.06	146.76	148.47	150.18
2.3	151.91	153.64	155.38	157.13	158.90	160.67	162.45	164.23	166.03	167.84
2.4	169.65	171.48	173.31	175.16	177.01	178.87	180.74	182.62	184.51	186.40
2.5	188.31	190.23	192.15	194.08	196.03	197.98	199.94	201.91	203.89	205.87
2.6	207.87	209.87	211.89	213.91	215.94	217.98	220.03	222.09	224.16	226.23
2.7	229.32	230.41	232.51	234.63	236.75	238.88	241.01	243.16	245.32	247.48
2.8	249.66	251.84	254.03	256.23	258.44	260.66	262.88	265.12	267.36	269.62
2.9	271.88	274.15	276.43	278.72	281.01	283.32	285.63	287.95	290.29	292.63
3.0	294.98	297.33	299.70	302.08	304.46	306.85	309.25	311.66	314.08	316.51
3.1	318.95	321.39	323.84	326.31	328.78	331.26	333.74	336.24	338.75	341.26
3.2	345.78	348.31	348.85	351.40	353.96	356.53	359.10	361.68	364.27	366.87
3.3	369.48	372.10	374.73	377.36	380.00	382.66	385.32	387.99	390.66	393.35
3.4	396.04	398.74	401.46	404.18	406.90	409.64	412.39	415.14	417.90	420.67
3.5	423.45	426.24	429.04	431.84	434.66	437.48	440.31	443.15	446.00	448.85
3.6	451.72	454.59	457.47	460.36	463.26	466.16	469.08	472.00	474.93	477.87
3.7	480.82	483.75	486.75	489.72	492.70	495.69	498.69	501.70	504.72	507.74
3.8	510.77	513.81	516.86	519.92	522.99	526.06	529.15	532.24	535.34	538.45
3.9	541.56	544.69	547.82	550.96	554.11	557.27	560.44	563.61	566.79	569.99

Flows in cubic metres per second

Rating table for station 1 : Jubba at Lugh Ganana

Rating A from 1 Jan 1951 $Q = 60.320 (h - 0.660)^{1.867}$ to 7.50 metres

Stage (m)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
4.0	575.19	576.39	579.61	582.84	586.07	589.31	592.56	595.82	599.08	602.36
4.1	605.64	606.93	612.23	615.54	618.86	622.18	625.51	628.85	632.20	635.56
4.2	638.93	642.30	645.68	649.07	652.47	655.88	659.29	662.72	666.15	669.59
4.3	673.04	676.49	679.96	683.43	686.91	690.40	693.90	697.40	700.92	704.44
4.4	707.97	711.51	715.05	718.61	722.17	725.74	729.32	732.91	736.50	740.11
4.5	743.72	747.34	750.97	754.60	758.25	761.90	765.56	769.23	772.91	776.59
4.6	780.29	783.99	787.70	791.42	795.14	798.88	802.62	806.37	810.13	813.90
4.7	817.67	821.45	825.24	829.04	832.85	836.66	840.49	844.32	848.16	852.01
4.8	855.86	859.73	863.60	867.48	871.37	875.26	879.17	883.08	887.00	890.93
4.9	894.86	898.81	902.76	906.72	910.69	914.67	918.65	922.64	926.64	930.65
5.0	934.67	938.69	942.73	946.77	950.82	954.87	958.94	963.01	967.09	971.18
5.1	975.28	979.39	983.50	987.62	991.75	995.89	1000.03	1004.18	1008.34	1012.51
5.2	1016.69	1020.88	1025.07	1029.27	1033.48	1037.70	1041.92	1046.15	1050.39	1054.64
5.3	1058.90	1063.16	1067.44	1071.72	1076.01	1080.30	1084.61	1088.92	1093.24	1097.57
5.4	1101.91	1106.25	1110.60	1114.96	1119.33	1123.71	1128.09	1132.48	1136.88	1141.29
5.5	1145.70	1150.13	1154.56	1159.00	1163.45	1167.90	1172.36	1176.84	1181.31	1185.80
5.6	1190.30	1194.80	1199.31	1203.83	1208.35	1212.89	1217.43	1221.98	1226.54	1231.10
5.7	1235.68	1240.26	1244.85	1249.44	1254.05	1258.66	1263.28	1267.91	1272.55	1277.19
5.8	1281.94	1286.50	1291.17	1295.85	1300.53	1305.22	1309.92	1314.63	1319.34	1324.07
5.9	1328.80	1333.54	1338.28	1343.04	1347.80	1352.57	1357.35	1362.13	1366.93	1371.73

Flows in cubic metres per second

Rating table for station 1 : Jubba at Lugh Ganana

Rating A from 1 Jan 1951 $Q = 60.320 (h - 0.660)^{1.887}$ to 7.50 metres

Stage (m)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
6.0	1375.54	1381.35	1386.18	1391.01	1395.85	1400.70	1405.55	1410.42	1415.29	1420.17
6.1	1425.05	1429.95	1434.85	1439.76	1444.68	1449.60	1454.54	1459.48	1464.43	1469.39
6.2	1474.35	1479.32	1484.30	1489.29	1494.29	1499.29	1504.30	1509.32	1514.35	1519.38
6.3	1524.43	1529.48	1534.54	1539.60	1544.67	1549.76	1554.84	1559.94	1565.05	1570.16
6.4	1575.28	1580.41	1585.54	1590.68	1595.84	1600.99	1606.16	1611.33	1616.52	1621.71
6.5	1626.90	1632.11	1637.32	1642.54	1647.77	1653.00	1658.25	1663.50	1668.76	1674.03
6.6	1679.30	1684.58	1689.87	1695.17	1700.48	1705.79	1711.11	1716.44	1721.77	1727.12
6.7	1732.47	1737.83	1743.19	1748.57	1753.95	1759.34	1764.74	1770.14	1775.56	1780.98
6.8	1786.40	1791.84	1797.28	1802.73	1808.19	1813.66	1819.13	1824.62	1830.11	1835.60
6.9	1841.11	1846.62	1852.14	1857.67	1863.20	1868.75	1874.30	1879.86	1885.42	1890.99
7.0	1896.58	1902.17	1907.76	1913.37	1918.99	1924.60	1930.22	1935.86	1941.50	1947.15
7.1	1952.81	1958.47	1964.15	1969.83	1975.51	1981.21	1986.91	1992.63	1998.34	2004.07
7.2	2009.80	2015.54	2021.29	2027.05	2032.81	2038.59	2044.37	2050.15	2055.95	2061.75
7.3	2067.56	2073.38	2079.20	2085.03	2090.87	2096.72	2102.58	2108.44	2114.31	2120.19
7.4	2126.07	2131.97	2137.87	2143.78	2149.69	2155.61	2161.55	2167.48	2173.43	2179.38

Flows in cubic metres per second

in

Summary of rating curves for station 2 : Jubba at Bardheere

Rating A from 1 Jan 1963 $Q = 54.680 (h + 0.350)^{1.727}$ to 7.00 metres

1 rating curves for this station

ih

Summary of rating curves for station 3 : Jubba at Jamame

Rating A from 1 Jan 1963 $Q = 16.840 (h + 0.090)^{1.727}$ to 7.50 metres

1 rating curves for this station

ih

Summary of rating curves for station 10 : Shebelli at Beled Weyn

Rating A from 1 Jan 1951 $Q = 25.850 (h + 0.210)^{1.655}$ to 7.00 metres

1 rating curves for this station

ih

Summary of rating curves for station 11 : Shebelli at Bulo Burti

Rating A from 1 Jan 1963 $Q = 12.760 (h - 0.610)^{1.772}$ to 10.00 metres

Rating B from 1 Jan 1976 $Q = 19.450 (h - 0.620)^{1.517}$ to 10.00 metres

2 rating curves for this station

Summary of rating curves for station 12 : Shebelli at Mahaddey Weyn

Rating A from 1 Jan 1963 $Q = 7.900 (h + 0.280)^{1.698}$ to 7.00 metres

Rating B from 1 Jan 1980 $Q = 4.990 (h + 0.070)^{2.092}$ to 7.00 metres

2 rating curves for this station

Summary of rating curves for station 14 : Shebelli at Afgoi

Rating A from 1 Jan 1963 $Q = 17.620 (h - 0.890)^{1.176}$ to 7.00 metres

1 rating curves for this station

Summary of rating curves for station 15 : Shebelli at Audegle

Rating A from 1 Jan 1963 $Q = 9.810 (h - 0.590)^{1.413}$ to 6.50 metres

Rating B from 1 Jan 1976 $Q = 11.860 (h - 1.140)^{1.388}$ to 6.50 metres

2 rating curves for this station
