AGRICULTURAL AND WATER SURVEYS

SOMALIA

FINAL REPORT

Volume V

ENGINEERING ASPECTS OF DEVELOPMENT

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

The Final Report on Somalia consists of the following volumes:

Volume I - General

An account of the objectives, work and findings of the entire project is given in this volume. The recommendations arising from the findings of the survey are summarized, and the volume concludes with an estimate of the total returns for all the development projects proposed. A summary of the report on the FAO Livestock Development Survey of 1966 in Somalia is included in the volume as an appendix.

The following technical reports were prepared by the Lockwood Survey Corporation, which carried out the corresponding surveys under the supervision of the Food and Agriculture Organization of the United Nations:

Volume II - Water Resources

The volume deals with climate, surface water and groundwater, and investigates the potential groundwater supplies for irrigation, and for the use of livestock, herdsmen and small communities. The text of the volume is abundantly supported with figures, tables and maps and with statistical appendixes.

Volume III - Landforms and Soils

Nineteen landforms are identified, some with subdivisions, in the first part of the volume, and the soils associated with each landform are described and classified. Landforms and soils are then discussed on the basis of the natural regions. The text concludes with a summary and with recommendations. Soil profile descriptions and the methods and results of chemical and physical soil analysis are given in appendixes.

Volume IV - Livestock and Crop Production

The volume describes the surveys carried out on agricultural production and on rangeland in the project area. Details are given of regional farm practices, of present land use from region to region, and of recommendations for crop improvement. There are conclusions and recommendations on the potential of rangeland and on problems in its development. The final chapter deals with the livestock count made during the project. Species and ground cover characteristics of the ecological formations are given in an appendix.

Volume V - Engineering Aspects of Development

The volume discusses in detail the possibilities of irrigation development on the Shebelle river. It also examines briefly the possibilities on the Juba river. Surface water supplies for human and animal consumption and the possibilities of development for small streams are investigated. An account of the topographical survey and mapping work carried out and extracts from the results of reconnaissance soil survey in the Bulo Mererta area are included in the volume.

Volume VI - Social and Economic Aspects of Development

The volume deals with land tenure conditions and agricultural economics in Somalia. A sample of economic returns to agriculture in the project area in 1963 is given, and the typical returns of banana plantations are included in the typical farming returns given for the various regions and sub-regions. The volume concludes with a detailed estimate of the total returns for all the development projects suggested. A revised recommendation for a rural development project for the improvement of traditional agriculture is given in an appendix.

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AGRICULTURAL AND WATER SURVEYS

SOMALIA

Final Report

Volume V

Engineering Aspects of Development

Report prepared for the
Food and Agriculture Organization of the United Nations

by

Lockwood Survey Corporation Limited

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Rome, 1968

CONTENTS

CHAPTER 1: TOPOGRAPHICAL SURVEY AND MAPPING

TEXT

MAPS

CONTENTS

CHAPTER 2: ENGINEERING CONSIDERATIONS OF SURFACE WATER DEVELOPMENT

TEXT

CONTENTS

CHAPTER 2: TEXT CONTINUED

CONTENTS

CHAPTER 2: TEXT CONTINUED

MAPS

FIGURES

CONTENTS

TABLES

CONTENTS

CHAPTER 2: TABLES CONTINUED

APPENDIX 1

TABLES

APPENDIX 2

TABLES

APPENDIX 3

CHAPTER 1

TOPOGRAPHICAL SURVEY AND MAPPING

INTRODUCTION

Purpose

1. The Plan of Operation allowed for the services of a Survey Engineer for twenty four months and a sum of $30,000 for photogrammetic mapping. The surveys conducted by this engineer and all maps produced would be for direct study purposes by other members of the Project. The survey programme would be governed by the necessity to concentrate on work which would be of the maximum benefit and could be produced in a rather limited time.

2. It was hoped that use could be made of existing survey information and the services of three U.N.T.A.B. advisors in topographical survey, photogrammetry and cartography, who were assisting the Somali government in the formation of a National Cartographic office.

Existing Survey Data

3. Although surveys had been executed in the past within the project area, there was no record of any usable survey information. The Italian government had established unconnected triangulation nets in the following areas:

(a) The lower Juba area
(b) A small area around Brava
(c) An area encompassing the entire Genale agricultural region
(d) The city of Mogadiscio

Some astronomical determinations had also been made throughout the project area in or near the larger villages.

4. In the early stages of the project repeated requests were made to the Italian government for records of this work. Unfortunately all records had been lost or destroyed during the war and there was no trace of any survey information in Mogadiscio. However, from an old map in Mogadiscio the elevation was shown of a bench mark situated beside an old tide gauge. The tide gauge had been destroyed but the bench mark was still existing. The old map elevation of this point was used as a datum for all elevation control established on the project. From a survey point of view it can be said that the project area was completely virgin country and all new schemes had to commence from first principles.

United Nations Technical Assistance Board

5. The three U.N.T.A.B. advisors whose job it was to set up a Survey and Mapping Office had a great deal of formative problems and at the start of the project were not able to give assistance to the Agricultural and Water Survey. This situation changed and a year after the initial surveys had commenced the UNTAB surveyor was in a position not only to give assistance but was able eventually to take over

all the necessary survey requirements for the project.

Survey Plan

6 The first survey engineer on the project commenced work in January 1963. survey plan was designed for the project bearing in mind the lack of survey information within the project area, the lack of trained local personnel, and the fact that UNTAB advisor would not be able to give any immediate assistance.

7. One of the principle project requirements was the setting up of gauging stations at various points on the two main rivers. The necessity of placing all these stations on the same elevation datum was obvious and an ambitious plan was formulated to establish a network of third order levelling over the entire project area encompassing all river stations.

8. This plan was completely dependent on the possibility of training a fairly large Somali staff to carry out the third order levelling and, once trained, on the ability of such a staff to produce at a reasonable rate.

9. It was also realised that, as the project developed, there would be need for some types of local surveys to give more detailed information in specific areas.

Progress and Training

10. A staff of ten Somalis was recruited in January 1963 which included three who had completed a secondary school course and two who had reached an intermediate standard.

11. With this staff the survey engineer commenced the levelling of the loop Mogadiscio - Afgoi - Balad - Mogadiscio. This loop of 120 kilometers was "double run" and the survey procedures adopted were those internationally accepted for this standard of levelling. The entire instrument work was done by the survey engineer with all other tasks being accomplished by Somalis. Near the end of this loop Somali instrument men were gradually trained and under close supervision were allowed to take charge of the levelling operation.

12. Under the direction of their own party leader the Somali Trainees by May 1963 were able to execute third order levelling on their own. At this stage however the survey engineer had always to be on the spot and closely supervise computations, compilation of results and photo identifications. Within one year a Somali survey party were capable in one day to complete a nine kilometer section of levels using two crews, compute the results and produce rudimentary bench mark descriptions. Towards the end of 1964 there existed a nucleous of survey staff well trained in third order levelling.

13. It was decided to form two level parties in order to speed up the completion of the basic network and to carry out some level surveys in areas of importance along both rivers. More trainees were recruited and by January 1964 there were in existence two fully trained level parties under the direction of two expatriate surveyors. The older of these two parties concentrated on local surveys along the Juba River while the new party completed the third order network. By the middle of March 1964 the third order committment was completed and survey effort was orientated towards specific areas.

14. In April 1964 the Survey and Mapping Department of the Somali Government was formed and the trained Somali staff was handed over to the UNTAB survey advisor who undertook further training and an obligation to execute certain surveys for the project.

15. The Agricultural and Water Survey was the inceptional force behind the formation of a National Survey and Mapping Department. The Project Manager in collaboration with the UNTAB advisors conceived the practical solution of handing over trained personnel to this new Department and to support it with such facilities as transport, premises and a Somali office administration.

SURVEYS ESTABLISHED

16. The following surveys were established directly by the Project and by the National Survey and Mapping Department at the request of the Project.

Third Order Network

17. The extent of this network is shown on Topographic Surveys Map 1. A total of approximately 2,000 kilometers were run and the network was designed so that all hydrological stations could be elevated on the same datum and a sufficient density of bench marks disposed within the area to facilitate ground water studies.

18. Over four hundred bench marks were established placed not more than five kilometers apart. They took the form of precast reinforced concrete monuments buried to a depth of a meter into the ground. An elaborate description has been made for every bench mark and these are now in the files of the Survey and Mapping Department.

19. With a thought to future mapping all these bench marks were accurately identified on existing aerial photography and this identification photography is also lodged in the files of the National Survey and Mapping Department.

20. The datum for this level network is best described as "Mogadiscio mean sea level". Elevations were computed from the old Italian bench mark already described and these elevations were "carried" to a preliminary mean sea level datum at Kismayu. This Kismayu datum was calculated from the results of a United States Corps of Engineer's tide gauge that had been in operation for only thirteen months. The closure obtained was well within that to be expected from the inherent errors of third order levelling and it can be assumed that the "Mogadiscio mean sea level" adopted is probably quite accurate and likely based on many years of tide gauge observation.

21. The files of the Survey and Mapping Department contain the following records.

(a) All original field books
(b) Level computation and adjustment forms
(c) Line diagrams for individual loops and lines
(d) Bench mark descriptions
(e) Aerial photography identifications.

Juba River Areas

22. Two areas along the Juba River were surveyed utilizing the same methods for each area. These areas are the Gelib - Fanole block of 300 square kilometers and the Camsuma - Giamama block of 360 square kilometers.

23. Elevation information was required in these areas of potential irrigation development. Both areas were covered by heavy bush and the only practical method of achieving quick information was by the levelling at regular intervals along bulldozed

lines placed every two kilometers apart. Approximately 400 kilometers were bulldozed and elevations established every 100 meters.

24. Compass azimuths were recorded along the cut lines and by plotting them on uncontrolled 1:30,000 mosaics it was possible to construct crude maps of both areas. The spot elevation density allowed for a reasonable interpolation of the five meter contour.

25. The originals of these maps are lodged in the map files of the National Survey and Mapping Department. Reductions are included at the end of this chapter. (Maps 2 and 3).

Shebelle Reservoir and Dam Site

26. This survey involved the heighting of a large number of vertical control points within a possible reservoir area abreast of the Shebelle and stretching for about forty five kilometers upstream from a point thirty kilometers upstream from Bulo Burti. All points were identified on existing 1:10,000 aerial photography.

27. The control was disposed to facilitate a general cross section study and to produce a reasonable accurate position of the vital contours on the extremities of the proposed area.

28. All information was transferred to the 1:30,000 uncontrolled mosaics and a crude map compiled. The original of this map is lodged in the map files of the National Survey and Mapping Department while a reduction is included with this volume.

29. In the area of the proposed dam horizontal and dense vertical photo control was established to enable the compilation of a 1:6,000 map from the existing 1:10,000 photography. This was done on a Kelsh plotter by the Photogrammetric Section of the National Survey and Mapping Department under the direction of a UNTAB photogrammetist. A reduction of this map is included in Chapter 2 of this volume. (Map 7).

Genale Area Control Survey

30. The intention of this survey was to fully control horizontally and vertically the 1:30,000 photography covering the present area of controlled irrigation centred on Genale as well as a large peripheral area. The reason for the survey was twofold:

(a) Some general information of elevation in this area of established irrigation was required.

(b) Mapping will be required if any rehabilitation is planned in the future for this area. It was therefore decided to control the photographic coverage of a large area encompassing all possibilities of future development.

31. During this survey 350 kilometers of levelling were run and over fifty permanent bench marks set up. Full vertical control was established on 75 per cent of the photography covering the 750 square kilometer area. Horizontal control in the form of a 1:5,000 traverse was 50 per cent complete.

32. If required, mapping at a scale as large at 1:3,000 with a four meter contour can be achieved from the existing photography. On the strength of this survey

a map has been constructed which shows the disposition of all control and in places a one meter contour is shown. This original mapping, traced from the mosaics, is lodged in the map files of the National Survey and Mapping Department and a reduction is included with this chapter. (Map 4).

Heighting Wells within the Project Area for the Ground Water Geologist

33. At different times during the Project wells were heighted by the Topographic Service. This involved levelling from the main network to wells designated by the ground water geologist, and in all accounted for over three hundred kilometers of fourth order levelling.

MAPPING AND DRAUGHTING

34. During the Agricultural and Water Survey, draughtsmen were trained and draughting supervised by the UN.T.A.B. Cartographer.

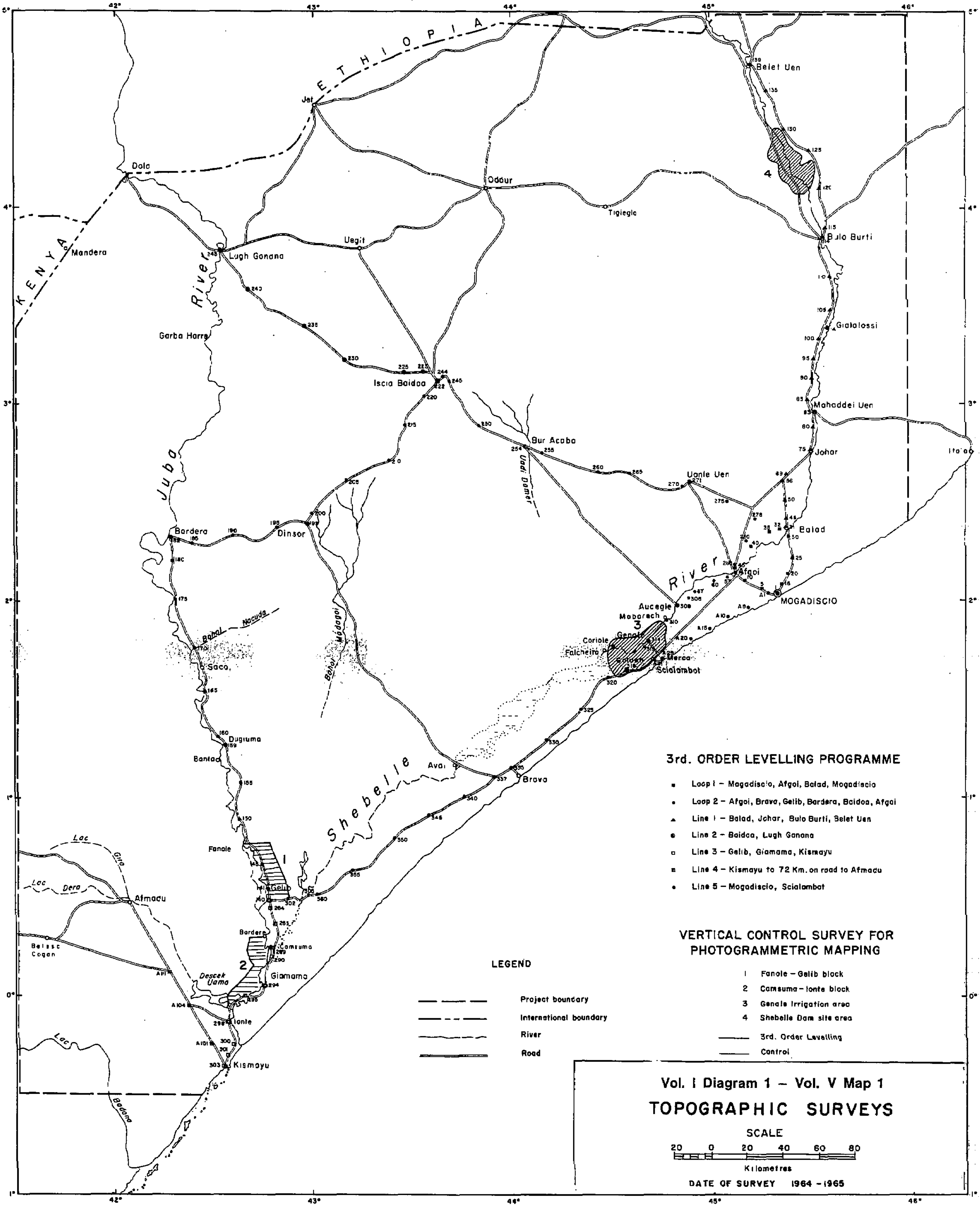
35. Two series of maps at 1:100,000 scale were produced, one showing Landforms and Soils, and the other Present Land Use and Range Ecology. There are 81 map sheets in each series. A sheet index of this mapping will be found at the end of this chapter. (Map 5).

36. All original survey records and the Landform and Soils and Present Land Use and Range Ecology maps are kept in the offices of the Surveys and Mapping Department, Ministry of Public Works, Mogadiscio.

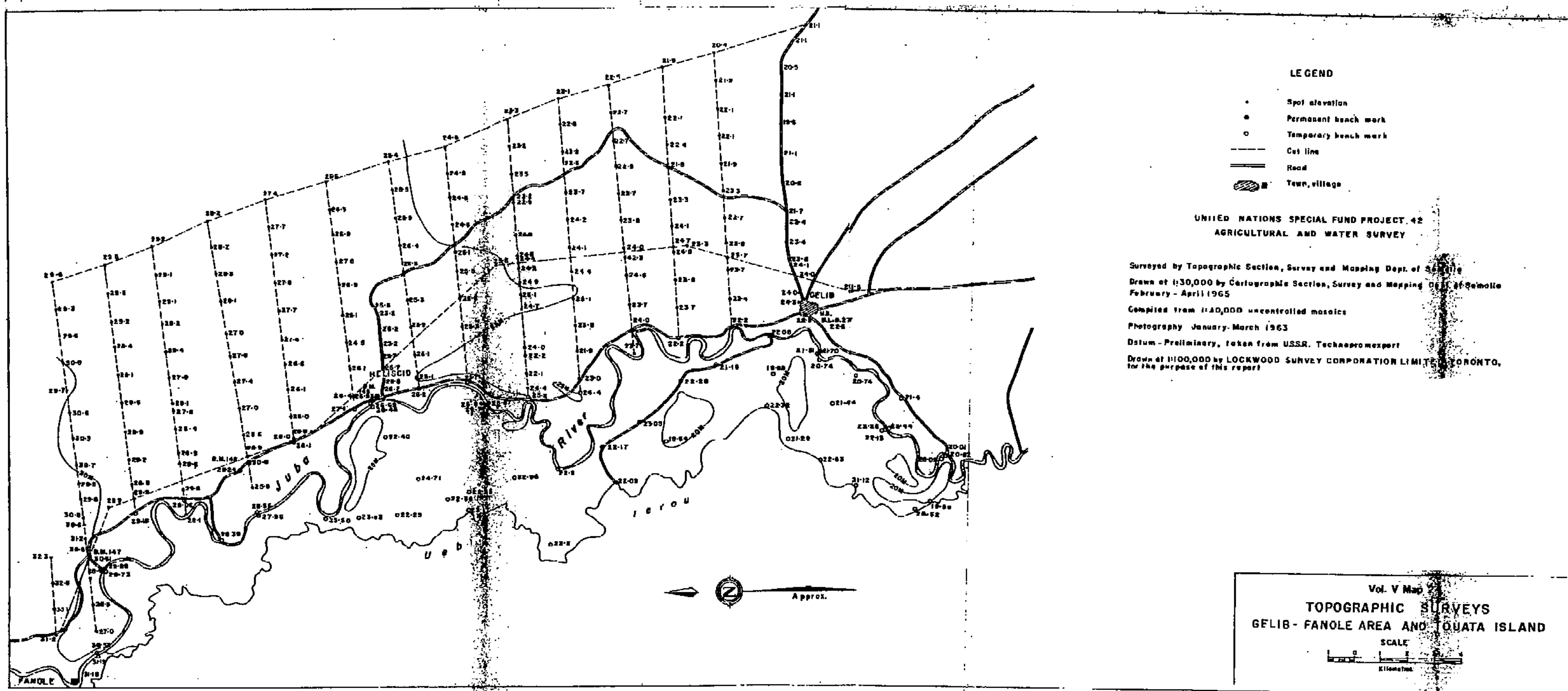
CONCLUSIONS

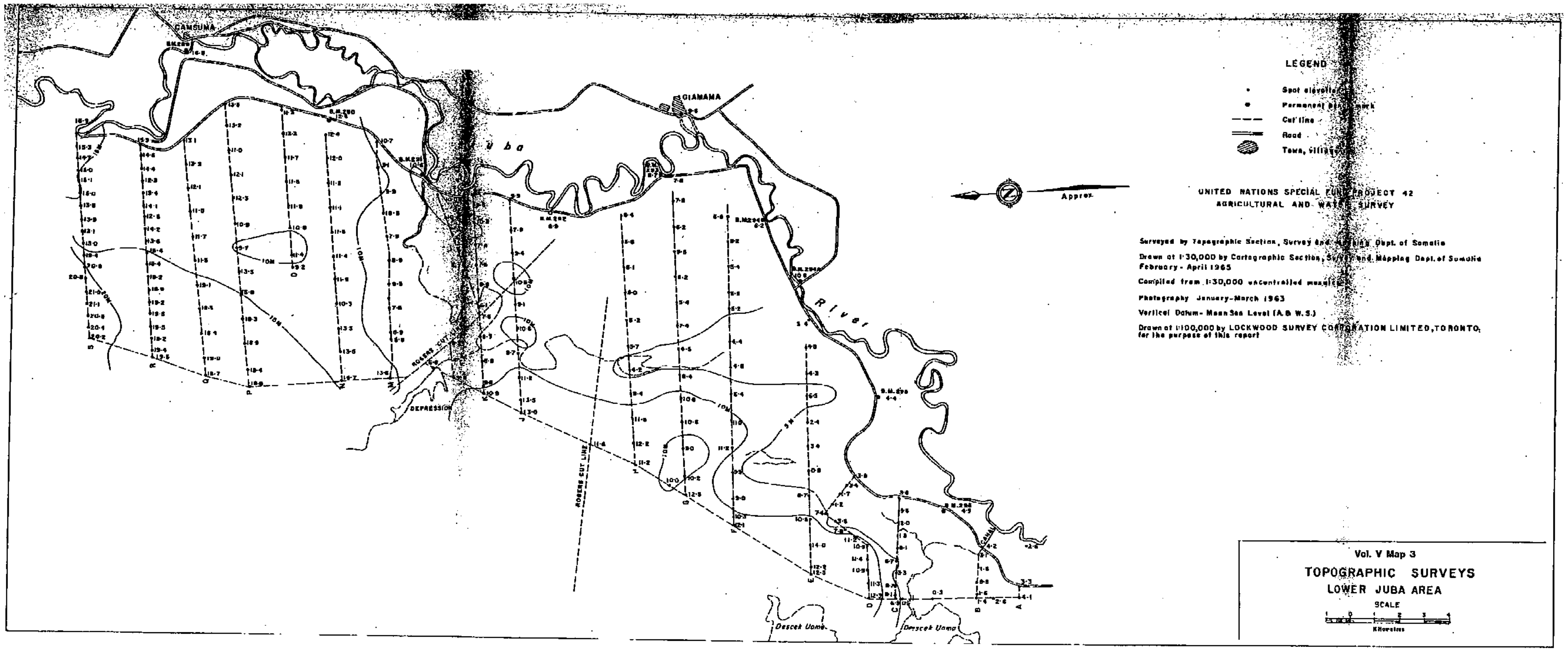
37. From the size and diversity of the survey jobs undertaken and the amount of survey control established in a relatively short time it would appear that, from very small beginnings, there now exists in Somalia a small but functional survey unit. By adhering to the principle of training personnel while actually engaged on important survey projects it has been possible to accomplish all the survey information required by the project and simultaneously build up a sound survey section. From the trainees point of view it is psychologically much more rewarding to learn while engaged on field work of obvious importance.

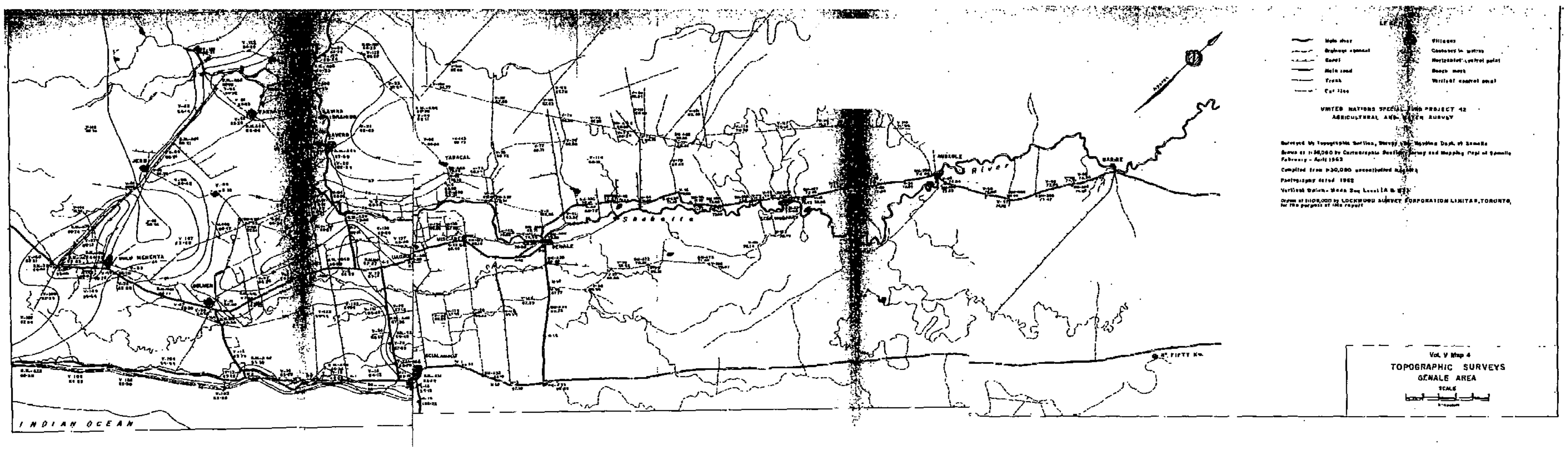
38. At the end of the project there was existing in Somalia a nucleus of staff who can accept responsibility, and are prepared to undertake exacting and often monotonous work under difficult physical conditions.

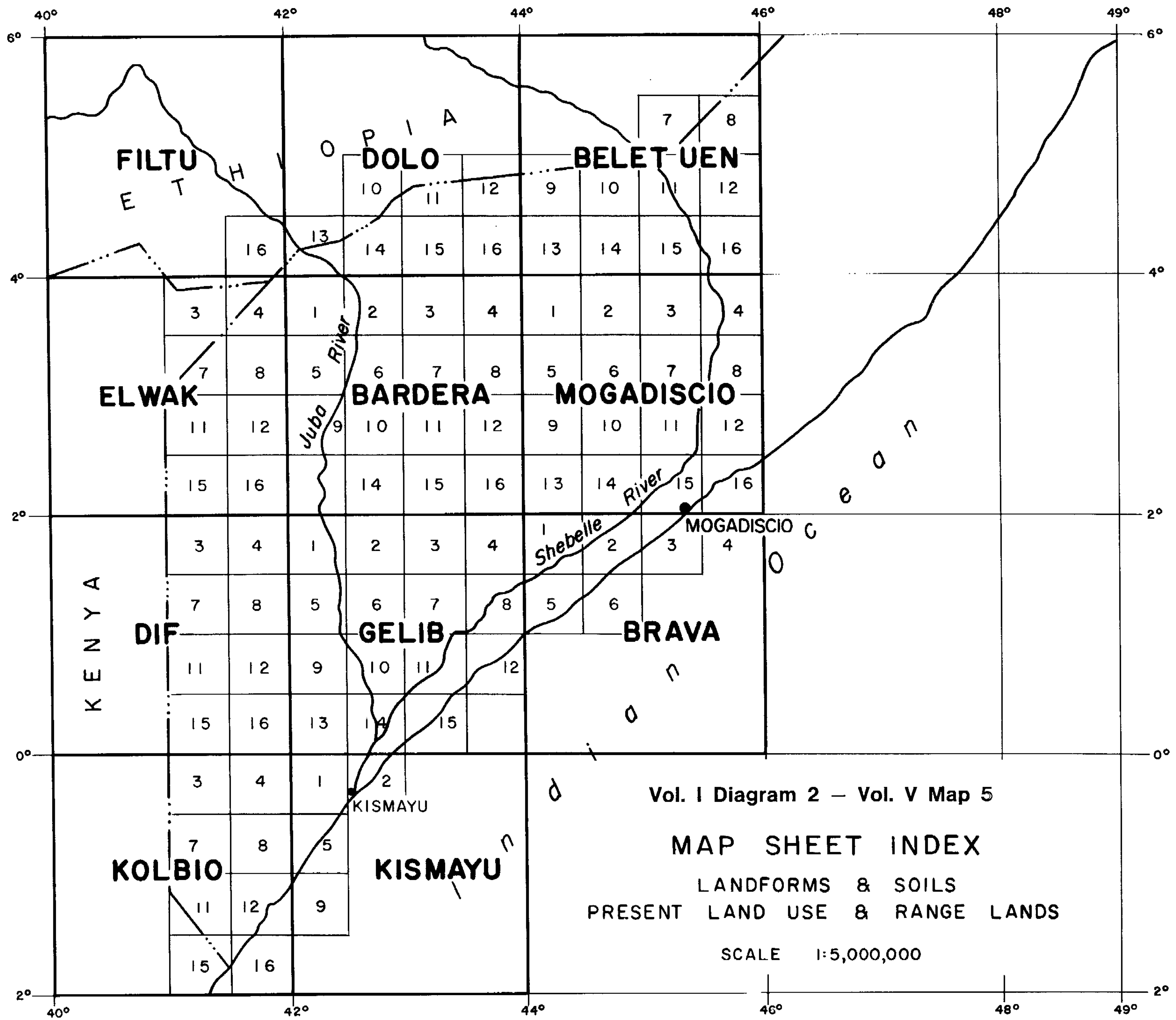


3rd. ORDER LEVELLING PROGRAMME
Loop I – Mogadiscio, Afgoi, Balad, Mogadiscio
Loop 2 – Afgoi, Brava, Gelib, Bardera, Baidoa, Afgoi
Line I – Balad, Johar, Bulo Burti, Belet Uen
Line 2 – Baidoa, Lugh Ganana
Line 3 – Gelib, Giamama, Kismayu
Line 4 – Kismayu to 72 Km. on road to Afmadu
Line 5 – Mogadiscio, Scialambot
VERTICAL CONTROL SURVEY FOR
PHOTOGRAMMETRIC MAPPING
1 Fanole – Gelib block
2 Camsuma – Ionte block
3 Genale Irrigation area
4 Shebelle Dam site area
3rd. Order Levelling
Control
LEGEND
Project boundary
International boundary
River
Road
Vol. I Diagram 1 – Vol. V Map 1
TOPOGRAPHIC SURVEYS
SCALE
20 0 20 40 60 80
Kilometres
DATE OF SURVEY 1964 – 1965
ETHIOPIA
KENYA
Juba River
Shebelle River
Dolo
Jet
Oddur
Belet Uen
Bulo Burti
Tigieglo
Uegit
Lugh Ganana
Mandera
Garba Harre
Iscia Baidoa
Bur Acaba
Uadi Damer
Uanle Uen
Mahaddei Uen
Giolalossi
Johar
Balad
Afgoi
MOGADISCIO
Ita'ala
Aucegle
Mobarech
Genale
Coriole
Falcheiro
Merca
Scialambot
Bardera
Dinsor
Bahal Nacuda
Saco
Bahal Madagoi
Dugiuma
Bantao
Avai
Brava
Fanole
Gelib
Lac Gira
Lac Dera
Afmadu
Belesc Cogan
Bardera
Camsuma
Giamama
Descek Uama
Ionte
Kismayu
Lac
Badana
42° 43° 44° 45° 46°
5° 4° 3° 2° 1° 0° 1°


LEGEND
Spot elevation
Permanent bench mark
Temporary bench mark
Cut line
Road
Town, village
UNITED NATIONS SPECIAL FUND PROJECT 42
AGRICULTURAL AND WATER SURVEY
Surveyed by Topographic Section, Survey and Mapping Dept. of
Drawn at 1:30,000 by Cartographic Section, Survey and Mapping
February - April 1965
Compiled from 1:40,000 uncontrolled mosaics
Photography January-March 1963
Datum - Preliminary, taken from USSR. Technopromexport
Drawn at 1:100,000 by LOCKWOOD SURVEY CORPORATION LIMITED, TORONTO, for the purpose of this report
GELIB
FANOLE
Juba River
Approx.
Vol. V Map
TOPOGRAPHIC SURVEYS
GELIB - FANOLE AREA AND OUATA ISLAND
SCALE
Kilometres


LEGEND
Spot elevation
Permanent bench mark
Cut line
Road
Town, village
UNITED NATIONS SPECIAL FUND PROJECT 42
AGRICULTURAL AND WATER SURVEY
Surveyed by Topographic Section, Survey and Mapping Dept. of Somalia
Drawn at 1:30,000 by Cartographic Section, Survey and Mapping Dept. of Somalia
February - April 1965
Compiled from 1:30,000 uncontrolled mosaics
Photography January-March 1963
Vertical Datum - Mean Sea Level (A.& W.S.)
Drawn at 1:100,000 by LOCKWOOD SURVEY CORPORATION LIMITED, TORONTO, for the purpose of this report
Approx.
CAMSUMA
GIAMAMA
Juba River
DEPRESSION
ROGERS CUT LINE
Descek Uama
Vol. V Map 3
TOPOGRAPHIC SURVEYS
LOWER JUBA AREA
SCALE
Kilometres


Main river
Drainage channel
Canal
Main road
Track
Cut line
Villages
Contours in metres
Horizontal control point
Bench mark
Vertical control point
AGRICULTURAL AND WATER SURVEY
Photography dated 1962
GENALE
River
INDIAN OCEAN
Vol. V Map 4
TOPOGRAPHIC SURVEYS
GENALE AREA
SCALE



Vol. I Diagram 2 — Vol. V Map 5

MAP SHEET INDEX

LANDFORMS & SOILS
PRESENT LAND USE & RANGE LANDS

SCALE 1:5,000,000

CHAPTER 2

ENGINEERING CONSIDERATIONS OF SURFACE WATER DEVELOPMENT

OBJECTIVES OF SURFACE WATER DEVELOPMENT STUDY

1. The objectives of the Agricultural and Water Survey were "to survey and evaluate the resources of land and water in the areas between and adjoining the lower reaches of the Uebi, Shebelle and Juba Rivers, and to develop a general policy and plan for improved use of these resources for agricultural and livestock production."

2. Within this framework the objectives of the Surface Water Development Study were:

To examine all existing irrigated areas in the project area, in respect of soils, crops, methods of irrigation, amounts of water used and agricultural production.

To study the possibilities throughout the area of improving and extending the use of irrigation by all feasible methods to grow short-term and plantation crops, drawing water from either rivers or groundwater supplies.

To study the economic and technical feasibility of using supplemental irrigation to increase agricultural production in the areas now used or suitable for dry farming, whether from rivers or from groundwater.

To study the possibilities of providing increased supplies of water within the grazing areas as part of a feasibility study to improve production.

A study of all aspects to control the river flows within the project area in respect of both, flood control and the provision of water for irrigation in the low season.

To formulate recommendations for improved use of the water resources within the project area.

3. As originally envisaged this study would have covered both the Juba and Shebelle Rivers, as well as any water courses lying between. However, early in 1963 the U.S.S.R., under a contract with the Government of the Somali Republic, commenced a study of the Juba River directed towards working out a scheme to utilize its waters for irrigation. A preliminary report on the results of this study was issued in mid-1964. From this it was apparent that this investigation would be more detailed and comprehensive than one which fell within the scope or capabilities of this Survey, considering the man-hours which could be allocated to it by the latter. As duplication of work was unjustifiable it was decided to concentrate the efforts of this Survey on the other portions of the project area, in particular the Shebelle River.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

DEVELOPMENT OF SHEBELLE RIVER

Conclusions

4. With little or no regulation of the flow of the Shebelle River it would be possible to add at least 20,000 hectares of land to that at present under controlled irrigation. This would be over and above the 4,000 hectares of cotton and 1,000 hectares of grapefruit already proposed and under serious consideration as additions to existing irrigated cultivation.

5. Due to lack of water during certain months of the year only seasonal crops could be grown, of relatively low unit value. It would be possible, nevertheless, to obtain a net additional average annual production of an at-farm value of not less than So. sh. 35,300,000.

6. The land selected for this development should be the idle land on the farms of the Societa Azonaria Concessionari Agricoli in the vicinity of Genale, in the first instance. When fully developed the next area selected should be the contiguous land on the down-stream side, known as the Bulo Mererta Project area. Considerably more than 20,000 hectares can be developed in these two areas.

7. If these areas are selected the development costs will be relatively low. The gross farm benefit/investment ratio would be in the order of 86 per cent and the net farm benefit/investment ratio 36 per cent.

8. This development would require some supplementary water in December. It appears to be both physically possible and economically feasible to obtain this from wells in the proposed areas. Consideration should, however, be given to reduce losses from the river channel in order to improve the river flow in the critical months.

9. There are strong indications that full regulation of the Shebelle might be technically feasible with a dam sited upstream of Bulo Burti. Such a dam might also be economically feasible and its construction possibly could be justified at some future date.

10. If this dam were to be found technically and economically feasible it would be possible to add 15,000 hectares of bananas to existing and other planned cultivation, in lieu of the 20,000 hectares of seasonal crops. If these could be marketed the annual at-farm return from the net additional produce would be in the order of So. sh. 147,000,000.

11. In this case, taking into account the cost of the dam, approximately So. sh. 102,000,000, the development costs would be high. However the benefits would be such that the gross farm benefit/investment ratio would be in the order of 104 per cent and the net farm benefit/investment ratio 58 per cent.

12. Until such time as agriculture in the Shebelle valley is developed to the point where maximum possible advantage is being taken of the unregulated flow, and optimum production per hectare is being obtained under these conditions, the construction of such a dam should not be contemplated.

13. A feasibility study of this project should, however, be carried out in the near future. This is essential in order to make decisions on alternative action should it be found not feasible. Interim action should be envisaged if the project appears feasible.

14. Whether the dam is found to be feasible or not, consideration should be given to immediate projects designed to divert surplus flood waters of the Shebelle into areas where they will be most beneficial to the economy. A feasibility study of proposals contained herein should be commissioned in the near future.

15. As the Shebelle River is one of the few known and easily exploitable resources of Somalia all its waters should be used, to the limits of technical practicability, in ways which provide the maximum economic return. Moreover development should proceed as rapidly as possible, particularly in view of the recurring food shortages.

16. To develop new irrigated land on the scale proposed, to do this within a reasonable number of years, and to obtain and sustain optimum crop yields will require:

(a) An overall plan to be drawn up for the Shebelle, with short and long term goals, which will provide for realistically phased development to take place over the next twenty years.

(b) Decisions on the best way of selecting farmers for the new development, the best form of land tenure, the best type of organisation through which to exercise control, and the best means of providing competent management at the outset and of training Somalis to take over every aspect of the operation in due course.

17. It is believed that the way most likely to be successful in providing the required initiative to start this development, and of ensuring its continuation in directions that are in the best interests of Somalia, would be by a Board or Authority set up for the purpose. It would be a semi-autonomous body, financed by charges levied for water use, which would be empowered to enforce relevant land tenure and water legislation in regard to the Shebelle. To engage consulting engineers and other specialists who would be required for plans and technical advice, to make the decisions referred to above, raise capital and make arrangements for management.

18. It is considered that the development of the full agricultural potential of the Shebelle in its unregulated state is technically simple. It is believed that the relatively small amount of capital required can be obtained without undue difficulty. The real problem is the lack of sufficient numbers of capable men at all levels and for all the many functions involved in modern, irrigated agricultural production. It is apparent that a number of expatriates will be required both for the initial organisation of the project or projects and to provide managerial and advisory services until Somali staff can be trained for these purposes.

19. There appear to be four alternative general lines of approach to the problem of obtaining most economically the administrators and agricultural specialists required, and of ensuring that Somalis are trained to take over in as short a time as possible. These are as follows:

(a) A partnership arrangement could be worked out between the Government and S.A.C.A. whereby this organisation was given full responsibility for the implementation of all development plans. This would include the responsibility for the maintenance and operation of the irrigation system, as well as its expansion as required. It would include the provision of all agricultural advisory services and the training of new farmers in the best irrigation and farming practices. This would merely require the expansion, with Government assistance, financial and otherwise, of the existing administration and the extension of services now being provided solely to the banana producers. If S.A.C.A. is to continue to exist, and there is no evidence that it is the intention of the Government to dissolve it, there is every reason for making the maximum possible use both of the services which the Society, as such, can provide and also of the skills and experience of its member farmers.

(b) One or more large cooperatives might be established by the Ministry of Agriculture or preferably by an Authority such as proposed above. Expatriate staff would be hired as required but the overall direction would remain in the hands of some Government Agency.

(c) A large private company might be set up, with combined Somali and foreign capital, to which would be given the major portion of the land to be developed on a long-term lease, say twenty years. Such a company would engage experienced management and hire agricultural and other labour to operate the scheme as a plantation. With proper contractual arrangements the long term interests of Somalia could be guaranteed and an early financial return to the Government assured.

(d) A variation on the last approach would be the Government entering into an agreement with an existing large and experienced international company to take over, develop and use the land for a pre-determined period. Again, arrangements could be made which were mutually attractive to both parties and which could result, in twenty years time, in an efficiently functioning irrigation development, completely Somali owned and operated. This would have been achieved with the minimum effort and financial outlay by the Government.

20. In cases (b), (c) and (d) above the cooperatives or companies could be given not all but a large fraction of the total area of land to be developed. The remainder could be organised under village cooperatives and it could be part of the terms of the contract between the Government and the former that they would provide all necessary advice and assistance, including marketing facilities, to the village cooperatives.

21. Central to the arguments which must precede a decision on the method of development is, of course, the extent to which it is decided that immediate and maximum economic return should or should not take precedence over involving as many independent farmers as possible in the benefits to be obtained. This is a matter entirely for Government policy to decide and no conclusions or recommendations are appropriate here.

Recommendations

22. Based on the foregoing conclusions it is recommended that the following steps be taken, approximately in the order listed, to ensure the earliest and most economically beneficial development of the Shebelle River:

(a) A Shebelle River Authority be established with full powers to plan and implement the development.

(b) Land tenure and water use legislation be formulated and passed. Until this is done no development can properly proceed.

(c) A feasibility study should be carried out of the possibility of diverting flood flows of the Shebelle to obtain the maximum possible benefits therefrom.

(d) The existing irrigation development centred on Genale, and certain portions of the contiguous land farmed with inundation irrigation, should be mapped.

(e) A feasibility study of a storage dam on the Shebelle, to be sited upstream of Bulo Burti, should be carried out at the end of 1966. In preparation for this an immediate start should be made on collecting certain missing requisite data, and on mapping the proposed reservoir area, as outlined in this report.

(f) Immediate steps should be taken to stop the proliferation of farms along the Shebelle River which make inefficient use of its waters.

(g) Maximum possible use to be made of the organisational, administrative and technical advisory services which may be provided by such agricultural organisations as now exist.

(h) The farmers now growing bananas in the Genale area should be pressed, by suitable systems of taxation or by legislation, into growing crops on all cultivable land on their farms to which water is now or can easily be provided.

SURFACE WATER SUPPLIES FOR HUMAN AND ANIMAL CONSUMPTION

Uars

Conclusions

23. Uars would be technically feasible on the Shebelle Flood Plain, the Lac Dera Plain, the Marine Plain and on the Central Uplands.

24. Due to climate and topography they are not economically attractive as sources of water supplies and are not recommended unless, in a given area, it has been proved that:

(a) No ground-water exists, or

(b) It exists but its quality is unsuitable for use, or

(c) It exists in adequate quantity and of satisfactory quality but the cost of establishing and maintaining a well can be proved to be economically unfeasible, and

(d) No improvement of ground-water supplies is possible.

25. If uars prove to be the only possible or practicable way of providing water in the above-noted regions, construction programmes which would provide them in sufficient numbers and of sufficient size have been estimated to require the following expenditure:

Shebelle Flood Plain	-	So. Sh.	2,115,179
Lac Dera and Marine Plains - total	-		2,976,407
Central Uplands	-		282,450

26. A uar location survey would be required for selecting sites on the Lac Dera and Marine Plains. This has been estimated to cost approximately So. Sh. 326,000.

27. Annual maintenance would be required and the costs of this have been estimated to be as follows:

Shebelle Flood Plain	So. Sh.	186,970
Lac Dera and Marine Plains - total -		270,400
Central Uplands		35,380

Recommendations

28. Until more data on ground-water supplies is available, and until other projects have been investigated, no action on uar construction should be taken on the Shebelle Flood Plain or the Marine Plain (Eastern Section).

29. The uar location survey required for the Lac Dera Plain and the Marine Plain (Western Section) should be carried out as soon as funds can be made available, and construction should follow as soon as possible.

30. The programme for the Central Uplands is of low priority but might be carried out in the near future in certain circumstances as explained hereinafter.

Small Streams

Conclusions

31. There are three small seasonally-flowing streams in the project area which might be developed to provide water supplies on a small scale. These are the Lac Badana, the Bohal Madogoi and the Uadi Damer.

32. The first might be dammed, suitable sites for ground-water dams and seepage galleries might be found on the second, and the last might be dammed at one point or sub-surface dams might be constructed at a number of points.

33. All these possibilities warrant detailed study in due course. This could best be done by combining a feasibility study of these projects with the proposed flood water diversion study of the Shebelle River.

Recommendations.

34. Feasibility studies of the suggested developments on the three streams should be carried out if and when a study is commissioned for the flood water diversion project.

IRRIGATION DEVELOPMENT OF THE SHEBELLE RIVER

REGIME OF THE SHEBELLE RIVER

35. The Shebelle River rises in Ethiopia, within which country lies virtually

all of its effective drainage basin, which has an area of approximately 212,000 square kilometers. The river enters Somalia at a point approximately 31 kilometers north west of Belet Uen and traverses a total distance of approximately 630 kilometers before the last significant traces of it disappear about 30 kilometers east of the Juba and about the same distance from the Indian Ocean. Throughout practically all this length it follows a meandering bed which increases actual channel distance within Somalia to approximately 1,100 kilometers.

36. The meandering nature of the river and the torrential nature of its flow causes the area of cross section of the channel to decrease progressively. These factors plus the reduction in slope, hence in velocity, and the fact that the river receives within Somalia little drainage water and that water is lost due to evaporation, infiltration, and use, means that each successive gauging station downriver from Belet Uen recorded lower discharges.

37. The maximum discharges which have been recorded at these stations by this project are as follows:

Belet Uen	-	281 Cumecs (cubic meters per second)
Bulo Burti	-	276 Cumecs
Mahaddei Uen	-	130 Cumecs
Balad	-	93 Cumecs
Afgoi	-	93 Cumecs
Audegle	-	80 Cumecs

38. When the discharge rate at one station exceeds the channel capacity of the next downstream section the excess overflows the banks and causes floods. This happens according to the above measurements especially in the section of the river between Bulo Burti and Balad. Some of this overflow is not "lost" in the strictest sense as it is often put to use and gives rise to the inundation irrigation farming on the flood plain.

39. Although the above is the case at high flows a different discharge pattern was observed at median and low flows. Depending upon the size of discharge, and on the season, there is often a small but definite increase in flow at the downstream gauging stations at Afgoi and Audegle. Some of these increases may be due to minor rainfall contributions but analysis of all the data by correlating rainfall and river flow information indicates that water lost through overflow at an upstream section reappears downstream at a later date.

40. After considering evaporation losses plus estimates of water used for irrigating present crops there are still considerable losses from overbank spillage and from water flowing to waste beyond Falcheiro into the swamps. It is this presently unused or inefficiently used surplus water, its possible storage, control, diversion and use which is considered in this section of this report.

41. The regime of the Shebelle River is described in Volume 2 of this report. Only a brief description of the water used and losses will be included here. Median monthly flows and changes of flow at all gauging stations are shown in Tables 1 and 2.

42. From Belet Uen to Bulo Burti the river flows in a wide valley. Rainfall is low in this area but some tributaries flow occasionally after rains. This is the only section of the river in Somalia where tributaries have any importance. High water flows flood certain sections of the valley.

43. From Bulo Burti to Mahaddei Uen the hills which form the upstream valley disappear and the flood plain begins. Peak flows again cause over bank spillage and subsequent loss of water in this area.

TABLE 1

SHEBELLE RIVER

MEDIAN MONTHLY TOTAL FLOW

PASSING GAUGING STATIONS

1000's of Hectare Meters

Station	J	F	M	A	M	J	J	A	S	O	N	D
Belet Uen	2.8	2.3	2.1	5.2	17.7	6.1	4.5	25.1	38.8	34.5	23.2	8.6
Bulo Burti	2.9	2.3	2.6	4.6	16.8	5.2	3.6	19.5	34.0	32.2	22.9	8.1
Mahaddei Uen	3.0	1.8	2.0	4.4	16.6	6.1	4.9	19.1	33.0	31.4	20.5	7.9
Balad	2.2	1.4	1.2	3.8	14.7	5.4	3.9	16.3	23.6	24.2	16.8	7.6
Afgoi	1.4	.5	.7	2.4	15.1	5.2	3.2	17.5	23.8	24.3	18.3	7.5
Audegle	1.9	1.1	1.2	3.5	14.3	5.6	3.7	14.0	20.2	20.7	16.3	7.6

TABLE 2

SHEBELLE RIVER

MEDIAN CHANGE IN TOTAL MONTHLY FLOW

BETWEEN GAUGING STATIONS

1000's of Hectare Meters

Between	J	F	M	A	M	J	J	A	S	O	N	D
Belet Uen and Bulo Burti	+ .1	0	+ .2	- .3	-1.6	- .9	- .2	-2.0	-2.2	-2.0	-1.4	- .8
Bulo Burti and Mahaddei Uen	0	- .3	- .2	- .35	- .4	+ .6	0	-1.3	-2.5	-2.2	-2.0	- .25
Mahaddei Uen and Balad	- .75	- .65	- .5	-1.0	-2.9	-1.2	-1.0	-2.4	-7.6	-7.2	-3.75	-1.3
Balad and Afgoi	- .75	- .65	- .75	- .7	+ .5	- .2	- .3	+ .25	+ .3	+ .1	+1.0	- .2
Afgoi and Audegle	+ .55	+ .55	+ .5	+ .5	-1.2	+ .4	+ .3	-1.3	-3.4	-3.1	-2.2	+ .2

44. From Mahaddei Uen to Balad considerable flooding occurs at high water periods along much of the course and the sugar plantation at Johar uses some of the water. Fanning out to the west from Mahaddei Uen are the remnants of several old river channels but the present course of the river is south to Balad. Between Mahaddei Uen and Johar the natural overbank spillage is aggravated by the weir constructed at Johar to provide the head for the Johar sugar plantation. When this weir was constructed the river banks were embanked to prevent this spillage. However, inadequate maintenance and control has made these embankments ineffective.

45. From Balad to Afgoi the channel is capable of carrying all the water downstream that reaches Balad. Therefore, there is no overbank spillage. Infiltration actually causes some increase in flow in this stretch at certain times of the year.

46. From Afgoi to Audegle again high flows cause overbank spillage but infiltration again is important in maintaining or increasing median and low flows. Water is pumped in this section for quite a number of plantations along the river bank.

47. From Audegle to Falcheiro there are three dams constructed to provide irrigation water for the S.A.C.A. banana concession plantations and for the Bulo Mererta Project area. Water is used by these farmers for about 12,000 hectares of crops and around the fringes of the developed area about 14,700 hectares are inundated regularly by overflow from the canals but the water in this area is controlled to such an extent that there is very little overbank spillage.

48. From Falcheiro to the end of the river there is very little use made of the waters. Water that passes Falcheiro flows almost immediately into the swamps covering about 61,800 hectares of land. It is estimated that annual losses of water in these swamps from evaporation, evapotranspiration and infiltration amounts to about 75,000 hectare meters. Beyond the swamps near Avai the river flows in one channel again continuously but at a greatly reduced rate. The river channel is observable for 110 kilometers beyond the swamp but in the median year water does not flow for much of this distance.

49. Tables 1 and 2 indicate the water available in the median year. However, irrigation plans cannot be based on the amount of water available one year out of two and the 75 per cent year has been selected for use in this report for irrigation projects. In Table 3 the quantities of water passing the gauging stations in the 75 per cent year are shown. This is the minimum water that is available three years out of four.

PRESENT STATE OF AGRICULTURE IN THE SHEBELLE VALLEY

Methods of Irrigation

50. The present state of agriculture in the Shebelle valley is best considered in terms of the same divisions as were used to discuss the regime of the river. Before examining the individual sections, however, it is necessary to explain the different ways in which water is applied to the farmland.

51. The most extensive but by far the most inefficient is inundation irrigation. This is the method in which advantage is taken of the water which spills over certain stretches of the banks (referred to previously as "reducible losses") either to saturate areas which are planted after the water has receded and/or infiltrated, or to water crops already planted which would otherwise be entirely dependent on rainfall. The latter is the more usual case.

TABLE 3

75% MONTHLY TOTAL FLOW PASSING VARIOUS STATIONS

1000's of Hectare Meters

	J	F	M	A	M	J	J	A	S	O	N	D	75% Annual Flow 1000's Hec.-Ms	Equivalent Average Discharge Cumecs
Belet Uen	2.5	1.80	1.95	2.50	15.00	4.10	2.70	9.60	24.10	23.20	14.60	5.20	154	49
Bulo Burti	2.65	1.90	2.10	2.40	13.20	3.05	2.65	7.60	23.50	22.05	14.00	4.80	148	47
Mahaddei Uen	2.20	1.10	1.40	2.20	13.10	4.00	2.50	7.20	21.20	21.35	12.30	4.80	138	44
Balad	1.65	.90	.95	1.70	11.10	3.30	1.85	7.00	19.10	18.30	11.10	4.60	112	36
Afgoi	.85	.30	.30	.70	12.20	3.25	1.05	7.30	20.15	19.50	12.25	4.05	110	35
Audegle	1.30	.70	.35	1.30	12.00	3.85	1.50	6.90	18.35	17.95	12.20	4.50	103	33

52. The crops grown with this form of irrigation are, with a few minor exceptions, maize and sorghum in the Gu season and these plus sesame in the Der. The production per hectare of each of these varies widely from season to season, year to year and from place to place as there are wide variations in the quantity of water applied by river and rainfall and in soil fertility, seed quality and farming practices.

53. Variation in water supply is probably the most important factor, as evidenced by the considerable difference in production on inundated land and that on land dependent on rainfall only. For purposes of comparison the present average yields for both types of farming are given in Table No. 4 together with the average value of produce per average hectare in each case. In the latter instance it has been necessary to make somewhat arbitrary assumptions as to the percentage of land sown to each kind of crop in rainfed and irrigation farming. These are, however, based on data obtained by field investigations carried out by this survey.

54. Also tabulated are estimated possible yields of these crops in the foregoing situations but with improved seed, pest and disease control and best field practices. These are optimum annual yields suitably reduced to average annual yields on the following assumptions. In the case of rainfed cropping there will be two good crops, one poor crop and two years of no crop in every five years. In the case of inundation irrigation in the same period there would be three good crops, one fair crop and one poor. A reduction is also made from the optimum to allow for the fact that under the widely scattered conditions of inundation irrigation adequate horticultural advice and assistance cannot be provided, unlike the case of a compact, controlled irrigation development.

55. Finally, optimum annual yields with controlled irrigation are tabulated, to provide a generalised indication of the actual monetary benefits to be obtained therefrom.

56. It is possible to carry out inundation irrigation over relatively large areas which extend for considerable distances away from the river because of a feature of the Shebelle which is common to all rivers with similar characteristics. This is the fact that over hundreds of kilometers of its length natural levees have been formed on its banks, the crests of which are considerably higher than the surrounding flood plain. These result from the overbank spillage which occurs during periods of high flows when the water is carrying very large quantities of sediment. This sediment tends to be deposited at maximum depth immediately adjacent to the river and levees are therefore formed which rise relatively steeply therefrom and slope gently down to the plain over distances varying from a few tens to a few hundreds of meters. The tops of these levees may be as high as 2 meters above normal ground level: limited observations indicate they may average about 1 meter. This feature is little in evidence upstream of Gialalassi, about half way between Bulo Burti and Mahaddei Uen, but becomes increasingly common as the latter village is approached. From this point downstream as far as Falcheiro the levees are practically continuous.

57. When the river rises sufficiently, water either overtops these banks or flows out through natural or man-made breaches in them. Where over-topping occurs the water does not return after the river level drops. If there has been a greater outflow than required for such crops as may be planted in the inundated area, the excess is wasted in evaporation and infiltration. Where broad natural breaches occur much of the water may return to the river as the level drops, particularly in the cases where it is ponded in a natural basin, called a "billich" or descek, adjacent to the river as occurs in a few instances. However an excess may still flow out onto the farmland or, if the submerged land is not farmed, the wastage is increased by an increase in the area exposed to evaporation and infiltration.

TABLE 4

COMPARISON OF RETURNS FROM RAINFED, INUNDATION AND CONTROLLED IRRIGATION CROPPING

		Average Annual Yield Per Average Hectare - Quintals						Average annual value of produce per average hectare So.	
		MAIZE		SORGHUM		SESAME			
		Present	Possible	Present	Possible	Present	Possible	Present	Possible
Rainfed Cropping	Area	.15 Ha.	.15 Ha.	.75 Ha.	.75 Ha.	.10 Ha.	.10 Ha.		
	No. Crops	1	1	1	1	1	1		
	Yield	31	100	270	1000	5	10	90/--	355/--
Inundation Irrigation	Area	.5 Ha.	.5 Ha.	.25 Ha.	.25 Ha.	.25 Ha.	.25 Ha.		
	No. Crops	1	1	1	1	1	1		
	Yield	320	1000	120	300	80	150	250/--	690/--
Controlled Irrigation	Area		.75 Ha.				.25 Ha.		
	No. Crops		2				2		
	Yield		3400				450		1980/--

TABLE 5

MONTHLY REDUCIBLE WATER LOSSES[1]

1000's of Hectare Meters

Between		J	F	M	A	M	J	J	A	S	O	N	D
Belet Uen and Bulo Burti	A	1.5	1.9	1.0	2.1	8.4	1.2	3.4	8.7	8.0	6.8	3.7	3.2
	B					1.2	.5		1.6	1.8	1.6	1.0	.4
	C					.6			1.0	.9	1.0	.4	
Bulo Burti and Mahaddei Uen	A	3.7	1.1	1.1	7.4	22.8	14.2	1.9	8.0	11.1	10.4	16.5	18.0
	B								.9	2.1	1.8	1.6	
	C												
Mahaddei Uen and Balad	A	1.6	4.6	1.3	7.3	19.0	6.6	1.8	6.4	9.4	9.4	13.1	9.4
	B	.2	.1		.5	2.4	.7	.5	1.9	7.1	6.7	3.2	.8
	C					1.6	.2		.8	2.2	2.6	1.2	
Balad and Afgoi	A	.8	.7	.8	2.1	2.8	.7	.8	.1		.5		.7
	B												
	C												
Afgoi and Audegle	A	.6	.9		7.2	3.6	3.3	.6	3.2	3.9	3.9	4.5	3.8
	B					1.0			1.1	3.1	2.9	2.0	
	C					.2			.2	1.8	1.4	.4	

A - Maximum Recorded
B - Median Monthly
C - 75% Monthly

1 Total losses minus present use and evaporation and infiltration from channel

58. Where man-made breaches occur these are generally small and in the form of canals and a certain amount of control is usually exercised by blocking them when required by earth plugs, resulting in what might be termed semi-controlled inundation irrigation. While the latter arrangements allow limitation of the water applied to the land the provision of sufficient water depends entirely upon the river's natural level. A modification of this method is the construction of a large-capacity canal, sometimes carrying water a considerable distance out from the river, the entrance of which is controlled by mechanical gates. These have been built at a number of points along the river, notably at Belet Uen, near Gialalassi, downstream of Mahaddei Uen and at Barire.

59. Controlled irrigation, mainly by gravity flow but augmented by pumping from the river and from wells when necessary, is carried out in the vicinity of Johar and Genale. Only about 23 per cent of the total area irrigated by water from the Shebelle is irrigated in this way but it accounts for approximately 86 per cent of the total value of all production on irrigated land along the river.

60. Controlled irrigation, with the water being lifted by pumps from the river at all seasons, except in rare instances, is carried out along the Shebelle on a small but increasing scale. In the vicinity of Afgoi, both upstream and downstream, it has been used for many years to grow bananas profitably with small areas of other crops in conjunction. Recently there has been a considerable increase in the area so irrigated downstream of Afgoi to Audegle and beyond, again with bananas as the main crop. This form of irrigation cannot be considered economic except with a very high value crop, such as bananas have been to date in Somalia, though a small profit might well be shown in certain instances with crops of lesser value.

61. The actual cost per cubic meter of water pumped will depend upon the height it must be lifted, the efficiency of the pump, the unit price of fuel, the operational life of the pump and power source, and whether the latter is an engine provided solely for pumping or is a tractor or machine with other uses on the farm.

62. Assuming the use of a pump of the standard pattern common to the area, with an average lift of 4 meters and a delivery of 1000 cubic meters per hour, driven by a diesel engine allocated only to this function, the pumping cost of one hectare meter of water put into the delivery canal will be approximately So. Sh. 375.

63. Assuming an overall water use efficiency of 60 per cent, the pumping cost for the water required for a hectare of bananas would be approximately So. Sh. 1050, for a hectare of maize So. Sh. 345.

64. It must be accepted that controlled irrigation is always preferable to uncontrolled from every standpoint. In Somalia, considering the extreme shortage of water and the fact that, as far as the Shebelle is concerned, there is no dearth of land on which to apply it, it is mandatory. Hence any plans for the full exploitation of the water of the Shebelle must be based on the principle of eventually eliminating all uncontrolled inundation irrigation except in instances where this is the only feasible way to use occasional flood peak flows. This approach underlies all arguments and recommendations in this report.

65. It can be argued that considering the scarcity of water it would be logical to employ sprinkler irrigation, as this is unquestionably a more efficient way of applying irrigation water than by surface irrigation. However sprinkler irrigation is usually only found economically attractive when one or more of the following conditions prevail:

(a) Soils are too porous for good distribution by surface methods.

(b) Slopes are steep and soils easily erodible.

(c) Land so undulating that it is too expensive to level for good surface irrigation.

(d) Water may be delivered to the land under gravity pressure.

(e) Alternatively cheap electric power or cheap fuel is available.

66. None of these conditions exist in Somalia and hence higher water-application efficiency is the only argument in its favour. As against this it would require a high capital investment in scarce foreign exchange, a continual drain on foreign exchange for fuel, oil and spares. It would require trained men to operate and maintain the system and would involve training the farmers away from a method they know and accept. In view of the many other unavoidable problems inherent in the expansion of irrigation in Somalia it is felt it would be most unwise to consider sprinkler irrigation at this time. If desired a small pilot scheme could be set up in a few years, perhaps as part of the programme of the Afgoi Agricultural Research Station, which would enable the practicability of this in Somalia to be determined. If real economic benefits were proven it would then be possible to train men in the use of this type of irrigation and gradually expand its use.

Regional Considerations

67. The present production of existing farmland irrigated by uncontrolled and semi-controlled inundation, and actual water requirements, where they differ from present water use, are discussed below. Also examined are the lands under controlled irrigation, their present water needs and predictable increases in these requirements for which allowance must be made. It should be clearly understood that all tabulated figures of monthly water requirements appearing hereunder are the quantities required for optimum production. In some months and in some areas these quantities are frequantly not available from the river and if they are provided at all they are obtained from wells or from water stored in surface reservoirs. However it is these totals which must be subtracted from the estimated flows, month by month, in order to determine the quantity which will be available for new irrigation developments.

Belet Uen to Bulo Burti

68. In this section, together with the stretch from Belet Uen to the Ethiopian border, there are a total of approximately 4100 hectares subject to inundation irrigation from time to time. This includes an area of approximately 1800 hectares in a shallow depression across the river from the southern edge of Belet Uen which is served by a large canal. This was constructed in 1959 for the main purpose of providing an escape for excess water when high floods threatened the village but considerable agricultural benefit was anticipated. This has not proved to be the case as since its construction the water has only once risen high enough to flood part of this area in the Gu season and only in about every second year in the Der.

69. Apart from this area the remaining 2300 hectares are distributed more or less uniformly along the 230 kilometers of river channel from the border to Bulo Burti, giving an average of 10 hectares per kilometer. There is practically no overbank spillage along this stretch during the April-May peak flows except in years when these flows are abnormally high. There is relatively little in the median year in September-November, in a dry year there may be none at all.

70. The topography of this area is such that, except in phenomenal years such as 1961, flooding never extends over a large area. It may be taken that, generally speaking, all land inundated would normally be planted in crops after the water's recession if not planted before inundation. Hence, using the computed reducible water loss in the median year in this section of 4000 hectare meters, it appears that in such a year an average depth of approximately one meter of water is applied to the cultivated land. This is very reasonable in terms of crop requirements. While there would be an excess in years of high flows the available records indicate that this would not be great enough, nor happen often enough, to warrant control measures to conserve this surplus.

71. Recently there have been two small cooperative farms started on this stretch based on controlled irrigation using water pumped from the river. Their combined areas total less than 200 hectares and it is not expected that this type of development will expand greatly in this region. While this is a great advance in the concepts of farming in the area, and is of undoubted value to the people involved, this method of irrigation is not economically sound when applied to the growing of maize and sorghum, the crops planted at present. If cotton is eventually selected, as a higher value crop, it is felt that the isolation of these farms will prevent their receiving the necessary assistance in disease and pest control and ultimately there would be no economic improvement. Moreover, as for farming generally in this area, the soils in this region are much less suitable than those further downstream, a large percentage having a high salt and/or gypsum content.

72. It is not anticipated that there will be any significant natural growth of farming and consequent increase in water demand in this stretch. Nor, in the interests of making the best use of this water, should appreciable development be encouraged.

73. Hence it will be assumed that there will be little change in the rates of flow at Bulo Burti as a consequence of upstream development. As noted above losses upstream of this station are unlikely to be reduced. The tabulated peak and 75 per cent monthly flows may therefore be taken as those which must be dealt with downstream in planning the river's control and exploitation.

Bulo Burti to Mahaddei Uen

74. Along this stretch of river there is a total of approximately 2000 hectares subject to inundation irrigation, again equal to an average of about 10 hectares per kilometer of channel. However, cultivation along both banks is much more continuous than in the previous case. There are no particularly large concentrations but the inundated and cropped land tends to extend further from the river in the southern part.

75. Generally speaking overbank spillage occurs with somewhat lower flows than is the case upstream of Bulo Burti; this is particularly true in the vicinity of Gialalassi. From the limited records, and from observations after the peak flows of May, 1965, it would appear that Gu season crops are inundated more frequently in this stretch than in the former. In the median year the overbank spillage losses per kilometer of channel are over 40 per cent greater than those in the first stretch considered. In years when high flows occur they are more than double.

76. When discharges are high the flood waters inundate very large areas, particularly east of the river; with moderate flows it appears that inundation is in the main confined to the cultivated land. It is not possible to make any meaningful estimates of the quantity of water applied to crops in this region.

77. While moderately high discharges result in inundation confined to the vicinity of the river along the whole length of the channel, very high discharges result in a localised loss of water in the vicinity of Gialalassi. Here large quantities of water escape from both sides of the channel along a stretch of approximately 20 kilometers. The bulk of this is lost on the eastern side where it spreads over a large plain between the river and the dunes. This undoubtedly provides a good season's grazing in the areas inundated, but a large proportion is lost with little benefit by infiltration into the dunes which are close, and for a short stretch actually contiguous, to the river in this locality.

78. The advisability and feasibility of taking steps to limit water losses in this stretch will be considered in the final section of this report.

Mahaddei Uen to Balad

79. Between these two villages there are approximately 26000 hectares that may be categorized as inundation-irrigated farmland, inasmuch as the whole of this area is flooded occasionally and parts of it in every Der season, if not in every Gu. Approximately 14000 hectares of this lie between Mahaddei Uen and Johar, a river channel distance of 33 kilometers, and the remainder is distributed along the 97 kilometers from Johar to Balad. The exceptionally large area upstream of Balad is the result of the backwater effect of the weir at Johar, mentioned previously.

80. When this weir was built, over 40 years ago, it was decided that rather than provide gates to pass the high discharges without substantially raising the water level upstream, the level would be allowed to rise but the water would be prevented from flooding the surrounding land by building embankments to contain it. Levees were constructed on both sides of the river from the site of the weir to about 4 kilometers from Mahaddei Uen. An agreement was drawn up by which the Government would be responsible for maintaining these banks and for regulating the making of openings in them. It was realised that the latter would be desired by the local farmers and it was agreed that they would apply to the Government for permission for each opening required and in each case a gate would be installed.

81. While the terms of this agreement may have been implemented for some years and the arrangements may have proved satisfactory, there has been no maintenance for many years and no control over breaching. As, without a gate, a small opening quickly becomes a large one, the levees have become totally ineffective. Hence with moderately high flows, quite apart from peak discharges, there is substantial overbank spillage on both sides of the river and inundation may extend out as far as 5 kilometers. Moreover, due to the fact that the land slopes away from the left bank of the river just north of the Johar plantation, a very large portion of the water which escapes from the channel flows towards a depression adjacent to the dunes which bound the flood plain to the east. It appears, in fact, that it is here that the major portion of the losses during high flows occur, though at medium flows there is also considerable inundation downstream of Johar, as is apparent from the extent of the cultivation.

82. This continues, with few breaks, nearly to Balad, extending out from the river on both sides in places as far as 4 to 5 kilometers.

83. Observations and enquiries indicate that the topography limits the further extension of this flooding during high discharges. Unfortunately until adequate contour mapping is available these assessments are necessarily speculative. Nevertheless a great deal of water is lost periodically due to the deterioration of the embankments above Johar and the restoration of these is discussed later in this report.

84. It may be seen from Tables 2 and 5 that median monthly losses are considerably higher in this stretch than in any other. This is partly due to the flooding of the farmland as noted above and partly due to very extensive flooding to the east of the river beyond the farmland, approximately midway between Johar and Balad. An extensive shallow depression exists in this area which receives a very large proportion of the water in excess of channel capacity during times of median discharge. Reference to Table 5 will show that when the discharge approaches peak recorded values more water is lost between Bulo Burti and Mahaddei Uen than in this stretch. However, except on such infrequent occasions, almost half the total reducible water loss from Belet Uen to Falcheiro occurs between Mahaddei Uen and Balad. Moreover, despite the large area nominally subjected to inundation irrigation, as a result of this overbank spillage, the economic return is not as great as might be expected.

85. A census carried out by this Survey has revealed that only an average of approximately 40 per cent of this land is planted in any year. Further, it must be assumed that normally inundation does not extend to its bounds which, generally very far from the river, will not be reached by flood waters in the median year. (This land seldom extends more than a kilometer from the river and generally less.) Hence it is considered to be a safe assumption that not more than 25 per cent of the total land in this category actually produces crops in an average year as a result of floodwater losses.

86. The water necessary for satisfactory irrigation of the net 6500 hectares would not be more than about 1500 hectares per month during September, October and November. It is apparent from the figures in Table 5 that in the median year there are substantial non-productive losses in these months and that the existing cultivation could be maintained with much less water than now leaves the channel. It is obvious that, if possible, the overbank spillage in this stretch should at least be limited to the quantity of water required for the crops on the land now being farmed, assuming it is considered necessary to perpetuate this inefficient usage for social and political reasons. The feasibility of so doing, and the alternative ways of making use of the surplus, are considered elsewhere.

87. Apart from the foregoing there is significant water consumption by the Societa Nationale Agricola Industriale plantation at Johar. The total area of this development is 8000 hectares of which 6450 are now or have been under cultivation. Of the latter area there were 5000 hectares planted in sugar cane in 1965 and about 50 hectares in other crops.

88. At the end of that year tentative plans had been made to plant 1000 hectares of grapefruit trees. The decision to proceed with this, however, depended largely on the results of drilling a few trial wells and carrying out pumping tests on them. An adequate supply of well-water would be essential as it was recognised that there is insufficient water available in the river from January to March to allow embarking on any more perennial cultivation which depended on the river alone. There were no plans to further increase the area planted to sugar cane.

89. At the present time the supply in the dry months is augmented by a surface reservoir of approximately 600,000 cubic meters capacity. This reservoir is formed by canal embankments on three sides and by an embankment specially built for the purose on the fourth. The present intention is to construct a second such reservoir of about 500,000 cubic meters capacity.

90. The average yearly water consumption during the period 1957 - 1963 was approximately 2200 hectare meters. This is based on an average of 1400 hectares of sugar cane under cultivation during that time. The area planted to cane was sharply increased in 1964 and again in the following year to the figure given above. The

TABLE 6

ANTICIPATED INCREASES IN MONTHLY WATER REQUIREMENTS

Mahaddei Uen to Balad

1000's of Hectare Meters

Crops:	J	F	M	A	M	J	J	A	S	O	N	D
Sugar	.56	.56	.56	.56	---	---	.56	.56	.56	---	.56	.56
Grapefruit	.08	.08	.08	.165	---	---	.165	.165	.165	---	.165	.165
Cotton	---	---	---	---	---	---	---	.225	.295	.315	.26	.215
Totals	.64	.64	.64	.725	---	---	.725	.950	1.020	.315	.985	.940

increase in the quantity of water required appears in the tabulation of anticipated increases, Table 6.

91. At the time of writing it was understood that fairly definite plans existed to grow, under irrigation, about 1000 hectares of cotton upstream of Johar as part of the supply required for the proposed textile mill to be built near Balad. For present purposes it will be assumed that these plans will be implemented.

92. Tabulated in Table 6 are the estimated increases in future monthly water requirements which must be subtracted from computed present monthly flows downstream in the process of deriving net available water for further developments.

93. The water requirements for the sugar have been computed on the basis of the present irrigation practice at Johar. This has been developed from experience and is based on irrigating in every month except May, June and October when the rainfall is adequate in normal years. There are 10 irrigations in the cycle and water is drawn from the river at the rate of 1400 cubic meters per hectare per irrigation. This is assumed to provide 1000 cubic meters per hectare, allowing for losses.

94. It is understood that grapefruit would be irrigated at the same rate and in the same months as the sugar cane but from 50 per cent to 100 per cent of the water requirements in January, February and March would be met from wells. The former allowance is made above.

Balad to Afgoi

95. As stated previously, there is no overbank spillage in this stretch of the river and hence no inundation irrigation, with one exception. A canal, 5.7 kilometers long, has been built on the north side of the river about 10.5 kilometers from Balad. It appears that the river level has seldom been high enough to flood the land it was intended to serve but a few hundred hectares may be inundated in exceptional years.

96. Between Afgoi and a point approximately 9 kilometers upstream, about 600 hectares of cultivated land are supplied with water by pumps from the river throughout the whole year as the water never rises high enough for gravity command. Bananas are the basic crop though some maize, sesame, vegetables and a little sorghum are grown. Assuming approximately 400 hectares of bananas the total average monthly water demand in this area would be in the order of 150 hectare meters.

97. There are no known plans for large scale expansion of such irrigation but for the purpose of estimating near future water requirements along this stretch of the river it will be assumed there will be a 25 per cent increase on the present use.

Afgoi to Audegle

98. Inundation irrigation is carried on fairly extensively on both sides of the river along about one half the channel distance between these two stations. It is particularly intensive along the last 10 kilometer stretch between Barire and Audegle. The total area inundated occasionally is about 6000 hectares and in an average year about 3000 hectares.

99. The topography along this stretch is as favourable to extensive inundation as that between Mahaddei Uen and Balad. It will be seen from Table 5 that the median monthly losses in the latter stretch are approximately double those in the stretch

under consideration and the channel lengths are in the same proportion.

100. Losses during periods of high discharges do not increase to quite the same extent as in the upstream stretch but they are considerable. Moreover the excess water tends to flood the farmland in this case as, generally speaking, there are no depressions beyond to receive it. An exception is the relatively small and slightly depressed area south of Audegle which often remains marshy during most of the year.

101. Apart from the inundation irrigation in proximity to the river there are approximately 300 hectares inundated on rare occasions by a relatively large canal extending 11.5 kilometers south of the river from Barire. This canal is provided with gates but the sill of this structure appears to be at too high an elevation for average high water levels. In any event an apparent total lack of maintenance has resulted in it having even less usefulness than the limited degree it might otherwise have.

102. Controlled irrigation with water pumped from the river, which is carried on upstream and in the vicinity of Afgoi, continues sporadically to Audegle and beyond. That in the vicinity of Afgoi is long-established, with a total of over 4000 hectares in concession farms the owners of which belong to S.A.C.A., a banana marketing cooperative discussed elsewhere. In recent years pump-irrigated farms have been started downstream by Somali farmers, both in the form of cooperatives of indigenous cultivators and as investments by absentee landlords. The latter type of development is increasing at a fairly rapid rate. In 1965 there were about 350 hectares of bananas and an equal area of other crops, chiefly maize, being pump-irrigated between the two villages.

103. The estimated monthly water requirements of this cultivation for which allowance must be made are given in Table 7. In the same table are given the estimated quantities required to maintain the present level of inundation irrigation. The latter figures are modifications of the desirable rates of application to conform to the probable effective availability of water, which depends entirely on the river levels relative to the land to be inundated.

Audegle to Falcheiro

104. Between these stations lies approximately 50 per cent of all the inundation-irrigated farmland of the Shebelle valley and approximately 70 per cent of the land farmed with controlled irrigation. The latter will be considered first.

105. Downstream from Mobarech, a village 14 kilometers downstream from Audegle, is the core of the agricultural development in this area and of the irrigation complex of the Societa Azonaria Concessionari Agricoli (S.A.C.A.). The original downstream limit of this concessional area is shown approximately on Map 10.

106. Within this area 182 farms of varying sizes were demarcated initially, a number of them being formed of two widely separated plots. The total area of these is 30,261 hectares, and the holdings vary in size from 40 hectares to 621 hectares, the average being approximately 166 hectares. These were originally all owned by Italians but at the present time about 15 are owned by Somalis. Relatively recently a further 49 farm concessions were formed, all Somali-owned. The areas of these are not available but it is believed they average about 60 hectares each. About 60 per cent of these are located along the northern edges of the original concessions and the remainder are scattered over a large area beyond the western extremity. The total area owned by members of S.A.C.A. is thus now about 33,250 hectares.

TABLE 7

ESTIMATED IRRIGATION WATER REQUIREMENTS

AFGOI TO AUDEGLE

1966 - 1969

Hectare-meters

	J	F	M	A	M	J	J	A	S	O	N	D
Controlled Irrigation												
Bananas	75	70	80	60	70	60	60	75	70	80	60	80
Other Crops				70	100	60	40	55	130	100	80	60
Inundation Irrigation					1300	450	400	200	1100	750	850	250
Total	75	70	80	130	1470	570	500	330	1300	930	990	390

107. Virtually the whole of the original area was at the outset irrigated by a system of canals radiating from a point immediately upstream of a dam sited at the village of Genale. There were three main canals on the right bank and seven on the left. A small portion of the land was irrigated by pumping water from the river into some minor canals at both the upstream and downstream ends of the area. Because the basic crop was bananas, which require water throughout the whole year, it was necessary to store water in surface reservoirs to carry over the period January to March when there is usually insufficient water and occasionally none.

108. In most of the past twenty-five years there has been inadequate maintenance of the canals and during many years none at all. As the Shebelle water is extremely turbid during flood periods many of the canals became filled with sediment. As a result of this and of uncontrolled growth of vegetation many kilometers were rendered completely useless. For this and other reasons a large number of the farms were entirely abandoned and others became only partially utilized.

109. A major cleanout of a number of the main canals was carried out in 1955. Thereafter little was done until 1965 when So. Sh. 1,200,000 was spent on cleaning and repairing about 60 kilometers of main canals, chiefly the Riva Destra, the Primo Secondario, the Coriole and the Bulo Bocore. This only partly checked the steady deterioration of the area which has taken place since the second World War. At the middle of 1965 there were 80 farms comprising about 33 per cent of the concession area completely unutilized, and of the farms being operated over 50 per cent of their total area was uncultivated.

110. Map 10 shows the inoperative canals and portions of canals, the farms which have been abandoned and, diagrammatically, the factions of the operating farms which are not cultivated.

111. In 1955 the Italian Administration began work on the Bulo Mererta Project with the stated intention of bringing 25,000 hectares under irrigation downstream from the existing development. Under this scheme it was intended to build three dams, at Gaivero, Coriole and Falcheiro to provide the head for a largely gravity-commanded system. Approximately half of the total area was to be north of the river and of this about 5000 hectares were to be served by a new main canal, the Coriole Canal, and the remainder by a series of short canals sited at intervals from Gaivero to many kilometers beyond Falcheiro. Those above the dam at the latter point were to be supplied by gravity; those below were to depend on gravity or pumping, according to the varying seasonal water levels.

112. The other half of the total area, south of the river, was to be served entirely by gravity through systems based on two main canals, the Fornari and the Bulo Bocore, and a few supplementary minor canals.

113. With very few maps available of the land to be irrigated, the total of 25,000 hectares had to be an estimation.

114. The three main canals were designed entirely on the basis of levels run along their arbitrarily chosen alignments. Construction was started in 1955 and completed by 1959. During this same period the Coriole and Falcheiro dams were built and the levees along the river banks upstream of them were raised. The dam at Gaivero was not built.

115. The Coriole canal, 5 kilometers in length, was completed in 1958 but, lacking topographic data, only a few laterals were constructed and these were located haphazardly. By 1960 silt deposits had considerably restricted the flow of water but

no maintenance was carried out until 1965 when it was thoroughly cleaned, re-shaped and lengthened to 6.5 kilometers. It was originally designed to serve 5000 hectares but at the time of writing only approximately 500 hectares of concession land were linked with it. However, in the 1965 Gu season some 1200 to 1500 hectares of maize were inundated by water from this canal as part of the extensive inundation irrigation carried on in the vicinity, which is discussed later.

116. The Fornari canal, 12.5 kilometers long, required the proposed dam at Gaivero to provide sufficient head for it to function properly. Without the dam the river level would seldom rise above the sill of the intake structure; only extreme floods would provide the 1.5 meter depth required for the design capacity of 11.5 cubic meters per second. Within a few years after its construction siltation had raised the level of the bottom until it became totally inoperative. It remained so until September, 1965 when a few kilometers of the upper end were cleaned out. It is not known how many hectares it was intended to serve. Its capacity is roughly that required for 11,500 hectares but not more than half this area lies within its zone of possible command.

117. The Bulo Bocore canal, 15.8 kilometers in length, was designed to carry just over 10 cubic meters per second but only four relatively small secondaries were built and these, in 1965, were serving only approximately 600 hectares. It is understood that the main reason why it has never been used to capacity is that there were and still are insoluble problems of land ownership in the area of its command. In any event its capacity had been seriously reduced by siltation in the upper half of its length and by siltation and vegetation in the lower half by 1965. During the first half of that year it was completely cleaned out and reinstated as part of the program referred to above.

118. About 30 of the new group of concession farms, mentioned previously, came into being as a result of the Bulo Meretta Project. However, as nearly as can be determined from analysis of incomplete data and considerable field investigation, the Project has resulted in the addition of less than 1000 hectares of land in operating farms, much of which area is uncultivated. It also provides periodic inundation irrigation for a maximum of about 3500 hectares.

119. Apart from the controlled irrigation carried on in the original concession area and the subsequent extensions within S.A.C.A. there has been, in recent years, considerable development between Audegle and Mobarech depending on water pumped from the river. It is estimated that a total of about 350 hectares is irrigated in this way.

120. The total area therefore which is theoretically being farmed with controlled irrigation between Audegle and Falcheiro is thus approximately 33,600 hectares. This is currently being used as follows;

Cultivation of bananas	5.700	hectares
" " maize	4,000	"
" " other crops	800	"
Uncultivated land on operating farms	11,275	"
" " " non-operating farms ..	11,825	"
Total	33,600	hectares

121. From the total of 23,100 hectares of uncultivated land a maximum of 5 per cent of the area may be subtracted for buildings, farm distributaries, etc. as roads and main secondary canals are not included in this area. A further 3 per cent may be subtracted for land unsuitable for cultivation due to soil structure and/or texture; it is understood that there has been no significant loss in area through

salinity problems. Hence there are approximately 21,000 hectares of cultivable land which at one time or another was irrigated and which is not now in use.

122. The future water requirements for controlled irrigation in the whole area under consideration will obviously depend on whether or not there is any substantial change in the fraction of the area actually cultivated and on the type of crops grown. For present purposes the water demand has been computed on the basis of the following assumptions:

(a) The area planted to bananas will rise to 6000 hectares and will not increase beyond that in the foreseeable future. It is understood that new methods of cultivation now being introduced are expected to double the production of bananas per hectare and that sales of more than double the present total are not envisaged as a possibility for very many years.

(b) The area planted to maize and other crops will remain relatively unchanged, barring a change in Government policy. A Government directive brought out in June 1965 laid down a schedule of required cereal production related to the size of banana quotas held by each farm. The present area of maize cultivation alone is slightly in excess of the official requirements.

(c) Approximately 3000 hectares of cotton will be grown on a quota system by the banana growers. This proposal is part of the present plans for the supply of cotton to the textile plant that is to be built near Balad.

123. Based on these assumptions the estimated average monthly water requirements in the Genale area over the next three years have been calculated and are given in Table 8. In each case the quantities are those which must be drawn from the river, when available, and include the appropriate allowance for losses. During the first three months of the year there will seldom be sufficient water in the river at this point and wells will supply lesser quantities, for the minimum necessary to maintain the crops.

124. Wells with static water levels varying from about 5 meters to 60 meters have been used increasingly in the past few years to make up water shortages when required and they have largely taken over this function from surface reservoirs. The latter, while extensively used at one time, are infrequently employed now despite the considerably higher cost of well-water. They had the obvious drawback of occupying large areas of land and, due to the high permeability of the soil in many localities, the water loss was often between 3 centimeters and 5 centimeters of depth per day.

125. Contiguous to the area under controlled irrigation are roughly 14,700 hectares which must be categorised as inundation-irrigated farmland. This is the total area which, it is estimated, receives at least one inundation in each Gu and Der season under average conditions. Occasionally a considerably greater area than this may be flooded, at other times less, the latter being the case particularly in the Gu season.

126. It is apparent from aerial photographs taken at different times, and from field inspection, that the specific areas, and the total area, under crops vary widely from season to season. It is also clear that there has been a steady increase in the area cleared and brought under cultivation. However, lacking up-to-date photography, maps or land records, it has been found quite impossible to form an accurate picture of the situation. This is unfortunate as it is clear that this is one of the most important agricultural areas dependent on the Shebelle, with a large and growing water requirement.

TABLE 8

ESTIMATED IRRIGATION WATER REQUIREMENTS

AUDEGLE TO FALCHEIRO, 1966-1969

Hectare-Meters

CROP	J	F	M	A	M	J	J	A	S	O	N	D
Controlled Irrigation[1]												
Bananas	1520	1430	1610	1210	1430	1140	1160	1510	1410	1580	1240	1580
Maize (2 crops)				140	823	690	660	390	1110	815	608	445
Cotton								670	890	945	667	628
Other Crops				140	155	140	140	175	170	175	150	175
Sub-total	1520	1430	1610	1490	2408	1970	1960	2745	3580	3515	2665	2828
Inundation Irrigation[2]					3410	1730	650	425	3080	3729	2000	660
Total	1520	1430	1610	1490	5818	3700	2610	3170	6660	7244	4665	3488

1. Figures given are actual crop requirements.
2. Figures given are allowances based on crop requirements - see text.

127. While much of the total area, particularly the portion on the fringes, far from the river, is farmed in a haphazard fashion in small plots and may receive river water only occasionally, a great deal is scarcely distinguishable from the land within the concession area. The latter, bordering on the concession farms and often on a main canal extending beyond these farms, is to all intents and purposes being farmed under controlled irrigation. The farms are usually large and mechanised, and while many may be owned and operated by groups of local farmers, tribal or cooperative, an increasing number are owned by absentee landlords.

128. Estimates of the water requirements of existing cultivation must take into account the needs of these farms as being of almost equal importance to those of the concession area, as far as crops other than bananas are concerned. From the appearance of the crops of maize in 1965 it would seem that production per hectare is relatively high and that the nature of this inundation irrigation farming is totally different to that upstream.

129. The foregoing remarks are mainly applicable to the 10,500 hectares of this farmland which stretches in a broad belt along the northern edge of the concession area from the vicinity of Mobarech to just beyond Coriole. Perhaps half of this falls within the category discussed above and, when computing water needs, it has been considered that 80 per cent of this will be put under crop each season.

130. Within the rough quadrilateral formed by the river on the north, the Bulo Bocore canal on the west, the Fornari canal on the east and the Gofca canal on the south are approximately 3000 hectares out of the total. This land is partly irrigated more or less regularly from canals supplying concession farms and partly by occasional flooding through hand-dug ditches at times of very high water.

131. South of the Gofca canal are the final 1200 hectares, surrounded by an equally large area of dry farming land which, though it may periodically receive some inundation, cannot properly be considered in that category. This land depends partly on surplus water from the canals supplying concession farms in this area and partly on flood water diverted down the Bulo Bocore canal into the old channel of the Uebi Gofca.

132. Estimated monthly quantities of water for which allowance should be made to maintain the present level of production are given in Table 8. In arriving at these extremely tentative estimates it was assumed that maize would be the only crop and that 10,000 hectares would be planted in the Gu season and 12,500 hectares in the Der. The theoretical water requirements were computed as for controlled irrigation.

133. There would normally be no water surplus to the requirements of the concession area in April, particularly as the first part of the rising spring flows occurring in that month are excessively saline and cannot be used for irrigation. Hence no water is shown as being supplied in that month and the requirement in May was increased appropriately. The allowance for July and August were arbitrarily reduced and those for September and October increased accordingly. November's allowance was reduced slightly and that for December drastically. The water that can be made available in this last month will be critical in the expansion of controlled irrigation, and that in August only slightly less so.

134. While this approach is admittedly very arbitrary it is considered that, while it appears to be necessary to allow for the water requirements of this semi-controlled inundation irrigation, such allowance must not be permitted to jeopardize the development of the maximum possible area of controlled irrigation. It is unfortunate that this relatively large scale unofficial use of water has become so

firmly established as it may be taken for granted that in general it is not being used with the efficiency that the Shebelle water should be used. It is strongly recommended that measures be taken to prevent further expansion of this as once started it is politically difficult to stop. In the cases where this usage now exists efforts can be made in due course to improve efficiency as part of an overall program of water control, which is basic to the development of this river.

135. It is obvious that water is being applied at present as and when it is available. This means that the Gu season crop probably receives only one flooding in May and usually depends entirely on rainfall in June and July. In the Der season there is normally a scarcity of water only at the beginning and end of the period, i.e. in August and December. In these months the available quantity applied to the land will be limited. In the intervening months there will usually be no limitation other than the farmers' judgement, which may or may not be sound. There is at present no method of measuring the rate of application nor can there be in the immediate future. Hence, while the water used by all the crops in the concession area can be predicted with a fair degree of accuracy, that used in the adjoining inundation farming area cannot. In view of this it is reiterated that the figures given in Table 8 are, as they must be, very rough approximations. They have consequently been considered to be reasonably elastic in later derivations of quantities available for future development.

Falcheiro to End of River

136. The inundation farming which is carried on upstream of Falcheiro continues downstream for a distance of approximately 6 kilometers, ending at the edge of the swamp. There are approximately 2800 hectares which may be considered to be irrigated periodically as a result of water passing the Falcheiro control gates. Most of this land is normally not inundated by the Gu season high water as a very large quantity must pass the gates to produce overbank spillage downstream. Such crops as are grown in this season are usually dependent on rainfall and in 1965 not more than 25 per cent of the area was under crop. In most years there will be flooding in the Der season, however, though probably not more than half the area would be inundated in the median year.

137. Such irrigation in the past has been practically the only benefit which has been derived from the annual loss in the swamps of very large quantities of water. Apart from this relatively minor benefit, this water provides a little stock watering along the edges of the swamps, very occasionally inundating small areas in the vicinity of Avai. This water also periodicaly recharges pools, water holes and shallow wells along the river's course to its termination.

138. Though these benefits extend over a large area they are of relatively limited economic value and the price paid to obtain them has been a complete waste, in the swamps, of approximately 75,000 hectare meters of water in the median year. The elimination of as much of this wastage as possible must be one of the prime aims of a development plan for the Shebelle. As far as it is feasible the only water which should pass Falcheiro should be such peak flood flows as cannot be diverted to use upstream, and the excessively saline water of March and April.

139. In the latter connection conductivity curves and chemical analyses of samples from all gauging stations are provided in Volume 2. These data show that the conductivity, as indicating total salt content, is normally higher than is acceptable for irrigation in March, April and, in some years, in the first week of May. This is on the basis of the widely accepted limitation of a maximum of 1,000 micromhos/centimeters as being tolerable by most plants under most conditions. During the remainder of the year, however, the salinity is at an acceptable level, and

the first flood waters salinity problems at Johar, Afgoi and Genale have been avoided, except in rare instances. Moreover, generally speaking, the soils of the areas herein proposed for irrigation are relatively permeable, the water table is very low and if salts did in time accumulate there would be no difficulty in leaching them out.

140. It is suggested that no allowance should be made for any water requirements downstream of Falcheiro. It is possible that a good part of the indigenous cultivation immediately downstream could be provided with seasonal floodwaters through canals taking off from above the Falcheiro control gates. This would not be controlled irrigation, in the proper sense, but should provide water no less frequently than overflows do at present. Though less water would be available it would be brought onto the land at a higher level and coverage would be improved.

141. Beyond the Swamps, to the river's end, uars could be constructed and wells if possible, to offset the reduction in natural water supplies where they are dependent on the river.

PROPOSALS FOR DEVELOPING THE FULL POTENTIAL OF THE SHEBELLE

Full Regulation and Development Possibilities

Site and Size of Required Reservoir

142. The best way to develop the full potential of the Shebelle River would obviously be to regulate its flow by means of a dam, control gates and a reservoir of sufficient size to level out the wide monthly and annual flow variations discussed above. Such a reservoir would preferably be sited as far upstream as possible in order to obtain maximum flood control and reduce losses to a minimum.

143. Unfortunately there are no good dam sites on the river in Somalia. There is, in fact, only one site which justifies study. This is at a point approximately 25 kilometers upstream from Bulo Burti. Here the low hills which define the valley from just north of that village to the Ethiopian boundary are about 9.5 kilometers apart and the closing of this gap with a dam would be aided by a knoll which lies between. Above this point the valley widens to over 20 kilometers for a considerable stretch, forming a superficially attractive reservoir site. The location of this is shown on Map 6.

144. Preliminary mapping of this area was carried out by the Survey and Mapping Department of the Government of Somalia. Sufficient levels were run to prepare a map of the reservoir area to a scale of 1:30,000 with 5-meter contours, based horizontally on uncontrolled photo mosaics. Adequate vertical control was established to enable a map of the proposed dam site to be prepared by photogrammetric methods. (Maps 7 and 8). All rough designs and computations were based on these, their accuracy being considered adequate for the present purposes.

145. As anticipated it was found that the reservoir would be exceptionally shallow and therefore have a very large evaporative area relative to its volume, as may be seen from the area and capacity curves appearing on Figure 1. For the same reason, and because the volume of water stored would be small, seepage losses would be significant. The latter is not usually the case but in this instance the losses, though not great in an absolute sense, would be large in relation to the inflow and would appreciably reduce the outflow.

146. Monthly total flows at Bulo Burti were derived from available data for the period 1954-64. A mass curve based on these indicates that a reservoir with a capacity of 220,000 hectare meters would have been required to regulate the total flow during this period to a uniform discharge at the outlet to 58.4 cubic meters per second. This is the theoretical average discharge over these eleven years, without taking into account losses due to evaporation and seepage.

147. When these are taken into account a much less encouraging situation is revealed. A modified mass curve was prepared incorporating an assumed evaporation loss of 175 millimeters per month, a seepage loss equal to this but reduced by a 25 per cent return due to bank storage, and a direct rainfall contribution of 400 millimeters per annum. This showed that in the same period the net outflow from such a reservoir would have been 1,186,760 hectare meters, giving an average annual flow of 107,887 hectare meters. This is equivalent to a uniform average rate of discharge of 34.2 cubic meters per second. A reservoir of 176,000 hectare meters capacity would have been required to provide this regulation.

148. This 11-year period, however, cannot properly be used in estimating water available for irrigation developments as it includes two years (1961 and 1963) of exceptionally high total annual flow: 260,900 hectare meters and 256,700 hectare meters respectively. Insufficient data is available to determine with any accuracy the probabilities of such occurrences. However on the slight evidence of this period it might be assumed that such flows would occur in the 15 per cent year. Conforti in his report* has tabulated annual flows at Mahaddei Uen for the period 1918 to 1933. These indicate that annual flows of over 250,000 hectare meters might be expected in the 10 per cent - 15 per cent year.

149. A reservoir of sufficient size would, of course, store such high flows but only at the cost of a greatly increased evaporative area and wetted surface subject to seepage losses. Moreover, they would be so infrequent and undependable that the extra flow that would be available from time to time could not in practice be used. Taking all relevant data into account it appears prudent to consider the period 1954 - 1959 only, this being the most representative sequence of years for which records are available.

150. In this case a reservoir of approximately 130,000 hectare meters would have been required for regulation. There would have been an average annual outflow of 92,000 hectare meters and the equivalent average rate of discharge would have been 29.2 cubic meters per second. Hence, for the purpose of examining the economics of damming the Shebelle, it will be assumed that a dependable flow of 30 cubic meters per second could be made available at Bulo Burti if a dam were built which would provide a reservoir of the last-stated capacity.

151. At this point another negative feature of the situation must be taken into account. As has been mentioned previously the Shebelle River is extremely turbid during periods of high flow and sedimentation of the reservoir would be a serious problem. While some sediment sampling was carried out during the last year of this project,insufficient data was obtained to attempt to make a meaningful quantitative estimate of the sediment content at varying discharges and to prepare a sediment rating curve. Without such data any estimates made should be considered tentative

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* La Valle dell' Uebi Scebeli - Dr. E. Conforti - 1955.

and the assumptions arbitrary. However, taking into account the rate of sedimentation of irrigation canals, and considering the fact that the reservoir would be exceptionally small in relation to the size of the drainage basin of the river, it appears necessary to assume that there will be a 2 per cent loss in reservoir capacity per annum.

152. As the capacity of 130,000 hectare meters includes no dead or inactive storage the initial capacity would have to be larger than this to provide proper functioning over at least the full term of the amortization period. If this is taken to be 50 years the constructed capacity would have to be 260,000 hectare meters if the required effective capacity were to be available to the end of that period.

153. Such a capacity would necessitate allowance being made for an eventual normal pool level of 166.9 meters. Considering the extreme length of the dam no allowance would be made for a higher flood level after the end of the 50-year period. It would be more economic to provide sufficient gated outlet capacity to pass extreme flows without a rise in level. Hence, if 2.6 meters are allowed for freeboard the required crest height of the dam would be 169.5 meters.

Design of Dam

154. No detailed geological and soils study of the reservoir and the proposed dam site have been made. The only sub-surface information available is provided by the log of a well drilled about 700 meters from the proposed axis of the dam. This reveals a 9-meter depth of sandy clay overlaying 18 meters of sandy marls on top of 12 meters depth of sand. It may be that the sandy clay is much shallower than this along much or all of the dam axis and that underflow would present problems. Only a detailed drilling programme can provide the answer to this important question but for present purposes it will be assumed that a dam would be technically feasible as far as foundation conditions are concerned.

155. A known adverse feature of the proposed reservoir area is the presence of large gypsum deposits in the vicinity. Depending on their size, location and degree of exposure these could both provide leakage paths and have a deleterious effect on the quality of the water for irrigation purposes. Only a very thorough examination, surface and sub-surface, of the whole of the area to be submerged will determine how serious this condition is. However, no outcrops of gypsum were observed in the vicinity of the dam site or along the parts of the edges of the reservoir examined during this investigation. Further, the floor of the proposed reservoir, which would account for at least 85 per cent of the wetted surface, is now covered with a blanket of alluvial deposits which would become thicker and more watertight as sedimentation took place.

156. Superficially it appears that there would be no unusual problems in constructing a homogeneous earth dam from the sandy clay of which the alluvial soils largely consist in the vicinity of the site; and a zoned earth fill would be available for an impervious zone. For the purpose of the present estimates it has been assumed that upstream and downstream slopes would not need to be flatter than 2½:1 and 2:1 respectively. These are minimum slopes and if a soils investigation indicated that flatter slopes would be required the cost would rise appreciably.

157. It must be assumed that a substantial filter drain under the downstream toe would be necessary and while rock for this could be quarried and crushed in the immediate vicinity a large quantity would be required and considerable cost involved. Because of the extreme drawdown range, the area of upstream-face rip-rap would be unusually large. Again this could be quarried locally and it has been assumed that the

appropriate percentage of the larger fragments needed for satisfactory gradation would be obtained without too much expense. This is not certain as out-crops show considerable jointing and hidden planes of weakness might result in a poor yield of large sizes from normal quarrying operations.

158. The spillway and outlet structure could be founded on rock which is exposed on the right bank of the river on the selected dam axis. Considerable grouting might be required both in the foundations and in portions of the adjoining knoll. A nominal allowance for this has been made in the estimates. It should be understood that the incorporation of the knoll in the alignment of the dam might not prove to be economical. The badly jointed limestone of which it appears to be mainly formed might, on close investigation, reveal the need for excessive and uneconomic grouting to render it sufficiently watertight. A thorough drilling programme would be required to determine this.

159. Little data is available of flood frequency and magnitude on the Shebelle. For estimating purposes it was assumed that it might be necessary to handle 300 cubic meters per second, with the reservoir full. A simple structure was designed for costing purposes which incorporated two gated outlet pipes which would discharge 40 cubic meters per second for irrigation purposes, with the reservoir at lowest operating level, and an overflow spill-way capable of passing 260 cubic meters per second with the reservoir at a maximum level of 166.9 meters. The latter would be provided with radial gates.

160. The site, plan and typical cross section of the proposed dam are shown on Map 8.

Estimated Cost of Dam

161. In the estimated cost of the dam only the items which are significant in terms of cost have been included. The quantities may be taken to be accurate to within plus or minus 10 per cent. The unit prices used are conservative if the foregoing assumptions are correct. The allowance for engineering and contingencies may be taken to include the cost of the feasibility study necessary before a decision on this project could be taken. Such a study, if the dam were found to be feasible, would provide the final design in general outline and an accurate revised cost estimate. The cost estimates for the Shebelle River Storage Dam is shown in Table 9.

162. Though this dam would be expensive in terms of the size of the reservoir produced and the quantity of water stored it would provide water under controlled flow at the outlet at a cost of approximately So. Sh. 50 per hectare meter. It is shown in a later section of this Volume of the report that under certain conditions, and assuming certain irrigation development, its construction would be economically feasible.

163. However it has yet to be proved that it is technically feasible and, if so, that the assumptions on which this estimate is based, and the indicated project's economic feasibility, are reasonably correct. This present examination has, nevertheless, proved that a feasibility study of this project is fully justified. Among the matters which are normally investigated as part of such a study, the following would require the expenditure of considerable time and money for their thorough investigation:

(a) The probable rate of sedimentation of the reservoir. It is believed that this is the one feature which might render this project uneconomic. The determination of this will require a thorough and carefully controlled

TABLE 9

ESTIMATE OF COST - SHEBELLE RIVER STORAGE DAM

ITEM	UNIT	QUANTITY	UNIT PRICE So. Sh.	AMOUNT So. Sh.
Clearing and Stripping	Sq.m.	679,000	2.00	1,358,000
Excavation Rock	cu.m.	2,000	40.00	80,000
Compacted Earth Fill	cu.m.	5,310,900	5.00	26,554,500
Filter Drain	cu.m.	151,800	60.00	9,108,000
Rip-Rap	cu.m.	328,900	90.00	29,601,000
Mass Concrete	cu.m.	4,400	350.00	1,540,000
Reinforced Concrete	cu.m.	1,575	450.00	708,750
Reinforcing Steel	Kg.	87,500	3.00	262,500
Outlet pipes and gates	Sum.			160,000
Spillway radial gates	Sum.			110,000
Gate operating equipment	Sum.			75,000
Allowance for grouting.	Sum.			200,000
Clearing reservoir area	ha.	40,000	200.00	8,000,000
Acquisition, compensation and resettlement	Sum.			500,000
TOTAL				78,257,750
Engineering and contingencies @ 30%				23,477,325
TOTAL				101,735,075

The annual cost of amortization over 50 years @ 4% interest 4,069,403 sedimentation sampling programme to be carried out over the next few years. It is essential that many samples be obtained for analysis at all seasons and over the widest possible range of discharge rates. To do this properly, a sampling station at Bulo Burti, will have to be established, manned by competent and completely dependable personnel. The project cannot be seriously considered until this data is available.

(b) The foundation conditions on the proposed dam site. This would include a very extensive drilling programme in both the alluvium and the rock. Considering the length of the dam this would be time-consuming and expensive.

(c) The location and size of gypsum deposits and their possible harmful effects.

(d) The availability of the required large quantities of rock suitable for the rip-rap and filter drain. This would include trial blasting and crushing to ascertain the breaking characteristics of the local limestone and, if it were found to be unsatisfactory, a suitable quarry site would have to be located elsewhere.

(e) The effect upon irrigation developments of the inclusion in the water supply of at least some portion of the excessively saline water normally flowing in March and April. The high salt content of the water in those months has not hitherto presented a problem as it has been possible to divert it into the swamps downstream of Falcheiro. The alternative methods of dealing with this under controlled conditions will require considerable study.

164. It is recommended that a feasibility study be commenced as soon as sufficient sediment data has been collected and adequate mapping of the reservoir area has been completed.

Consequent Irrigation Development

165. Control within Somalia would, as has been shown, provide a minimum dependable average annual flow downstream at Bulo Burti of 95,000 hectare meters. In this case approximately 50 per cent of the inflow to the reservoir has been taken as being lost by evaporation and seepage. As sediment deposits build up it is probable that the seepage loss will be reduced. To be conservative, no such decrease and consequent increase in available water has been assumed in calculating the benefits.

166. To derive the net quantity that would be available for expanded agriculture it is necessary to subtract the channel losses between the reservoir outlet and the point of use and also the requirements of present and immediately planned controlled irrigation. The first would amount to approximately 11,850 hectare meters per annum if the point of use were taken to be downstream of Afgoi. The second would total about 31,000 hectare meters. This would allow for 6,000 hectares of bananas, 5,000 hectares of sugar cane, 4,000 hectares of cotton and 1,000 hectares of grapefruit. The annual quantity available for new development would thus be in the order of 42,000 hectare meters.

167. As this could be provided at a uniform rate throughout the year it would obviously be desirable to apply it entirely to high-value perennial crops, such as bananas, sugar cane or grapefruit. These would show the greatest increase in agricultural benefits. They would also require the highest degree of farming competence and organisation to obtain the optimum yields and, more important, would require the

establishment of markets and marketing arrangements for commodities for which much uncertainty about the future exists.

168. Hence the economic benefits of controlling the flow of the Shebelle have been calculated on the basis of two alternative types of irrigation development which might make use of the water. In the first case it is assumed that all the water would be applied to growing bananas, as the crop which would be most likely to provide the highest return if all necessary conditions were fulfilled. In the second case it has been assumed that, except for 20 per cent of the land sown to alfalfa, no perennial crops would be grown. Instead two crops a year would be planted of rice, maize and tomatoes, these being selected in order to make an easy comparison with the increased benefits possible without river regulation, as discussed and estimated in a later section of this volume of the report. The possible benefits resulting from the construction of the dam should then lie somewhere between these approximate upper and lower limits.

169. The first alternative would result in the addition of 15,100 hectares of bananas, and this would require the development of 19,000 hectares of new land to maintain that level of production annually. The average yield should be not less than 300 quintals per hectare per annum and it is considered safe to assign an at-farm value of So. Sh. 35 per quintal. This would enable these bananas to be marketed competitively if the farm-to-consumer costs were brought into line with those of other banana-producing countries. The gross annual value of this crop would thus be So. Sh. 158,500,000.

170. In order to compare the benefits of fully regulated flow with those obtainable from maximum development of unregulated or partially regulated flow, which are estimated hereinafter, certain deductions must be made. Full regulation would mean an end to inundation farming along the Shebelle; land now so used would presumably revert to dry farming. The consequent drop in annual income of the farms concerned has been estimated to be in the order of So. Sh. 660,000. Further, in later computations of water requirements to maintain present agriculture, as part of a programme for maximum development with uncontrolled flow, an allowance is made for 4000 hectares on concession farms in the Genale area producing two crops of maize per year. This would not be included under the controlled conditions assumed above and there would be an appropriate reduction in the gross annual value of crop production on the land already being farmed of So. Sh. 10,800,000. The approximate net increase in the annual value of agricultural production would thus be So. Sh. 147,000,000.in the first case.

171. In the second case it has been assumed that the available water would be applied to 14,250 hectares of maize in the Gu season, the same area of rice in the Der season, two crops of tomatoes on 950 hectares and 3800 hectares of alfalfa. This would require the development of 19,000 hectares in all.

172. The estimated total annual value of these crops would be So. Sh. 65,910,000. After making the same deductions as above this would leave a net annual increase in value of produce of So. Sh. 54,450,000.

173. Estimates are derived hereinafter which show that it is possible to increase the annual value of crop production based on the Shebelle by not less than So. Sh. 41,500,000 without a dam. As the annual cost of amortization of the dam would be in the order of So. Sh. 4,750,000 it is apparent that under certain conditions the construction of the dam would be justified if it were found to be technically feasible.

174. Its' economic feasibility is discussed in detail as part of the overall

economics of the development of the Shebelle which are considered in the final part of this section of the report.

Partial Regulation and Development Possibilities

175. On the assumption that it may not prove technically feasible to dam the Shebelle other steps should be considered to make maximum possible use of its water, in full recognition of the fact that no other measures can provide equal economic benefits. Such measures will fall into one of the following three categories:

(a) Making optimum use of all dependable flows in the 75 per cent year in controlled irrigation system.

(b) Diverting peak flows which occur in certain months and which cannot be used for such irrigation into areas where maximum benefits may be derived.

(c) Ensuring that such inundation irrigation as must be carried on produces the highest possible yields.

180. Recommendations for the implementation of the foregoing are discussed hereunder.

Development of Controlled Irrigation

Available Water

181. It is proposed, for reasons which are discussed hereinafter, that all future development be carried out downstream of Afgoi. The quantities of water available are given in Table 10. While the basic computations have been made for the 75 per cent month in each case, the quantities that would be available in the 50 per cent or median month are also tabulated as there is a very significant difference in some months, particularly May, August, and December.

182. It is apparent from these figures that no more land can be brought under perennial irrigation which is based on water from the Shebelle only. Even the area at present planted to the perennial crops, sugar and bananas, cannot be supplied with all its water requirements without recourse to well-water during several months of the year. Under present arrangements the sugar plantation at Johar has first call on the river water and there is normally sufficient, aided by a certain amount of flood-water storage in surface reservoirs. The shortage is felt in the Genale area and due to the unusually high value of the banana crop it has been possible to accept the cost of pumping for a few months each year. This would have been uneconomic for any of the other crops for which there is a market at present. It is almost certain to continue to be uneconomic for any crops for which a local or export market can be envisaged. Moreover, and this is the more important point as far as planning is concerned, there is no certainty that sufficient ground-water is available to plan for any marked increase in its use.

183. Proposals for expansion of controlled irrigation must therefore be based on making the best possible use of such water as is intermittently available from the river. Significant quantities are available only in May and in the period August to December inclusive.

184. The latter period is long enough to grow the three crops frequently suggested as being most suitable for this country from all standpoints, cotton, maize and rice. However it is obviously undesirable for an irrigation system to lie idle for over half the year. A cropping pattern that will make maximum use of the May

TABLE 10

ESTIMATED WATER AVAILABLE FOR NEW IRRIGATION DEVELOPMENTS

DOWNSTREAM OF AFGOI - 1966-1969

75% Months

1000's of Hectare-Meters

	J	F	M	A	M	J	J	A	S	O	N	D
Available in 1965[1]	.85	.30	.30	.70	12.2	3.25	1.05	7.3	20.15	19.50	12.25	4.05
Anticipated increased Demand Upstream of Afgoi[2]	.64	.64	.64	.73			.73	.95	1.02	.32	.99	.94
Anticipated Quantity Available at Afgoi 1966-1969	.21	0	0	0	12.2	3.25	.32	6.35	19.13	19.18	11.26	3.11
Anticipated Demand Afgoi - Audegle[3]	.08	.07	.08	.13	1.47	.57	.50	.33	1.30	.93	.99	.39
Anticipated Demand Audegle - Falcheiro[4]	1.52	1.43	1.61	1.49	5.82	3.70	2.61	3.17	6.66	7.24	4.66	3.49
Total Anticipated Demand Afgoi - Falcheiro	1.60	1.50	1.69	1.62	7.29	4.27	3.11	3.50	7.96	8.17	5.65	3.88
Estimated Quantity Available for New Development	0	0	0	0	4.91	0	0	2.85	11.17	11.01	5.61	0
Estimated Quantity if Median Months considered	0	0	0	0	7.81	.93	0	13.05	14.82	16.29	11.17	2.68

1. From Table 3
2. From Table 6
3. From Table 7
4. From Table 8

water also should be adopted if at all feasible. One possible crop selection and cropping pattern that appears to satisfy the various requirements is presented below.

Crops and Cropping Patterns

185. In the section on Agricultural Economics (Volume 6) in this report it is recommended that new irrigation developments be based on family units or holdings of 5 hectares. Recommendations will here be presented in terms of such a size of holding. Later in this report a layout is presented for a typical development comprising 400 such holdings and a cost estimate for such a scheme is provided.

186. It is proposed that 30 per cent of each holding be planted in rice or cotton, 35 per cent in maize, 30 per cent in alfalfa and 5 per cent in tomatoes. Rice may prove preferable to cotton as the latter requires more rigorous control of field practices to keep diseases in check than might be possible with many small holdings worked by relatively inexperienced farmers. In any event rice has been used rather than cotton in computing water needs as it has the greater requirement.

187. A forage crop is essential as it is considered that livestock must play a fairly large part in the economy of such farming; this is discussed fully in the section on Agricultural Economics. Alfalfa appears to be the best such crop as, with its very deep root system, it is the most likely to survive under the unfavourable circumstances of intermittent flooding and periods entirely without water. It would be left planted for a two or three year period.

188. Tomatoes are suggested as it is believed they could be the basis of a new export industry in the form of tomato paste for which, it is understood, there is a steadily expanding market in the Middle East.

189. The foregoing would be the basic crops but ground nuts could be grown in the Gu season on the land later to be sown either to maize or to rice or cotton. There appears to be no reason why they could not be grown successfully with irrigation in May and rain in June and July. Their short growing season and relatively low water requirement makes them unusually suitable as a spring crop. There does not seem to be any other crop that is equally attractive for this season, taking everything, including markets, into account. Some vegetables could obviously be grown but due to limited markets the quantity would not be large enough to be included in a computation of water needs.

190. If fallow land was to be kept to an absolute minimum, a Gu crop of maize could be sown in some years on the land not planted to ground nuts. This could be considered as basically a rain-fed crop but in at least three years out of five there would be some irrigation water available for it.

191. The suggested growing seasons, and the areas to be planted to each crop, are shown in Table 11. The growing seasons proposed have been selected to suit, as far as possible, the months when water would normally be available.

192. The monthly water requirements for the selected crops, as computed by the Blaney-Criddle formula (see Appendix 1), are given in Table 12. Also tabulated are the quantities to be supplied from the river each month, in view of the water actually available. These latter figures incorporate appropriate reductions for water to be supplied by precipitation (see Appendix 2) and they are also suitably adjusted to allow for soil storage of water. Water must be stored in the soil prior to the consumptive use by the crop; this has the effect of allowing the application of less water than the consumptive use requirement towards the end of the growing season.

TABLE 11

PROPOSED CROPS - AREAS AND GROWING SEASONS

5-Hectare Holding

Crops	Area per Holding Hectares	Growing Seasons											
		J	F	M	A	M	J	J	A	S	O	N	D
Rice or Cotton	1.43	 C							R C	R C	R C	R C	R C
Ground Nuts AND Maize	0.95 1.90				GN	GN	GN	GN		 M	 M	 M	 M
Tomatoes	.24					T	T	T		T	T	T	
Alfalfa	1.43	A	A	A	A	A	A	A	A	A	A	A	A

TABLE 12

CONSUMPTIVE USE OF SELECTED CROPS AND

PROPOSED APPLICATION OF IRRIGATION WATER

Depths in mm.

Crop		J	F	M	A	M	J	J	A	S	O	N	D	Total Effective Precipitation	Total Irrigation Water	Total Consumptive Use
	C.U.								163	183	216	202	185			949
Rice	E.P.							35				23		58		
	P.A.								180	210	244	137	120		891	949
	C.U.	85							98	119	149	137	118			706
Cotton	E.P.							35				23		58		
	P.A.								113	153	163	113	106		648	706
	C.U.				51	120	105	53								329
Ground Nuts	E.P.				36	20	36	17						109		
	P.A.					220									220	329
	C.U.									103	125	129	118			475
Maize	E.P.											23		23		
	P.A.								50	150	110	82	60		452	475
	C.U.					87	88	90		79	91	88				265 258
Tomatoes	E.P.				36	20	36	35				23		127 23		
	P.A.					138			25	75	82	53			138 235	265 258
	C.U.	25	39	79	92	113	145	155	163	135	133	80	75			1234
	E.P.				36	20	36	35				23		150		
	P.A.					180				320	334	180	70		1084	1234

C.U. - Consumptive Use E.P. - Effective Precipitation P.A. - Proposed Application

193. The figures given are the actual growth requirements. The field and diversion requirements will be considerably more, as discussed elsewhere. It is worth noting here that the diversion requirements, i.e. the quantity of water taken from the river, will be roughly double the consumptive use. In the months when none of the required water can be taken from the river the crops would be entirely dependent on stored soil moisture and on precipitation. It is not assumed here that groundwater supplies would be available.

194. It will be noted that for Gu season crops it is necessary to depend heavily on rainfall and on the ability of the soil to store a good deal of the water which is available in May. No data is available on the moisture retaining capacity of the soil in the root zone but there are no indications that it is lower than average. This soil property is obviously of great importance in the successful growing of alfalfa based on supplying water as proposed. The assumption is here made that the heavy application possible in October and November will store sufficient water to carry this crop over the critical period of January to approximately mid-April. This would not be possible with many crops but the unusually deep root system of alfalfa gives promise of maintaining a perennial crop under these unfavourable conditions.

195. The economic success or failure of these proposals depends on the Der season crops, and it is the area that can be dependably provided with water for these crops which will determine the total area that can be brought under irrigation. It will be apparent that the critical month in this season is December and growing seasons have been selected as far as possible to minimize water demand in that month.

196. In theory, of course, no water will be available then in the 75 per cent month as shown in Table 9. However, a reasonable amount would be available in the median month and, as the expansion of controlled irrigation is obviously dependent on making some water available in December in at least three years out of four, this could be done in a number of ways. The December application to the maize and cotton in the S.A.C.A. area could probably be reduced without ill effect by applying more in November. Similarly it would be worthwhile, considering the relative values of the crops, to allow no water for the inundation irrigated lands in December. Moreover the quantity allocated to bananas in that month could be reduced as, in terms of the country's economy, the relatively slight cost of pumping from wells in that month in some years would be more than offset by the value of rice or cotton which it would thus be possible to produce. It has therefore been assumed, in the derivation of the area of land which could be brought under irrigation, that there will be 2.5 hectare meters of water available in December in the 75 per cent month, instead of the zero which was obtained by the procedure shown in Table 10.

197. In like manner the 2.85 hectare meters obtained for August has been raised to 3.5 hectare meters, in order that an artificial limitation should not be imposed on the estimate of land to be developed. This was considered justifiable inasmuch as the computations based on the limited data available provide a figure of 13.05 hectare meters for the 50 per cent month. It is believed that if more yearly records were available the 75 per cent month figure would be significantly higher; the increase to 3.5 is felt to be conservative.

198. August is the second most critical month and, as rice and cotton would both have to be planted at that time in order to obtain water for the required length of growing season, maize is shown as being started in September and running through to December. However in years when the July rainfall was particularly good this crop could be started much earlier and the low flow of December would be available entirely for cotton or rice.

199. In deriving the proposed monthly applications from the theoretical requirements the moisture holding capacity of the soil has been assumed to be average, as previously noted. If it is found to be better than expected, much more of the excess water normally available in October and November would be stored and the irrigation requirement in December would be further reduced. It will be apparent that if the total area put under all crops is limited to the anticipated quantity of water available in August and December, and as a general rule this would have to be done, then there will always be a surplus available in September, October and November. Provided this surplus, however great, could be applied to some crop or other without actual harm this would be done and the critical month might be found to be August. It is obvious this would allow a considerable increase in the area cultivated. It will be observed from Table 13 that flows in September, October and November are relatively dependable.

TABLE 13

TOTAL MONTHLY FLOWS PASSING AFGOI - AUGUST TO DECEMBER

1000's of Hectare Meters

	Aug.	Sept.	Oct.	Nov.	Dec.
Maximum Recorded (1951-1964)	24.0	24.4	24.9	24.9	24.9
Minimum Recorded	4.4	16.9	11.4	9.0	0.4
Median	17.5	23.8	23.9	18.3	7.5
Coefficient of Variation	0.47	0.11	0.22	0.32	0.82

200. Based on the foregoing cropping patterns and related water needs the monthly irrigation water requirements for the assumed typical 5-hectare farm are shown in Table 13. These requirements have been derived, in the first instance, assuming rainfall contributions equal to the estimated 75 per cent month precipitation in each case. However, as relatively few years of rainfall records are available and as rainfall is extremely erratic in the area concerned, the extent to which rainfall should be relied upon in reaching decisions on irrigation developments is necessarily largely a matter of personal opinion. Hence, for easy reference, irrigation requirements have also been computed and tabulated using rainfall figures for the median months and the driest year of record. In all cases the records used are of precipitation at Genale. The question of precipitation as it bears upon irrigation in the Shebelle valley is discussed in Appendix 2 to this report.

201. Finally, in Table 14, are given the equivalent monthly diversion requirements, i.e. the quantities of water which must be taken from the river in order to supply the computed water needs. These have been derived assuming main canal efficiency as 95 per cent, lateral canal efficiency as 90 per cent and field efficiency as 60 per cent, giving an overall efficiency of 51.3 per cent.

Estimated Possible Area of New Irrigation Development

202. Sufficient data has been derived and presented in the previous sections to allow fairly close estimates to be made of the area of new land which may be brought under controlled irrigation with the flow of the Shebelle uncontrolled by dam and reservoir. The essence of this data is summarized in Table 15. The figures used

TABLE 14

MONTHLY IRRIGATION WATER USE PER 5-HECTARE FARM - HECTARE METERS

Crop	Area		J	F	M	A	M	J	J	A	S	O	N	D	Annual Totals
Rice	1.43	A								.257	.300	.349	.196	.172	1.274
	Der	B								.200	.300	.343	.172	.143	1.158
		C								.257	.300	.400	.192	.172	1.321
Maize	1.90	A								.095	.285	.209	.156	.114	.859
	Der	B								.038	.285	.209	.156	.050	.738
		C								.095	.285	.256	.152	.114	.902
Ground Nuts	.95	A					.211								.211
	Gu	B					.156								.156
		C					.229								.229
Tomatoes	.24	A					.033			.006	.018	.020	.013		.090
	Gu &	B					.023				.012	.020	.011		.066
	Der	C					.039			.006	.018	.025	.013		.101
Alfalfa	1.43	A					.258				.457	.478	.258	.100	1.551
		B					.258				.400	.478	.171	.057	1.364
		C					.258				.472	.532	.258	.100	1.620
Monthly Totals		A					.502			.358	1.060	1.056	.623	.386	3.985
Net Irrigation		B					.437			.238	.997	1.050	.510	.250	3.482
Needs		C					.526			.358	1.075	1.213	.615	.386	4.173
Monthly Totals		A					.979			.697	2.063	2.058	1.215	.752	7.764
Diversion		B					.852			.464	1.940	2.045	.995	.487	6.783
Requirements		C					1.025			.697	2.095	2.362	1.200	.752	8.131

A - 75% Months B - Median Months C - Driest Year of Record

TABLE 15

ESTIMATED AREA POSSIBLE NEW IRRIGATION DEVELOPMENT

	May	Aug	Sept	Oct	Nov	Dec
Estimated Quantity Water Available for New Development - Hectare Meters	4,910	3,500	11,170	11,010	5,610	2,500
Estimated Water Requirements per 5-Hectare Farm	.979	.697	2.063	2.058	1.215	.752
Number of 5-Hectare Farms Possible	5,015	5,021	5,414	5,349	4,617	3,324
Total Area of Possible Development - Hectares	25,075	25,105	27,070	26,745	23,085	16,620

for both available water and precipitation are those for the 75 per cent months.

203. It will be seen from the table that it is possible to so arrange rates of water application, in accordance with accepted principles, that water availability would allow about 25,000 hectares of new irrigation development were it not for a serious shortage in December, previously discussed. Should the moisture holding capacity of the soil be below average in substantial parts of the developed area, and should it not prove possible to draw on heavy applications made in the previous months, the situation would be even worse than that indicated.

204. There are, of course, again as noted previously, a number of possible ways of dealing with the December shortage and a combination of these might remove the present limitation. One would be supplementing the river supply with ground-water, as is now done extensively for the banana crop in the Genale area. However, while there is no evidence that water is at present being withdrawn from the good aquifer underlying that area at a faster rate than it is being recharged, there is no certainty that further large withdrawals will be possible. While data on the depth and quality of ground-water elsewhere along the Shebelle is available no pumping tests have been carried out to provide any indications as to quantity. It is strongly recommended that such tests be carried out as early as possible in the areas selected for development. The quantity of ground-water available will obviously have a very great bearing on the total extent of development possible. The unit value of most of the crops likely to be grown would not allow entire dependence on ground-water, considering the average depth it would have to be lifted, even if sufficient quantities were found to be available in some localities. There is no doubt that rice or cotton could easily bear the extra cost of the relatively small quantity of supplemental water that would be required for short periods in some, not all, years.

205. The other possible method of improving the present low December flows may be the reduction of upstream losses in that month. Insufficient data exists to prove the economic feasibility of this but there is good reason to believe that much could be done. This matter is discussed further in a later section.

206. In the light of the foregoing it seems reasonable to suggest that it should be possible to add approximately 20,000 hectares to the total of the area at present under controlled irrigation and, the area for which reasonably definite plans already exist, i.e. 4000 hectares of cotton and 1000 hectares of grapefruit.

207. Moreover, this land, would be intensively cultivated and if farmed with optimum efficiency should be able to grow produce of a total value of approximately So. Sh. 41,500,000 per annum. This is based on the planned yield in three years out of four. In 25 per cent of the years there would be less water available than that required for full production. If it is assumed that the yield in such years would average 50 per cent of the normal, the long term average annual value of the new production would be approximately So. Sh. 36,300,000.

208. This estimate is based on the crops and cropping pattern previously developed and it is only intended to provide an indication of the economic potential of the Shebelle River without control by dam and reservoir. It is not suggested that these crops are the only ones that should be considered, or that the percentages of land assigned to each are necessarily the optimum. The findings of the Afgoi Agricultural Research Station will in due course determine the crops suited to the local conditions. Developments in local and world markets will have much bearing on the crops finally selected for production.

Proposed Location of New Irrigation Development

209. The factors which must be taken into consideration in deciding on the best

location for an irrigation development are many and varied. The suitability of the soils would normally be the first criterion, followed closely by the topography. The quantities of irrigation water available at alternative sites, if there was a substantial difference, would be taken into account as would variations in rainfall. The possibility of supplementary supplies of water from wells might be important in this connection. In some regions there might be sufficient differences in the skill and experience of farm labour to warrant taking this into account. Nearness to markets or shipping points and the quality of road access must be considered. Existing development in the areas under consideration could have a bearing on a decision. These factors, and others, are discussed below in relation to the possibilities of the Shebelle valley.

210. Considering soils first, in this case there are no indications that soils are better in one area than in another, from Mahaddei Uen to Falcheiro, though above the former point there is a deterioration in quality. While a detailed soils survey has not been made, a general survey was made as part of the work of this project and samples were taken for description and analysis at numerous locations in the Shebelle valley. The data derived from these is given in Volume 3 of this report. A reconnaissance soil survey was also made by USAID personnel in 1961 in the Bulo Mererta area. A summary of the results of this survey, and a tabulation of essential data, is given in Appendix 3 to this Volume. The locations at which all samples for analysis were taken in both these surveys are shown on Maps 9 and 10.

211. These data reveal, as might be expected in a flood plain, that the soil components range from fine sand to clay throughout the whole area. They are not uniformly mixed and there are considerable local variations in soil composition. Hence, within a very small area, the soil may range from clay to clay loam to sandy clay loam to sand. It appears that everywhere in the area, as a consequence, there are occasional patches of soil where the structure and texture are not suitable for agriculture, because of difficulty in working, poor drainage, poor moisture retaining capacity, etc. It is understood that in the Genale area approximately 2 to 3 per cent of the land is in this category. No data is available to show that this percentage is substantially different elsewhere in the portion of the flood plain under consideration.

212. The chemical analyses which have been carried out, though limited in number, also give no indication that any one locality is superior to any other. Generally speaking the salt and sodium hazard is low to medium in all parts of the area.

213. Topographically there appears to be little to choose between one part and another. However, there are no maps of the region with the one-meter contours which would be the minimum required for sound assessment. Some levelling was done in the Genale area as part of this project, and a chain of bench marks was established more or less parallel to the river from Genale to Mahaddei Uen and beyond. Ground levels are available along the alignment of the new highway from Afgoi to Scialambot and along the line of the 12-kilometer canal running out from the river at Barire.

214. The indications from this inadequate data are that the land slopes generally parallel to the run of the river with slopes ranging from 0.00015 to 0.0003. Apart from the slopes of the natural levees adjacent to the river, discussed previously, there is little or no slope at right angles to the river between Afgoi and Audegle. Between Audegle and Falcheiro there is a progressively increasing tilt of the land from the river towards the dunes which attains slopes of approximately 0.0005 downstream of Genale. Upstream from Audegle no slope determinations are possible at this time.

215. It can be stated categorically that slopes are generally favourable to

irrigation everywhere in the region, though the land is too level for the most economical canal construction and drainage might prove a problem in some localities. The area between Falcheiro and Mobarech has more favourable slopes than that between Mobarech and Afgoi and this is probably one of the reasons this area was originally selected for development in preference to others.

216. Considering the availability of water, from the foregoing discussions and tables it is evident that, as a general rule, the river's discharge decreases progressively from upstream to downstream. Hence it would seem desirable to select a site as far upstream as possible, all other factors being equal.

217. A deterioration in the suitability of the soil, among other factors, precludes consideration of sites upstream of Mahaddei Uen. The decrease in the quantity of water available between that point and Audegle should therefore be examined. Tabulated below are the quantities of water available in the 75 per cent month downstream of Audegle, as percentages of that available immediately downstream of Mahaddei Uen. In computing these reductions the flows at Mahaddei Uen have been reduced appropriately to allow for the water which must be reserved for the plantations at Johar.

TABLE 16

WATER AVAILABLE AT AUDEGLE IN 75% MONTHS

AS A PERCENTAGE OF

THAT AVAILABLE AT MAHADDEI UEN

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
67	83	74	67	94	102	67	99	88	85	97	99

218. As new irrigation developments will not be able to draw water from the river except in May and in August to December it is only the reductions in these months which need to be considered. As shown previously only May, August and December are critical. It is apparent, therefore, that while a little more land could be brought under irrigation immediately downstream of Mahaddei Uen than downstream of Audegle the difference is relatively slight. It is suggested that other considerations which favor the downstream site far more than counterbalance this upstream advantage.

219. One of these is the more favourable rainfall pattern in the downstream region. The total annual rainfall meausred at Johar is considerably greater than that measured at Genale: the average annual amount at the former site being 590 millimeters as compared with 430 millimeters at Genale. The distribution of this throughout the year, however, is more in line with crop requirements at Genale than at Johar. Tabulated below are average monthly totals in millimeters for each place, based on 7 years of records at Genale and 26 years at Johar.

TABLE 17

AVERAGE MONTHLY RAINFALL (MILIMETER) FOR JOHAR AND GENALE

	J	F	M	A	M	J	J	A	S	O	N	D
Johar	7.8	3.3	29.9	92.7	131.8	30.8	31.9	17.3	5.0	126.7	101.2	19.6
Genale	1.7	0.0	13.3	89.2	56.4	62.3	62.6	21.6	13.7	12.9	86.3	10.1

220. It is apparent that the excess rain at Johar falls mainly in May and October, months when the water available from the river is at a maximum. Genale, on the other hand, receives twice the amount that Johar does in June and July. These are the months when rain is most essential for the success of a Gu crop, which may be started in May by irrigation but will require as much precipitation as possible in the following two months to supplement stored soil moisture.

221. Another argument, which may in time be proved to be invalid, is the possibly better availability of ground-water to supplement river water in the Genale area. Here there are proven supplies in fair quantity at depths which are not completely uneconomic, at least for banana production. It has been established, in fact, that there is a very good aquifer underlying this area. It may be that equally good aquifers underly the area between Mahaddei Uen and Balad though as yet there is no data available to determine this. This question is dealt with fully in the Ground-Water section of Volume 2.

222. From the point of view of access there is little to choose between any locality from Mahaddei Uen to Falcheiro, apart from the distance from Mogadiscio, as a paved road parallels the river throughout the whole of this stretch.

223. Despite the foregoing points which favour a downstream location, it could be contended that there are no technical arguments, in the narrowest sense, which unquestionably point to any particular locality, at least as far as can be seen from data now available. It is considered, however, that there are very sound economic arguments in favour of siting downstream of Audegle and these are presented below. They are based on the following premise, unarguable from a technical point of view (any other is outside the scope of this section of the report): the water in the Shebelle is so limited in quantity and is so important a resource of Somalia that the over-riding consideration in determining where and how it is to be used must be this: what will bring the maximum monetary return per cubic meter of water used?

224. As a basic principle it is considered most advisable to concentrate all irrigation development in as small an area as practical. This would be desirable in any country in order to minimize costs of administration, maintenance and the provision of services. In Somalia, with the extreme scarcity of trained and experienced administrators, engineers and agriculturists, it is essential.

225. Any irrigation system requires continual methodical maintenance to keep the canals free of sediment and vegetation, their banks intact and structures in operating condition. The many kilometers of canals and thousands of hectares of land which have fallen out of use in the Genale area is the consequence almost entirely of lack of maintenance.

226. With the supply of water as limited as it is in this case it is more than usually necessary to ensure that it is used with maximum efficiency. This entails not only extreme care to prevent over-watering but also ensuring that water is applied at the optimum intervals and in the most carefully gauged quantities possible to obtain best crop production.

227. With the water applied to the land with maximum efficiency the best returns will only be obtained if all other farming practices are of the same high standard. Preparation of the soil, times and methods of planting, the seed used, weed control, pest and disease control, application of fertilizer; all these factors must be taken into account and dealt with in the most scientific manner possible.

228. To provide the necessary overall direction and the specialised assistance and advice to carry out all this work properly will not be easy for Somalia for many

years. At the present time, the Government is unable to make more than a gesture in this direction in the Genale area; S.A.C.A. necessarily confines its activities to maintaining and improving banana production only, and has as a general principle no control over the operation and maintenance of the canal system.

229. If, in the next decade or so, the Government succeeds in doing its part in bringing the presently irrigated land in the Genale area up to optimum production in terms of available water it will be straining its manpower resources to the limit. If the men can be found, and an efficient organization built up which is capable of providing the high level of direction and advice required, all newly irrigated land on the Shebelle should, if feasible, be placed under this same control. To build up a second or third team of such men would be most difficult and, it is suggested, a misuse of manpower considering the other unavoidably widespread needs of the country.

230. The foregoing arguments are equally applicable to the machinery and equipment required to maintain the canals, work the land and harvest the crops. Investment will obviously be kept to a minimum if the work can be concentrated. Moreover equipment requires maintenance and it is clearly easier and cheaper to set up one good workshop than two or more.

231. No matter how much is provided by the Government in the way of direction, advice and assistance maximum production will depend to a very great extent on the knowledge, experience and attitude of the farmers. In the vicinity and downstream of Audegle is to be found the highest concentration of farmers who are used to controlled irrigation. Both from working on the concession farms in the S.A.C.A. area and, in many cases, from irrigating their own lands with hand-dug canals these men have learned to use and value this type of farming. While it may be politically and socially desirable to settle others in new irrigated lands, strictly in terms of the best interests of the economics of the country as a whole it would be best to take advantage of this reservoir of experience. Much of it now extends over two generations.

232. The foregoing are arguments for developing irrigation downstream of Afgoi, in fact downstream of Audegle unless lack of sufficient land should force some portion of the development above that point. It is contended further, that there are irrefutable technical and economic arguments for rehabilitating the whole of the S.A.C.A. concession area in the first instance and, in the second, continuing to the limits of feasibility the development of the Bulo Mererta Project area. (See paragraph 3). Thereafter, if sufficient water is available and if a satisfactory formula for a necessary minimum amount of Government control over land and water use can be devised, much of the presently inundation-irrigated land to the north of the concession area could be served with controlled irrigation. These recommendations are dealt with in order below.

233. As has been stated previously there are 21,000 hectares of cultivable land lying idle on the farms in the S.A.C.A. concession area. Of this, 10,400 hectares are on farms which are at present producing bananas, if nothing else. Sixteen of these farms are divided into two plots, widely separated from each other, one of which in each case is no longer served by water due to deterioration of canals. It is estimated that the area of the latter totals about 1600 hectares.

234. There are, therefore approximately 8800 hectares of land in the hands of experienced farmers, and now served by water, which are at present not producing crops. It seems self-evident that this is the first category of land that should be brought into production as to do so would require the least possible expenditure by Government. Some expenditure would be involved as, due to siltation, canal capacities in some cases might not be equal to the increased water demand. Some light

clearing would also probably be required but this cost would be borne by the farmers concerned.

235. Apart from these minor expenditures all that would be needed would be appropriate Government action to force these farmers into total production. This might take the form of an article in the new land tenure laws which are now being formulated to the effect that land served by irrigation water would revert to the Government after a specified period if it was unused. Or, alternatively, an amendment to a directive relating to this matter, which was issued in June 1965, would serve the purpose. This instruction requires holders of banana quotes to plant areas of cereal crops in proportion to the size of the quota held by the farm. As the maximum area which must be planted in accordance with this regulation is 30 hectares, in both Gu and Der seasons, and as the areas of the farms in this category are all over 300 hectares, this is now only a token solution of the problem. There is no obvious argument against making it fully effective. Another possibility would be the imposition of a land tax which would be light on producing land but heavy on non-producing land.

236. It is clear that the total cost of bringing this land into production would be considerably less than that for an equivalent area of virgin land elsewhere. The actual cost has been estimated to be in the order of So. Sh. 350 per hectare. This is based on allowing So. Sh. 250 per hectare for the light clearing required and So. Sh. 100 per hectare for cleaning and improving canals. The total expenditure for this block of 8800 hectares would therefore be So. Sh. 3,080,000.

237. The next area to be put into production would logically be the 10,600 hectares on the 80 farms not now served by water plus the 1600 hectares noted above. This would require the rehabilitation of approximately 60 kilometers of main and secondary canals at a cost which should not exceed So. Sh. 2,400,000. It would also require the clearing of about 4000 hectares which have become overgrown with light bush, and some minor clearing on the remainder. Allowing So. Sh. 500 per hectare for the former and So. Sh. 250 per hectare for the latter the clearing cost would be So. Sh. 4,050,000.

238. Thus for an approximate total cost of So. Sh. 9,530,000 it would be possible to bring 21,000 hectares into production. This represents an average cost of about So. Sh. 454 per hectare. This is to be compared with a figure of approximately So. Sh. 3400 per hectare, derived later, for virgin land requiring a new irrigation system.

239. As a corollary to the foregoing it should be pointed out that if an approximation of the cropping pattern previously presented were to be followed, including the proposed rates of water application, the canals of the concession area would not have the capacity to serve the whole 21,000 hectares. The reason for this is that instead of irrigating in accordance with crop requirements, with regular applications at fairly uniform rates as is done at the present, it would be necessary to apply large quantities of water in very short periods, when the water was actually available.

240. Due to the essentially torrential nature of the Shebelle, as will be seen by a study of the hydrographs in Volume 2 of this report, water tends to be available in high flows of short duration and the canal system must deal with this. Referring to Table 14 it will be noted that virtually all the water available for the Gu season crops would have to be applied in May, and that heavy applications would have to be made to the alfalfa in September and October, coincident with normal applications to the rice, maize and tomatoes. Even in these months it would often be impossible to draw water at a uniform rate as the bulk of the month's total flow might occur within a two-week period.

241. It has been estimated, however, that at least 10,000 hectares could be dependably irrigated if all canals were cleaned out and restored to their original capacities. This is approximately one half the additional area that could be brought under irrigation according to previous computations.

242. It is recognised that objections may be raised on the grounds of land ownership problems but these need not be insuperable and, practically speaking, should be easier to solve than the financial problems associated with the much higher cost of a development elsewhere. Moreover, considering the land tenure problems that arose immediately after the construction of the main canals of the Bulo Mererta project, it is felt that such difficulties will present themselves at any point along the lower reaches of the Shebelle.

243. Apart from the lower initial cost there are other advantages to the rehabilitation of this land. Land slopes in this area are much more favourable from the point of view of drainage than in any other known area downstream of Afgoi. Road access is exceptionally good. Most important, however, is the following consideration.

244. It is assumed that this land would be divided into much smaller plots than the average 166 hectare size of the present farms: possibly into 5 hectare holdings as previously discussed, or into a mixture of these, larger cooperative holdings and a few Somali-owned farms of the present size. It is also assumed that it would be considered desirable for this land to pass largely into the hands of the local population, particularly many of those who are landless and now work on the concession farms. These people, having the maximum experience, would be the ones most likely to achieve maximum production with the minimum of guidance, and it is this last which will present the greatest problems in the settlement of people and the development of irrigated land. Moreover, as these new farms will be started adjacent to well-established ones much will be learned by example. Further, S.A.C.A. already has a skeleton agricultural advisory service that could augment the Government service and these together could supply the necessary advice, direction and assistance with the greatest efficiency in the formative years.

245. In short, the most efficient farming in the Shebelle valley, apart from the sugar plantation at Johar, is now being carried on by the farmers of the S.A.C.A. concession area. It seems self-evident that the best course for development would be to improve this nucleus to the maximum extent possible and then build on this in a progressive and orderly fashion. Somalia has neither the resources of money nor trained manpower to afford to start and staff completely new developments unless no alternative exists. In this case there is an alternative, and however difficult the political and social problems may appear, and undoubtedly are, it is suggested that meeting them and settling them will be easier than dealing with the other problems involved in virgin-land development.

246. There can be no doubt that the course here recommended will produce the maximum economic return from the water of the Shebelle. If the settlement of nomadic people, the re-settlement of certain groups, or any social or political considerations whatsoever are allowed to cloud the matter, the economic return from this valuable resource will inevitably be reduced.

247. Following on the above reasoning the next area which should be developed is the Bulo Mererta project area, which is the land commanded by the Bulo Bocore, Coriole and Fornari canals (Map 10). It is not possible to be precise as to the total area which could feasibly be irrigated by these canals but from the facts available at the time of this study the following general assertions can safely be made.

248. Within the quadrilateral formed by the river, the Bulo Bocore and Fornari canals on the north, west and east respectively, and by the Gofca canal on the south which is an extension of the original irrigation system, there are approximately 10,500 hectares gross, which should provide a net cultivable area of about 9,500 hectares. Of this there are approximately 1850 hectares in concession farms and, as stated previously, about 3000 hectares of inundation irrigation.

249. In 1960-61 the Government, assisted by USAID, had a topographic survey of most of this area carried out. Subsequently USAID engineers drew up plans for two lateral canals and associated sub-laterals which would irrigate 2100 hectares on the left side of the Bulo Bocore canal at its lower end. Study of the level grid produced by this survey indicates that it should be feasible to irrigate not less than 2500 hectares more between this scheme and the river to the north. As the canal has a capacity sufficient to serve from 10,000 to 12,000 hectares it could also provide water for about 2000 hectares which it is believed could be commanded on its right side, outside the area under consideration.

250. The Fornari canal would theoretically serve over 11,000 hectares, if the projected dam at Gaveiro were built. Again a study of the available levels indicates that approximately 4000 hectares could be commanded by this canal within the quadrilateral, and perhaps 500 hectares outside, on its' left side at the lower end. It appears that the remainder of the 9,500 hectares, i.e. 900 hectares, could be irrigated directly from the river in the north and from the Gofca canal in the southern part.

251. As stated previously, the Coriole canal was designed with a capacity sufficient to serve 5000 hectares. If it was in fact constructed in accordance with the drawings and with the slope as indicated thereon it would carry sufficient water for between 6,000 and 7,000 hectares if required. No ground levels are available on which to base calculations of the area which could actually be commanded. However, observations indicate that it is able to inundate at least 1500 hectares at the present time despite the fact there are less than half a dozen functioning turnouts and no laterals at all in the true sense. What little channelled distribution there is, is done mainly through hand-dug ditches. Field inspection and a study of aerial photographs indicate that not less than 2500 hectares could certainly be developed based on this canal.

252. To summarize, while it appears most improbable that the three main canals of the Bulo Mererta project could provide irrigation for the originally proposed 25,000 hectares, there is adequate data available to show that they could irrigate at least 13,600 hectares. Moreover, this could be done with less expenditure here than would be required for an equivalent area anywhere else in the Shebelle valley, except on the abandoned concession farms previously discussed.

253. The diversion dams and main canals, plus many kilometers of river embankment, were constructed in the period between 1954 and 1960 at a cost of over So. Sh. 5,000,000. Approximately So. Sh. 500,000 were spent in 1965 on the re-construction and lengthening of the Coriole canal and cleaning out the Bulo Bocore canal. The net result of this expenditure to date is the controlled irrigation of not more than 1000 hectares. It therefore seems reasonable to propose that the necessary further expenditure be made to obtain the appropriate benefit from the initial and subsequent investments.

254. The requisite control structure at Gaivero, to divert water into the Fornari canal, has been estimated to cost approximately So. Sh. 550,000 and upstream embanking approximately So. Sh. 120,000. Cleaning and rehabilitating the canal would involve moving an estimated 55,000 cubic meters of earth. This would cost

So. Sh. 146,000 at the current rate of So. Sh. 2.65 per cubic meter. The other two canals and their diversion dams are now in good order and an expenditure of not more than So. Sh. 50,000 would be required for upstream embankment repairs. The total cost per hectare of these elements would therefore be So. Sh. 64.

255. The current average cost of clearing, levelling, ploughing and preparing new land for irrigation is an average of So. Sh. 1850 per hectare, based on recent experience at Johar and in the area south-west of the lower end of the Bulo Bocore canal. If it is assumed that the clearing accounts for one third of this and that only about 15 per cent of the 13,600 hectares would need clearing due to the widespread inundation and dry farming already practised in the area, the cost of these elements in developing this land would average So. Sh. 1340 per hectare.

256. In deriving the cost of irrigating a typical 2000 hectare block of virgin land upstream an average cost of So. Sh. 816 per hectare was obtained for laterals and their associated structures and drainage ditches. As the slopes assumed for this typical area were less favourable than the actual slopes in the area under consideration the cost of these elements in the Bulo Mererta area may safely be assumed as So. Sh. 750 per hectare.

257. The total cost per hectare, therefore, of bringing the lands in the Bulo Mererta project area into production is thus estimated to be So. Sh. 2154. When compared with the total unit cost for virgin land of So. Sh. 3411, the derivation of which is discussed hereinafter, it is apparent that a good economic argument exists for selecting the former area for development. Moreover the other strong arguments presented in favour of developing the idle concession-farm land apply equally here.

258. It will be noted that while the capacities of the Coriole, Fornari and Bulo Bocore canals are adequate to serve approximately 5,000, 11,000 and 11,500 hectares respectively, it is proposed that they irrigate total areas in each case of only 2500, 4500 and 6600 hectares. Hence they would be able to provide water at the abnormally high rates previously discussed.

259. The foregoing has shown that there are approximately 24,500 hectares of cultivable land well-situated for irrigation and that there are numerous reasons why this land should be the first to be developed in this way. Further, figures have been presented which show that unless upstream control measures are proved to be feasible there is not sufficient water available in the Shebelle in a 75 per cent year or in the median year to irrigate even one crop a year on such an area.

260. This land cannot be intelligently developed until it has been suitably mapped. It is therefore recommended that, if and when a decision is taken to develop the areas herein proposed, mapping be immediately started. The requisite map should cover the whole of the concession farm area lying between Mobarech and Falcheiro and include all the lands in the Bulo Mererta project area. It should also extend over the whole of the cultivable land lying west of the Bulo Bocore canal and cover the land now used for inundation irrigation farming contiguous to the northern boundary of the concession area. The scale should be not smaller than 1:10,000 and the contour interval should be one half meter. All property lines should be shown and cross sections and slopes of all canals should be included.

261. If it is deemed necessary to sidestep problems of land tenure, despite the consequent higher development cost and reduced efficiency and economic return, serious consideration might be given to all development being carried out upstream of the S.A.C.A. concession area. An estimate has therefore been prepared of the cost of developing a typical 2000 hectare block, in the form of 400 5-hectare holdings.

Layout and Cost of Typical 2000 Hectare Irrigation Scheme

262. No detailed topographic maps exist of any portion of the flood plain upstream of Mobarech but sufficient level data was obtained during this survey to form a general idea of slopes in the area which might be considered for development. These slopes are not favourable as it appears that the slope parallel to the river is generally not more than 0.00025 and there is little if any slope at right angles to this. It may be that a survey would reveal areas with slopes as favourable to drainage and to economic canal construction as those within the S.A.C.A. concession area but there is no indication of this from any data available. There is a depressed area south-east of Audegle, revealed by the levels run for the Barire-Danane canal, but this is believed to be a shallow basin and drainage problems would preclude its use.

263. The proposed layout of this scheme, shown on Figure 2,is necessarily more geometric than it would probably be in actuality, though the Johar plantation conforms to a rectangular grid and it is possible this could be adhered to and the inherent economies obtained. It might be found, despite present indications, that there are localities where the land slopes away from the river. If so, command of the area could be obtained with a lower pond level, less embanking of the river would be required upstream of the dam and the cost of the main canal could be significantly reduced.

264. As this is a generalized layout, prepared only to obtain a good indication of the cost of such a development, it has been considered satisfactory to base the canal design on monthly water requirements, rather than the shorter periods which would be appropriate to a final design. The canals were designed with more than twice the capacity that would be usual for a development of this size for the reason previously set forth. Inevitably this has had a considerable effect on the cost of the scheme.

265. In the cost estimate shown in Table 18 the following structures have been assumed. The diversion dam would be a simple R.C. structure carrying manually-operated steel sliding gates. The canal headworks would be of similar design; no desilting basin would be provided. The main canal would have three checks and be provided with two vehicular bridges and three footbridges. The five laterals would each be bridged with three vehicular bridges and six footbridges and would have three checks. Each lateral would have twenty turnouts, each turnout serving four 5 hectare plots.

266. Surface drains only have been assumed as there is no indication from experience at Johar or Genale that sub-surface drainage would be required. The minimum allowance has been made for roads and the cost included in the cost of clearing and levelling.

267. The total average cost per hectare is considerably higher than average figures which have been used in estimates included in applications for assistance to the European Economic Commission during 1965. The figure here derived, however, is based on actual unit costs now applicable in the Genale area. All structures were costed on the prevailing average rate of So. Sh. 550/- per cubic meter for reinforced concrete, including formwork, which is extremely high. The unit cost of earthwork is slightly higher than it should be for this class of work. The cost of clearing and levelling, as previously noted, is based on current actual costs.

268. Also as previously mentioned the whole irrigation system was designed with a capacity much greater than would be usual with a development of this size. Apart from the increased quantity of earthworks required in consequence, all structures are increased in size proportionately. If the flow of the Shebelle could be complet-

TABLE 18

ESTIMATED COST - 2000-HECTARE IRRIGATION SCHEME

Diversion structure - one fifth of cost[1]	So. Sh. 84,000
Main canal headworks	45,000
Main canal hydraulic structures	93,000
Lateral canal hydraulic structures	163,000
Bridges - main and lateral canals - vehicular and foot	175,000
Main canal embankments - 110,000 cu.m. @ So. Sh. 4.00	440,000
Lateral canal embankments - 155,000 cu.m. @ So Sh. 4.00	620,000
River embankments - 40,000 cu.m. @ So. Sh. 4.00 - one fifth of cost	32,000
Drainage ditches - 250,000 cu.m. @ So. Sh. 3.00	750,000
Sub Total	So. Sh. 2,402,000
Engineering and contingencies @ 30%	720,600
Total	So. Sh. 3,122,600

Average cost per hectare	So. Sh. 1,561
Unit cost of clearing, levelling, etc.	So. Sh. 1,850
Total average cost per hectare	So. Sh. 3,411

[1] It is assumed that in practice at least 10,000 hectares could and would be developed through the construction of one diversion dam and associated upstream embankments; hence only one fifth of the total cost is properly chargeable to this scheme.

ely regulated, and normal rates of water application adhered to, it is estimated that there would be a saving in the cost of the distribution system of approximately So. Sh. 400 per hectare. This would reduce the total average cost per hectare to approximately So. Sh. 3000.

269. It should be pointed out, however, that while the 5 hectare family holding is herein proposed in order to settle the maximum number of people on the land, optimum production would be difficult to acheive by this manner of farming. The estimated return per hectare would only be obtained if the activities of the farmers were closely controlled by an able and experienced management. There are a number of ways in which the settlers on the irrigation scheme outlined above might hold their plots, be organised, advised and when necessary directed. The methods employed on the successful Gezira Scheme in the Sudan are one approach and their applicability to Somalia would be worth careful study.

270. It is worth noting here, however, that at this point in the development of Somalia the maximum return from each hectare meter of water used would undoubtedly be obtained by a private company operating a farm of at least 5000 hectares. Such a company, which might be formed with a combination of Somali and foregin capital, would have the means to employ top quality management. Such management would have the power to ensure that farming was carried on with the most efficient techniques and equipment to obtain certain economics of scale. While this approach to development is the least attractive socially and politically it is worth serious consideration as probably the best means of training Somalis in the methods of modern agriculture at all levels from manager downwards. Trained and experienced Somalis do not now exist in sufficient numbers to reap the maximum potential of the Shebelle River, however much money is made available for the construction of irrigation schemes.

271. It is this fact that presents the real problems in the full exploitation of this river; the technical problems are relatively minor. A partial solution to the manpower problem is making maximum use of the experience of the Italian farmers still resident in the country. Another partial solution would be the encouragement of large scale private enterprise in the agricultural field, Somali or foreign, for the next decade or two. Sufficient government controls could prevent the evils so often attendant on such enterprises and could ensure their gradual dissolution when they had served their purpose to the country.

<u>Reduction of Overbank Spillage Losses</u>

272. Table 5 shows that there are significant losses, other than those due to evaporation and infiltration from the Channel, in the critical months of May, August and December between Belet Uen and Bulo Burti and between Mahaddei Uen and Balad. If the overbank spillage which produces them could be reduced, the quantity of water available for irrigation would be proportionately increased.

273. The feasibility of so doing cannot be determined without mapping the river banks to at least one-meter-contour accuracy, obtaining a large number of cross sections and carrying out much field inspection in the localities where the main losses occur. It is recommended that this work be done as a matter of fairly high priority. While no final conclusions can be drawn here, it seems worth making the following observations.

274. From a study of the aerial photographs and flights over the area it does not seem likely that much improvement could be made economically between Belet Uen and Bulo Burti. It appears that losses are not localised in this stretch but occur in very many places throughout the whole distance between these villages. Even if

it were feasible to construct the numerous sections of embankment required to prevent escape of water where it now occurs, gates would have to be provided to allow the continuation of the associated inundation irrigation and governmental control over the operation of these gates would be required. Moreover the embankments would have to be continuously inspected and maintained to repair damage which would be caused accidentally by livestock and quite probably deliberately by the local farmers.

275. It may be that detailed investigation would reveal that most of the losses occur in one or two relatively short stretches. In this case something might be done. If the situation is as it is believed to be, control works would not be practical.

276. There are indications that conditions are considerably different between Mahaddei Uen and Balad. It is known that losses are considerable upstream of Johar in consequence of the deterioration of the impounding embankments upstream of the weir, as discussed previously. While considerable losses occur between Johar and Balad during the peak flows of May, it may be that most of the losses which occur during the lower flows of December occur above Johar. Only a detailed study will determine this.

277. In any event it is strongly urged that the embankments be restored, such control gates as exist be made to function and as many more be added as are required. This would, of course, necessitate setting up an effective inspection and control organisation such as was originally envisaged. This work could be done confidently, without much prior study, in the knowledge that while it might not be the total solution it would certainly enable increased quantities of water to be passed downstream at certain times. It would have the additional benefit of improving the return from the inundation irrigated land in the vicinity as a much greater measure of control could be exercised over the times and quantities of water application.

278. The extent of inundation irrigation south of Johar indicates that at higher flows at least water escapes from the channel over a very long distance, perhaps 30 kilometers. It is unlikely that such a length of embankment could be justified and its maintenance would be completely impractical. However a detailed investigation may show that during the critical December period, losses are confined to a much shorter stretch, the embankment of which might be entirely feasible.

279. It has been estimated that in the median December approximately 1000 hectare meters of water are lost outside the channel. If half of this could be retained it would allow the irrigation of a further 4500 hectares as there is ample water in the four previous months to support it. Hence it is felt that a thorough investigation of this matter be carried out, even though it would necessitate some relatively expensive photogrammetric mapping. This investigation could, however, be combined with another study, discussed hereunder, and some of the costs shared between the two projects.

Diversion of Flood Flows

280. Another aspect of water loss which warrants early and careful investigation are the very high losses which occur every year at times of peak flood discharge. Generally speaking there is no way, apart from a detention dam and reservoir, that this water can be used in controlled irrigation. These peak flows occur normally in May, September, October and November, i.e. in the months when the base flow is already more than sufficient for the total irrigated area. Abnormally such peaks occur in June and December also, but they are again surplus to requirements as crops cannot be planted in anticipation.

281. On these occasions large volumes of water flood over three main areas. These are indicated roughly on Map 6. Available discharge figures indicate that at extreme flows the largest portion of this water escapes the channel between Bulo Burti and Mahaddei Uen. As was noted earlier the maximum flow recorded at Bulo Burti was 276 cumecs. and that at Mahaddei Uen 130 cumecs. There are few years of record in which the discharge at Bulo Burti has not exceeded 175 cumecs at some time or other and held this flow for several days or weeks. It is apparent that in some locality between these stations channel restrictions and escape possibilities restrict the flow reaching Mahaddei Uen to 130 cumecs. Field observations and enquiries indicate that these occur within a stretch of about 20 kilometers in the vicinity of Gialalassi.

282. Here some water floods out into a depression adjacent to the right bank but most of it escapes on the left side where it floods a larger depression between the river and the dunes. Hydrographs show that a small portion of this is returned to the river as the flood peak recedes. Most of it is not, and is lost by evaporation and infiltration, the latter being aided by the relatively high permeability of the dune sand. In some parts of the flooded area crops are planted after the water has receded and there is considerable benefit at times in the improvement of natural grazing.

283. The next area which receives flood water is approximately 80 kilometers further south where a second large depression exists between the left bank of the river and the dunes. Water flows into this depression both from a point immediately above the Johar weir and from a stretch about half way between Johar and Balad. Again, it may be observed, that while the discharge at Mahaddei Uen seldom fails to reach 130 cumecs. and hold for several weeks every year, the discharge at Balad never exceeds approximately 93 cumecs. This water is not returned and is lost by evaporation and infiltration. At moderately high flows more water is lost here than in the vicinity of Gialalassi and the flooding takes place over a very wide area. There are some agricultural benefits and greater grazing benefits. The latter, however, are not as large as might be expected for a considerable part of the flooded area has become waterlogged and saline. These conditions are aggravated by the fact that the drainage system of the Johar plantation empties into this depression also.

284. Most of the water of these flood peaks ends in the swamps, as previously discussed, and in extreme cases causes flooding nearly as far as the Juba River. The benefits derived from this disposition of flood water are infinitesimal in proportion to the quantity involved.

285. As an alternative to the foregoing it is suggested that serious consideration be given to the possibility of diverting most flood water onto the flood plain to the right of the river, downstream of Mahaddei Uen. Before the feasibility of this proposal can be determined, and dependable cost estimates prepared, some fairly extensive mapping will be required. However, here again enough level data has been produced by this project to indicate its probable feasibility and to allow a rough estimate to be made of the cost.

286. Study of aerial photographs reveals that in the relatively recent past the Shebelle River flowed in various channels well to the right of its present one in that portion of the flood plain lying downstream from Mahaddei Uen. In fact, as has been noted previously, the river now flows on the extreme left-hand side of its flood plain from that point to well beyond Falcheiro, a distance of over 200 kilometers.

287. Fanning out to the right from the vicinity of Mahaddei Uen are a number of channel remnants which resolve themselves into three well-defined ones about 35

kilometers south of this village. They can be observed to continue, with varying degrees of clarity, virtually to the beginning of the swamps. On the ground they are in places barely perceptible and in others channels several meters deep remain, overgrown with many years' growth of trees and bush. They traverse a largely waterless area of over 5,000 square kilometers which provides excellent grazing after the rains.

288. This land slopes very gently parallel to the run of the river and does not appear to have any general cross slope. There are, however, a number of localised irregularities produced by vestiges of channel depressions and ridges formed by the associated natural levees. There is no evidence of a depression to the west of Balad as has been mentioned by previous investigators. In fact the only departure from what would otherwise be a featureless plain are the very slight and very irregular roughly longitudinal corrugations produced by the old channels.

289. These facts have been deduced from levels provided by the relevant portions of the third-order level net run by this project, a few lines of levels specially run for the purpose, and field observations. The area concerned is criss-crossed with oil exploration cut-lines along which levels had been run by parties associated with seismic crews and a good deal of time was spent in attempting to correlate their levels with those provided by this project. The attempt was ultimately abandoned as they were found to be insufficiently accurate for the purpose. The spot elevations used and contour indications based thereon are shown on Map 9, on which also appear indications of the old channels.

290. It is into the "corrugations" noted above that it is proposed to divert surplus water by means of a dam near Mahaddei Uen and a canal, which might be from 5 to 10 kilometers long, running westwards. The feasibility of this proposal would depend upon the extent to which the water would flow largely in a sheet parallel to the river and thereby flood the very large area of fertile soil that is available. It is recognised that there would be a tendency for one or more new channels to be formed, particularly as fragments of old channels exist which lend themselves to extension. However, there would undoubtedly be a very large dispersal of much of it as evidenced by the area which is flooded in years of phenomenally high flows.

291. The benefits to be derived from this diversion would be as follows:

a. Large new areas of good grazing would be produced.

b. The areas in which inundation irrigation could be practised would be greatly increased.

c. Through infiltration there would be a large increase in the ground water which would be available for extraction in areas where stock watering points are required, and which might, in due course, provide supplementary irrigation water for developments based on the river downstream of Johar.

d. Surface reservoirs, natural and man-made, would be annually re-charged in an area where uars are needed and are herein proposed.

e. A measure of flood protection would be provided downstream in the provision of another flood water relief area.

f. Some degree of water level control downstream would be provided which could be of benefit to the extensive inundation irrigation between Mahaddei Uen and Balad.

292. The economics of this proposal are virtually impossible to analyse at this stage and even when complete topographical information is available the cost-benefit ratio would be difficult to determine with any accuracy. However, provided it is not found that land slopes are such that 50 kilometers or more of embankment would be required to protect the Balad-Mahaddei Uen road, this project might well be considered worthwhile in view of the need to take all possible steps to make the most use of the Shebelle waters.

293. As an indication of the approximate cost of such a project the following estimate has been prepared, based on providing a canal which would carry 100 cumecs. This capacity has been selected on the basis that the maximum flow reaching Mahaddei Uen is approximately 130 cumecs and the maximum discharge that could be beneficially used downstream for controlled irrigation would be in the order of 30 cumecs. From limited levelling carried out south-west of Mahaddei Uen it appears that the length of canal required would be approximately 6 kilometers. The water level required at the intake would be 2.5 meters above the present maximum water level and this would necessitate embanking the river for approximately 7 kilometers upstream.

294. A possible signficant additional cost which cannot be even roughly estimated at this time would be incurred if the flooding necessitated appreciable raising of the grade of the proposed Afgoi-Bur Acaba road. This would cross the inundated area and while the only consequence of this diversion might be the relatively unimportant increase in the sizes and costs of culverts, the topography might be such that the grade would have to be raised or embankment protection provided.

295. A feasibility study of this project should not cost more than So.Sh. 250,000 and it is recommended that an investigation should be carried out in the near future. Even if the dam above Bulo Burti were found to be feasible it is unlikely that it would be constructed during the next ten to fifteen years. This diversion could prove to be of great value during that period and might have its place in an overall flood control scheme afterwards. An indication of the benefits that might be derived is given by the fact that had such a canal existed in 1964 it would have been possible to divert approximately 87,600 hectare meters of surplus water onto the fertile Shebelle Flood plain. This is equivalent to an average depth of 0.3 meters on 3,000 square kilometers.

296. Another investigation that might be warranted, as an extension to the foregoing, is an examination of the desirability and practicality of diverting the flood water at some point north of Mahaddei Uen or of increasing the quantity of water which reaches that point. In 1964 a further 35,000 hectare-meters of water which passed Bulo Burti did not reach the former village. The mapping of the channel, recommended previously as part of a study directed at reducing December losses, might reveal that only a small amount of embanking would considerably increase the flow at Mahaddei Uen. It might also be found that a sufficiently large part of the losses occurring in this stretch were taking place far enough downstream from Bulo Burti that a channel to the right at this point would be more worthwhile than one at Mahaddei Uen. A careful study of the existing aerial photography gives no evidence that a more, or even equally, favourable diversion point exists than the one selected but the possibility cannot be ruled out.

297. A third diversion possibility would be the following. A dam could be constructed about ten kilometers downstream of Afgoi which would raise the level sufficiently to provide gravity command of the farms now being irrigated by water pumped from the river. This would require the river to be embanked upstream of the dam for approximately twenty kilometers. It has been estimated that dam and embankments might cost about So.Sh. 1,250,000. To amortize this amount over 25 years at 4 per cent interest would cost approximately So.Sh. 80,000 per annum. If 500 hectares of bananas

TABLE 19

APPROXIMATE COST OF DIVERSION

Clearing for canal and embankments	So. Sh.	60,000
Earthwork - canal		3,800,000
Earthwork - river embankments		210,000
Diversion dam and canal headworks		550,000
Outfall		150,000
Bridge		100,000
	So. Sh.	4,870,000
Engineering and contingencies @ 30%		1,461,000
Total	So. Sh.	6,331,000

were thus provided with irrigation water this would represent an annual cost for water of So.Sh. 160 per hectare. This is considerably less than the present cost of pumped water. Hence charges for water could be levied which would be attractive to the banana growers, pay for the cost of the project and provide a small surplus to the Government.

298. If the topography were found to be suitable a canal might then be built, starting immediately upstream of the dam and running approximately south-east, roughly at right angles to the Afgoi-Merca road. This could be designed to carry about 20 cumecs, and it would be approximately seven kilometers long. Turnouts could be placed along the downstream side, spaced perhaps one kilometer apart. By this means a portion of the periodic flood water, otherwise wasted, could be used to inundate a considerable area between the river and the road. Encouragement could be given to the development of inundation farming in this area and a large area of good grazing would also be created. In due course, if desired, lateral canals could be constructed and an area of controlled irrigation be developed. The location of this project is shown on Map 9.

299. Insufficient level data is available at present to determine the feasibility of this proposal, but indications are favourable. If the construction of the dam and embankments were found to be economically feasible, with the costs being met as suggested, and ground slopes proved to be suitable for the inundation proposal, this project might be considered attractive whether or not it was found feasible to eventually completely regulate the Shebelle. The cost of the canal cannot be accurately computed at this time but it has been estimated that it would be in the order of So.Sh. 1,500,000 including turnouts.

300. It might be found that it would be more economic to site the dam further upstream than suggested above, as indicated on the map, and convey water to the farms downstream of it in a canal paralleling the left bank of the river. In fact a site in the vicinity of Afgoi might be indicated. If so, the possible savings that might be made by combining this structure with the new bridge which will be required for the Afgoi-Baidoa road should be investigated. Such an upstream siting would, of course, increase the costs of the flood diversion canal.

Improvement of Inundation Irrigation

301. It will be clear from all the foregoing that if complete control of the flow is not effected a good deal of inundation irrigation will continue indefinitely along the whole length of the Shebelle River. Hence it is important that Government take all possible steps to improve the per unit output of this farming, particularly as the implementation of some proposals recommended herein would reduce its extent.

302. Improvement will depend largely on the effectiveness of the Government agricultural extension services. It is suggested that this will be increased more by example than by verbal advice and instruction, useful as they may be. To that end it is recommended that small but efficient demonstration farms be set up in strategic locations. A large investment would not be required for a program such as is here envisaged as it would consist of one farm near Audegle, one or if possible two between Balad and Johar, the same between Johar and Mahaddei Uen, and one near Gialalassi. These would be central to the most extensive inundation farming areas. Others might be added later when more trained personnel became available.

303. These farms might be organized in any one of a number of ways. One possibility would be to make use of a cooperative farm, of the type which are at present

being encouraged by the Government, provided the members were prepared to accept and act on instruction and direction, rather than merely being offered advice. There would be resident on each of these farms, an agricultural technician who had been well trained by the Afgoi Agricultural Research Station in a very few specific functions directed mainly towards increasing the per hectare yield of maize, sesame and perhaps one or two carefully selected crops. Such a man would not need to be trained in agriculture in the broad sense and would be selected on the basis of reliability, energy, interest in the work and ability to get along with the farmers concerned. He would preferably be recruited in the area in which he was to work.

304. He would maintain continous close liaison with the Research Station and would be responsible for ensuring that the best seed, provided by the Station, was properly planted in correctly prepared soil. He would ensure that the specified cultivation and weed control was carried out as required, that disease and pest control measures were applied as deemed necessary by the Station and that watering was carried out as well as possible under inundation conditions. He would maintain records on cost of the application of a limited amount of mechanisation which should be applied to these farms experimentally, and of supplementary irrigation by diesel driven pump taking water from the river.

305. As and when the Research Station becomes satisfied that a new seed or a new crop should be introduced, these demonstration farms would perform a valuable service in their dissemination, as an adjunct to the village cooperatives established in the dry land farming areas by the Rural Development Board.

306. In some localities where there is extensive farming within a reasonably small radius, such as between Balad and Mahaddei Uen, the use of tractors will undoubtedly be economic if they can be employed on large enough areas. Ideally they would in due course be owned by cooperatives, or by private individuals who would do ploughing, etc. on contract. Initially they would probably have to be provided by the Government.

307. Used judiciously, and again in connection with large enough areas, pumps to provide a small fraction of the total water requirements would probably be economic, even with relatively low value crops. These also would probably have to be supplied by the Government in the first instance and it seems reasonable to suggest that they might be mounted on rafts and thus moved up and down the river as required.

308. Another method of establishing a demonstration farm would be to attempt to find, in each area, a progressive farmer of the right type who would be sent to the Research Station for instruction. It could be shown that it would be well worth his while to join such a program and there would be the advantage that no salary would have to be paid. Moreover, as he would be working for himself there would be more likelihood of his being conscientious and hard working than would be the case with a civil servant.

309. A third possibility would be an arrangement whereby the Government purchased land and handed it over to an experienced farmer to operate, with most of the profits going to him. Again the farmer would be trained in the essentials and he would hold tenancy of the land as long as his work was satisfactory.

310. Whatever approach were selected it is suggested that, if at all possible, the involvement of a purely salaried civil servant be avoided. It is obvious, moreover, that a great deal would depend upon the type of man chosen and selection on any basis other than apparent suitability for the work be fatal to the project.

311. There are some parts of the valley, particularly north of Gialalassi, where

due to the topography inundation farming will continue to be scattered along the river in small and relatively uneconomic-sized units. Due to their individual size and their isolated locations it is unlikely that many of them will ever be able to support mechanisation of any kind. In due course and attempt should be made to introduce oxen, with ploughs of modern design if it could be demonstrated that this would have a real advantage over hand cultivation. Such an innovation, which will not be accepted readily, could only be brought in on a demonstration farm with any hope of success. Further, experiments could and should be made on the practicability of lifting small quantities of water from the river onto the land by simple and cheap wind or water driven pumps which might be devised.

312. It should be reiterated that, as a general principle, inundation irrigation should give way to controlled irrigation wherever possible as the aim must be to obtain the maximum benefit to the country's economy, even at the cost of some local dislocation of livelihood. On the other hand where such practices must inevitably continue a serious effort should be made to bring about maximum efficiency as the total output of this sector of agriculture could become an important contribution to the national product. When the tsetse fly problem is eliminated, which is completely practical along the Shebelle, the increase of livestock on these farms should make them among the most prosperous in the region.

Economics of Irrigation Development

Development With No or Partial Regulation of Flow

313. It has been shown in the foregoing that with no regulation of the flow of the Shebelle, or with partial regulation designed to increase the available water in the critical months, it should be possible to add 20,000 hectares of irrigated land to that now under irrigation or for which irrigated production is already fairly definitely planned. The latter has been taken to include 6,000 hectares of bananas, 4,000 hectares of maize and 3,000 hectares of cotton in the Genale area, 500 hectares of bananas in the vicinity of Afgoi, 5,000 hectares of sugar cane and 1,000 hectares of cotton in the adjoining area.

314. It has been shown also that, through rehabilitation of existing canals and farms, 21,000 hectares could economically be developed within the confines of the S.A.C.A. concession farm area centred on Genale. As a modification of this it has been assumed that only one half of this might be developed under conditions of uncontrolled flow because the capacities of the existing canal system would be inadequate to take the unusually large quantities of water which it would periodically be necessary to accept.

315. Further, it has been shown that the next most favourable area for development would be the Bulo Mererta area, contiguous to and downstream of the first. Here 13,600 hectares could be developed for irrigation considerably more cheaply than would be possible on virgin land, and there would be other advantages also to the selection of this locality.

316. Estimated unit costs of bringing the various categories of land under controlled irrigation were derived and are as follows:

Cost per hectare for 10,000 hectares in the Genale area	So.Sh.	454
Cost per hectare for 13,600 hectares in the Bulo Mererta area		2,154
Cost per hectare on virgin land		3,411

317. The estimated average annual gross at-farm value of the additional crops which could be grown on 20,000 hectares was shown to be So.Sh. 36,300,000.

318. On the basis of these figures, and using relevant data and costs given in Volume 6 of this report, the following analysis has been prepared. (Table 20) It has been assumed throughout that all development programmes would be implemented, and all farming subsequently carried out, under completely adequate management. This would involve a substantial administrative structure with all the necessary personnel and equipment to provide the quality of direction and assistance of every sort that would be necessary to obtain the production targets assumed. A large initial capital investment would be required for this and the cost of its amortization would have to be added to the other costs which the farm income would have to bear.

319. It is suggested that a reasonable, and realistic, time table for this development would be to aim at developing and bringing up to optimum production 10,000 hectares in 10 years and the remaining 10,000 hectares in the following 5 years.

Development With Full Regulation of Flow

320. It has been shown that, if techncially feasible, full regulation of flow of the Shebelle could be obtained by an estimated capital expenditure of approximately So. Sh. 101,750,000. The annual cost of amortizing such an investment over 50 years at 4 per cent interest would be So. Sh. 4,736,000. The life of the reservoir at the capacity required for full regulation has been assumed as being limited to 50 years because of sedimentation. It is estimated that there would be an annual cost of So. Sh. 200,000 to maintain and operate the dam and control gates and to replace the mechanical equipment once during this period.

321. It has been pointed out that while the maximum agricultural benefits from full regulation would be obtained if all the water were applied to the irrigation of high-value perennial crops, marketing conditions might prevent such an optimum return Annual benefits were therefore computed for this form of development, in the first instance, and for a minimum type development which would involve common, lower value seasonal crops as an alternative.

322. In the first case the net annual increase in return due to the additional crops produced was estimated to be So. Sh. 147,000,000. This would require the development of 19,000 hectares of land. This land could be developed in the same areas and at the same unit costs as for non-regulated flow development.

323. In the second case the increase in annual return was estimated to be So. Sh. 54,450,000. The same area would require to be developed.

324. The economics of development in the two alternative cases are set out in Tables 21, 22, 23.

325. It is apparent from the foregoing analysis that there would be good economic justification for constructing the proposed dam if the agricultural development dependent upon it could be implemented as suggested in Case No. 1. However, to bring the required 19,000 hectares under irrigation, and to grow and to market annually the 4,530,000 quintals of bananas involved would be no easy matter.

326. It would require a very high degree of organisation, in the first instance, to set up operations on such a large scale and to maintain a steady level of production. Highly competent management would be needed and while the top levels could be imported, a large number of Somalis at intermediate and lower levels would be involved. Moreover many thousands of Somalis would be required for the various aspects of field

TABLE 20

CAPITAL COST OF ADDITIONAL DEVELOPMENT

Total Area developed - 20,000 Ha.	
Total direct cost of development @ So. Sh. 1,300. per Ha	So. Sh. 26,000,000.
Total cost of management infrastructure -	So. Sh. 15,000,000.
Total capital cost of development	So. Sh. 41,000,000.

ANNUAL COSTS OF ADDITIONAL DEVELOPMENT

Amortization of Capital cost 30 years @ 4% interest	So. Sh. 2,371,000.
On-farm operating expenses 20,000 Ha. @ So. Sh. 860 (including 100 So. Sh. hired labour)	So. Sh. 17,200,000.
Management Cost	So. Sh. 1,300,000.
Irrigation system operation and maintenance Cost	So. Sh. 1,500,000.
Total Annual Costs	So. Sh. 22,371,000.

ADDITIONAL ANNUAL INCOME

Gross annual value of additional crops	So. Sh. 36,300,000.
Less net income of 4,000 Ha. removed from production under inundation irrigation	So. Sh. 1,000,000.
Total	So. Sh. 35,300,000.

NET ANNUAL FARM BENEFIT

Total additional annual income	So. Sh. 35,300,000.
Total additional costs	So. Sh. 22,371,000.
Net Annual farm benefit	So. Sh. 12,929,000.

FARM BENEFIT / INVESTMENT RATIOS

Gross farm benefit/investment ratio 86%

Net farm benefit/investment ratio 32%

TABLE 21

CAPITAL COST OF ADDITIONAL DEVELOPMENT

Total area developed - 19,000 Ha.

Average direct cost of development per Ha. - So. Sh. 1,300

Total direct cost of development @ So. Sh. 1,300. per Ha.	So. Sh. 24,700,000.
Total direct cost of management infrastructure	So. Sh. 14,250,000.
Cost of dam and reservoir	So. Sh.101,750,000.
Total Capital cost of development	So. Sh.140,700,000.

TABLE 22

ANNUAL COSTS OF ADDITIONAL DEVELOPMENT - CASE NO. I

Amortization of development and infrastructure costs	So. Sh. 2,253,000.
Amortization of river regulation costs	So. Sh. 4,736,000.
On-farm operating expenses 15,000 Ha. @ 3,100 So. Sh. per Ha. (Not including hired labour)	So. Sh. 46,500,000.
Management costs	So. Sh. 9,050,000.
Irrigation system operation and maintenance	So. Sh. 1,500,000.
Operation and maintenance dam and regulation equipment	So. Sh. 200,000.
Total Annual costs	So. Sh. 64,239,000.

ADDITIONAL ANNUAL INCOME

Annual value of additional crops	So. Sh. 147,000,000.
Less net income of 5,000 Ha. removed from production under inundation irrigation	So. Sh. 1,000,000.
Total annual income	So. Sh. 146,000,000.

NET ANNUAL FARM BENEFIT

Total additional annual income	So. Sh. 146,000,000.
Total additional annual costs	So. Sh. 64,239,000.
Net annual farm benefit	So. Sh. 81,761,000.

FARM BENEFIT / INVESTMENT RATIOS

Gross farm benefit/investment ratio	- 104%
Net farm benefit/investment ratio	- 58%

TABLE 23

ANNUAL COSTS OF ADDITIONAL DEVELOPMENT - CASE NO. 2

Amortization of development infrastructure costs	So. Sh. 2,253,000.
Amortization of river control costs	So. Sh. 4,736,000.
On-farm operating expenses 19,000 Ha @ So. Sh. 1,100 (Not including hired labour)	So. Sh. 20,900,000.
Management Costs	So. Sh. 1,235,000.
Irrigation system operation and maintenance	So. Sh. 1,500,000.
Operation and maintenance, dam and regulation equipment	So. Sh. 200,000.
Total Annual Costs	So. Sh. 30,824,000.

ADDITIONAL ANNUAL INCOME

Gross annual value of additional crops	So. Sh. 54,450,000.
Less net income of 5,000 Ha. removed from production under inundation irrigation	So. Sh. 1,000,000.
Total Annual Income	So. Sh. 53,450,000.

NET ANNUAL FARM BENEFIT

Total additional annual income	So. Sh. 53,450,000.
Total additional annual costs	So. Sh. 30,824,000.
Net annual farm benefit	So. Sh. 22,626,000.

FARM BENEFIT / INVESTMENT RATIOS

Gross farm benefit/investment ratio	38%
Net farm benefit/investment ratio	16%

labour concerned.

327. It is not believed that a sufficient number of competent and experienced Somalis now exist to make a success of such an operation at the present time, nor are they likely to be found for many years, considering the many demands on the limited numbers of trained and capable men available.

328. Further, it has yet to be proven that Somalia can establish herself in the world banana market on anything approaching this scale, and there can be no assurance that it would be possible to enter competitively into the markets for sugar, grapefruit or other high-value perennial crops. The questions of markets can be settled over a number of years under the present conditions of unregulated flow and when and if expanding markets appear to be assured, in which Somali agriculture can compete, the matter of a dam can then be seriously considered.

329. If development proceeded along the lines suggested in Case No. 2 the question of markets would not arise to any serious extent. However, the other objections stand and are even more significant as with the greatly lowered maximum value of production there would be less margin to offset inefficiency.

330. If a dam were constructed the country would be committed to an annual expenditure of approximately So. Sh. 5,000,000. Obviously this could not be contemplated unless it were virtually certain that this cost could be met, with a good margin, out of annual charges levied, and collected, for water used.

331. It is therefore recommended that the damming of the Shebelle should not be contemplated for at least fifteen years. During this period every effort should be made to attempt to bring up to maximum efficiency agricultural production based on the unregulated flow of the Shebelle. This in itself will be difficult enough but at least the development would not be burdened with the high amortization costs of a dam on top of the other unavoidable expenditure. The irrigation development itself can be carried out with a relatively small capital outlay. That can and should be expended progressively as personnel gain sufficient experience and as an organisation comes into being capable of employing capital wisely and with assurance of a fair return on the investment.

332. It is recommended, however, that a feasibility study of this project be made within the next few years. This is essential in order to make the necessary decisions on the alternative possibilities of embanking and flood water diversion. With this in view regular sediment sampling should immediately be started at Bulo Burti, as mentioned previously, and a very thorough sampling programme carried out, particularly during the months of high and turbid flows. Discharge measurements should be continued with emphasis on the higher flows. Horizontal control and additional vertical control should be carried out in the reservoir area and this area mapped by photogrammetric methods from existing photography, prior to the commissioning of consulting engineers to carry out the study. It is suggested that this last be done in the latter part of 1966, if, by that time, the sedimentation data has in fact been collected and the reservoir mapping has been completed.

Irrigation by Groundwater

333. In recent years groundwater has been used increasingly in the vicinity of Genale to supplement irrigation supplies from the Shebelle during periods of low flow. The wells that have been drilled for this purpose have indicated that a good acquifer underlies the S.A.C.A. concession farm area and that a considerable quantity of water suitable for irrigation may be drawn from it. It is believed that this acquifer is recharged by infiltration of irrigation water and that it is to this that its good

quality is owed, a quality that is only maintained a relatively short distance from the river. The main underflow, approaching the river from the north and west, is too saline for irrigation use. This matter is discussed fully in Volume 2.

334. There is reason to assume that there are extensive deposits of good acquifer materials underlying and adjacent to the Shebelle throughout its length, and there is a possibility that in certain areas the groundwater yield might be sufficient to maintain considerable irrigation farming quite apart from supplies from the river. Moreover the natural yield might be increased artificially by judicious flooding of selected areas with surplus water when available. While this would raise the cost of production very considerably it could still prove to be economic with certain crops and with highly efficient farming. The water, at least in the Genale area and probably in other localities also, is not at greater depths than have proved economic elsewhere.

335. To date, however, no adequate pump-testing has been carried out anywhere in the valley to determine the magnitude of sustained yield that might be expected. Until this is done, and observations made over a number of years, and results found to be positive, no consideration can be given to irrigation based solely on groundwater. A feasibility study is required, as recommended in Volume 2, to make an intensive and extensive investigation of the groundwater potential of the Shebelle Valley. This should be carried out over the next few years because, if sub-surface conditions were found to be exceptionally favourable, it might be found preferable to store, in effect, surplus water underground rather than in the proposed reservoir. Losses might be less under these conditions than the extremely high evapouration losses which are inseparable from the only surface reservoir site available in Somalia. Such sub-surface storage might be considered if an excessive sedimentation rate rules out a dam.

336. In any event irrigation by groundwater should only be contemplated after the surface supplies of the Shebelle and the Juba have been exploited to the full. By that time it is reasonable to assume that agricultural efficiency will have reached a point where crops could be grown profitably with more expensive water than that drawn from the rivers. This development, if found to be feasible, might be expected to be started in from ten to fifteen years time.

IRRIGATION DEVELOPMENT OF THE JUBA RIVER

INTRODUCTION

337. In 1960 a survey team from the United States International Cooperation Administration made a study of the Inter-River region of Somalia, the boundaries of which were roughly similar to those of the project area of this Survey. As regards irrigation development that study concentrated on the Juba River, as the time allocated did not allow consideration of the Shebelle also. The report, published in January, 1961, included the results of a reconnaissance soil survey of the soils of the Lower Juba and outline plans and cost estimates for irrigation schemes covering approximately 160,000 hectares. This was the area for which it then appeared there was sufficient water, for both perennial and seasonal crops, based on the very limited river flow data available.

338. Early in 1963 a team from the U.S.S.R. commenced a second study of the

Juba River in accordance with the terms of a contract signed with the Government of Somalia. The purpose of this study was to "work out a scheme on utilizing the Juba waters for irrigation" and the work to be carried out under this contract included the following:

(a) Selection of areas to be irrigated by the Juba waters and their size.

(b) Selection of sites for water intake for irriagion systems.

(c) Time taken to build up irrigation systems and to develop land for farming.

(d) Terms and priortiy of works.

(e) Capital investments, maintenance expenses and payback periods.

339. In the middle of 1964 a preliminary report on this investigation was issued, the final report being due in 1965. It was apparent from the former report that this study would provide a comprehensive scheme for developing the irrigation potential of the Juba and that no useful purpose would be served by duplication of this work in this present study.

340. Accordingly only a brief summary of the main features of the Juba River and the adjoining irrigable lands is presented here. An indication is given of the scale of development involved and an estimate of the order of benefits that may accrue in due course. Detailed proposals, including areas, crops, costs and priorities will be provided by the team from the U.S.S.R. in their final report.

AREA AND LOCATION OF IRRIGABLE LANDS

341. The physiography of the Juba River valley within Somalia differs considerably from that of the Shebelle. The river traverses a distance of about 530 kilometers with a channel length of approximately 730 kilometers whereas the channel length of the Shebelle is nearly double the distance traversed. From Dolo, where it enters Somalia from Ethiopia, it flows between relatively stable banks of alluvium in a wide valley, defined by hills of fair height, to a point about 30 kilometers south of Lugh Ganana, a total channel distance of about 125 kilometers. For the next 175 kilometers the valley narrows, the river banks are rocky, and there is a marked reduction in sinuosity. Thereafter the valley widens and the surrounding hills progressively disappear until, about 40 kilometers upstream of Dugiuma, a flood plain begins. Through this plain the river meanders the remaining distance to the sea, about 200 kilometers.

342. This plain is thus relatively short; it is considerably shorter than the flood plain of the Shebelle. It is also narrow, even at its widest portions, as may be seen on Map 6. Moreover, parts of it are broken by low hills and other portions are extremely level and at low elevations, making irrigation and drainage of much of the area difficult and expensive. These drawbacks are aggravated by the fact that the soils are generally much less permeable than those along the Shebelle and drainage would present problems in many localities regardless of topography.

343. The consequence of the foregoing is that the total area of irrigable land is only approximately equal to that for which irrigation water is available, with the flow unregulated. If the flow were to be regulated there would be considerably more water available than could be utilized on land adjoining the Juba River, the converse of the case of the Shebelle.

344. The main area of irrigable land lies downstream of Fanole, extending south for a distance of about 105 kilometers to the vicinity of Ionte, approximately 15 kilometers from the mouth of the river and 25 kilometers from Kismayu. It occurs on both banks of the river but preponderantly on the left bank in the northern half of the area and with a slight preponderance on the right bank in the southern half.

345. The total area of the foregoing appears to be in the order of 165,000 hectares. Even so it is not all Class I land, as is the case with all land proposed for development on the Shebelle. The latest available figures, produced by the study carried out by the U.S.S.R. team, give classifications as follows:

Class I	-	59,400 hectares
Class II	-	45,200 hectares
Class III	-	42,900 hectares
Class IV	-	17,500 hectares

346. This team has also examined a second major area upstream of Dugiuma. As a result of soil surveys and its findings and preliminary estimates have indicated, a total of over 100,000 hectares is suitable for irrigation.

347. There are thus approximately 265,000 hectares of land in the Juba Valley which can be irrigated, with varying degrees of difficulty and expense. At the present time approximately 1800 hectares are being used for banana production and approximately a further 550 hectares are planted to other crops, all irrigated by water pumped from the river. There are also roughly 22,000 hectares under inundation irrigation.

QUANTITY OF IRRIGATION WATER AVAILABLE

348. The Juba river has a considerably higher flow than the Shebelle, the approximate average discharge at Bardera over the period 1951 - 1964 being 176 cumecs, its flow, however, is equally torrential in nature. As the catchment areas of the two rivers are contiguous, and are subject to roughly the same rainfall pattern, their flow patterns are very similar. There are, however, certain significant differences which are made clear in Table 24.

349. This table shows, for each river, monthly flows of 75 per cent probability as percentages of the synthetic total annual flow resulting from summing these monthly flows. The figures are based on discharges at Bardera for the Juba and at Audegle for the Shebelle.

TABLE 24

MONTHLY RIVER FLOWS AS PERCENTAGES OF ANNUAL FLOWS

	J	F	M	A	M	J	J	A	S	O	N	D
Juba	1.6	.8	.4	2.1	8.6	5.2	9.3	13.3	14.2	21.9	15.7	6.9
Shebelle	1.6	.9	1.0	1.6	14.8	4.7	1.8	8.5	22.6	22.0	15.0	5.5

350. It will be immediately apparent that the selection of crops, and their growing seasons, suited to the Juba valley are, in general, subject to the same limitations that pertain in the case of the Shebelle. Most notably, the extremely low flows during January, February and March seriously restrict the growing of perennial crops. Another similarity is the relatively low flow in December, which here again limits the area which might otherwise be planted to cotton or rice. Because of considerably higher flows in the Juba in July this might be offset in the case of rice by planting in July instead of August, if other weather requirements and conditions would allow this, and thereby avoid water demand for this crop in December. Otherwise the higher flows in June and July are not of as much value as they might appear at first sight except insofar as they could be used to produce fodder. It appears unlikely that the reasonably high level of flow maintained during these months would allow the growing of a large second crop of maize in the 'Gu' season. Such a crop would have to be started in April and available data indicates that during at least the first half of this month the water would be too saline to be used.

351. It is known that ground water with a quality probably suitable for irrigation occurs in the narrow riverine zone as an underflow of the river. An exploration program may indicate that this water is available in sufficient quantities to augment the supply from the river in the critical months of February and March. Until the availability of ground water is determined however, it would appear that the low flow in the months of February and March would limit perennial crops to approximately 5,000 hectares, as a conservative estimate.

352. With this area assumed to be planted to bananas, and subtracting the appropriate monthly water requirements from the estimated 75 per cent monthly flows, the figures in Table 25 are obtained. These are the approximate gross quantities passing Bardera which would be available for irrigating seasonal crops. The net amounts available at the various sites proposed for development downstream between this point and Ionte will, of course, vary considerably due to channel losses by evaporation infiltration and the occasional contributions of ephemeral tributary streams and temporary storage in 'desceks'. The figures given will nevertheless enable the irrigation potential to be demonstrated in general terms. More detail will be found in the final report of the team from the U.S.S.R.

TABLE 25

75% MONTHLY FLOWS AT BARDERA AVAILABLE FOR SEASONAL IRRIGATION

1000's of Hectare-meters

APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
7.8	35.0	20.8	37.7	54.5	58.5	91.8	65.0	27.6

SCALE OF POSSIBLE DEVELOPMENT

353. Due to the extensive distribution of the irrigable lands along the Juba, their variation in quality, and the wide differences in magnitude of the works required to irrigate and provide flood protection for the various portions, development

here will be much more complicated than in the case of the Shebelle. It will, in consequence, probably take place over a much longer period and the bulk of the land may well be developed when the requirements of domestic and foreign markets have changed drastically. However, in order to show the approximate scale of development possible, its potential may be considered in terms of some of the crops proposed for the Shebelle though without attempting at this time to assign percentages of the total area to each crop.

354. In Table 26 the estimated monthly irrigation water requirements for four typical crops are given. These are the gross diversion requirements (assumed as double the net consumptive use) after making allowance for the effective monthly precipitations shown. These latter figures were derived from the average rainfall figures for Gelib, this station being selected as the most central point for which records are available.

355. Possible growing seasons for two crops of maize are shown for completeness but, as mentioned previously, it is not believed that the first of these would prove practicable due to salinity problems. Moreover, if it were determined that ripening and harvesting were not seriously affected by moving the 'Der' season crop ahead to avoid the low-water month of December, it might well be found that the return from this would be greater than that from two crops subject to the April and December limitations. As noted previously the production of rice might be increased by moving its growing season but the more conservative case has been used; this applies equally to the second crop of ground nuts.

356. Based on the foregoing, and on the figures of water availability in Table 25, the following areas which could be planted to various crops have been computed, as limited by months of critical flow.

Maize - one crop (Aug - Nov): 246,000 hectares
two crops (Apr - July): 37,000 hectares; (Sept - Dec): 140,000 hectares

Cotton : 212,000 hectares

Rice : 83,000 hectares

Ground Nuts : 'Gu' season : 142,000 hectares
'Der' season : 153,000 hectares

357. There would, of course, be much surplus water available in September, October and November under any circumstances, and depending on the choice of crops, a considerable quantity in all other months except January to April. This could be applied to grazing land, or the growing of alfalfa might prove feasible. It must be reiterated that these estimates of possibilities are extremely rough, but they are based on sufficient factual data that it is believed they are conservative.

358. While there are indications that a detention dam and possibly a storage dam might prove to be feasible, no such assumptions can be made at this time. However, in order to round out the picture, it is worth indicating the agricultural possibilities <u>if</u> this feasibility were to be proved.

359. The 75 per cent annual flow at Bardera may be calculated to be approximately 595,000 hectare-meters, from the 14 years of data mentioned above. If this could be regulated by a detention reservoir, with evaporation and seepage losses from reservoir and channel assumed as 30 per cent, the available monthly flow would be in the order of 34,700 hectare-meters, which is approximately equal to the present 75 per cent monthly flow in May. This would provide for the irrigation of at least 130,000 hectares of bananas, but this quantity of water would only be assured in three years out of four.

TABLE 26

MONTHLY IRRIGATION WATER REQUIREMENTS

Hectare-meters per 1000 Hectares

	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Maize									
One crop					196	238	190	100	
Two crops	106	176	194	174		206	174	132	198
Rice					310	366	356	278	332
Cotton				142	228	286	206	100	130
Ground Nuts									
Two Crops		118	146	158			156	84	180
Assumed eff. precip. - mm	57	63	32	27	8	0	38	63	19

360. If a larger, storage reservoir were feasible the average 100 per cent monthly flow which then might be provided, again based on the same period of records, would be in the order of 32,300 hectare-meters. This would provide for the dependable irrigation of approximately 120,000 hectares of bananas.

361. It should be noted that while a relatively good dam and reservoir site appears to be available in Somalia, the feasibility of regulation may be determined by other than topographic or geologic factors. Sedimentation and salinity problems may be serious. The latter might prove a particular hindrance in that a large portion of the soils proposed for irrigation are not as well-drained as desirable, and conditions of incipient salinity are much more pronounced here than in the case of the Shebelle.

ORDER OF DEVELOPMENT

362. The order of development of the various portions of the irrigable land will be greatly influenced by their location relative to logical water diversion points and by development now in hand. Of the 165,000 hectares first above mentioned, approximately half lies between Fanole and Camsuma. Within this area the U.S.S.R. is developing about 10,000 hectares in the form of two state farms, one for cotton and the other for oil crops - see Map 6. To provide the irrigation water for these a diversion dam, sited at Fanole, and a canal with a maximum capacity of nearly 10 cumecs are being built.

363. The location of this diversion structure is such that other canals may be taken out from above it, on both sides of the river, to serve a further 65,000 hectares on the island of Touata which contain the best soils along the lower Juba. A further 15,000 hectares of Class I and Class II land lie in a relatively narrow strip along the right bank. Reconnaissance surveys have shown that there are not less than 40,000 hectares of Class I and Class II soils along the left bank and perhaps an equally large area of Class III soils adjoining. The last-mentioned could also be commanded by a canal from the same diversion dam and this area would be suitable for development when more water was made available through full regulation of the flow.

364. Due to the limited capital, management and trained manpower of all kinds available, and to the difficulty of settling nomadic people on the land, it does not seem realistic to expect this whole area to be developed in less than 20 years. It is recognised, however, that development might be greatly accelerated if very large blocks were taken up by private companies on a plantation basis and it is suggested that serious consideration be given to this.

365. When the full potential of the diversion at Fanole has been exploited a second diversion dam may be constructed in the vicinity of Bardera. This would provide for the command of not less than 25,000 hectares of Class I and Class II land on the right bank between Bardera and Ionte and about 20,000 hectares of these Classes of land on the left bank. Here again, on the left bank, further large areas of Class III lands are available for eventual development when water is available.

366. The final area to be developed, under unregulated flow conditions, would be the lands on the left bank upstream of Dugiuma. Preliminary surveys have indicated that there are between 25 and 30 thousand hectares of Class I soils and between 20 and 25 thousand hectares of Class II soils in this region all well placed for irrigation.

367. Most of the land included in the first two areas described above is subject to flooding practically every year, to a greater or lesser extent. Consequently the

cost of the necessary measures to protect the land would be a significant part of the total development costs of these areas. The first-mentioned area can be protected reasonably economically by levees, in conjunction with the embankments of the main canals. It is believed that the second area, that lying downstream of Bardera, will be more economically protected by the construction of a flood detention reservoir in the upper reaches of the Juba. A suitable site appears to exist about 25 kilometers upstream of Bardera. It is also believed that a dam built at this site could, at a later date, be increased in height and produce a storage reservoir, thus providing full regulation of the flow of the river. These suggestions are, of course, based on assumptions only, as a thorough study of this matter has not yet been carried out.

368. It is understood that the U.S.S.R. team has made a preliminary investigation of these possibilities but a feasibility study should be commissioned in the near future. It is essential that, well before development of the first area is completed and that of the second area is planned, the relative costs of flood protection by detention dam or levees should have been determined with accuracy. The potential of such a dam and reservoir for future enlargement to provide full regulation should also be thoroughly investigated. While it is unlikely that the construction of this final element of the river development works will be justified for at least twenty years, this could have a bearing on the economic feasibility of constructing the first stage.

369. The final stages of development, if a storage dam should prove feasible, would be the conveying of the water surplus to possible utilization in the Juba valley to some other areas. It has been tentatively suggested by the U.S.S.R. investigators that it might be practicable to run a large canal east or south-east from the vicinity of Dugiuma to carry water to the fertile land along the extreme lower reaches of the Shebelle. Considerable topographic mapping and soils studies will be required to determine the technical feasibility of this. It is known, however, as a result of the soil survey carried out by this present project, that throughout the first 75 kilometers at least which would be traversed by such a canal the soils are not suited to irrigation.

SURFACE WATER SUPPLIES FOR HUMAN AND ANIMAL CONSUMPTION

UARS

370. Uars, the local name for natural or man-made ponds or reservoirs in which rain water is collected and stored, have been and will continue to be the main source of water supplies in many parts of the project area. While most of the man-made uars have been excavated by hand near villages by the inhabitants, and a few on cattle trails at particularly favourable locations, a fair number have been constructed in the last ten years or so by machines.

371. The latter construction has been carried out under various projects prior to Independence, by U.S. AID programmes between 1959 and 1963 and by the Public Works Department since then. Nine uars, of an average capacity of 5,500 cubic meters each, were excavated under an AID programme in the general vicinity of Afmadu between August, 1959 and August, 1961. During the year ending March, 1963 fourteen uars of a similar size were constructed on the Baidoa Plain. The machines used for excavating these were left in that area and subsequently several more were constructed near Bur Acaba.

372. While initially being of great benefit to the areas in which they were locat-

ed, they have silted-up at varying rates since their construction and many inspected during the course of this Survey were found to be virtually useless. Some maintenance has been carried out in the Bur Acaba-Baidoa region but in a haphazard way as no maintenance programmes were included as part of the construction projects. It is apparent that these are essential if such projects are to have lasting value in the solution of the water supply problem rather than merely temporarily relieving distress due to water shortages.

373. The following is an attempt to prepare a rational programme of uar construction and maintenance, as part of an integrated plan for providing water supplies in the project area and basing priorities on data collected by this Survey. While in the Ground Water chapter of Volume 2 water requirements for stock watering, irrigation and human consumption have been treated separately, such a division has not here been made. Uars as a source of water for irrigation would not be practical in the project area. As sources of water for human consumption only they would be so insignificant as not to justify separate treatment. They will in the future, as in the past, provide water for man and animal alike for the survivial of both are inseparable in the areas they serve.

Regional Requirements

374. In approaching this subject as part of an overall development plan for the project area, the first requirement is to establish where it would be desirable to construct uars, as alternative water sources to rivers or wells, and where, in such areas, it will be both technically feasible and economically justifiable to do so. The second requirement will be to establish priorities for the foreseeable future. Thereafter designs must be considered, specific programmes proposed and costs of construction and maintenance estimated.

Basis for Estimation

375. In Table 27 are given some extracts of data from the Rangeland Survey and the Ground Water Survey which appear elsewhere in this report. Water requirements in the various regions vary widely, depending essentially on the size of the human and animal population, present and potential, and the former will be directly related to the latter. Hence, as a first guide to requirements, the carrying capacity, in animal units per square kilometer, of the various regions are listed in order of magnitude together with the suggested sources of water as proposed by the Range Ecologist. With reference to the latter it should be understood that these suggestions were based on necessarily superficial assessments and, in some cases, by the process of elimination of the obviously impractical sources. Consequently where wells are suggested it may be that in some cases they are not practical for various reasons; this matter is dealt with fully in the section on Ground Water. Similarly in the cases where uars are proposed conditions favourable to such construction may not in all cases exist; this subject is dealt with fully hereunder. Also tabulated, for each region, are the sources of water suggested by the Ground Water Geologist, and the above comments as to the practicability of uars again apply.

376. The estimated carrying capacities are based on estimated forage·production and will, of course, only hold good if adequate water supplies can be made available. The tabulated data indicate that such water supplies may, to a greater or lesser degree, depend in part upon uars in all regions except the Fafadun Plain, the Coastal Dunes, Upper Juba Valley, Mudugh Plain and the Upper Shebelle Valley.

377. Uars may, in fact, very well have a significant role in providing water in the Fafadun Plain and this will be discussed later. In the Castal Dunes uars are obviously impractical because of the extreme permeability of the sandy soil. In the

TABLE 27

ESTIMATED ANIMAL CARRYING CAPACITIES AND SUGGESTED WATER SOURCES

Region	Carrying Capacity in animal units per sq. km.	Sources of Water suggested by Range Ecologist	Sources of Water suggested by Ground Water Geologist
Shebelle Flood Plain	22.4	wells-uars-river	wells-uars-river
Lower Juba Shebelle Flood Plain	22.0	river	river-uars
Lac Dera Plain	20.8	wells-uars	wells-uars-wadi barrages
Dudomali Plain	20.0	wells-uars	wells-uars-wadi barrages
Eluviated Plain	16.5	wells-uars-river	wells-uars-wadi barrages
Marine Plain	13.4	wells-uars	uars
Fafadun Plain	11.1	wells	wells-river
Bur	8.6	wells-uars	wells-uars-wadi barrages
Coastal Dunes	8.0	wells	wells
Upper Juba Valley	5.8	river	river-wells
Central Uplands	5.6	wells-uars	wells-uars
Mudugh Plain	4.0	wells	wells
Mande a El Wak Uplands	3.9	wells-uars	wells-uars
Upper Shebelle Valley	3.8	river	wells-uars-wadi barrages

Upper Juba Valley Region the soil is too shallow for uar excavation, even when the clay content is sufficiently high, except in the valley bottom adjacent to the river where they are unnecessary. In the Mudugh Plain the soil is generally sandy and highly permeable. In the Upper Shebelle Valley uars would again be possible in the clay soils of the flood plain but here also they are unnecessary, and the soils of the higher lands more distant from the river are sandy and rocky.

378. In all other regions, however, it would appear that uars would have a place in the provision of water supplies, essential in some areas as the only presently apparent source and of varying degrees of value in others as a supplement to rivers, wells, wadi barrages and, in possibly a few cases, small dams. Given unlimited resources of money and man-power for construction and maintenance it would obviously be desirable to construct as many as possible in all these regions, with the only limitation being the avoidance of providing so much water that over grazing became a danger. As money and man-power are limited, and will be in the forseeable future considering the many demands upon such resources in a developing country, it is obviously necessary to select with care the areas in which they should be constructed during the next ten years or so. Such a selection should be based only on consideration of the economic potential of a particular region relative to that of others and on the practicability and economic feasibility of uars relative to other sources of water. The question is considered hereunder, region by region, leading to recommendations for areas for immediate attention and for those of slighly lesser priority. The boundaries of the regions are shown on Map 6.

Lower Juba-Shebelle Flood Plain

379. Most of this region is within ranging distance from the river or desceks, in the case of the Juba, and of various billichs in the case of the Shebelle. The tsetse fly presents a serious problem but the provision of uars and/or wells as alternative water sources at a sufficient distance from the infested areas does not appear to be the best solution in such instances. In the case of this region, as delineated, it would generally not be possible to provide water beyond the infested areas. A program of uar construction is thus not recommended in this region, though this obviously does not preclude the excavation of one or two in specific locations where circumstances might dictate.

Shebelle Flood Plain

380. It will be noted that the carrying capacity of this region is the second highest per unit area in the project area. Moreover, because of its relatively large size, its total carrying capacity is among the highest of any region, and it is estimated that its capacity would allow the grazing of three times the present number of cattle. Further, of the regions capable of producing large numbers of cattle it is the closest to potential markets and shipping points and, at present, the best served by all-weather roads. In view of the foregoing, and bearing in mind the advantages of this region for the development of finishing farms (discussed fully elsewhere in this report) it appears to be beyond argument that the provision of adequate water for stock raising and related human consumption should be given top priority here.

381. At present water is obtained mainly from wells and the river and only to a small extent from uars, which, except for two or three excavated by machine by the Government in the past two years are all hand-dug and very small. The river could be used much more than it is at present if the tsetse fly were to be controlled and the south eastern edge of this region could be well-served by it. High priority should also be given to dealing with the tsetse fly in this area as apart from its bearing on effective water supply it would open up a great deal of very good grazing,

as mentioned in other sections of this report. Whatever is done about this matter, however, at least a third of this region is beyond extreme ranging distance from the river and more than half could be considered further than it is desirable to have cattle travel for water for efficient production. Hence much of the region must depend upon wells and uars.

382. A further argument for placing high priority on providing water supplies in this region, whether by wells or uars, is the contribution it would make to the solving of the water supply problem in the portions of the Eluviated Plain Region which abut it. In these areas there is little promise of adequate ground water supplies and the soils, over very large tracts, are totally unfavourable to uar construction.

383. There is evidence that wells are possible in many parts of this region and, where found to be feasible, their numbers should be increased. In particular there is an urgent necessity to provide a few more permanent watering points west of the river and south of the Afgoi-Uanle Uen road, where there are now very few and those that there are, concentrated in a small area.

384. However, even if wells are found to be practicable in a fair percentage of the total area, they are relatively costly to construct, operate and maintain (particularly in terms of foreign exchange) relative to the quantity of water they are likely to be able to provide. Moreover the quantity which the average well will be able to supply as a sustained yield has yet to be determined.

385. Serious consideration will have to be given to widespread construction of uars in this region except in the localities where a drilling and testing programme demonstrates that wells would provide adequate quantities of good quality water more dependably and economically. It is known, however, that over a good part of this region the water quality is unsuitable for consumption and wells will therefore only be a partial solution. Fortunately conditions are reasonably favourable for uar construction, if not ideal in all respects. Generally speaking the soils have a sufficiently high clay content to be relatively impermeable. The topography has gentle slopes which, though flatter than desirable, are high enough to provide fair run-off but not so high as to produce excessive velocities and serious silting problems. Most of the region lies within the zone on the highest rainfall in Somalia.

386. Where uars are indicated, therefore, the highest priority should be given to their construction in this region. A detailed program is presented in a later section. This is of necessity very generalised as far as actual locations are concerned as sites can only be decided after the ground water potential has been fully explored.

Lac Dera Plain and Marine Plain (Western Section)

387. These two regions abut each other and together form a rough rectangle approximately 120 kilometers by 150 kilometers, more or less centered on Afmadu. Because they are such a geographical unity and because ground water conditions are similar throughout the whole area they will be considered together.

388. In forage production per square kilometer, and hence in animal carrying capacity per unit area, the Lac Dera Plain ranks third and the Marine Plain sixth highest in the project area. At the time of the cattle count there were approximately 140,000 animals in the Marine Plain (Western Section) and its estimated capacity is 188,000; there were about 207,000 cattle on the Lac Dera Plain and its estimated capacity is 330,000. While there is thus scope for an increase of about 60 per cent on the Lac Dera Plain, only in the order of a 35 per cent increase would be possible withough over-grazing on the Marine Plain. The range-land survey shows that there are regions offering a considerably greater increase in animal production than the

latter, and significantly more than the former. However, because rains, and hence forage production, are relatively dependable in these regions, and the area as a whole is one of the most accessible to markets (being the immediate hinterland behind Kismayu with its new port and meat packing plant) it is considered that these regions should be given second priority in regard to improvement of water supplies. A further argument in favour of concentrating immediate effort here is that apart from relatively easy access necessary for the maintenance of water supply facilities, the area is better situated than many otherwise favourable regions in regard to the provision of veterinary and advisory services aimed at improving the quality of livestock, of equal importance to improvement of the quantity.

389. As explained fully elsewhere in this report the ground water conditions are poor in both these regions and while encouraging prospects for very deep wells have recently come to light about 30 kilometers and 70 kilometers west of Afmadu as a result of exploration for oil, if water supplies are to be increased this will have to be done mainly by the construction of uars. In a few localities small dams and wadi barrages may be practical but at best they will have little bearing on the region as a whole. Hence a large scale uar construction program is recommended for these regions, of only slightly less priority than that proposed for the Shebelle Flood Plain, and detailed proposals for this appear hereinafter.

Dudumali Plain

390. As stated in the Rangeland Section, this region is already grazed to capacity though there are no wells and very few uars within its bounds. Obviously it would be desirable to provide a few water supply points to alleviate hardship but even if it were decided to do so uars would not likely be practical except in a few localities. Most of the soil of this region is sandy and highly permeable. It is not recommended that uar construction be considered in this region at the present time.

Eluviated Plain

391. This region is the fifth highest in unit carrying capacity, and the number of cattle in the area at the time of the count was just over 40 per cent of its estimated potential. At first sight, therefore, it would appear to qualify for immediate expenditure on increasing water supplies within its bounds in order to bring up its stock production more nearly in line with its capacity. Unfortunately the provision of adequate water supplies in this region is likely to prove extremely difficult. Topographically it is a gently sloping virtually flat plain. It includes no water courses of any significance except the Bohol Madagoi, an intermittent stream, west of the Avai-Dinsor road. While this stream may be developed within the Bur region is unlikely to be practical. As discussed in the Ground Water Section of this report, little is known about ground water conditions in this region but all available evidence indicates the prospects are poor.

392. Between 15 and 20 per cent of the region contains soils which are too shallow for uar construction and in the remainder of the area the soils range from sandy loam to sandy clay, with only occasional patches of clay. Soils in this area examined during this survey contained too little clay to be sufficiently impermeable for practical uar construction. It is possible that an extensive and detailed soil survey might locate localities where the clay content was high enough for the purpose. It is suggested that such a survey should be carried out concurrently with the drilling for water recommended elsewhere.

393. Considering the carrying capacity of this region a considerable expenditure, in due course, is justified on attempting to provide watering points within its bounds. However, as the promise is poor both for sub-surface and surface supplies it is not recommended that much effort be spent on this in the immediate future. Funds avail-

able could be put to better use, with guaranteed return, in the construction of uars just outside its southern bounds in the favourable soils of the Shebelle Flood Plain and the Marine Plain, and on uars and possibly wadi barrages and small dams in the Bur Region to the North. While this would not enable the Eluviated Plain to be used to its full capcity as determined by its forage production it appears to be the best solution for the next few years.

Marine Plain (Eastern Section)

394. This region is the sixth highest in unit carrying capacity. Due to flooding of large parts of it by exceptionally heavy rains at the time of the cattle count in June 1964, and to the evident seasonal concentration of cattle in the Eluviated Plain to the north (particularly marked between the Juba River and the Brava-Dinsor road) the number of animals normally carried by this region cannot be estimated with any degree of accuracy. However it is known that at present the adjoining portions of the Eluviated Plain cannot be used to their capacity due to lack of water during most of the year.

395. If the Marine Plain were to be considered by itself it might be placed relatively low on a list of priorities for provision of water supplies. It is relatively well provided with watering points in that it is roughly bisected by the end reaches of the Shebelle River which, though it carries little water during most of the year, does have a number of permanent watering points along its length and, in the form of billichs, many semi-permanent ones. Considered with the adjoining eastern half of the Eluviated Plain, as it should properly be in view of apparent seasonal cattle migrations, there is a strong argument in favour of giving relatively high priority to the construction of a chain of uars in the northwestern edge, i.e. parallel to the Shebelle River and as far from it as soil suitability allows.

396. In terms of priorities, after the recommended uar construction in the Shebelle Flood Plain and the Lac Dera Plain Regions, it is suggested that the choice should lie between this region and the Fafadun Plain, discussed below. Both are promising regions which are now relatively neglected by the nomads with their herds (the latter much more so than the former) and, up to this date, have been neglected by successive administrations. Much will depend upon the development of roads in these areas. If the proposed all-weather road from Mogadiscio to Gelib were to be routed north of the Shebelle River (and there are sound arguments for doing so) the Marine Plain would be the logical choice for uar construction. Money spent for such purposes should be spent where there is the greatest probability of maximum return. This will be the case where, as mentioned above, the provision of water is accompanied by the provision of veterinary and other services and all circumstances are favourable to getting the maximum number of cattle to market in the best possible condition with the greatest facility.

Fafadun Plain

397. Though this area has only approximately half the carrying capacity of the best regions, its grazing is by far the least used relative to its potential. This survey has adduced no reason other than shortage of water to account for this, though there well may be other contributory factors. It is clear, however, that watering points are badly needed and their provision would undoubtedly increase the use of the grazing in this region. Away from the vicintiy of Bardera there are virtually no wells and, due to the flat topography, few natural water holes, Practically no uars have been dug throughout most of the region though the generally clay soil is suitable. It is a region which would benefit greatly from a program of uar construction but whether the benefits to the inhabitants would be accompanied by sufficient benefits to the economy of the country as a whole to justify such a program in the near future is open to question.

398. The development of the stock raising potential of this area will be a logical extension of the development of the Lae Dera and Marine Plain regions to the south. Moreover with the development of the latter there will almost certainly be over-grazing in many parts until effective range management is in operation. Adequate water supplies in the Fafadun Plains would allow the grazing there to relieve the pressure on these other regions to the south and it would become a valuable addition to what will perhaps continue to be the most important cattle producing region in the country. When attention should be given to this area is a matter for Government policy to decide in the light of future developments.

399. It is sufficient to state here that there appears to be no reason why a network of uars should not be constructed in this area with complete success. The extent to which this will ultimately be done will, of course, depend in part on the extent to which it is found possible and economically feasible to develop such ground water supplies as would appear to exist.

Bur Region

400. This region is at present being grazed virtually up to its capacity with water being obtained mainly from natural uars during and after the wet seasons and, in some cases, from hand-dug wells many of which provide water all year round though often in limited quantity. Some of these wells are permanent and others are temporary, being dug in the dry beds of streams which flow very briefly during the rains. Of the regions so far considered this is by far the best-favoured for the natural storage of rainwater. This is partly because of the undulating topography which gives rise to ephemeral streams and to basins and partly due to sub-surface basins in the basement rocks. The soils generally are sandy and relatively pervious except in the vicinity of Bur Acaba where fairly large areas of sandy clays and clays are found. In this locality are many hand-dug uars and a few that have been machine-dug by the Government in recent years.

401. Additional watering points are of course desirable in this region in order to relieve hardship during the dry months but it does not appear that they would be of significant benefit to the economy of the country. If it were decided to increase water supplies in this region uars are indicated in the Bur Acaba plains area but not to any extent elsewhere. Even in this area a detailed study might disclose that money would be better spent on wells and wadi barrages, to take advantage of existing underground supplies and to increase these. Evaporation losses are so high in this country that the storage of rainwater above ground in uars should only be chosen if the alternative is not practical. Uar construction is not recommended in this region until the more important requirements of other regions have been fully satisfied.

Central Uplands

402. This region has a very low unit carrying capacity, only approximately one quarter that of the Shebelle Flood Plain. However, due to its very large size (its area is nearly equal to the total of the first six regions considered above) and to the fact that its present cattle density is only 40 per cent of its estimated potential, an increase of nearly 300,000 cattle within its bound appears possible. To achieve this will require the provision of a very large number of additional watering points, both wells and uars, and undoubtedly in due course these will be constructed. At the present time, in view of requirements elsewhere, expenditure in this region does not appear to be justified, except in one locality, the Baidoa Plain.

403. This is one of the best dry farming areas in the country; it is intensively cultivated and relatively heavily populated. Except for wells along the escarpment, particularly in the vicinity of Iscia Baidoa, there are no wells actually within this

sub-region and water is obtained almost entirely from uars, of which there are very large numbers. Most of them have been hand-dug but, as previously noted, fourteen were excavated by machine by an U.S. AID project in 1962 - 1963. A few wells may in time be sited in this area, as discussed in Volume 2, but uars should continue to be the main water source both for the domestic water requirements of the farmers within the area and for their stock and that of nomads who use the grazing of the surrounding lands.

404. A relatively small-scale program for improving existing uars, constructing new ones and maintaining all of them on a methodical and continuing basis is therefore recommended. As it would not involve great expenditure it could be given fairly high priority without jeopardizing other work. Details of such a program are set out in a following section.

Mandera El Wak Uplands

405. This region has the second lowest unit carrying capacity of all. While the rainfall is low and unreliable this area is reasonably well provided with natural uars due to the undulating nature of the topography. Uars could be excavated in some localities if necessary but over most of the region the soil is too shallow and rocky. It is not recommended that any consideration be given to uar construction in this region until all the more economically promising regions have been fully developed.

Uar Design

406. Before outlining suggested programmes for uar construction and maintenance, and estimating costs, it will be necessary to propose a general design on which these will be based. It is recognised that uar design will vary according to generally accepted rules depending on the geology, topography and meteorology of the regions for which they are required. However, within any particular environment, the design finally chosen will depend very largely on personal opinion, which will be formed by the designer's individual views of many factors outside the sphere of engineering. Many designs have been proposed and many have been built ranging from the simplest possible hole in the ground at the centre of a depression to those including elaborate catchment canal systems, silt traps, masonry spillways and wind or engine-driven pumps to extract the water as required to use. Good arguments can be produced in favour of almost any feature depending on the environment, availability of construction materials, remoteness of site, degree of difficulty of access, availability and cost of maintenance facilities and cultural patterns of the users.

407. After due consideration the writer has decided that the criteria of overriding importance in the project area at the present time and in the forseeable future are: lowest possible first cost, lowest cost and maximum simplicity of maintenance and operation. Considering the innumerable calls on development funds over the next decade or so it is essential that money provided for uar construction be spent so as to provide the maximum quantity of water only; at this stage in the development of Somalia there is neither the money nor the technical and administrative skills to spare to provide refinements aimed at easing the burden on the stock owners in the actual process of watering their stock or at attempting to extract sediment outside the reservoir. The most water for the least money is what matters now - refinements may come later.

408. The type of uar proposed, therefore, is a simple basin as shown on Figures 3 and 4. The length and breadth will vary according to the required capacity in any given area but the depth should be 10 meters, if soil conditions allow, with side slopes of 1.5;1. Access should only be possible at one end and, if supervision is not provided, the slope at that end should be maintained sufficiently steep that animals

cannot be brought safely to drink directly from the uar, thus forcing the herdsmen to carry water for their stock in the interests of hygiene.

Uar Capacities and Sites

Shebelle Flood Plain

409. It is proposed that uar capacity should be determined by the estimated quantity of water required at a watering point for a four-month period. This period is taken to be December 15 to April 15 on the assumption that the last rainstorm of a sufficient size to leave the uar full will probably occur prior to the former date, and such rainfall data as is available inciates that significant rains seldom occur before the latter date in this region. The estimated water requirements as set out in Table 2 of the Ground Water Chapter of Volume 2 are as sound an approximation as is possible considering the many unknowns and variables in the situation. From this Table a figure of 300 cubic meters per day is obtained, or 36,000 cubic meters for the four-month period.

410. Water losses through evaporation and seepage will be considerable. The former may be kept to a minimum by keeping the surface area as small as possible through excavating to the maximum practicable depth. Ten meters has been chosen as a nominal figure, which is more than twice the depth that appears to have been used hitherto in Somalia. Even this depth is relatively arbitrary as there is no reason for not going deeper, if soil conditions allow, except the increasing difficulty of access to the water as the uar is emptied. In calculations herein evaporation losses have been assumed to be 225 milimeters per month during the dry period.

411. The main losses will be by seepage and the magnitude of these initially will depend upon the permeability of the soil in which the uar is excavated; the surface permeability, and losses, will normally be gradually reduced by the deposition of silt and clay particles brought in by the stored water. For estimation purposes it will here be assumed that seepage losses will be approximately 50 per cent of the stored water during the four-month period, an assumption based on observations and interrogations in the project area. Such a rate of loss is only about one-third of that which would be computed using the U.S. Bureau of Reclamation 'C' for estimating seepage losses in unlined canals in clayey loam. However water has been observed in uars, initially not more than 2 meters deep, over two months after the last rainfall in the vicinity, despite seepage, evaporation and use. It is strongly advised that when each site for a uar has been selected, after soil grain size analysis has shown the soil to be of suitable type, field permeability tests should be carried out in order that the dimensions of each uar could be adjusted before construction commences. Thus, with a relatively small expenditure on the test equipment and time for the test, a significant saving could probably be made in keeping excavation to the calculated minimum required to obtain the desired net capacity.

412. As a corollary to the foregoing it should be pointed out that as the soils in this region have been deposited alluvially the coefficient of permeability in the horizontal direction may be many times that in the vertical direction. Hence an increase in depth of the uar, which for a given capacity will both reduce surface area and evaporation losses and the ratio of wetted area to volume and thus seepage losses, may actually increase seepage losses by intercepting a stratum of particularly high horizontal permeability. It is emphasized that an extensive uar construction program must include the provision of the personnel and equipment to carry out a few simple but essential field and laboratory soils tests if maximum benefits are to be obtained from the money spent on excavation.

413. Based on the foregoing it may be computed that a uar with surface dimensions

of 130 meters by 80 meters, 10 meters deep and with side slopes of 1½:1 would give a volume of 77,000 cubic meters which, if the above assumptions are reasonably correct, would provide 36,000 cubic meters of water over a four-month period.

414. Table 2 of the ground water chapter of Volume 2, referred to above, recommends that 46 water points would be required in this region. This figure is arrived at mathematically, and follows logically on the assumptions used. Taking into account existing wells, the Shebelle River, the irrigated area centred on Genale and the swamps to the west, and the many calls on development funds, it is here recommended that an initial program should include 20 uars, sited approximately as shown on Map 6. When the livestock in this region increases sufficiently to justify it, more could be excavated progressively in localities then to be decided. If the tsetse fly along the Shebelle River is brought under control a considerable reduction in the number of uars required would be possible.

Lac Dera Plain and Marine Plain (Western Section)

415 The same Table recommends 37 water points, each capable of providing 280.8 cubic meters per day, in the Lac Dera Plain and 34 water points (by proportion) in the Western Section of the Marine Plain, each of a 179.6 cubic meters per day capacity.

416. Unlike the Shebelle Flood Plain, the soils in these regions vary widely in characteristics from area to area. From field investigations carried out during this survey it has been found that while suitable soils do exist in many localities, there are large areas in which uars will be completely out of the question. This is particularly the case in the southern half of the Marine Plain and in significant portions of the north western quarter of the Lac Dera Plain. This is not to suggest that it will not be possible to find satisfactory locations for many good uars; a number now exist, including some of those constructed under the U.S. AID program, in particular one about 30 kilometers north of Afmadu. On the other hand a number of these have been completely unsatisfactory.

417. Before a construction program in this area is planned, therefore, a thorough survey of the area must be carried out to find suitable locations. To do this properly will be a fairly major task as the area concerned is over 9,000 square kilometers. Such a survey would include taking probably several hundred soil samples, carrying out mechanical analyses on these, and performing the field permeability tests referred to previously. It should be considered a project in itself and a cost estimate is given hereinafter.

418. While requiring what may appear a relatively large expenditure, it would lead to the greatest possible benefits from the money later spent on excavation. It is easily observed in this area that the haphazard and unscientific siting of uars in the past has led to the excavation of many thousands of cubic meters to virtually no purpose.

419. Until such a survey has been completed it will not be possible to make a meaningful estimate of the number or the size (which will be closely related in this case) of uars for either of these regions. It is probable that an ideal distribution will not be possible due to soil limitations and in this case a few very large uars may be indicated where exceptionally impermeable soil exists. An example is the area in the vicinity of Haie, about 25 kilometers northeast of Belesc Cogani, where the surface soil at least has a much higher clay content than any soil observed in the Shebelle Flood Plain.

420. A study of the only relevant rainfall records available for these regions (10 consecutive years at Afmadu) indicates that uars in this case need only be designed to hold a three-months' water supply and their dimensions may be scaled down accordingly.

421. Despite the foregoing, if an estimate for a construction programme for these regions is to be provided, as a guide to planning, some assumptions have to be made. Accordingly it will be assumed that 20 uars can satisfactorily be sited in the Lac Dera Plain, each of a gross capacity of 55,000 cubic meters, and 15 in the Marine Plain, each of a gross capacity of 40,000 cubic meters. The locations of these as shown on Map 6 are diagrammatic only and are assumed in order to estimate access costs.

Marine Plain (Eastern Section)

422. The general soil survey shows the same types of soil in this region as in the Western Section and it may be assumed that a detailed survey would reveal the same variability in clay content, and suitability for uar construction, from one locality to the next. It is most desirable, however, to construct a chain of uars along its northern boundary if at all possible, as previously suggested. The feasibility of this will have to be determined by a uar-location survey as recommended for the western section of the Marine Plain and the Lac Dera Plain, and an estimate of cost of such a survey is included below.

423. For the time being it will be assumed that it will be possible to find sites for 10 uars, each with a gross capacity of 50,000 cubic meters, located very approximately as shown on Map 6. A cost estimate for a construction program based on these assumptions is provided in a later section.

Central Uplands

424. As discussed previously it is considered that a small scale program of uar construction along the periphery of the Baidoa Plain could be justified at this time. A gross capacity of 20,000 cubic meters each is suggested, and 8 might be excavated approximately in the locations as shown on Map 6. The soil of this plain is extremely uniform and experience has shown that uars can be constructed practically anywhere within the area with very satisfactory results. An estimate for a program is given hereinafter.

Hydrology and Uar Catchments

425. Hand-dug uars are generally sited where it has been observed either that water collects in the bottom of a shallow natural basin or that a temporary streamlet flows during a rainstorm in a channel formed by a road, camel or cattle tracks or natural erosion. In some areas there is sufficient natural ground slope that it has been possible to dig uars where desired, such as adjacent to a village, and collect sufficient water to fill it by a relatively short hand-dug ditch which intercepts the run-off of a comparatively small area.

426. Many machine-dug uars have also apparently been sited where small water channels existed to fill them. Where this condition coincided with the most favourable soil conditions the results have been very satisfactory. Such coincidence has not always been the case. If, within a planned uar construction program, advantage can be taken of existing channels for water collection without prejudicing either the planned location of the uar as part of a chain or net or the most important requirements of maximum water retention, this will of course be done. However in the Shebelle Flood Plain, where except for the Baidoa Plain soil conditions will allow the greatest freedom in uar location, there are few such water courses. There are considerably more in the Marine and Lac Dera Plains but the soil characteristics are such that they can seldom be used.

427. Hence, and particularly in view of the large size of uars proposed, considerable expenditure will be necessary on the construction of water collection ditches.

To ensure as far as practicable that every uar is filled during each rainy season it is essential that very extensive systems of ditches be provided for each uar at the time of construction, that their collecting efficiency be observed as carfully as possible during the first few rainy seasons to which they are exposed, and that they be extended if and when so indicated, quite apart from the carrying out of normal maintenance.

428. While all the uars proposed will lie within an area receiving an average of more than 400 millimeters of rain per year, the pattern of this rainfall is definitely not favourable to filling them. In the first place storms are extremely localised. This is observedly the case to anyone resident in the project area during a rainy season. One may assume that the total rainfall averages out in any one locality over the course of a year in which case the end result would be satisfactary. However, sufficient data is available to indicate that this is not the case, even with total rain fall. When considering storms of the minimum intensity necessary to provide run-off into a uar, the situation is worse.

429. In the sugar-growing area at Johar eight rain gauges are maintained within an area roughly 5 kilometers by 9 kilometers. The annual totals recorded by each of these gauges for the years 1962 - 63 - 64 are shown in Table 28. It will be noted that while some stations seem to consistently receive less rain than others, there are also marked differences which are not part of any perceptible pattern. For instance 'Gauge No. 3' which received 1.62 times as much rain as 'Village' in 1962, received 0.99 as much in 1963. These stations are less than 6 kilometers apart.

TABLE 28

TOTAL ANNUAL RAINFALL RECORDED BY S.N.A.I. GAUGES AT JOHAR

Millimeters

Gauge No.	1962	1963	1964
1	396.0	385.5	498.5
2	447.5	404.5	595.5
3	539.0	461.0	605.0
4	522.5	473.5	668.0
5	577.5	478.0	679.0
6	446.5	412.5	523.5
'Burei'	320.0	430.0	467.5
'Village'	332.5	466.0	441.5

430. More significant differences appear in monthly totals and in the total falling in run-off-producing storms. In order to fill a uar prior to the long dry period it will generally be necessary for its catchment to be subjected to a rainstorm in December. In December 1962, Gauge No. 1 recorded a total of 23.0 millimeters of which 21.0 millimeters received on one day. Gauge No. 3 recorded a total of 15 millimeters which fell in increments of 5.5 millimeters, 7.0 millimeters and 2.5 millimeters over a period of 16 days. In December 1963 Gauge No. 1 recorded a total of 24.5 millimeters, the maximum in one day being 12.5 millimeters. In the same period Gauge No. 5 recorded a total of 66 millimeters, with 31.0 millimeters and 28.0 millimeters being received on successive days.

431. Considering the low runoff coefficient consequent on the high infiltration losses due to dry soil and very flat slopes, it is apparent that a uar situated a the site of Gauge No. 3 would have received no water in December 1962, and one at the site of Gauge No. 1 would have gained little if any in December 1963. These gauges are 3 kilometers apart.

432. The foregoing is presented to demonstrate the importance of giving adequate attention to the extent of catchment-ditch systems. It is recommended that where there are no existing channels or water courses of which to take advantage, and there are no localised slopes or undulations to take into account, and the uar must be sited on a virtually flat, gently sloping plain, catchment ditches should be provided which extend not less than 2½ kilometers out from the uar on each side along the slope.

433. The duration and intensity of the rainstorms upon which uar replenishment will depend requires equal consideration in the design of catchment systems. Unfortuately very little data is available on these aspects of rainfall in the project area. In the eastern part of the area there are only two automatic rainfall recorders at Baidoa and Mahaddei, and these were installed in mid-1963. Moreover, due to poor maintenance, they have not functioned well and portions of their recordings are undecipherable.

434. Of 15 storms recorded at Baidoa of which the records are usable the average total rainfall per storm was 30.0 millimeters, the average duration was 1.53 hours and the average intensity was 27.0 millimeters per hour. At Mahaddei, during the same period, usable records of 16 storms are available. The average total of each storm was 35.7 millimeters, the average duration was 1.55 hours and the average intensity was 30.8 millimeters per hour.

435. Apart from the foregoing the only rainfall details available are daily totals for Johar for 23 years between 1939 and 1964. Study of the recordings from Mahaddei and Baidoa shows that a day's rainfall generally falls in one well-defined storm. Hence for present purposes it will be acceptable to take each day's recorded total at Johar as being a storm of that magnitude.

436. It is not believed that a storm of less than 15 millimeters will provide any appreciable run-off and contribute towards filling a uar as storms occur at infrequent intervals. Therefore the rain will more often than not fall upon unsaturated ground. Moreover, as noted above, slopes are gentle and run-off will be slow, giving considerable time for infiltration. Neglecting, therefore, all daily totals (storms) of less than 15 millimeters it has been calculated that the total precipitation of the average storm during the critical Der rains is 27.3 millimeters. The number of such storms ranged from one per season in three of the years of record to twelve in the Der of 1941, with the average being five. In the less critical Gu season (less critical in that the following dry season is shorter) the rainfall total of the average storm was 29.1 millimeters and the average number of storms was 5.7.

437. An accurate computation of the catchment area required for a given uar is not possible but a rough approximation may be made assuming a run-off coefficient of 0.2. (Such a coefficient might be attained with a well-designed system of collection ditches.) Taking the average storm as 27.3 millimeters each cubic meter of uar capacity would require a catchment area of 183 square meters. Hence one such storm would require a catchment area of 14.1 square kilometers to completely fill a uar of the size proposed for the Shebelle Flood Plain; five such storms would require a catchment area of 2.8 square kilometers.

438. A single storm, in fact, even if of phenomenal intensity and duration,

would not in practice fill such a uar as for it to do so would require a catchment ditch system of such an extent and capacity as to be economically unfeasible to provide. From the meagre level data available for the Shebelle Flood Plain it appears that the maximum average slope is approximately .0005. (Localised undulations in the vicinity of old river channels produce more favourable slopes in some localities and advantage may be taken of these in some instances.) In the general case, therefore, the maximum practical slope for the main supply channels would be in the order of .00025 - Assuming such channels are cut by motor grader they would probably be V-shaped and would be unlikely to exceed 2.5 meters in width and 0.5 meters in depth. Their maximum carrying capacity would then be approximately 550 cubic meters per hour. Two of these channels feeding a uar would therefore require to carry water at full capacity for approximately 70 hours to fill the size of uar under consideration.

439. To fill these channels it would probably be necessary to cut, by plough, many kilometers of feeder ditches as indicated on Figure No. 3. It might even prove necessary to clear, partially or completely, the whole of the catchment area in some instances in order to increase the rate of run-off and reduce infiltration losses. The work required can be determined only by experience and it will probably be essential, in order to make a uar programme of the size here proposed fully effective, to establish a rain gauge and an observer at the site of selected uars during the first few seasons after construction to ascertain catchment requirements.

440. It should be realised that the foregoing is a discussion of what is believed to be the worst case, the Shebelle Flood Plain, where slopes are exceptionally flat and no natural catchments exist. However it cannot be assumed that in the Marine and Lac Dera Plains such extensive development of catchment areas will not be necessary in the cases of many uars.

441. In the western part of the project area there are two recording rain gauges. One of these, that at Giamama, may be considered as providing data relevant to the proposed uar construction. This gauge has only been in operation since June 1963 and, like those at Mahaddei and Baidoa, it has not functioned well. Consequently it has not been possible to draw any conclusions about duration and intensity of rainfall in this area except that storms appear to be of somewhat longer duration and to provide greater totals of rainfall than those in the east. This is consistent with the greater total rainfall occurring over the Marine Plain region. It appears therefore, that rainfall in the western areas may be somewhat more favourable in regard to uar replenishment than in the Shebelle Flood Plain region but probably not to any significant extent.

442. In view of the foregoing it could be argued with justification that there would be more likelihood of collecting at least some water from rainfall in a given area by doubling the number of uars and making each of them half the proposed size. This process could, of course, be continued to the point that uars were spaced not more than, say, 3 kilometers apart, with the size in proportion so that the total excavation would be the same. Two apparent objections to this would be that the total expenditure on collection channel systems would probably be greater, and when there were good rainfalls on a catchment the uar capacity might well be too small to take full advantage of them.

443. Moreover it is believed that the Government might wish to exercise control of the uars and levy charges, even if small, for the water used. In this case it would be desirable to have as small a number as possible in order to keep down the costs of administration. If it were found that the uars were not filling well despite good rainfalls in the vicinity it is felt it would be preferable to increase the size of the catchment rather than construct others. These, and other aspects, are matters for government policy to decide.

444. The total costs of programmes adequate to the probable water requirements of the areas considered would be very roughly the same if it were decided to change the size and spacing within reasonable limits. Moreover, if it were found in practise that uars in a certain region were consistently not being filled though the average rainfall in the region was normal, they could be allowed to partially silt up and the money saved on maintenance applied to new construction between the existing ones. While this trial and error approach is obviously undesirable the only way to avoid it would be to establish a very large number of rain gauges in the areas concerned and maintain careful records for at least ten years before making decisions on construction. It is believed that there would be no possibility of obtaining competent and reliable staff in sufficient numbers for such a program for many years, nor would this alternative be attractive to Government in any event.

445. It will be clear from the foregoing that neither the total rainfall, its characteristics nor the topography of the project area are favourable to the use of uars for water supplies in terms of reliability and cost. The fact that in certain localities hand-excavated uars have been of considerable benefit is irrelevant to present considerations. These were constructed virtually without expenditure, using labour which did not have to be diverted from other more productive activities, in fact which would not otherwise have been employed.

446. If the Government embarks on a program of uar construction it will be part of a serious and determined effort to provide a permanent solution to the problem of providing adequate water supplies in the areas which need them. While uars, as one answer, have been much discussed and often recommended they should only be considered in areas where wells have been proved to be completely unfeasible for geologic, hydrologic or economic reasons. Uars, as will be seen from the estimates which follow, are relatively expensive to construct, expensive to maintain and, no matter how elaborate the water collection arrangements provided, in the end are undependable as water sources. The programmes of construction herein recommended are all based on the premise that it has been or will be demonstrated in the areas concerned that there are no better alternatives.

447. The program outlined for the Shebelle Flood Plain should only be considered after the proposed flood water diversion project has been investigated and, if found feasible, implemented. This could totally change the water supply situation over a very large part of this region, both in surface supplies and in usable ground water supplies through greatly increased infiltration. Further test drilling may yet reveal well possibilities southwest of the Afgoi-Uanle Uen road. Decisions on uar construction in this region should therefore also await the collection of a great deal more data on ground water supplies than now exists. Recommendations in this regard are made in Volume 2.

448. Similarly no action should be taken on uars in the Marine Plain (Eastern Section) until the test drilling is completed in the vicinity of the Dinsor-Brava road, also as recommended in Volume 2. This drilling might lead to the discovery of ground water possibilities to the west of this area along the southern edge of the Eluviated Plain. This could totally change the number and siting of uars which might be justified in the Marine Plain to the south.

449. It is recommended that the proposals for the Lac Dera Plain and the Marine Plain (Western Section) should be implemented as soon as funds can be made available. It appears that, generally speaking, there are no prospects in these areas for obtaining good quality ground water at economic depths. The only exception to this is a possible increase in the number of relatively shallow wells which now exist at scattered points along the beds of the intermittent water courses: Lac Dera, Lac Bissigh and Lac Gira. These possibilities could be explored by the uar location survey crew

during the course of that survey which, as previously noted, is a necessary preliminary to construction in these regions. The power-auger with which this party would be equipped would be very suitable for rapid probing in the wadi beds to the depths envisaged.

450. The construction program proposed for the Central Uplands region might be implemented in the next few years but it is considered to have a low priority in relation to the programmes for the other regions, and to other development work to which funds must be allocated. There are, however, two tractors and scrapers available in that area which were brought in for the U.S. AID uar construction program in 1962. If no more urgent work could be found for these machines they could be assigned to this.

Uar Maintenance

451. Uars will require considerabe maintenance, in the form of sediment removal and collection channel reinstatement, to retain effectiveness and the continuing cost of this must be taken into account in costing any uar construction program. If the cross-sectional area of collection channels are not to be impracticably large, water velocities will have to be at least 0.35 meters per second and preferably nearer to 0.5 meters per second. While such velocities will keep scour to a minimum, and will not transport the larger particles of sand, there will still be a good deal of clay and silt carried into the uar. The weight of sediment in each cubic meter of water reaching the uar will vary widely, depending on the grain size distribution of the surface soils, their organic content, the vegetation cover, the slopes of land surface and of channels and the intensity of the rainfall. The quantity of sediment deposited in a uar in a year will depend on the foregoing and on the total quantity of water entering the uar, during the period which may be less than its capcity or several times more, depending on the water lost through seepage, evaporation and use and the sufficiency of rainfall to replenish as required. Observations indicate that for estimating maintenance costs an average sedimentation rate of 10 per cent of the volume per year should be assumed.

452. Silt traps, i.e. settling ponds designed to bring about the deposit outside the uar of the major portion of the suspended sediment load, are sometimes recommended. The writer sees no advantage in such arrangements considering the added complications and first costs and the fact that it is unlikely to be cheaper to periodically remove the sediment from a trap than directly from the uar.

453. It is considered that sediment removal every two years should be planned. If a uar is being filled annually and retaining water satisfactorily it would theoretically not be possible to clean out the sediment with a tractor-drawn scraper as envisaged and it would be necessary to resort to a drag-line -- quite impracticable considering the erratic nature of the rainfall it is probable that each uar will be dry for several weeks at least every two years. The cost estimate is based on this assumption.

Construction Programmes and Cost Estimates

Uar Location Survey

454. It is assumed that a soil survey of these areas could be completed in approximately 15 months, which would be timed to include two dry seasons. This would allow about 10 months of good field conditions.

455. The work would be carried out by a Soils Engineer, two Somali technicians, and the necessary support staff of drivers, cook etc. A power-driven auger mounted

on a 4-wheel-drive vehicle would be used to take soil samples rapidly to a depth of 15 meters. Equipment would be provided to carry out field permeability tests in boreholes and to do gradation analysis of soils in the field. A trailer would be used which would provide combined living accommodation and a laboratory for the Soils Engineer. A 4-ton truck would be required to haul water for the tests.

456. In the estimate below (Table 29) the amount allowed for the Soils Engineer includes return air fare from Europe and for leave pay at the rate of one month per year. Allowance has been made for considerable overtime pay in the case of the Somali staff.

457. The equipment costs given are based on charging to the project 60 per cent of the cost of the smaller vehicles, 40 per cent of the cost of the 4-ton truck and 100 per cent of the cost of all other equipment. All equipment has been assumed to be duty-free. Petrol costs are based on the assumption that each vehicle will average 2500 kilometers per month. Only 10 per cent of the cost of the vehicles has been allowed for spares as it is assumed the vehicles will be new at the start of the project.

458. Though the cost of this investigation may appear somewhat high it must be recognized that it will insure, as far as possible, that the planned benefits will be obtained from an expenditure of about ten times this amount on uar construction in these areas. It cannot be emphasized too strongly that construction without adequate prior investigation can lead to great waste of development funds. A large number of uars that have been excavated in this and other regions, and which have failed to fulfill their purpose, are proof of this.

Construction Programme - Shebelle Flood Plain

459. This program, as previously detailed, would involve the construction of 20 uars of an excavated volume of 77,000 cubic meters each (net effective water capacity: 36,000 cubic meters), the requisite collection channels for each, and approximately 350 kilometers of access track.

460. The various types of earth-moving equipment that might be used to excavate the uars have been considered in detail. For several obvious reasons drag-lines would be completely impractical. Self-propelled scrapers or scrapers drawn by rubber-tired tractors would not be as economic as crawler-tractor drawn scrapers considering the short hauls involved nor would they be as satisfactory in operation during wet weather.

461. In theory the cost of excavation would be slightly less using bulldozers than using scrapers. However the operators would require to develop more skill to obtain optimum production with bulldozers than with scrapers. It is also believed that scrapers would have more value for other earth-moving projects in Somalia when the uar construction was completed.

462. Hence it is proposed that scrapers be used for excavating, without the assistance of pusher tractors for loading as it is not believed these would be necessary in the material concerned. It has been assumed, in consequence, that the scrapers would not be fully loaded and allowance has been made for this in computations.

463. Unit costs of excavation have been calculated using 120 Hp., 160 Hp. and 235 Hp. crawler tractors with matching scrapers. The most economical machine would be the 160 Hp., followed by the 120 Hp. and then the 235 Hp. However, as using the 120 Hp. would only increase the cost by approximately 5½%, and as it is felt that this size of machine might be more generally useful in Somalia for other projects

ESTIMATED COST UAR LOCATION SURVEY

Personnel		
1 Soils Engineer	So. Sh. 125,000	
2 Technicians	22,500	
1 Driver-Mechanic	6,700	
3 Drivers	18,000	
1 Cook	5,200	
4 Labourers	15,000	
Total	So. Sh. 192,400	So. Sh. 192,400
Equipment - Capital Cost		
1 4-wheel-drive station wagon	So. Sh. 16,400	
1 " " ½-ton pick-up truck	14,000	
1 " " ½-ton truck with power auger	21,850	
1 " " 4-ton truck	18,000	
1 Trailer - combined living and laboratory	20,000	
1 set equipment for gradation analysis of soils	3,500	
1 " " for field permeability tests	3,500	
Tents, camp and miscellaneous equipment	10,000	
Total	So. Sh. 107,250	So. Sh. 107,250
Equipment - Operation and Maintenance		
Petrol, oil, lubricants	So. Sh. 15,000	
Spares	11,000	
Total	So. Sh. 26,000	So. Sh. 26,000
Total		So. Sh. 325,650

(easier to transport around the country, more adaptable to smaller projects, more machines would allow more concurrent works to proceed), the 120 Hp. crawler tractor and matching scraper have been selected and estimates based thereon.

464. It is suggested, however, that one 160 Hp. bulldozer be employed for making access tracks as the experience gained by the oil companies in making cut-lines has shown this machine to be the best size for the purpose. This would not be purchased for the project as there would be insufficient work to justify it and such a machine would be rented as required. Bulldozer blades would be provided for half the 120 Hp. tractors for generally clearing and trimming.

465. Collection channels would be excavated by a 115 Hp. Motor Grader along lines previously cleared by bulldozer. Other methods of forming these channels have been considered but this machine appears to provide the most economic solution.

466. It will be apparent that there would not be sufficient work to keep this grader fully occupied but one would probably have to be purchased as it is unlikely one would be available for rental. It is assumed that only one would be purchased for all the uar construction in the four regions as herein proposed. The capital cost of this is shown divided equally between the Shebelle Flood Plain program and the Lac Dera/Marine Plain program.

467. In estimating efficiency of production, in order to arrive at realistic figures on which to base costs, it has been assumed that there will be good supervision and adequately trained operators which provides an operator efficiency of 80 per cent. Machine availability has been taken as 95 per cent. Thus overall production efficiency has been assumed to be 76 per cent of the theoretical. It has been assumed that each machine would work 10 hours a day, 20 days a month.

468. Based on the foregoing, and using 30 per cent swell of material and 85 per cent of heaped load due to non-employment of pusher, the monthly production of the tractor-scraper combination selected has been computed to be 18,250 cubic meters. Hence four such units could excavate the required size of uar in a month. The number of months required to complete the program of 20 uars would depend almost entirely on the weather as with proper operation and maintenance there should be no 'down time' of the machines beyond that allowed for above. It will be assumed here that three months will be lost per year and that the total time required for this program will be 26 months.

469. The decision to base this estimate on employing sufficient equipment to produce one uar per month is, of course, purely arbitrary. If a smaller number of machines were to be used the capital investment required would be less but the unit cost of excavation would go up slighly as supervision and general overhead of the construction unit would continue over a longer period. If a large number of machines were employed unit costs could be reduced but at the end of the programme it might be found that capital was tied up in more machines than could be usefully employed on other subsequent projects. A firm recommendation on this matter is outside the scope of this report as the final decision on the investment to be made and the rate of excavation will depend upon the availability of capital, machine requirements for other projects and, probably, various social and political considerations.

470. It is considered advisable to provide two operators for each tractor to ensure continuous operation at maximum efficiency over the period of the program and this has been allowed for in the estimates.

471. It is assumed that access tracks to the sites can be cleared and prepared to an adequate standard at the rate of 4.5 kilometers per 10-hour day per machine:

the machine being a 160 Hp. bulldozer as noted previously. This production rate is also based on the local experience in oil exploration. The clearing required for collection channels will be done at the same rate.

472. The excavation of these channels could theoretically be done by motor grader at the rate of 0.6 kilometers per hour at 100 per cent efficiency. It is considered that in this instance only 50 per cent efficiency will be attained as considerable skill would be required to attain optimum production and supervision will necessarily be limited. As discussed previously only experience will determine the total length of collection channels required to fill a uar in an average rainy season. For this estimate it has been assumed that a total of 20 kilometers per uar will suffice. This would entail 45 hours of work by bulldozer for the clearing and 67 hours work by the motor grader for excavation.

473. In computing the hourly owning and operating costs a 10,000-hour depreciation period has been used for the tractors, a 16,000-hour period for the scrapers and a 12,000-hour period for the motor grader, with depreciation being taken over 5 years. Though it is appreciated that the motor vehicles used on this program would have possibly a 25 per cent residual value at completion the entire cost has been charged to the project in order to be conservative.

474. Travelling time for the equipment will be significant for construction and even more so for maintenance. As an hour spent in travel results in less wear and tear than an hour at work, factors have been computed to reduce travel hours to estimated equivalent working hours. These have been taken as 84 per cent for the tractor-scraper and 78 per cent for the grader.

475. The capital investment required, in U.S. dollars, for the earth moving equipment would be approximately as follows, the prices being FOB Mogadiscio, duty unpaid:

4 - 120 Hp. tractors complete with bulldozer @ $31,500	-	$ 126,000
4 - 13 cu.m. scrapers @ $21,000	-	84,000
1 - 115 Hp. Motor grader: 50 per cent of cost of $24,000	-	12,000
Total		$ 222,000

Construction Program - Lac Dera and Marine Plain

476. The numbers and sizes of uars proposed for these regions in the previous sections were as follows:

Lac Dera Plain	- 20 @ 55,000 cu.m.	Total -	1,100,000 cu.m.
Marine Plain (Western Section)	- 15 @ 40,000 cu.m.	Total -	600,000 cu.m.
Marine Plain (Eastern Section)	- 10 @ 50,000 cu.m.	Total -	500,000 cu.m.
	45		2,200,000 cu.m.

477. This is more than twice the number of uars proposed for the Shebelle Flood Plain and approximately 43 per cent more excavation. It is proposed that a single construction unit excavate all these and that 5 tractor-scraper combinations be employed. These machines would excavate 91,250 cubic meters per month and the total excavation would be completed in 24.1 working months. Allowing, as in the previous case, a loss of three months per year due to bad weather the total elapsed time for the program would be 32 months.

TABLE 30

COST ESTIMATE OF UAR CONSTRUCTION - SHEBELLE FLOOD PLAIN

(26-month period)

Personnel Costs		
1 Construction Superintendent	So. Sh. 180,000	
8 Tractor operators	84,000	
2 Motor Grader operators	21,000	
2 Mechanics	21,000	
2 Mechanics' helpers	15,000	
4 Drivers	47,000	
4 Labourers	21,000	
1 Cook and assistant	12,000	
Total	So. Sh. 401,000	So. Sh. 401,000
Equipment Costs		
Owning and operating costs - tractors and scrapers: 20 uars @ 800 machine hours ea. plus 430 hours travel time @ So. Sh. 81.50 per hour	So. Sh. 1,339,045	
Owning and operating costs - motor grader: 20 uars @ 1379 machine hours plus travel time @ So. Sh. 39.50 per hour	So. Sh. 54,490	
Rental of bulldozer for channel clearing: 20 uars @ 45 machine hours ea. plus 60 hours travel time @ So. Sh. 70.00 per hour	67,200	
Rental of bulldozer for clearing access tracks 350 kilometers @ 0.45 Km/hr @ So. Sh. 70.00 per hour	54,444	
Purchase of following equipment to be written off against project:		
1 4-wheel drive station wagon	27,300	
2 " " pickup trucks	46,700	
1 " " 3-ton truck	40,000	
1 house trailer	20,000	
Tents, camp equipment, tools etc.	20,000	
Vehicle operating costs:		
Petrol, oil lubricants	30,000	
Spares	15,000	
Total	So. Sh. 1,714,179	So. Sh. 1,714,179
		So. Sh. 2,115,179

Average cost per uar - So. Sh. 105,759

Average cost per cubic meter of excavation - So. Sh. 1.37

Average cost per cubic meter of net effective water capacity - So. Sh. 2.94.

478. As it is believed that it will be possible to take advantage of natural drainage channels to a certain extent in these areas, in contrast to the Shebelle Flood Plain where none exist, an allowance will be made for only 12 kilometers of collection channels per uar. This also allows for the fact that these uars, being smaller, require proportionately less catchment area. This length of channel would require 27 hours of work by bulldozer for clearing and 40 hours work by the motor grader for excavation.

479. There is little basis at present for a rational estimate of the number of kilometers of access track which would be required, considering that sites will depend on the survey discussed above. However, though the total area involved is large, it is thought that the requirements may not be too high as it is probable that the grid of oil exploration cut-lines can be used to a considerable extent. A fairly arbitrary allowance of 400 kilometers of track has been assumed for cost computations.

480. The capital investment required, is US dollars, for the earth moving equipment would be approximately as follows. The prices are FOB Mogadiscio, duty unpaid.

5 - 120 Hp. Tractors complete with bulldozers @ $31,500	-	$ 157,500
5 - 13 cu.m. scrapers @ $21,000	-	$ 105,000
1 - 115 Hp. Motor grader: 50 per cent of cost of $24,000	-	$ 12,000
Total		$ 274,500

Construction Programme - Central Uplands

481. The program proposed for this area is relatively small, consisting as it does of 8 uars of 20,000 cubic meters capacity each. It could logically follow on after the completion of the Shebelle Flood Plain program, using some of the machines which had been employed thereon.

482. As less than 9 machine months would be required for this excavation it is reasonable to assign two tractor-scraper units and the motor grader to this program. All the vehicles would be transferred. The program could be fitted to a dry season and 5 months allocated to complete it.

483. While relatively flat, the Baidoa Plain has some natural drainage and the soil has good runoff characteristics. Because of this, and because the uars are comparatively small, it is assumed that not more than 5 kilometers of drainage channel will require to be excavated for each uar. This length of channel would require about 11.5 hours of work by bulldozer for clearing and 17 hours work by the motor grader for excavation.

484. Though approximately 150 kilometers of access track may be required, much of the area is either already cleared or covered with very light bush. Hence it is assumed that not more than 75 kilometers of access track will require bush clearing of the same degree of difficulty as in the other regions.

Maintenance Programmes and Cost Estimates

Shebelle Flood Plain

485. As stated previously it will be assumed that on an average the uars will be filled with sediment at the rate of 10 per cent of the volume per annum. The collection channels will undoubtedly also need periodic reinstatement, involving widely varying amounts of work. For estimation purposes it will be assumed that it

TABLE 31

COST ESTIMATE OF UAR CONSTRUCTION - LAC DERA AND MARINE PLAINS
(32-month Period)

Personnel Costs			
1 Construction Superintendent	So. Sh. 210,000		
10 Tractor operators	129,500		
2 Motor grader operators	26,000		
2 Mechanics	26,000		
2 Mechanics' helpers	18,500		
4 Drivers	58,000		
4 Labourers	26,000		
1 Cook and assistant	15,000		
Total	So. Sh. 509,000	So. Sh. 509,000	
Equipment Costs			
Owning and operating costs - tractors and scrapers: 24.1 months @ 1,000 machine hours per month plus 750 hours travel time @ So. Sh. 81.50 per hour	So. Sh. 2,025,275		
Owning and operating costs - motor grader: 45 uars @ 40 machine hours ea. plus 50 hours travel time @ So. Sh. 39.60 per hour	73,260		
Rental of bulldozer for clearing channel: 45 uars @ 27 machine hours ea. plus 80 hours travel time @ So. Sh. 70.00 per hour	90,650		
Rental of bulldozer for clearing access tracks: 400 kms. @ 0.45 kms./hr. @ So. Sh. 70.00 per hour	62,222		
Purchase of following equipment to written off against project:			
1 4-wheel drive station wagon	27,300		
2 " " pickup truck	46,700		
1 " " 3-ton truck	40,000		
1 house trailer	20,000		
Tents, camp equipment, tools, etc.	25,000		
Vehicle operating costs:			
Petrol, oil lubricants	37,000		
Spares	20,000		
Total	So. Sh. 2,467,407	So. Sh. 2,467,407	
		So. Sh. 2,976,407	

Average cost per uar - So. Sh. 66,142

Average cost per cubic meter of excavation - So. Sh. 1.35

Average cost per cubic meter of net effective water capacity - So. Sh. 2.91

TABLE 32

COST ESTIMATE OF UAR CONSTRUCTION - CENTRAL UPLANDS
(5-month period)

Personnel Costs

1 Construction Superintendent	So. Sh.	32,000		
4 Tractor operators		8,000		
2 Motor grader operators		4,000		
1 Mechanic		2,000		
2 Mechanics' helpers		3,000		
4 Drivers		9,000		
4 Labourers		4,000		
1 Cook and assistant		2,300		
Total	So. Sh.	64,300	So. Sh.	64,300

Equipment Costs

Owning and operating costs - tractors and scrapers: 5 months @ 400 machine hours per month plus 180 hours travel time @ So. Sh. 81.50 per hour		177,670		
Owning and operating costs - motor grader: 8 uars @ 17 machine hours ea. plus 30 hours travel time @ So. Sh. 39.60 per hour		6,574		
Rental of bulldozer for channel clearing: 8 uars @ 11.5 machine hours ea. plus 90 hours travel time @ So. Sh. 70.00 per hour		12,740		
Rental of bulldozer for clearing access tracks: 75 kms. @ 0.45 kms./hr @ So. Sh. 70.00 per hour		11,666		
Vehicle operating costs:				
Petrol, oil lubricants		6,000		
Spares		3,500		
Total	So. Sh.	218,150	So. Sh.	218,150
Total			So. Sh.	282,450

Average cost per uar - So. Sh. 35,306

Average cost per cubic meter of excavation - So. Sh. 1.77

Average cost per cubic meter of net effective water capacity - So. Sh. 3.80

will be necessary to apply each year 10 per cent of the number of motor grader hours originally employed in their construction.

486. If the uars were to be filled regularly and were to retain water for the length of time planned it would obviously be difficult, in many cases, to bring equipment to bear when they were dry enough to allow efficient re-excavation. It will therefore be assumed that it will be necessary to provide sufficient equipment to reinstate half the uars per year and to carry out the work in a period of four months.

487. This would be equivalent to 154,000 cubic meters in the period or 38,500 cubic meters per month. Re-excavation would be considerably easier than the original excavation and it is therefore assumed that 90 per cent of heaped load would be attained and that there would be 90 per cent production efficiency. On this basis the monthly production per unit would rise from 18,250 cubic meters to 20,350 cubic meters, the latter rate being equivalent to an hourly production of about 102 cubic meters.

488. Two tractor-scrapers would therefore be employed and one motor grader would also be required. The excavation would require 1,510 machine hours and there would be approximately 125 hours travelling time for each tractor. With the latter adjusted to equivalent working hours the total tractor-scraper hours would be 1,725. The total hours for the motor grader would be 170, including travelling time. It is assumed that the Maintenance Unit would be based at Uanle Uen, where machine repairs and maintenance would be carried out. Travelling time is estimated from this point.

Lac Dera and Marine Plains

489. Because the uars in these regions will be scattered over a wide area, and because of the barrier of the Juba River and the short season available for maintenance, it would be impractical to maintain them all with one set of equipment. Two maintenance organisations should be established, one based at Afmadu and one at Gelib.

490. The former would maintain the proposed total of 35 uars on the Lac Dera Plain and the Marine Plain (Western Section) and the latter would cover the 10 uars proposed for the Marine Plain (Eastern Section). Estimates for these units are provided below.

Maintenance Unit No. 1 - Based at Afmadu

491. Using the foregoing assumptions the total annual re-excavation required would be 170,000 cubic meters or 42,500 cubic meters per month. This would entail 417 machine hours per month for 4 months and the work could therefore be carried out by two tractor-scraper units, each working 208.5 hours per month instead of the previously assumed 200. Travel time would be about 120 hours per machine or, reduced to equivalent working hours, a total of 200 machine hours. The total number of machine hours would be 1,868.

492. Only one motor grader would need to be provided for the two areas under consideration because this machine is much more mobile than the tractors and a relatively small number of working hours would be required from it. The working hours would be 140 and the actual travel time 45 hours making the total machine hours for costing purposes 175.

Maintenance Unit No. 2 - Based at Gelib

493. The total annual re-excavation required is estimated to be 50,000 cubic meters. This could be carried out by one tractor-scraper unit in 2½ months and

TABLE 33

ANNUAL UAR MAINTENANCE COSTS - SHEBELLE FLOOD PLAIN

(4-month working period)

Personnel Costs				
1 Foreman	So. Sh.	3,000		
3 Tractor operators		4,800		
1 Motor grader operator		1,600		
1 Mechanic		1,600		
1 Mechanics' helper		1,000		
3 Drivers		5,400		
2 Labourers		1,600		
1 Cook		1,200		
Total	So. Sh.	20,200	So. Sh.	20,200
Equipment Costs				
Owning and operating costs - tractors and scrapers: 1725 hours @ So. Sh. 81.50		140,590		
Owning and operating costs - motor grader: 170 hours @ So. Sh. 39.60		6,730		
1 4-wheel drive station wagon: depreciation - 4/36 of So. Sh. 27,300		3,030		
1 4-wheel drive pickup truck: depreciation 4/36 of So. Sh. 23,350.		2,590		
1 4-wheel drive 3-ton truck: depreciation 4/48 of So. Sh. 40,000		3,330		
Tents, camp equipment, tools, etc.		5,000		
Vehicle operating costs:				
Petrol, oil lubricants		3,500		
Spares		2,000		
	So. Sh.	166,770	So. Sh.	166,770
Total			So. Sh.	186,970

TABLE 34

ANNUAL UAR MAINTENANCE COSTS - LAC DERA AND MARINE PLAINS UNIT NO 1

(4-month working period)

Personnel Costs

These will be the same as for the Shebelle Flood Plain Maintenance Unit plus an estimated 5 per cent for overtime			So. Sh.	21,210

Equipment Costs

Owning and operating costs - tractors and scrapers: 1,868 hours @ So. Sh. 81.50	So. Sh.	152,240		
Owning and operating costs - motor grader: 175 hours @ So. Sh. 39.60		6,930		
1 4-wheel drive station wagon: depreciation - 4/36 of So. Sh. 27,300		3,030		
1 4-wheel drive pickup truck: depreciation - 4/36 of So. Sh. 23,350		2,590		
1 4-wheel drive 3-ton truck: depreciation - 4/48 of So. Sh. 40,000		3,330		
Tents, camp equipment, tools etc.		5,000		
Vehicle operating costs:				
Petrol, oil lubricants		3,500		
Spares		2,000		
	So. Sh.	178,620	So. Sh.	178,620
Total			So. Sh.	199,830

TABLE 35

ANNUAL UAR MAINTENANCE COSTS - LAC DERA AND MARINE PLAINS UNIT NO 2

(2½-month working period)

Personnel Costs				
1 Foreman	So. Sh.	1,900		
1 Tractor operator		1,000		
1 Motor grader operator		1,000		
1 Mechanic		1,000		
1 Mechanics' helpers		650		
3 Drivers		3,400		
2 Labourers		1,000		
1 Cook		750		
	So. Sh.	10,700	So. Sh.	10,700
Equipment Costs				
Owning and operating costs - tractor and scraper: 541 hours @ So. Sh. 81.50	So. Sh.	44,090		
Owning and operating costs - motor grader: 60 hours @ So. Sh. 39.60		2,380		
1 4-wheel drive station wagon: depreciation - 2.5/36 of So. Sh. 27,300		1,900		
1 4-wheel drive pickup truck: depreciation - 2.5/36 of So. Sh. 23,350		1,620		
1 4-wheel drive 3-ton truck: depreciation - 2.5/48 of So. Sh. 40,000		2,080		
Tents, camp equipment, tools, etc.		4,000		
Vehicle operating costs:				
Petrol, oil, lubricants		2,300		
Spares		1,500		
	So. Sh.	59,870	So. Sh.	59,870
Total			So. Sh.	70,570

490 machine hours would be entailed. Actual travel time would be approximately 60 hours, equivalent to 51 working hours. The total machine hours would therefore be 541.

494. The working hours of the motor grader would be 40 and the actual travel time 25 hours. The total machine hours would be 60.

Central Uplands

495. Annual re-excavation would here be in the order of 16,000 cubic meters which would be less than one month's actual excavation for a tractor-scraper unit. It is suggested, however, that one unit be based at Baidoa after the completion of the uar construction program. Apart from maintaining the uars of this program there are about 14 uars constructed in the past with US AID assistance which should be maintained. Moreover, as time allowed, it would be well worthwhile continuing to add uars on the Baidoa Plain as it is the most important dry farming area in the inter-river region. The estimate below is confined to the uars of the proposed program.

496. Tractor-scraper hours for re-excavation would be approximately 152 and the travel time would be equivalent to 90 hours making a total of 242 hours. It is assumed the working hours for the motor grader would be about 4 whereas the travel time to make the full circuit would be 30, as for the construction, making the total 34. One and one half months are allowed for the work as in this case the making and breaking of camp would be disproportionate to the quantity of excavation involved. Two vehicles would be sufficient as all the work is relatively close to a source of supplies.

497. The proposals for maintenance as here presented result in all equipment being under-employed if only applied to this work. This would particularly be the case with the machines allocated to the Marine Plain (Eastern Section) and to those assigned to the Central Uplands, as previously noted. However the actual working periods may well turn out to be longer than those estimated, with time lost due to weather between re-excavation of one uar and the next. Moreover in the drier years it might be possible to maintain well over half the total; in wet years, if water remained in the uars longer than anticipated, it might be possible to re-excavate only a few. A maintenance program such as this must necessarily be very flexible and the machines must be available to carry out the work as and when conditions allow.

498. It is assumed, however, that when not engaged on maintenance the equipment would be fully employed on new construction. The owning and operating costs have been based on this assumption, with the maintenance bearing only its proper share of interest on capital invested.

DEVELOPMENT OF SMALL STREAMS

499. Except for the Juba and Shebelle Rivers there are no permanent streams in the project area. There are, however, three intermittent streams which might be considered for development in due course. These are, in order of size, the Bohol Madagoi, the Lac Badana and the Uadi Damer. Their locations are shown on Map 6. There are also a number of small water courses in the vicinity of Bur Acaba, Baidoa and Dinsor which carry brief torrential flows on the rare occasions of heavy storms over their drainage basins. The latter streams do not justify attention at the present time. The former might be studied to advantage and they are discussed in sequence hereunder.

500. Though the Bohol Madagoi is the largest of the three in terms of length and

TABLE 36

ANNUAL UAR MAINTENANCE COSTS - CENTRAL UPLANDS
(1½-month working period)

Personnel Costs				
1 Foreman	So. Sh.	1,150		
1 Tractor operator		600		
1 Motor Grader operator		600		
1 Machanic		600		
1 Mechanics' helpers		400		
2 Drivers		1,300		
2 Labourers		600		
1 Cook		450		
	So. Sh.	5,700	So. Sh.	5,700
Equipment Costs				
Owning and operating costs - tractor and scraper: 242 hours @ So. Sh. 81.50 per hour		19,720		
Owning and operating costs - motor grader: 34 hours @ So. Sh. 39.60 per hour		1,350		
1 4-wheel drive station wagon: depreciation 1.5/36 of So. Sh. 27,300		1,140		
1 4-wheel drive pickup truck: depreciation 1.5/36 of So. Sh. 23,350		970		
Tents, Camp equipment, tools, etc.		3,500		
Vehicle operating costs:				
Petrol, oil, lubricants		2,000		
Spares		1,000		
	So. Sh.	29,680	So. Sh.	29,680
Total			So. Sh.	35,380

also, it is believed, in the quantity of water is carries when it is in spate, it appears from available data to offer the least possibilities for development. Aerial photographs give no indication of possible dam sites. Moreover the soils in the region are very permeable, the runoff coefficient would be extremely low, and only very occasional storms of high intensity would produce any runoff at all.

501. There is an underflow which is tapped at present by scattered wells in the upper reaches. This might be developed by means of seepage galleries or ground water dams should suitable conditions be found to exist. A survey to determine the possibilities could be carried out as a follow-on project by the party established to locate uar sites, as discussed in the previous section. Two months should be adequate for the purpose and the cost would therefore be in the order of So. Sh. 50,000.

502. Lac Badana is only partly within the project area but it is considered here as it is the most promising of the three streams. Further, it is on the fringes of an area which normally provides very good grazing.

503. It was dammed during the Italian Administration and it is understood that water was held within its channel for a distance of over 20 kilometers upstream. Due to inadequate spillway capacity or faulty design at the abutments or toe it was washed out during the floods of 1961. An earth embankment was formed across the stream on this site in the spring of 1965 which would be of only temporary benefit as no spillway was provided.

504. No maps exist from which to determine the size of its catchment basin or on which to locate a dam site, if any, which would provide a reservoir extending outside its channel. The largest scale aerial photography available is 1:60,000. This, while adequate to estimate the catchment and hence flood flows and required spillway capacity, is not suitable for dam and reservoir location as the topography of the area is of very low relief.

505. A thorough reconnaissance survey should be carried out along a 25 kilometer stretch of the lower reaches of this stream. If any dam sites appear to exist which give promise of providing a large reservoir at reasonable cost it would be worth photographing a 10 kilometer wide strip when aerial photography is next carried out in the project area. If no such sites are apparent consideration could be given to running levels along this stretch to obtain the long profile. If a dam within the channel would in fact back up the water for 20 kilometers or more a structure could be justified in due course. It is believed that it would be relatively expensive as the flow is torrential and considering the size of the channel cross-section in the lower reaches very large flood-flow capacity would be required, preferably in the form of gates.

506. The Uadi Damer is the smallest of the three but there are arguments for considering it for development first. Its course passes through the centre of the Bur Acaba Plain which is an important dry farming area now and likely to become more important when the Afgoi-Baidoa all-weather road is completed. Water in this region is provided, at present, by a few deep hand-dug wells and by uars both hand and machine excavated but it is often in short supply.

507. During the dry season shallow wells are dug in the dry stream bed and a small but apparently fairly dependable supply is obtained along the least 20 kilometers of channel. The feasibility of increasing this by seepage galleries or ground water dams should be investigated. The cost of such an investigation would not be high and it could be carried out by existing Government staff.

508. This stream also was dammed, a few kilometers south of Bur Acaba, and the

dam was also subsequently washed out. This dam, too, produced a reservoir which was confined to the channel. In this case it is doubtful that it was of any great size as the fall of the stream bed appears to be relatively steep.

509. Aerial photography at a scale of 1:30,000 is available covering this area. A study of this, plus field observations, indicated that a reasonably wide reservoir might be produced south of Bur Acaba but as the slope of the bed is unknown its length cannot be estimated. However this would require a dam of quite disproportionate size and it is not felt that the cost of a detailed investigation would be likely be justified.

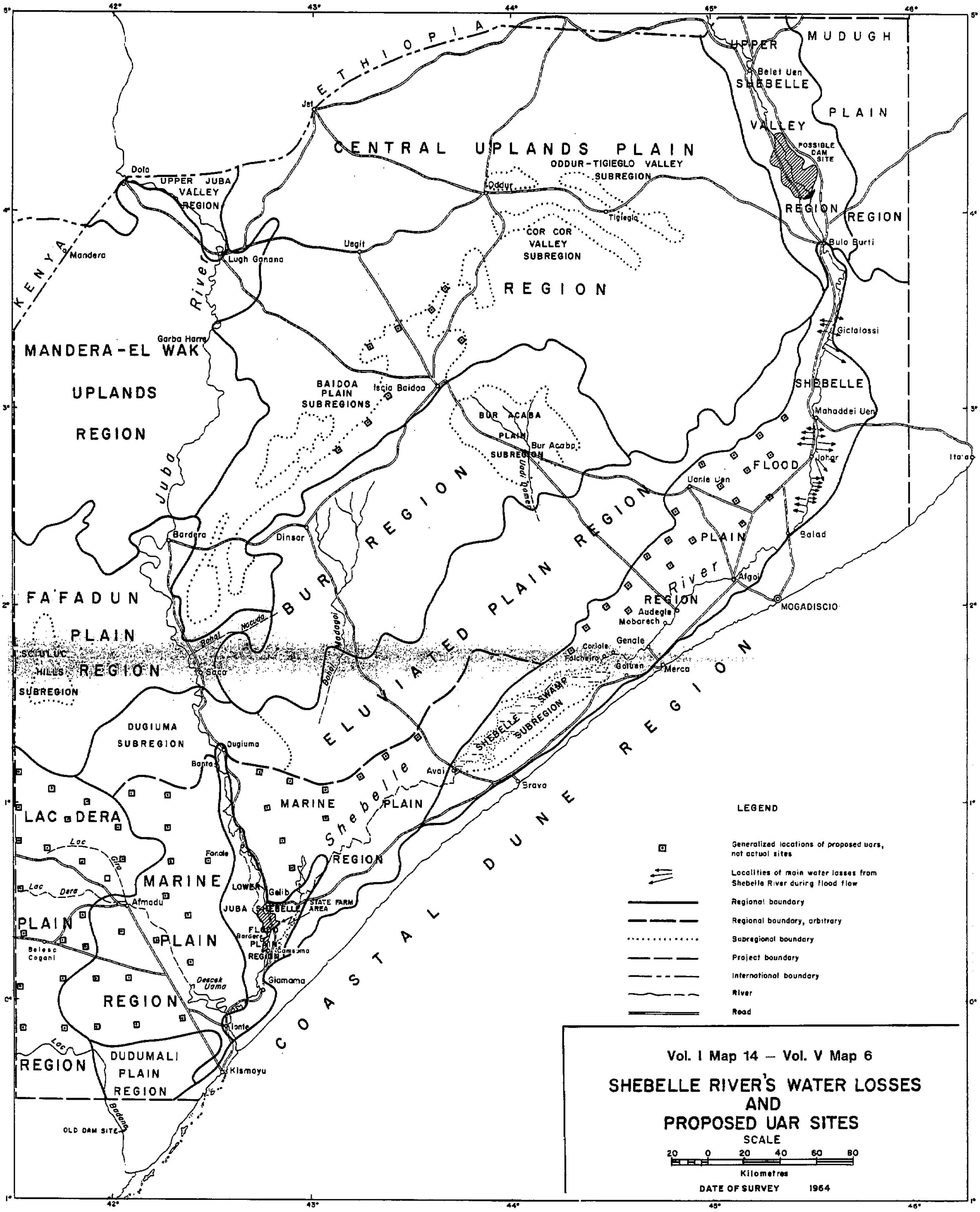
510. An examination of one possible development is recommended. The new highway will require a bridge to cross this stream. When the alignment of the road is established, if the crossing is at a suitable point consideration should be given to combining the bridge with a dam and gate structure. While the cost might be prohibitive, as gate and spillway capacity would have to be extremely large to ensure complete safety of the road, this possibility should be studied and the cost estimated.

511. Such a structure would provide a reservoir which was more or less confined to the channel and the project could only be justified if the pond was of considerable length. Levels should therefore be run along the course of this stream to determine its slope in the immediate future. This could be done by personnel of the Survey and Mapping Department and the cost would be nominal.

512. If it were decided to proceed with the construction of this dam it should be done with full recognition of the fact that the life of the reservoir would probably be short as the result of sedimentation. Due to the nature of the soil, the scarcity of vegetation and the high intensity of the rainstorms which produce flow in this and similar streams in the project area, erosion is very severe. Flood flows are extremely turbid and it could be taken for granted that the reservoir would fill rapidly, particularly in view of its small size. Unfortunately as flows are infrequent and of short duration a sediment sampling program to determine the sediment load would not be practical and even a rough computation of reservoir life would be very difficult.

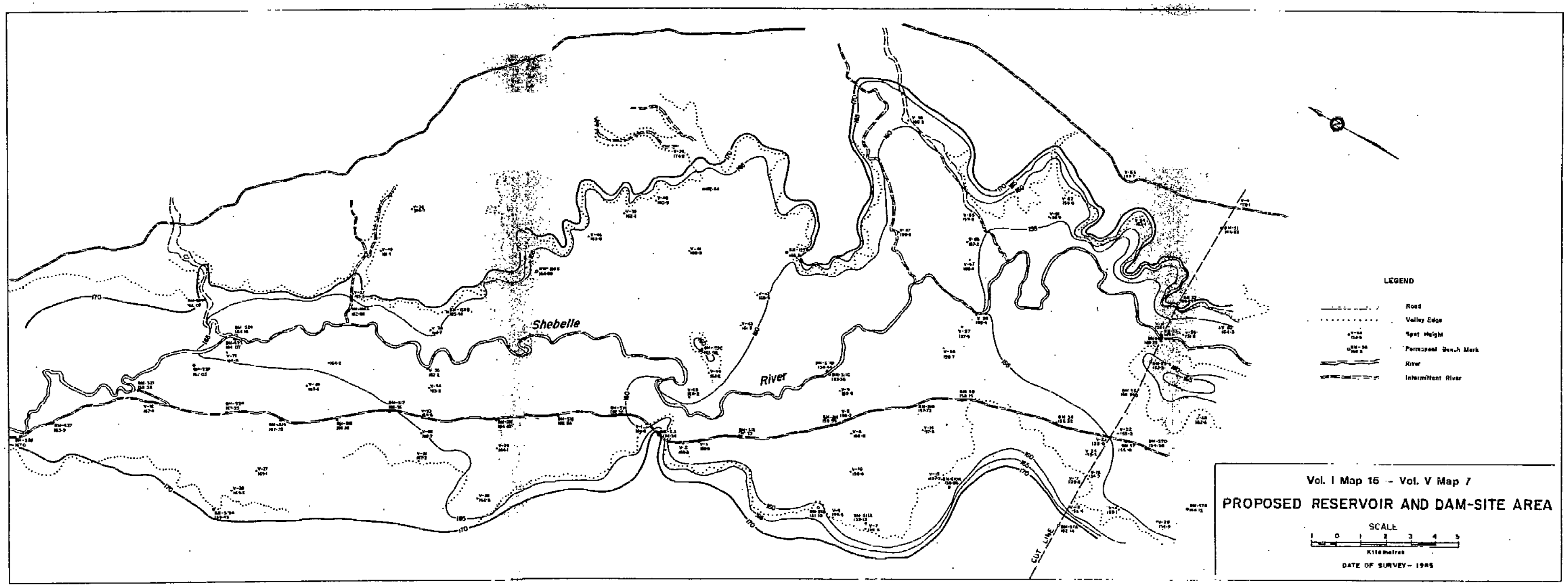
513. While the above proposal might be considered to be worthwhile because of the special circumstances, in general it is believed that sedimentation problems would rule out small surface dams in this region. Seepage galleries and ground water dams are much more likely to prove satisfactory.

514. The feasibility of damming the Lac Badana and the Uadi Damer could well be combined with the proposed study of diverting flood flows of the Shebelle. Though widely separated geographically these three projects together could justify bringing a small engineering team to Somalia to study them after the requisite mapping for the last-mentioned has been completed.

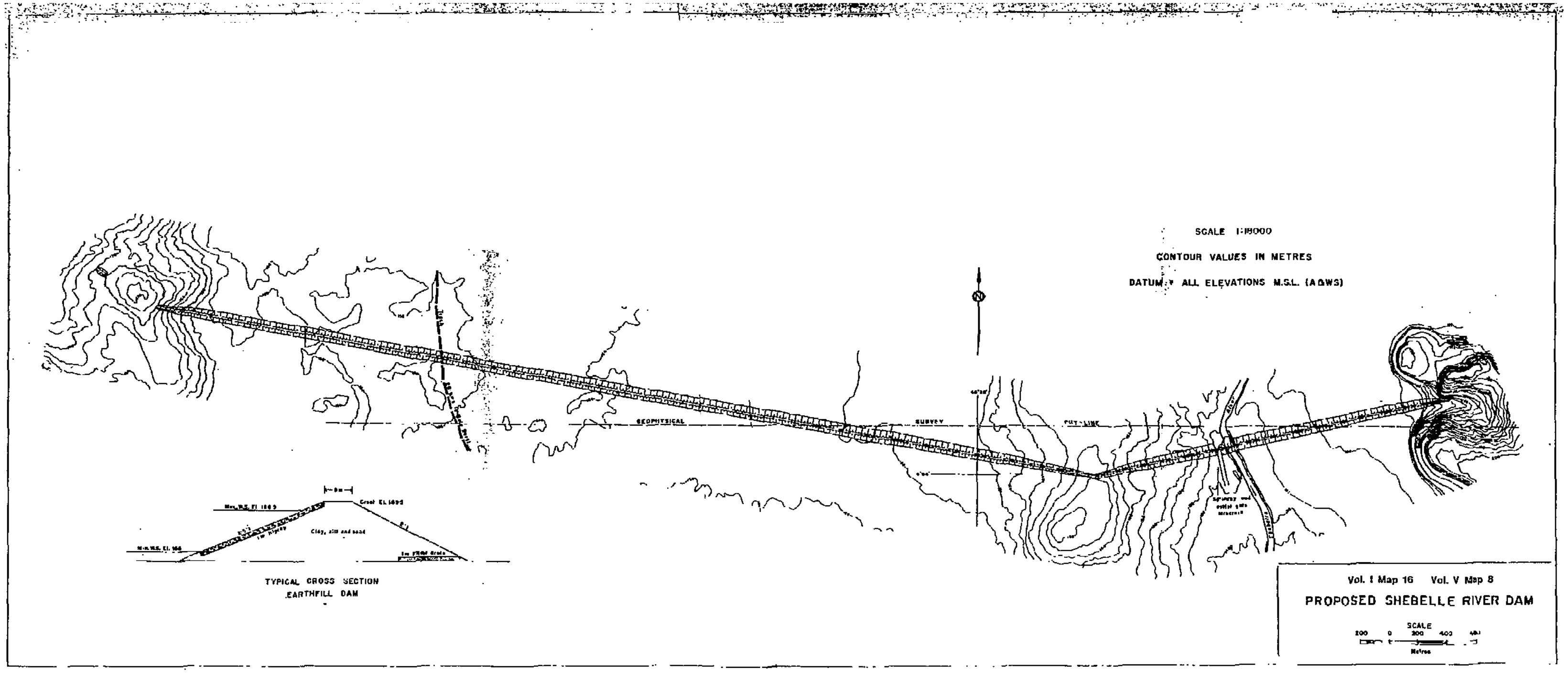


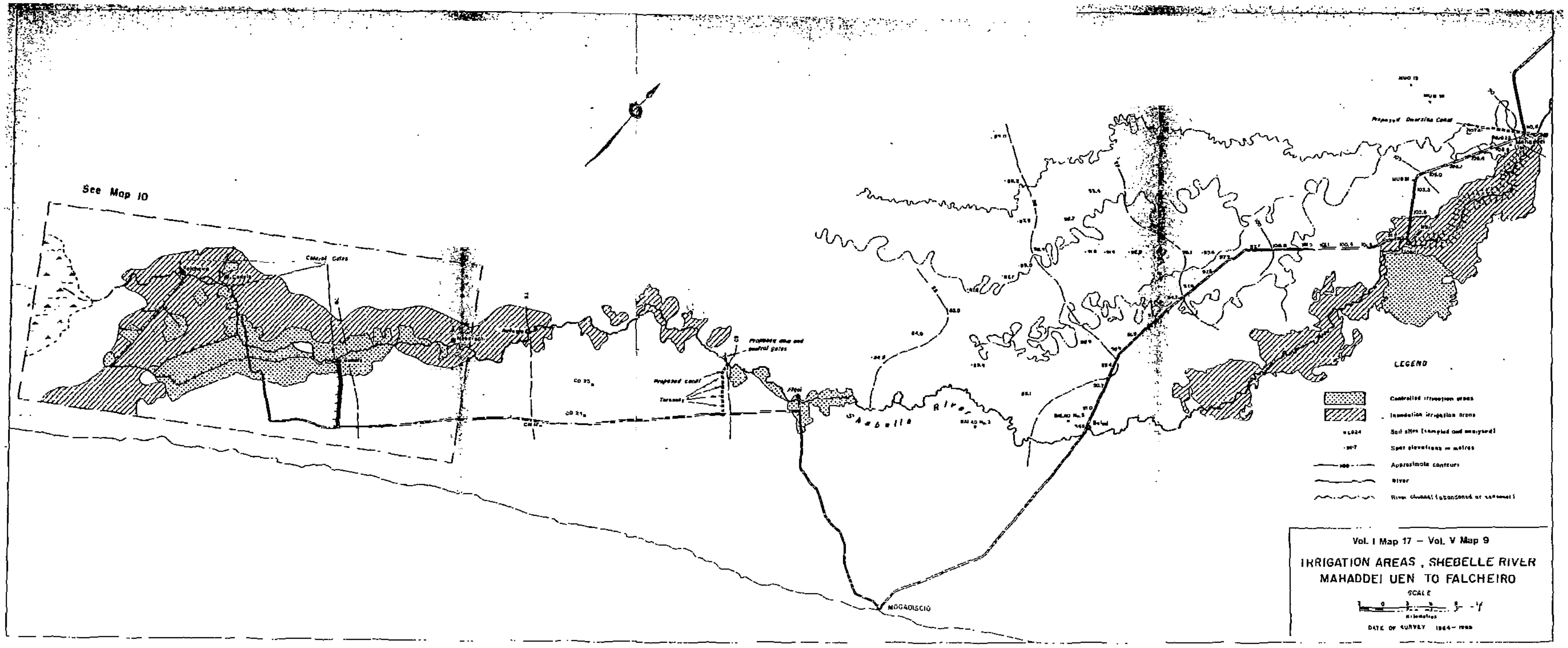
Vol. I Map 14 — Vol. V Map 6

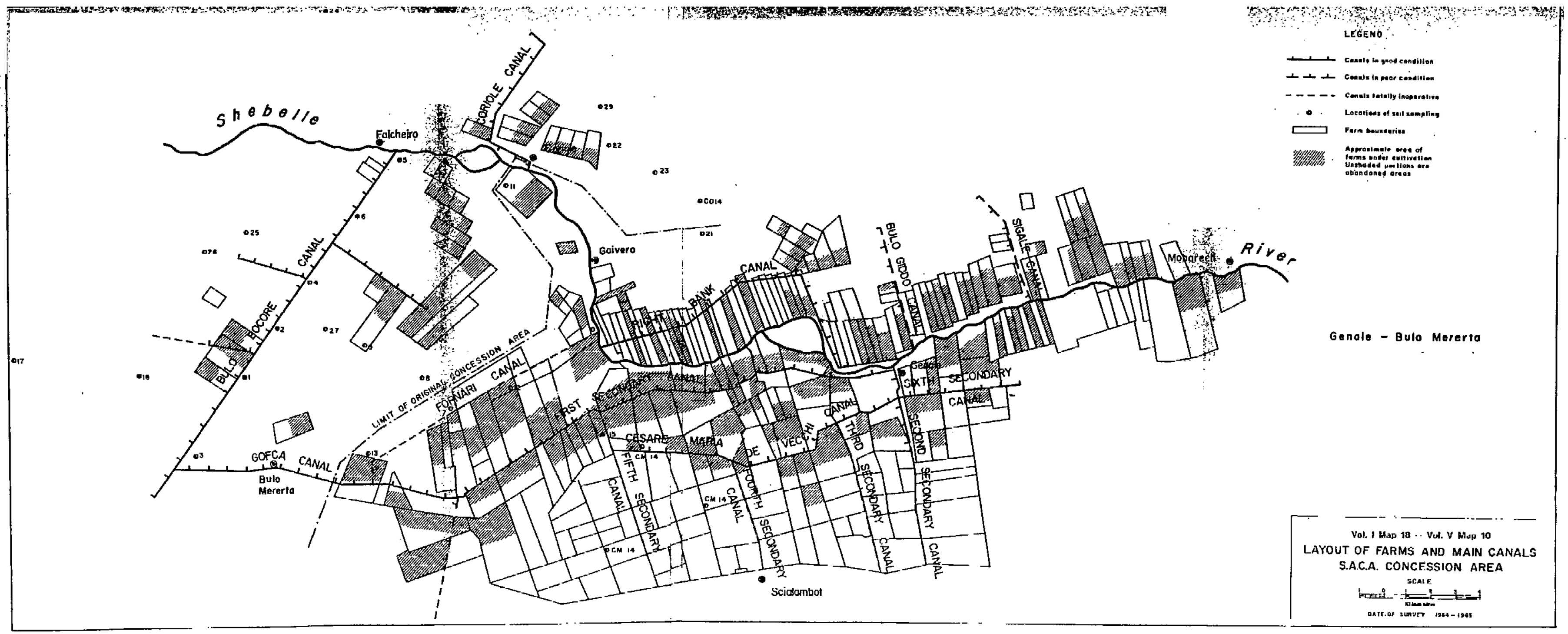
SHEBELLE RIVER'S WATER LOSSES AND PROPOSED UAR SITES

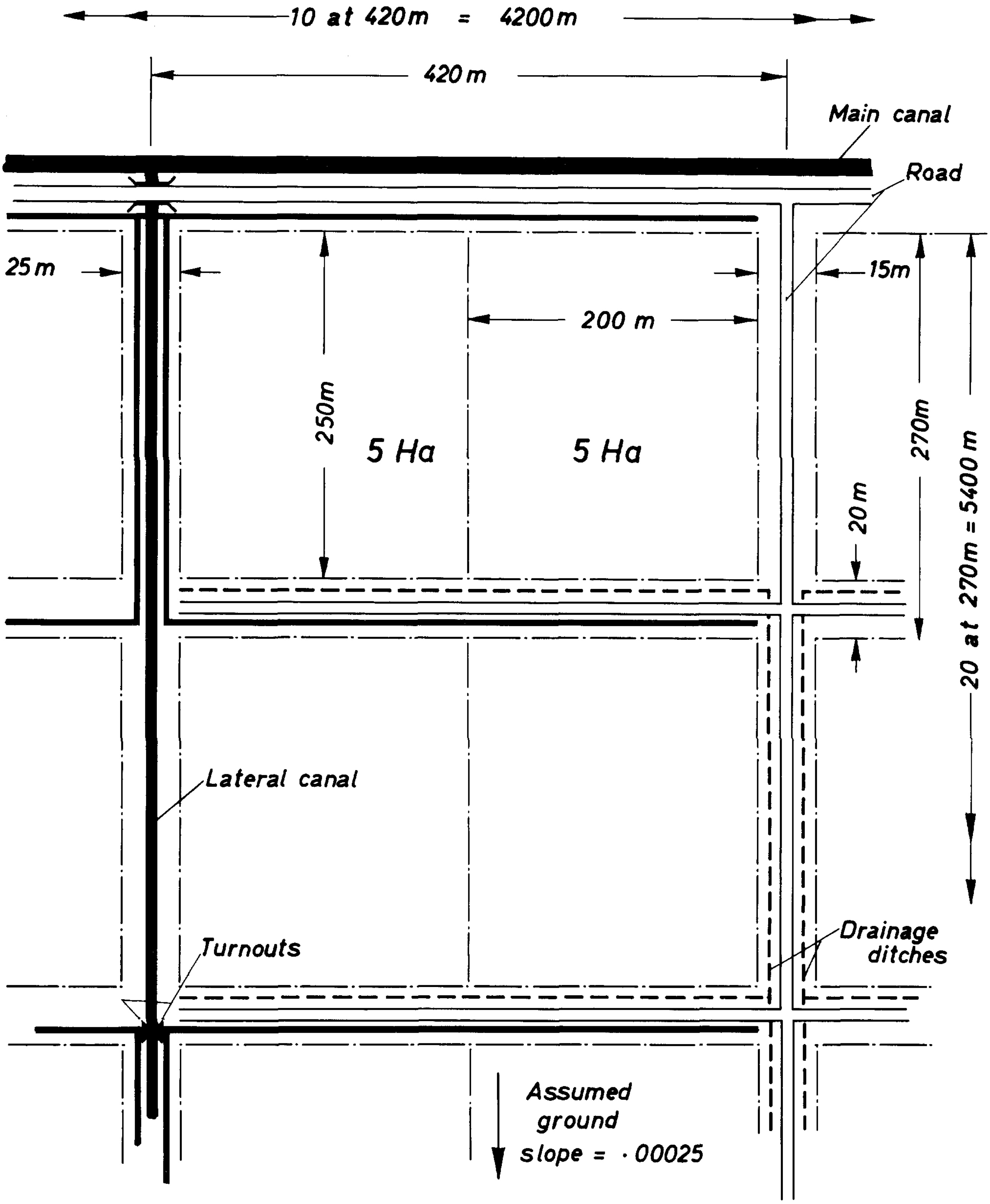


Vol. I Map 16 - Vol. V Map 7
PROPOSED RESERVOIR AND DAM-SITE AREA
SCALE
Kilometres
DATE OF SURVEY- 1965
LEGEND
Road
Valley Edge
Spot Height
Permanent Bench Mark
River
Intermittent River
Shebelle
River
CUT LINE


SCALE 1:18000
CONTOUR VALUES IN METRES
DATUM: ALL ELEVATIONS M.S.L. (ADWS)
GEOPHYSICAL
SURVEY
CUT-LINE
TYPICAL CROSS SECTION
EARTHFILL DAM
Crest EL 1692
Clay, silt and sand
Vol. I Map 16 Vol. V Map 8
PROPOSED SHEBELLE RIVER DAM
SCALE
Metres

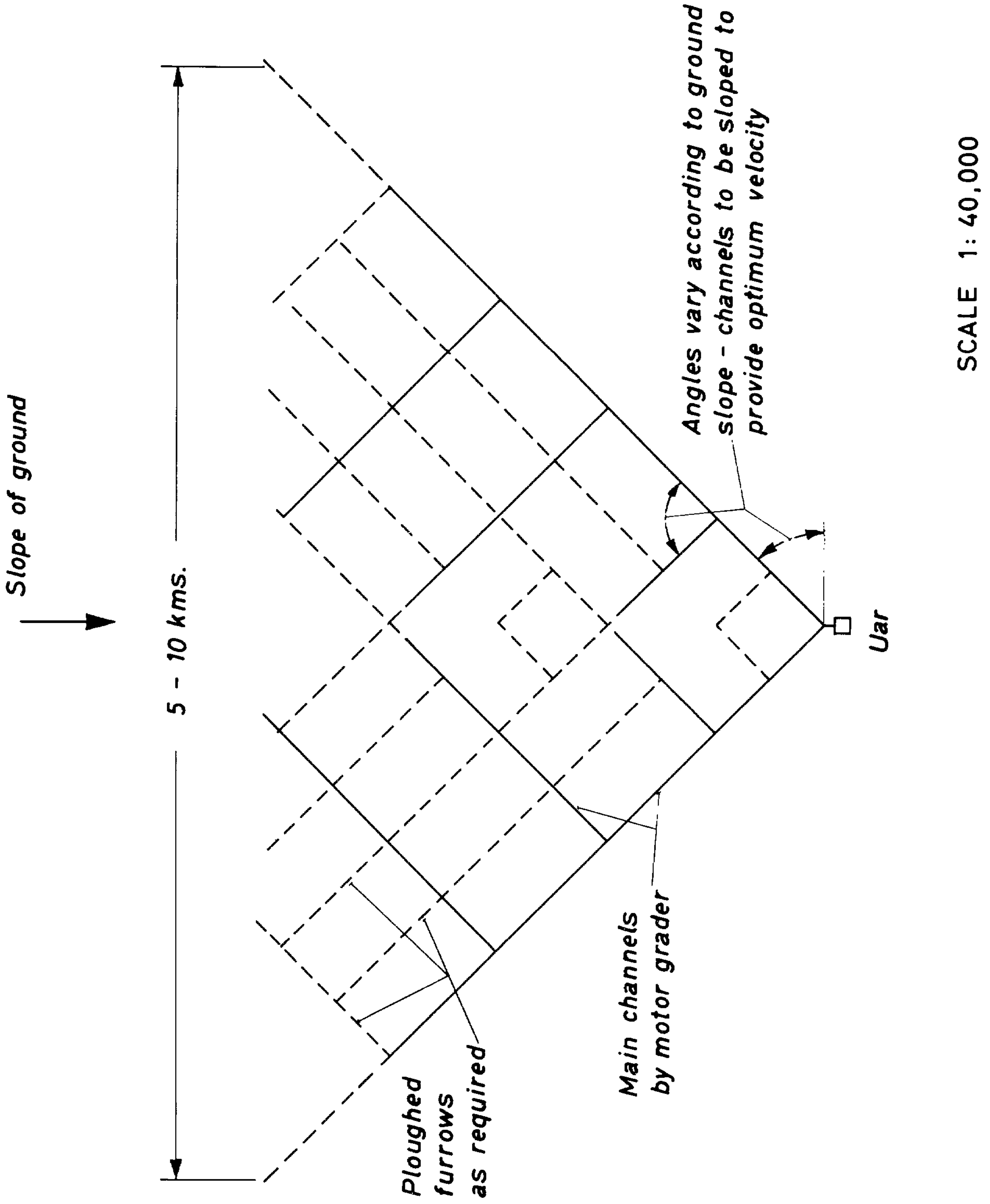

See Map 10
Canal Gates
Proposed Canal
Mogadiscio
LEGEND
Controlled irrigation areas
Inundation irrigation areas
Approximate contours
River
Vol. I Map 17 – Vol. V Map 9
IRRIGATION AREAS , SHEBELLE RIVER
MAHADDEI UEN TO FALCHEIRO
SCALE
DATE OF SURVEY 1964–


LEGEND
Canals in good condition
Canals in poor condition
Canals totally inoperative
Locations of soil sampling
Farm boundaries
Approximate area of farms under cultivation Unshaded portions are abandoned areas
Genale – Bulo Mererta
Shebelle River
Falcheiro
Goivero
Mobarech
Genale
Sciolambot
Bulo Mererta
CORIOLE CANAL
BOCORE CANAL
BULO
GOFCA CANAL
LIMIT OF ORIGINAL CONCESSION AREA
FORNARI CANAL
FIRST SECONDARY CANAL
RIGHT BANK CANAL
BULO GIDDO CANAL
SIGALE CANAL
SIXTH SECONDARY CANAL
SECOND SECONDARY CANAL
THIRD SECONDARY CANAL
FOURTH SECONDARY CANAL
FIFTH SECONDARY CANAL
CESARE MARIA DE VECCHI CANAL
Vol. I Map 18 -- Vol. V Map 10
LAYOUT OF FARMS AND MAIN CANALS
S.A.C.A. CONCESSION AREA
SCALE
DATE OF SURVEY 1964 – 1965

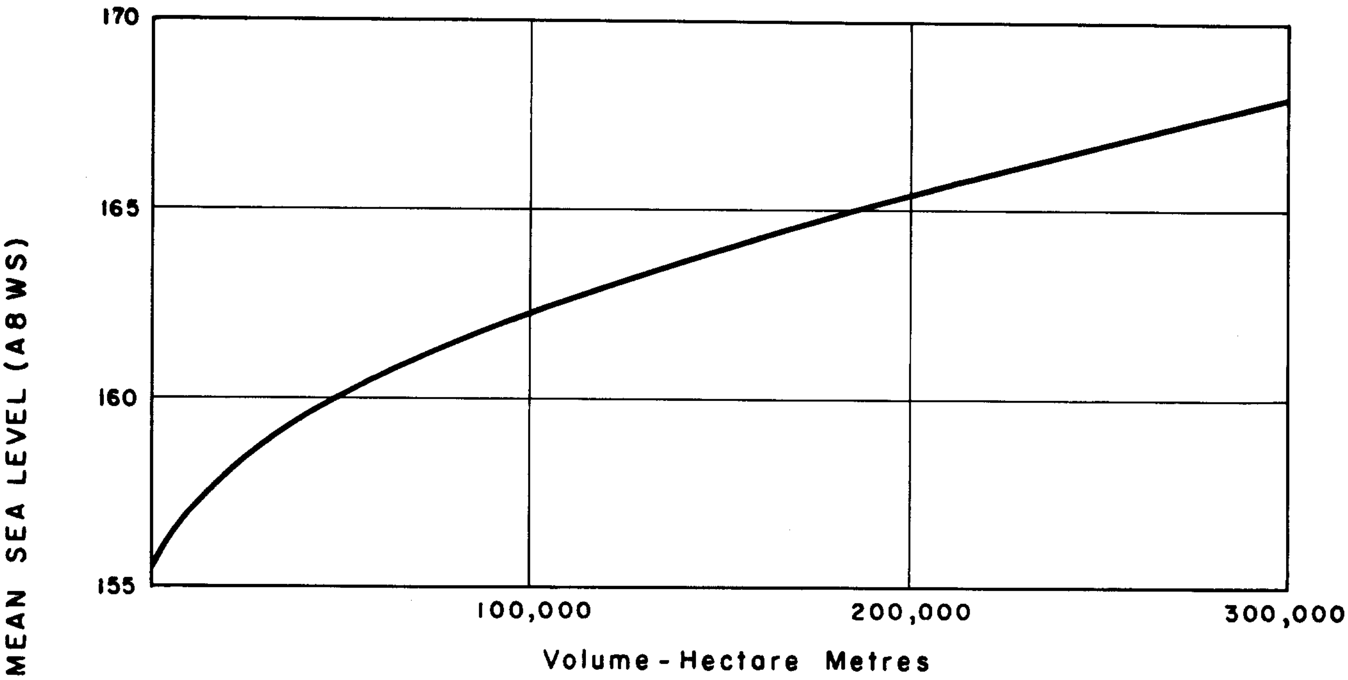


LAYOUT OF TYPICAL 2,000 HECTARE IRRIGATION SCHEME

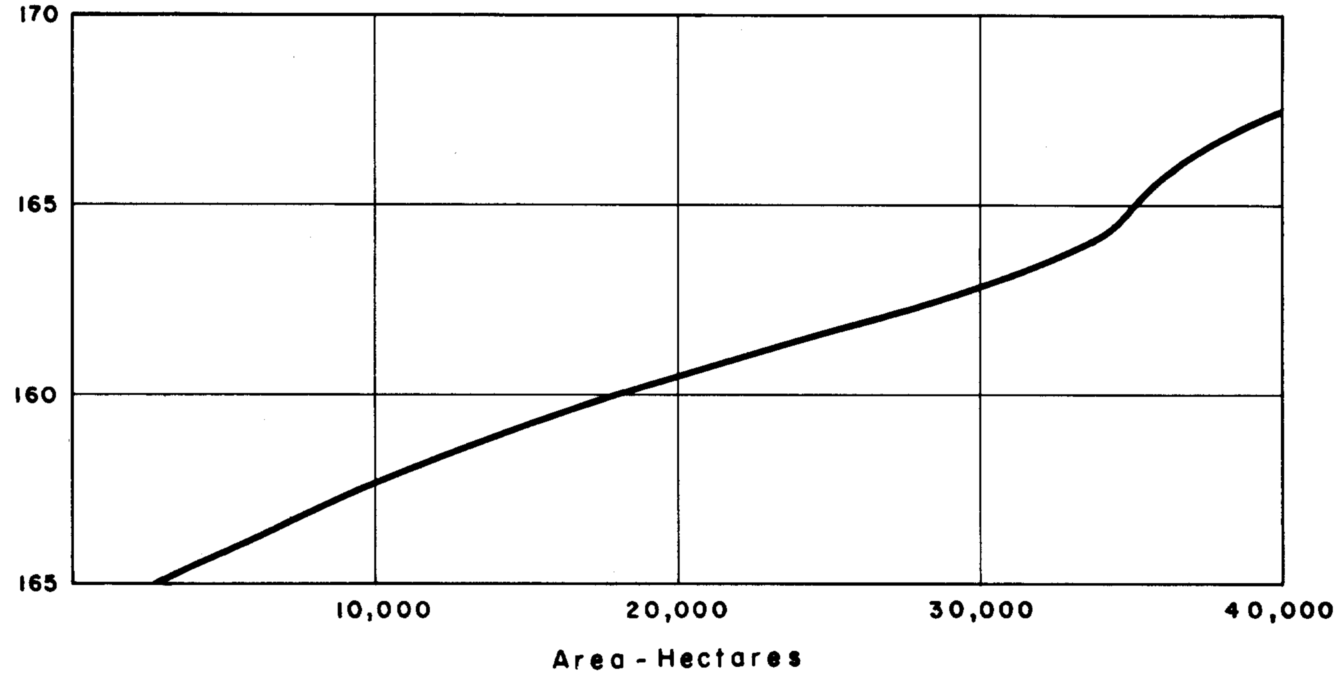
NOT TO SCALE



LAYOUT OF UAR COLLECTION CHANNELS



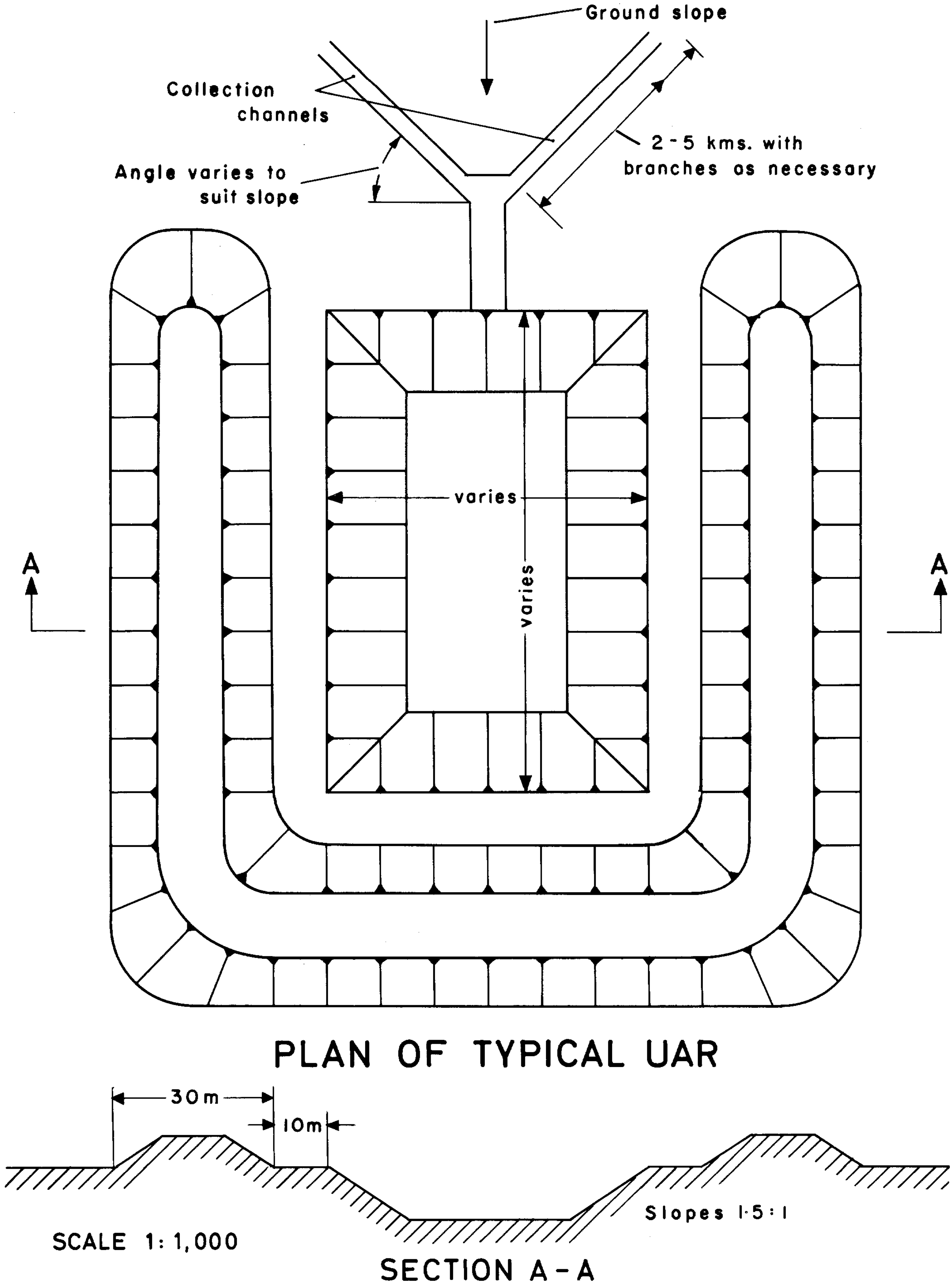
CAPACITY CURVE



AREA CURVE

RESERVOIR AREA AND CAPACITY CURVES

Vol. I Fig. 11 — Vol. V Fig. 1


Ground slope
Collection channels
Angle varies to suit slope
2 - 5 kms. with branches as necessary
varies
varies
A
A
PLAN OF TYPICAL UAR
30m
10m
Slopes 1·5 : 1
SCALE 1: 1,000
SECTION A - A

APPENDIX 1

DETERMINATION OF WATER REQUIREMENTS OF SELECTED CROPS

1. In determining the water requirements, or consumptive use, of the crops selected for proposed irrigation developments the Blaney-Criddle method was used. This is an empirical method first suggested about twenty years ago. It was developed for use under arid conditions and has been used extensively since its introduction both in the arid western portion of the United States and in various countries in the world where similar climatic conditions prevail.

2. The procedure for determining consumptive use by this method is relatively simple as it takes into account only temperature and day-time hours in any particular locality, ignoring the important factors of wind speed and relative humidity and relying on an empirical coefficient to cover these and other factors involved. Because of this simplicity the formula used has limitations, particularly when applied in a new situation such as Somalia where locally applicable coefficients have yet to be developed. For present purposes, however, it is considered to be adequate, but in any event there are insufficient data available to apply more refined approaches.

3. In this method it is assumed that the monthly consumptive use varies directly with the mean monthly temperature multiplied by the monthly percentage of day-time hours of the year. This product is multiplied by the appropriate empirical coefficient to obtain the depth of water required. The depth of irrigation water required is the difference between this computed depth and the effective rainfall.

4. Expressed mathematically, in terms of the metric system, the monthly consumptive use is:

$$u = kf = kp\ (8 - 0.45t)$$

where u = monthly consumptive use in millimeters of depth

k = coefficient for the crop, and month, concerned

f = the climatic factor

p = the month's percentage of total annual day-time hours

t = the mean monthly temperature in degrees Centigrade

5. In Table A-1 are shown (p), (t) and (f) for each month for Latitude 2° North, in the Afgoi-Genale region.

6. The selection of the correct monthly coefficient (k) for a particular crop in a particular locality presents considerable difficulty. Obviously it will depend on the stage of growth and on a number of factors which will vary from place to place. In due course the Agricultural Research Station at Afgoi will arrive at unappropriate value for use in this region. At present the value selected will necessarily be arbitrary as they will be based on each individual's assessment of the applicability of various published data.

TABLE A-1

CLIMATIC DATA FOR DETERMINATION OF CONSUMPTIVE USE

Month	Mean Monthly Temperature (t) - °C	Monthly % Annual Day-time Hours (p)	Climatic Factor(f) p (8 - 0.45t)
January	26.9	8.43	170
February	27.8	7.62	156
March	28.3	8.47	175
April	27.7	8.22	168
May	27.6	8.51	174
June	25.7	8.25	161
July	24.6	8.52	163
August	24.8	8.50	163
September	25.4	8.20	159
October	26.0	8.45	166
November	26.1	8.16	161
December	26.4	8.42	168

7. Alfalfa is something of a special case. The monthly values of (k) used for it are based on water requirements found from experience in hot and arid regions in California, with the actual growing season assumed to be from May 1 to November 30 and just sufficient water supplied in the other months to maintain the crop. When it is considered that the seasonal consumptive use in different parts of the State of Nevada has been found to vary from 355 millimeters to 1420 millimeters it will be appreciated that the values used here are extremely tentative and only suitable for the approximations of this section of the report.

8. Otherwise the coefficients used herein are generally acceptable averages and while time may prove them to be incorrect in many instances, the errors should not be great enough to have a significant effect on the end product of this study: an estimate of the total area of land which may be brough under controlled irrigation.

9. Using the monthly values for (f) previously tabulated, and coefficients (k) as shown in each case, the estimated monthly consumptive use of various crops suitable to the region and marketing possibilities are given in Table A-2. The growing seasons used have been modified from the most desirable to those which fit as closely as possible the periods of water availability. The lengths of season may be shortened with some varieties of cotton, maize and rice but it was considered safer not to make such assumptions in this study.

10. It is worth reiterating that the figures given are the theoretical net consumptive use in every case. The actual monthly application will vary considerably in many cases as in the first place it may be reduced by rainfall in the second place it will be out of phase with consumptive use due to soil storage of water. The quantity of water to be diverted from the river may be approximately double the tabulated figures due to distribution and irrigation inefficiencies.

MONTHLY CONSUMPTIVE USE OF VARIOUS CROPS

ALFALFA

Month	(f)	(k)	Depth mm.
Jan.	170	.15	25
Feb.	156	.25	39
Mar.	175	.45	79
Apr.	168	.55	92
May	174	.65	113
June	161	.90	145
July	163	.95	155
Aug.	163	1.00	163
Sept.	159	.85	135
Oct.	166	.80	133
Nov.	161	.50	80
Dec.	168	.45	75

MAIZE

(Two Cropping Seasons)

Month	(f)	(k)	Depth mm.
April 15 - August 15			
Apr.	168	.65	55
May	174	.75	131
June	161	.80	129
July	163	.70	114
Aug.	163	.65	53
September 1 - December 30			
Sept.	159	.65	103
Oct.	166	.75	125
Nov.	161	.80	129
Dec.	168	.70	118

RICE

Month	(f)	(k)	Depth mm.
Aug.	163	1.00	163
Sept.	159	1.15	183
Oct.	166	1.30	216
Nov.	161	1.25	202
Dec.	168	1.10	185

COTTON

Month	(f)	(k)	Depth mm.
Aug.	163	.60	98
Sept.	159	.75	119
Oct.	166	.90	149
Nov.	161	.85	137
Dec.	168	.70	118
Jan.	170	.50	85

GROUND NUTS

April 15 - July 15

Month	(f)	(k)	Depth mm.
Apr.	168	.60	101
May	174	.70	122
June	161	.65	105
July	163	.65	106

TOMATOES

(Two Cropping Seasons)

Month	(f)	(k)	Depth mm.
May 1 - July 31			
May	174	.50	87
June	161	.55	88
July	163	.55	90
September 1 - November 30			
Sept.	159	.50	79
Oct.	166	.55	91
Nov.	161	.55	88

APPENDIX 2

EFFECTIVE RAINFALL RELATIVE TO IRRIGATION DEVELOPMENT

1. The subject of the rainfall in the project area, in all its general aspects, is covered in Volume II of this report. Hereunder are discussed the particular aspects which relate to irrigation development and figures are derived for the monthly quantities of precipitation used in the process of computing irrigation water requirements in the Afgoi-Genale area.

2. The extremely wide variation in annual precipitation, and the much wider variation in monthly precipitation, makes it a most difficult matter to decide on the monthly figures which may safely be used. Only 8 complete years of records are available for the Genale area but these show annual totals ranging from 148.9 millimeters to 626.1 millimeters with the average 430.1 millimeters. Ten complete years of records are available for Afgoi, with annual totals ranging from 191.6 millimeters to 655.8 millimeters with the average 448.4 millimeters.

3. A study of the rainfall records for Afgoi and Genale, in Appendix 1a of Volume 2 of this report, showns monthly totals ranging from zero to over 250 millimeters, and coefficients of variation ranging from 0.6 to 3.0. From the monthly minimums given in these tables it will be seen that despite the relatively high averages in a number of months it is quite possible to have an effective total of virtually zero in any month of the year. The selection of monthly totals to incorporate in derivations of irrigation water demand hence becomes relatively arbitrary.

4. It has been decided herein to use the 75 per cent month totals which, in each case, is the minimum which may be expected to be received in three years out of four. The periods of record on which these totals are based are, of course, too short to provide a dependable picture and it must be accepted that, as in the case of other data used in this report, conclusions drawn can only be tentative.

5. Attention is called to the Afgoi precipitation data as well as that of Genale to indicate that the latter is not unique and that the region in which irrigation development is proposed has a relatively uniform rainfall pattern. In computations, however, only the Genale figures have been used as this station is central to the area suggested for most of the development.

6. Having determined the 75 per cent monthly totals it is necessary to reduce these to what is termed "effective" precipitation. The total rainfall is never effective in providing the water requirements of the crops and the percentage of the total that may be so used depends on the rate at which it falls, the characteristics of the soil, the slope of the land, the depth of the root zone and a number of other factors. It is obvious that an accurate determination of this percentage is impossible. In order to arrive at safe approximation it is common practice to use a relationship proposed by the U.S. Bureau of Reclamation, which is given in Table A-3. This has been used here, in view of the lack of any other generally acceptable method, though it is felt the results may be somewhat conservative considering the very level terrain and the apparently good moisture-holding capacity of much of the soil. The latter has been judged to be the case from appearances of crops which have been watered by a single inundation and little following rain.

TABLE A-3

RELATIONSHIP OF ACTUAL MONTHLY TO EFFECTIVE PRECIPITATION

Monthly Rainfall Increment mm.	Effective Precipitation Percent	Effective Precipitation Accumulated Total mm.
25.4	95	24.1
50.8	90	46.8
76.2	82	67.9
101.6	65	84.5
127.0	45	96.0
152.4	25	101.6
Over 152.4	5	

7. Another reduction from the total has been made in this study because of an observed characteristic of the rainfall in the area concerned. This is the fact that a significant percentage of a month's total is made up of a great number of small increments due to very scattered showers. No daily totals are available in the bulk of the Genale records but 25 years of these are available for Johar. These totals were processed by discarding all daily totals less than 3 millimeters and all daily amounts less than 5 millimeters which fell on days separated from other days of rain. It was assumed that all such increments would not enter the soil but would be lost by immediate evaporation. The total reduction to be applied in consequence was found to be an average of 14 per cent.

8. In Table A-4 are given the effective rainfall totals for each month computed in accordance with the above procedure. They are given for the 75 per cent month and the median month in each case and also for the driest year of record. Figures have not been included for the driest months of record because this would have been zero for every month except April and June and these dry month totals are insignificant in terms of crop requirements.

TABLE A-4

EFFECTIVE PRECIPITATION - GENALE

mm.

Month	Mediam Month	75% Month	Dry Year
January	0	0	0
February	0	0	0
March	0	0	0
April	57	36	14
May	33	20	38
June	51	36	25
July	52	35	25
August	18	0	0
September	10	6	0
October	0	0	0
November	51	23	0
December	8	0	0

APPENDIX 3

EXTRACTS FROM RESULTS OF RECONNAISSANCE SOIL SURVEY IN THE BULO MERERTA AREA

1. In the period February to April inclusive, 1961, a reconnaissance soil survey was made in the Bulo Mererta area and adjacent territory. This was carried out by Dr. Harvey P. Newton, Soils Advisor, US AID. The area was examined through soil pits and auger holes. A total of 30 stops were made, of which 15 were in the central portion of the Bulo Mererta project area. A total of 94 soil samples were taken and several analytical determinations were made on each in the laboratory.

2. The full results of this investigation have been published in the Annual Report-Number I-of the Agricultural Experiment Station, Afgoi - dated December, 1964. As much of this data is relevant to the areas herein proposed for development, permission was requested and kindly granted to include certain excerpts in this report. Accordingly the general observations from the Summary are presented hereunder and the tabulated results of the sample analyses will be found in Appendix 3 of Volume 3.

1. The soils of the area are of alluvial origin.

2. The texture generally is heavy. There is a small, very variable area 2.4 kilometers east of Gero.

3. All soils are extremely deep. They range from a small area near Scingani of 70 centimeters to over 2.5 or 3 meters in most of the area.

4. Generally there is no visible evidence of poor internal drainage, except that the subsoils between Gero and Coriole (north end of central portion) are very heavy.

5. Physical conditions of the soil generally are pretty good.

6. Field observation indicated good stands of sesame, and fair to good stands of corn and cotton.

7. All soil profiles gave a strong reaction in all horizons to HCl, indicating the presence of free CaCo3.

8. The analysis of samples in the laboratory gave these results:

    a) 90 samples were checked for their pH with a colorimetric field kit. All these samples read close to pH 8.

    b) The total salt determination indicated that the surface soils in almost all cases had no salt hazard (14 samples) or a low one (13 samples). The lower horizons (B's) showed mostly a low (16 samples) or medium (22 samples) salt hazard.

    c) The determination of sodium status indicated that almost no sodium hazard exists anywhere in the area. (86 samples).

d) The analysis of 4.6 samples for $CaCo_3$ equivalents showed a range of 17.0 per cent to 27.1 per cent in the surface soils and 15.3 per cent to 27.2 per cent in all samples. No concentration at any special depth was observed.