Government of Ethiopia
Water Resources Development Authority
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Development of Irrigated Agriculture
Contract No. DP/ETH/82/008-1/AGOE

KESEM IRRIGATION PROJECT FEASIBILITY STUDY

FINAL REPORT

Volume 1: Main Report

VOLUME 1

Sir M MacDonald & Partners Limited
Demeter House, Station Road, Cambridge CB1 2RS, England

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ABBREVIATIONS

(Annex A has another list, with specialised abbreviations related to soils)

AADC	Awash Agricultural Development Corporation
AIMC	Agricultural Inputs Marketing Corporation
AMC	Agricultural Marketing Corporation
ARC	Agricultural Research Centre at Melka Warer
AVA	Awash Valley Authority
AVSA	Awash Valley Settlement Agency
C	Cotton
CIF	Carriage Insurance Freight
DFC	Direct Foreign Currency
DM	Dry matter
DPSA	Development Projects Study Agency
EBJV	Ethio-Bulgarian Agricultural Joint Venture of Kesem Kebena
EELPA	Ethiopian Electric Light and Power Authority
EIRR	Economic Internal Rate of Return
el.	Elevation (above sea level)
ELACO	Ethio-Libyan Joint Agricultural Company
EOPEC	Ethiopian Oilseeds and Pulses Export Corporation
ESTC	Ethiopian Science and Technology Commission
ETMC	Ethiopian Tobacco and Matches Corporation
FAO	Food and Agriculture Organization of the United Nations
FOB	Free on Board
G	Gurmile
H	Horticulture
HDC	Horticultural Development Corporation
IAR	Institute of Agricultural Research
IBRD	International Bank for Reconstruction and Development
ID and FP	Irrigation, drainage and flood protection
IFC	Indirect Foreign Currency
ILCA	International Livestock Centre for Africa
KIP	Kesem Irrigation Project
KSFO	Kesem State Farm Office
KSO	Kesem Settlement Office
KWRO	Kesem Water Resources Office
LC	Local Currency
LLU/LSU	Livestock Unit
MAADE	Middle Awash Agricultural Development Enterprise
MADC	Middle Awash Development Corporation
MAP	Mean annual precipitation
MAR	Mean annual runoff
MCH	Maternal and Child Health
MMP	Sir M. MacDonald & Partners Limited (the Consultant)
MOA	Ministry of Agriculture
MOH	Ministry of Health
MSFD	Ministry of State Farm Development
MWRC	Melka Warer Research Centre
N	North
NEADE	Nura-Era Agricultural Development Enterprise
NERDU	North-East Rangelands Development Project
NOMADEP	A French-financed programme of aid to the Afar, now discontinued
NWRC	National Water Resources Commission
O&M	Operation and maintenance

ABBREVIATIONS (cont.)

PCC	Project Control Centre
PMF	Probable maximum flood
PMP	Probable maximum precipitation
PV	Present value
RAM	Readily available moisture
RDP	Rangelands Development Project
RRC	Relief and Rehabilitation Commission
S	South
SCF	Standard conversion factor
SCS	Soil Conservation Service - (USA)
SD	Standard deviation
SDU	Staged Development Unit
SF	State farm
SST	Sea surface temperature
STD	Sexually transmitted diseases
T	Tobacco
TOR	Terms of Reference
UNDP	United Nations Development Programme
USBR	United States Bureau of Reclamation
VADA	Valleys Agricultural Development Authority
WRDA	Water Resources Development Authority
4WD	Four-wheel drive
2WD	Two-wheel drive

UNITS

All units and their abbreviations are SI (Systeme Internationale), which are usually equivalent to metric units, except the following:

qt	quintal (100 kg)
yr	year
d	day
md	man-day
MM	man-months

The specialised abbreviation list at the beginning of Annex A mentions many units, and includes a note on the units for electrical conductivity.

CURRENCY

Unless stated otherwise all financial and economic calculations are made in the Ethiopian currency unit, the Birr, at 1986 prices. The exchange rate used is the official rate, namely Birr 2.07 to US$ 1.

CHAPTER 1

INTRODUCTION

1.1 Background

In the early 1960s a major river basin study was undertaken for the Awash river (Ref. 1). Among the areas identified for potential irrigation development was the Kesem-Kebena plain, a relatively flat area of some 20 000 ha on the left bank of the Awash in its middle course, intersected by the tributary rivers, Kesem and Kebena, flowing off the western escarpment of the Great Rift valley. The report on this basin study, issued by FAO in 1965, recommended:

(a) in Stage 1 of the development of the upper and middle valleys, the use of run-of-river water supplies in the Kesem and Kebena to irrigate, at most, 2 000 ha;

(b) in Stage 3, after developments on the right bank of the Awash, the construction of a major dam and reservoir on the Kesem and the development of a large irrigation scheme on the plain.

The 1965 report, using a reconnaissance-level soil survey, concluded that a gross area of 17 550 ha on the Kesem-Kebena plain could be irrigated throughout the year by gravity from the Kesem, although this included a 'micro-relief' area of 1 600 ha (Ref. 1, Vol. V, p.15).

During the 1970s and early 1980s the right bank developments of the Amibara system, representing Stage 2 of the 1965 report's programme, were constructed. The completion of the Bolhamo scheme and its linking to the Amibara canals reached final design stage in 1986. (The location of these schemes relative to the Kesem-Kebena plain is shown on Drawing Nr 1 in Album 1.) In the early 1970s some fragmentary basin-wide studies threw doubt on the size of the irrigable area on the Kesem-Kebena plain, indicating that it might be less than 10 000 ha gross.

No further field studies were undertaken until this study, but a 1984 report by the Bulgarian organisation Agrocomplect proposed a run-of-river development for the Kesem and Kebena, irrigating 1 350 ha gross in the dry season and 6 500 ha in the rainy season (Ref. 7, p.65).

In 1985 the Ethiopian Water Resources Development Authority (WRDA) issued terms of reference for this comprehensive feasibility study of the Kesem Irrigation Project (KIP). In January 1986 the work was entrusted to Sir M. MacDonald & Partners Ltd. (MMP), under a contract with FAO, which in turn is acting for UNDP. Work began in January 1986 and field investigations, including geological and hydrogeological subsurface drilling and testing carried out by the Government of Ethiopia, continued until February 1987. An Interim Report was discussed in December 1986 and the Draft Final Report was submitted for discussion in July 1987. This document is the Final Report.

Some changes have been made to the scope and timetable of the study during the course of the work. Firstly, the area covered by the soil survey was raised from 17 550 ha (a figure derived from the 1965 report's proposed gross irrigation area) to nearly 22 000 ha so as to cover the whole plain, the observation density being maintained at eight observation sites per square kilometre. Secondly, the geological drilling programme was extended in duration and was complemented by geophysical investigations using a hired seismograph. Thirdly, extra mapping was undertaken, to extend the 1985 mapping in certain places. The overall duration of the study was extended by about seven months because of the extension of the field work.

1.2 Objectives

The objectives of the project are to use all resources to maximise agricultural potential under a balanced environmental and ecological system, producing cash and industrial crops for export and/or import substitution, plus food crops at least for local self-sufficiency (Ref. 14). This emphasis on maximisation rather than optimisation is significant and will be discussed in later chapters: some compromises are needed in planning the joint use of the resources of land, water, human potential and capital.

The objective of this study is to enable WRDA to determine the relative priority of the Kesem Project within the overall development of the Awash valley (Ref. 15). The study is therefore intended primarily for comparison with other relevant studies, rather than for isolated appraisal against national or international criteria, which is significant for the interpretation of the economic analysis. It will be useful at this point to explain the use of the word "settlement". Except for very occasional use to mean a place where people live, like a village, it is used in this report to indicate all aspects related to the present indigenous occupants of the project area. For historical and institutional reasons, this usage is retained despite the fact that the semi-nomad people are not expected to settle in the forseeable future.

An initiative which is closely linked to the Kesem Irrigation Project is the Ethio-Bulgarian Agricultural Joint Venture of Kesem Kebena (EBJV), which is described in Section F1.5 in Annex F. Formed in late 1984, it aims to develop parts of the KIP area by run-of-river irrigation, without a dam. Towards the end of the study period of this report, the EBJV took over the existing state farm in the area, and has plans to extend it. The Joint Venture can become an alternative project if KIP is not implemented, or a management and finance package for KIP's first stage if it is: in either case the new field data contained in this report will be valuable for the EBJV's planning and design process. The link which has been established through EBJV's recent involvement in KIP's Steering Committee should be actively maintained.

1.3 Arrangement of the Report

This report's detailed technical information is contained in the 14 annexes of the report, which are bound in Volumes 2 to 5 and in two albums of drawings. Many of the annexes have their own appendices; the particularly bulky ones of Annexes A and I are bound separately in Volume 6, but otherwise the appendices are bound with their annexes. The arrangement of the report is illustrated by a diagram at the beginning of each volume.

Within this Main Report there is a separation between the description of the proposed project, in Chapter 5, and the discussion of the reasoning behind it which is in Chapter 4. These are preceded by a summary of the resources and the present situation in Chapter 3, and followed by the project evaluation in Chapter 6. Brief conclusions are set out in Chapter 7 and references are listed at the back of this volume as well as in most of the annexes.

1.4 Acknowledgements

Although the Consultant takes final responsibility for this report, the study has been a cooperative effort by many people. For the fieldwork in 1986 an integrated team was formed by WRDA and MMP, consisting of about 40 professionals and a larger number of assistants, technicians and administrators.

Many and varied practical problems, particularly in matters of logistics, were overcome in a spirit of teamwork and flexibility. Much assistance was given by the Project Control Centre at Amibara, and by other Ministries.

The completion of the analysis and reporting stages of the study was marked by similar cooperation. Three WRDA engineers worked in the Consultant's offices for a while. Two major reports and several progress and supplementary reports were systematically reviewed by WRDA, other concerned Ministries, FAO and MMP, in review meetings lasting several days, and the review of the Draft Final Report was particularly fruitful because of the use of six technical sub-committees. These formal meetings were supplemented by innumerable specialist meetings and discussions.

The Consultant therefore acknowledges with gratitude the assistance, throughout the study, of many people in Ethiopia and Rome, from department heads to drivers. To name them all would require a fifteenth annex, so it must suffice to mention in particular Ato Mekuria Tafesse, Ato Tesfaye Gizaw, Ato Telahoun Eshetu, Ato Tefera Woudeneh, Dr Kandiah, and Mr Mather. Some of the annexes of this report contain further acknowledgements related to particular disciplines.

CHAPTER 2

PREVIOUS STUDIES AND REPORTS

2.1 General

Previous reports which refer to the Kesem-Kebena plain are:

- the 1965 report on the 'Survey of the Awash River Basin', by SOGREAH for FAO (Ref. 1);

- the series of technical reports and assignment notes prepared by Australian specialists from 1972 to 1974 under the overall title 'Development of the Awash Valley' (Ref. 3);

- a prefeasibility study of 1980 for a proposed Ethio-Yemeni joint venture (Ref. 5);

- a report dated 1984 on a proposed Ethio-Bulgarian Joint Venture (Ref. 7);

- an updated profile on KIP prepared internally by the WRDA/FAO team in 1985 (Ref. 11).

The first two of these reports give the results of field investigations, while the other three consist mainly of the re-presentation of selected field data from the first two, plus updated cost and benefit estimates and some new proposals for action.

A series of reports relating to the Amibara, Angelele and Bolhamo schemes (irrigated from the Awash river and located to the north-east of KIP) are very relevant to this study. The main ones are:

- the 1969 feasibility study report for Melka Sadi-Amibara, by Italconsult (Ref. 2);

- the 1975 feasibility study report on the extension of the Amibara system to include the Angelele and Bolhamo areas, by Sir William Halcrow & Partners (Ref. 4);

- a reappraisal and updating of the Angele-Bolhamo study in 1982, followed by final designs in 1986, by NEDECO (Refs. 6 and 12);

- three reports dated 1985 relating to drainage problems on the Amibara system (Refs. 8, 9 and 10), particularly the Master Drainage Plan by Sir William Halcrow & Partners.

Many of the annexes of this report contain references to, and comments on, these and other earlier reports. The rest of this chapter is devoted to a brief general review of the more relevant reports.

2.2 The 1965 FAO/SOGREAH Report

The 1965 SOGREAH report (Ref. 1) covered the KIP area only as one part of the whole Awash basin, but gave considerable attention to the Kesem dam as one of two suggested major storages (the other being Tendaho on the Lower Awash). The soil survey of the Kesem-Kebena plain had an observation density of about one per 200 to 300 ha (compared with one per 12.3 ha for this study), and was plotted at the relatively large scale of 1 : 100 000 using air photographs at 1 : 40 000. Soils were classified by suitability for irrigation using US Bureau of Reclamation criteria, and some 18 700 ha on the Kesem-Kebena plain were classified as Class II, leading to the proposal for irrigation of 17 550 ha gross. This now turns out to have been an over-estimate of the area of suitable land by a ratio of around 1 : 1.4. The reasons are complex, but one significant factor is that the extent of highly saline and sodic soils is much greater than was recognised in the low-density soil survey for the 1965 report.

For regulation of the flow of the Kesem, the 1965 report identified a potential reservoir volume of 370 hm^3, but this study has shown that the maps used in 1965 were inaccurate and a volume of 500 hm^3 can in fact be stored. This was however offset, in the 1965 report, by a relatively low estimate of the sedimentation rate (2 to 3 hm^3/yr compared with this study's estimate of 5.7 hm^3/yr), and a high estimate of the catchment's water yield (600 hm^3/yr compared with this study's 500 hm^3/yr). The reservoir was seen as a seasonal rather than an over-year storage (initial live storage 48% of average annual yield instead of 100% in this study), so its regulated output was seen as unrealistically reliable. The 1965 report accordingly estimated that the reservoir could irrigate 22 500 ha and provide firm power of 4.8 MW, both of which now appear too high. Before completion of the dam there was to be a run-of-river phase irrigating "at most 2 000 ha of land."

The SOGREAH study identified two damsites within the 1 km long gorge on the Kesem river. Either site would use the same reservoir. That study included some drilling and permeability testing at the downstream site, which was preferred to the upstream site because of the supposed better shape of the gorge. This now turns out to be due mainly to inaccurate mapping. High permeabilities were measured at the downstream site (probably related to a nearby fault) and were countered by proposals for a very extensive, probably excessive, grout curtain rather than by closer consideration of the upstream site. Both rockfill and hollow gravity concrete dam types were proposed and the report left the choice to be determined by later studies, though stating the expectation that rockfill would probably be favoured.

In summary, the 1965 report identified the Kesem Irrigation Project and gave an initial estimate of its extent and merits which, though qualitatively correct, were quantitatively somewhat optimistic. The area of suitable soils and the regulated yield of the reservoir were the crucial parameters which appear to have been over-estimated. These comments should not, however, be interpreted as criticism of the SOGREAH study; the database, especially topographic maps and soil surveys, was very limited, and KIP was only one part of the 1965 report's subject matter.

2.3 Other Reports about the Kesem-Kebena Plain

The series of 32 monographs produced between 1972 and 1974 by Australian experts for FAO (Ref. 3) also covered the whole Awash basin, but they gave considerable attention to the Kesem-Kebena area because the 1965 report had identified its potential. Their usefulness is however very varied. One particularly significant one was Informal Technical Report 23, by H.E. Voelkner, on the Afar pastoralists and the problems of settling them on irrigation schemes (Annex C, p.C-47). Voelkner's demographic work was especially valuable. On the subject of soils and land suitability, Informal Technical Report 14 by D.T. Currey questioned the 1965 estimate of suitable land area, suggesting that the true figure was only 9 150 ha, little more than half of that estimate. The reasoning behind this assertion was not well founded, however, and Currey did not carry out or have access to data from any significant new soil survey. The report dealing with organisational structure (Nr 6, by Donohoe; Annex F pp. F-3 and F-37) recommended a single organisation dealing with agriculture and engineering, which was the practice at the time.

Perhaps because of the weak basis of Currey's challenge to the 1965 estimate of irrigated area, or because of the fragmented nature of the Australian reports, the three desk studies of the early 1980s tended to go back to the 1965 report for their base data. In the matter of soil suitability this is unfortunate, since the time-honoured figure of 17 550 ha for the irrigation area appears again and again.

Because of its connection with forthcoming action, the Bulgarian report of January 1984 is the most significant of the three. For the first phase of the joint venture's operations it proposed run-of-river development using both the Kesem and Kebena rivers. A much larger total area was proposed (6 500 ha) than can be irrigated in the dry season (nominally 1 350 ha), but the nominal wet season irrigation period was assumed long enough to irrigate cotton as well as relatively small areas of citrus, bananas and vegetables. The Kebena river was estimated to have a much higher dry season flow than the Kesem, which is contrary to the present Consultant's field observations and is probably due to gauging errors at low flows. This led to estimates of cropping intensity of 114% on a total area of 6 500 ha, which is considered unrealistically high and is also incompatible with the 1984 report's own summary of 1 350 ha in the 'dry season'. The proposed cropping pattern was dominated by cotton (63.5%) and tobacco (9.1% but double-cropped). This January 1984 report formed the basis for the joint venture agreement of December 1984, which mentions the total area of 6 800 ha but not the intensity (see Annex F, p.F-5). In early 1987, with design imminent, the management was envisaging irrigation of 3 500 ha in the dry season. The 1984 report also proposed an intensive dairy unit using irrigated alfalfa, and this too is part of the joint venture's intended development. In general, the 1984 study suffers from its lack of new field data, particularly on soils and on Kebena river hydrology. It treats the presence of the Afar as a social problem to be solved in advance by the Ethiopian authorities, rather than as an existing fact which the project must deal with.

2.4 Other Middle Awash Reports

Large-scale development of the Amibara area, on the other side of the Awash river to the north-east of the Kesem-Kebena plain, began in the 1970s and is still continuing. To the north of Dofan volcano, which bounds that plain on its northern edge and has caused an eastward loop of the Awash river, there is further irrigable land in the Bolhamo area (see the map in Drawing 1, Album 1). Some of this is already irrigated by pumping from the Awash, but proposals are well advanced, in the Angelele-Bolhamo scheme, to extend the irrigated area and supply most of it by gravity from the Amibara main canal. This takes water from a weir and right bank headworks on the Awash just upstream of the Kesem confluence.

The earlier-developed parts of the Amibara complex, particularly the Melka Sadi area, have suffered groundwater and salinisation problems within a few years after the start of large-scale irrigation. This has led to a pilot drainage scheme and a master drainage plan, and further investment in drainage works is expected during the late 1980s.

Feasibility study and design reports on these schemes appeared from 1969 to 1986 (Refs. 2, 4, 6 and 12), while the drainage problems and their proposed solutions were covered by three reports in 1985 (Refs. 8, 9 and 10). These have all been used in the course of this study, and have produced valuable information on the Awash river, construction costs, and some other aspects. There is however one fundamental difference between the Amibara system and KIP which limits the transferability of experience between them. The soils in the Amibara system are mostly basin clays and levee soils related to the Awash, whereas on the Kesem-Kebena plain the predominant soils are those developed on alluvial fan deposits related to the rivers and wadis flowing eastward from the rift valley escarpment. For this reason, most of the conclusions reached in this report on matters related to soils, particularly land suitability, drainage, and crop yields, are based on the present Consultant's fieldwork and wider experience and owe little to the previous reports.

Many other and more specialised reports have been used in the course of this study and are mentioned in the relevant annexes. Material from the NOMADEP project, which promoted development among the Afar on the Kesem-Kebena plain, has been valuable, as have documents of the Ministry of Agriculture's Third Livestock project and of the International Livestock Centre for Africa (Annex C). Various government statistical publications, and also the reports and budgets of the Ministry of State Farm Development and its branches, have been valuable for agricultural and economic data (Annexes B and N). Agricultural information was also of course gained from many reports of the Institute of Agricultural Research. On organisation and management, a Halcrow - ULG report of 1982 was useful (Annex F). Specialist reports on seismology and power planning are mentioned in Annex J.

In addition to all the reports and documents specific to the Awash valley or to Ethiopia, a number of international publications have been used, notably the Soils Bulletins and the Irrigation and Drainage Papers produced by the FAO.

Finally, the written sources have been supplemented by many interviews and conversations with people having relevant experience, both in government departments such as WRDA, MOA and MSFD and also in independent or United Nations agencies such as FAO, NOMADEP and ILCA.

CHAPTER 3

THE RESOURCES AND THE PRESENT SITUATION

3.1 Land Resources

The Kesem-Kebena plain covers an area of about 22 000 ha. It is part of the floor of the Great Rift Valley, which in this area is oriented roughly north-south and drained by the Awash river flowing northward. The plain lies on the west bank of the Awash and is about 12 km wide, bounded on the west by the dissected foothills of the rift valley's western escarpment. Figure 3.1, which is bound at the back of this volume, shows the main features, and the wider surroundings are seen on Drawing 1 in Album 1. To the north the plain is bounded by Mount Dofan, a small volcano joined to the escarpment by a ridge running east-west: this volcano pushed itself up right on the line of the Awash, causing the river to deposit sediment upstream of the blockage and eventually to form a new course round the volcano on its east side. The north-east corner of the plain is formed of these deposits, characterised by very flat topography and heavy soils, and tends to resemble the Melka Sadi area, part of the Amibara Irrigation Project, on the other side of the Awash. The rest of the plain is, however, mostly made up of alluvial deposits brought down from the escarpment to the west by various watercourses, notably the Kesem and Kebena rivers and Wadi T'unfeta. These two rivers are wide and braided where they enter the plain, becoming narrower between their own levees, and eventually showing a tendency to meander in the last few kilometres before joining the Awash. The wadis that drain the foothills immediately to the west, which tend to have catchments extending only 5 to 30 km westward, only flow briefly after storms and do not reach the Awash at all. Wadi T'unfeta ends in a pronounced conical fan in the north-east, while several wadis, end in an ill-defined basin south-west of Gurmile Hill, separated from the Kesem by that river's left levee. To the south, some 25 km south of Dofan, the plain is bounded by higher ground that extends eastwards from the large Fantale Volcano to the Awash and, in the south-eastern corner, by the Filweha stream at its foot. This stream is unlike any other watercourse in the area because it rises in a group of hot springs related to the area's widespread volcanicity, and carries a remarkably steady flow (1 to 2 m^3/s) of sediment-free, warm and slightly saline water. In the middle of the plain is a group of volcanic craters and their side slopes, collectively called Gurmile Hill. This feature is about 2 km in diameter.

This study included a semi-detailed soil survey and a land suitability classification which are described in Annex A and mapped at 1 : 20 000 in Drawings A1 to A4 in Album 1. The fieldwork, done from February to June 1986, covered some 21 820 ha with a total of 1 768 auger holes and pits, and also involved numerous infiltration and hydraulic conductivity tests. The overall observation density thus exceeded 8 per km^2, and the auger holes were mostly 3 m deep, some 4.5 m. Use of the 1 : 20 000 air photographs taken in advance of the study (1984) enabled the large volume of data from these field investigations to be plotted as soil maps (Drawings A1 and A2) which record the very fragmented soils in some detail.

This soil survey shows that the soils of the plain are very variable, both laterally and within individual profiles, and that large areas are affected by problems of salinity and/or sodicity. Most of the soils in the area are developed on a complex pattern of intercalating alluvial fans. Along the banks of the major watercourses, particularly the Awash and Kesem rivers, a narrow trip of levee soils may be found. Relict levee soils may also be found along old dry watercourses throughout the area, but their extent is very limited.

Soil textures vary considerably, reflecting the very complex recent geomorphological and hydrological history of the area. Alluvial fans continue to be developed, as meandering watercourses repeatedly alter their courses. Air photographs taken over the last 20 years indicate, for instance, that the outwash fan from the Wadi T'unfeta has gradually moved south away from Dofan Mountain. Extreme spatial variation in soil textures indicate that this phenomenon has been common throughout the area for some time. Most of the soils are predominantly medium textured: typically silty loams, silty clay loam, very fine sandy loam and very fine sandy clay loams, with potentially moderate to high water holding capacities. Although some of these soils are well or moderately well drained, many are imperfectly to very poorly drained. In some cases this is due to the presence of underlying heavier textured material, but more often because of the massive nature and inherently poor physical characteristics of the silty material itself.

The soil classification scheme uses 13 soil types, subdivided according to salinity and sodicity, and 6 miscellaneous land categories, resulting in some 74 mapping units which are described in Chapter A4 of Annex A. Silty soils predominate, comprising 49% of the surveyed area as compared with 13% for the sandy and coarser soils and 20% for the clays (these figures exclude the miscellaneous land categories, some of which are also silty soils but unusable because of extreme topography, salinity or sodicity).

The land suitability classification, unlike those in previous studies which used USBR methods, is based on FAO guidelines published in 1984. The new approach defines land suitability for irrigation in a manner specific to particular land uses rather than in a general sense, as well as taking into account non-soil factors like water resources, social constraints, and economic aspects. This means that several classifications have been made, one for each of six potential land uses (details in Annex A, Chapter A5). Since it would be impracticable to map all six, and to use such maps for designing an irrigation layout, a generalised classification has also been developed and this is mapped in Drawings A3 and A4 in the Album. Its seven classes or 'mapping units', were designed specifically for this project and are not related to any standard or other classification scheme.

The results of the survey indicate that some 17 200 ha (79% of the area surveyed and mapped) are at least marginally suitable for some form of irrigated development, though some of this cannot be commanded for gravity irrigation. However, for many of the land utilisation types under consideration the areas of suitable land are significantly smaller, as shown in Table 3.1. It can be seen that for cotton, the main cash crop and not a particularly demanding one as far as soils are concerned, only 62% of the gross area, or 13 400 ha, is suitable. A further 3 800 ha can be used for irrigated pasture or woodlots but not for high-value or annual crops, and even this only brings the total gross suitable area to 17 200 which is considerably less than the 1965 report's estimate for undifferentiated irrigable land (18 700 ha).

TABLE 3.1

Summary of Areas Suitable for Irrigation by Land Utilisation Type

Land utilisation type	Most suitable land Classes S1 and S2 (ha)	(%)	Total suitable land Classes S1 to S3 (ha)	(%)
Irrigated pasture	13 536	62	17 195	79
Woodlots	14 222	65	17 135	79
Cotton (state farm)	11 408	52	13 422	62
Smallholders	7 004	32	12 822	59
Citrus (state farm)	3 872	18	8 087	37
Tobacco (state farm)	3 682	17	6 878	32

Total surveyed and mapped 21 823 ha (100%).

Source: Table A7.1.

Practical constraints of topography and layout, which is difficult because of the fragmentation of the soils, bring the effective gross usable area down to about 15 700 ha, including pasture and woodlots, of which only about 12 000 can be used for cotton or other annual or high-value crops. These areas can only be developed by reclaiming about 1 800 gross ha of the saline and sodic areas, mostly for cotton, which will delay the start of profitable farming on those lands by about one year.

Adoption of skilled soil and water management practices will be crucial to the success of irrigation development in the area. In addition to the practices necessary to combat and prevent excessive sodicity and salinity, measures will also be needed to overcome the poor physical properties of many of the soils. Potentially the most serious of these include the tendency of the siltier textures to form surface crusts (thereby reducing the rates of infiltration); a general lack of good soil structure, and the inherently low soil permeability of the heavier textures which are widespread as depositional bands or major soil layers. These inherent deficiencies would be aggravated by poor soil management, notably by inopportune timing of field operations, especially those using heavy farm machinery which is liable to cause compaction and surface smearing in the silty soils. Significant improvement of soils by good agricultural management is not possible.

To summarise the position with regard to land resources, the soils of the Kesem-Kebena plain have been found to be less good than was indicated by the 1965 study. The main problems are:

- widespread salinity and sodicity;
- high variability of soils, horizontally and vertically;
- high silt contents leading to poor soil structure and a danger of further deterioration of structure under mechanised cultivation;
- low permeabilities and widespread occurrence of layers of heavy soil within coarser textures, which restrict drainage.

The soils are generally unlike those of the Amibara system, and crop yields cannot be expected to match those of the Amibara farms. Nevertheless, there is potential for irrigation, with appropriate cropping patterns and some reclamation, of the order of 12 000 to 16 000 gross ha on the plain.

3.2 Water Resources

3.2.1 Groundwater

This study included a programme of drilling and testing of eight boreholes, together with observations of surface features and existing wells and springs, so as to investigate the groundwater under the Kesem-Kebena plain in relation both to its interaction with any future irrigation scheme and to its use as a water source. This programme and its results are described in Annex H.

The plain's surface soils are underlain by sedimentary deposits over volcanic bedrock which is extensively faulted. In places, particularly in the north-west, the sedimentary deposits are underlain by and partly interbedded with conglomeratic formations and layers of basalt, ignimbrite and associated volcanic strata. The depth of alluvium increases from zero in the west to 150 m or more in the east, probably in a series of steps corresponding to faults in the bedrock. Permeability in the upper layers, usually 20 to 50 m thick, is low, generally less than 1 m/day and with effective vertical permeability often much lower, typically 0.005 m/day, because of occasional relatively impermeable layers within the complex sequence. In lower layers of the alluvium, and in the underlying volcanics, transmissivity and permeability are higher.

The watertable generally slopes eastward, like the ground surface, but less steeply so that depth to watertable decreases from around 20 m along the plain's western edge to around 3 m over large areas in the east: piezometric level also tends to vary with depth, since there are appreciable vertical hydraulic gradients between strata. One borehole encountered artesian conditions, but this is not typical of much of the plain.

The general flow of groundwater is from west to east, mostly within the lower strata. The Filweha springs, with a flow of warm water measured as 1 850 l/s, tap the volcanic aquifer to the south and do not have much relevance to the groundwater balance of the plain: nor do the smaller springs in the north that are associated with Dofan volcano. The main sources of recharge for the aquifer under the plain are:

- subsurface flow from the volcanic bedrock in the west and south and from underlying bedrock aquifers;
- infiltration in the beds of the rivers and wadis that cross the plain from the west;
- infiltration over wide areas after floods;
- deep percolation from the existing irrigation areas at Awara Melka and Yalo.

Groundwater outflow is to the east, to and under the Awash river. It is estimated (see Annex H, p. H-9), that the aquifer receives recharge at an average rate of about 80 000 m^3/d (930 l/s): 80% of this occurs in the western third of the plain and nearly 90% of it is then lost to evapotranspiration in the eastern two-thirds, where the watertable is shallow. The wadis and rivers contribute only 15% of the recharge, while more than 70% comes from bedrock aquifers.

Chemically, the higher groundwater has fairly high levels of sodium and potassium relative to calcium and magnesium, and also high and variable fluoride levels. In places the water is hot, locally exceeding 50°C, which gives rise to the localised high soil temperatures noted in the soil maps (see Drawing A2). All these properties reflect the influence of vulcanism. In the deeper aquifer however, at depths down to 100 m, water quality is quite good: total dissolved solids range from 250 to 1 000 mg/l and fluoride is generally below 1 mg/l. For drinking water supply, wells should be situated near the Kesem and Kebena rivers to ensure acceptable fluoride levels. For irrigation, the deep aquifer's water is usable, with medium to high salinity hazard and low to medium sodium.

There is thus good potential for the use of groundwater as a source of domestic water, and yields of around 20 l/s can be expected from wells 100 m deep and 200 mm or 250 mm diameter. Use of groundwater for irrigation is also feasible, but the quantity would only be of the order of 20 hm^3 per year. This can of course be pumped in particular months, to complement run-of-river surface supplies, and the practicalities of this are discussed in Chapter 5 and in Annex L in connection with the 'Small Project' development scenario.

3.2.2 Surface Water

The only significant surface water source for large-scale irrigation is the Kesem river. The Kebena has a smaller catchment, lower dry-season flow, and no suitable site for a seasonal or overyear storage reservoir, so it is only of interest for medium-scale irrigation in conjunction with groundwater, as is envisaged for the 'Small Project' scenario described elsewhere in this report.

The hydrology and sediment transport of the Kesem have been studied in some detail, as is described in Annex I. There are now over 20 years of flow measurements at the Awara Melka gorge, whose catchment is very little different from that of the dam sites. After detailed study and revision of rating curves as part of this study, they indicate a mean annual flow volume of 500 hm^3 for this period, which includes a sequence of particularly dry years since the mid-1970s. For the regulated yield of a reservoir, the low flows and the shape of the recessions are more significant than the mean annual yield, because in wet years much of the water will spill anyway. Studies of the dam sites in the Kesem gorge (Annex J) show that it is feasible to build a dam there to form a reservoir of volume up to 500 hm^3.

The 22-year sequence of monthly flows, derived from the Awara Melka gauge records, was used to simulate the operation of the Kesem Reservoir under 32 different combinations of target draw-off and reservoir sedimentation (see Chapter I7, Annex I). These showed that, with a 500 hm^3 reservoir containing no sediment, the drawoff could reach about 450 hm^3 in most years. It was assumed that the relative monthly distribution of drawoff volumes would follow the pattern of the proposed KIP cropping systems, but the absolute volumes would be maximised. Exploitation to this relatively high level (90% of mean annual yield) would involve occasional water shortages, some restrictions in about one year in four, and a severe shortage about once a decade. The impact of shortages would be easy to minimise because they would be predictable several months in advance and crop plantings could be modified. Reducing the target drawoff to 350 hm^3/year would increase the reliability so much that a water shortage would be very rare - one in 20 years or less, but average agricultural production would be much reduced.

The reservoir would, however, not remain free of sediment for long. Estimation of future sedimentation rates is very difficult, but for this study a thorough investigation has been made, involving sampling and photograhic analysis at many points in the catchment, with access by helicopter. An intense suspended sediment sampling programme was carried out by a resident WRDA team at Awara Melka during the 1986 wet season, and data from other reservoirs such as Koka were also used. Because no one method is reliable, nine new estimates were made and compared with three from previous studies. They gave widely differing results (0.6 to 11 million tons per year), but the methods are not all of equal relevance. Taking the average of the four estimates most likely to be correct for the Kesem, this study arrives at a working estimate of 8.3 million tons, equivalent to about 5.7 hm^3 per year. The proportion made up by bed-load is relatively high, 30% to 40% according to the estimates that make specific forecasts for bed-load. These figures compare with the apparent estimate of the 1965 report (Ref. 1) of 5.4 million tons per year.

The effect of sedimentation on the useful regulated yield of the Kesem Reservoir has been estimated from the 32 cases for which its operation was simulated for 22 years. The simulation covered silting of up to 60% of the reservoir volume, which would reduce the achievable target regulated yield, at constant reliability level, from 450 hm^3 to 300 hm^3 per year. If the forecast siltation rate of 5.7 hm^3/yr is correct, this condition would be reached in about 50 years. With the overall cropping pattern and irrigation efficiency of the proposed KIP this means that the new reservoir could irrigate around 17 000 ha, while sedimentation would reduce this to about 13 000 ha in the first 50 years.

The simulation of reservoir operation shows that sequences of dry years are very significant: unless the reservoir was being worked excessively hard, the 1982 to 1985 dry sequence would have been more severe in its effects than the isolated very dry year 1972. The reservoir would therefore normally be used as an overyear rather than merely a seasonal storage, having a live storage approaching the mean annual flow.

3.3 Human Resources

The area's traditional inhabitants are mostly pastoralists. Members of the Afar group of tribes, they are transhumants who own and live off large quantities of livestock: camels, cattle, sheep and goats. The Kesem-Kebena plain serves about 12 000 of them as dry-season pasture: they graze their herds there during the dry months, making use of the vegetation resulting from seasonal flooding of the flat land. During the rainy season they take most of their livestock into the hilly country to the north, west and south, as described in Annex C (particularly Figure C1.1). But they maintain permanent settlements in the plain, where children and aged or sick people and animals stay even in the wet season. They are traditionally not much interested in agriculture, but under the pressure of recent difficult years some of them have begun practising irrigated agriculture using water from the Kesem and Kebena rivers. Some of these small schemes are linked to the existing state farm, while some are spontaneous. The Afar sell some of their animal produce and buy grain and other commodities.

In the reservoir area there live about 200 people, called Soudanis, who are pastoralists and who also practice irrigated and rainfed agriculture. Many of the men also take paid employment.

For the purposes of a large irrigation project, these present inhabitants do not represent the relevant human resources for the development. The human resources, at least in the short term, are the highlanders who would come down into the rift valley, as permanent workers with families or as migrant labour, in the way that they already come to the existing state farms on both sides of the Awash river.

Although they do not usually have a long tradition of irrigation behind them, they do come from a very well-established agricultural tradition and are well suited to the work. The population of the highlands is large and expanding fast, so there is in effect an adequately large source of workers for Middle Awash projects. But it is not easy for farms in the Middle Awash area to attract suitably motivated people, either as managers, technical staff or labourers. At present, on existing state farms in the region, the standard rate of pay for labourers is Birr 2.00 (about US$ 1) per day, and housing for migrant labourers is of low standard. Mobilisation of large numbers of labourers for KIP will require an improvement in one or both of these factors.

3.4 Existing Agriculture

In the Kesem-Kebena plain at the present time there are three forms of agricultural enterprise, all irrigated, which use only a fraction of the available land. The first is the Awara Melka State Farm, which has three units at Awara Melka, irrigated by run-of-river abstractions from the Kesem, and a fourth unit called Yalo some 15 km to the north-east, on the Kebena. The second is official "settlement schemes" for Afar, attached to the state farm units and drawing water from them. The third is a number of very small spontaneous schemes started by some of the Afar pastoralists, mainly in response to the recent sequence of hungry years.

The main part of the state farm, at Awara Melka itself, is an old scheme that has been extended over the decades. It was started in 1905 by a Frenchman whose name, Saboret, is now borne by the village that overlooks the farm and is almost synonymous with Awara Melka. For a while it was under private Italian ownership, and in the mid-1970s it was taken over by the government as a state farm.

The farm is described in Annex L (Section L2.4). It draws water from a rudimentary gated headworks structure and partly collapsed weir in the small gorge at Awara Melka, from which the flow passes through a short feeder canal to the scheme's north-west corner and thence eastward in a main canal along the Kesem's right bank levee. The scheme once covered 1 400 ha, but the effective area is now less than 800 ha because of salinisation and abandonment of some areas, and because of water shortages. The rubble bank that is built each year in the gorge cannot divert all the Kesem's low flow into the intake, and distribution is poor because there are few gates and no measuring structures. The main crops are fruit trees (270 ha) and tobacco (300 ha), the latter being planted continuously on the same land which implies a risk of disease buildup. There is no drainage system and, over most of the scheme, no watertable problem.

The Yalo unit of the same state farm is much younger, having been started in 1963 and having a present effective area of about 400 ha: over 600 ha was developed, but some has been abandoned because of salinity and flooding. The crop is cotton and the yield is low at about 1.5 t/ha. Pumping from the Awash was considered but never done, and the Kebena's flow dwindles to nothing, or very little, in most dry seasons.

The main official "settlement scheme" is at Doho, on the eastern end of the Awara Melka farm and receiving water from its main canal. It dates back to the drought of the early 1970s, when a relief settlement was set up at Doho, involving distribution of food rations. Self-help irrigation was introduced with the help of NOMADEP, the French aid project serving the Afar, based on family smallholdings. This was then taken under the control of the government's settlement and famine relief organisation (RRC) and converted into a collective farm. The area cultivated, once 356 ha, is now between 60 ha and 80 ha, and the

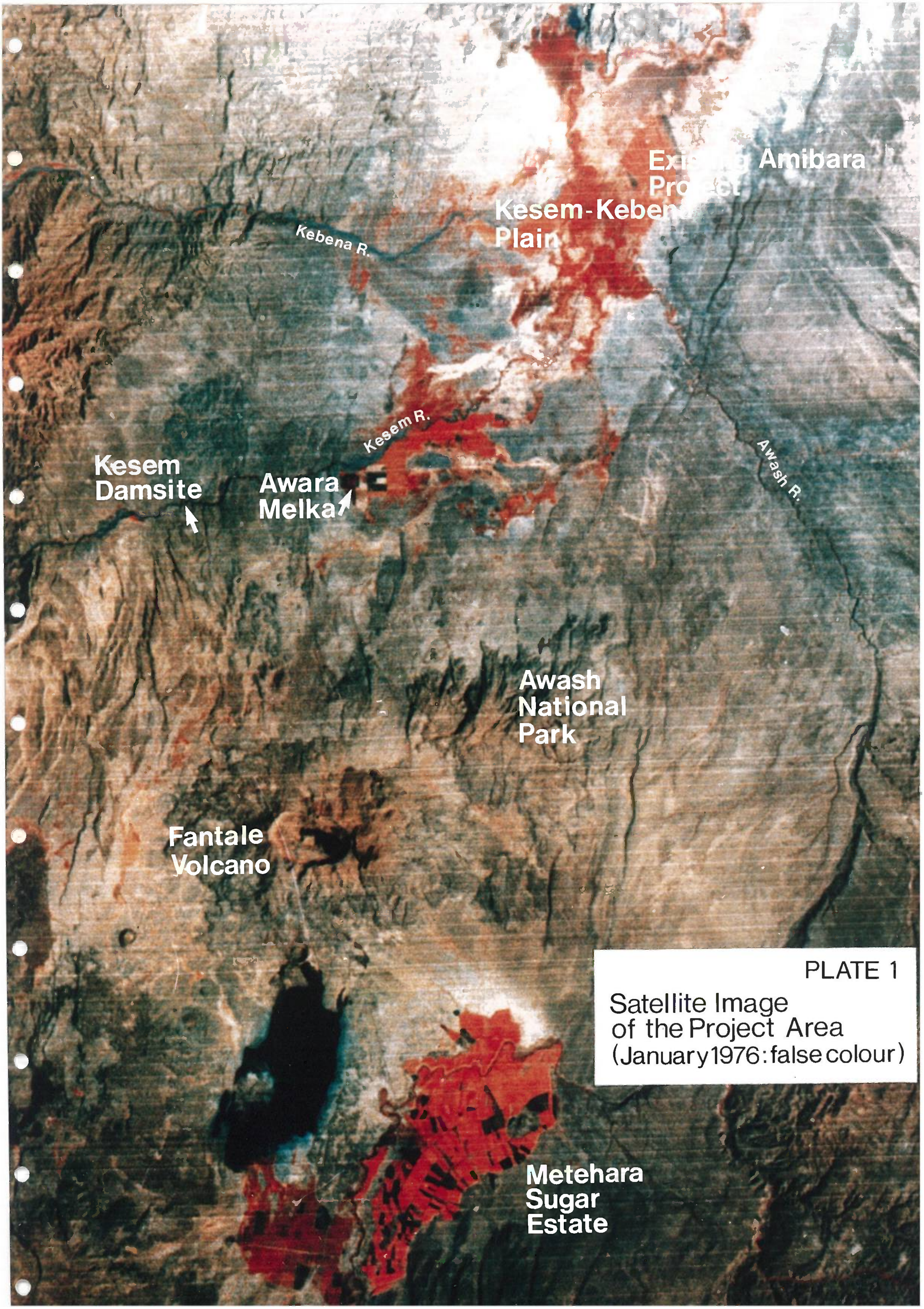


PLATE 1

Satellite Image of the Project Area (January 1976: false colour)

PLATE 2

Awara Melka from the West

Background	:	Southern block of Kesem-Kebena plain, with Awara Melka State Farm
Centre right	:	Saboret village on the ridge
Centre left	:	Awara Melka gorge, diversion weir site
Foreground	:	Kesem river cutting through heavily faulted escarpment foothills between dam and diversion weir sites

(Photo : December 1986)

collective farm's membership has declined from 300 families to about 170. This farm suffers from the fact that its irrigation water source is the tail of the Awara Melka State Farm's canal, which is naturally very variable and unreliable. Other problems are crop losses to wild animals, and the management of the collective farm. Morale of both staff and farmers is low. The main crops are cotton and maize.

At Yalo there was also a small NOMADEP-assisted attempt at irrigated agriculture by Afar, which in this case became a co-operative. It cultivates only 5 ha and only about ten people work on the fields, though in its other role as a supply organisation the co-operative has some 200 members. Despite its size, this farm is significant as the home of one legacy of the now-terminated NOMADEP project, namely a camel trained for ploughing, together with the necessary equipment and knowledge.

The third form of irrigated agriculture is the spontaneous schemes set up by the Afar. Annex C contains details of five such schemes on the plain, all near the places where the Kesem and Kebena emerge from the hills (and mostly just outside the proposed KIP scheme). They are very small, and are significant mainly for the precedent that they represent for irrigated farming by the Afar. Their hydraulic arrangements are extremely crude and vulnerable to floods, but with periodic repair the water usually reaches the fields and cropping is fairly successful. Most produce is food, especially maize, but some cash crops are grown. Cultivation is entirely by hand, except where the Soudanis bring in ox-ploughing.

These Soudanis, 200 of whom live in the proposed reservoir area in an isolated and ethnically distinct community, practise both rainfed and irrigated agriculture as well as keeping livestock. They are generally enterprising people, and have become involved to some extent in Afar irrigation down on the plain. In one place the Afar pay the Soudanis in cash to plough their land with oxen. In another (on the Kebena) some 16 Soudani households are farming on Afar land in co-operation with 7 Afar households, the Afars having invited the Soudanis to join the venture because they themselves lack most of the necessary skills. This is the only, but not the first, such scheme and appears successful after 2 years. The Soudanis are willing to join it because they are short of good irrigable land in their own area, where they irrigate 15 ha to 20 ha from the Kesem, growing maize and other food crops.

In summary, the existing agriculture of the area is characterised by deficient infrastructure and declining cropped areas, apart from a few recent tiny schemes. The total cropped area is around 1 300 ha, less than a tenth of the available land on the plain.

The state farm has recently become part of the Ethio-Bulgarian Joint Venture described in Annex F (Section F1.5). It proposes to increase the run-of-river area to 6 800 ha (which implies low cropping intensity) and to prepare for eventual development of the whole plain, but work has not yet started.

3.5 Infrastructure and Services

Almost all of the existing infrastructure and services on the Kesem-Kebena plain are associated with the Awara Melka State Farm. There is an all-weather road some 32 km long linking the farm's headquarters at Saboret with the Addis Ababa/Assab highway. Passing round the north and west sides of Fantale volcano, it is gravelled and usable in all seasons, although it occasionally suffers slightly from flows in small watercourses coming off the volcano. Beyond Saboret to the north there are no all-season tracks, so that Yalo farm tends to be cut off at times during the rainy season. There is a ford across the Kesem at Saboret and another one 15 km downstream, not far from the confluence with the Awash, but both are impassable for days at a time during or after floods. The downstream ford links with a track from Awash town, which becomes very muddy in the rains. There is also a third track to the highway, south-eastwards from Saboret via the Filweha springs, but it passes through the National Park and is seldom used. As a result of this study there are several rough tracks to and around the dam site, on both banks.

The main settlement on the plain is Saboret (or Awara Melka), which is on the slopes of the easternmost ridge of the rift valley escarpment and just south of the Kesem river. There is an old fort-like structure, some more recent offices, and a few hundred houses of traditional construction. Further out on the plain there are the state farm's staff houses, built of blockwork and with corrugated roofs. The only other modern-style buildings are the few sheds and offices of the settlement authorities at Doho. Yalo is a small settlement of traditional houses strung out along the right levee of the lower Kebena river. The Afar have mobile dwellings of sticks, grass and animal skins.

Public services are almost entirely absent from the area. There is no post office or telephone. Some of the state farm houses have a simple water supply but most inhabitants of Saboret take domestic water from the canals, while the Afar use rivers and a few dug wells. The state farm management, in the absence of other civil authorities or police, is the effective representative of the state.

Relative to other services, the provision of health care is slightly better than one might expect. Detailed studies for this report are described in Annex E. The state farm runs two clinics (at Saboret and Yalo), while the Ministry of Health runs two ex-NOMADEP clinics at the same places and a smaller clinic at Doho - these Ministry clinics are however not open every day. The main diseases treated are malaria, respiratory infections and dysentery. Maternal and child health is largely neglected, and the clinics are understaffed. The Afar have traditional midwives who provide not only services related to childbirth but also general medical help: some of them were trained by NOMADEP and their skills represent a base on which part of any future medical service to the Afar can be built.

3.6 The Environment

A brief account of the area's surroundings and environment is given in Annex D, and more detail is given for the Kesem-Kebena plain itself in Chapter A2 of Annex A.

The vegetation of the plain, which is mapped on Drawings A7 and A8 in Album 1, is mostly deciduous bushland. Towards the Awash river on the east there are some patches of thick bush and forest, but elsewhere there is generally a mixture of perennial and annual grasses. Westward of the plain are the hills and valleys of the lower escarpment, including the reservoir area, dominated by thorn trees and grass. The Awash National Park, a game reserve to the south of the plain, includes deciduous bushland and extensive grassy plains. Topographically the area is dominated by the obvious volcanoes Fantale, Dofan and Gurmile, shown on Drawing 1 in the Album and already mentioned in Section 3.1 above, and by the north-south faulting associated with the rift valley. In the area traversed by the Kesem river between the dam sites and the plain, a number of dramatic faults, some with the downthrow side on the west contrary to the overall trend, have made a series of sharp-edged tectonic ridges and trenches (horsts and grabens), which the river breaks through in a series of gorges (and which incidentally make east-west road building impracticable). Further north, in the catchments of the wadis that disgorge onto the plain, the landscape is dominated by more normal dendritic watercourse patterns between branching ridges. The western edge of the plain is interrupted at many places by north-south scarps and intrusive ridges.

These surrounding areas are important for the project not only as the source of storm runoff and sediment but also as the wet-season grazing lands of the Afar and Soudanis, who use some 1 500 km^2 to 2 000 km^2 for this purpose. To the south-west their grazing areas meet those of the more aggressive Kerayu tribe. All these pastoralists take their animals to the wet-season grazing lands as soon as new grass begins to grow there each year, leaving some people and a few animals on the plain. They tend to return after the rains in response to shortage of drinking water for livestock, rather than staying longer and exhausting the grazing completely.

The Awash National Park, some 20 years old, aims to conserve the fauna and flora of a sample of the semi-arid environment. It succeeds in doing this in its central and south-eastern parts, on both sides of the railway and highway that run from Awash town to Metahara. Parts of its nominal area, which extends north-west to Fantale volcano and north almost to Saboret, are however not under the park authorities' effective control. In the west, particularly, the Kerayu both live and graze their animals within the park's boundaries. In the north the Afar of the Kesem-Kebena plain tend to bring their animals into the park occasionally, but their dwellings remain outside it.

These incursions reduce the effective area of the National Park, but the pastoralists' livestock are using grazing that would otherwise mostly go to waste, as does much of the grass in the effective part of the park.

3.7 Institutions

Government departments already involved in the Kesem-Kebena plain are the Ministry of State Farm Development (MSFD) as operators (until very recently) of the state farm, the Ministry of Agriculture (MOA) as successors to RRC in taking responsibility for the settlement farms, and the Water Resources Development Authority (WRDA) which operates river gauges and organised this study. Existing large-scale irrigation schemes on the other side of the Awash bring together the same three departments (WRDA is part of the Water Resources Commission, which does not come under any ministry and reports directly to the Council of Ministers, so that for many practical purposes it is like a ministry). The three are independent of each other and each has its own local offices, MSFD and MOA operating these through intermediate regional offices. The situation is described in Annex F and illustrated diagrammatically there by Figure F1.1.

Until 1981 the water resources, agricultural and settlement functions were all exercised by a single integrated authority in the Awash valley, but then the present vertically separated structure was introduced. This present structure has advantages in that the different objectives of the various functions are clearly identifiable at all levels and choices on priorities and emphasis can be made at national level. It also has disadvantages at local level, particularly a frequent lack of communication, co-ordination and co-operation among the local offices of the three organisations. These disadvantages can be counteracted, for instance by the setting-up of a non-executive project-level co-ordinating committee, and on the Amibara scheme changes are in hand to improve co-ordination.

Towards the end of the information-gathering phase of this study, in late 1986, the Awara Melka State Farm was handed over formally by MSFD to the Ethio-Bulgarian Joint Venture. This undertaking, formed in 1984, is described in Section F1.5 of Annex F. Its objective is to develop the Kesem-Kebena plain for irrigated agriculture, starting with run-of-river schemes, based on the existing farms but larger. By the time of writing this report the institutional change had not yet had practical consequences in the field.

CHAPTER 4

OPTIONS AND CHOICES

4.1 General

This chapter discusses the options that have been analysed in the course of the study, describing the choices that have been made and the reasons behind them. It is left to Chapter 5 to describe the project.

In accordance with the Terms of Reference and with the objectives of the Ethiopian Government, the starting point for the formulation of the project was the maximisation of the use of the resources described in the previous chapter. The area covered by the soil survey was extended by almost 25% to take in all of the Kesem-Kebena plain, some 21 800 ha. The topographic mapping was also extended to cover the whole reservoir area and the whole plain. The soil survey and land suitability classification showed that only about 17 000 ha of the plain is suitable for irrigation, and some of this is out of command. The maximum practicable net irrigated area is about 14 000 ha, of which only about 10 000 ha is suitable for cash crops. The project was initially formulated to use all of this. The reservoir formed by the highest practicable Kesem dam was found able to provide more than enough regulated flow for 14 000 ha of irrigated land, at least at the beginning of its life before its effectiveness is reduced by sedimentation. This led to the formulation of the so-called 'Large Project', which is the development to which most of this report refers.

The maximisation of use of resources does not, however, necessarily lead to optimum development. Reductions in the size of the dam do not offer useful economies, but it was found worthwhile to investigate the merits of irrigating less than the maximum area of land on the Kesem-Kebena plain. This was done by formulating an alternative scenario involving the irrigation of only the better lands on the plain, about 9 000 ha. This scenario is referred to as the 'Medium Project', and is of course only one of any number of intermediate cases that could be formulated. To investigate the possibility of developing irrigation on the plain without a dam, a third scenario called the 'Small Project' was also roughly formulated, but this was outside the scope of the data collection work of this study so that the formulation is less precise than the other two. All three were considered in the economic analysis (Annex N).

When the Kesem Reservoir can provide more regulated flow than is needed by the Kesem Irrigation Project (KIP), it can be used to increase the area irrigated by gravity or pumping from the Awash river, into which the Kesem and also all KIP's drainage flows discharge. Although the details of such downstream irrigation are outside the scope of this study, it is considered in the evaluation of KIP.

The main components of KIP, arising from the approach outlined here, are:

- a dam, in a gorge some 10 km west of the plain, for seasonal and over-year storage of the flow of the Kesem;

- an irrigation system leading water from a simple diversion weir on the Kesem to all the usable land on the plain;

- a drainage system to remove excess rain and irrigation water, to control groundwater levels, and to enable saline and sodic soils to be leached;

- flood control works to protect the irrigated lands from the large rivers and also from the wadis that enter the plain from the foothills of the rift valley escarpment;

- provision for replacement of the Afar pastoralists' dry-season grazing that will be taken for other uses;

- a range and environmental management programme for the surrounding area;

- provision of services needed by the people involved in these activities, including health services, schools and civil administration;

- provision of the necessary infrastructure to support all these activities;

- a small hydropower station at the dam, if worthwhile, to exploit the energy potential there;

- appropriate institutional arrangements for the establishment and operation of the project.

The studies relating to these components are described in the appropriate annexes of this report. In this Main Report the discussion of options and choices for all components is brought together in this chapter, separate from the summaries of the resources in Chapter 3 and the proposals in Chapter 5.

4.2 Crops and Farming Systems

The choice of crops was guided by the Government's objective of increasing production of cash and industrial crops for export and for import substitution, and of ensuring at least local self-sufficiency in food production (Ref. 15). Selection was also of course conditioned by the soils of the plain, which are not good: they permit a fairly wide range of crops but have properties, particularly their high silt content, which will always restrict yields.

The objectives give rise to a fundamental distinction between two types of enterprise within the irrigation scheme: those devoted primarily to cash and industrial crops and those intended to provide for the pastoralists. The management aims of these two land uses are so different that they need to be physically distinct and also separately managed. In accordance with government policy the cash and industrial crop enterprises are assumed to be state farms, although in principle any type of large-scale farming operation could be used. The areas devoted to the needs of the pastoralists are called settlement areas, although the Afar are not expected to settle immediately, as discussed in the next section. Table 4.1 lists the crops covered by the detailed discussion in Chapter B2 in Annex B, distinguishing between the two farming systems.

TABLE 4.1

Summary of Crops Considered

Crops for state farms	Crops for settlement areas	Crops considered but found unsuitable
Citrus	Pasture	Mangoes
Tobacco	Cowpea	Bananas
Cotton	Groundnuts	Sugar
Wheat	Sesame	Rice
Maize	Wheat	Kenaf
Woodlots	Maize	Safflower
		Teff
		Haricot beans
		Tomatoes

Citrus is already being grown in the area and shows the highest returns, of the order of Birr 10 000 per hectare per year. Oranges and grapefruit are the best types. Market considerations limit the area to about 400 or 450 ha, and there are sufficient suitable soils for this: export is not a practicable proposition because of quality problems and heavy competition on the world market.

The next most attractive crop in terms of gross margin is Virginia tobacco, which can serve as a substitute for imports from Zimbabwe and Malawi. A small area is already being grown at Awara Melka, but not on the most suitable soils and with a continuous farming system which in the long run would be susceptible to disease problems. On the plain as a whole there are enough soils usable for tobacco to crop nearly 2 000 ha every year on a 2-year rotation, but they are fragmented in a way that makes it difficult to design a manageable irrigation layout for more than 3 000 ha net, i.e. 1 500 ha cropped each year. The market is also limited, and the estimated long-term maximum marketable from KIP is also about the production from 1 500 ha annually, Thus, for this crop, the soil and market constraints coincide and result in the selection of an area of a little over 3 000 ha, with a 2-year rotation and therefore about 1 500 ha in production every year. For good utilisation of curing barns and other facilities it is proposed that planting and harvesting should proceed continuously throughout the year: with the crop in the ground for 4 months out of the 24, only one-sixth of the tobacco land would be occupied by tobacco at any one time.

The project's main potential export crop is cotton. It is already grown extensively in the region, particularly on the other side of the Awash river, and the market for high-quality hand-picked cotton is effectively unlimited. It can be grown on the same land every year, and is reasonably tolerant to saline and sodic conditions. This enables it to be grown on all the area suitable for annuals that is not chosen for one of the priority crops, citrus or tobacco. Land preparation and cultivation can and should be extensively mechanised, because labour in the area is scarce and the cropping calendar leaves limited time for the preparation. Mechanical picking is possible and has been experimented with in the area, but it suffers from several disadvantages. It does not allow the picking to be spread in time, so that early and late-opening bolls are lost. It requires different varieties which are not available for the area, and different cropping techniques including the use of defoliants. Ginning costs tend to be higher due to the unclean seed cotton. Finally it results in lower quality than hand-picking, and it is the high quality of hand-picked Ethiopian cotton which the export market particularly values. It is therefore recommended that cotton should be picked by hand, even though this requires large numbers of labourers to be brought from other parts of the country.

The tobacco crop occupies the land for only 4 months in 24, and the cotton crop for 6 or 7 months out of 12, although there is also a period needed for land preparation outside these months. There is therefore scope for growing break crops within the cropping systems dominated by the two main crops. Figure 4.1 shows the crops chosen and the proposed cropping calendars, which have been chosen for the reasons set out in the next two paragraphs.

In the case of the cotton system, the time is limited but it is possible to grow wheat between November and February. Because of the time constraint this will be limited to half the area, so each field within the cotton-wheat system can grow two crops of cotton and one of wheat in every two years. Wheat is chosen because it can grow in the cool season, is valuable as a food crop, and can use the same soils as cotton.

In the areas devoted primarily to Virginia tobacco there is time for more than one break crop. The first choice is cotton, because of its high return, its value as an export crop, and its suitability to all the soils likely to be chosen for tobacco. It would be grown at its optimum time, that is mid-April to December, using all the land vacated by tobacco in the 12 months ending each April: with a 2-year rotation for the tobacco this means half the area every year. This leaves gaps of several months between tobacco and cotton crops, but the timing varies. Land vacated by tobacco between May and October inclusive has a winter gap of 7 to 11½ months which is suitable for growing wheat, and this crop is chosen for the same reasons as in the cotton-wheat system. Land vacated by tobacco between November and April inclusive would then have a cotton crop, as stated above, leaving a gap of 8½ to 12 months before the next tobacco crop. Although some of the cotton would be off the land by mid-October, some of it would only be harvested in December: in theory a part of the land could be planted to wheat, with the same quick turn-round as is proposed for the cotton-wheat system, but this would be very difficult to manage in an already complicated rotation, so the whole of this area is proposed for another crop. The one chosen is maize, which is a valuable food crop and can be grown between December and May, leaving enough time to prepare the land for the following tobacco crop.

The cropping intensity for each of these two cropping systems, which are proposed for state farms, is 150%. The cotton-wheat lands have two cotton and one wheat crop per 2 years, and the tobacco system lands have either a tobacco-wheat-cotton or a tobacco-cotton-maize rotation, thus also three crops in 2 years. The existing irrigated state farms have not as yet practised multiple cropping on a large scale, but the Ministry of State Farm Development (MSFD) recognises that such farming will be necessary in the future and is ready to begin developing the appropriate management and agricultural skills. An intensity of 150% is considered to be near the limit for practicable application, and even this level will not be easy to achieve. The calendars on Figure 4.1 show that all lands would have a fallow period of 4 months or more in alternate years, which should be sufficient for maintenance of irrigation and drainage systems.

Table 4.2, taken from Annex B, summarises the estimated financial crop gross margins of these state farm crops. The state farm areas will inevitably, because of the fragmentation of soils, include a proportion of land that is not suitable for any of these crops: mapping unit 4 in the KIP general suitability classification. Where they occur in large areas, such soils will not be devoted to state farms at all, but to settlement areas. The small areas surrounded by better soils cannot be used in that way. Such patches of land would be bordered by canals and drains anyway, even if unused, so in accordance with the objective of maximum use of land resources it is proposed to plant woodlots on them. These would normally be irrigated, but because the trees would be fairly tolerant of

TABLE 4.2

Summary of Gross Margins for State Farms
(Ethiopian Birr at 1986 financial prices)

Crop	Situation	Gross margin per hectare	
		Initial	Final
Tobacco	better soils	2 870	4 630
	poorer soils	2 000	3 350
Cotton	cotton/wheat system	1 200	2 220
	tobacco system	1 160	2 230
Wheat	both systems	260	710
Maize	tobacco system	140	580
Oranges	horticulture	-1 170	9 720 to 15 640
Grapefruit	horticulture	-910	8 620 to 12 580

TABLE 4.3

Summary of Gross Margins for Settlement Areas
(Ethiopian Birr at 1986 financial prices)

Crop	Gross margin per hectare		Gross margin per labour day	
	Initial	Final	Initial	Final
Wheat	-38	660	-0.2	16.5
Maize	-170	340	-0.8	5.3
Groundnuts	560	1 680	2.6	22.4
Cowpeas	660	920	10.9	14.0
Sesame	190	810	1.6	14.0

water shortage, and of relatively low value, their irrigation can be stopped during times of peak requirements or in seasons of water shortage. Their inclusion in the scheme therefore increases the scope for flexibility in management. The fuelwood they produce will play an important role in preserving the environment in the surrounding areas, by satisfying the demand for fuel for domestic cooking and also, potentially, for tobacco curing barns. Several tree species have been identified, including some, like Acacia nilotica, which are already growing in the area.

Gross margins for the crops considered suitable for settlement areas are given in Table 4.3. For settlers and part-time pastoralists the return to labour will be of more interest than the return per unit of land, and crop choice will also be governed by tastes and habits and by the local market. Cowpea is popular because of its relatively low labour requirement, ability to grow in almost any season, and versatility as a food and fodder crop at a range of growth stages. Groundnuts are favoured in the diet and are presently considered too labour-intensive, but with higher yields this might be seen as worthwhile. Sesame is suitable for cultivation for its edible seed. Wheat would probably be grown on a part of the settlement arable area, but maize, though grown to a small extent by settlers now, is not attractive in terms either of return to land nor return to labour. The Afar should begin to use animal power for most land preparation and cultivation; there is already one camel trained for draft work, and oxen can be used in the usual way. This will require a small input of training and development work by outsiders. Some Afar elsewhere are already using tractors, but until the KIP Afar learn mechanical skills this is not recommended because of the resulting dependence.

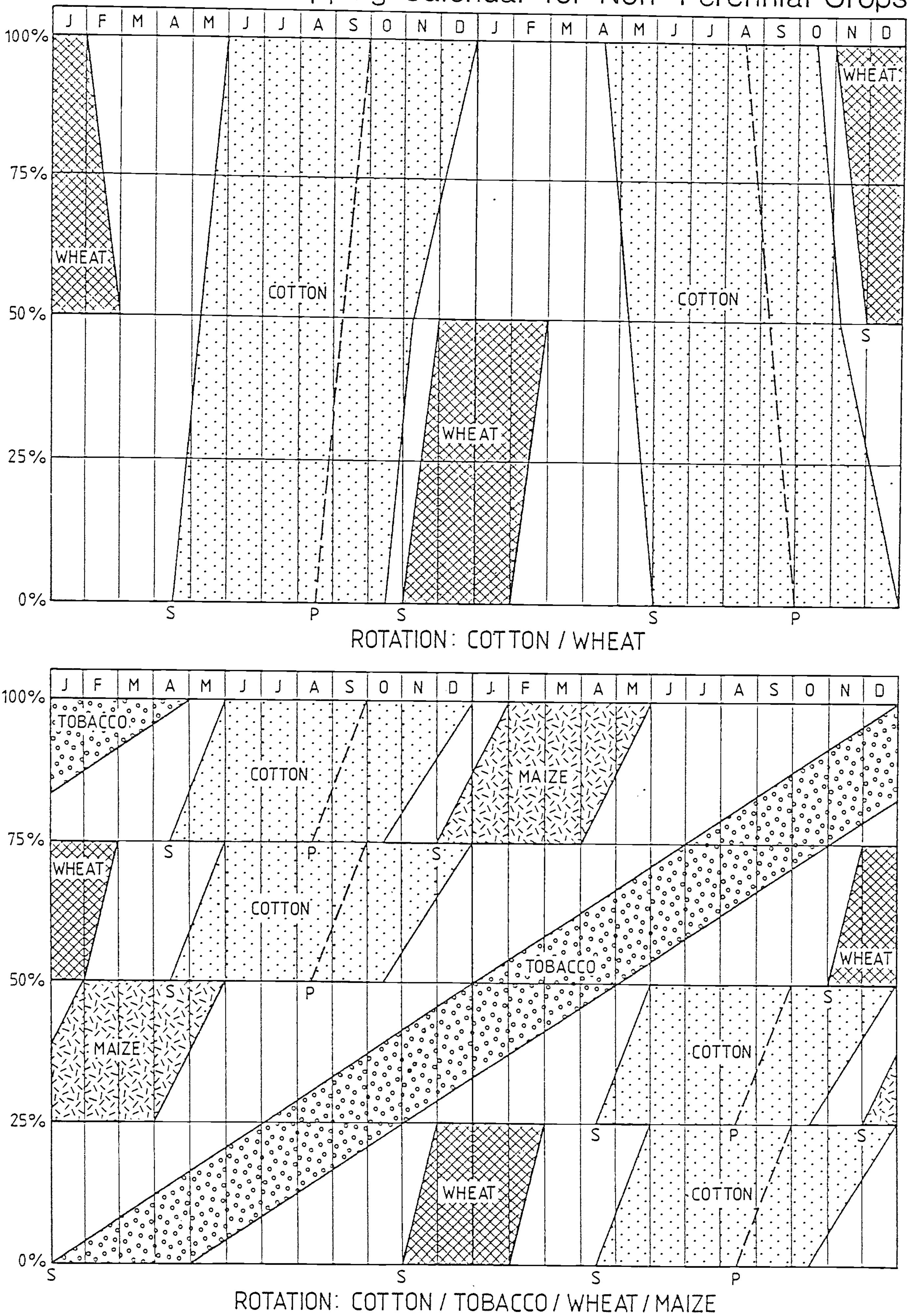
Among the crops not recommended, bananas and mangoes are being grown now on the Awara Melka State Farm. The area of bananas is however quite small, yields are not good, and the relevant ministry had already decided to centralise the Awash Valley's banana production elsewhere. It is however possible that recent changes in development plans for the Lower Awash will cause a reversal of this decision, in which case a small area of bananas would be included in KIP. Mangoes on the other hand may well have some long-term potential in the KIP area, when sufficient research has been done and markets identified.

Sugar is grown not far to the south on the Ethiopian Sugar Corporation's Metehara estate. Agronomically, sugar could be grown on KIP, but the distance to the Metehara factory (35 km and more) is too high for processing there, while the area of really suitable soils at KIP, and the likely yields, do not justify a new estate and factory. The world market price is relatively low, and at the national level a further development at Finchaa, under more suitable conditions, is planned.

Rice could grow well at KIP, and could use considerable areas of low-lying land with heavy soils that are not suitable for other annuals. It is excluded from consideration for this project because of the lack of research information on rice culture in the Middle Awash region, and the lack of a large internal market because of dietary habits. The areas it would use can also be used for pasture. Kenaf could, in principle, be grown as a substitute for imported jute but it is not included because of the lack of experience of its production and processing. Teff, the staple food of highland Ethiopians who grow it as a rainfed crop at higher altitudes, cannot be recommended unless or until a variety is found or developed which can do well at KIP's altitude and under irrigation. Haricot beans and tomatoes both show some promise, but research and variety trials are needed before they can be recommended for large-scale production: the beans can be exported but the tomatoes might face market limitations. All these crops

Figure 4.1

Cropping Calendar for Non-Perennial Crops



NOTE: S - Sow
P - First pick of cotton

might be introduced into the project later, when and if the relevant research and development are successful, but their inclusion at the start would be risky and would complicate the farming systems, which already represent a considerable increase in complexity compared with existing experience on both state farms and settlement schemes. Safflower is, however, never likely to be favoured.

For irrigated pastures (whose place in the project is explained in the next section), several fodder species could be used, but the choice is limited to some extent by the fact that the irrigated fodder would be grazed rather than cut. It is recommended that Cenchrus ciliaris should be used, possibly with Chloris guyana (Rhodes grass) as well, while the present research should continue and field trials should be made of other species. Trees should be left standing at intervals in the irrigated grazing areas, to provide shade and fuelwood, and more should be planted to replace those that die.

4.3 The Pastoralists and the Environment

The two hundred Soudanis who live in the potential reservoir area are both pastoralists and farmers, with some experience of rainfed and irrigated cropping and an enterprising approach to the future. They will need to be provided with land to replace what they lose to the reservoir, but in view of their traditions and their small number this is no problem either for the project or for them. The Afar on the other hand are about 12 000 in number and are traditionally pastoralists, transhumants, and little interested in manual work or agriculture. Many of them are not well disposed towards any change in their lifestyle, but others, a significant number, have already begun to practise irrigated agriculture on a small scale. In accordance with government policy the project is to provide compensation for any grazing land which is removed from their use, and to encourage them gradually to settle and become less dependent on livestock alone.

This situation has arisen on several other irrigation schemes in the region in the past. It is natural that the very tracts of land favoured for such schemes tend also to be the seasonally flooded lands that the Afar use for dry-season grazing, which is a vital part of their livestock system. Starting at Tendaho in 1961, a succession of irrigation schemes has taken over such land, as is described in Chapter C2 of Annex C. In that first case no provision was made for the Afar and, particularly in dry years since 1968, they have suffered losses as a consequence. This experience made the Afar suspicious of irrigation developments, and subsequent experience has not entirely allayed their worries. At Amibara a special settlement scheme was started for them, but this has not been a success as a settlement initiative: significant production of cotton has been achieved in some years but the farming has mainly been done by the settlement authorities, not the Afar. The further development of the Amibara system has been accompanied by some conflict and by alienation of the Afar from the scheme intended to help them. In the 1980s the idea of settling the Afar in one step has been replaced by a policy of replacing the dry-season grazing that they lose but also letting them continue to use the surrounding countryside for wet-season grazing in a continuation of their transhumant pattern of life. This change of policy is currently culminating in the Third Livestock Project's so-called '3 000 hectare project' for 9 000 displaced Afar in the Amibara area. Cattle are to be grazed on the irrigated pasture (camels and goats being discouraged), and the scheme's management proposals stress the importance of full and voluntary cooperation by the Afar, and their gradual taking over responsibility for the scheme.

The 12 000 Afar in the KIP area are well aware of this history and are still suspicious of large-scale irrigation development. However, they have the experience of some very dry years in the recent past which have convinced many of them that they cannot continue indefinitely to rely entirely on livestock, and they have the example of the small initiatives which a few of them have undertaken in irrigated agriculture, supported by an outside organisation (NOMADEP) in the 1970s and to some extent by the existing small state farm in the area. They have in one place called on the Soudanis to help and advise them, and they are also receiving significant assistance from a few individuals at the agricultural research station.

For the Kesem project, therefore, it is proposed to follow a similar policy to that of the 3 000-hectare scheme, and also to precede the main development with an advance programme. This would aim to build on the Afar's existing insights and experience of irrigated agriculture, limited though they are, and prepare the Afar to take advantage of what KIP will eventually offer them. The programme will also enable the project authorities to build up a working relationship with the Afar and to overcome their suspicions, which will take time. The scale should be small and the pace should be sensitively matched to the Afars' own changing attitudes. Training should be included, and visits to other Afar projects will be useful. The programme must include the use of animal traction for cultivation.

When and if the large-scale irrigation project is eventually developed, provision must be made for an adequate area of irrigated pasture for the Afar. If the whole of the available area on the Kesem-Kebena plain is developed for the irrigation scheme, it is estimated that about one-third of a hectare per head of the Afar population (as on the 3 000-hectare scheme at Amibara) will be suitable, or 4 000 ha replacing 17 000 ha of existing dry-season grazing. If only part of the plain is developed, so that some of the present dry-season area remains usable by the Afar, the area of irrigated pasture needed will be considerably less. The order of development must provide adequate grazing during the construction period. The pasture areas should be located on the periphery of the project area on the north, west and south sides, so that the Afar can continue to have direct access from and to the surrounding wet-season grazing areas and so that they can live outside the scheme boundaries but near the pastures. The areas can consist mainly of soils that are not suitable for state farm crops, but there needs to be a proportion of better soils so that as the Afar gradually take up the growing of food and cash crops they can develop these on parts of the allocated areas. Not more than 20% of the area is expected to be used in this way in the long run, and it does not matter if the patches of better soils are fragmented, since the farming will be fragmented anyway. This means that there is little difficulty in finding land to allocate to the Afar which is not much use for state farms.

The project will also need to concern itself with the wider area used by the Afar for grazing, which, though not precisely bounded, is estimated to extend to roughly 2 000 km^2. A range and environment management programme will be needed, to improve grass species, resist tendencies to deforestation, and protect the environment from other pressures of increasing population. Simple measures to improve the retention of rainwater should be used, in conjunction with the efforts to improve pasture.

4.4 Irrigation, Drainage and Flood Protection

4.4.1 Irrigation System

The main factors governing the choices of irrigation method, layout and design are:

- the fact that water is relatively plentiful in comparison with land;
- the proposed crops;
- the nature and distribution of the soils;
- the land slopes and microtopography;
- the institutional arrangements;
- the need to limit the number of places where irrigation water is conveyed across the eastward-flowing rivers.

The detailed discussion of the choices proposed for this project, and the reasoning behind them, is in Annex L. After consideration of sprinkler, trickle, sub-irrigation and five types of surface irrigation, it is proposed that the annual crops should be irrigated by sloping furrows. Level furrows or basins would require too much land levelling, sprinkler or trickle would require pumping which would increase cost and complexity, and soils are not suitable for corrugations. Border strips could be used, but furrows are well-proven in the area and familiar to managers. For citrus it is recommended that furrows should be used, the trees being grown on beds between widely-spaced furrows. This will require less labour than the present small-basin method, and will also improve access and help to avoid diseases associated with standing water in contact with tree-trunks. For irrigated pasture, to keep capital costs low, a simple controlled flooding system is proposed: water would be released from small contour canals and would flow down the slope, any tendency to concentrate canals being countered by short, level spreader furrows. These will be periodically renewed or added to in the light of the local behaviour of water flows.

The operation method of an irrigation scheme needs to be well matched to the design of the physical works, although the latter should wherever possible be adaptable to different operating methods if future changes make them desirable. For this project it is proposed that the operation should be as simple as is consistent with good efficiency. It is proposed to base the layout and the operation on a basic land unit of standard size 22.5 ha net (25 ha gross), which will make the rotation of irrigation water supplies relatively simple. The larger canals will flow continuously and the smaller ones be rotated, so as to avoid operating canals with very low discharges relative to their design condition.

Most cross-regulators will be long weirs, which operate automatically without any complex control gear and thus need no adjustment and little maintenance. Only the larger cross-regulators will have gates and need to be monitored and adjusted. Where a smaller canal draws water off a larger one, the head regulator of the smaller one will be a movable weir, which provides for adjustment and measurement of flow according to need. This is considered preferable to the use of constant-head orifice gates. Head regulators of field canals are simple gated structures, since they only need to pass about 100 l/s.

The use of lined canals has been carefully considered, but soil permeabilities are relatively low and water loss by seepage is not a serious problem because drains are provided anyway and water will often need to be passed to the Awash river for downstream schemes, so that drainage water will be re-used. In some places, canals will need lining over short distances through sandy patches, and this can best be done with clay imported from drain excavations in suitable soils. Concrete is used for the first stretch of the North Primary Canal, where it passes out of the Awara Melka gorge and on to the plain.

The layout of the irrigation system has involved some compromises, as discussed in Chapter L3 of Annex L and shown on the drawings. The fragmentation of the soils results in a very patchy map of suitable land. The horticulture area is small for market reasons, and the first effective priority was to find about 3 000 ha suitable for tobacco, so as to harvest about 1 500 ha of tobacco each year in a 2-year rotation with other crops, this being the estimated market limit. This proved just possible, with three tobacco-system farms of which two draw water from the main canal system in only one place each. The third tobacco farm will have to draw water in two places. The remainder of the land suitable for annual crops was nearly all allocated to cotton and its break crop wheat, while large blocks of land of suitability mapping unit 4 (good only for pasture or woodlots) were allocated to the so-called settlement areas for the Afar and Soudanis: the extent of such areas matches well with the estimates of areas needed for irrigated pastures and small gardens. Because of the fragmentation of soils, there are small patches of mapping unit 4 land enclosed within the state farm areas, and small patches of better land enclosed within the settlement areas. As mentioned above, the former are assumed to be used for irrigated woodlots, since they will be adjacent to canals and drains anyway and can thus be served at minimal cost; fuelwood will be needed for domestic and crop processing purposes, although partially replaceable by hydro-electric energy from the dam, and a plentiful supply will be a valuable factor in combatting deforestation of the surrounding country by the increased population. The latter areas are expected to be used for the gradual adoption of irrigated agriculture by the Afar, for whose purposes the fragmentation of the soils will not be as serious a disadvantage as it would be for the state farms' large-scale operation.

One objective of the layout design was to permit handover of water to each user organisation, such as a state farm or one of three settlement offices, at few places, preferably only one. This is valuable for the establishment of clear-cut divisions of responsibility, and for measurement of water and collection of payments. Another objective was to place the settlement areas on the periphery of the scheme along the north, west and south sides, so that the Afar can move to and from the surrounding hills without crossing the state farms; this proved quite easy to achieve.

It is debatable whether it is worthwhile to take a canal across the Wadi T'unfeta in the north of the plain: the soils north of it are generally poor and the north-eastern corner is also subject to flooding and cannot economically be provided with deep drainage. In the area-maximising scenario, the Large Project, this northern area of 1 460 ha is used entirely as a settlement area, and is good for this purpose because it is on the periphery and has a natural border to the state farm area in the form of the wadi itself and a floodway. When the objective is selective land use, as in the Medium Project, it is considered better to terminate the canal system on the south side of the T'unfeta and save the cost of the inverted siphon. This still leaves the land on the north side for the Afar, but without formal irrigation. The primary canal must however terminate in an escape structure, and it would be easy and advantageous to discharge some water, except at times of water shortage, into the wadi to be used by local informal canals on its north bank.

To the south of the irrigation area is the Filweha Spring, which produces a remarkably steady flow. The possibility of using this for irrigation was considered but rejected. The water, though hot, is probably just usable for irrigation from a chemical point of view, provided care were taken. But the location of the spring is too low for gravity irrigation of any but a very small area. Since KIP will normally be passing water into the Awash river anyway, it is considered better to leave the Filweha Spring water to flow into the Awash and be diluted by normal surface water, as is already happening, after which it can be used for downstream irrigation. This will avoid any possibility of problems caused by any long-term changes in the chemical composition of the spring water.

This report assumes seven state farms for the Large Project. In practice these could be separate units of one or two state farms, with negligible difference in staffing costs.

4.4.2 Drainage and Reclamation

A considerable proportion of the usable soil on the Kesem-Kebena plain is saline or sodic and needs reclamation before it can produce good crops. An even larger proportion needs artificial drainage. Though mostly dominated by silt rather than clay particles, these soils have fairly low permeabilities, indeed their permeability may be lower than that of many clay soils because of their lack of structure.The watertable is now fairly deep in the western parts of the plain, but shallower than 10 m in the eastern half, and as shallow as 3 to 5 m in many places. Vertical drainage using pumped wells has been considered, but in the absence of a thick and permeable aquifer it offers no advantages, and conventional horizontal drainage by perforated pipe drains at around 2 m depth is proposed. Buried pipe collector drains are preferred over open collectors, which would lose considerable areas of land and increase maintenance problems. The necessary spacing of field drain pipes has been estimated by an economic optimisation procedure balancing the initial cost of closely-spaced drains against the slight loss of crop yield associated with drainage that is less than complete over all the area all the time. The result of this calculation is that the returns to cotton justify quite closely-spaced drains, and large areas with drains at 20 m spacing are proposed. Some soils, because of relatively impermeable layers above drain depth but too deep to be broken up by ripping, will benefit by treatment to penetrate these layers: it is proposed that the project should, after the construction is over, retain one or two trench-type drain-laying machines and use them, without drain pipes, to excavate and backfill trenches almost down to field drain depth and transversely at right angles to the field drains. This can be done during fallow periods at any time, in fields that show signs of inadequate drainage, but for some areas it is proposed as part of the initial construction process.

The extent of piped drainage works has been determined from the soil investigations by means of a specially developed drainability classification (described in Annex A) and a matching set of drainage treatments (Annex L). The treatment of each 25-ha unit of land was decided separately on the basis of its drainability class, proposed crop, and location. This last consideration is important in some low-lying areas, where deep drainage might appear worthwhile but in fact is not because it would make a large main drain considerably deeper for the sake of a small land area. If necessary the crop was changed on small areas.

Water drained from the eastern parts of the plain will need to be pumped up into the Awash or its tributaries at times of high water levels in the Awash, which persist for days or weeks in most years. The pumping head is minimised by avoiding deep drainage in some low areas, as just mentioned, and the volume pumped is minimised by separating the whole drainage network into gravity-drained networks for the higher western areas and pumped networks for the lower eastern ones. The higher areas can drain into the Kesem, Kebena or T'unfeta except briefly during flash floods. The lower areas will not require pumping all the time, since flap-gated bypasses will allow the water to drain by gravity whenever the Awash is low enough. The recurrent costs of pumping are therefore not very great, but the pumpstations add both to the initial cost and the operational complexity of the project. In the Medium Project case, therefore, low-lying areas are excluded from the scheme so that no pumped drainage is needed. The same measure reduces flood protection costs, and it happens that the areas affected are generally not those with the best soils.

Most areas will either need drainage within the first 5 years, because of low permeabilities or shallow watertables now, or they will never need deep drainage at all because of adequate permeabilities and a high or sloping location. Permeability in the top 3 m is much more important than watertable rise in determining drainage requirements, in contrast in the Amibara case. The scope for improving economic indicators by delaying the installation of field drains until watertables rise is therefore very limited. Nor is there significant scope for improving permeability by agricultural management. Only in the existing state farm at Awara Melka is it proposed to provide for possible future drain installation. That area has good natural drainage: the Frenchman Saboret must have been either clever or lucky in his selection of a place for his farm.

Once deep drainage and controlled irrigation have been provided for, the reclamation of the saline and sodic lands will proceed in the usual way, mainly by leaching. Some soils will also require the application of gypsum.

4.4.3 Flood Protection

The irrigable area is threatened by flooding in three ways: from the Awash for days or weeks at a time, from the Kesem and Kebena rivers for hours or a day or two, and from the wadis on the west for even briefer periods. Protection from all three needs to be built into the project.

Along the eastern edge of the Large Project, flood banks are proposed, to protect against floods to about the 1-in-20 year probability level. They are set quite far back from the river and leave most of the floodplain for the passage of floods. The floodplain is already slightly restricted on the other bank by the Amibara Project's flood bank, but it is heavily forested and has very low hydraulic conveyance anyway. For the Kesem and the Kebena, and also for the T'unfeta where relevant, flood banks are provided, but they are generally not very high except in the east where the rivers back up from the Awash. They also are designed for the 20-year floods. The Kesem will be regulated by the reservoir and will not have large flood peaks except in very rare floods whose volume is large compared with that of the reservoir.

Protection against the wadis that now discharge on to the plain from the hills to the west presented considerable problems for the design of the project. The chosen solution is to provide crossings over the northbound primary canal for the two largest wadis, and to divert most of the flow of the smaller wadis into those two or the rivers, well upslope of the canal. Special measures are proposed (Chapter L9 of Annex L) to deal with sediment in the wadis, and the slopes of the diversion channels need to be carefully chosen. Wadi A is to be led across a small part of the irrigation scheme and into the Kesem river, but Wadi F is larger and less conveniently located. After comparative studies of various options, it is proposed to let it cross the main canal and then spread out into a large area of useless soils, as it already does. The floodwater flowing on down the slope will then be collected by a drain and led into the Kesem by gravity, except for large floods which will be temporarily stored and discharged into the Kesem later through a flap gate.

4.5 Dam and Hydropower

4.5.1 Dam Location, Type and Design

Section 3.2.2 above has mentioned the presence of dam sites in the Kesem gorge. These are located about 10 km upstream of Awara Melka and the diversion weir site, where the Kesem river breaks eastwards through a sequence of predominantly volcanic rocks that are extensively faulted north-south as part of the rift valley escarpment. The reservoir basin is shown on Drawing I1 in Album 1 and the topography and geology of the gorge are described in Annex G and illustrated in Album 2. Dams and hydropower are covered by Annex J.

There are two potential dam sites in the gorge, about 900 m apart and both capable of creating the same reservoir, which is in a wide basin immediately west of the gorge. The strata through which the gorge has been cut dip upstream (west) at less than 10° and there is a major transverse fault with a 50 to 60 m downthrow on the east side, just east of the upstream site, which has the result that the same sequence of strata appears at more or less the same levels in each of the two sites.

The sequence consists of thick ignimbrite layers at the top and bottom, separated by two thinner (15 to 20 m thick) ignimbrite layers and a varying number of layers of basalt (see Drawing G4 in Album 2). The tops of some of these volcanic layers have been extensively weathered before being covered by the next layer, resulting in tuffs (red bole) and there also tends to be a layer of pumice tuff above a layer of red bole and at the bottom of a superimposed layer of ignimbrite. The above-mentioned large fault just downstream of the upstream site, which can be seen on Drawing G4, is matched by another large north-south fault just downstream of the downstream site. In both cases there is some increase of jointing and shattering near the large fault, but it is more severe at the downstream site. This downstream site is the one that was investigated for the SOGREAH report of 1965 (see Section 2.2 above).

Geologically the two sites are similar, though the rock at the downstream site, as well as having more of the fault-related fracturing, is generally more jointed. Its red bole layers are slightly thicker. It is also much nearer to an active fault so that seismic problems would be more severe. In all, the geological differences between the sites are differences of degree, but they all favour the upstream site.

Topography also shows little difference between the two sites. Comparative cost studies for similar embankment dams at the two sites show the upstream site marginally cheaper for a low dam and equal for a high dam. The upstream site is slightly wider, but the bed level is also a few metres higher so dam volumes are very similar for any particular crest level. Conditions for location of appurtenant works, particularly a separate spillway, are also similar at the two sites.

Leakage through abutments would need to be restricted by a grout curtain at either site, but the downstream site, because of the topography and the jointing on the right abutment particularly, is slightly more likely to show unexpected leakage. Leakage that does not endanger the structure can be tolerated anyway, because the drawoff for irrigation is 10 km downstream.

With the geology of the two sites so similar, the choice of site is in effect separate from the choice of dam type. Although the differences are not drastic, the upstream site is preferred on grounds of geology, seismicity, topography and leakage. It is therefore recommended for the dam.

The two dam types most likely to be best are:

- rockfill embankment with clay core;

- hollow mass concrete gravity dam.

Others were considered, including the arch type, but rejected. Some of the rock layers, especially the red bole, are not strong enough for an arch dam, and large-scale replacement of these layers with concrete would not be economic.

Suitable materials are available locally for both rockfill and hollow mass concrete dams. The rockfil dam is definitely feasible, but the design of a concrete dam would probably encounter difficulties because of a fracture zone running along the gorge. Relative cost estimates show the rockfill type cheaper by a small margin (10 to 15%), so it is recommended. The rockfill embankment is accordingly assumed for estimation and project evaluation and is shown in the drawings in Album 2, while both are discussed and illustrated in Annex N. The choice of type should be reviewed, after further site investigation, at final design stage.

The design of ancillary works, particularly the spillway, is bound up with the choice of dam type because a concrete dam can have an integral spillway in the dam wall while an embankment must have a separate spillway, and similarly with diversion, drawoff, bottom outlet and hydropower works. These have therefore been included in the cost comparison. The use of one or more emergency spillways on saddles has been considered and rejected because of ground conditions, the effects on side valleys, and the economies of scale. With a rockfill dam the preference is for a single ungated overflow weir spillway discharging into the gorge via a concrete chute and flip bucket. The small hydropower station, with bypass for irrigation releases, can conveniently and economically be accommodated in part of the foundations of the flip bucket. The bottom outlet can be constructed in the diversion tunnel after the diversion phase is over.

For any useful reservoir level, a saddle dam will be needed in a valley 2.5 km north of the main dam. By locating it slightly away from the watershed it has been found possible to keep its length down to about 350 m, and a semi-homogeneous embankment about 25 m high is appropriate.

For reservoir storage levels in the region of 930 m above sea level, a number of low bunds would be needed to prevent spillage of water over saddles at levels of 936 to 940 m. They would however be very low (up to 5 m) and only wetted briefly during major floods. A main dam crest level of 941 m would require six such bunds totalling 3 km in length but making up only 3% of dam costs. Higher levels would begin to involve bunds to a much greater extent, and they would be higher and more critical, while lower levels would lose active storage at the rate of over 30 hm^3 per metre for relatively small cost savings, so the proposed crest level is 941 m above sea level. With due allowance for freeboard (taking into account spillway optimisation), this corresponds to a regulated storage level of 930 m above sea level and a total storage volume of 500 hm^3. This makes the main dam about 90 m high.

Another choice involved in the dam design at this stage is the type and height of cofferdam and size of diversion. Economic optimisation shows a preference for a high cofferdam and small tunnel and the choice also involves practical considerations like access, timing, and inundation of a borrow area. The proposed cofferdam is about 30 m high and is subsequently to be incorporated into the upstream shell of the rockfill dam; the proposed diversion tunnel diameter is 5 m.

The possibility of a very small dam in the gorge, of the order of 25 m high, has been very briefly considered. It would fill up with sediment in five or ten years unless a way were found to flush nearly all the river's sediment load through the dam, retaining water only after the end of the flood season. In view of the reservoir shape and the relatively high proportion of coarse bed load, this is not considered practicable, and such a dam is not recommended.

4.5.2 Energy and Hydropower

The project and its population will need energy for:

- domestic cooking and water-heating;
- pumping for domestic water supply;
- lighting;
- workshops (and light industry, if any);
- agricultural processing, mainly tobacco curing;
- pumping of drainage water when river levels are high (a few weeks per year).

Of these, the tobacco barns and the domestic purposes can use either electric energy or fuelwood, while the others need electricity.

The proposed dam and reservoir would be operated primarily for irrigation, there being nothing to be gained by supplying energy from Kesem into the national grid. This means that the reservoir would sometimes be drawn down very low so that the head would be too little for hydropower operation. The reliable or firm power potential is therefore effectively nil. At other times the site could produce fairly cheap electrical energy up to about 6 MW continuous (50 GWh/year), seldom falling below 2 MW continuous (18 GWh/year). This matches quite well with the project's estimated demand of about 20 GWh/year, assuming all the above uses are supplied by electricity. It is therefore proposed that the project should include a 6 MW power station at the dam and that most of the considerable quantities of fuelwood produced by the state farms should be used elsewhere. In dry years when the reservoir level was low, energy would be bought in from the national grid via a transmission link that would be needed in the construction phase anyway, and some substitution by firewood would take place. A cost-benefit analysis (reported in Section J9.5 of Annex J) shows the inclusion of the hydropower component to be just economic (EIRR 11% at the present national economic energy value) and financially attractive. But it represents only 2% of the project and could be included or excluded later without affecting decisions on the project as a whole. Future national tariff policy may turn out to be the deciding factor. In any case the selling of power from KIP to the grid is not feasible, since KIP has no firm energy to offer and since the grid will always have plenty of cheap secondary energy from other and much bigger hydropower plants.

4.6 Services and Infrastructure

Because there are now no public services and very little infrastructure in the project area, the project package will have to include these. Without them it would not be possible to build, staff and operate a large irrigation project, so they are prerequisites or essential components rather than optional extras added for social reasons.

The components involved, all of which are treated as parts of the project at least for cost estimating purposes, include the following:

- roads;
- power supplies;
- housing;
- domestic water supply;
- offices and workshops;
- clinics and health services;
- schools and education;
- police and civil administration;
- recreational facilities.

There is already a reasonable all-weather road from the Addis Ababa/Assab highway to Awara Melka at the south-west corner of the scheme. The project would improve and maintain it but not replace it. It is recommended that the track from Awash town to the south-east corner should not be developed as an access road, and the track through the National Park via Filweha Springs should be closed at its northern end and not used at all for the project: the purpose of these measures is to avoid damage to the ecological balance of the National Park. At the north of the scheme a connecting road should be built to link the project with the extended Bolhamo irrigation scheme, north of Dofan mountain, which is expected to be in operation by that time and to have a bridge over the Awash to the Amibara area. This will provide a second outlet on to the Assab highway and will facilitate contact with the Amibara system and the research station that it contains. With the access thus provided at the north end of the plain and at its south-west corner, the project needs a main spine road from which feeder roads can branch. The best route for this north-south road is along the western side of the irrigation scheme, uphill of the main canal. This location keeps it on well-drained and hard soils, gives the road designer freedom to choose a good alignment without constraints from numerous canals and drains, avoids having to cross these, and separates long-distance from local traffic. Major project roads will branch from this spine road and serve the irrigation areas and settlements, giving traffic access to the roads that are proposed alongside all canals and drains. These major roads, and the north-south spine road, will be raised to avoid wetness and also surfaced with selected gravel, which is plentiful near the western edge of the plain.

Electric power supplies will be needed during construction and can be provided from the national interconnected system by installing a 15 kV power line from the existing substation at Awash Town, which connects both to the existing 132 kV line and to the proposed 220 kV line. It is proposed to extend the 15 kV line to the dam site for power supply during construction, and also so that it can afterwards bring power in the other direction, from the Kesem hydropower plant to the rest of the project area. This plant will not be able to supply power to the national grid because of its small size and low reliability, but it can provide cheap local energy for domestic, pumping and crop processing within the project.

Because of the unwillingness of the Afar to undertake manual work in agriculture, and the size of the project's labour demand, large numbers of labourers as well as staff and managers will have to come from elsewhere. The project there-therefore needs to provide housing for large numbers of immigrants, generally from the highlands. The number of employed persons is estimated at slightly less than one per net irrigated hectare, and with dependants this can mean an immigrant population of up to 60 000 people. This compares with the present Afar population of about 12 000. The choices to be made in project planning concern what sort of housing will be provided for the various categories of immigrants, it being assumed that the Afar will continue to build and use their traditional mobile houses.

For senior and intermediate staff it is assumed that permanent houses will be built by the project of sand-cement blockwork with asbestos-cement or similar roofs, to the normal standard for government employees, i.e. Type C or Type D houses according to seniority. The more difficult choice is the type of housing for agricultural labourers, who are of course much more numerous, constituting 85% of the immigrant employees. It also has to be decided how many of them are to be permanent residents and have housing for their families. In recent years the state farms in the Middle Awash have experienced increasing difficulty in attracting enough labourers for the cotton harvest, which is seasonal work relying mainly on migrant ('casual') labourers. For KIP there is a slightly less seasonal demand for labour because of the break crops, but the cotton-wheat system still needs 1.2 labourers per ha in September, less than 0.2 in March, and about 0.7 on average. The patterns for all cropping systems have been analysed (Chapter F5 in Annex 5), and the proposal for purposes of analysis in this study is that the proportions of permanent and casual labour should be such that the permanent labourers are occupied for 90% of the time, the remaining 10%, or five weeks per year, being left for holidays and sickness. This assumption results in a pattern where casual labourers do about 10% of the work on the tobacco system and 22% on the cotton-wheat system, but make up 30% and 44% respectively of the September workforce. For the project as a whole they would represent 35% of the peak number. This proportion is important for estimating housing requirements because a permanent labourer, having his family with him, needs about four times as much housing space as a migrant casual labourer. The casual labourers would stay in the area, on average, 3 to 4 months. The proposed proportion of permanent labourers is higher than on existing monocrop state farms in the area but, as stated above, state farms are finding it difficult to attract enough labour and improved provision of housing for families is a factor in easing this problem.

The housing for agricultural labour is a major cost component for the whole project (15% to 30% depending on housing type), so it is important what standard of house is chosen. It could be the government standard Type G housing, which costs about Birr 23 000 (US$ 11 000) per labourer with family. This is more than the project can possibly afford. At the other extreme it could be a 'site-and-services' approach whereby the labourers were allocated space to build their own houses, perhaps being provided with some free materials. As a reasonable compromise, the assumption for analysis in this study is that a housing type, or a choice of options, would be developed so as to keep the average cost to Birr 6 000 per labourer with family, only a quarter of the Type G cost. The details would be worked out on site, using local materials and some degree of occupant participation, but this amount could cover a minimal structure of concrete floor, blockwork walls and metal or asbestos-cement roof, or alternatively a more extensive dwelling of cheaper materials. On a project of this size it will be worthwhile to set up an experimental programme to develop the most economic solution locally by trials and experimentation. It is assumed that the relatively small number of non-agricultural labourers and junior staff will have Type G housing.

The project package will of course include offices and workshops for the agricultural, engineering and social services involved, as well as the necessary vehicles and equipment.

Water supply for the large population will need to be provided, but this is not a problem since groundwater conditions are quite favourable: proposals are described in Annex M. Sanitation is also necessary, and is accounted for in the cost estimates. The Afar will be provided with simple water supplies and stock watering points to improve health and living standards and to help keep the livestock away from irrigation canals.

The large new population will require the usual range of state services, particularly health, education and civil administration (including police, telecommunications, etc.). Since there are no facilities in the area now, all these are costed as part of the project for economic analysis, though the costs are not very high in comparison with the agricultural sector. The project will place considerable emphasis on preventive health care and on health education. Primary schools and basic clinics will be distributed throughout the area, normally two of each per state farm plus three clinics for the Afar, while a single secondary school will be built at the Project Centre. This central township is proposed to be built on a presently vacant site half-way along the north-south road and just to the west of the irrigated area, where there is a patch of good soils that are too high to be included in the gravity irrigation scheme. Other buildings will generally be located within the scheme boundaries but on land that is not usable for agricultural purposes: each state farm will have a headquarters area and one other housing area ('village'), both including labour housing with a school and clinic. Recreational facilities, such as sports fields, will be provided, though they have not been detailed at this feasibility study stage.

4.7 Institutions

There are decisions to be made about the project's institutional arrangements which will be important for its performance and success but which do not need to be made at feasibility-study stage. Annex F contains a discussion of the options, particularly the choice between integration and separation of functions, and the choice between national-level centralisation and project-level autonomy. The two choices are linked and two combinations are singled out for serious consideration, namely the centralised and functionally separated structure which operates at comparable projects now (called Model A), and a possible integrated project structure with a degree of local autonomy (Model C). Both models have disadvantages, and in each case there are measures that can be taken to minimise those disadvantages. In an absolute sense and for the long term, the Consultant would recommend Model C, and it may be worthwhile for the authorities to consider changing to such a structure for all large irrigation projects at some future date when there are more of them than at present. But it is unlikely that a change from the present national policy would be made just for Kesem, so the proposal on which this study bases its estimates and further analysis is a modified form of Model A, called Model AX in Annex F. The modifications, some of which have already been proposed or are in the course of being introduced on other projects, concern coordination at project and national level between the main functions (agriculture, water resource control, and settlement services). These modifications would go a long way towards removing the disadvantages of the centralised-separated structure.

not be regarded as decisive. The Small Project in any case represents a much smaller undertaking and the regulation of the Kesem's flow has wide implications for the whole Awash basin.

All three of these EIRR values are far below the levels usually considered for financing by organisations with a commercial or banking outlook, so that any decision on project implementation will be made on wider criteria: similarly the decision on project size cannot be made on economic grounds alone. In keeping with the underlying policy to maximise the use of all resources, the Large Project is the subject of most of this report, the Medium Project being analysed alongside it in relevant places. The rest of the economic evaluation, and the recommendations, are the subjects of later chapters of this Main Report. The next chapter describes the proposed project, with the dam and reservoir, distinguishing between the Large Project and the Medium Project where necessary. Whenever the distinction is not mentioned, the Large Project is described. Further consideration of a small project, with conjunctive use of groundwater but no dam, is outside the scope of this study but should receive attention, beginning with new data collection. The concept is close to that of the Ethio-Bulgarian joint venture.

CHAPTER 5

THE PROJECT

5.1 General

The purpose of this chapter is to describe the proposed project in summary form. Details can be found in the relevant annexes in Volumes 2 to 5, and in the drawings in Album 1 (irrigation, drainage and flood protection) and Album 2 (dam). The reasoning behind these feasibility-study-stage designs has been discussed in the previous chapter, so this one is generally confined to a concise and quantitative description of the proposed project.

As explained at the beginning of Chapter 4, the project has initially been designed to make maximum use of the land resources of the Kesem-Kebena plain, in accordance with government policy. This concept is called the Large Project to distinguish it from alternative scenarios called the Medium and the Small Projects, which are based on the alternative strategy of selective land use. Because much of the land on the plain is of poor quality, the selective approach turns out to be economically more attractive, so the Medium Project must be taken seriously. The scheme of that name which is described here, irrigating 8 920 ha net, is one representative of a range of possible schemes that could be formulated. Depending on the criteria used, the best size might be anywhere between about 7 000 and 11 000 ha. The Small Project represents the potential for a scheme with no dam for seasonal storage of river flow, relying only on the natural flows of the Kesem and the Kebena plus supplementary pumping from groundwater in the dry season: at 4 315 ha it is probably near the upper size limit for such a run-of-river scheme with normal cropping intensities.

The dam and hydropower station would be the same for the Large or Medium Project. Many other project elements would differ little between those two cases. Unless stated otherwise this report refers to the Large Project, but the differences are mentioned when they are significant.

5.2 Irrigation Scheme

5.2.1 Layout and Cropped Areas

The extent of the Kesem-Kebena plain which can be commanded by a gravity offtake from the Kesem river at the Awara Melka gorge is about 21 000 ha. The quality of much of the land is, however, significantly worse than was thought at the time of the 1965 report (Ref. 1), which estimated a gross irrigable area of 17 550 ha. The much more detailed soil survey and suitability classification done as part of this study indicates that, when topographic limitations are also taken into account, only about 15 700 ha gross can be usefully irrigated, and of that only about 10 000 ha gross are suitable for annual cash crops. The better soils are also fragmented, so compromises must be made whereby some cash crop units contain patches of poor soil while some small patches of good soil may not be fully used. The maximum practicable extent of irrigation is illustrated by Figure 5.1, which shows the Large Project layout. A more selective and more economic use of land is illustrated by the Medium Project in Figure 5.2. Both these figures are bound at the back of this volume.

The net and gross irrigated areas achieved by these two layouts are set out and compared in Table 5.1. The areas devoted to the higher-value state farm crops, citrus and tobacco, are limited by market considerations to about 450 ha and 3 000 ha respectively. The rest of the land of mapping units 1 to 3, in the suitability classification of Annex A, is allocated to the cotton-wheat farming system, which is the next highest in gross returns and has no effective marketing limit. In the Large Project most of the land of unit 4, which is suitable only for irrigated pasture woodlots, is allocated to the 'settlement areas', i.e. to irrigated pasture and gardens for the Afar and Soudani populations. Exceptions to this target allocation include considerable areas of unit 4 land in small patches surrounded by state farm lands, and patches of better soils within the settlement areas. The former are used for woodlots within the state farms and the latter are suitable for the gradual adoption of irrigated agriculture, on up to 20% of the settlement land, by the Afar. The detailed layout for the Large Project is shown on Drawings L1 and L2 in Album 1.

TABLE 5.1

Net Irrigated Areas

Cropping system	Medium Project (ha)	(%)	Large Project (ha)	(%)
Horticulture (citrus)	430	5	430	3
Tobacco and break crops	3 160	35	3 120	22
Cotton and wheat	3 410	38	5 340	38
Woodlots	660	7	1 020	7
(Sub-total, state farms:	7 660	86	9 910	70)
Settlement (pasture and food crops)	1 260	14	4 180	30
TOTAL	8 920	100	14 090	100
(Gross areas)	(10 030 gross)		(15 660 gross)	

It can be seen that the differences in cropped area between the Large and Medium Projects are almost entirely in the cotton/wheat area and the settlement area. This is because the citrus and tobacco system areas, being limited by markets, can and should be maintained near the market limits.

The tobacco and cotton/wheat areas have a cropping intensity of 150% in each case, with the cropping patterns of Figure 4.1. This results in the annual cropped areas set out in Tables 5.2 and 5.3. A comparison between the two tables shows that the exclusion of the poorer eastern areas from the Medium Project has drastically reduced the proportion of woodlots in the cotton/wheat state farms. In fact, when planning for selective rather than maximum land use one could decide to omit woodlots altogether leaving unused patches in the state farms. The Medium Project as formulated here, however, keeps about two-thirds of the Large Project's woodlot area.

TABLE 5.2

Farming Systems and Net Cropped Areas - Large Project

	Total net area (2)	Annual area cropped, net ha						
		Tobacco	Cotton	Wheat	Maize	Citrus	Woodlots	Pasture
State Farm Systems								
Tobacco/ break crops	3 120	1 560	1 560	780	780	-	-	-
Associated woodlots	690	-	-	-	-	-	690	-
Cotton/wheat	5 340	-	5 340	2 670	-	-	-	-
Associated woodlots	330	-	-	-	-	-	330	-
Citrus	430(1)	-	-	-	-	430	-	-
Sub-total, SF	9 910	1 560	6 900	3 450	780	430	1 020	-
Settlement System								
Pastures with gradual introduction of arable farming	4 180	-	-	-	-	-	-	4 180
Total	14 090	1 560	6 900	3 450	780	430	1 020	4 180

Notes: (1) Includes 268 ha of existing plantations.
(2) Gross areas are 11 260 ha for state farms and 4 400 ha for settlement, totalling 15 660 ha.

TABLE 5.3

Farming Systems and Net Cropped Areas - Medium Project

	Total net area (2)	Annual area cropped, net ha						
		Tobacco	Cotton	Wheat	Maize	Citrus	Woodlots	Pasture
State Farm Systems								
Tobacco/ break crops	3 160	1 580	1 580	790	790	-	-	-
Associated woodlots	600	-	-	-	-	-	600	-
Cotton/wheat	3 410	-	3 410	1 705	-	-	-	-
Associated woodlots	60	-	-	-	-	-	60	-
Citrus	430(1)	-	-	-	-	430	-	-
Sub-total, SF	7 660	1 580	4 990	2 495	790	430	660	-
Settlement System								
Pastures with gradual introduction of arable farming	1 260	-	-	-	-	-	-	1 260
Total	8 920	1 580	4 990	2 495	790	430	660	1 260

Notes: (1) Includes 268 ha of existing plantations.
(2) Gross areas are 8 700 ha for state farms and 1 330 ha for settlement, totalling 10 030 ha.

5.2.2 Irrigation System

Irrigation water will be extracted from the Kesem river by a gravity headworks structure in the Awara Melka gorge, approximately at the site of the existing and partially broken weir. The intakes can be combined with the weir abutments, and it will probably be convenient to combine the necessary road bridge with the same structure. A simple mass concrete ogee weir is proposed, as shown on Drawing L7 in Album 1. For the Large Project the offtakes will be designed for 12 m^3/s on the north bank and 6 m^3/s on the south bank. They will skim the water laterally from the river just upstream of the main weir, then pass it through trash screens and gates and out of the gorge in rectangular concrete flumes. Some way downstream, when any coarse sediment in the flow has concentrated near the bottom of the flume, a horizontal slab will skim off the relatively clean irrigation water and the water from the bottom of the flume will be returned to the river through a gated scour sluice, except at times of water shortage when the river water will be carrying little sediment anyway. Once the dam is operating the river's sediment load will be small, but during the run-of-river phase it will carry its full load and there will always be some sediment from the river bed and tributary catchments downstream of the dam.

From the headworks the water will be conveyed by two primary canals, as shown on Drawings L1 and L2. The north one, 16.4 km long, will begin with a piped reach to take the water round the corner from the gorge as far as the flood bund, and thereafter there will be a short concrete-lined reach. Otherwise the canals will all be unlined, except locally where passing through sandy patches, where an imported clay lining, using material from drain excavation, will be used. The North Primary Canal will be aligned across the land slope, crossing two large wadis (A and F) and the Kebena river, by means of reinforced concrete inverted siphons (Drawing L9 in Album 1). The southern primary, only 5.5 km long, will go down the slope close to the right bank of the Kesem, generally following the route of the existing scheme's main canal: that canal will, however, need extensive remodelling for the larger discharge, and new drop structures.

Distribution of water to the field units and pasture areas will be by a system of secondary and tertiary canals with discharges from 0.2 to 2.6 m^3/s. Their total length is 175 km. For state farm areas, they will supply water to field canals each of which will irrigate an area of about 22.5 ha net. Furrow irrigation will be used on these field units. The irrigated pasture areas for the Afar will also be supplied by field canals (not shown on Drawings L1 and L2), but they will not serve a standard area and will be curved, following the topography at minimal slope. Water will be released at intervals from these field canals and will flow across the natural ground surface, being repeatedly distributed laterally by contour furrows or 'spreader ditches', which can be cheaply added to when necessary. This provides a cheap distribution system for the low-value land.

Canal cross-regulators will be gated on the primary canals, but secondaries and tertiaries will have long weirs of duckbill shape to maintain near-constant upstream water levels with a minimum of operation input. Head regulators on secondaries and tertiaries will be movable weirs provided with flow measuring facilities. All primary, secondary and tertiary canals will have escape structures.

The Large Project layout is such that the central water resources authority will hand over measured quantities of water to the state farms and settlement offices at only eleven places in the northern primary's system and ten in the south. This is the result of careful adaptation of the layout to the soils. No state farm or settlement unit will have to convey water through its area and hand it on to another party, and most of them will receive water at only one or two places.

In the area of the existing farms, some of the canals can be retained: at Awara Melka the eastward-flowing canals will be used as field canals but new tertiaries will be built along the lines of the former southbound canals which are now generally out of use. At Yalo it is not worth while to retain the canals because the layout can be improved to bring in more of the unit 1 land and exclude poor land from a tobacco farm.

5.2.3 Drainage and Flood Protection

Most of the land will need subsurface drainage installed at the time of initial construction. The drainage treatments are shown in Drawings L1 and L2 by the designations D1 to D6, whose meanings are set out in Table 5.4. The table also gives the net areas in each category. The intense drainage, i.e. treatments D4 to D6, covers 7 900 ha or 56% of the Large Project area, entirely on state farms. The low-intensity drainage (D2 and D3) totals 14% of the project and is mostly on settlement areas. On the 1 860 ha of land classified 'L', the cost estimates include the provision of open drains deep enough to take field drains later, but no field drains or collectors: these are not expected to be needed at all, since permeabilities are relatively high and the deep open drains will probably be sufficient to intercept any rising groundwater.

TABLE 5.4

Land Drainage Treatments

Treatment designation	Description	Net area drained (ha)
D1	No buried drains; open drains 1.0 to 1.5 m deep	2 290
D2	Buried field drains about 1.0 m deep, 40 m spacing	120
D3	Buried field drains about 2.0 m deep, 80 m spacing	1 910
D4	Buried field drains about 2.0 m deep, 40 m spacing	820
D5	Buried field drains about 2.0 m deep, 20 m spacing	3 330
D6	As D5 and with transverse trenching above drain depth to break up impermeable layers	3 760
L	No field drainage now, but open drains designed to allow its later installation	1 860

The field drains will be perforated plastic pipes with filter surrounds, laid by trenching at a depth of about 2.0 m below the surface, the total length of pipe being about 3 600 km. They will discharge into 240 km of buried plastic pipe collectors with buried manholes at the junctions (most of the buried collectors will serve two field units, one on each side). They in turn will discharge into open drains totalling 182 km.

In the Large Project (Figure 5.1) all the drains of the South Block, and the eastern parts of the other blocks, will lead to drainage pumpstations. For most of the time the water will discharge by gravity, bypassing the pumps through flap gates, but for a few weeks each wet season the Awash river's water level will be too high and the drain water will be pumped, usually against heads of around 3 to 4 m. The more westerly parts of the Gurmile and North Blocks will, however, be drained directly into the rivers or the T'unfeta floodway, without pumping. In the north-east corner the pasture land is low but its value does not justify a fourth pumpstation so some flooding will be accepted.

In the case of the the Medium Project (Figure 5.2), pumping of drainage water is avoided altogether. The open drains discharge either into the rivers or onto the low-lying eastern parts of the plain, where the drainage water will be beneficial in promoting growth of grass in the dry season for the Afar livestock.

To protect the irrigated land from floods in the Awash, Kesem and Kebena rivers and the Wadi T'unfeta, earthern flood bunds totalling 85 km in the Large Project case are proposed. The average height is about 2.5 m and the maximum 5 m, allowing a 0.5 m freeboard over the estimated 1-in-20 year flood levels. Nearly all of this is avoided in the Medium Project, since the flood banks along the tributary rivers in the western part of the plain do not need to be high.

About ten ephemeral wadis discharge floodwater onto the plain from the escarpment foothills to the west. The proposed protection involves six interceptor channels totalling 19 km and designed for discharges of up to 110 m^3/s to divert flood flows into the rivers. Their alignments are designed for adequate slope, and storm runoff from the land between them and the main canal will be picked up by another drain just west of the main canal. On each wadi, upstream of the point where it is diverted into an interceptor, there will be a flow dispersion structure designed to promote deposition of part of the sediment load. All these works will be designed on the best available information and then constructed and watched carefully, modifications and improvements being made after each major flood in the light of the new information it provides. This approach is more economic than an attempt to design against any flow and sediment behaviour from the start, which would inevitably lead to overdesign.

5.2.4 In-field Works

Preparation of the land for irrigated agriculture will involve bush-clearing, land levelling and land planing. The present vegetation cover (see Drawings A7 and A8 in Album 1) varies from almost nothing to thick riverine forest. For most of the bush-clearing the recommended method is raking and root ploughing by heavy crawler tractors, the woody vegetation being then used for firewood wherever possible. The approximate areas involved are 3 000 ha of dense bush, 3 300 ha of medium bush, and 6 400 ha light bush. In the irrigated pasture areas some large trees, up to about 10 per hectare, should be left standing to provide shade.

The term land levelling means the movement of soil to produce uniform slopes within ranges required for particular irrigation methods, rather than production of level surfaces. In the state farm areas land levelling will be done in plots of area about 1 to 5 ha, limiting cut and fill depths to 0.5 m. The estimated total areas are:

- light levelling requirement (up to 200 m^3/ha): 1 600 ha
- medium levelling requirement (200 to 500 m^3/ha): 4 200 ha
- high levelling requirement (500 to 1 000 m^3/ha): 4 000 ha

Laser-controlled elevating scrapers and motor graders are recommended for the land levelling. The land preparation will be completed by land planing to give uniform land slopes within about $\pm$ 5 cm. Settlement areas require no land levelling nor planing.

Cost estimates include the provision of 16 400 siphon pipes for furrow irrigation, and 1 200 groundwater observation pipes so that the movements of the watertable can be monitored.

5.3 Dam and Hydropower Station

These works are described in Annex J, and the reasoning behind their design has already been discussed in Section 4.5 above.

The proposed main dam is a rockfill embankment some 90 m high. With its 10 m high wing embankment along the left abutment it is about 440 m long, but the crest of the effective high dam is only about 225 m long. With side slopes of 1 in 1.95 upstream and 1 in 1.6 downstream, plus a 10 m wide crest and some berms, its dimension from toe to toe along the river bed is about 500 m. The retention level is 930 m above sea level, the forecast extreme flood level 940 m, and the nominal crest level 941 m.

Watertightness is provided by a central clay core tapering in thickness from over 60 m at the base to about 6 m at the crest, protected by fine and coarse filters in the usual way. An adequate quantity of material, generally an inorganic silty clay of intermediate plasticity, has been identified on the watershed just west of the saddle dam site and only 3 to 4 km from the main dam.

The rockfill material of the embankments, of which over 1 000 000 m^3 is required, will be the stronger grades of ignimbrite, which are available 3 km from the dam site on the south side. This is preferred to the basalt because most of that is too vesicular, and to conglomerate which would be usable but expensive to prepare. Material for concrete aggegates, filters and rip-rap are also locally available.

The saddle dam, also with a crest level of 941 m, will be a semi-homogeneous embankment some 25 m high and 350 m long. Proposed side slopes are 1 in 3.0 upstream and 1 in 2.5 downstream, and the material will be selected from the nearby borrow area for the main dam's core. The ten small bunds closing saddles at levels over 936 m, with a combined length of 3 km and heights up to 5 m, will be of homogeneous earthfill.

The bottom outlet will make use of the 5 m diameter concrete-lined diversion tunnel in the left abutment. After diversion is over the low-level intake will be blocked and replaced by a drop-inlet shaft. Just downstream of the dam axis a gate chamber will be installed, with a 2.35 m wide by 3.50 m high gate and a slightly smaller guard gate, both hydraulically operated from a cavern above. Acess to the cavern will be by an almost horizontal adit. The pressure tunnel upstream of the gates will be circular and the free-flow tunnel downstream will have a horseshoe section. The latter will terminate in a simple stilling basin 12 m wide.

The spillway will be an ungated concrete structure passing through the left abutment, well clear of the main dam, though intersecting its low wing embankment. The ogee crest at level 930 m will be 100 m long, slightly curved in plan, and accompanied by a road bridge. Downstream of the weir the chute floor will drop immediately by about 5 m, then remain near horizontal for a length of about 60 m while tapering to 70 m wide, then turn down to a steep chute terminating in a flip bucket at level 866 m. Rock anchors and underdrains will be provided to prevent uplift problems, and the flip bucket will be located just short of the fault zone to avoid foundation problems. Much of the rock excavated to form the spillway will be used in the dam.

The 6 MW hydropower system will incorporate a bypass so that its tunnel can pass irrigation water even when the turbines are not running. A separate intake on the left abutment will control the flow of water into a horizontal concrete-lined low-pressure tunnel at about level 930 m. A little downstream of the dam axis this will join with a sloping tunnel containing steel penstocks leading to two horizontal-axis Francis turbines in a small powerhouse located under the spillway's flip bucket and thus sharing its foundations. The draft tube below will lead laterally and discharge into the bottom outlet's stilling basin.

Two generators will pass power at 6.6 kV to transformers supplying the 15 kV transmission line. This line will initially, during the dam construction period, bring power from the national grid's substation at Awash Town, and will then take power in the other direction, from the new station to the project. The link to the grid will remain, being used during dry years when the reservoir is drawn down too low for hydropower operation.

5.4 Pastoralists, Livestock and the Environment

Provision for the Afar and Soudanis is closely linked with the project's environmental impact and the environment-related elements of the project package. The relevant aspects are:

- irrigated pasture to replace lost dry-season grazing;
- gradual adoption by the Afar of the growing of annual crops under irrigation;
- an advance programme of assistance to the Afar before the project is in full operation;
- a range management programme for the surrounding wet season grazing area;
- design criteria to protect the National Park.

As stated in Section 5.2, the Large Project proposals include provision of 4 180 ha net as so-called 'settlement area'. Figure 5.1 (bound at the back of this volume) shows how this area, which will be mainly irrigated pasture, is made up of five patches arranged on the northern, western and southern edges of the irrigation scheme.

About 80% of the land is suitable only for pasture or woodlots (general suitability unit 4), so the loss of potential cash crop land is not large. The remainder, about 800 ha, consists of better soils in small patches which can be used for growing food and cash crops.

As mentioned in Section 5.2, the pasture areas will be provided with secondary and tertiary canals supplying water to field canals aligned almost along the contours rather than parallel and straight. Water will be released from these by gaps in their banks and will flow downslope, being spread by short contour furrows. The naturally occurring grasses will be complemented, and partially replaced, by improved grasses such as Cenchrus ciliaris and possibly Rhodes grass. The Afar and Soudanis are expected gradually to take up the growing of food crops such as cowpea, groundnuts, sesame, maize and wheat plus perhaps some cash crops. Land will be allocated to clans and lineages within the existing tribal structure, and the involvement of the Afar both in the allocation and the water management will be maximised.

The Afar will live outside the irrigated area but close to their irrigated pastures, and will never need to cross the state farms. In the Gurmile Block their pastures lie to the north and south of the wedge of very poor land where Wadi F now discharges, and this area will provide both access and living space for the Afar.

In the case of the Medium Project, as can be seen in Figure 5.2, a strip of low-lying land 2 to 4 km wide and 14 m long, along the eastern edge of the plain, will be left unused by the formal irrigation scheme but will be watered locally by the drain outfalls. This is also the area which is naturally flooded by the rivers, and is thus an important part of the Afar's dry-season grazing area at present. With this land still available for the Afars, and its dry-season grass production slightly enhanced by drain discharges, it is considered that the irrigation scheme, covering about 11 000 ha gross, will only need to include about 1 300 ha net of irrigated pasture and gardens. The provision in the South Block is the same as for the Large Project because the state farm area in that block is hardly reduced at all, but in the other blocks there are only small areas of irrigated pasture. As well as the eastern strip, the whole of the area north of Wadi T'unfeta is left for the Afar, without formal irrigation. Other arrangements concerning the Afar will be the same in the Medium and Large Projects.

Once the project is in full operation, the overall supervision of the settlement areas will be from three field offices located near the Afar villages, and a headquarters office in the project centre. Each field office will include a health centre. Before and during the construction period there will be an advance programme to prepare the Afar for the changes brought by the project. This will begin with the existing spontaneous irrigation schemes operated by small groups of Afar and Soudanis, and will foster development of irrigated agriculture, animal power, local participation and responsibility, and improved health for people and livestock. A modest 8-year programme of outside inputs is proposed (Annex C), costing about Birr 655 000 which is only about 0.1% of Large Project costs.

For the surrounding areas, which will continue to be used by the Afar for wet-season grazing, a small range and environment management programme is proposed. Its main elements will be water harvesting and improvement of the mix of grass species, and details will be progressively adapted in the light of experience. The cost, for the initial 6 years, is estimated at only Birr 600 000 and the continuation thereafter will be part of the settlement authority's work.

The project's south-western and main access road will pass through the Awash National Park, but near its edge and following the route of the existing road. That part of the park is not completely effective anyway, so the increase in road traffic will not represent a serious loss in the conservation work of the park authorities. The present track from Awash Town to the south-east corner of the Kesem-Kebena plain will not be developed as a major access road, so as to minimise effects on the park on that side. The central track, through the most effective part of the park south of Saboret and Doho, will be closed at the northern end to prevent project traffic from disturbing the wildlife. The project's provision of irrigated pasture and woodlots should reduce the incursions of pastoralists and fuelwood seekers into the fringes of the park.

With all these provisions built into the project, its environmental impact will be slight and generally positive (a more detailed statement is in Annex D, Section D3.6). The project will provide on-going monitoring of the environment.

5.5 Infrastructure and Services

Since the area is now almost entirely without infrastructure and social services, the project will provide most of these, in particular:

- roads and airstrips;
- power supplies;
- housing;
- domestic water supply and sanitation;
- offices, stores and workshops;
- clinics and health services;
- schools and education;
- police and civil administration;
- recreational facilities.

Apart from the details of health services, which are described in Annex E, all these project elements are described in Annex M. The reasoning underlying the project provisions has been discussed in Section 4.6 above.

The project will upgrade the existing 32 km long access road between Awara Melka and the Addis Ababa/Assab highway, and then extend it northward with a 21 km long main road, 8 m wide and gravelled, along the western side of the irrigation scheme. From the north-western corner of the scheme there will be a link road about 16 km long, 4.5 m wide and gravelled, passing over the western flank of Mount Dofan to link with the roads in the Bolhamo scheme and thus with that scheme's proposed bridge over the Awash to Amibara. The north-south road will cross the Kesem by a high-level bridge and the other watercourses by causeways with culvert pipes (Irish bridges). Within the irrigated area there will be a minimum network of gravelled through roads with one more crossing of each of the two rivers: these total 56.5 km and will be 7 m wide. They will give access to the roadways beside all secondary and tertiary canals and drains, so that wheeled access will be provided to every field unit. They will also link all the settlements. New access roads will be provided to the dam site on both banks. Airstrips will be provided, for light aircraft from other parts of the country and for crop-spraying.

Electricity supplies will be provided to all the settlements. In the early stages of project development a power line will be built from the grid's existing major substation at Awash town. This will be at 15 kV, passing north from Awash along the eastern edge of the National Park, then west to Saboret and the dam site with a branch to the Project Centre: a total distance of 50 km. If and when a hydropower station is built at the dam, it will provide power to the whole project area most of the time, using the same network, but the connection to the grid will be retained for use when the reservoir water level is too low to drive the turbines.

Housing is a major cost element. With the assumptions discussed in Section 4.6 above, the numbers of buildings required is as given in Table 5.5. Senior staff, in accordance with national policy, will have Type C houses (about 58 m^2 gross), intermediate staff Type D (47 m^2) and junior staff Type G (40 m^2 with separate communal shower and toilet blocks). To keep costs down, Types C and D units are built in pairs and Type G units in blocks of four. For agricultural labourers the non-standard low-cost housing described in Section 4.6 will be used, in blocks which each accommodate 4 permanent labourers and their families, or 16 'casual' (migrant) labourers without families.

TABLE 5.5

Numbers of Buildings, Large Project

Type	Project Centre and dam site	State farms	Settlement authority outstations	Total
Type C housing (2 units)	19	53	3	75
Type D housing (2 units)	49	191	17	257
Type G housing (4 units)	44	273	28	345
Type Z housing (4 units)	-	2 088	-	2 088
Office	8	7	3	18
Workshop	2	7	-	9
School	2	14	-	16
Clinic	1	14	3	18

Note: (More detailed breakdown in Annex F, p. F-32).

The locations of the settlements are shown on Drawings L1 and L2. The Project Centre contains the whole water resources staff and the central, project-level offices of the state farms and settlement authorities, as well as offices and housing relating to the other services. Each state farm has a headquarters and one outlying village, each of these sites having a primary school, a clinic, and about half the housing. These settlements, as well as the three outstations of the settlement authority, will be on land that cannot be used for irrigation, while the Project Centre site is on land with good soils but out of command from the North Primary Canal. The central workshops of the Water Resources Authority, located at the Project Centre, will maintain the vehicles of the Settlement Authority and the various service offices, which are not big enough to justify their own workshops.

Domestic water supply, which is discussed in Chapter M4 of Annex M, could come from the rivers or groundwater. The most attractive arrangement, and the one assumed for costing purposes, involves two separate systems distributing water from wellfields near the Kesem and Kebena rivers respectively. Treatment by chlorination will be simple and recharge from the rivers will keep fluoride levels down. Trunk mains will be of ductile iron and distribution pipework of uPVC, leading water to every office, workshop, school, clinic or Type C or D house. For the housing of Types G and Z there will be one standpipe and one shower unit for each 4-family block. For the Afar, standpipes for domestic water and animal watering will be provided from the piped system, where convenient, and by wells elsewhere.

Sanitation will be by improved ventilated pit latrines for housing of Types G and Z and waterborne sewerage for other buildings. This will lead to individual or group septic tanks except at the Project Centre, where a small centralised sewerage system will be provided.

The proposed health services within the project are described in some detail in Annex E. Up to 18 clinics are to be provided, mostly on the state farms. Emphasis is to be placed on health education, maternal and child health and preventive health care, both for immigrant workers on the state farms and for the Afar, whose traditional midwives will receive training and medical supplies. The proposed housing, water supply and sanitation facilities are obviously important for the improvement of health, and the reduction of the proportion of seasonal migrant labourers will help to reduce the incidence of sexually transmitted diseases. The use of agricultural chemicals will be carefully controlled and monitored.

The list of buildings given above includes provision for all the services mentioned, including civil administration. Apart from the primary schools and the clinics, the relevant offices and housing will all be concentrated at the Project Centre. Recreational facilities have not been specifically designed at this stage but will be covered by the cost allowance for 'miscellaneous items', which, in relation to buildings alone, amounts to Birr 15 million.

The project also provides for the purchase, maintenance and periodic replacement of about 130 personnel-carrying vehicles, in addition to plant and machinery.

It is estimated that the total population served by this infrastructure will be over 70 000, more than 80% of these people being immigrants to the area, mainly highlanders.

5.6 Institutions

As explained in Section 4.7 above, it is assumed for the purposes of this study that the present policy will be maintained and the main functions will be exercised by separate project-level offices of the relevant national bodies, rather than by an integrated project organisation. To avoid the potential disadvantages of a separated system while retaining its advantages, a project-level non-executive coordinating committee is proposed (Annex F, p. F-15).

The three main functions would be exercised by the following organisations:

- the Kesem Water Resources Office (KWRO), operating the dam and power station, the larger canals and drains, drainage pumpstations and major roads;
- the Kesem State Farm Office (KSFO), supervising the individual state farms and liaising with regional and national offices of MSFD;
- the Kesem Settlement Office, responsible for the welfare of the Afar and Soudani populations and operating through three outstations.

Estimated staffing numbers are set out in Annex F (Chapter F5) and used for cost estimating. Table 5.6 summarises the totals, assuming that all teachers live at the Project Centre (which they might not). The table excludes the 7 352 permanent and 3 984 casual agricultural labourers.

The project formulation includes provision for a permanent monitoring and reporting programme. Although this will cover all aspects of the project and its environmental interactions, it is suggested that it should be coordinated by the KWRO. The programme, which is also mentioned in Section D3.7 will cover operation and maintenance work, the state of the canals, drains, flood protection works, structures and buildings, the wider environment and its vegetation cover, soil chemistry, water quality, livestock, environmental health and social conditions.

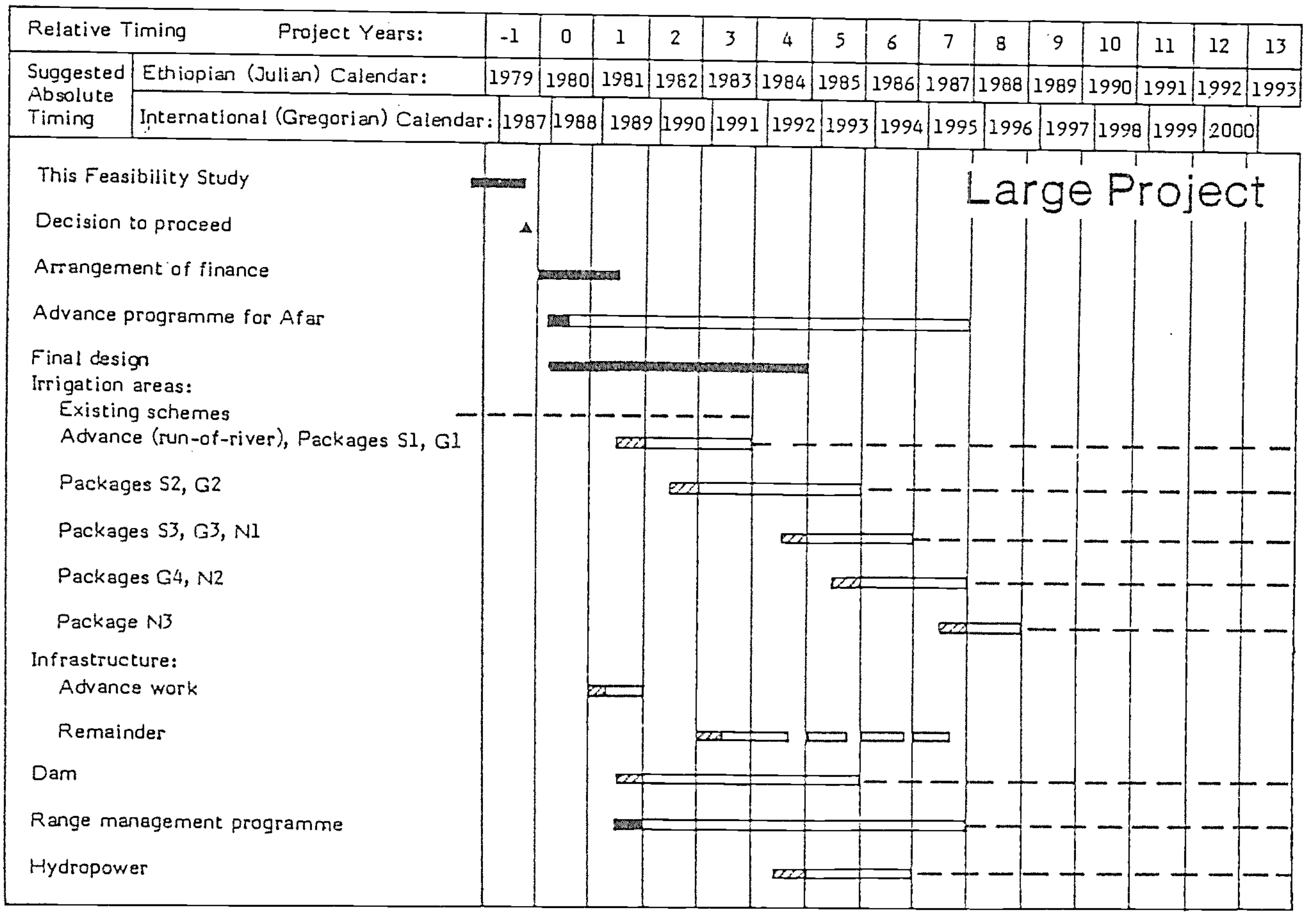
5.7 Implementation

The implementation programme for KIP is discussed in Annex K, from which the bar charts are reproduced here in Figure 5.3. These represent the quickest practicable programmes and the start dates may be postponed, for instance due to the need to await completion of other studies before deciding on implementation of KIP.

The critical path runs through the arrangement of finance, the design of priority works and the construction of the dam. With a four-year dam construction period this means that the regulated irrigation water supply will not be available earlier than six years hence, in 1993. In the mean time an advance phase of irrigation development can take place, using run-of-river supplies from the new Kesem diversion weir and a cheap temporary Kebena offtake combined with the road crossing. The proposed phasing of irrigation development is summarised in Table 5.7, from which it can be seen that the advance package is the same for the two scenarios: the figure shows a two-year construction period so that the advance areas only precede the rest by two years, though any delay in starting or completing dam construction would stretch this gap. The next phase is timed to come into production the year after the dam's completion, and in view of the need to set up camps and infrastructure a three-year construction programme is assumed, so that work overlaps with the advance phase's completion. In the Medium Project the area after the advance phase is commissioned in three successive years, the second and third phases being built in only two years because a momentum would by this time have been established. For the Large

Figure 5.3

Tentative Project Development Programmes



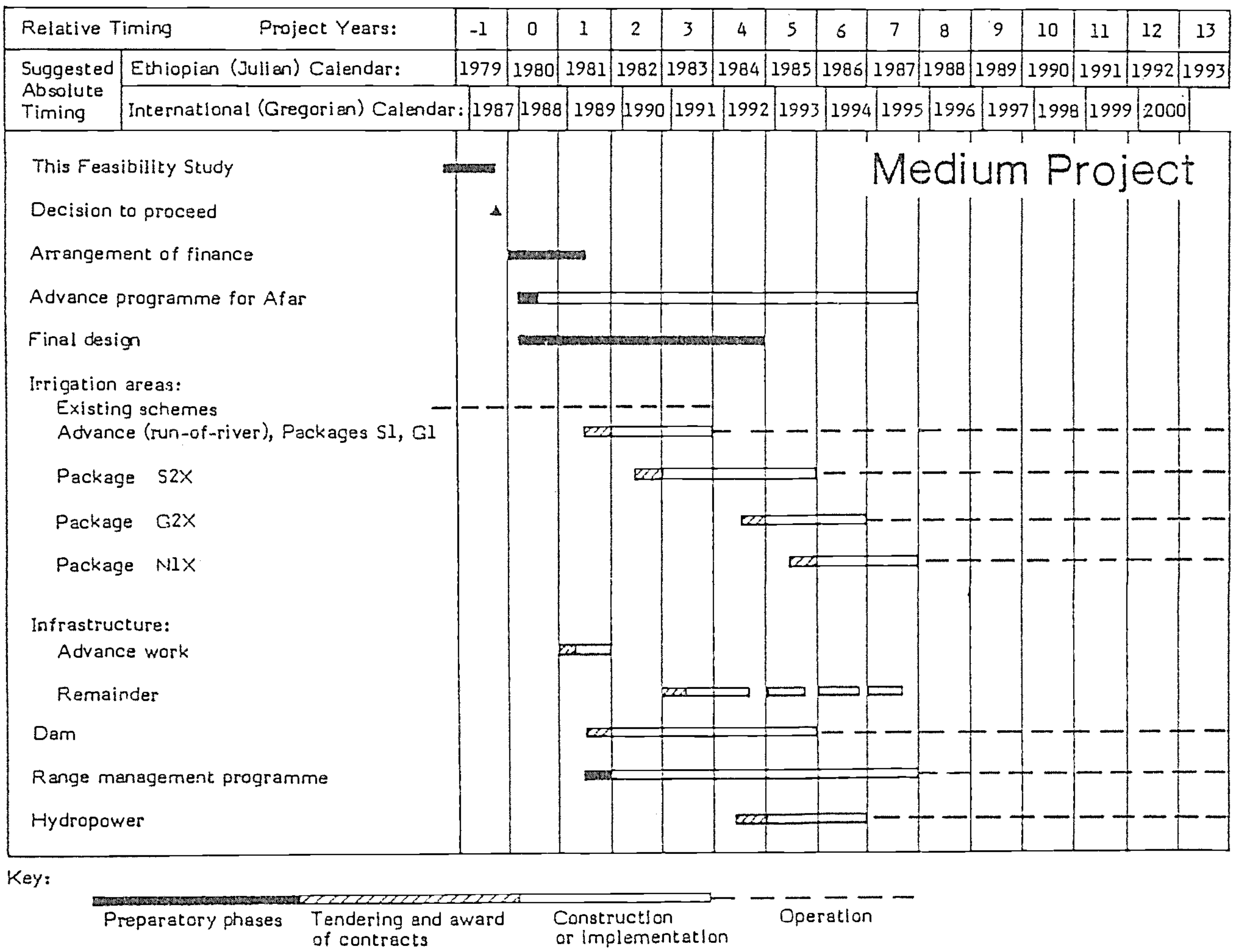


TABLE 5.6

Staff Numbers, Large Project

	Senior	Intermediate	Junior	Total
KWRO	8	43	85	136
KSFO (Central)	5	13	12	30
7 state farms	99	379	1 085	1 563
Sub-total, state farms	(104)	(392)	(1 097)	(1 593)
KSFO (Central)	3	3	4	10
3 outstations	3	36	114	153
Sub-total, settlement	(6)	(39)	(118)	(163)
Services (Central)	22	39	75	136
Sub-total at Project Centre	38	98	176	312
Sub-total outside Project Centre	102	415	1 199	1 716
Total	140	513	1 375	2 028

Note: Details and breakdowns are in Tables F5.3 to F5.8 in Annex F.

TABLE 5.7

Staged Development of Irrigated Areas

Year of first production	Large Project		Medium Project	
	State farms (net ha)	Settlement (net ha)	State farms (net ha)	Settlement (net ha)
Run-of-river (advance phase):				
4	1 520	400	1 520	400
Using Reservoir:				
6	2 500	1 360	2 670	280
7	2 400	960	1 770	380
8	3 060	800	1 700	200
9	430	660	-	-
Total	9 910	4 180	7 660	1 260

Note: Further breakdowns in Tables L3.3 and L11.2 in Annex L.

Project the pattern is similar except that a relatively small amount of work is held back until Year 8 and commissioned for Year 9: this comprises the low-lying north-east corner of the project and is delayed to reduce the pressure of construction, particularly large-scale earthworks for drains and flood protection, in Years 6 and 7. Thus the bulk of the construction is concentrated into five years.

Other elements of the programme are self-explanatory. The advance programme of assistance to the Afar, and the range management programme, start relatively early and the on-going work in those fields is to be handed over to the settlement office after the project is fully operational. Some of the infrastructure is needed early ('advance work'), such as access roads, some housing, basic water and power supplies; the rest is built progressively in step with the irrigation areas that it serves. The design process is shown spread over four years, although it could be done more quickly, because it is advantageous to do the detailed design for irrigation and drainage works during the construction period (much topographic survey is involved, for land levelling particularly).

The Ethio-Bulgarian Joint Venture (EBJV) has now formally taken over the Awara Melka State Farm and was preparing to start design work during 1987. It should be regarded as a financing and implementation package rather than as an alternative project, and it has the great advantage of being already in place, while any project arising out of this report will take some time to set up. The EBJV had not, at the time of completion of this study, issued any detailed implementation programme, so the project planning in this study has not taken special account of it. It may prove possible and advantageous for the EBJV to undertake the advance (run-of-river) phase of the KIP proposed here, but two difficulties can be foreseen: firstly, the land blocks suitable for run-of-river irrigation will later be separated by other blocks and will not form a coherent unit in the long term, and secondly the EBJV is not at present organised or motivated to include significant provision for the Afars. With close cooperation it should be possible to overcome these difficulties and integrate the two initiatives. It might be convenient to allocate the whole South Block (4 600 ha net) to the EBJV, since this is a distinct unit with its own primary canal and contains most of the existing state farm. No use could then be made of the Kebena river as a water source, but its dry season flow is anyway much less than the Kesem (contrary to EBJV estimates).

5.8 Estimated Costs

The initial and recurrent costs of all the proposed project elements have been estimated, in both financial and economic terms. These are 'best estimates' or, in statistical terms, expected values: they therefore do not include a contingency allowance in the sense of a safety margin against underestimation. Such bias in cost estimating is considered appropriate for budgeting but not for economic analysis. For budgeting purposes it would be prudent to add a contingency allowance of 10% or 15% to the financial figures given here. The estimates do, however, include allowances for miscellaneous or unbilled items, as well as for design, supervision and administration.

An abstract of the estimates of initial costs is presented here in Tables 5.8 and 5.9, and the Appendix to this volume gives per hectare costs and the breakdown by years. In this context 'initial' costs include the procurement of agricultural machinery in the first ten years, although the subdivision in Annex N is slightly different. Details are in the annexes and a key to their location is given in Chapter N5 of Annex N, which also summarises all costs.

The relative sizes of the different cost elements, expressed by the percentages on the right hand side of Tables 5.8 and 5.9, are of particular interest, as is the distribution of costs between state farms and settlement functions (common

TABLE 5.8

Summary of Initial Costs, Large Project

(Million Ethiopian Birr at 1986 financial prices)

Category	State Farms		Settlement		Total	%
Irrigated area:						
- irrigation system and land preparation	92.1		27.3			
- drainage system	82.8		8.4			
- flood protection	20.2		5.2			
Sub-total		195.1		40.9	236.0	39
Major roads[1]		17.2		7.4	24.6	4
Dam and associated structures		76.0		32.6	108.5	18
Hydropower station		8.2		3.5	11.8	2
Buildings and services:						
- housing	114.8		8.0			
- other buildings	9.1		1.1			
- water supply and sanitation	16.4		2.0			
- electricity supply	1.5		0.7			
Sub-total		141.8		11.8	153.6	25
Afar, range and environmental		0		1.2	1.2	0.2
Vehicles and equipment:						
- agricultural[2]	29.8		0			
- non-agricultural	9.1		1.9			
Sub-total		38.9		1.9	40.7	7
Design and engineering		4.2		1.8	6.0	1
Supervision and administration		22.8		5.8	28.6	5
Total Initial Costs[3]		504.1		106.9	611.0	
Relative Initial Costs		83%		17%	100%	

Notes:
(1) Minor roads are included in irrigation system costs.
(2) Agricultural machinery costs in years 1 to 9, see Table N5.5.
(3) 'Initial costs' in this table includes not only the costs thus named in Section N5.1 of Annex N, but also the initial agricultural machinery costs of Section N5.4.
(4) Exchange rate Ethiopian Birr 2.07 to US$ 1.

TABLE 5.9

Summary of Initial Costs, Medium Project

(Million Ethiopian Birr at 1986 financial prices)

Category	State Farms		Settlement		Total	%
Irrigated area:						
- irrigation system and land preparation	78.8		8.5			
- drainage system	54.1		3.9			
- flood protection	8.0		0.8			
Sub-total		140.9		13.2	154.0	32
Major roads[(1)]		19.2		3.1	22.3	5
Dam and associated structures		93.3		15.2	108.5	22
Hydropower station		10.1		1.7	11.8	2
Buildings and services:						
- housing	95.2		6.2			
- other buildings	8.4		0.9			
- water supply and sanitation	14.6		1.3			
- electricity supply	1.9		0.3			
Sub-total		120.0		8.8	128.9	26
Afar, range and environmental		0		1.2	1.2	0.3
Vehicles and equipment:						
- agricultural[(2)]	24.5		0			
- non-agricultural	7.7		0.9			
Sub-total		32.2		0.9	33.2	7
Design and engineering		3.6		0.6	4.2	0.9
Supervision and administration		20.3		2.4	22.6	5
Total Initial Costs[(3)]		439.6		47.1	486.7	100
Relative Initial Costs		90%		10%	100%	

Notes:
(1) Minor roads are included in irrigation system costs.
(2) Agricultural machinery costs in years 1 to 9, see Table N5.5.
(3) 'Initial costs' in this table includes not only the costs thus named in Section N5.1 of Annex N, but also the initial agricultural machinery costs of Section N5.4.
(4) Exchange rate Ethiopian Birr 2.07 to US$ 1.

costs have been divided in the ratio of the water volumes used). The settlement function represents only 17% of initial costs for the Large Project and 10% for the Medium Project. Buildings make up a quarter of the initial costs in either case, which is more than the cost of the dam and hydropower station.

Within the irrigation area, which at 30 to 40% is the largest cost category, deep drainage accounts for more than a third. A more detailed breakdown of irrigation, drainage and flood protection costs is given in Annex L. The total of these categories amounts to some Birr 16 000 per hectare, equivalent to about US$ 8 000 per hectare which is, by international standards, not unreasonable in a situation with quite heavy drainage needs and fairly awkward topography.

The distinction between 'design and engineering' and 'supervision and administration' is an arbitrary one, and the estimate for the former may be too low, depending on the arrangements adopted. Some elements (like irrigation systems) have relatively higher design costs than others (like buildings).

In the annexes, all costs are broken down into local currency, direct foreign currency, and indirect foreign currency components. Direct foreign currency accounts for some 53% of initial costs, distributed as detailed in Appendix 1.

The estimates of recurrent costs are summarised in Table 5.10 and breakdowns by category and function are given in the last two tables of the Appendix. To enable their significance, relative to initial costs, to be assessed, Table 5.10 gives the discounted Present Values of the total estimated recurrent costs, for a nominal 50-year period and for different discounting rates. It must be remembered that these figures for recurrent costs are at full development, i.e. from year 20 onwards (costs are less in some earlier years), and also that agricultural inputs and labour wages are excluded (being accounted for in crop gross margins). The settlement function accounts for only 5 to 8% of recurrent costs, with common services' costs being divided in the proportion of water use.

TABLE 5.10

Summary of Recurrent Costs

(million Ethiopian Birr at 1986 Financial Prices)

	Large Project	Medium Project
Annual recurrent cost	19.85	15.78
Present value over 50 years:		
at 5% discount rate	362	288
10% discount rate	197	156

These tables exclude the Small Project, the costs of which have been estimated in less detail and only in economic terms. Most of the discussion of this scenario is in Section L11.3 of Annex L. The total economic initial cost is Birr 160 million (without agricultural machinery), compared with Birr 477 million for the Large Project and Birr 380 million for the Medium Project.

CHAPTER 6

EVALUATION

6.1 Methodology

The evaluation of the project has been carried out by an economic cost-benefit analysis using border pricing. The methodology follows the relevant guidelines published by the Ethiopian Government in 1981 (Ref. 13). It has been discussed with the responsible department (DPSA, authors of the guidelines) and with the WRDA/FAO economists: the guidelines are under review in 1987 but no changes had been issued at the time this analysis was done. The treatment of foreign exchange is that it is not itself shadow-priced, but all local currency elements are multiplied by a Standard Conversion Factor of 0.75, which is equivalent to a 1.33 factor on foreign exchange. Unskilled labour is shadow priced by applying a factor of 0.67 relative to other local costs, giving a Specific Conversion Factor of 0.50 to convert unskilled labour wages to border prices. The border prices of traded inputs and outputs have been calculated by allowing for freight and insurance in the usual way. Details are given in Annex N, particularly Chapter N4.

To give adequate weight to the dam and other civil engineering works which have long economic lives, the analysis was calculated over a period of 75 years, i.e. for the first 70 years of the dam's operation.

6.2 Economic Benefits and Costs

Application of the above factors to the estimated input and output costs for the relevant crops gives the economic crop gross margins listed in Table 6.1 and detailed in Annex N. These margins are the returns from crop production less the direct agricultural production costs, which for the more significant crops vary between 15% and 26% of the returns. Agricultural labour costs are only a part of these direct costs, amounting to about 7% of returns for cotton, 4% for tobacco and wheat and below 3% for maize.

TABLE 6.1

Summary of Economic Crop Gross Margins

	Range of economic gross margins(1) (Birr/ha)
State farm crops:	
- citrus	6 400 to 11 700
- tobacco	5 400 to 7 000
- cotton	2 200
- maize	2 200
- wheat	1 700
Smallholder food crops	600 to 1 300

Note: (1) Ranges of values are given where different varieties or cropping systems or soil types have been analysed.

(2) Details in Annex N, Table N4.3 and Appendix N2: values at full development are given here, rounded to the nearest 100 Birr.

The higher value crops, citrus and tobacco, face marketing constraints which have been taken into account in planning the proposed project. The others have effectively unlimited markets. The total gross margin grows by about year 20, to around Birr 31 million per year for the Large Project, or Birr 30 million for the Medium Project.

For convenience the Medium and Small Project cases have been evaluated with the same weighted average yields as the Large Project. Since their selective land use would enable more of the poorer soils to be avoided, their average yields would in fact be slightly higher, so this represents a slight bias against them in the analysis.

The economic costs have been calculated in parallel with the financial costs throughout this study. Most of the initial costs are broken down into four types:

- unskilled labour;
- skilled labour;
- imported materials;
- imported equipment.

The sub-totals for these types have then been subdivided into direct and indirect foreign exchange and local currency, and converted to economic costs by factors laid down by the government's Development Projects Study Agency (DPSA). Unskilled labour costs are 100% local currency and are converted to economic costs by the Specific Conversion Factor of 0.50. Skilled labour is also 100% local currency but subject to the Standard Conversion Factor of 0.75. Imported materials are estimated to include, on average, 40% direct foreign currency, 31% indirect foreign currency and 29% local currency, with a weighted average conversion factor of 0.78 (these costs include cement, which though now partially imported will in future be locally made, and this is allowed for here). The corresponding percentages for imported equipment, allowing for local handling and transport, are 90%, 2% and 8%, and the factor is 0.98. Engineering recurrent costs were subject to a weighted mean factor of 0.78. With the exception of fuel costs, all the financial costs exclude taxes, because a clearly-defined project like KIP can obtain tax exemption. Direct foreign currency accounts for 51% of initial financial costs (excluding agricultural machinery).

The economic costs are summarised along with the financial ones in Chapter N5 of Annex N: for the initial costs they turn out, in total, to be numerically just over 82% of the financial costs which have been summarised at the end of the preceding chapter.

A deduction is made in the economic analysis for the expected future returns to agriculture in the area without the project. The 'without-project' situation is defined, for this analysis, as comprising the continuation of the existing state farm with foreseeable changes due to the age of the standing fruit trees. The cropped areas are 210 net ha of citrus, 300 net ha of tobacco and 410 net ha of cotton, giving a total economic gross margin of Birr 3.75 million per year in the long term (details in Annex N, Table N4.8).

The classification of costs used in these tables, for instance into initial and recurrent costs or into agricultural and non-agricultural, is arbitrary and there are some items, like workshops used to maintain agricultural machines, which could be classified in different ways. For detailed breakdowns the reader is referred to the annexes. One matter, however, goes beyond mere classification details, namely, the cost of attracting adequate labour to the area. In this analysis the wages (which are low) appear under crop gross margins and the housing costs (which are high) appear under initial costs, but in fact there is a potential trade-off between these two. It might be possible and advantageous to provide less housing and pay the labourers more, perhaps assisting them to build their own houses. This would change the balance between the figures in this analysis, even if there were no net change.

6.3 Results of Economic Analysis

The results of the cost-benefit analysis, which are given in full in Annex N, are summarised here in Table 6.2. They are presented in terms of the economic internal rate of return (EIRR) and the other columns of the table serve to indicate the relative sizes of different scenarios.

Part A of the table gives the base case results for all three scenarios, though the cost and benefit estimates for the 'Small Project' are considerably less precise than for the others. The Large Project's EIRR is only 0.55%, a very unfavourable result. The Medium Project shows a rate of 2.11%, indicating that a selective rather than a maximising approach to land use is preferred by economic criteria, but this is still very low. The Small Project's rate is a little better, at 2.5%, but in view of the imprecision of this scenario's analysis this 0.4% difference is not of great significance.

Sections B and C of Table 6.2 give the results of sensitivity tests on the Large Project and, more significantly in view of its better Base Case indicator, the Medium Project. The first sensitivity test places a value on the excess capacity of Kesem Reservoir to produce regulated flows, in its first few decades until sedimentation brings its yield down to the level appropriate to KIP alone. This is done by assuming 'downstream benefits' from other irrigation schemes further down the Awash which could use the extra dry season flow resulting from regulation of the Kesem. The initial and recurrent costs have been fully taken into account, but although it is known that suitable areas are available their characteristics are of course unknown and the estimates are correspondingly approximate. The same applies to crop yields and margins, although it is quite likely that soils on such schemes would be better than the average KIP soils. The results of this slightly conservative sensitivity test show that the valuation of extra reservoir capacity in this way does not make much difference to the economic analysis, indeed it depresses the EIRR slightly because of the balance of crops. This should, however, not be thought to throw doubt on the appropriateness of a dam of the proposed size, since a lower dam would more quickly silt up and become unable even to serve the KIP area. A more precise analysis of downstream irrigation using water storage on the Kesem must await a basin-wide study.

The remaining sensitivity tests investigate the relative economic importance of such project features as the social and infrastructure costs, the provision for the Afar, the break crops and also the importance of estimates of costs, yields and labour valuation. The tests show that the EIRR cannot realistically be expected to rise above about 4% under any reasonably likely set of circumstances. The social and infrastructure costs, which make up about 30% of the

TABLE 6.2

Summary of Economic Analysis Results

	Net ha irrigated	Initial economic cost, M Birr(1)	EIRR(2)
A. Base Case			
Large Project	14 090	477	0.55
Medium Project	8 920	380	2.11
Small Project	4 315	160	2.5
B. Sensitivity Tests on Large Project			
Base case	14 090	477	0.55
Downstream benefits valued	16 000	535	0.2
Omit most initial social and infrastructure costs	14 090	342	1.5
Omit provision for Afar	9 910	435	0.9
C. Sensitivity Tests on Medium Project			
Base case	8 920	380	2.1
Downstream benefits valued	16 000	596	1.4
Omit most initial social and infrastructure costs	8 920	262	3.3
Omit maize and wheat	8 920	380	0.3
Cotton yields up 30%	8 920	380	3.0
Tobacco yields up 30%	8 920	380	2.9
Cotton and tobacco yields up 30%	8 920	380	3.7
All net benefits up 30%	8 920	380	3.8
Double cost of agricultural labour	8 920	380	1.6
Initial cost up 30%	8 920	494	1.0
Initial cost down 30%	8 920	266	3.6
Engineering recurrent cost down 50%	8 920	380	2.65

Notes: (1) These initial costs exclude agricultural machinery costs, which amount to Birr 29 million for the Large Project and Birr 24 million for the Medium Project.

(2) Economic internal rate of return.

project costs, are moderately significant and contribute a differential of about 1% to the EIRR. Provision for the Afar, representing only about 9% of initial costs, contributes about 0.3% to the Large Project's low EIRR. It must be kept in mind that the irrigated pasture uses low-value land suitable for little else, and has low development costs per hectare, so the areas, if compared with those of the state farms, tend to give an exaggerated impression of importance.

The growing of break crops, maize and wheat, contributes nearly 2% to the EIRR and is thus of considerable economic significance as well as being decisive for local and regional self-sufficiency in food production. The EIRR is moderately sensitive to estimates of crop yields and to cost estimates.

According to DPSA criteria, the minimum EIRR for favourable consideration in national planning and financing is about 10%. It is however not necessarily right to apply such a criterion uniformly to all kinds of project. This project develops an area which is currently almost completely without infrastructure and services, and these have been fully costed as a prerequisite of the development and thus a necessary part of the project. This study has taken account of drainage and salinity problems in the irrigated areas, which has not always been done in the feasibility studies of other projects. KIP's economic result should therefore be compared not primarily with a hypothetical, nation-wide and multi-sector target like 10%, but rather with the results of appraisals of other rural projects that provide their own infrastructure, carried out in a comparable way. In the light of criteria beyond the purely economic, it might be found desirable to implement the project despite its forecast EIRR in the range 1 to 4%.

6.4 Other Benefits

There are a number of benefits of the KIP which have not been taken into consideration in the numerical economic analysis. The more notable ones are:

(a) Employment: the project would provide employment for up to about 7 000 people permanently and a further 4 000 intermittently, depending on the scenario chosen, together with housing for up to 55 000 people.

(b) Welfare of pastoralists: KIP would, if the measures to integrate and benefit the Afar were successful, improve living conditions for about 12 000 Afar. Their average-year conditions would be better with more scope for growing food crops and more employment opportunities, but the bigger difference would be in their vulnerability to droughts, which would be very drastically reduced. Health could also be expected to improve.

(c) Environment: the project includes components that would safeguard the surrounding woodlands, firstly by the range management programme and secondly by growing fuelwood in excess of its own requirements, thus reducing pressure towards deforestation in the whole region.

(d) The Awash valley: the reservoir's regulation of Kesem floods and dry season flows would slightly improve conditions in the downstream parts of the Awash valley.

6.5 Finance

This study includes, in Annex N, a financial analysis for the project and for its two productive subdivisions, the state farms and the settlement authority. Not surprisingly in view of the results of the economic analysis, the financial internal rate of return is negative. With the hypothetical assumption of a 'soft' loan of 476 million Birr (of which 14 million is for working capital) with a grace period of 15 years and interest rate of 2%, the project still has an accumulated deficit of over 500 million Birr after 30 years. Such a loan package might be approached by separating the 'settlement' element, which represents just over 10% of the total initial costs for the Medium Project, from the state farm element. All these figures are at 1986 prices assuming a foreign exchange rate of 2.07 Birr per US dollar: with 5% annual inflation the 'price contingencies' would add 40% to the nominal financial cost.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

This chapter brings together the main conclusions of the whole study. To enable the reader to obtain an overview of what is a very complex study, the chapter is kept extremely brief and details must be sought elsewhere in this volume or in the annexes.

The Kesem Irrigation Project (KIP) is found to be technically feasible. On the Kesem-Kebena plain a gravity irrigation scheme can extend to about 14 000 ha net, though the soils are variable and generally fairly poor and it is preferable to restrict the formal irrigation to the better areas, the optimum being probably between 8 000 and 10 000 ha net.

Preferred main crops are tobacco and citrus, which attain good returns but face limited markets, plus cotton, wheat and maize. Soils usable for these crops are sufficient for 7 000 to 10 000 ha net, and further areas can be used for woodlots to produce fuelwood and for irrigated pasture to compensate the 12 000 Afar pastoralists for the loss of their present dry-season grazing area. Maximum use of the land resources implies the inclusion of about 4 000 ha of such pasture, but selective land use could leave much of the present grazing area to the Afar and thus reduce the need for formally irrigated pasture.

The project requires regulation of the Kesem river's highly seasonal flow by means of a dam about 90 m high, for which a suitable site and materials exist. The reservoir formed by the dam would be filled with sediment, probably in less than 100 years, but would provide water for KIP for around 70 years. In earlier decades, before sediment deposits build up, it could provide regulated flow for other schemes in the Awash Valley, and later these schemes could be provided for by other reservoirs, either new or re-allocated.

Use of less than the maximum technically feasible area on the Kesem-Kebena plain represents a modification to the project's objectives, which have been defined as aiming to maximise agricultural potential under a balanced environmental and ecological system. The maximisation should however be viewed for the Awash basin as a whole, and since there are better soils further down the valley it would be inappropriate to irrigate KIP's poorest soils. It is therefore recommended that the plain should be used selectively, irrigating 9 000 to 10 000 ha net as in the 'Medium Project' scenario of this study. At the same time the question of developing a much smaller area, such as 4 000 ha, with no dam, should be investigated.

The area now has little infrastructure and the project would open up some 22 000 ha on the plain and a much larger area in the foothills of the escarpment. It would link with the proposed extended Bolhamo scheme to the north. KIP would bring up to 60 000 people, mostly highlanders, into the area and would provide housing for these immigrants and work for up to 13 000 of them, as well as health and education facilities. The environmental impact is small but positive.

This project is not economically attractive. A careful economic analysis, which takes account of all the relevant costs including social and infrastructure components and the need for drainage and reclamation of unfavourable soils, shows an economic internal rate of return of just over 2%. Under some circumstances it might rise to 4%. Financing would be difficult and would probably require separate packaging of the components dealing with the Afar.

The Consultant's recommendation is that this project should be compared with other projects in the same sector, preferably after they also have been studied in a compatible manner. Projects that can take advantage of pre-existing infrastructure and services may appear economically preferable to KIP, but the economic criteria are not the only ones, and in the development of a country like Ethiopia the opening-up of new areas may be a target in itself. The provision of housing and livelihood for some 60 000 people from the highlands is also a factor, the valuation of which is beyond the scope of this study. Such a comparison might show KIP to be one of the better rural development projects available.

In the mean time, the Ethio-Bulgarian Joint Venture is already active in the project area, with aims that are more limited than those of KIP but not incompatible with them. It is not an alternative or competing project, but a financing and execution package. As such it has the advantage of being already in place, whereas any project springing from this report will take at least two years to reach the stage of action in the field. Integration of the two initiatives should be pursued as soon as possible, using this report to help plan the EBJV's first phase as part of a larger project. In particular, new data should be gathered on relevant matters which were outside the scope of this project, such as the low flows of the Kebena river.

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8.	Halcrow	1985	Master Drainage Plan for Melka Sadi and Amibara Areas (Draft Final Report of March 1985 and Final Report of July 1985).
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13.	DPSA	1981	Guidelines for Project Planning in Ethiopia.
14.	WRDA	1986	Kesem Irrigation Project, Feasibility Study, Comments of the Steering Committee on the Inception Report, Section 4.2.
15.	WRDA	1875	Kesem Irrigation Project, Feasibility Study, Terms of Reference, Clause 1.1(c).

APPENDIX 1 TO MAIN REPORT

FINANCIAL COST DETAILS

TABLE 1/1

Initial Costs per Hectare, in US Dollars

(Thousand US$ per ha, at 1986 financial prices)

Category	Large project		Medium project	
Irrigated area:				
- irrigation system and land preparation	4.09		4.73	
- drainage system	3.13		3.14	
- flood protection	0.87		0.47	
Sub-total		8.09		8.34
Major roads		0.84		1.21
Dam and associated structures		3.72		5.88
Hydropower station		0.40		0.64
Buildings and services:				
- housing	4.21		5.49	
- other buildings	0.35		0.50	
- water supply and sanitation	0.63		0.86	
- electricity supply	0.08		0.12	
Sub-total		5.27		6.97
Afar, range and environmental		0.04		0.06
Vehicles and equipment:				
- agricultural	1.02		1.33	
- non-agricultural	0.38		0.46	
Sub-total		1.40		1.79
Design and engineering		0.21		0.23
Supervision and administration		0.98		1.23
Total Initial Costs		20.95		26.35

Notes: (1) Exchange rate Ethiopian Birr 2.07 to US$ 1.

(2) For explanation of categories see Table 5.8.

TABLE 1/2

Breakdown of Initial Costs Over Time, Large Project

Total Financial Cost (in million Ethiopian Birr at 1986 Financial Prices)

Description	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Total	Direct foreign exchange (%)
Irrigated area:											
- irrigation system and land preparation	-	-	5.96	13.08	7.12	20.42	24.35	13.43	6.48	90.83	51
- deep drainage	-		4.54	10.70	6.16	18.00	20.62	10.82	3.37	74.22	49
- major canals and diversion weir		1.56	4.32	6.61	3.07	6.26	4.74	2.06	-	28.60	43
- large drains and pumping stations	-	-	1.15	3.27	2.13	5.28	3.52	1.07	0.53	16.94	59
- flood protection works	-	-	0.32	1.87	1.55	4.82	5.12	2.35	9.34	25.37	63
Sub-total	-	1.56	16.29	35.53	20.03	54.78	58.35	29.73	19.72	235.96	51
Major roads:											
- access to Awara Melka	-	0.88	0.66	0.44	0.22	-	-	-	-	2.20	63
- Awara Melka to project centre	-	1.60	1.20	0.80	0.40	-	-	-	-	4.01	60
- access to dam site	-	0.57	0.43	0.29	0.14	-	-	-	-	1.43	60
- gravelled roads	-	-	2.56	3.77	1.21	1.62	2.25	2.25	-	13.66	62
- other major roads	-	-	-	-	-	1.67	1.67	-	-	3.34	57
Sub-total	-	3.05	4.85	5.30	1.97	3.29	3.92	2.25	-	24.64	61
Dam and associated structures	-	-	21.71	21.71	32.56	32.56	-	-	-	108.53	59
Hydropower station	-	-	-	-	-	5.89	5.89	-	-	11.77	83
Buildings and services:											
- housing	-	1.86	1.39	12.74	18.19	29.54	29.54	29.54	-	122.80	34
- other buildings	-	0.30	0.23	1.10	1.49	2.36	2.36	2.36	-	10.23	36
- water supply and sanitation	-	1.47	1.10	2.20	2.57	3.67	3.67	3.67	-	18.36	51
- electricity supply	-	0.88	0.66	0.44	0.22	-	-	-	-	2.20	52
Sub-total	-	4.51	3.38	16.48	22.47	35.57	35.57	35.57	-	153.59	37
Afar, range and environmental	0.12	0.12	0.20	0.15	0.15	0.15	0.15	0.15	-	1.18	59
Vehicles and equipment:											
- agricultural	-	-	-	-	3.32	-	8.21	6.38	11.86*	29.77	90
- non-agricultural	-	0.22	0.16	0.11	1.10	2.60	2.60	3.13	1.04	10.97	90
Sub-total	-	0.22	0.16	0.11	4.42	2.60	10.81	9.51	12.90	40.74	90
Design and engineering	-	2.41	1.81	1.21	0.60	-	-	-	-	6.03	45
Supervision and administration	-	1.34	3.70	3.77	5.57	7.34	4.00	2.22	0.62	28.58	52
Total initial costs	0.12	13.21	52.10	84.26	87.77	142.18	118.69	79.43	33.24	611.02	53
Relative initial costs	-	2%	9%	14%	14%	23%	19%	13%	5%	100%	

Note: * Includes costs for Year 9.

TABLE 1/3

Breakdown of Initial Costs Over Time, Medium Project

Total Financial Costs (in million Ethiopian Birr at 1986 Financial Prices)

Description	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Total	Direct foreign exchange %
Irrigated area:											
- irrigation system and land preparation	-		5.96	12.30	6.34	15.24	14.99	8.20	-	63.02	52
- deep drainage	-		4.54	11.40	6.86	16.03	10.73	3.84	-	53.41	49
- major canals and diversion weir	-	1.56	4.32	4.20	0.67	3.65	4.62	1.34		20.36	42
- large drains	-		1.15	1.87	0.72	2.88	1.92	-	-	8.53	56
- flood protection works	-		0.32	0.40	0.07	3.25	3.91	0.76	-	8.72	57
Sub-total		1.56	16.29	30.17	14.66	41.05	36.17	14.14	-	154.04	50
Major roads:											
- access to Awara Melka	-	0.88	0.66	0.44	0.22	-	-	-	-	2.20	63
- Awara Melka to Project Centre	-	1.60	1.20	0.80	0.40	-	-	-	-	4.01	60
- access to dam site	-	0.57	0.43	0.29	0.14	-	-	-	-	1.43	60
- gravelled roads	-	-	2.56	2.56	-	2.02	4.27	2.25	-	13.66	62
- other major roads	-	-	-	-	-	-	0.50	0.50	-	1.00	57
Sub-total		3.06	4.85	4.09	0.76	2.02	4.77	2.75	-	22.31	61
Dam and associated structures	-	-	21.71	21.71	32.56	32.56	-	-	-	108.53	59
Hydropower station	-	-	-	-	-	5.89	5.89	-	-	11.77	83
Buildings and services:											
- housing	-	1.36	1.02	20.27	19.93	29.39	29.39	-	-	101.35	35
- other buildings	-	0.31	0.23	1.87	1.79	2.57	2.57	-	-	9.35	36
- water supply and sanitation	-	1.48	1.11	3.19	2.82	3.68	3.68	-	-	15.97	51
- electricity supply	-	0.88	0.66	0.44	0.22	-	-	-	-	2.20	52
Sub-total		4.03	3.02	25.77	24.76	35.64	35.64	-	-	128.87	37
Afar, range and environmental	0.12	0.12	0.20	0.15	0.15	0.15	0.15	0.15	-	1.18	59
Vehicles and equipment:											
- agricultural	-	-	-	-	3.32	0	8.06	6.23	6.89*	24.50	90
- non-agricultural	-	0.22	0.16	0.11	1.68	2.43	2.43	1.62	-	8.66	90
Sub-total	-	0.22	0.16	0.11	5.00	2.43	10.49	7.85	6.89	33.16	90
Design and engineering	-	1.69	1.27	0.84	0.42	-	-	-	-	4.22	45
Supervision and administration	-	0.64	2.85	4.26	3.74	6.04	3.96	1.07	-	22.57	52
Total Initial Costs	0.12	11.32	50.35	87.10	82.05	125.78	97.07	25.96	6.89	486.65	53
Relative Initial Costs	-	2%	10%	18%	17%	26%	20%	5%	1%	100%	

Note: * Includes costs for Year 9.

TABLE 1/4

Recurrent Costs, Large Project

(Million Ethiopian Birr per year at 1986 financial prices, at full development, excluding agricultural inputs and labour)

Category	State Farms		Settlement		Total	
Staffing:[1]						
- state farms	2.85		0.00		2.85	
- settlement	0.00		0.26		0.26	
- water resources	0.18		0.08		0.26	
- other services	0.29		0.12		0.41	
Sub-total		3.33		0.46		3.79
Agricultural machinery:[2]						
- replacement	4.04		-		4.04	
- operation	5.22		-		5.22	
Sub-total		9.26		-		9.26
Engineering O&M:[3]						
- plant and vehicles	2.73		0.57		3.30	
- building maintenance	0.92		0.08		1.00	
- ID and FP	1.32		0.28		1.60	
- miscellaneous	0.63		0.27		0.90	
Sub-total		5.60		1.20		6.80
Total Recurrent Costs		18.19		1.66		19.85
Relative Recurrent Costs		92%		8%		100%

Notes: (1) Details in Annex N, Section N5.3 and Appendix N4.

(2) Details in Annex N, Section N5.4 and Appendix N5.

(3) Details in Annex L, Section L12.4; excludes staffing.

TABLE 1/5

Recurrent Costs, Medium Project

(Million Ethiopian Birr per year at 1986 financial prices, at full development excluding agricultural inputs and labour)

Category	State Farms		Settlement		Total	
Staffing:(1)						
- state farms	2.36		0.00		2.36	
- settlement	0.00		0.11		0.11	
- water resources	0.22		0.04		0.26	
- other services	0.35		0.06		0.41	
Sub-total		2.94		0.21		3.15
Agricultural machinery:(2)						
- replacement	3.13		-		3.13	
- operation	4.10		-		4.10	
Sub-total		7.23		-		7.23
Engineering O&M:(3)						
- plant and vehicles	2.32		0.28		2.60	
- building maintenance	0.79		0.06		0.85	
- ID and FP	1.10		0.10		1.20	
- miscellaneous	0.64		0.11		0.75	
Sub-total		4.85		0.55		5.40
Total Recurrent Costs		15.02		0.76		15.78
Relative Recurrent Costs		95%		5%		100%

Notes: (1) Details in Annex N, Section N5.3 and Appendix N4.

(2) Details in Annex N, Section N5.4 and Appendix N5.

(3) Details in Annex L, Section L12.4; excludes staffing.

Figure 3.1

The Project Area

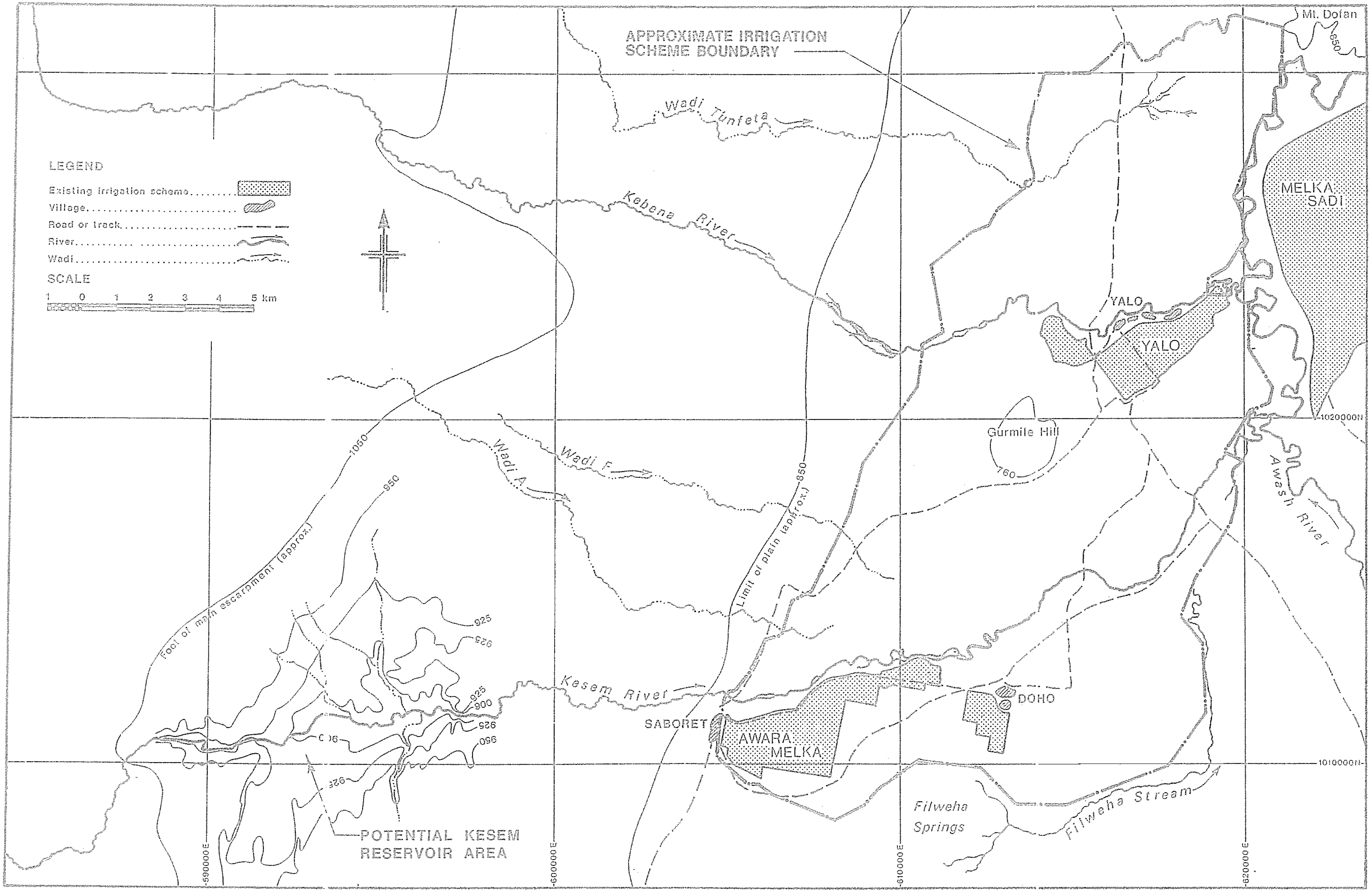

Figure 5.1

Project Layout (Large Project)

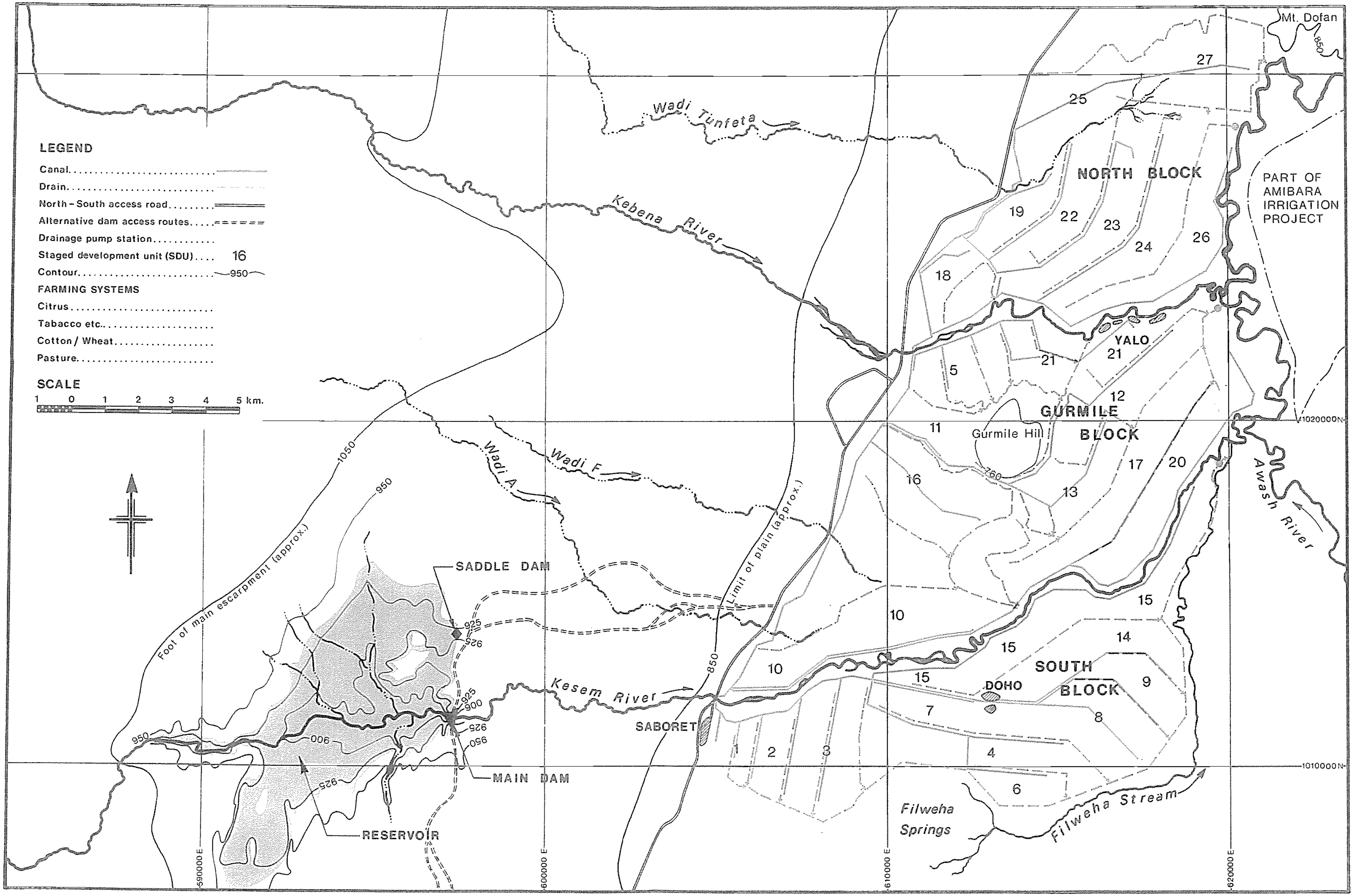

Figure 5.2

Project Layout (Medium Project)