The World Bank

SHEBELLE RIVER - WATER BALANCE STUDY

- IMPACT OF WATERSCARCITY ON EXTENT OF IRRIGATION
- IMPACT OF RIVERREGULATION AND IRRIGATION IN ETHIOPIA ON WATERSUPPLY TO SOMALIA

SEPTEMBER 1987

LAHMEYER INTERNATIONAL

SUMMARY

1. The objective of the present study was defined in the Terms of Reference as follows: "to assess the availability of water from the Shebelle River in Somalia and the expected levels of water use for the rehabilitation and development planned, with a view to analyze possibilities of potential disruptions, should there be a reduction in the current streamflow reaching Somalia".

2. The net irrigable area along the Shebelle River in Somalia is approximately 132 000 ha. About 12 000 ha are grown to perennial crops; this latter figure includes about 6 000 ha of sugarcane land which is at present not productive.

3. Water is the limiting factor as far as irrigation development is concerned. Even when storage facilities would be available at Duduble, in addition to Jowhar, the possible seasonal cropping intensities for annual crops would be limited, when related to the area of 120 000 ha available for annual crops

- when about 6 000 ha of perennial crops are grown: 35% (Gu season) and 60% (Der)
- when about 12 000 ha of perennial crops are grown: 50% (Gu) and 65% (Der)

Because irrigation schemes are only feasible when the seasonal intensity is about 75%, it may be necessary to ultimately reduce the area.

4. The emphasis of intensification of water use for irrigation in Somalia should be on rehabilitation. Rehabilitation measures should fit in an overall, regional water allocation plan. Such a plan does not exist; its preparation is recommended.

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5. The intensive use of groundwater should be delayed until surface water resources are better exploited.

6. The autorities, responsible for exploitation of the Shebelle waters will have to decide, within the frame of a water allocation plan, on extension of perennial crops versus annual crops.

7. The Malka Wakana Hydropower Project in Ethiopia has a positive effect on water supply to Somalia as a result of its regulating effect on streamflow.

8. The reduction of water supply to Somalia due to irrigation development in Ethiopia would be partly mitigated as a result of large swamps upstream of the Somali-Ethiopian border.

9. The combined impact of the Malka Wakana Project and of various levels of irrigation development in Ethiopia on water supply to Somalia is summarized as follows (figures indicate the average change in supply as percentage of average present annual supply):

Malka Wakana alone	+3%
Malka Wakana + 5 000 ha	+1%
Malka Wakana + 15 000 ha	-2%
Malka Wakana + 25 000 ha	-6%

The negative figures are higher in absolute terms for high flow and lower for lower flows (the latter are decisive for the extent of irrigation).

It is concluded that there is no immediate danger for reduced water supply to Somalia. In the long run, however, a bilateral agreement on exploitation of the Shebelle waters will be required.

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10. When losses to the swamps in Ethiopia are reduced, the influence of irrigation development in Ethiopia on water supply to Somalia could be reduced accordingly.

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1. INTRODUCTION

In September 1986, the draft report of the Genale Irrigation Rehabilitation Project (Ref. 3) was completed. This study was prepared by TAMS, by order of the Ministry of Agriculture, Somalia. The study concerned 10 300 ha of irrigated or formerly irrigated land in the Lower Shebelle Region. The area was identified earlier in the Genale-Bulo Marerta Project study (Ref. 2). In this pre-feasibility study, the area was recommended for rehabilitation together with a number of other areas in the same region of in total 67 000 ha. The first mentioned study concerns two units: Shalambood, 5 300 ha and Faraxaane, 5 000 ha (gross). The World Bank has shown interest to finance follow-up studies for the Faraxaane project. In the meantime, other agencies also have shown interest in taking part of the rehabilitation program proposed in Ref. 2:

- in part of the Qoryoley area (phase I, 2 200 ha), rehabilitation works have started in 1986; the project is financed by the African Development Bank
- the Shalambood area will probably be rehabilitated as part of the recently started USAID assistance program for improvement of water use in the Shebelle Valley.

At the same time rehabilitation works are planned and/or being implemented for projects in other areas, for instance the Afgoi-Mordiinle Project, the Balcad Project and the Jowhar Sugar Estate. All these projects and many other irrigation schemes are supplied from the same source of water, the Shebelle River. Hence, every plan, in which the use of water is involved, must form an integrated part of an overall water allocation plan for all irrigation centres along the river. When it is thus considered to implement the Faraxaane project in accordance with the proposals in the feasibility report, one of the questions to be raised is, if the total water requirement of the envisaged cropped area is in agreement with the allocated portion.

The issue of water allocation is not limited to Somalia alone. The Shebelle river rises in the Ethiopian highlands and passes over several hundreds of kilometers through a partly flat area in this country before entering Somalia.

Apparently, little irrigation is practised until now in Ethiopia but it seems that there is a potential for development, although details are not known (it is at this present time not possible to obtain relevant information). A bilateral agreement on exploitation of the Shebelle waters will thus be indispensable in future. This matter will need its time, however, and it is not possible for Somalia to postpone improvements of irrigation - one of the cornerstones of agricultural development in the valley - until such an agreement is established. Neither is this a necessity, because development of the Shebelle Valley on the Ethiopian side will be a matter of decennia, rather than years. Nevertheless, an indication should be available on what the impact of irrigation development and, more generally, river regulation in Ethiopia, on water availability in Somalia will be.

It is known that recently a hydropower project has been completed at Malka Wakana, in the upper course of the Shebelle and that there are plans for irrigation development downstream of this dam. Although details on the hydropower project are not available, data could be adopted which are sufficiently realistic to estimate the impact on watersupply to Somalia, assuming at the same time various stages of irrigation development.

Before deciding on further definite steps to be taken with regard to Faraxaane, the World Bank wishes to have the above questions (water allocation in Somalia; river exploitation in Ethiopia) dealt with and charged Lahmeyer with a study on these subjects.

This study is presented herewith. In chapter 2, the problems in connection with water allocation are discussed. Matters in connection with irrigation and river regulation in Ethiopia are dealt with in chapters 3 and 4.

All computations have been based on net irrigation requirements given in Ref. 4 (see Table 1).

Table 1: Net Irrigation Requirements in mm

Crop		J	F	M	A	M	J	J	A	S	O	N	D	Total
Bananas		168	166	187	121	118	88	96	121	151	144	108	138	1606
Sugar Cane		152	149	181	95	91	98	96	119	160	84	92	118	1435
Maize	Gu					37	108	103	19					267
Maize	Der	47								9	33	110	150	349
								(earlier:	4	66	125	113	29)	
Sesame	Der									15	76	102	54	247
Citrus		93	95	97	38	37	44	45	64	82	48	37	70	653
Cotton		74							10	118	131	133	119	585
Pulses	Gu				0	53	77	19						149
Pulses	Der	28									5	72	125	230
Vegetables		119	121	133	62	61	63	66	87	107	72	59	94	1044
Tomatoes	Gu				0	76	111	52	25					264
Tomatoes	Der	51								39	87	112	77	366
Other (gr. nuts)	Gu				12	70	110	82						274
Other (gr. nuts)	Der	155	17								28	82	158	714
Rice	Gu				214	109	162	149	65					699
Rice	Der									389	150	140	66	745

2. WATER REQUIREMENTS AND WATER ALLOCATION ALONG THE SHEBELLE RIVER IN SOMALIA

2.1 PRESENT SITUATION

A simple comparison of water availability and land potential in the Shebelle Valley (Figure 2.1) demonstrates that water is and will remain a scarce good:

The area of soils of irrigation suitability class 2 is 770 000 ha; the average annual streamflow at Belet Weyn, where the first hydrometric station is situated in the Shebelle river on the Somali side of the border, amounts to an average of 2 200 million m^3. This would be sufficient for the irrigation of 190 000 ha of land, planted to maize in the Gu season and to sesame in the Der season, for a gross annual irrigation requirement of 11 600 m^3/ha (45% efficiency) and assuming the ideal situation that no on-river losses would occur.

Even when groundwater resources were fully exploited, water would remain scarce because most of the groundwater recharge stems from the river.

The present area with irrigation infrastructure in Somalia is little over 170 000 ha (see Table 2.1).

FIGURE: 2.1

SHEBELLE WATER BALANCE STUDY

SHEBELLE RIVER
- SOMALIAN SIDE -

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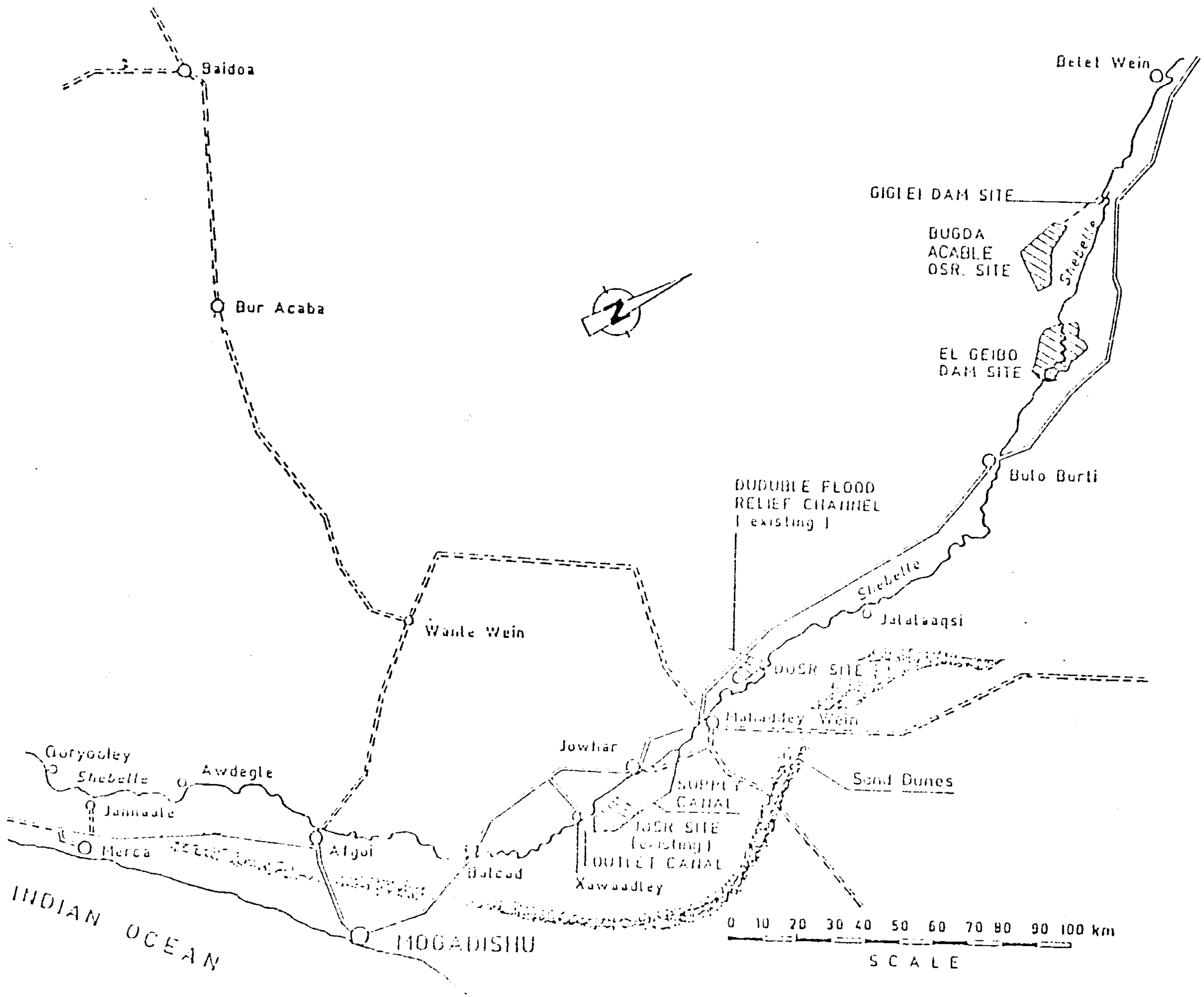

<u>Tabel 2.1:</u> Irrigation areas along the Shebelle River

Region	District	Gross Area with Irrigation Infrastructure (ha)	
Hiran	Belet Weyn	?	(1)
	Bulo Burti	680	
	Jalaalaqsi	900	
	Subtotal	1 580	
Middle Shebelle	Jowhar	26 490	
	Balcad	7 810	
	Subtotal	34 300	
Lower Shebelle	Afgoi	20 990	
	Merka	73 170	
	Qoryooley	26 710	
	Kurtun Waarey	8 760	
	Brava	980	14 490
	Sablaale	4 750	
	Subtotal	135 360	
Total		171 240	

Source: Ref. 4

(1) not fully covered by aerial photographs

It is estimated that the net irrigation area is about 132 000 ha, of which 12 000 ha are planted to perennial crops and 120 000 ha to annual crops (the 12 000 ha include however about 6 000 ha of sugar cane land at Jowhar which is actually not productive). The seasonal cropping intensity is between 40 and 50%, hence, 48 000 ha to 60 000 ha are seasonally used for annual crops, mostly maize and sesame.

For a good understanding of what is meant by "irrigation" it should be noted that many village-schemes can only receive water in "flood"-periods, when the river water is high enough. These periods vary between several weeks and 2 to 3 months (april - may, september - october - november) and the area of irrigated land as well as crop yields vary accordingly. With respect to these schemes it is noted that an increasing use is made of pumps.

In schemes with controlled water supply (either pumps or gravity-supply) the efficiency of water use is very low and varies between 7 and 21% in large schemes (over 1 000 ha) and 14 and 34% in small schemes (200 - 500 ha).

2.2 DEVELOPMENT POTENTIAL

In the Shebelle Water Strategy Study (Ref. 4), the potential of irrigation has been elaborated for various storage options.

The results of three situations are discussed here below.

The first situation concerns the present situation, with the Jowhar Offstream Storage Reservoir as storage facility (199 million m^3 active storage volume). The reservoir operation study for this situation is summerized as follows.

It has been estimated that the following crops other than maize and sesame are actually irrigated:

upstream of the Jowhar off-stream reservoir:

sugar cane	:	2 275 ha
paddy (2 crops/year):		440 ha
citrus	:	50 ha

downstream of the Jowhar outlet:

bananas	:	2 880 ha
citrus	:	760 ha
pulses and various other crops	:	700 ha

Furthermore, water is required for domestic purposes, livestock etc. The monthly water requirements for the above irrigation and other purposes are given in Table 2.2.

The reservoir operation study has been conducted to assess how many hectares of annual crops can be grown in addition to the above, assuming that water requirements are covered in 80% of the years.

The annual crops are maize in the Gu-season and 1/3 maize - 2/3 sesame in the Der-season. This is the pattern which is approximately practised by farmers with regular water supply.

The results of the operation study are:

upstream of Jowhar outlet:	14 000 ha maize;	16 000 ha maize/sesame
downstream of Jowhar outlet:	24 000 ha maize;	29 000 ha maize/sesame
total :	38 000 ha maize;	45 000 ha maize/sesame

Table 2.2: Water requirements for irrigation of crops other than maize and sesame and for other purposes - present situation (million m^3)

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Upstream Jowhar outlet	7.80	7.64	9.20	7.02	5.71	6.58	6.35	6.73	11.97	5.76	6.07	6.67	87.33
Downstream Jowhar outlet	12.31	12.18	13.60	8.51	9.18	7.89	7.89	8.82	11.02	10.31	8.42	12.40	121.87
Other purposes	4.80	4.80	4.80	0.70	0.50	0.70	0.80	0.80	0.70	0.50	0.50	4.70	24.30
Total	24.91	24.62	27.60	16.23	15.39	15.17	14.94	16.35	23.69	16.57	14.99	23.77	233.50

Source: Ref. 4

assumed irrigation efficiency: 45%

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The total water requirements for this situation are summarized in Table 2.3.

The next situation is as follows:

It is assumed that in addition to the Jowhar reservoir, the Dububle reservoir is available for storage. The active capacity is 199 + 187 = 386 million m^3.

A future situation is assumed in which several areas for specific crops, like the Jowhar Sugar Estate and the Balcad cotton scheme have been rehabilitated, such that then, apart from maize and sesame, the following crops are grown:

Upstream of the Jowhar outlet:

sugar cane:	5 600 ha
citrus :	50 ha
paddy (2 crops/year):	1 500 ha

Downstream of the Jowhar outlet:

bananas:	3 800 ha
citrus and other fruit trees:	3 000 ha
cotton (Der-season):	2 500 ha
vegetables (year-round):	2 000 ha
tomatoes, paprika etc.(Gu+Der):	1 100 ha
pulses (Gu+Der) and various other crops	3 000 ha

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Table 2.3: Total present water requirements in the Shebelle Valley (million m^3)

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Transfer Table 2.2	24.91	24.62	27.60	16.23	15.39	15.17	14.94	16.35	23.69	16.57	14.99	23.77	233.50
Maize					31.24	91.20	86.98	16.04					255.45
Maize/ sesame	15.62								12.02	61.70	104.72	85.99	280.04
Total	40.53	24.62	27.23	16.23	46.63	106.37	101.92	32.39	35.71	78.27	119.71	109.76	768.99

The water requirements for these crops and for other purposes (which have been adopted as constant) are given in Table 2.4.

Under these conditions the following areas of maize and maize/sesame can be grown:

upstream of Jowhar outlet	11 000 ha maize;	12 000 ha maize/sesame
downstream of Jowhar outlet	26 000 ha maize;	51 000 ha maize/sesame
total	37 000 ha maize	63 000 ha maize/sesame

Discussion:

The first scenario is now compared with the actual situation. It was observed that between 48 000 ha and 50 000 ha are planted to annual crops seasonally, in addition to perennial crops. However, sufficient water is available for only about 39 000 ha in the Gu season and 46 000 ha in the Der season, even when a reasonable efficiency of 45% is assumed. This situation leads to the conclusion that additional storage room is required.

With additional storage room at Duduble and taking into account rehabilitation of projects like Jowhar Sugar Estate and Balcad (cotton) and extension - as envisaged - of perennial crops like bananas and fruit trees, the situation for annual crops would still improve: about 42 000 ha of maize could be grown in the Gu season and 70 000 ha of maize/sesame in the Der season.

It has now furthermore been investigated, as a third scenario, how many additional hectares of annual crops could be grown when Duduble is available in addition to Jowhar, but when no additional perennial crops are grown.

Table 2.4: Water requirements for irrigation of crops other than maize and sesame and for other purposes - further situation (million m^3)

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Upstream Jowhar outlet	19.04	18.64	24.40	19.20	15.02	17.62	16.98	17.09	32.96	15.49	16.16	16.93	229.53
Downstream Jowhar outlet	34.31	25.91	28.18	15.64	20.73	21.38	17.29	19.53	24.84	22.29	22.89	32.00	285.00
Other purposes	4.80	4.80	4.80	0.70	0.50	0.70	0.80	0.80	0.70	0.50	0.50	4.70	24.30
Total	58.15	49.35	57.38	35.54	36.25	39.70	35.07	37.42	58.50	38.28	39.55	53.63	538.83

Source: Ref. 4

In this case, about 57 000 ha of maize could be grown in the Gu season and 76 000 ha of maize/sesame in the Der season.

It is concluded that, whatever option is selected with regard to extension of perennial crops, the tilled area of annual crops will be limited when compared with the total available area (115 000 - 120 000 ha).

When thus the total available area would be used, cropping intensities would have to be limited to between 35% and 50% in the Gu-season and between 60% and 65% in the Der-season. The various feasibility studies which have recently been prepared on irrigation projects have demonstrated that the seasonal intensities should be at least between 70 and 80% to make a project economically feasible.

This means that probably the total present irrigation area cannot be fully used in future.

In order to give an impression of the magnitude of the required reduction, the following computations have been preformed:

- a summary has been made of the irrigation requirements of all those projects which are presently rehabilitated, which are in the planning stage or of which it can reasonably assumed that rehabilitation will be done in the near future.

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- computations of irrigation potential, expressed as the area of maize (Gu-season) and maize/sesame (Der-season) assuming:

  case 1.1: Jowhar Reservoir in operation; no extension of perennial crops

  case 1.2: Jowhar Reservoir in operation; extension of perennial crops:

  bananas to 3800 ha
  sugarcane to 5600 ha
  fruittrees to 3000 ha

  case 2.1. Jowhar and Duduble Reservoirs in operation; no extension of perennial crops

  case 2.2: Jowhar and Duduble Reservoirs in operation; extension of perennial crops as in "case 1.2".

A summary of cropped areas in projects is presented in Table 2.5. The diversion irrigation requirements are summarized in Table 2.6.

The results of the computations for cases 1.1 to 2.2 are presented in Table 2.7. The computations are based on the discharge of the Shebelle which is exceeded in 80% of the year. It appears that the additional irrigable area varies from 47300 ha (case 1.2) to 32400 ha (case 2.1).

A summary of the total cropped areas is given in Table 2.8. From this Table it can be concluded that when a seasonal cropping intensity of about 75% is applied, the total possible irrigable area (annual crops and perennial crops) is 11 800 ha at maximum. This figure is still substantially below the identified area in the Shebelle Water Strategy Study (120000 ha for annual crops, 1200 ha perennial crops).

Table 2.5 Cropped areas in existing and planned irrigation projects (hectares)

	Su	Ser	Perennial
[illegible] Rice Project (440 ha)			
(existing)			
paddy	440	440	
Jowhar Sugar Estate			
(existing)			
sugarcane			2275
Balcad Cotton Scheme (2000 ha)			
(rehabilitation expected)			
cotton	750	750	
maize	750	750	
Afgoi-Mordiile Project (2520 ha)			
(under construction)			
maize	750		
cowpeas	204		
vegetables	271		
paddy/vegetables		269	
cotton		269	
sesame		738	
banana			288
fruittrees			252
Shalambood (4153 ha)			
(planned)			
maize	2379		
legumes	43	43	
sesame		2250	
vegetables		198	
watermelon		188	
banana			400
Genale Project (2[illegible] ha)			
(under construction)			
maize	990	609	
paddy	560	436	
forage	593		
sesame		507	
groundnuts		537	
banana			200
Grapefruit Project [illegible]			
(partly existing)			
grapefruit			200
Farahaane (2910 ha)			
(planned)			
maize	1955		
legumes	[illegible]	987	
sesame		2146	
vegetables		176	
watermelon		296	
[illegible] refugee project (1500 ha)			
(rehabilitation expected)			
maize	[illegible]		
sesame		1230	
[illegible] refugee project (375 ha)			
(rehabilitation expected)			
maize	375		
sesame		375	
Summary			
sugarcane			2275
banana			888
fruit			452
maize	7885	1359	
sesame		9016	
paddy	920	1310	
forage	[illegible]		
cotton	750	1219	
legumes, cowpeas	1454	1150	
groundnuts		537	
watermelon		488	
vegetables	271	569	
Total	12560	14168	3615

Total net irrigable area in defined projects: 22525 ha

Table 2.6: Diversion irrigation requirement of projects (approximately 45% efficiency assumed)

- in million m^3 -

	jan.	feb.	mar.	apr.	may	jun.	jul.	aug.	sept.	oct.	nov.	dec.	
Baarow Weyne													14
Jowhar Sugar Estate (2275 ha)	7.68	7.53	9.13	4.89	4.60	4.96	4.84	6.02	8.09	4.24	4.64	5.96	71
Balcad Sheme				4.21	2.12	3.20	2.96	1.29	7.90	3.32	2.82	1.22	28
Afgoi-Mordiinle	3.33	1.88	1.97	1.41	2.33	4.24	4.21	1.21	2.38	4.59	5.26	3.48	37
Shalamboot	7.51	1.87	2.00	1.43	2.07	4.15	7.50	6.45	3.05	4.12	6.66	11.83	59
Genaale	2.68	0.70	0.82	0.47	1.83	2.06	2.18	1.24	2.30	3.86	3.84	4.50	27
Grapefruit Project	0.41	0.42	0.43	0.16	0.16	0.20	0.21	0.35	0.37	0.23	0.21	0.32	3
Faraxaane	6.02	0.15	0	0	0.73	3.20	6.64	5.24	1.37	2.57	5.67	10.74	42
Kurtun Waarey	1.25				1.00	2.88	2.75	0.51	0.40	2.03	2.72	1.44	14
Sablaale	1.02				0.81	2.33	2.33	0.41	0.32	1.64	2.20	1.17	12
													307

Table 2.7: Irrigation potential in addition to defined projects

	seasonal ropped areas (1) (=75% of irrigable areas) - ha -	irrigable areas - ha -
case 1.1 with Jowhar, no extension per crops (2)	54000	72000
case 1.2 with Jowhar, extension per crops (3)	35500	47300
case 2.1 with Jowhar/Dudub-le, no extension per crops (2)	69300	92400
case 2.2 with Jowhar/Dudub-le, extension per crops (2)	50200	66900

(1) Gu-season: maize; Der-season: 1/3 maize/2/3 sesame

(2) banana: 2880 ha (total)
sugar cane: 2275 ha
fruit trees: 500 ha (total)

(3) banana: 3300 ha
sugar cane: 5600 ha
fruit trees: 3000 ha

Table 2.8: Total cropped areas for different cases (hectares)

	Case 1.1	Case 1.2	Case 2.1	Case 2..
sugar cane	2275	5600	2275	5600
banana	2880	3800	2880	3800
fruit	500	3000	500	3000
annual crops Gu-season	65560	47060	80860	61760
annual crops Der-season	68970	50470	84270	65170
Total area Gu	71215	59460	86515	74160
Der	74625	62870	89925	77570

As a consequence, the responsible authorities will have to set up rules, in which the delivery of water to each region and district is laid down.

Examples of a water allocation plan are presented in figures 2.2 A to D for the herefore mentioned four cases.

In these figures, water requirements have been given for the additional irrigable areas which have been tentatively subdivided for the various districts in proportion to the actual area of irrigation land (in total 120 000 ha); only for the Hiran district, the same area has been adopted for all alternatives (Table 2.9).

In the Jowhar and Balcad districts, these areas include small village schemes, but also areas served by government-managed larger canals as well as state farms.

The same applies to the Afgoi district and to the area upstream of the Genaale barage, where however the area of village schemes is more important.

The area between Genaale barage and Falkeerow barrage belongs to the "Genaale-Bulo Mareerta" area, of which the Faraxaane Project constitutes one part.

Finally, a complete water balance is presented in Figure 2.3 (for case 2.1).

It is conluded that parallel to the programme for rehabilitation of existing irrigation schemes, there is an urgent need for the establishment of a water allocation plan in the way as discussed above, which should, among others, be based on detailed information is particularly lacking in the areas upstream of Genaale, where classification work has only been done in project areas. An important issue with regard to water allocation will be the repartition between annual and perennial crops.

Table 2.9: Tentative subdivision of irrigated land in addition to projects

	with Jowhar no extension of perennials	with Jowhar extension of perennials	with Jowhar/Duduble no extension of perennials	with Jowhar/Duduble extension of perennials
	- 75% seasonal cropping intensity -			
Hiran District (upstream Duduble)	1200	1200	1200	1200
Jowhar area	15600	10100	20000	14500
Balcad area	5000	3200	6400	4600
Afgoi area (1)	12000	7800	15500	11200
Genaale area (1)	25500	16700	32800	23600
Qoryooley area	9200	6000	11900	8500
Kurtun Waarey/ Sablaale	3500	2300	4600	3300
	72000	47300	92400	66900

(1) plus 2000 resp. 5400 ha banana and fruittrees in the Afgoi-Genaale areas

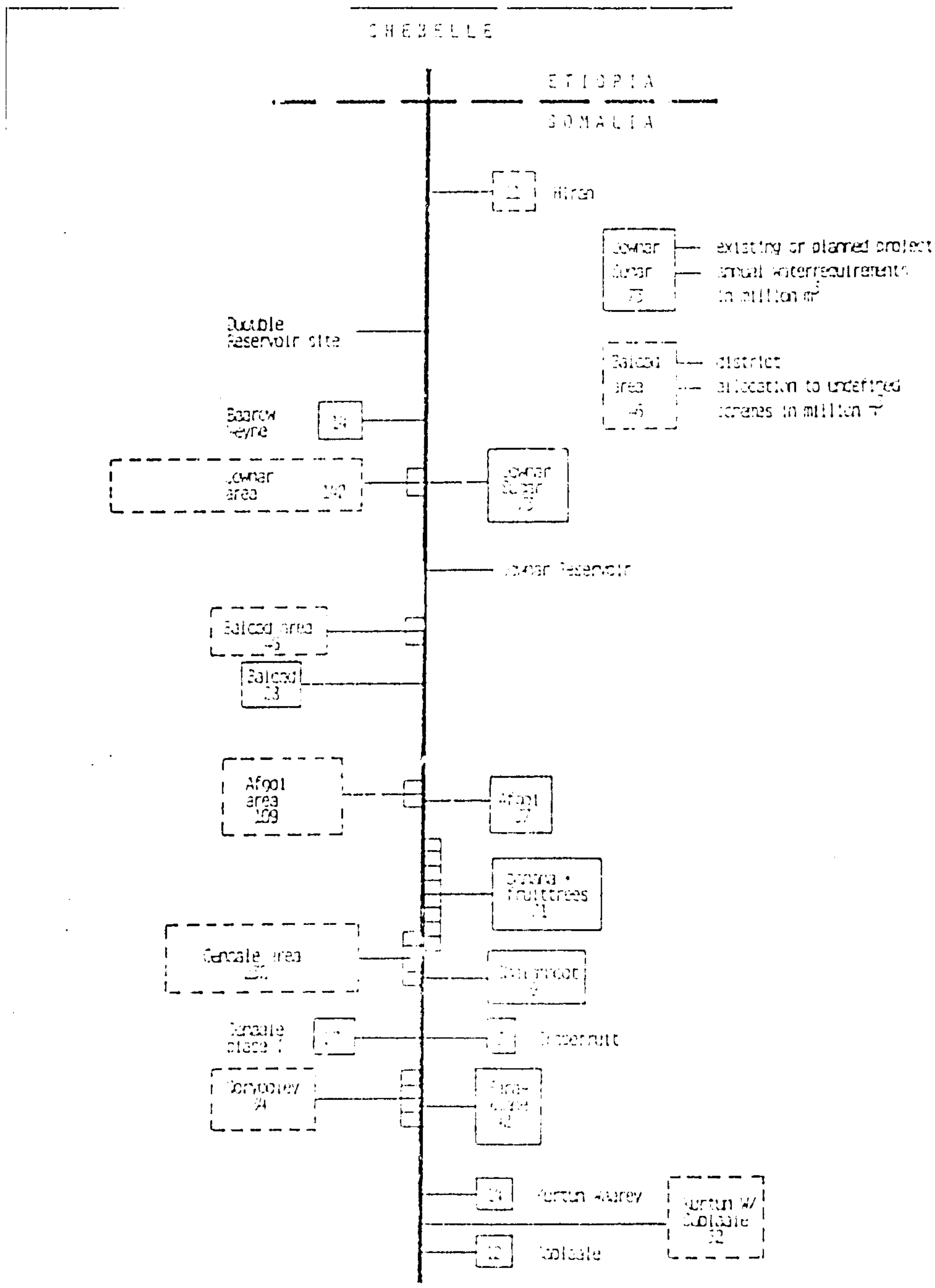

FIG. 2.2A WATER ALLOCATION PLAN FOR CASE 1.1

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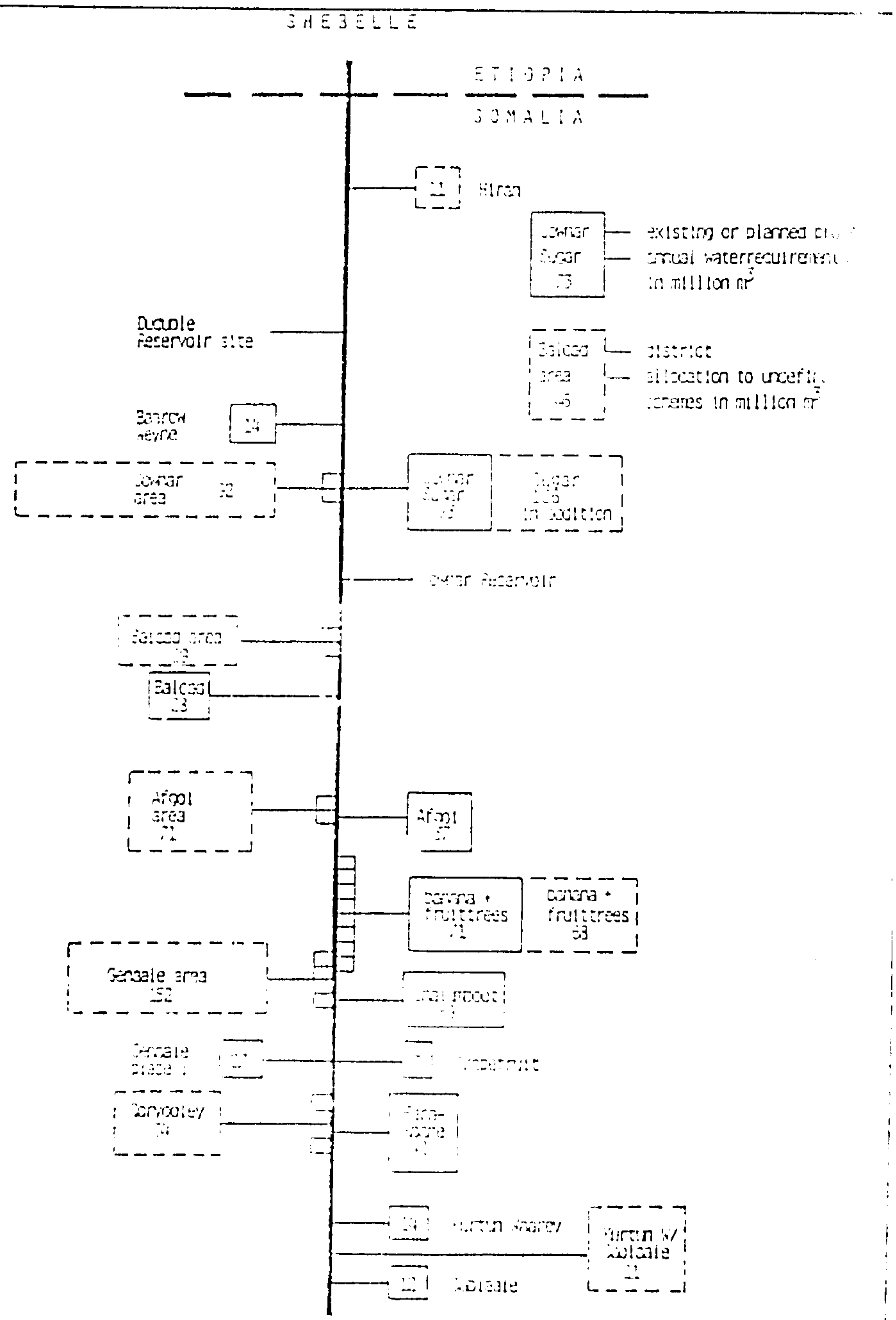

FIG.: 2.2B WATER ALLOCATION PLAN FOR CASE 1.2

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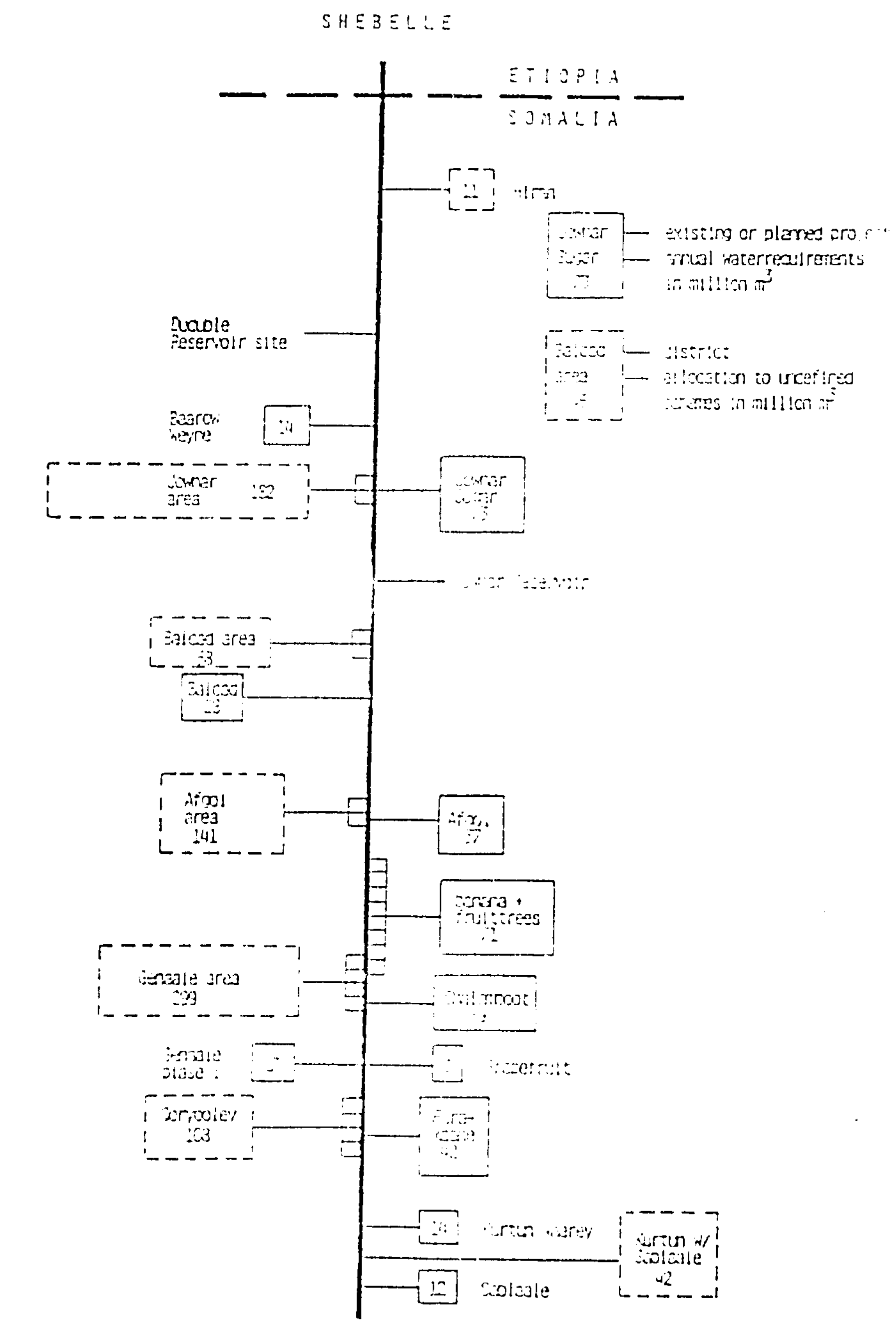

FIG.: 2.2 C | WATER ALLOCATION PLAN FOR CASE 2.1 | LAHMEYER INTERNATIONAL

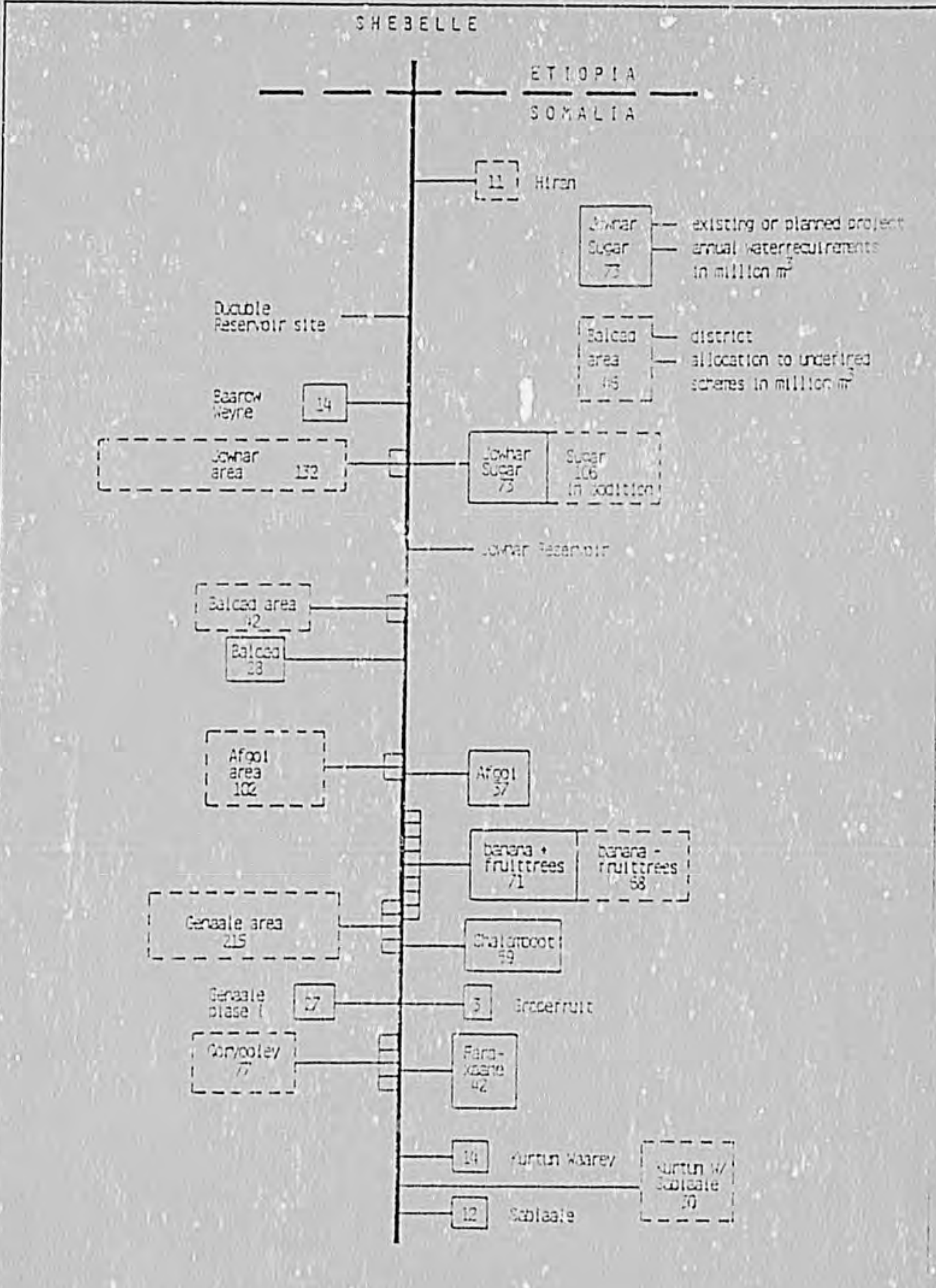

FIG.:22 D WATER ALLOCATION PLAN FOR CASE 2.2

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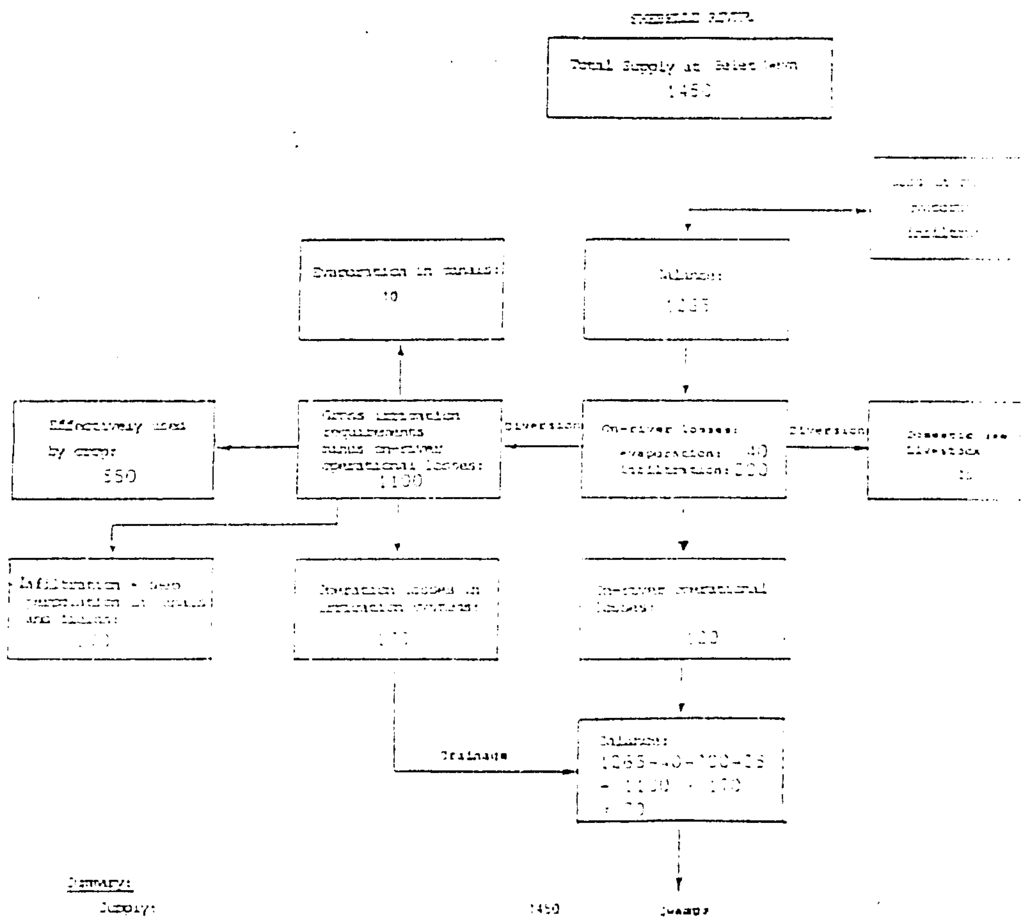
Figure 2.[illegible]:
Water balance for irrigated area case 2.[illegible] and 1450 million m³ discharge at Belet Weyn (80% exceedance probability; figures in million m³)

Reservoirs: Jowhar + Duduble



Summary:

Supply:	1450
Lost by evaporation: 165 + 40 + 10 =	215 -
Lost by percolation to groundwater: 10 + 200 + 170 =	[illegible] -
Balance	845
Effectively used: domestic + livestock	25 -
evaporation + evapotranspiration at irrigated fields:	[illegible] -
Balance (flow to swamps at downstream end)	[illegible]

3. IMPACT OF RIVER REGULATION AND IRRIGATION IN ETHIOPIA

3.1 GENERAL

It is at present not possible to obtain up-to-date data about the development activities in the Shebelle Valley in Ethiopia.

However, it is known that with Russian assistance, a dam has been completed recently at MALKA WAKANA for the principal purpose of hydropower generation. Data on dam height, reservoir volume and other relevant characteristics are not available. But in 1982, the Canadian firm ACRES have conducted a power planning study in which the possibility of a dam at MALKA WAKANA was also investigated (Ref. 5). A preliminar optimum design was prepared and in the present study it is assumed that the selected dam and reservoir characteristics do not deviate too much those proposed in 1982.

As far as irrigation is concerned, it seems that there are plans for a project of about 5000 ha downstream of the dam and that flooding is actually practised in the flat areas further downstream. For the purpose of the present study, in which the impact of irrigation is investigated, a lower limit of 5 000 ha of irrigated land has been adopted. The upper limit has been arbitrarily fixed at 25 000 ha, assuming that it would take at least 15 to 20 years to develop such an area, a period in which it should be possible to conclude a bilateral agreement on exploitation of the Shebelle River.

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3.2 INFORMATION ABOUT THE MALKA WAKANA RESERVOIR

The Malka Wakana project is located on the eastern edge of the Ethiopian Highlands (Figure 3.2) nearly 1 200 km upstream of the gauging station Belet Weyn in Somalia. Its catchment area is 5 300 km^2. The long term average flow was initially estimated at

$$Q = 27{,}5\ m^3/s.$$

The project concept, as determinated by EDF-BCEOM (Ref. 5) comprises a 40 m high dam immediately upstream of the first Malka Wakana Falls with a gross storage volume of 765 million m^3. The active storage volume is about 500 million m^3.

The ratio of active storage to the average annual inflow volume is 0,58.

Evaporation in the catchment area of Malka Wakana dam is about 1 600 mm per annum. The average precipitation is 900 mm.

The reservoir surface is approximately 57 km^2.

An average annual loss of volume of $V_{EVP} = 40 \times 10^6 m^3$ is expected that corresponds to an average discharge of 1,3 m^3/s.

The calculation of the storage filling on the basis of monthly values is shown in Table 3.1 and Figure 3.1. For the available data of six years it appears that nearly 12% of the inflow passes as unregulated flow over the spillway or evaporates. The ratio of sum of regulated quantity to sum of inflow is thus 88%.

Table 3.1: Shebelle River, Balance of Storage at Malka Wakana

Year	Month	Malka Wacana	inflow *(10^6)m^3	outflow *(10^6)m^3	Evaporation *(10^6)m^3	Volume difference *(10^6)m^3	storage volume *(10^6)m^3	spills *(10^6)m^3
1967	Jan						500.00	
	Feb	4.60	11.13	63.38	3.14	-55.40	444.60	0.00
	Mar	4.40	11.78	70.17	3.48	-61.87	382.73	0.00
	Apr	6.40	16.59	67.91	3.37	-54.69	328.04	0.00
	Mai	8.80	23.57	70.17	3.48	-50.09	277.95	0.00
	Jun	6.40	16.59	67.91	3.37	-54.69	223.26	0.00
	Jul	35.00	93.74	70.17	3.48	20.09	243.35	0.00
	Aug	78.70	210.79	70.17	3.48	137.13	380.48	0.00
	Sep	72.80	188.70	67.91	3.37	117.42	497.90	0.00
	Oct	68.40	183.20	70.17	3.48	109.55	500.00	107.45
	Nov	43.00	111.46	67.91	3.37	40.18	500.00	40.18
	Dez	8.77	23.49	70.17	3.48	-50.17	449.83	0.00
1968	Jan	4.20	11.30	70.17	3.48	-62.35	387.48	0.00
	Feb	15.60	37.74	63.38	3.14	-28.79	358.69	0.00
	Mar	21.10	56.51	70.17	3.48	-17.14	341.55	0.00
	Apr	68.50	177.55	67.91	3.37	106.27	447.82	0.00
	Mai	32.80	87.85	70.17	3.48	14.20	462.02	0.00
	Jun	20.30	52.62	67.91	3.37	-18.66	443.36	0.00
	Jul	43.90	117.58	70.17	3.48	43.93	487.29	0.00
	Aug	74.30	199.01	70.17	3.48	125.36	500.00	112.65
	Sep	43.00	111.46	67.91	3.37	40.18	500.00	40.18
	Oct	23.20	62.14	70.17	3.48	-11.52	488.48	0.00
	Nov	9.64	24.99	67.91	3.37	-46.29	442.19	0.00
	Dez	5.69	15.78	70.17	3.48	-57.88	384.31	0.00
1969	Jan	9.49	25.42	70.17	3.48	-48.24	336.07	0.00
	Feb	17.70	42.82	63.38	3.14	-23.71	312.36	0.00
	Mar	40.50	108.48	70.17	3.48	34.82	347.18	0.00
	Apr	19.20	49.77	67.91	3.37	-21.51	325.67	0.00
	Mai	22.30	59.73	70.17	3.48	-13.93	311.74	0.00
	Jun	9.39	24.34	67.91	3.37	-46.94	264.80	0.00
	Jul	43.20	115.71	70.17	3.48	42.05	306.85	0.00
	Aug	89.30	239.18	70.17	3.48	165.53	472.38	0.00
	Sep	50.20	130.12	67.91	3.37	58.84	500.00	31.21
	Oct	14.00	37.50	70.17	3.48	-36.15	463.84	0.00
	Nov	6.62	17.16	67.91	3.37	-54.12	409.72	0.00
	Dez	4.97	13.31	70.17	3.48	-60.34	349.38	0.00
1970	Jan	8.50	22.77	70.17	3.48	-50.89	298.49	0.00
	Feb	5.16	12.48	63.38	3.14	-54.04	244.44	0.00
	Mar	29.30	78.48	70.17	3.48	4.82	249.26	0.00
	Apr	31.00	80.35	67.91	3.37	9.07	258.33	0.00
	Mai	16.40	43.93	70.17	3.48	-29.73	228.60	0.00
	Jun	6.63	17.18	67.91	3.37	-54.10	174.51	0.00
	Jul	28.70	76.87	70.17	3.48	3.21	177.72	0.00
	Aug	99.80	267.30	70.17	3.48	193.65	371.37	0.00
	Sep	74.20	192.33	67.91	3.37	121.05	492.42	0.00
	Oct	34.50	92.40	70.17	3.48	18.75	500.00	11.17
	Nov	10.80	27.99	67.91	3.37	-43.29	456.71	0.00
	Dez	4.61	12.35	70.17	3.48	-61.31	395.41	0.00
1971	Jan	4.65	12.45	70.17	3.48	-61.20	334.20	0.00
	Feb	4.05	9.80	63.38	3.14	-56.73	277.47	0.00
	Mar	4.55	12.19	70.17	3.48	-61.47	216.00	0.00
	Apr	12.90	33.44	67.91	3.37	-37.84	178.16	0.00
	Mai	22.70	60.80	70.17	3.48	-12.86	165.30	0.00
	Jun	25.90	67.13	67.91	3.37	-4.15	161.16	0.00
	Jul	57.30	154.01	70.17	3.48	80.35	241.51	0.00
	Aug	90.20	241.59	70.17	3.48	167.94	409.45	0.00
	Sep	52.30	135.56	67.91	3.37	64.28	473.73	0.00
	Oct	47.30	126.69	70.17	3.48	53.03	500.00	26.76
	Nov	12.40	32.14	67.91	3.37	-39.14	460.86	0.00
	Dez	7.27	19.47	70.17	3.48	-54.18	406.68	0.00
1972	Jan	5.48	14.68	70.17	3.48	-58.98	347.70	0.00
	Feb	13.30	32.18	63.38	3.14	-34.35	313.35	0.00
	Mar	14.00	39.64	70.17	3.48	-34.02	279.33	0.00
	Apr	43.70	113.27	67.91	3.37	41.99	321.32	0.00
	Mai	18.90	50.62	70.17	3.48	-23.03	298.29	0.00
	Jun	8.98	23.28	67.91	3.37	-48.00	250.28	0.00
	Jul	39.20	104.99	70.17	3.48	31.34	281.62	0.00
	Aug	55.50	148.65	70.17	3.48	75.00	356.61	0.00
	Sep	42.90	111.20	67.91	3.37	39.92	396.53	0.00
	Oct	9.27	24.83	70.17	3.48	-48.83	347.70	0.00
	Nov	7.77	20.14	67.91	3.37	-51.14	296.56	0.00
	Dez	4.76	12.75	70.17	3.48	-60.91	235.66	0.00
sums: (10^6m^3):			5235.01	4887.29	242.50	105.23		369.57
[illegible]			[illegible]	[illegible]	[illegible]	[illegible]		[illegible]

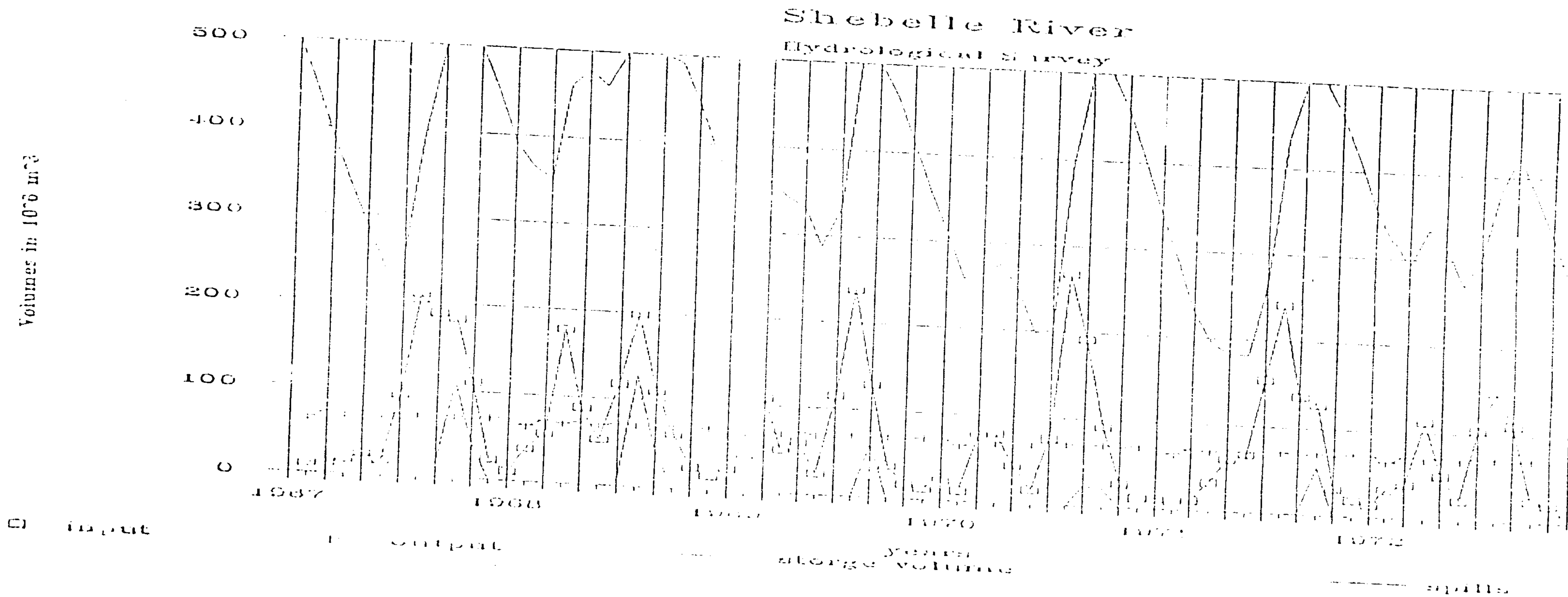

FIG.: 3.1 | MALKA WAKANA - SIMULATION OF STORAGE FILLING

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The inflow/outflow results given in Table 3.1 can be summarized as follows:

- Because of the losses of evaporation the average discharge is reduced by about 1.3 m^3/s to 26.2 m^3/s.

- Nearly 7% of the inflow leaves the storage through the spillway.

- As a result of the use of the storage for hydraulic power generation the outflow from the reservoir is relatively constant, also from November to January and in June when natural flow is low (4 to 10 m^3/s).

- The reservoir has a flood mitigation effect which is ilustrated in Figure 3.1.

3.3 WATER AVAILABILITY FOR IRRIGATION DOWNSTREAM OF MALKA WAKANA

As it was said before there is no information available about size, location and development schedule of irrigation projects on the Shebelle river in Ethiopia.

Therefore, the impact of irrigation on water availability in Somalia has been estimated for adopted total areas varying in size from 5 000 ha to 35 000 ha. Furthermore it is assumed that annual crops are grown of which the water requirements are similar as those for maize and maize/sesame as discussed in Chapter 2. Data on irrigation requirements, per ha and for the adopted areas, are summarized in Table 3.2.

Table 3.2: Gross Irrigation requirements for adopted areas

		May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Maize	m^3/ha	822	2400	2289	422					5933
Maize (1/3)+ Sesame (2/3)	m^3/ha					267	1371	2327	1911	6223
Irrigation area:		Demand in m^3/s								Average
5000 ha		1.53	4.63	4.27	0.79	0.52	2.56	4.49	3.57	1.93
10000 ha		3.07	9.26	8.55	1.58	1.03	5.12	8.98	7.13	3.85
15000 ha		4.60	13.89	12.82	2.36	1.55	7.68	13.47	10.70	5.78
20000 ha		6.14	18.52	17.09	3.15	2.06	10.24	17.96	14.27	7.71
25000 ha		7.67	23.15	21.37	3.94	2.58	12.80	22.44	17.84	9.64
30000 ha		9.21	27.78	25.64	4.73	3.09	15.36	26.93	21.40	11.56
35000 ha		10.74	32.41	29.91	5.51	3.61	17.92	31.42	24.97	13.4
40000 ha		12.28	37.04	34.18	6.30	4.12	20.47	35.91	28.54	15.42
45000 ha		13.81	41.67	38.46	7.09	4.64	23.03	40.40	32.11	17.3
50000 ha		15.34	46.30	42.73	7.88	5.15	25.59	44.89	35.67	19.27
55000 ha		16.88	50.93	47.00	8.67	5.67	28.15	49.38	39.24	21.20
60000 ha		18.41	55.56	51.28	9.45	6.18	30.71	53.87	42.81	23.13

From Table 3.2 it can be concluded that when the discharge is kept at 25.2 m^3/s , i. e., when priority is given to energy generation, it is possible to irrigate about 27 000 ha immediately downstream of the dam.

Herewith the average water demand for irrigation which will be taken form the Shebelle river downstream of Malka Wakana can be estimated:

$$Q_{irr} = 10,4\ m^3/s.$$

The given information on the characteristics of the discharge of the Shebelle river will help to determine the amount of discharge reduction noticed at the gauge of Belet Weyn in Somalia.

3.4 CHARACTERISTICS OF THE SHEBELLE RIVER IN ETHIOPIA

Figure 3.2 shows the drainage area of the Shebelle river. The principal hydrometric stations in Ethiopia and Somalia are shown and the area with highest run-off is marked.

The total drainage area of the Shebelle is about 300 000 km^2, of which more than two third are upstream of BELET WEYN (211 000 km^2). The main share of run-off comes from the area north of IMI, with a surface of about 92 000 km^2. The catchment area of MALKA WAKANA Dam with about 5 300 km^2 covers only about 6% of this area.

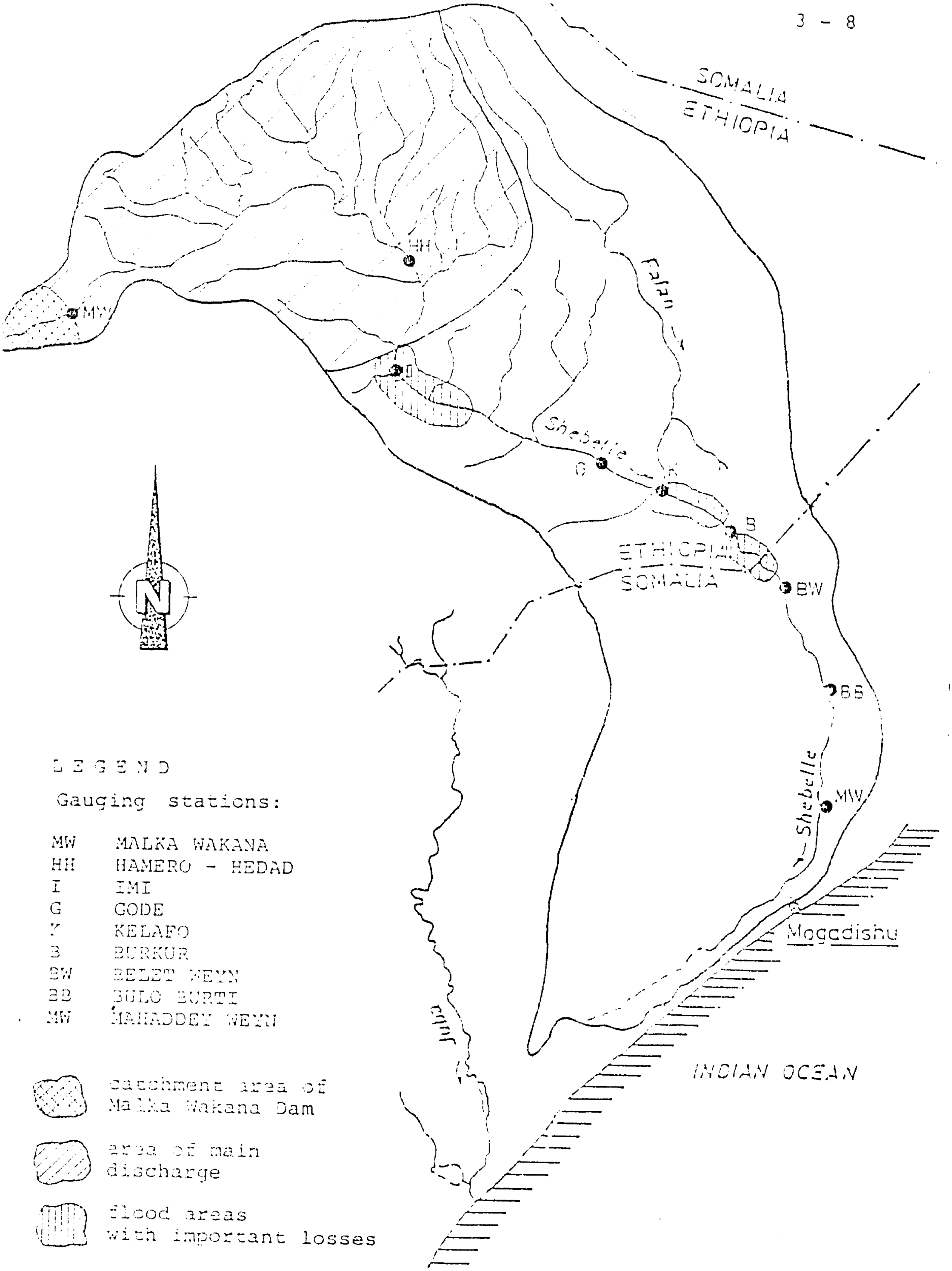
In the upper course, below the Malka Wakana falls the Shebelle flows in a very deep gorge steeply sloping down the first five kilometers (25 m/km) after which the gradient gradually decreases. This deep channel stretches down to 30 km to the north of IMI along 600 km. From IMI, after the exit of the gorge, the Shebelle flows in a vast alluvial plain with a very gentle slope (0.25 to 0.35 m/km).

From a hydrographical point of view this lower valley can be divided into five large zones:

- from the exit from the gorges down to Cugno, nearly 60 km downstream of IMI the slope is gentle and the banks are relatively low. The Shebelle meanders through alluvial deposits and overflows during the flood period. Its changing streamflow often cross-cuts its meanders.

- from Cugno to 30 kilometers upstream of Kelafo, the Shebelle bed is incised to a depth of 8 to 9 m and no longer overflows. The banks are relatively stable.

- from Kelafo nearly 90 km downstream the river-banks are lower again and the gradient of slope decreases (0,20 m/km). In this reach, the banks of the Shebelle are


SOMALIA
ETHIOPIA
HH
MW
I
Falan
Shebelle
G
K
B
ETHIOPIA
SOMALIA
BW
BB
Shebelle
MW
Mogadishu
Juba
INDIAN OCEAN
LEGEND
Gauging stations:
MW MALKA WAKANA
HH HAMERO - HEDAD
I IMI
G GODE
K KELAFO
B BURKUR
BW BELET WEYN
BB BULO BURTI
MW MAHADDEY WEYN
catchment area of Malka Wakana Dam
area of main discharge
flood areas with important losses

approx. 5 meters high . During floods, the Shebelle inundates the adjacent areas in this basin. In this reach, uncontrolled flooding is practized by the local farmers, as it is still done in some areas in Somalia, but the extent is not known.

- in the following river reach, down to Burkur, the Shebelle course is confined between limestone hills and flows once again in a well defined channel.

- Downstream of Burkur, the banks are again very low and the river overflows during floods.

In figure 3.2 the flood areas are indicated. In these areas, evaporation losses are important, but it seems that infiltration losses are little (Ref. 1).

3.5 CHARACTERISTICS OF DISCHARGE

The flow regime of the Shebelle river is principally controlled by rainfall in the Ethiopian high lands. The inflow from other areas is relatively little. In Ref. 1 information is given about discharges. Characteristic data are summerized in Table 3.4. Information for the Ethiopian gauging stations exists only for a few years, six years at maximum for the station MALKA WAKANA.

For the station of Belet Weyn, data are available since 1951 (see Table 3.5). At this station, the annual average discharge is 71 m^3/sec at present, or 2240 million m^3 per year. The discharge, decisive for irrigation (80% exceedance probability) is <u>46</u> m^3/sec, corresponding to <u>1450</u> million m^3 per year. The approximate monthly discharges corresponding to the latter annual discharge are (in million m^3):

j	f	m	a	m	j	j	a	s	o	n	d
22	16	17	107	174	67	77	220	335	257	114	45

Table 3.3 comprises the most important information of the gauging stations. The mean annual discharges in the last column are based on reconstituted 20 year-series, related to the station at Belet Weyn.

Table 3.3: Mean annual discharge of gauging stations on the Shebelle river

Station	Catchment area km^2	Location km	Discharge m^3/s
Malka Wakana	5290	1198	27.5
Hamero-Hedad	64450	698	101
Imi	91600	578	103
Gode	127300	304	102
Kelafo	139100	194	94
Burkur	144000	70	86
Belet Weyn	211000	0	70.5

Table 3.3 shows the development of discharge along the river which is also demonstrated in Figure 3.3. It is interesting to remember that about 27% of the mean discharge registered at the station of IMI originates from the small catchment area at MALKA WAKANA.

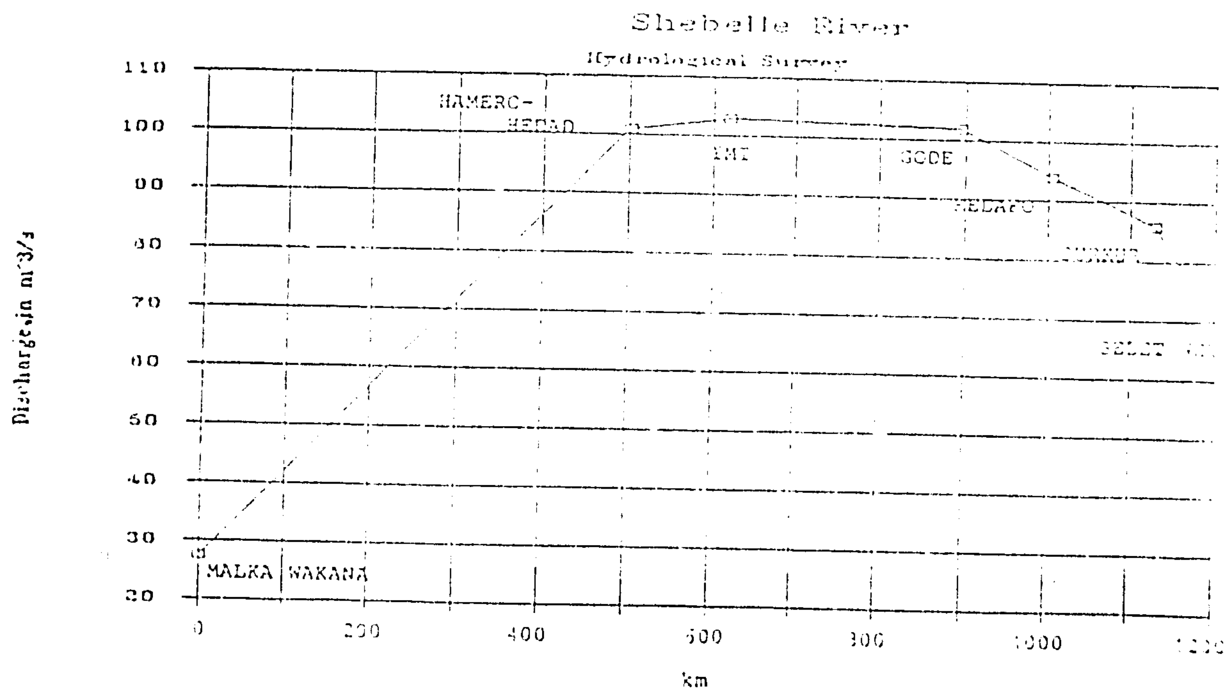


Figure 3.3: Development of discharge at Shebelle river

Table 3.4: Gauging stations at the Shebelle river, mean monthly discharge (in m^3/sec)

Year	Month	Dodola	Malka Wacana	Lege Hida	Hamero Hedad	Imi	Gode	Kelafo	Burkur	Belet Weyn	Bulo Burti
1967	Jan									2.30	11.30
	Feb	1.34	4.60							2.10	3.63
	Mar	1.23	4.40							0.70	1.30
	Apr	1.91	6.40							45.30	39.20
	Mai	2.46	8.30							132.50	120.30
	Jun	1.71	6.40							53.00	61.50
	Jul	10.20	35.00							28.00	29.70
	Aug	18.40	70.70							114.80	96.60
	Sep	24.60	72.80							206.30	163.50
	Oct	21.00	68.40				311.00			244.90	191.90
	Nov	16.10	43.00				231.00			163.00	141.20
	Dez	2.34	3.77				92.10			160.00	142.10
		9.23	30.66							76.03	83.62
1968	Jan	1.39	4.22				32.50	30.10		25.10	29.20
	Feb	2.55	15.60		47.10		57.20			16.20	16.60
	Mar	3.49	21.10		36.20		38.00			67.50	69.10
	Apr	18.10	68.50		371.00		362.00			95.10	84.10
	Mai	9.36	32.80		193.00		232.00			245.70	263.00
	Jun	8.59	20.30		119.00		112.00			137.80	150.70
	Jul	7.85	43.90		136.00		104.00			76.70	78.90
	Aug	11.80	74.30		242.00		213.00			123.00	116.50
	Sep	17.30	43.00		164.00		136.00			145.20	137.20
	Oct	7.17	23.20		100.00		99.00			107.50	112.50
	Nov	1.92	9.64		66.10		65.50			50.60	53.70
	Dez	1.64	5.39		37.50		39.60			50.60	54.30
		7.61	30.20		141.99		128.57			104.25	97.24
1969	Jan	3.24	9.49		29.10		19.10	17.30		20.70	18.40
	Feb	4.39	17.70		102.00	75.00	54.20	48.50	29.10	23.50	18.30
	Mar	6.75	40.50		187.00	130.00	168.00	191.00	124.00	112.20	109.40
	Apr	3.43	19.20		109.00	106.00	103.00	115.00	115.00	97.60	99.60
	Mai	4.75	22.30		160.00	147.00	179.00	176.00	151.00	134.40	131.10
	Jun	4.06	9.39		46.30	36.20	36.40	33.30	40.70	37.40	44.30
	Jul	14.30	43.20		119.00	108.00	95.10	87.30	64.00	52.00	49.20
	Aug	29.70	89.30		240.00	222.00	215.00	202.00	148.00	127.70	118.30
	Sep	16.40	50.20		160.00	152.00	165.00	162.00	166.00	151.50	143.20
	Oct	3.56	14.00		47.40	50.20	69.30	69.50	32.40	74.10	31.30
	Nov	1.92	5.62		32.60	31.60	45.60	46.20	41.70	33.00	37.03
	Dez	1.50	4.97		14.50	15.60	14.00	14.00	14.70	15.00	11.60
		7.34	27.24		103.83	102.15	98.64	96.38	39.72	73.83	71.93
1970	Jan	2.47	3.50		25.90	25.20	16.10	12.40	9.63	9.50	6.70
	Feb	1.64	5.16	12.00	18.60	17.00	22.00	20.70	21.30	20.50	16.70
	Mar	7.21	29.30	148.00	178.00	175.00	170.00	132.00	76.40	59.90	51.20
	Apr	7.37	31.00	93.00	120.00	148.00	207.00	179.00	115.00	96.70	96.00
	Mai	5.70	16.40	54.50	81.30	107.00	126.00	129.00	166.00	161.90	155.60
	Jun	2.73	6.63	16.10	22.60	19.90	25.50	22.80	26.30	26.20	24.90
	Jul	7.65	28.70	82.90	78.70	73.70	54.60	42.90	30.00	24.40	17.30
	Aug	26.10	99.80	287.00	317.00	330.00	294.00	240.00	142.00	119.10	108.70
	Sep	22.40	74.20	168.00	228.00	249.00	242.00	223.00	226.00	223.40	198.20
	Oct	8.34	34.50	89.50	132.00	154.00	180.00	159.00	171.00	171.30	161.40
	Nov	2.24	10.50	28.10	48.30	46.80	68.90	64.20	91.40	90.80	93.50
	Dez	1.43	4.61	9.20	17.30	13.60	18.00	15.30	17.70	16.60	16.60
		8.00	29.13	69.85	112.94	121.27	128.00	111.63	98.46	85.03	79.01
1971	Jan	1.64	4.65	8.00	12.90	12.20	11.50	9.22	9.71	10.50	8.00
	Feb	1.37	4.05	6.92	10.80	11.30	8.77	6.87	6.16	7.70	6.20
	Mar	1.71	4.55	12.40	16.30	19.90	7.54	3.93	3.76	6.50	4.00
	Apr	3.13	12.90	47.80	70.10	84.10	98.60	73.40	56.60	14.20	10.30
	Mai	7.14	22.70	56.10	110.00	114.00	129.00	113.00	96.90	36.60	88.90
	Jun	9.08	25.90	58.50	79.00	77.00	78.90	61.10	60.00	49.10	49.30
	Jul	20.30	57.50	114.00	118.00	130.00	124.00	99.50	94.00	75.40	80.40
	Aug	29.50	70.20	160.00	202.00	205.00	192.00	160.00	122.00	100.40	97.20
	Sep	14.70	52.30	97.80	155.00	159.00	171.00	149.00	160.00	136.60	143.60
	Oct	11.40	47.30	32.80	98.50	123.00	132.00	112.00	114.00	98.10	100.40
	Nov	3.52	12.40	53.50	74.20	79.30	68.40	73.00	76.10	65.90	68.40
	Dez	2.52	7.27	14.20	24.80	26.60	28.60	22.90	29.80	29.40	29.20
		8.36	28.48	59.34	80.97	86.77	89.36	73.66	69.11	60.08	59.78
1972	Jan	2.10	5.48	8.90	19.70	18.00	14.10	11.10	12.10	12.10	9.20
	Feb		13.30							31.40	17.60
	Mar		14.50							15.90	13.30
	Apr		43.70							48.00	41.30
	Mai		18.90							179.60	175.00
	Jun		3.93							60.30	57.00
	Jul		39.20							75.70	73.10
	Aug		55.50							114.40	113.40
	Sep		42.90							143.40	141.60
	Oct		9.27							100.60	104.80
	Nov		7.77							65.40	68.30
	Dez		4.76							19.20	16.00

Table 3.5:

SHEBELLE WATER STRATEGY STUDY AND DUDUBLE FEASIBILITY STUDY SOMALIA - MONP

BELET WEYN
SHEBELLE RIVER

STATION CODE: BELE ELEVATION: . . M LATITUDE: LONGITUDE:
RIVER BASIN : SHEBELLE DRAINAGE AREA:211600 KM2

DISCHARGES (CUBIC METRES/SECOND) EXTENDED DATA (PREL.

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY MEAN
1951	10.46	9.84	12.75	182.00	270.00	219.70	23.90	54.90	72.90	75.60	216.40	88.80	103.01
1952	10.30	11.66	15.55	45.56	78.90	23.30	32.03	26.20	125.60	75.40	37.70	12.94	41.30
1953	7.40	6.75	8.03	35.76	85.13	34.25	38.37	91.79	136.50	113.10	67.63	22.51	54.13
1954	10.34	9.72	12.56	41.91	57.00	23.90	30.81	72.10	167.70	240.90	75.90	31.40	64.79
1955	6.80	7.59	8.76	37.72	37.40	12.30	19.14	21.90	90.10	139.70	36.70	7.40	35.57
1956	5.13	5.03	5.02	27.55	265.80	25.80	24.60	89.90	164.50	157.50	254.50	27.40	88.18
1957	12.40	12.09	17.14	51.50	228.20	161.70	45.20	127.70	124.70	46.50	52.60	37.20	72.03
1958	9.00	17.00	39.60	19.60	57.70	11.00	13.70	115.60	181.70	199.00	80.30	17.60	63.71
1959	8.60	8.00	10.15	39.21	68.40	22.20	14.10	67.70	154.90	124.20	120.60	21.60	55.02
1960	10.19	10.22	13.35	19.81	56.07	35.93	17.54	35.30	78.49	80.45	36.34	12.63	34.14
1961	10.50	9.81	11.10	40.39	44.90	19.33	25.86	119.60	233.90	250.60	243.90	317.10	111.00
1962	11.56	16.92	25.30	11.12	53.10	14.02	21.23	70.53	66.43	70.47	38.96	13.51	34.84
1963	11.65	10.86	20.46	49.00	362.50	121.40	50.70	100.20	176.60	93.60	47.60	75.90	93.70
1964	35.10	16.70	8.70	39.10	30.90	20.00	35.40	115.10	174.80	174.00	90.10	19.50	63.44
1965	41.20	9.40	5.20	8.90	38.10	5.00	4.50	28.40	56.80	97.70	118.50	26.50	37.10
1966	5.20	3.30	25.20	36.80	76.90	34.30	34.20	64.20	125.50	99.20	57.80	10.90	47.95
1967	2.30	2.10	0.70	45.30	132.50	53.00	28.00	114.80	206.30	244.90	163.00	160.00	96.55
1968	26.10	16.20	69.50	95.10	315.70	137.80	76.70	128.00	145.20	109.50	50.60	50.60	104.88
1969	20.70	23.60	112.20	97.60	134.40	39.40	52.00	127.70	151.50	74.10	38.00	15.30	74.17
1970	9.50	20.50	59.90	96.70	161.90	26.20	24.40	119.10	223.40	171.30	90.80	16.60	85.25
1971	10.50	7.70	6.50	14.30	86.60	49.40	75.40	100.40	116.80	90.10	65.90	29.40	60.30
1972	12.10	21.10	15.90	10.60	178.60	60.30	75.70	114.40	143.40	100.60	65.40	18.20	71.45
1973	9.50	6.40	4.50	6.30	18.30	24.40	26.30	62.40	124.70	90.90	24.60	6.53	38.06
1974	3.40	2.28	1.47	63.10	58.00	64.50	67.10	97.60	125.00	72.30	19.40	7.50	46.60
1975	3.50	2.92	1.37	25.57	71.20	39.90	63.50	123.30	219.20	136.70	30.10	10.60	60.64
1976	3.60	3.00	2.41	28.30	213.70	209.20	71.40	128.80	172.80	139.50	131.10	56.20	96.96
1977	10.70	20.07	12.17	98.40	210.10	55.70	71.90	111.50	142.20	162.70	305.30	129.20	111.08
1978	25.00	13.20	69.80	16.70	78.80	28.60	57.30	140.80	187.00	170.60	112.30	29.10	80.30
1979	20.28	57.59	15.28	63.89	74.97	93.26	55.16	95.00	61.74	67.62	49.73	13.70	58.09
1980	8.41	5.53	3.49	12.70	41.83	15.84	22.27	72.09	69.75	47.50	16.81	6.30	30.69
1981	3.40	0.10	71.60	413.30	383.00	33.80	24.90	101.10	220.50	248.00	16.50	16.10	131.53
1982	12.10	10.10	11.70	68.50	131.50	97.90	48.50	99.80	120.30	139.20	284.90	79.30	85.72
1983	32.10	22.70	17.50	13.20	97.40	174.00	65.10	160.60	360.60	337.90	122.90	40.70	123.10
1984	22.50	16.20	10.90	11.25	35.10	53.80	51.50	91.20	111.20	74.00	19.90	8.05	42.25
MEAN	13.09	12.24	22.23	59.77	127.72	58.69	40.76	93.43	138.96	133.07	92.14	42.10	70.58
MAX	41.20	57.59	112.20	413.30	383.00	219.70	76.70	160.60	360.60	337.90	305.30	317.10	131.53
MIN	2.30	0.10	0.70	6.30	30.90	5.00	4.50	21.90	56.80	46.50	16.81	6.30	30.69
STDV	9.10	10.26	25.80	71.52	100.13	55.40	21.01	33.91	61.52	68.73	74.79	59.96	28.07

SOURCE OF RAW DATA: MONP

MISSING DATA INDICATED BY A DASH

Down to the gauging station HAMERO-HEDAD the discharge increases noticeably. Between HAMERO-HEDAD and GODE the total discharge almost stays constant. The losses in the flood areas are obviously compensated by lateral inflows. The highest losses occur by flooding the lower regions between KELAFO and BELET WEYN.

The monthly discharges of the gauging stations MALKA WAKANA, GODE and BELET WEYN are shown in Figure 3.4. The travel time between the gauging stations Malka Wakana and Gode is only 3 to 4 days. The travel time between GODE and BELET WEYN is about 20 days. This time lapse must be taken into account when comparing monthly averages.

Figure 3.4 shows that the highest losses always appear simultaneously with high discharges. At low-flow conditions, the discharge at GODE and BELET WEYN is nearly the same.

3.6 ESTIMATION OF LOSSES DUE TO FLOODS

Between Gode and Burkur, there is practically no inflow, rainfall is little (150 to 300 mm) and most of the water carried by tributaries does not reach the river but spreads over the vast alluvial plain or in closed endhoreic basins.

Between Kelafo and Mustahil the stream-flow of the Shebelle is greatly influenced in this reach by the existence of large flood plains stretching over approximately 600km^2 30 km downstream. 140 km^2 of these plains are flooded throughout the year and form a permanent swamp.

These flood plains have a double effect, i. e.:

- They control runoff by a reduction of flood peaks as shown in Figure 3.5.

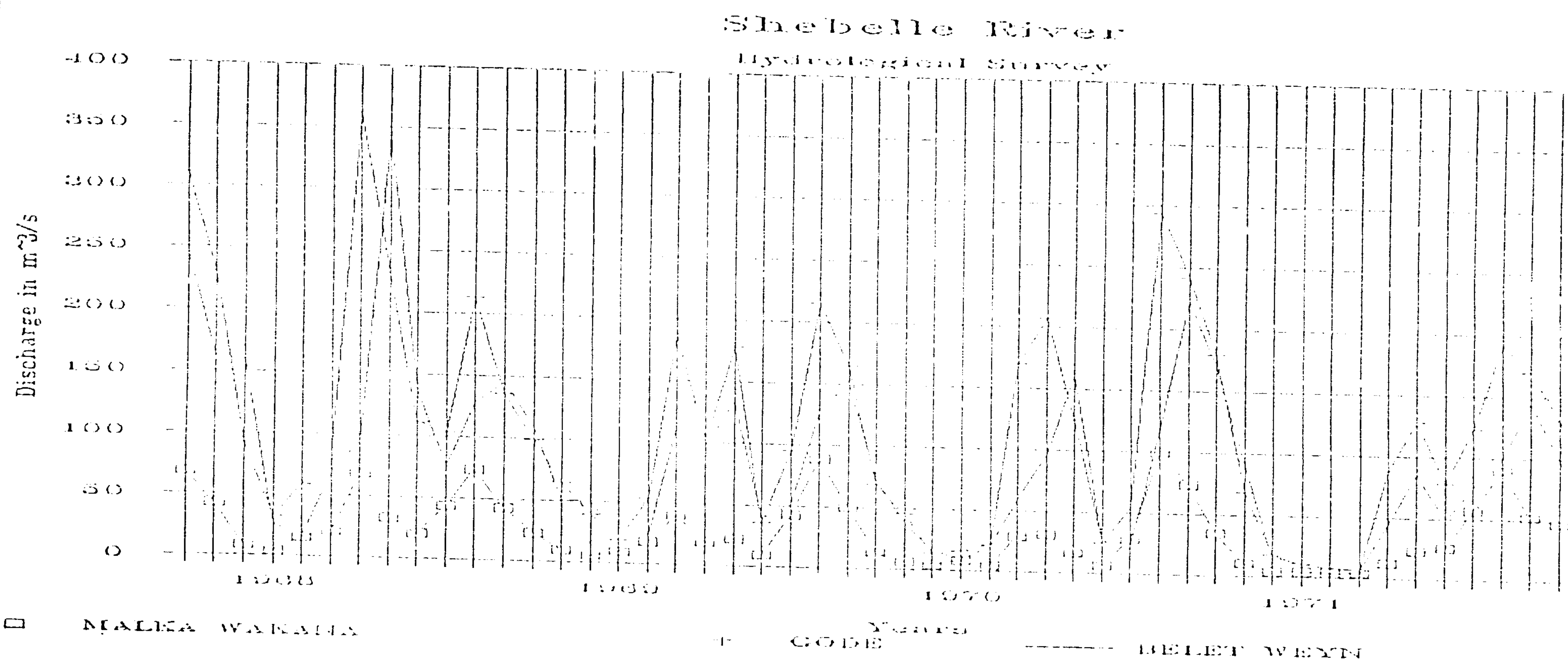
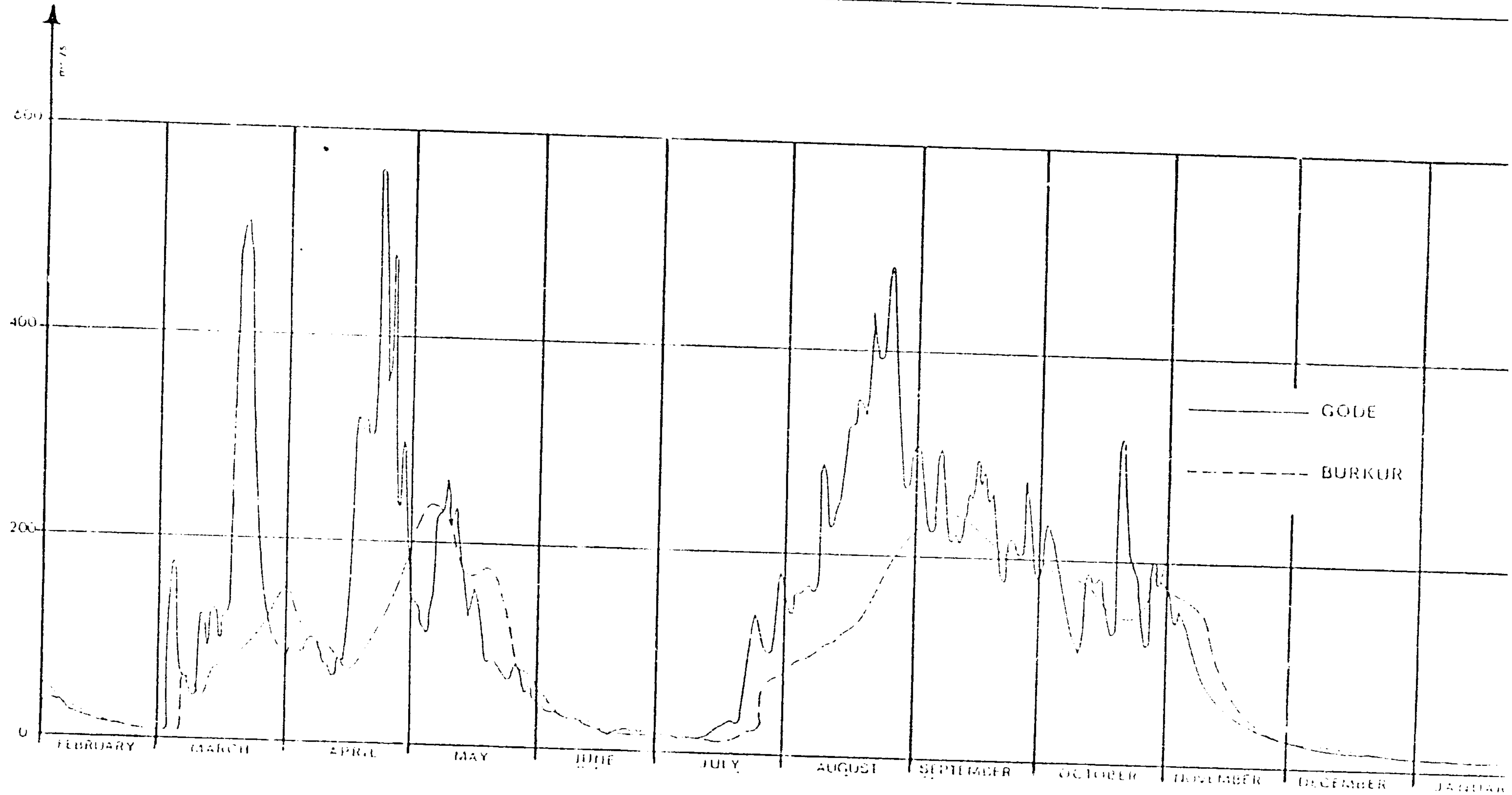


FIG: 3.4 SHEBELLE RIVER - COMPARISON OF MONTHLY DISCHARGE



Source: Ref. 1

FIGURE: 3.5

INFLUENCE OF THE FLOOD AREA ON THE HYDROGRAPH OF BURKUR

LAHMEYER INTERNATIO

- They withdraw an important amount of the inflow. The water collected in the flood plains partly supplies the ground water table, a great portion evaporates and another part flows back to the river when the river level decreases.

The balance of losses for three successive years is given below:

Tabel 3.6: Losses between GODE and BURKUR

Years	Run-off at Gode		Run-off at Burkur		Losses between Gode and Burkur	
	$10^6 m^3$	m^3/s	$10^6 m^3$	m^3/s	$10^6 m^3$	m^3/s
1969-1970	3 116	98.8	2 627	83.3	489	15.5
1970-1971	3 753	119	2 883	91.4	870	27.6
1971-1972	2 807	89.0	2 195	69.6	612	19.4

Table 3.6 shows the amount of total annual losses. Based on these examplary data the discharge losses of the Shebelle in the Ethiopian swamps are estimated at 16 to 23%.

It is noted that the volume of losses does not only depend on the volume of inflow into the flood plains, but also to the filling stage of these plains at the end of the dry season. It is easy to understand that when the low-flow period is short, a smaller portion of the first following floods is stored - and partly lost - than when the low-flow period is longer.

To demonstrate the relation between the losses and the peak discharges alone the influence of the different long lasting dry periods has to be excluded. This is possible when only the flood waves in the second half-year are considered: the plains are filled by the first flood wave; between the first flood wave and the second, there is normally only one single month with lower discharge.

The volumes of discharge of the gauging stations HAMERO-HEDAD and BURKUR have been compared for this purpose. In 1969, the peak discharge at HAMERO-HEDAD was about 280 m^3/s, in 1970 around 500 m^3/s. The balance of both events is shown in Table 3.7 and Figure 3.6 and 3.7.

Tabel 3.7: Volume losses between HAMERO-HEDAD and BURKUR

		HAMERO-HEDAD		BURKUR
1969	Volume of			
(Jul-Nov)	flood wave [$10^6 m^3$]	1586		1327
	Difference [$10^6 m^3$]		259	
	Diff. in %	16		19.5
1970	Volume of			
(Jul-Nov)	flood wave [$10^6 m^3$]	2132		1743
	Diff. ($10^6 m^3$)		389	
	Diff. in %	18		22

The results of the comparison of the flood waves of 1969 and 1970 lead to the conclusion that with a growing peak discharge the loss percentage also increases.

Figures 3.6 and 3.7 show the retention effect of the large flood plains are illustrated in figures 3.6 and 3.7.

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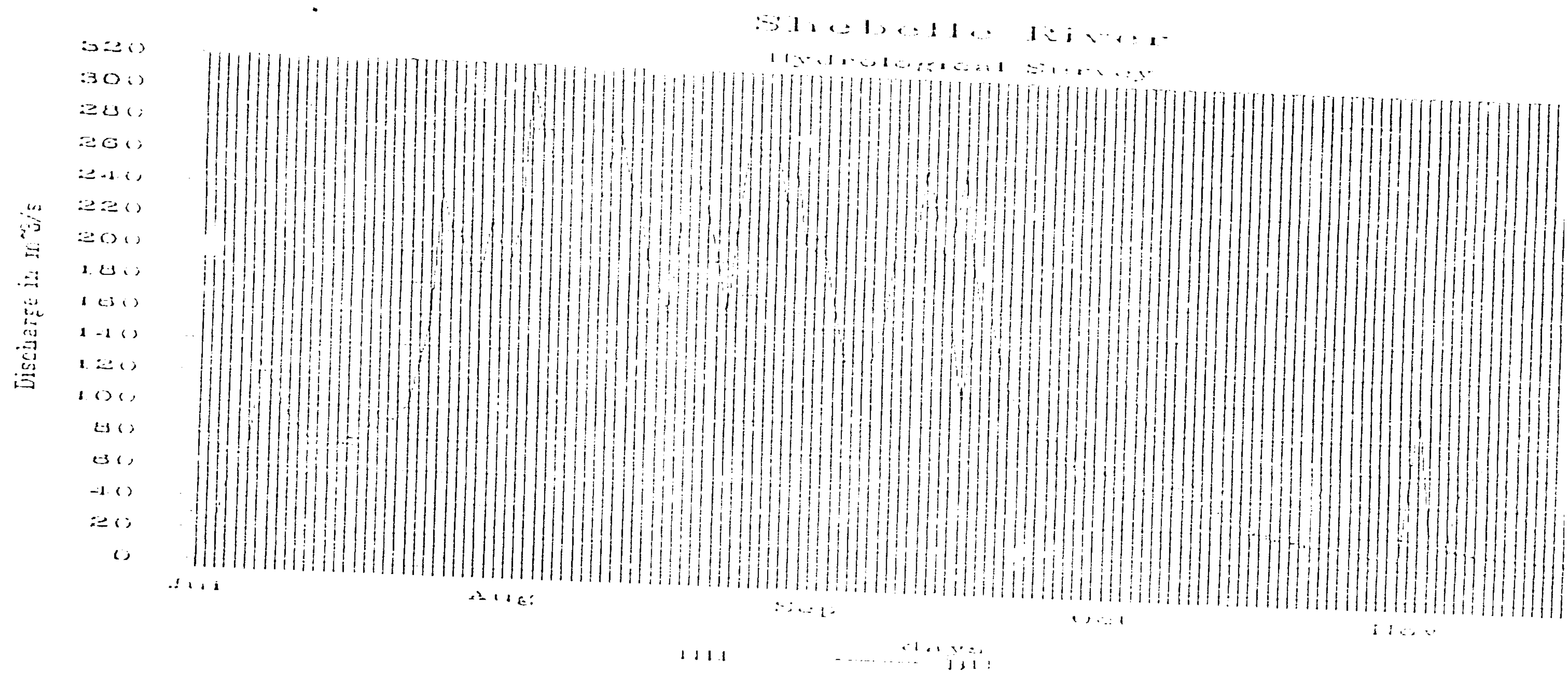

FIG.: 3.6

COMPARISON OF FLOODWAVES
HAMERO HEDAD AND BURKUR (1969)

LAHMEYER INTERNATIO

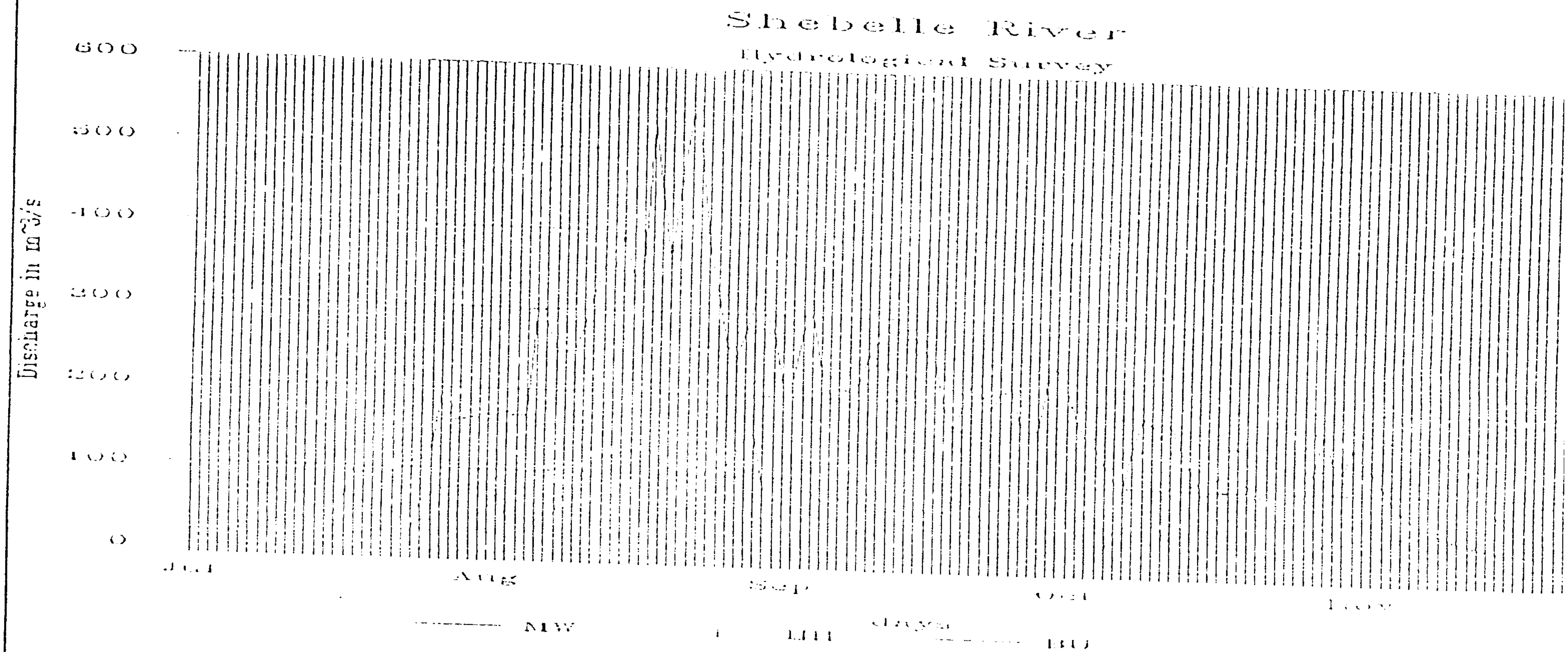

FIG. 3.7

COMPARISON OF FLOODWAVES
MALKA WAKANA, HAMERO-HEDAD AND BURKUR (1970)

LAHMEYER INTERNATI

3.7 ESTIMATION OF LOSSES UNDER LOW-FLOW CONDITIONS

Between MALKA WAKANA and HAMERO-HEDAD the low discharge increases owing to the inflows of permanent tributaries. Between HAMERO-HEDAD and BURKUR the discharge decreases except in the reach between HAMERO-HEDAD and IMI (see Figure 3.8 A). The increase of discharge in the latter reach is due to supply from ground water.

Between IMI an GODE, the low discharge decreases very distinctly. This is due to evaporation losses and particularly to infiltration in the channel bed.

The decrease of low water discharge between GODE and BURKUR is much less. This is due to slow restitution of water stored in the flood plains which partly compensates for evaporation losses and infiltration in the channel. Between BURKUR and BELET WEYN the low discharge shows the same characteristics as in the reach between GODE and BURKUR.

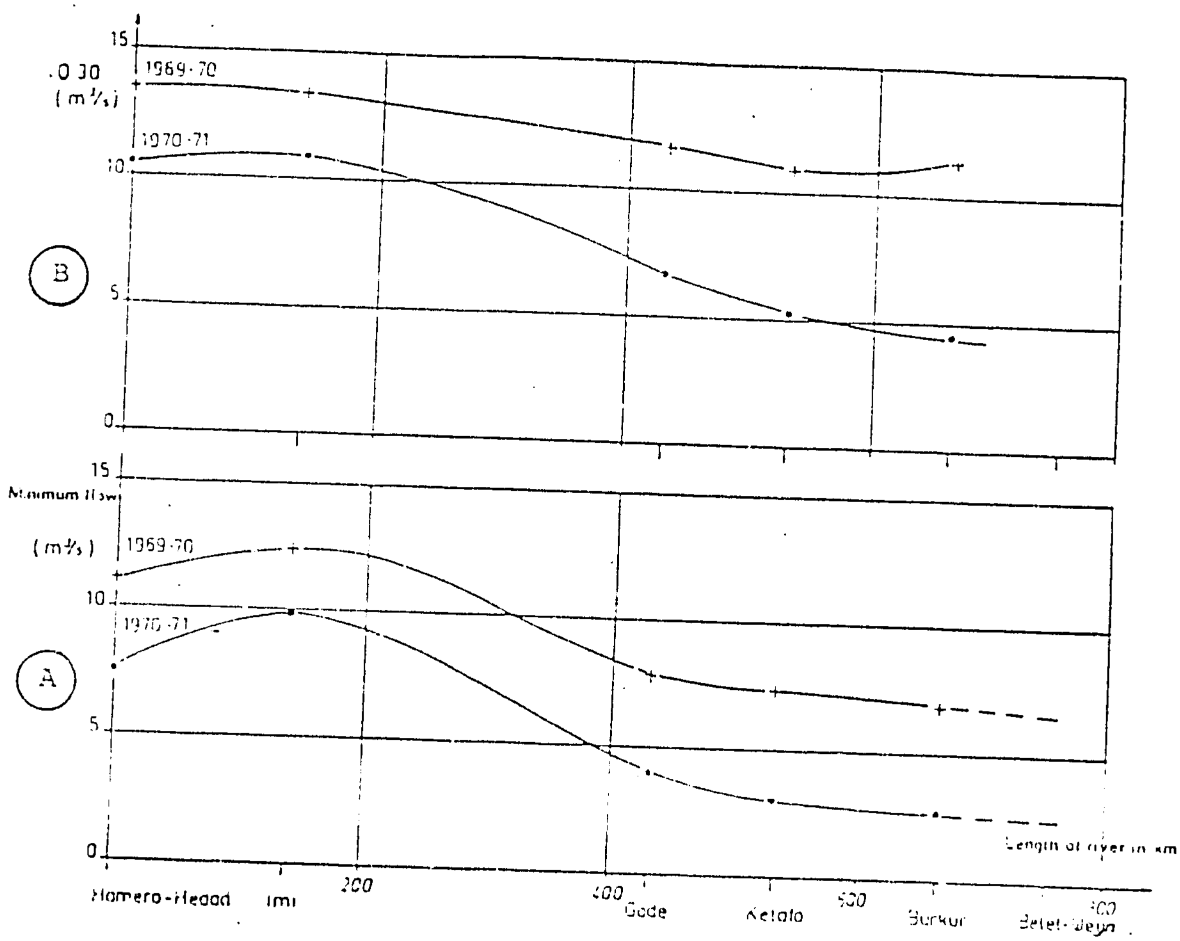

Figure 3.8: Evolution of minimum flow between HAMERO-HEDAD and BELET WEYN

Contrary to the values of the minimum flow, the values of lowest 30-day flows show fewer losses (Figure 3.8 B).

The percentage of losses at low flow conditions in relation to the total losses is rather low (about 8%).

4. ASSESSMENT OF THE INFLUENCE OF THE MALKA WAKANA PROJECT AND IRRIGATION AREAS ON THE DISCHARGE PATTERN OF THE SHEBELLE RIVER

With the information on the discharge pattern of the Shebelle discussed in chapter 3.5, the influence of changes in the upper course can be transferred to the lower course.

- Storage and hydro-power utilisation

The storage reservoir dam leads to additional evaporation losses estimated at 1.3 m^3/s. This reduction of discharge (less than 2% of the average discharge at Belet Weyn) has no noticeable influence on the lower course.

The regulated discharge from the reservoir results in an increase of low discharges whilst peak floods are reduced. The average discharge at MALKA WAKANA is 27% of the average discharge at IMI. The <u>maximum</u> monthly discharges in this place are even between 35 and 45% of the maximum discharges at HAMERO-HEDAD and GODE. The retention of the reservoir causes thus a significant reduction of the peak floods up to GODE. The influence on peak discharges in Somalia is however of minor importance because the floods are mitigated by the natural retention of the flood plains (see Figures 3.6 and 3.7)

- Impact of irrigation and swamps on discharge

To assess the available water supply of the Shebelle river in Somalia after implementation of irrigation works in Ethiopia, the effect of the flooding areas on decreased inflow has to be regarded.

In 3.6 it was stated that reduction of peak discharges results in lower quantities of losses in the swamps. It was shown exemplary that a reduction of the peak flow from 500 to 280 m^3/s (reduction of 44%) entails a reduction in losses from 389 to 259 m^3/s (33%).

A relation between discharges at the gauging stations GODE and BELET WEYN has been established on the basis of monthly values (Figure 4.1). For shorter periods of time a significant relation could not be found.

The relation on the basis of monthly values seems to be sufficient for this approximate assessment.

Q_G smaller than 113 m^3/s : $Q_{BW} = \frac{Q_G - 3}{1.1}$

Q_G greater than 113 m^3/s : $Q_{BW} = \frac{Q_G + 67}{1.8}$

The relevant data for the calculation are given in Table 4.1. The initial data are the monthly discharges (m^3/s) at the gauging station GODE (Column 4). Column 6 shows the discharge values at gauging station GODE considering the changes at MALKA WAKANA. The discharge at the gauging station BELET WEYN is determined without and with the changes at MALKA WAKANA by applying the values of columns 4 and 6 in the relations given above; the results are given in columns 7 and 8.

The differences of columns 4 and 7 as well as of 6 and 8 give the quantities of loss, expressed in m^3/s (columns 9 and 10 respectively). The difference between columns 9 and 10 shows the change in monthly losses which result from the new conditions at MALKA WAKANA. The results in Table 4.1 are computed with an average discharge from the reservoir of 26.2 m^3/s and monthly irrigation demands of which the annual average is 9.6 m^3/s (25 000 ha of irrigated land, see Table 3.2). In this case the average reduction of losses is 5 m^3/s.

Figure 4.2 presents the chronological course of the discharges at the gauging stations GODE and MALKA WAKANA and the results of the loss reduction (Column 11, Table 4.1)

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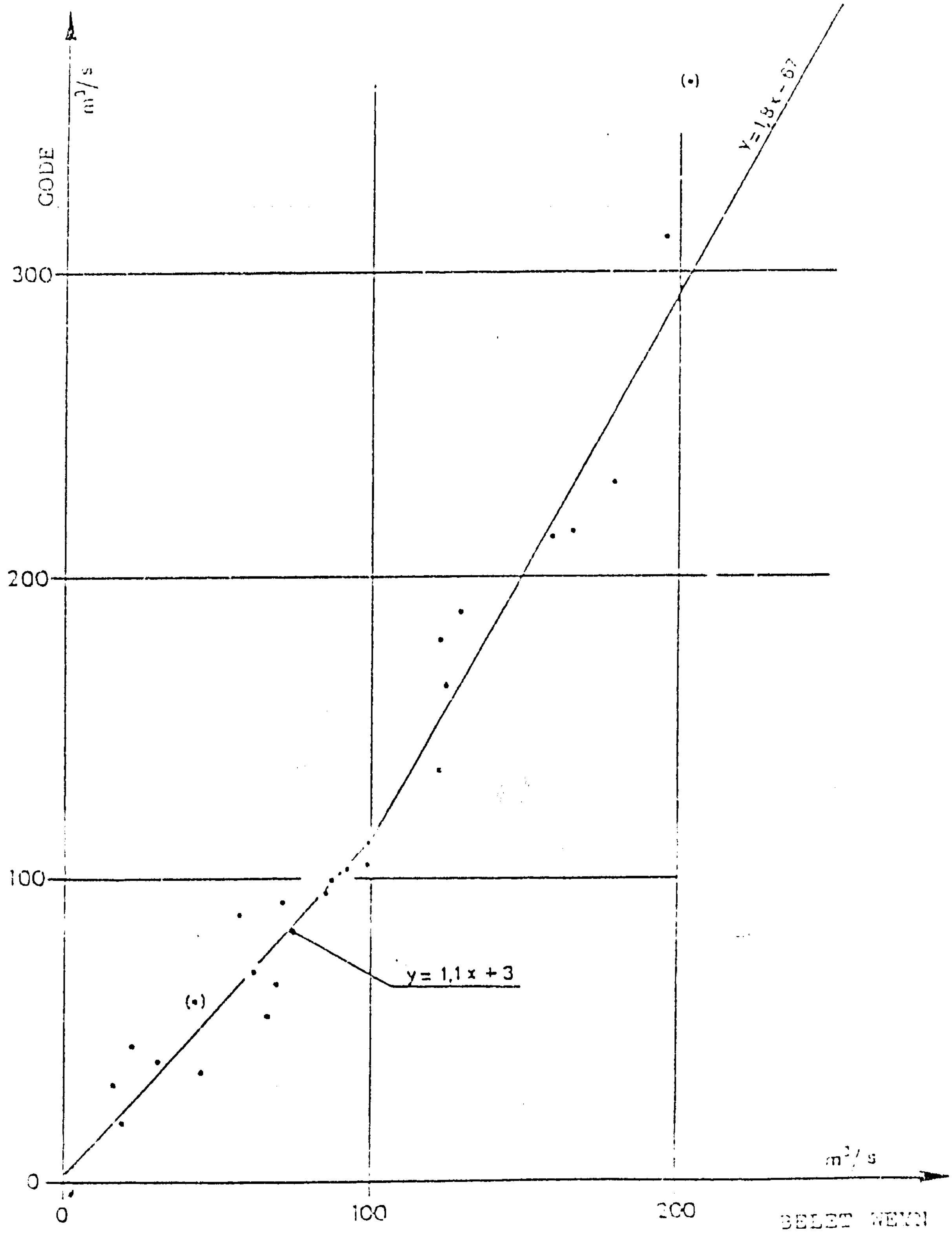
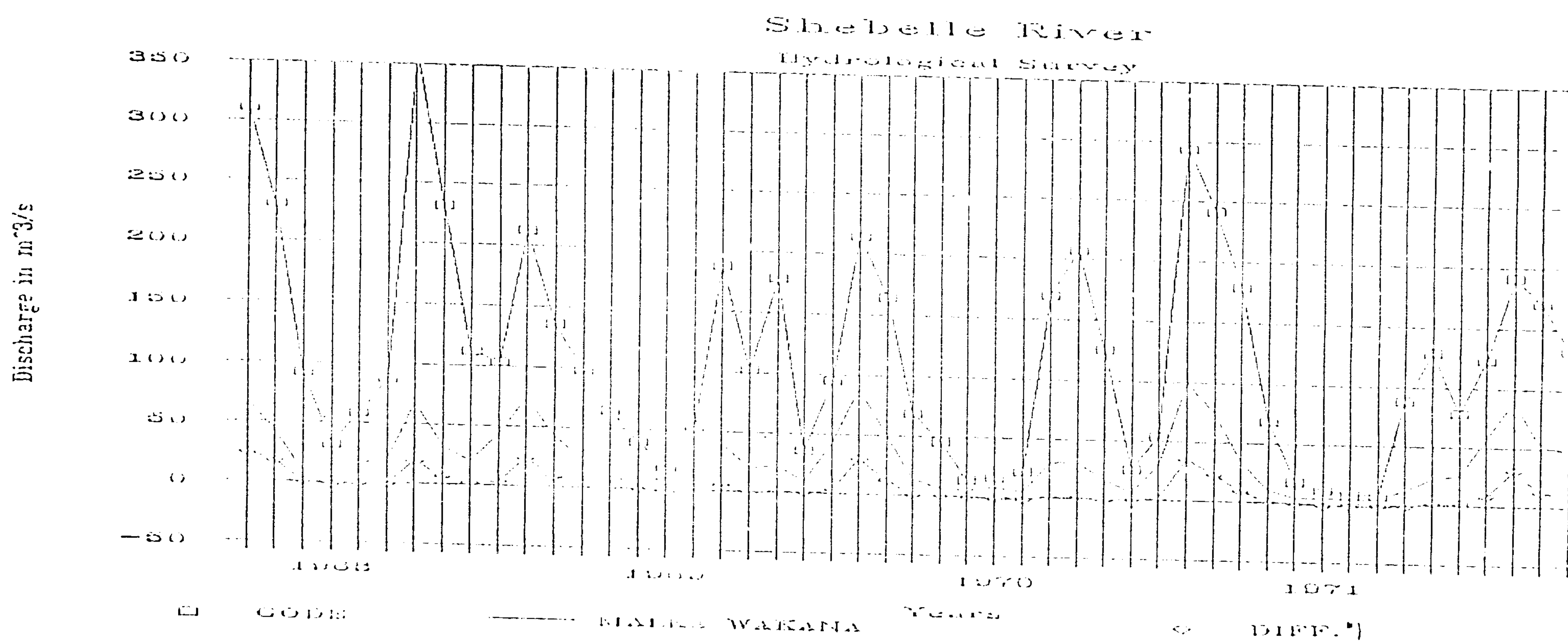


Source: Ref. 1

FIG.: 4.1	RELATION BETWEEN MEAN MONTHLY DISCHARGE AT BELETWEYN AND GODE	LAHMEYER INTERNATIONAL

Table 4.1: Relation between mean monthly discharge at BELET WEYN and GODE, reduction of losses (25.000 ha)

Year	Month	MALKA WAKANA	GODE	BELET WEYN	GODE-MALKA WAKANA	BWf(G)	BWf(G-MW)	G-BW(G)	(G-MW)-BW(G-MW)	Diff
		m^3/s								
		3	4	5	6	7	8	9 4-7	10 6-8	11 9-10
	Oct	68.40	311.00	244.90	256.00	210.00	179.44	101.00	76.56	24.44
	Nov	43.00	231.00	163.00	191.76	165.56	143.76	65.44	48.00	17.44
	Dez	8.77	92.10	160.00	91.69	81.00	80.63	11.10	11.06	0.04
1968	Jan	4.22	32.50	26.10	54.48	26.82	46.30	5.68	7.68	-2.00
	Feb	15.60	59.20	16.20	69.30	51.09	60.73	8.11	7.07	-0.96
	Mar	21.10	90.00	69.50	93.10	77.27	81.91	13.73	11.19	-0.46
	Apr	58.50	362.00	95.10	319.70	238.33	214.03	123.67	104.87	18.80
	Mai	32.30	252.00	245.70	217.70	166.11	158.18	65.09	59.55	6.04
	Jun	20.30	112.00	137.00	94.75	99.09	83.41	12.91	11.34	1.57
	Jul	43.90	104.00	76.70	64.93	91.82	56.30	12.18	8.63	3.55
	Aug	74.30	213.00	128.00	160.96	155.56	125.64	57.44	34.32	23.13
	Sep	43.00	136.00	145.20	116.52	112.78	102.31	23.22	14.61	8.61
	Oct	23.20	99.30	109.50	89.20	87.27	78.36	11.73	10.84	0.89
	Nov	9.64	65.50	50.60	59.62	56.82	51.47	8.68	8.15	0.53
	Dez	5.89	39.60	50.60	42.07	33.27	35.52	6.33	6.55	-0.22
1969	Jan	9.49	19.10	20.70	35.81	14.64	29.83	4.46	5.98	-1.52
	Feb	17.70	54.20	23.60	62.70	46.55	54.27	7.65	8.43	-0.77
	Mar	40.50	198.00	112.20	173.70	141.67	133.72	46.33	39.98	6.36
	Apr	19.20	103.00	97.60	110.00	90.91	97.27	12.09	12.73	-0.64
	Mai	22.30	179.00	134.40	175.23	136.67	134.57	42.33	40.66	1.68
	Jun	9.39	36.40	39.40	30.06	30.36	24.60	6.04	5.46	0.58
	Jul	43.20	95.10	52.00	56.73	83.73	48.85	11.37	7.88	3.49
	Aug	99.30	215.00	137.70	147.96	156.67	119.42	58.33	29.54	29.30
	Sep	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Oct	14.00	67.00	74.10	68.70	60.27	[illegible]	[illegible]	[illegible]	[illegible]
	Nov	6.62	45.60	38.20	42.74	38.73	36.13	6.87	6.61	0.26
	Dez	4.37	14.00	15.00	17.09	10.00	10.08	4.00	4.31	-0.31
1970	Jan	3.50	15.10	9.50	33.30	11.91	28.00	4.19	5.00	-1.61
	Feb	5.16	22.00	20.50	43.04	17.27	36.40	4.73	6.64	-1.91
	Mar	29.30	170.00	59.90	166.90	131.67	129.94	38.33	36.96	1.38
	Apr	31.80	207.00	96.70	202.20	152.22	149.56	54.78	52.64	2.13
	Mai	16.40	126.00	161.90	128.13	107.22	108.41	18.78	19.72	-0.95
	Jun	6.63	25.50	26.20	21.92	20.45	17.20	5.05	4.72	0.33
	Jul	28.70	54.60	24.40	30.73	46.91	25.21	7.69	5.52	2.17
	Aug	99.80	294.00	119.10	216.46	200.56	157.48	93.44	58.98	34.46
	Sep	74.20	242.00	223.40	191.42	171.67	143.67	70.33	47.85	22.48
	Oct	34.50	180.00	171.00	158.70	137.22	125.06	42.78	33.40	9.38
	Nov	10.30	68.20	80.50	61.36	59.91	53.51	8.39	8.05	0.64
	Dez	4.61	18.00	16.60	21.75	13.64	17.35	4.36	4.70	-0.34
1971	Jan	4.65	11.50	10.30	33.05	7.73	27.02	3.77	5.73	-1.96
	Feb	4.05	8.77	7.70	30.72	5.25	25.03	3.52	5.54	-2.01
	Mar	4.55	7.54	6.50	29.19	4.13	23.61	3.41	5.38	-1.97
	Apr	12.90	88.60	44.30	101.90	77.82	89.91	10.78	11.99	-1.21
	Mai	22.70	129.00	36.60	124.33	108.39	106.57	20.11	18.26	1.85
	Jun	25.70	78.30	49.40	36.05	69.00	48.23	9.30	7.32	2.08
	Jul	57.30	124.00	75.40	71.33	106.11	62.12	17.89	9.21	8.68
	Aug	90.20	192.00	100.40	124.06	143.89	106.14	48.11	17.92	30.20
	Sep	52.30	171.00	136.00	142.32	132.22	116.29	38.78	26.03	12.75
	Oct	47.30	132.00	93.10	98.10	110.56	96.45	21.44	11.65	9.80
	Nov	12.40	88.40	65.90	79.76	77.64	69.79	10.76	9.98	0.79
	Dez	7.27	23.60	29.40	29.69	23.27	24.26	5.33	5.43	-0.10
1972	Jan	5.48	14.10	12.10	34.82	10.09	28.93	4.01	5.89	-1.88
Avarage:		28.97	112.63	85.75	100.29	87.29	80.24	25.39	20.05	5.34



*) DIFF = SURPLUS IN CONSEQUENCE OF THE REGULATION OF DISCHARGE AT MALKA WAKANA

FIG: 4.2	COHERENCE OF DISCHARGE AND REDUCTION OF LOSSES (COMPARE WITH TAB. 4.1)	LAHMEYER INTERNATI

It should be underlined that the calculations shown above are approximations based on data of a few years only. This becomes apparent when comparing the calculated discharges at the gauging station BELET WEYN (column 7) with the measured ones (column 5): some single values show larger discrepancies. However, the average values are very close to each other. The discrepancies are levelled off because the decisive comparison is between columns 7 and 8, of which the values have been established with the same magnitude of accuracy.

The above computations have been made for four situations: no irrigation in Ethiopia; 5 000 ha irrigated; 15 000 ha irrigated and 25 000 ha irrigated. The results are summarized in Table 4.2 and graphically presented in Figure 4.3.

Table 4.2: Balance of discharge at the gauging station BELET WEYN

Irrigation area (ha)	Storage losses at Malka Wakana and irrigation demand (m^3/s) (1)	Reduction of losses in swamps (m^3/s) (2)	Mean discharge at BELET WEYN (Table 4.1, column 7) (m^3/s) (3)	Reduced losses (1-2) in relation to the uninflu- mean discharge at BELET WEYN (3) (4)
0 (without storage)	0	0	87.3	0
0 (with storage)	1.3	3.7	89.7	+3 (surplus)
5000	3.2	4.1	88.2	+1 (surplus)
15000	7.2	5.2	85.3	-2
25000	10.9	5.3	81.7	-6

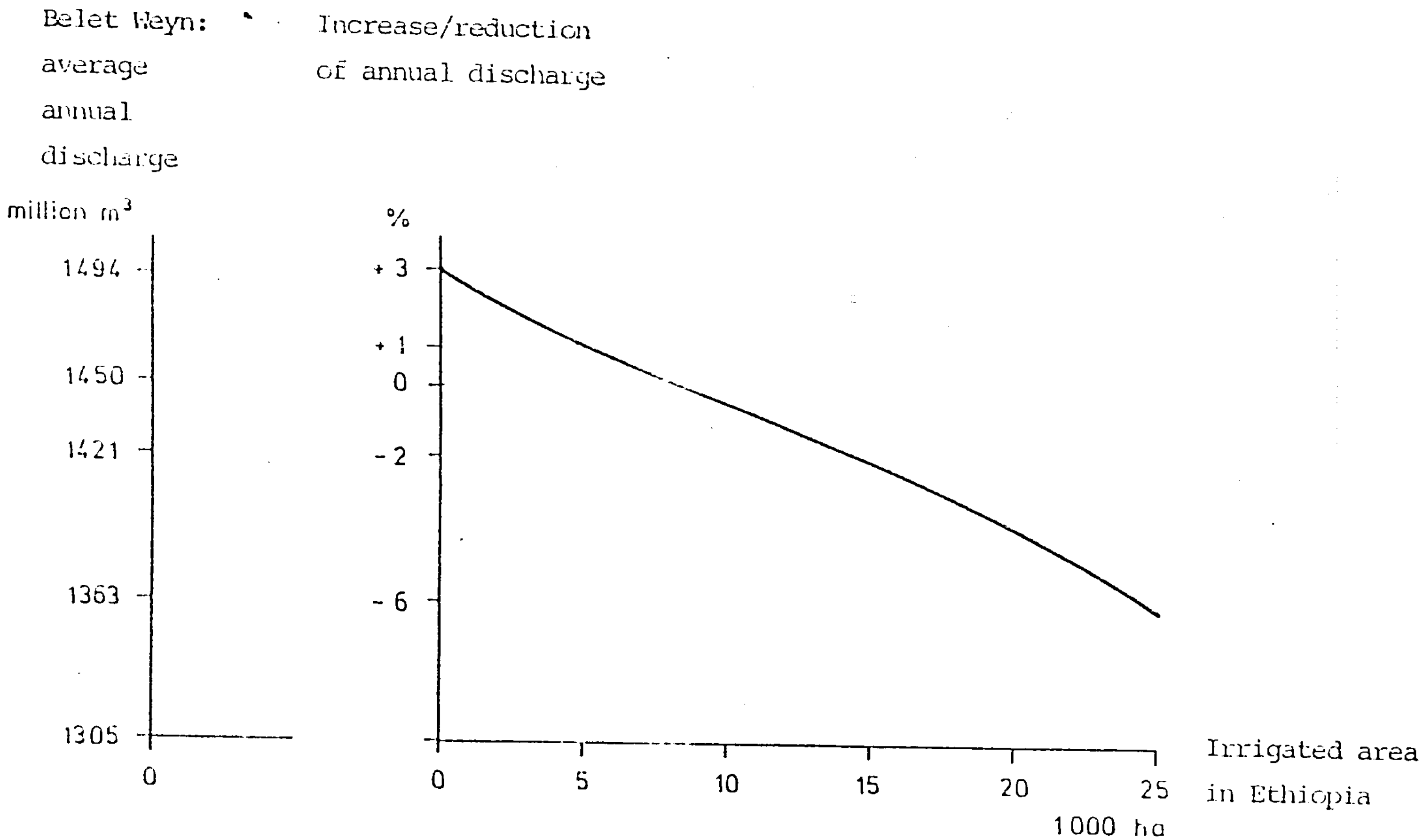


FIG.: 4.3

IMPACT OF MALKA WAKANA STORAGE RESERVOIR AND OF IRRIGATION ON AVERAGE DISCHARGE TO SOMALIA

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The figures shown in the last column are annual averages. Based hereupon it may be concluded that even when 15 000 ha are irrigated in Ethiopia, the influence on discharge to Somalia is hardly noticeable.

The above calculations were made assuming irrigation of maize (Gu-season) and 1/3 maize/2/3 sesame (Der-season). To demonstrate the effect when perennial crops are grown, comparable calculations have been made assuming a varying area of year-round grown vegetables and of bananas (irrigation requirements as given in Table 1). Simulations have been made for the standard case 25 000 ha/1% reduction of discharge. The results are given in Figure 4.4. It appears that the reduction in area grown to annual crops is somewhat more than proportional which is probably due to an increase of evaporation losses in storage reservoirs.

As it was indicated before, streamflow regulation at Malka Wakana has a positive effect on the streamflow to Somalia (3% more annual discharge). The other important streamflow influencing factor are the swamps. Apparently, up to a certain extent, it makes little difference whether water is used in irrigated land or in the swamps.

The above mentioned statement about the influence of irrigation in Ethiopia on discharge to Somalia is rather generalized as the figures on losses in Table 4.2 are averages of annual values. As the overwhelming part of the water to Somalia is also used for irrigation, the flow reduction during the irrigation season has to be investigated as well. This has been done for two periods: from february to august and from september to january. There is no need to investigate shorter periods because of the regulating effect of the existing Jowhar Offstream Storage Reservoir.

The results of this analysis, using figures of Table 4.3,are given in Table 4.3. They are also graphically presented in figure 4.5.

Table 4.3: Seasonal flow reduction at Belet Weyn with Malka Wakana in operation and 25 000 ha irrigated land in Ethiopia

Season	Total streamflow at Belet Weyn (un-reduced) in million m^3	reduction in % of unreduced flow
1968 feb - aug	2312	11
1968 sep - jan	802	3
1969 feb - aug	1816	11
1969 sep - jan	655	- 1
1970 feb - aug	1792	8
1970 sep - jan	1025	6
1971 feb - aug	1365	11
1971 sep - jan	929	8

Although the data are not enough to establish a relationship of sufficient significance between streamflow and losses, they demonstrate that the higher the streamflow, the more the losses in the swamps are, as a result of the decreasing influence of Malka Wakana. Taking into account that the potentially irrigable area is based on the streamflow exceeded in 80% of the years (the storage reservoir in Somalia is for seasonal regulation), it can be assumed that the above conclusion is on the safe side: irrigation in Ethiopia may be extended to between 15 000 ha and 25 000 ha before a noticeable effect (say 5% reduction) on streamflow to Somalia is reached.

In this respect it is interesting to note that in 3 out of the 4 years,,mentioned in Table 4.1, the annual streamflow at Belet Weyn was more than average:

average: $71 m^3/s$
1968: $134 m^3/s$
1969: $74 m^3/s$
1970: $85 m^3/s$
1971: $60 m^3/s$

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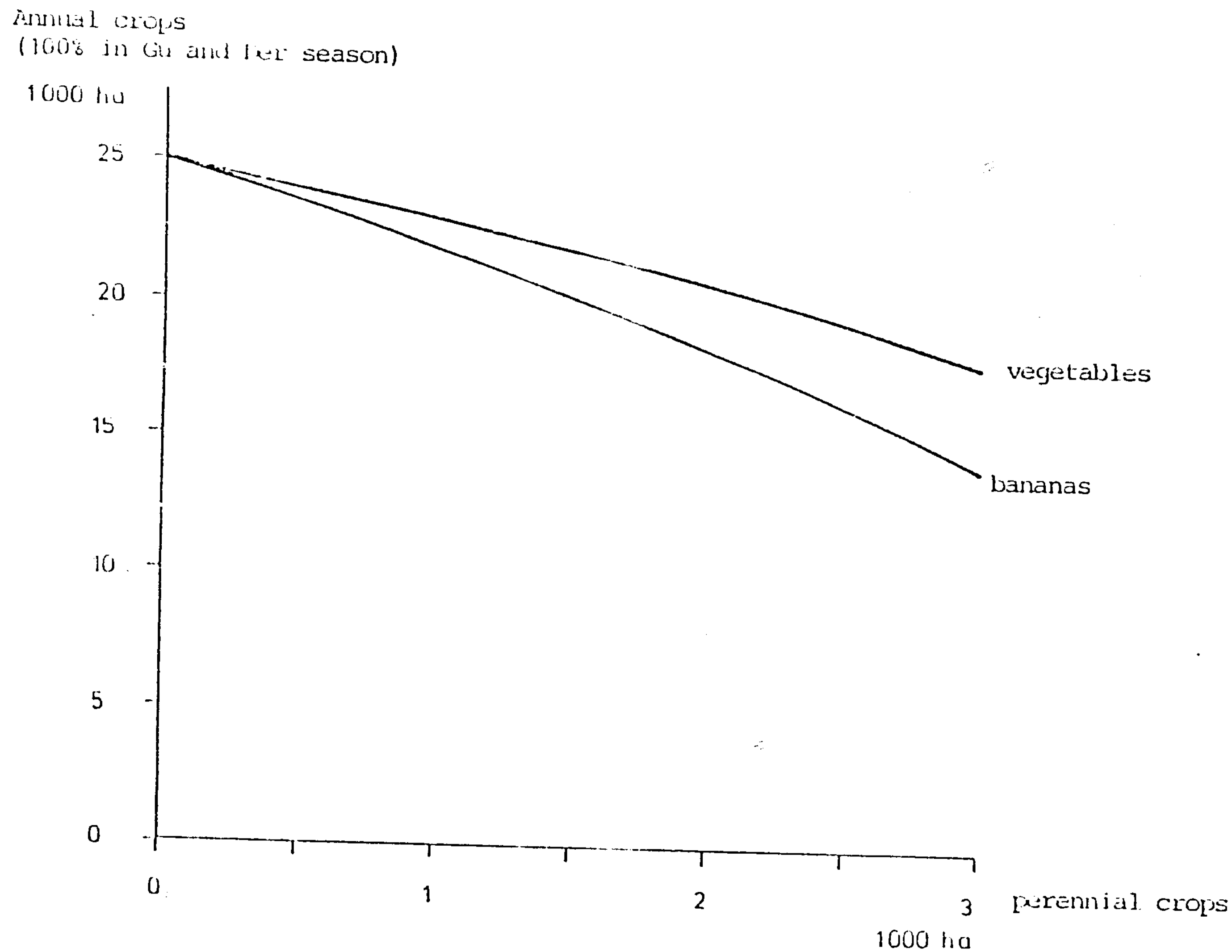

FIG: 4.4

RELATION BETWEEN INCREASING AREA OF YEAR-ROUND VEGETABLES, RESP. BANANAS AND DECREASING AREA OF ANNUAL CROPS; 6% REDUCTION IN FLOW AT BELET WEYN

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Apart from the above conclusion it should be observed that the streamflow to Somalia may be left untouched, or even improved when irrigation development in Ethiopia would be accompanied by further streamflow regulation measures upstream of the swamps, to reduce the losses in this area.

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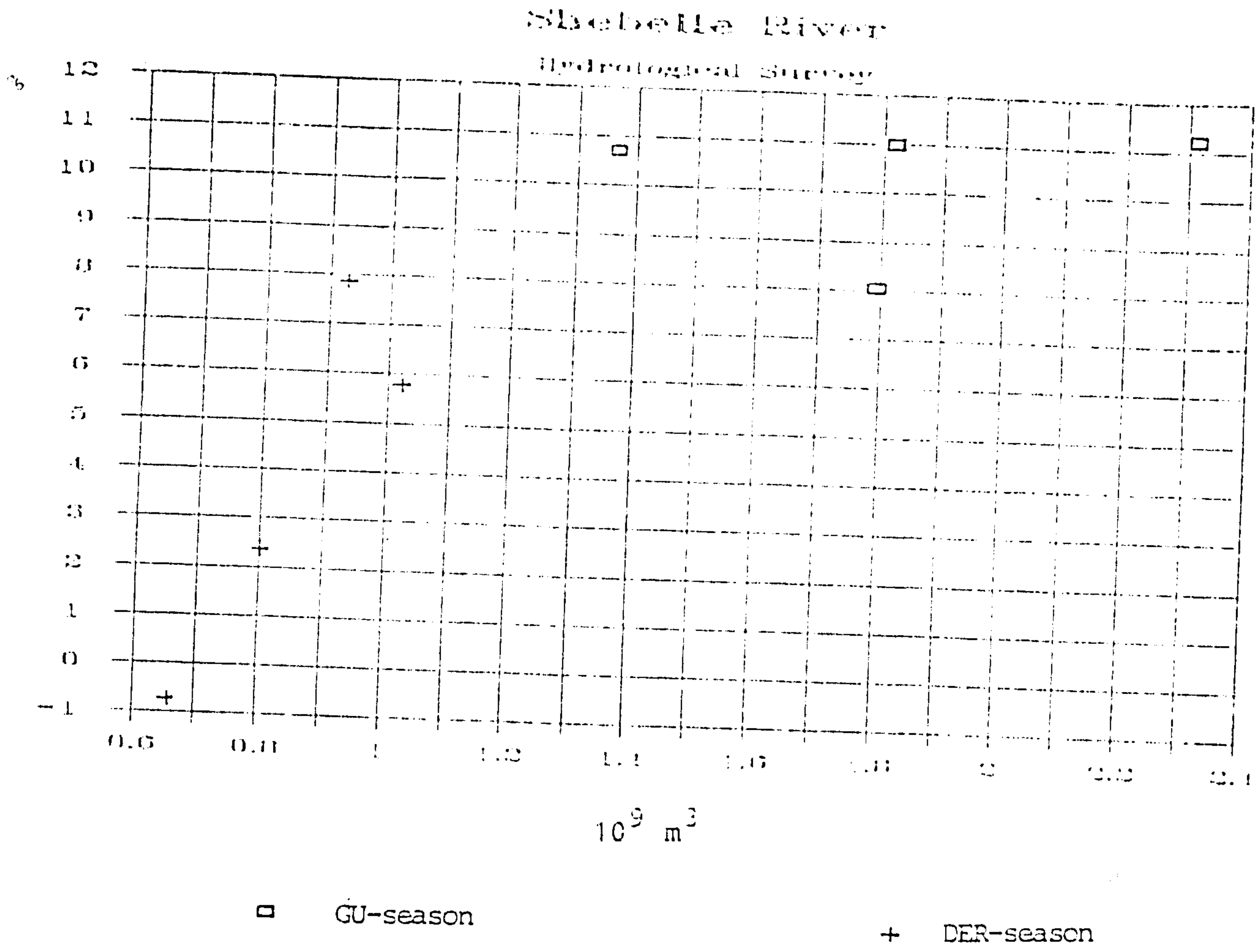

Figure 4.5: Seasonal flow reduction as percentage of total uninfluenced stream flow at Belet Weyn with Malka Wakana in operation and 25 000 ha irrigated in Ethiopia

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