JAMHUURIYADDA DIMOQRAADIGA SOMAALIYA
WASAARADDA BEERAHA
SOMALI DEMOCRATIC REPUBLIC
MINISTRY OF AGRICULTURE

DARA SALAAM BUSLEY AGRICULTURAL DEVELOPMENT PROJECT

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Soils

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ABBREVIATIONS FREQUENTLY USED IN THE REPORTS

AFMET	Agriculture, Farm Management Extension and Training Project
API	Aerial photographic interpretation
CARS	Central Agricultural Research Station - Afgoi
CIF	Carriage, insurance and freight
CSB	Commercial and Savings Bank
DLF	Development Loan Fund
EAA	Euro Action Acord
EC	Electrical conductivity
ECU	European Currency Unit
EDF	European Development Fund
ENB	National Banana Board or Ente Banane
FAO	Food and Agriculture Organization, United Nations
FOB	Free on board
HASA	Hides and Skins Agency
HTS	Hunting Technical Services Limited
GOS	Government of Somalia
GTZ	German Technical Aid
id	Internal diameter
IRAS	Inter-Riverine Agricultural Study
IRR	Internal rate of return
JSP	Juba Sugar Project
IBRD	International Bank for Reconstruction and Development
IDA	International Development Association (of the IBRD)
ILCA	International Livestock Centre for Africa
IMF	International Monetary Fund
ITCS	Inter-Tropical Convergence Zone
MLFR	Ministry of Livestock, Forestry and Range
MMP	Sir M. MacDonald & Partners
MOA	Ministry of Agriculture
NCA	Net cultivated area
NFMAS	National Farm Machinery and Agricultural Service
NTTCP	National Tsetse and Trypanosomiasis Control Project
ODA	Overseas Development Administration, British Government
ONAT	Former name of NFMAS
SACA	Societa Azionari Concessionari Agricoli de Genale
SAR	Sodium adsorption ratio
SC	Specific capacity
SDB	Somali Development Bank
SoSh	Somali Shilling
SY	Specific yield
TOR	Terms of Reference
UNCDF	United Nations Capital Development Fund
UNESCO	United Nations Educational, Scientific and Cultural Organization
USAID	United States Agency for International Development
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture

SPELLINGS OF PLACE NAMES

Throughout the report Somali spellings have been used for place names with the exception of Mogadishu and Afgoi where the English spelling has been used. To avoid misunderstanding, we give below a selected list of Somali, English and Italian spellings where these differ.

Somali	**English**	**Italian**
Afgooye	Afgoi	Afgoi
Aw Dheegle	-	Audegle
Balcad	Balad	Balad
Baraawe	Brava	Brava
Buulo Mareerta	Bulo Marerta	Bulo Mererta
Falkeerow	-	Falcheiro
Gayweerow	-	Gaivero
Golweyn	-	Goluen
Hawaay	Avai	Avai
Janaale	Genale	Genale
Jelib	Gelib	Gelib
Jowhar	Johar	Giohar
Kismaayo	Kisimaio	Chisimaio
Marka	Merca	Merca
Muqdisho	Mogadishu	Mogadiscio
Qoryooley	-	Coriolei
Shabeelle	Shebelli	Scebeli
Shalambood	Shalambot	Scialambot

GLOSSARY OF SOMALI TERMS

Cambuulo	-	Traditional dish of chopped boiled maize with cowpeas or green grams
Chiko	-	Chewing tobacco
Der	-	Rainy season from October to December
Dharab	-	Five jibals or approximately 0.31 ha
Gu	-	Rainy season in April and May
Hafir	-	Large reservoir on farms for storing water for use in dry periods
Haagai	-	Climatic season June to September characterised by light scattered showers
Jibal	-	Area of land approximately 25 m by 25 m or 0.0625 ha
Jilaal	-	Dry season from January to April
Kawawa	-	Two-man implement for forming irrigation borders
Quintal		Unit of weight measurement equivalent to 100 kg
Uar	-	A stock watering pond
Yambo	-	Small short-handled hoe
Zareebas	-	Thorn stock pen

ANNEX 1 - SOILS

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CHAPTER 1

INTRODUCTION

1.1 Location of Study Area

The project is located on the left bank of the Lower Shabeelle river between latitudes 1°46' and 1.58'N and longitudes 44°43' and 44°55', 80 km south-west of Mogadishu (see Figure 1.1) at an altitude of approximately 60 to 80 m above sea level.

The area lies on alluvial lands between the present course of the river and the coastal sand dunes. The project boundaries, as revised by MOA after the Consultant team's arrival, are shown in Figure 1.2. They now include wetter lands (Jilaal Moogi swamp area), but exclude a central block of approximately 5 400 ha, at the time of carrying out the study, reserved for development as a fuelwood lot.

1.2 Objectives of the Study

The primary objective of the soil and land suitability studies was to provide basic data for assisting with project planning, notably evaluating the potential of the land for irrigated and rainfed agricutural development. The Terms of Reference (TOR) of the study are in Appendix I.

1.3 Background to the Study

The soils of the project area are developed by the Shabeelle river floodplain and consist predominantly of vertic clays interspersed with relic river channels and their associated coarse and medium textured deposits.

The approach was based on a review of the relevant literature, followed by an aerial photo interpretation (API) appraisal of the major natural resource units, and a short field survey and sampling programme to characterise the major soil types and constraints to agricultural development. Since measurements of soil physical parameters, such as surface infiltration rates, subsoil hydraulic conductivities and moisture retention were not included in the TOR, data from an earlier (1975) study by the Consultant in the adjoining area were extrapolated.

Since project boundaries were subsequently redefined, the siting of soil observations in some cases are outside the project area. Due to difficulties of access, the Jilaal Moogi area (Annex 9) has not been surveyed in detail; should any major changes in current land use be contemplated, further investigations would have to be carried out.

Observations have been confined to the major landform units suitable for further development. Any areas of obvious unsuitability for agricultural development on topographical grounds have been surveyed at a minimal intensity, to enable the collection of maximum information on areas with good agricultural development potential.

1.4 Report Format

This report consists of a brief description of the environment (Chapter 2) followed by a detailed presentation of the soils information gained during the fieldwork (Chapter 3). It includes a detailed review of previous soil studies of particular relevance to the project area which provide additional information. The characteristics of the soil mapping units as outlined in Chapters 3 and 4 are supported by detailed descriptions and laboratory analyses in Appendices III and IV. The information contained in Chapters 3 and 4 was used to assess the land suitability of the various soil mapping units for particular land utilisation types, described in Chapter 5.

The work detailed in Chapters 2 to 5 enables the production of three thematic maps, numbered 1A, 1B and 1C on land use, soils and land suitability respectively, which are to be found in folders at the end of this annex.

Figure 1.1

Location of the Study Area

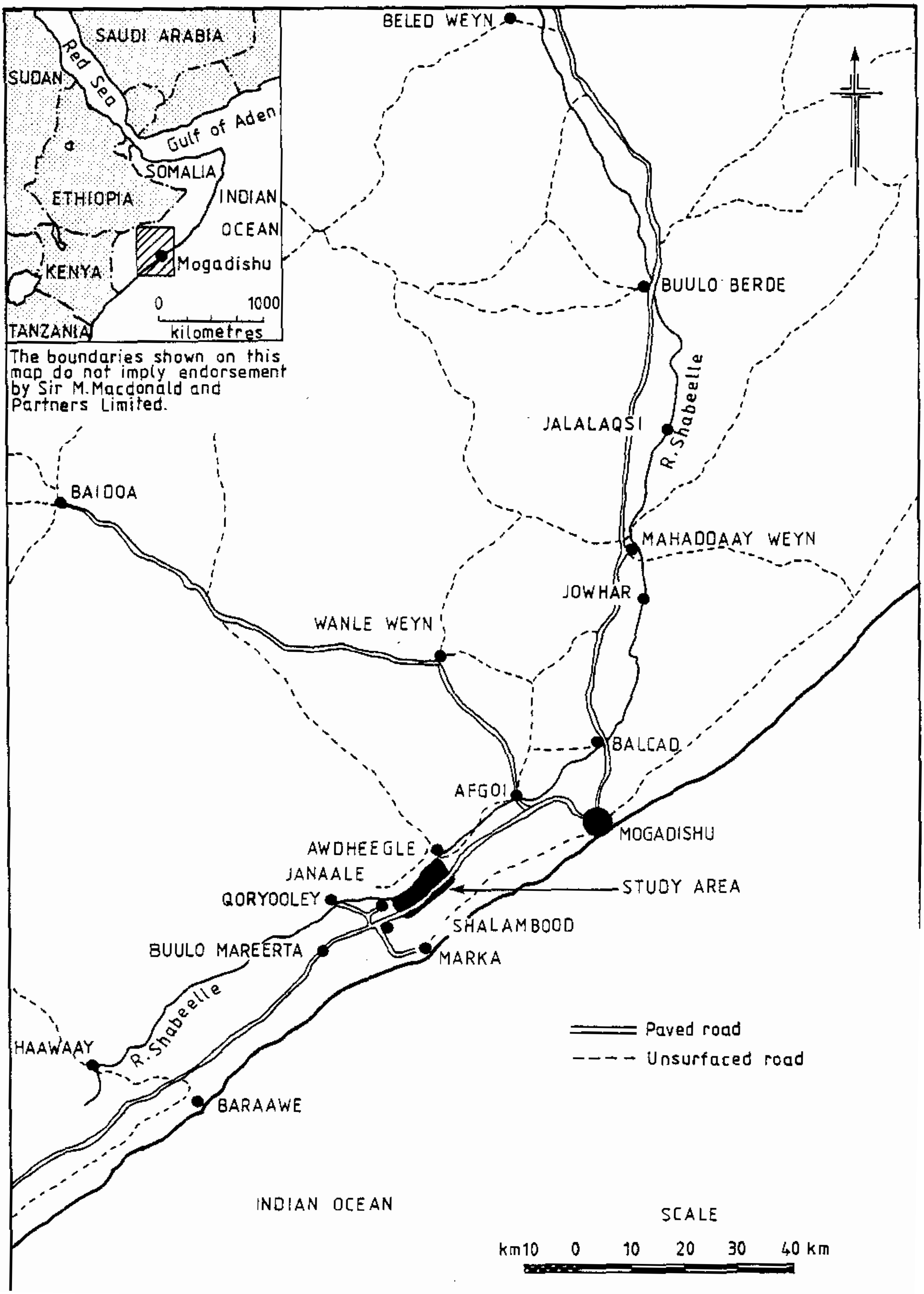
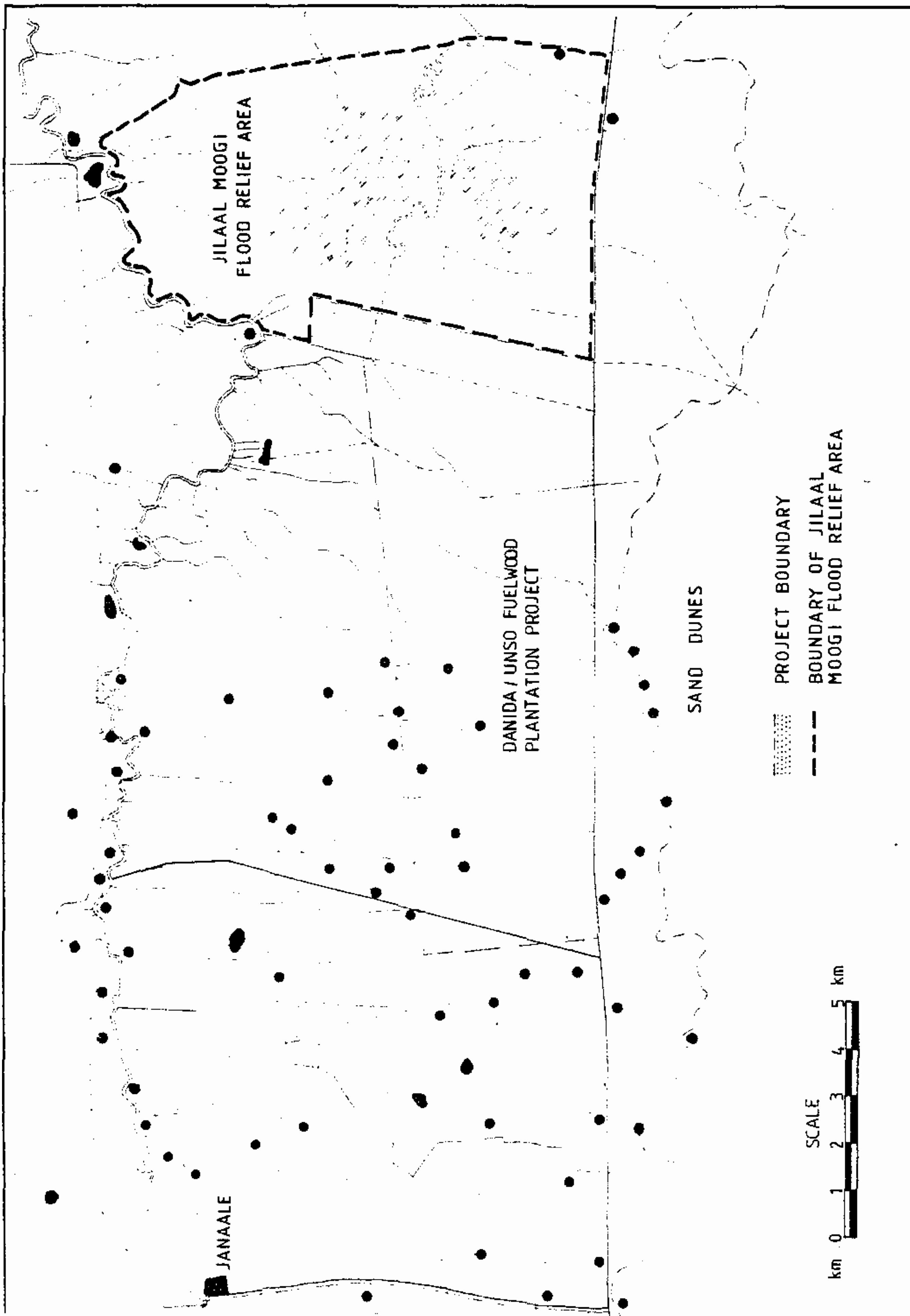


Figure 1.2

Revised Project Area Boundaries



CHAPTER 2

ENVIRONMENT

2.1 Geomorphology and Parent Materials

The source of parent material from which the project area soils are developed is the result of the various depositional and erosion activities of the Shabeelle river within its present and former meander floodplains. Considerable variation of past river activities is observed in the floodplain, which has produced noticeable geomorphological features, notably channel remnants, meander scars and associated levees.

Some areas of the floodplain in close proximity to the present course of the river are still undergoing modification due to further alluvial deposition. Other areas further from the present river course are outside present river influences, although further erosional activity is expected due to surface runoff caused by the high-intensity rainfall.

The presence of alluvial material of varying ages formed a fundamental basis for soil mapping, (MMP 1978), in which soils were initially divided into those of recent, semi-recent or old Shabeelle alluvium in the Genale-Bulo Marerta area.

This complex depositional history is repeated in the Dara Salaam-Busley area and has produced several landform sub-divisions within the main meander floodplain. The soils associated with these features show considerable variations in texture. Some landforms exhibit relatively simple depositional patterns resulting in more uniformly textured, but less well drained, fine textured vertic clays, which form the major soil mapping units. In contrast, the significantly more limited areas of medium textured soils are associated with the levees and upper cover plains in closer proximity to old channel remnants, running generally parallel to the current river course. Other minor channel remnants, meander scars and associated overflow channels form less extensive and more localised coarse and medium textured soils.

2.2 Climate

The climate is tropical, semi-arid. The mean annual precipitation over the project area is in the region of 480 mm as recorded at the Janaale meteorological station. Temperatures are uniform throughout the year: mean monthly maxima range from 29°C to 33°C and minima from 21°C to 24°C. Open-pan water evaporation is estimated to be about 5.4 mm/d; the highest values occur during the hot dry season from January to April. Detailed descriptions of climate are in Annex 2.

The success of rainfed agriculture is dependent on sufficient rainfall. Precipitation occurs mostly in two distinct seasons, the gu and the der. A major proportion of the yearly precipitation occurs during the gu which normally extends from mid-April to July, with following lighter haagai rains until August or September. The der season with generally lower and less reliable rainfall than the gu is between November and December when risk of crop failure is higher than in the gu. The season extending from January until the onset of the gu rains is the jilaal, which is the hottest and driest period of the year: flows in the Shabeelle drop considerably and, before the construction of the Jowhar storage even dried up altogether. It is during this period of scarcity of surface water that orchard crops are irrigated by groundwater, which is often of low quality.

The mean annual precipitation over the project area influences land suitability assessments for rainfed agriculture. In this report rainfall class limits have been adopted from the Inter-Riverine Study by Hunting Technical Services (HTS) (1977) which states that land in areas of mean annual precipitation between 400 and 500 mm can be considered as only marginal for rainfed cropping.

2.3 Vegetation and Land Use

2.3.1 Vegetation

The present pattern of land use has resulted in the removal of much of the original vegetation. Most of the area has been under some form of cultivation and areas of regenerating secondary thicket and bushland can be seen in old abandoned fields. Species of Acacia, including A. mellifera, A. nilotica and A. tortilis dominate. Other woody shrubs found in association with this primary vegetation are Terminalia orbicularis, Euphorbia robecchu, Commiphora spp and Grewia spp.

Typical species of deciduous bushland and shrubland which often remain drought dormant through much of the year include A. bussei, A. seyal, A. nilotica, A. nubica, A. senegal, Dichrostachys spp and Salvadora persica. On land that has been more recently cultivated and is currently fallow, other species include Thespesia spp, Abutilon spp, Echinochloa spp and Ipomoea spp. Intensive farming on irrigated areas have given rise, in many areas, to a distinctive parkland type vegetation with a landscape dominated by widely scattered mature Dobera glabera with localised grasses and herbs on non-cultivated margins.

In the wetter Jilaal Moogi area, grasses such as Echinochloa spp and Andropogon spp are found, adding further to accumulated organic matter debris. In the swamp area large communities of Typha latifolia occur.

2.3.2 Land Use

The main land use features of the project area have been prepared from an uncontrolled mosaic of the March 1983 aerial photography and areas subsequently calculated by the use of a squared grid. The details of the gross areas are presented in Appendix IV, Table IV.1. A representative map from which area measurements were derived is shown on map 1A at the end of the report, together with the soils and land suitability maps. A simplified summary is shown in Table 2.1. The present land use in close proximity to the river is based on irrigation agriculture which commenced in the 1930s and covers some 21% of the area. Perennial irrigated crops appear to occupy a very small proportion of the irrigated area, which has probably decreased since the original installation of the irrigation schemes. The majority of the irrigated area appears to consist of flood irrigation for annual crops, including maize, sesame, tomatoes, melons and cotton, away from the river; their distribution being affected by availability of irrigation water. Approximately 17% of the irrigated areas is fallow.

The more marginal areas away from sources of irrigation water are under rainfed subsistence cropping; maize and sesame are the major crops which occupied 5% of the project area under cultivation in 1983. Fallow areas include long- and short-term fallow; they occupy 15% of the rainfed area.

TABLE 2.1

Land Use in March 1983

	Broad land use categories	Area (ha)	Area (%)
1.	Irrigated perennial crops (bananas and grapefruit)	115	0.5
2.	Irrigated annual crops	4 335	20.0
3.	Grazing and browse vegetation	14 060	63.5
4.	Marginal rainfed crops	1 150	5.0
5.	Dense bush	900	4.0
6.	Swamp	1 310	6.0
7.	Villages and main road	265	1.0
Total		22 135	100.0

Note: Area figures are derived from Table IV.1 in Appendix IV.

The cropped areas in both irrigated and rainfed zones have increased since 1983 as was apparent in the Consultant's field surveys. It is in part attributable to relaxation of GOS price and marketing controls.

Livestock and browsing is generally confined to the fallow areas, non-cultivated field, canal margins and uncultivated areas including large extents of grassland found in the Jilaal Moogi flood relief areas occupying approximately 63% of the project area in 1983.

Further details of areas and explanatory notes are to be found in Appendix IV of the report and in Annex 9.

CHAPTER 3

SOILS

3.1 Methods of Study

The survey was carried out in March 1987 in accordance with the Terms of Reference with regard to the type of survey, overall observation density and sampling programme.

From an examination of previous studies as described in Section 3.2 and interpretation of the 1 : 30 000 scale aerial photographs, the major soil, land-form and vegetation units were delineated, although this was complicated by the existing and abandoned irrigation schemes.

Following the initial phase of extensive aerial photo interpretation, a field reconnaissance was made to assess the soil and land capability characteristics of the area. This field survey consisted of 40 free survey auger borings to a depth of 1.2 m where soil conditions permitted, supplemented by 10 soil pits excavated to a depth of 2 m at carefully selected sites in major soil mapping units. This produced an overall density of one site per 420 ha.

The pits were described in accordance with the FAO Guidelines for Soil Profile Description (1977). The following morphological properties were included for each pedologically significant horizon:

- soil colour and mottling (using Munsell notation);
- texture and consistency;
- structure and pore size distribution;
- soluble salts and carbonates;
- nodule contents;
- rooting patterns;
- boundary conditions.

The major pedological horizons at each pit site were sampled at an average of four samples per pit. In all some 40 samples were submitted to the Central Agricultural Research Station, Afgoi, for the following analyses:

- pH;
- electrical conductivity (EC);
- cation exchange capacity;
- available phosphorus and potassium;
- total carbonate;
- organic carbon and nitrogen (topsoil only);
- gypsum content;
- soluble anions and cations on samples where the EC of the saturation extract exceeds 2 mS/cm;
- particle size.

Further studies of relevant literature and aerial photography together with soil data obtained from the survey enabled an initial compilation of the soil and land suitability maps at a scale of 1 : 30 000 from an uncontrolled mosaic, which was subsequently reduced to fit the 1 : 50 000 scale of the project base map.

The distribution of the soil mapping units and soil classes are shown in Map 1B, together with the location of soil observation sites. The soil mapping units were reinterpreted to show land suitability for selected land utilisation types under irrigated and rainfed conditions and are shown in Map 1C.

3.2 Review and Interpretation of Previous Studies

The most extensive soil survey undertaken in the Shabeelle valley was that carried out by Lockwood/FAO (1968) producing maps of landform/soil units at 1 : 60 000 scales. These data were reinterpreted by HTS (1977) without additional fieldwork to produce maps at 1 : 500 000 scale for land suitability assessments for irrigated and rainfed agriculture. According to these studies the Dara Salaam-Busley area lies within the Golweyn soil unit which is a chromic vertisol developed in the old floodplain alluvium.

In addition there have been a number of review studies as well as semi-detailed and detailed soil and land classification surveys in Southern Somalia; those of direct relevance to the Dara Salaam-Busley Project are listed in Table 3.1.

TABLE 3.1

Previous Relevant Studies

Survey organisation	Title of study
TAMS(1) (1986)	Genale Irrigation Rehabilitation Project Feasibility Study.
Citaco(2) (1974)	Final design for a Grapefruit Plantation (near Buulo Mareerta).
MMP(3) (1978)	Genale-Bulo Marerta Project
MMP(4) (1978)	Jowhar Sugar Estate: Drainage and Reclamation Study
MMP(5) (1985)	Farjano Settlement Project
LRDC(6) (1985)	Resource Development in the Shabeelle Valley
LRDC(7) (1985)	Land Use in Tsetse-affected Areas of Southern Somalia
HTS(8) (1977)	Inter-Riverine Agricultural Study
FAO/Lockwood(9) (1968)	Agriculture and Water Surveys, Somalia.

Note: Numbers in brackets are referred to in text.

To make the soil classification of the present study compatible with previous studies in the area, interpretation of the soil data from the present study have been based on MMP(3). The adoption of broad soil classification and mapping units sufficient to delimit the main soil types at a feasibility level have been correlated as far as possible to those of MMP(3) in Chapter 4 of this report.

The study of MMP[3] based initial soil series identifications on Saruda and Golweyn soil units as defined by Lockwood/FAO[9] and further defined nine additional soil series. The relationship of these soil series to physiography, age of parent material and soil class are shown in Table 3.2. The soil classification adopted by MMP[3] was the same as the present study, being based on the Legend of the FAO Soil Map of the World (1976). The study by MMP[3] report a predominance of two major soil classes (see Table 3.2) consisting of chromic vertisols, eutric and vertic cambisols which were distinguished by mode of deposition, the less well drained vertisols being confined to the main floodplain and the cambisols being largely located on the narrow ridges of former river levees. Distinctions have been outlined by MMP[3] between the older dark greyish brown and brown clays which contain significant amounts of shell fragments, and the reddish brown clays of more recent alluvial origin.

TABLE 3.2

Review of Soils of Janaale-Buulo Mareerta Area

Soil series	Physiography	Soil class
Soils derived from Old Floodplain Alluvium:		
Saruda	Main floodplain	Chromic vertisols
Dhoblow	Meander scars	Vertic cambisols
Golweyn	Main floodplain	Chromic vertisols
Majabto	Floodplain near channel remnant, depressions	Vertic cambisols
Shalambood	Channel remnant levees	Vertic cambisols
Soils derived from Semi-recent Floodplain Alluvium:		
Madhuulow	Main floodplain	Chromic vertisols
Qoryooley	Main floodplain	Chromic vertisols
Mukoy Dumis	Main floodplain	Chromic vertisols
Buulo Mareerta	Minor channel remnants and low ridges	Eutric cambisols
Soils derived from Recent Floodplain Alluvium:		
Faraxaane	Minor overflow channel remnants	Eutric cambisols
Gayweerow	Overflow channels and levees of Shabeelle river	Vertic cambisols

Source: MMP[3] 1978

Reports by MMP[3] note that there may be a significant difference between subsoil permeabilities of the old and semi-recent alluvial vertisols based on the degree of development and retention, when saturated, of soil structure. However, all drainage classes of the major mapping units of vertisols are classed as moderate in the MMP[3] study. The difference in drainability of the subsoils MMP[3] was used as a primary criteria in land suitability assessments. However, only limited measurements of hydraulic conductivities were made in the vertisols by MMP[3]; in particular there are limited data on the long-term effects of continuous irrigation apart from visual field observations. The soil pits opened during the present study on land which has been influenced by irrigation for more than 50 years did not reveal any observable differences in structures or drainage status (as indicated by mottle colours and distribution) between vertisols of old and semi-recent alluvium within the irrigated areas. For planning purposes these soils have been included in the same drainability class; however, this could be subject to modification following more detailed site measurements.

The floodplain vertisols are reported by LRDC[6] to accumulate electrolytes such as salt, gypsum or calcium carbonate which implies that under sustained irrigation, especially if supplemented with low quality irrigation water, careful water management is a pre-requisite for successful crop production. Evidence for potential problems is outlined by MMP[4]. However, there is currently no evidence from recent soil analysis in the project area, even in soils that have been irrigated for over 50 years, to suggest that soil salinity is currently a problem. This indicates that the water management techniques presently adopted provide for sufficient leaching of soluble salts under the current intensity of perennial cropping.

Other soil classes have been distinguished in other studies MMP[3][5] and TAMS[1] in some detail, which include cambisols and fluvisols of most relevance to our study. These occupy a comparatively small area, are of minor importance for irrigated agriculture, and have not been studied or classified in detail. Preliminary studies suggest that the levee soils of the more recent alluvium consist predominantly of eutric or calcaric fluvisols. Soils in similar landscape positions on old alluvium consist largely of eutric or vertic cambisols since these older profiles are more likely to have undergone secondary weathering in situ since deposition. The soil profiles are generally stratified and of variable medium textures with waterholding capacities varying from moderate to poor depending on texture.

Investigations on Lower Shabeelle soils are documented more fully in MMP[5] with regard to rainfed suitability, although limited data are available on moisture holding characteristics. Other data used in assessing the suitability of the major soil classes is provided by HTS[8] and show that most of the EAWC accounts for much less of the total AWC in the fine textured vertisols compared to many of the medium textured, non-vertic soils. However, MMP[5] suggest that the vertisols have a good potential for rainfed cropping due to the extensive cracking system and surface mulch which allows a good capacity for receiving rainfall when not extensively cultivated. This property facilitates a rapid recharge of soil moisture. Under natural conditions where no or minimal surface cultivation is practised, the nature of the surface horizons has important consequences for the ability of the soil to recharge moisture under brief but heavy inundation by rainfall. This has been shown to be an important factor in relation to the variable but generally medium textured cambisols and fluvisols. In their natural state they cap with no evident self-mulching processes, which causes rapid surface runoff of rainfall with little initial wetting of the deeper root zone. The variation in texture in some cases from coarse to medium are reported to exacerbate the situation by allowing rapid draining of any accumulated water in the profile which may be preceeded by surface cultivations. Other reports, MMP[3][5], Lockwood[9], indicate a greater tendency of these soils to show accumulations of salts nearer the profile surface, although this was not confirmed in the present study.

Studies by HTS[8] and MMP[5] show that the overall suitability of all soils for rainfed cropping is further influenced by rainfall which means that even soils with the most favourable characteristics are downgraded to a marginal status when rainfall is between 400 to 500 mm/year. This has important consequences for the coarser and medium textured soils which have more limited capacities to receive rainfall under natural conditions which means that they cannot be considered currently suitable at this level of investigation. This brief review of previous studies together with comments on current findings highlight the more salient points that need to be considered in greater detail in further sections of this report.

3.3 Soil Origins

The soils confined to the lower level intervening floodplain areas are mainly vertisols of old and semi-recent alluvium and those in higher positions in close proximity to old channel remnants are mainly eutric and vertic cambisols and eutric and calcaric fluvisols depending on alluvial age.

3.3.1 Fine Textured Meander Floodplain Soils

The soils mapped were mainly clayey in texture and were probably deposited from the series of remnant river courses of variable age which are clearly visible from aerial photography. A common feature of these older clay textured soils are their dark brown to greyish brown colours and presence of many shell fragments, representing former swampy conditions. Another feature is the presence of fine $CaCO_3$ concretions and soft powdery $CaCO_3$ in the profiles which may have developed as part of pedogenic processes during vertisol formation after the disappearance of former inundated conditions. Gypsum crystals are also observed at depth in the majority of profiles.

A further important feature of these predominantly clay soils is their surface microrelief characterised by gilgai formation, which is the result of seasonal shrinkage and swelling of montmorillonitic clays. The resultant development of characteristics associated with these processes is well documented by MMP (1978).

The associated microtopography produces a series of hollows and raised areas of varying amplitude which have been characterised by MMP (1985). During the dry season a surface mulch forms and where it obscures cracks, sink holes develop. The extent of development of these surface features has been documented by MMP (1985).

The processes of gilgai formation will cause movement of subsoil units to produce slickensides and broken shell fragments. The above mentioned factors are most pronounced in the rainfed areas of old alluvium in contrast to those under varying intensities of irrigation where gilgai are less well developed or absent altogether.

The more recent vertisols, developed in semi-recent alluvium, consist mainly of reddish brown clays in similar landscape positions. They overlie the older alluvium in varying depths. Similar surface and profile features were observed in these soils to those of the vertisols developed in older alluvium, although shell fragments, $CaCO_3$ concretions and gypsum crystals were only few or absent, these being confined to the deeper lying older alluvium.

3.3.2 Medium Textured Meander Floodplain Soils

Medium-textured soils were encountered mainly on higher areas adjacent to prominent abandoned channels of the Shabeelle river. These soils occur throughout the project area, having a firm capped surface which does not exhibit any gilgai or surface mulch development. Shell fragments are not common. $CaCO_3$ concretions are also generally few but the profiles are strongly calcareous. The profiles have mainly stratified horizons of friable dark brown to dark yellowish brown clays, clay loam, silt loam, sandy clay loam, sandy loam and silty clay loam textures. Not all textural groupings are necessarily found in one profile and considerable variations are observed depending on location. These soils are found on both old and semi-recent alluvium in the project area and have been shown to contain fluvisols in the semi-recent alluvium and most likely to include a predominance of eutric or vertic cambisols in the old alluvium (MMP 1978), although at this level of investigation these statements must be regarded as tentative.

3.4 Soil Classification

The soils in the project area have been classified according to the FAO/UNESCO Legend (1974). This is a tentative classification since soils other than chromic vertisols, which represent the major area of soil mapping units, have not been investigated by pit excavation at enough sites within representative mapping units. The classification is shown in Table 3.3 and correlation has been made, as far as possible, with USDA Soil Taxonomy (1975).

TABLE 3.3

Soil Classification - FAO and USDA Systems

Soil mapping unit	FAO	USDA (Soil taxonomy)
A1	Chromic vertisol	Paleustollic Chromusterts
A2	Chromic vertisol	Paleustollic Chromusterts
A3(1)	Vertic cambisol	Vertic Ustropept
B1	Chromic vertisol	Paleustollic Chromusterts
B2	Calcaric fluvisol	Typic Ustifluvent
C1(1)	Pellic vertisol	Typic Pellustert

Note: (1) The criteria for classification of these mapping units are provisional and are based on experience gained on the Genale-Bulo Marerta Project (MMP 1978), and Farjano Settlement Project (MMP 1985).

3.5 Soil Characteristics

3.5.1 Soil Morphology

(a) Soil texture

Soil textures for the representative profiles as determined by laboratory analysis are summarised in Table 3.4 and further details are recorded in Appendix III.

TABLE 3.4

Soil Textures for Representative Soil Classes

Site number	Mapping unit	Texture sequence	Mean clay (%)(1)	Classification
PG 01	A1	C	62	Chromic vertisol
PG 02	A1	C	56	Chromic vertisol
PG 03	A2	Zc	45	Chromic vertisol
PG 04	B1	Zc-C-Ls	46	Chromic vertisol(2)
PG 05	B2	Scl-Zl-Scl	24	Calcaric fluvisol
PG 06	A2	C	55	Chromic vertisol
PG 07	B1	C	72	Chromic vertisol
PG 08	A2	Zc-C	53	Chromic vertisol
PG 09	B1	C	60	Chromic vertisol
PG 10	A1	C	59	Chromic vertisol

Notes: (1) Data for mean clay (%) in top 120 cm.

(2) Satisfies soil classification criteria for vertisols, but loamy sand texture below 76 cm.

The majority of soils have moderate to high clay contents with high proportions of silt fractions associated with these textures (Appendix III). These fine textured vertisols fall predominantly into the clay classes with some silty clays present in a small number of profiles. The derived cation exchange capacities (CEC) for the clay fractions in the vertisols are greater than 25 meq/100 g soil, indicating a predominance of illitic or montmorillonitic clay minerals.

The clay content is lower in the soils occuring on minor ridges associated with channel remnants and overflow channels in the central part of the area, and while PG 05 cannot be considered truly representative of these variable textured soils, it indicates significant textural differences from the fine textured vertic clays. Auger hole observations on soils in similar landscape positions on old alluvium in mapping unit A3 confirm that field textures are significantly different from the vertic clays in these soils, although further investigations by pit excavation are necessary to confirm these findings. Textures for these field auger hole observations are shown in Appendix V. Similarly those textures noted in mapping unit C1 are inferred from field texturing of auger hole observations.

Pit number PG 04 satisfies the FAO criteria for inclusion in the soil class of chromic vertisol even though a significant textural change is noted below 76 cm. This coarse textured subsoil appears to represent a buried soil, possibly of old aeolian dune or sandy alluvial deposit from the river Shabelle.

Analysis of the sand fraction is required to enable any correlation to other sand parent material sources. However, this profile does not appear to be representative of the mapping unit as delineated from aerial photographic interpretation, and a significant increase in soil observation density would be required to identify these profile characteristics as typical of a separate mapping unit.

Reference is made to FAO textural groupings throughout this report and the definitions of these coarse, medium and fine textured groupings are shown in Figure 3.1.

(b) Soil Structure and Consistency

Soil structure has important consequences for root penetration, drainability and tillage. The structures in vertisols were examined in the dry state when structural development is most pronounced and are described in the soil profile description, in Appendix III. Aggregate stability observed on wetting was poor. This could be expected to produce a structureless profile in the wet state. Initial water penetration is known to be high on dry vertisols due to extensive vertical cracking but ultimately under saturated conditions water movement will be significantly reduced.

Tillage on these naturally self-mulching soils is limited since in the dry state the soils are very hard. Ploughed fields examined in this survey had a surface layer of large hard clods. Effective ploughing in this condition will require a high power input, especially if reasonable seedbed conditions are to be created. In contrast any attempted tillage under wet conditions produces a structureless puddled soil which means that the range of moisture contents in which tillage is feasible is limited. The natural self-mulching processes can be expected to provide a good seedbed without soil preparation. However, ploughing may still be required for weed control. Soil mapping units A1, A2 and B1 which represent vertisols on old and semi-recent alluvium respectively showed considerable variation in compactness of subsoil horizons, the larger structural units in some cases being friable and breaking into smaller structural units. However, the conchoidal blocky structures observed (MMP 1978) in semi-recent alluvial vertisols which are believed to aid profile drainage were not noted in this survey based on its limited number of observations.

3.5.2 Soil Moisture Relations

No tests were carried out to assess the soil-water relations of the soils of the study area. Therefore a brief review of data (MMP 1978) relevant to the soil series described in the mapping units of this report will give general guidelines. Comprehensive studies were carried out in the Genale-Bulo Marerta Project (1978) on comparable soil types.

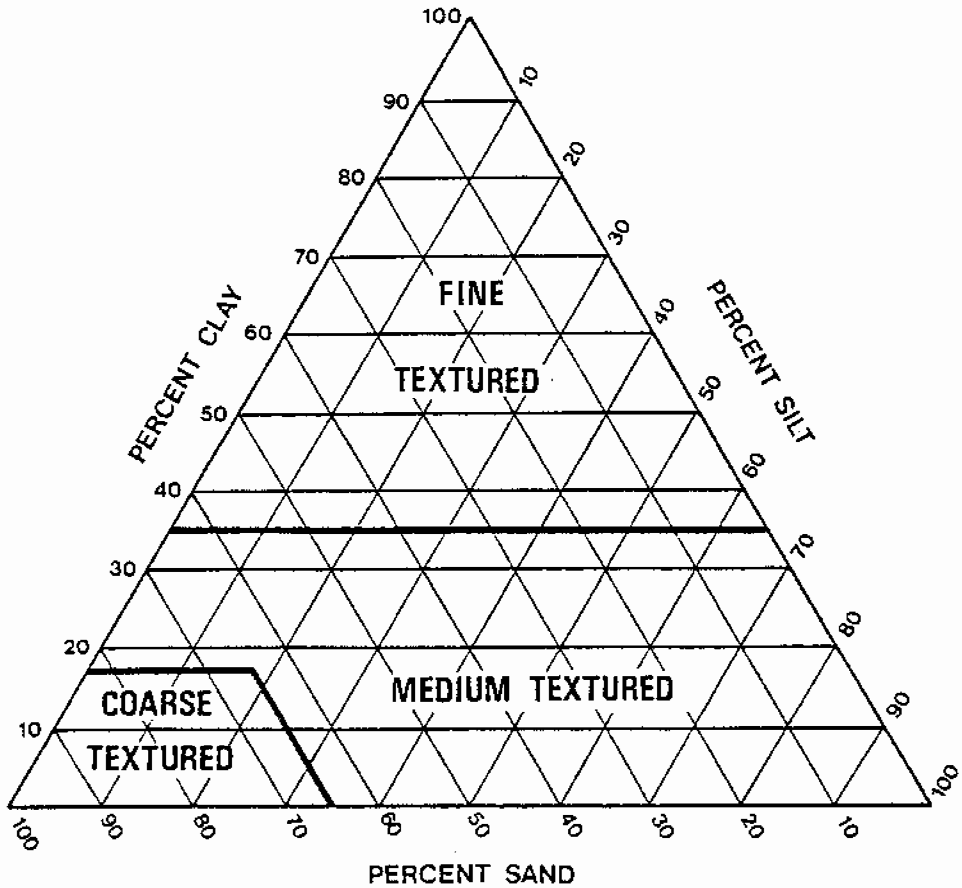
(a) Infiltration

Reliable estimates of infiltration are difficult on vertisols since initial entry of water in the dry cracked state is determined by the volume of cracks. Data obtained by MMP (1978) illustrate a cumulative infiltration of 300 mm in 5 hours in an initially cracked dry soil of the Saruda Series. This series is developed in old alluvium and corresponds to mapping unit A2. Under a normal irrigation regime in which cracking is absent the 8 hour cumulative intake capacity was in the range 75 to 85 mm. It was also noted that water intake continued in vertisols of the semi-recent alluvium after 8 hours but ceased in the vertisols of the old alluvium (MMP, 1978).

Soils with significant medium textured horizons showed a greater cumulative intake with rates of entry between 5 and 10 mm/h after 7 hours.

Figure 3.1

F.A.O. Land Classification Textural Groupings



1. Coarse textured: sands, loamy sands and sandy loams with less than 18 per cent clay, and more than 65 per cent sand.

2. Medium textured: sandy loams, loams, sandy clay loams, silt loams, silt, silty clay loams and silty clays with less than 35 per cent clay and less than 65 per cent sand, the sand fraction may be as high as 82 per cent if a minimum of 18 per cent clay is present.

3. Fine textured: clays, silty clays, sandy clays, clay loams and silty clay loams with more than 35 per cent clay.

(b) Available Water Capacity

Previous studies (MMP 1978) on vertisols in the Genale-Bulo Marerta area recognise that most of the water is held in the less available water capacity (AWC) range (1 to 15 bars) and that the readily AWC accounts for less of the total AWC than on the medium textured levee soils. Unlike the medium textured soils the lower limit of availability is recognised as 0.0 bar, i.e. saturation, as there was no clearly defined point at which depletion of moisture under gravity ceases. It was also recognised that additional retentive forces due to the presence of dissolved salts, which are variable, will also reduce moisture available to plant roots.

Data provided for vertisols (MMP 1978) on old alluvium show a range of AWC values from 197 to 226 mm in the upper 1.0 m of profile with a corresponding readily AWC value between 44 to 65 mm. The data from a medium textured vertic cambisol show an AWC of 163 mm/1.0 m profile and a corresponding readily AWC of 58 mm. Similar figures were obtained on semi-recent alluvium and indicate that all soils have relatively high AWCs. The important conclusions are that the presence of medium textured horizons increases the amount of easily available moisture: the levee soils have more favourable characteristics than the clay textured vertisols.

(c) Sub-soil Hydraulic Conductivities

Assessments by MMP (1978) of soil drainability were made by determination of the average horizontal hydraulic conductivities of the more typical profiles. Deep infiltration tests also provided information of vertical hydraulic conductivities.

Horizontal hydraulic conductivities for vertisols were shown to decrease with depth from 0.32 m/d to 0.08 m/d (2 to 4 m depth) in the dark greyish brown clays, indicating a probable drainage restriction on this old alluvium. Greater values were observed when layers of medium textures were present, indicating easier drainability of these soils (MMP 1978).

Vertical hydraulic conductivities indicated the presence of anisotropic conditions, i.e. vertical values are lower than horizontal values (MMP 1978). The Genale-Bulo Marerta Study (MMP 1978) indicates that vertical fissures are lost under saturated conditions and thus cannot aid drainage in the old alluvial soils. Evidence is also presented for the greater persistence of the conchoidal blocky structure in semi-recent alluvial vertisols under saturated conditions and data from vertical hydraulic conductivities (MMP 1978) indicate this to be the case. However, only limited studies on soil moisture relations were made by MMP (1978) and more data on the effects of long-term irrigation are required before definitive statements can be made on the suitability of different soils of the old and semi-recent alluvium.

Limited observations in this study on irrigated areas did not indicate any significant observable difference in structure and drainage status between the soils of mapping units A1, A2 and B1, as indicated by degree and depth of mottling. Therefore, for planning purposes, as already discussed in Section 3.2, these soils have been included in the same drainability class for land suitability assessments. However, this could be subject to modification following more detailed site measurements under different irrigation intensities and duration.

3.5.3 Soil Chemical Properties

The major chemical factors in a semi-arid environment limiting agricultural land use are usually associated with the accumulation of salts in the profile. In this section attention is therefore focused on the assessment of the type and amount of soluble salts present and the amount of exchangeable sodium associated with the soil clay.

The methods of laboratory analysis are outlined in Appendix II and detailed soil profile descriptions and related chemical data for the selected ten representative soil profiles are given in Appendix III.

(a) Soil Salinity

Salinity does not appear to be a major hazard in the study area even in soils that have been irrigated for over 50 years. It must be stressed that the results obtained are only from a limited number of sites and considering that there is a degree of soil variability in the old and semi-recent alluvium it may be that salinity problems could arise at some locations if irrigation is introduced to land where soil profile characteristics prevent adequate drainage.

Representative soil profile pits were analysed for EC on the saturation extracts (EC_e) on pedologically significant horizons. Mean values which have been calculated to allow for comparable depth comparisons to be made are shown in Table 3.5 for the various mapping units. Values for individual horizons are shown together with soil profile descriptions in Appendix III.

TABLE 3.5

Salinity of Sampled Mapping Units (EC_e) in Relation to Depth

Mapping unit	Parent material	FAO soil unit	Depth (cm) 0-50	50-100	100-150
B1	Semi-recent alluvium	Chromic vertisol	0.94	2.32	3.33
B2	Semi-recent alluvium	Calcaric fluvisol	1.67	1.78	1.78
A1	Old alluvium	Chromic vertisol	1.17	3.30	4.33
A2	Old alluvium	Chromic vertisol	1.27	2.94	3.78

Note: EC_e values in mS cm^{-1}.

Salinity classes have been defined following FAO standards and are shown in Table 3.6.

TABLE 3.6

Salinity Classes and Corresponding EC_e Ratings

Salinity class		Range of EC_e (mS cm^{-1})
I	Negligible	0 - 2.5
II	Low	2.6 - 5.0
III	Moderate	5.1 - 7.5
IV	High	7.6 - 10.0
V	Very high	10.0

Values for EC_e are seen to increase with depth on the vertisols which is presumed to reflect the degree of leaching of soluble salts. No significant differences were observed between the major mapping units sampled, i.e. A1, A2 and B1 in this study. Salinity values are mainly in the negligible to low ranges within the top 1 m although some individual variations may be found. In certain profiles (see Appendix III) some values below 150 cm may fall within the moderate class.

These results confirm that salinity is not regarded as a serious limiting factor, although some yield reduction can be expected on the more sensitive orchard crops such as banana and grapefruit when values for EC_e exceed 2.5 mS cm^{-1} (MMP 1978). However local experience would suggest that yield reductions caused by salinity are not severe enough to warrant inclusion of this factor as a subclass limitation in land suitability assessments at the time of this survey.

(b) Sodium Hazard

The sodium hazard is commonly expressed in terms of exchangeable sodium percentage (ESP) of the cation exchange capacity which is occupied by exchangeable sodium. High levels of exchangeable sodium on the cation exchange complex can result in deflocculation and reduced permeability. The ESP value at which this occurs varies from soil to soil, but in the absence of local limits derived from local practice, soils are considered sodic when their ESP exceeds 15 (USDA 1954) : this is the conventional limit beyond which deterioration in the soil's physical properties will excessively affect crop performance and cultivation.

ESP classes as defined by MMP (1978) are shown in Table 3.7.

TABLE 3.7

Exchangeable Sodium Classes

Class		ESP limits
A	Negligible	0 - 4.9
B	Low	5.0 - 9.9
C	Moderate	10.0 - 14.9
D	High	15.0 - 19.9

Calculation of ESP values were made for all representative soil profiles and mean values have been calculated to show general trends over fixed depths and are shown in Table 3.8. Values for individual horizons are shown in Appendix III.

TABLE 3.8

ESP Values of Sampled Mapping Units by Depth

Mapping unit	Depth (cm)		
	0-50	50-100	100-150
B1	4.1	5.0	6.4
B2	6.6	8.5	8.5
A1	4.1	5.5	5.9
A2	3.5	4.2	5.9

Note: For parent material and soil classification of mapping units refer to Table 4.1.

Values for ESP on the major mapping units A1, A2 and B1 are seen to increase with depth and fall within the negligible class A for upper horizons (0 to 50 cm) but increase into the low Class B in the lower horizons (50 to 150 cm). It can therefore be tentatively concluded that few soils are likely to have ESP values in excess of 5 in the top 100 cm which is generally regarded as the upper limit for favourable soil properties in the vertisols.

A low sodicity hazard was also noted in other studies (MMP 1978) in which a more intensive sampling programme was employed on similar soil types. Consequently current data on soils and local experience indicate that sodicity is not considered to be a limiting factor at the present time. Although some variation in yield reductions may occur in more sensitive crops, the extent to which this can be linked to these low ESP values is uncertain.

(c) Soluble Salts

Analyses were performed on soils from representative pit sites to determine principal cations (Ca^{++}, Mg^{++}, Na^{+}, K^{+}) and anions ($CO_3^{=}$, HCO_3^{-}, Cl^{-}, $SO_4^{=}$), the complete results are shown in Appendix III. The dominant soluble ions in the soils are calcium and sulphate and significantly lower levels are noted in the medium textured fluvisol analysed.

Soluble salt composition varied between samples from similar mapping units but cations, Ca^{++}, Mg^{++}, and Na^{+} generally increase with depth, unlike K^{+} which is present in low amounts in a more variable distribution with depth. Since the majority of soils sampled were under some form of irrigation the movement of soluble salts down the profile can be expected. Not all results were available for chloride and sulphate, so detailed comparisons on ratios could not be made, although the results available showed most ratios were below 1.0 indicating that leaching of soluble salts occurs down the profile.

The relative mobility of individual ions is confirmed by MMP (1978). The soils examined have a relatively low proportion of toxic ions such as Na^{+} and Cl^{-} and this together with high amounts of Ca^{++} and SO_4 and low exchangeable sodium percentages should not seriously affect ionic balances between monovalent and divalent ions under leaching.

The conditions discussed in previous sections, especially with regard to soil salinity, reflect present conditions. Attention should be given to apply water in excess of crop requirements, to allow leaching of soluble salts from the profile, especially if lower quality sources of groundwater are increasingly used.

(d) Soil Fertility

(i) Nutrient Retention Capacity

All soils, especially the vertic clays, have relatively high clay contents in which montmorillonitic clay minerals are dominant. Consequently they have high cation exchange capacities (Appendix III). This, combined with the high base saturation percentages, indicates a favourable capacity for the retention of mineral nutrients against leaching.

(ii) Exchangeable Bases

The exchangeable forms of calcium, magnesium and potassium constitute one of the major sources for plant nutrition. The analyses indicate increasing concentrations of Ca^{++} and Mg^{++} with depth, those for K^{+} being more variable. Calcium is the dominant cation, followed by magnesium, and potassium. There are no significant differences between different mapping units on the vertic clays, and levels of the three exchangeable cations are invariably high.

Calcium to magnesium ratios range from 2 : 1 to 5 : 1 with the majority of values within 3 : 1 and 4 : 1, which is about the optimum range for most crops. The relatively high levels of exchangeable calcium and magnesium means that (Ca + Mg) : K ratios are high which is likely to cause problems of induced potassium deficiency, indicating the need for fertiliser K.

(iii) Organic Matter and Total Nitrogen

Organic matter and total nitrogen were determined in the topsoils only, since it was expected that recorded values would be very low. Chemical analysis (Appendix III) confirms that levels of organic matter are low to very low and total nitrogen levels are very low, which indicates that applications of fertiliser nitrogen would produce favourable crop responses.

(iv) Phosphorus

This nutrient was determined as the 'available' form. The limited data suggest that the highest level of P occurs under irrigated bananas: 11.5 ppm. Values under irrigated annual crops range from 5.4 to 9.8 ppm and those in uncultivated or long term fallow areas range from 2.3 to 5.6 ppm P. Mean values are not quoted due to the small sample sizes. The lowest value recorded of 2.3 ppm was found in the medium textured fluvisol which was uncultivated which may reflect previous fertiliser practices on the irrigated areas especially on banana plantations.

Guidelines for available phosphorus interpretation for Olsen's method (Landon, 1984) suggest that values less than 5 ppm can be considered low and that medium levels are between 5 and 15 ppm. This suggests that applications of phosphatic fertilisers are likely to produce favourable crop responses on soils in the project area since their pH values, being greater than 7.0, are outside the range of optimum phosphorus availability.

(v) Potassium

Available potassium was determined as the exchangeable and water soluble K extracted from the soil, since exchangeable K values are only of limited value for predicting crop response. However the assessments of available K are unfortunately not reliable since they do not give any index of the rate of K release over time. The results obtained, and shown in Appendix III, indicate that available potassium is low on all soils which may reflect the relatively low availability of this nutrient due to unfavourable (Ca + Mg) : K ratios since exchangeable potassium values do not indicate deficiencies as discussed in Section (ii).

(vi) Calcium Carbonate

Calcium carbonate was found in all profiles analysed with apparently no significant trends in distribution down the profile. Amounts ranged from 13% to 29% with no observable differences between mapping units.

(vii) Soil Reaction (pH)

Values are measured in terms of pH of the saturation extract which approximate more closely to actual field conditions and range from 7.6 to 7.9. This indicates a negligible sodicity hazard as is confirmed by the generally low exchangeable sodium levels. It must also be remembered that some reduction in the availability of phosphorus and micronutrients, except for molybdenum, can be expected to occur at these pH values.

CHAPTER 4

SOIL MAPPING UNITS

4.1 Introduction

The soil survey was based primarily on the identification and mapping of FAO soil units, as only limited field observations were possible within the TOR of this study. Further sub-divisions of the soil units into soil series were attempted on a limited basis by field observation of soil morphological properties and division of parent materials into respective ages as outlined by MMP (1978) further to delimit soil mapping units.

Considerable reliance on aerial photographic interpretation of the major land-forms was required to characterise the mapping units, especially where limited observations were made, together with previous experience gained on similar mapping by MMP (1978). This method of approach was adopted to make the soil classification comparable, as far as possible, with previous studies MMP (1978); the same basic principles of soil classification being adopted based on the legend of the FAO Soil Map of the World (1976).

Locations where only limited soil observations were made were confined to areas considered of little importance for irrigated agricultural development. These areas include unsuitable medium textured soils confined to channel remnants and their associated features which occupy a comparatively small area, and the Jilaal Moogi area which consists of large areas under rainfed grazing and lower lying swamp areas.

Seven mapping units have subsequently been defined and are considered sufficient to identify the main soil types within the constraints of this study. In this chapter the principal features of each mapping unit are described, including their physiography and principal profile characteristics which are shown in Table 4.1. Their distribution is detailed in Table 4.2. The mapping units have been mapped separately, and absolute purity of these units cannot be guaranteed at this level of investigation.

TABLE 4.2

Area Measurements of Soil Mapping Units

Soil mapping unit	Area (ha)	Area (% of project area)
A1	8 462	39
A2	2 270	10
A3	1 810	8
B1	4 403	20
B2	440	2
C1	3 175	14
C2	1 310	6
Villages and main road	265	1
Total	22 135	100

TABLE 4.1

A Summary of Soil Mapping Unit Characteristics

Map symbol	Physiography	Parent material	Soil unit	Drainage	Profile characteristics
A1	Main floodplain; level	Old alluvium	Chromic vertisols	Moderate	Dark yellowish brown to dark brown clay; strongly calcareous
A2	Main floodplain; gilgai	Old alluvium	Chromic vertisols	Moderate	Very dark greyish brown to dark greyish brown clay; strongly calcareous
A3	Channel remnant levees	Old alluvium	Vertic(2) cambisols	Good to moderate	Dark yellowish brown to dark brown alternating layers of clay loam, silt loam, silty clay loam and clay; strongly calcareous
B1(1)	Main floodplain; gilgai	Semi-recent alluvium	Chromic vertisols	Moderate	Dark reddish brown clay over dark brown clay subsoil; strongly calcareous
B2	Predominantly minor channel remnant levees	Semi-recent alluvium	Calcaric fluvisols	Good	Stratified horizon of dark yellowish brown to brown sandy loam, sandy clay loam and silt loam horizons; strongly calcareous
C1	Main floodplain; gilgai	Old alluvium(2)	Pellic(2) vertisols	Imperfect to poor	Very dark grey clay; common mottling in upper horizons; strongly calcareous
C2	Permanent swamp	(Permanently waterlogged area - not surveyed)			

Notes: (1) Includes recent alluvium in close proximity to Shabeelle river but not mapped separately at this scale.

(2) Provisional.

4.2 Soils of the Old Floodplain Alluvium

The landscape on the main floodplain is level or gently sloping, with slopes of mainly less than 1%, unless dissected by former river channels. The level areas consist of deep dark yellowish brown to dark greyish brown calcareous clays, while the areas bordering former river channels consist of predominantly dark brown silt loam, silty clay loam and clay loam textures.

4.2.1 Mapping Unit - A1

These soils are characterised at pit sites PG 01, PG 02 and PG 10 which have predominantly uniform dark yellowish brown and dark brown profiles. The soils crack deeply when dry and produce a surface mulch between 2 and 5 cm thick, with sink holes 5 to 10 m apart. These features were not easily visible in irrigated areas. Structures in the dry state range from angular blocky through prismatic to massive.

Variable degrees of mottling were observed ranging from few, fine and faint at depths generally ocurring below 70 cm to common, fine, distinct mottles below 100 cm depending on the profile location. Shell fragments, calcium carbonate and gypsum crystals are common, some occurring throughout the profile, others increasing with depth, being especially common below 80 to 100 cm.

This mapping unit occupies approximately 39% of the project area and has not been correlated with any soils on old alluvium as described by MMP (1978), since it lacks the brown colours of the Golweyn series and the dark greyish brown colours of the Saruda series and clearly does not exhibit reddish brown colours characteristic of the semi-recent alluvium. The Golweyn soil unit defined by FAO/Lockwood (1968) was described as a dark brown to brown Grumosol but was subsequently redefined by MMP (1978) as the Golweyn series with predominantly brown colours developed on old floodplain alluvium. Mapping unit A1 is provisionally shown as the Golweyn series subject to further field studies.

4.2.2 Mapping Unit - A2

Representative profiles are PG03, PG06 and PG08, which have texturally uniform clay profiles of very dark greyish brown to dark greyish brown colours developed on old alluvium. The soils crack deeply in the dry state, show weak gilgai relief, common sink holes and variable surface mulch, often greater than 5 cm thick. Variations in the degree of mottling development were noted between profiles with generally few fine faint mottles confined to the top 100 cm and the density and prominence increasing, to varying degees, with depth depending on the location of the pit site. Surface shell fragments are common and throughout the profile. Calcium carbonate nodules and soft accumulations increase with depth as does gypsum. This mapping unit covers 10% of the project area and closely resembles the Saruda series of chromic vertisols.

4.2.3 Mapping Unit - A3

This landform unit was clearly delineated from the aerial photography and occurs on more elevated areas associated with channel remnants in the old alluvial floodplain. This area is of little significance for the development of rainfed and irrigated agriculture and occupies 8% of the project area and was investigated on a limited basis by auger observation only.

The soils exhibited stratified horizons of friable dark brown to dark yellowish brown clay loams, silt loams and silty clay loams with considerable variation between sites. Surface observations did not reveal any great tendency for the soils to exhibit vertic characteristics, although in some cases they were weakly developed. The soils appear to be well to moderately well drained with little or no mottling visible from auger observations.

Previous studies by MMP (1978) have noted that the presence of these narrow sinuous land tracts represented a complex of eutric and vertic cambisols of the Shalambood series. It is therefore provisionally assumed from auger observations and field textural class determinations that comparable landforms in the project area contain similar soil series. As no pit profile observations were made in this mapping unit, no observations of structure or profile development were possible to confirm the findings of MMP (1978) as to the presence of minor soils of the Majabto or Dhablow series which occur in association with Golweyn or Saruda series soils.

4.3 Soils of the Semi-Recent Floodplain Alluvium

These soils are located in a broad tract of land adjacent to the Shabeelle river and extend into the central region of the project area in which the floodplain has predominantly level relief. The area is dissected by a major channel remnant running parallel to the present course of the river with its associated more elevated, weakly undulating areas. Further from the river the main floodplain of vertic clays is interspersed with minor channel remnants and associated localised areas of more elevated relief containing medium textured soils, showing a distinctive micro-relief pattern on the aerial photographs.

4.3.1 Mapping Unit - B1

The soils in this unit are predominantly dark reddish brown vertic clays and are characterised by pit site PG 07 and PG 09, ranging in depth from 115 to 168 cm over older alluvium.

The surface features include 5 to 10 cm wide surface cracks with moderately well developed gilgai and a 5 cm deep surface mulch with no visible sink holes. The surface cracks extend down to about 140 to 150 cm in the profile and the structures as observed in the dry condition were generally medium to coarse prismatic.

Only faint mottling was observed in both profiles but depths at which this was evident were variable and more common. Prominent mottles were encountered in the underlying old alluvium. It can be noted from the two profiles that the depth to underlying, more mottled, old alluvium is very variable and MMP (1978) record that the presence of old alluvium can occur within 100 cm of the surface. Only few shell fragments were observed throughout the profile and any calcium carbonate or gypsum accumulations were mainly confined to the underlying old alluvium. These profiles are most closely related to the Qoryooley series of chromic vertisols as described by MMP (1978) and occupy 20% of the project area.

Pit site PG 04 is not considered as representative of this mapping unit, although being classified as a chromic vertisol, its depth over the underlying sandy substratum is only 76 cm. Greater densities of soil observations are needed to identify the variations in depth of this chromic vertisol since no estimates of its extent could be made from aerial photographic interpretations.

4.3.2 Mapping Unit - B2

This unit was delineated almost entirely from aerial photographic interpretation. It is associated with one major and many minor channel remnants and overflow channels which showed up as prominent micro-relief patterns. The pit profile examined, PG 05, was located on a slightly elevated ridge and showed a stratified medium textured profile of dark yellowish brown sandy clay loam and silt loam. The surface features show no evidence of vertic properties and most sites visited were not cultivated. Where areas had been heavily grazed, wind erosion was a problem.

This soil unit is interspersed predominantly within the vertic clays of the semi-recent alluvium and was classified as a calcaric fluvisol being of more recent alluvial origin with no visible subsequent profile development since deposition. However, this profile may not be representative of the mapping unit as a whole but until further detailed investigations are carried out the unit has been represented by PG 05 and covers 2% of the project area. No attempt at correlation with other soil series was carried out since this mapping unit was not described previously by MMP (1978).

4.4 Soils of the Recent Floodplain Alluvium

Previous studies have indicated that these soils are confined to levee and overflow channels in close proximity to the Shabeelle river. However, since auger site observations did not reveal any stratified soils characteristic of recent alluvium at the sites investigated, it has been grouped with mapping unit B1.

4.5 Jilaal Moogi Area

Inspection of aerial photographs suggests that the area can be broadly divided into two mapping units. This was tentatively confirmed by ground observations. Other mapping units do extend into the area; these have been mapped from aerial photographic interpretation.

4.5.1 Mapping Unit - C1

This area surrounds the much lower swamp basins, mapped as unit C2. The auger observations revealed very dark grey clays with common distinct mottles in the upper horizons, and common gypsum crystals at about 100 cm. Moderately well developed gilgai were observed in the north of the mapping unit.

This mapping unit is also characterised by its dominant land use pattern of extreme grazing by livestock. A dense cover of grass with a thick surface layer of roots and plant debris was present in many of the areas visited. Further investigations are needed in this mapping unit to characterise fully these soils, especially if major changes in land use are contemplated.

Preliminary findings suggest that large proportions of this mapping unit consist of poorly drained pellic vertisols which occupy approximately 14% of the project area.

4.5.2 Mapping Unit - C2

This unit occupies the lowest area in the flood relief landscape and is almost certainly permanently waterlogged. The soils were not investigated due to problems of access: the area was under deep water at the time of the field studies. Consequently this unit has been delineated on landform and vegetation characteristics from aerial photography.

The area is dissected by numerous drainage channels and characterised by a dense vegetative cover of Typha spp which is mainly used for thatching. This unit occupies approximately 6% of the project area.

CHAPTER 5

LAND SUITABILITY

5.1 Introduction

The land suitability evaluation follows the FAO Framework (1976) and the Land Evaluation Guidelines for Rainfed and Irrigated Agriculture (1979 and 1985). In the FAO system there are suitable and non-suitable orders which are subdivided into suitability classes. In addition there is a conditionally suitable phase which can be used where improvements are likely to result in upgrading from non-suitable to suitable orders. These FAO guidelines are listed briefly as follows:

Suitability Order - S, highly suitable

"Land on which sustained use of the kind under consideration is expected to yield benefits which justify the inputs, without unacceptable risk of damage to land resources."

Suitability Class - S1, suitable

"Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level."

Suitability Class - S2, moderately suitable

"Land having limitations which in aggregate are moderately severe for sustained application of a given use: the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land."

Suitability Class - S3, marginally suitable

"Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, this expenditure will only be marginally justified."

Phase - Sc, conditionally suitable

"Land which if certain conditions are met is given a suitable class, but which otherwise is unsuitable."

Suitability Order - N, not suitable

"Land which has qualities that preclude sustained use of the kind under consideration."

Suitability Class - N1, currently not suitable

"Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner."

Suitability Class - N2, permanently not suitable

"Land having limitations which appear so severe as to preclude any possibilities of successful sustained use of the land in the given manner."

Suitability Class - NR, not relevant

"Land which has not been assessed for a given use, because the application of the use to that area is precluded by the initial assumptions of the evaluation."

The mapping units discussed in Chapter 4 and their corresponding land characteristics are evaluated against a series of class-determining factors or limitations which enables the designation of a subclass based on these limitations. The class-determining factors or limitations indicate features that affect the productivity of the land. The major kinds of land use envisaged are irrigated and rainfed agriculture and in order to assess land suitability for more specific systems a series of land utilisation types (LUT) is described in broad terms for the project area together with specific crop types:

(i) LUT 1 - gravity and pumped irrigation of perennial orchard crops; primarily banana and grapefruit together with other orchard crops;

(ii) LUT 2 - flood irrigation of annual crops, maize, sesame, tomato, water melon and cotton;

(iii) LUT 3 - rainfed cultivation of annual crops; primarily maize and sesame;

(iv) LUT 4 - livestock grazing.

The primary assessments of land suitability of the various mapping units into broad divisions for irrigated and rainfed agriculture have been made using information from the nearby Genale-Bulo Marerta Study (MMP 1978) but have been modified to suit local physical, agro-economic and social conditions.

Further information used in modifying the basic land suitability classes is based on the effects of existing land use patterns, which are essentially similar to the proposed land utilisation types, on actual soil morphological features as observed during this survey. The relation of these features together with the effects of the landscape on present land use types has also been used to determine overall land suitability assessments, drawing on local knowledge and conditions. Soil requirements for the different crop types have also been taken into account in deciding on the final land suitability classes. These assessments can only be regarded as provisional since no infiltration, permeability or AWC data were collected in this study and broad assessments have relied on experience gained by MMP (1978). Therefore, further modifications could be made during implementation following more detailed on site measurements.

The factors determining class for land utilisation types are discussed in Sections 5.2 and 5.3.

5.2 Land Utilisation Types 1 and 2

Preliminary assessments have been made in relation to the various soil mapping units using criteria outlined in Table 5.1. This has been adopted for this study using basic information from MMP (1978) as outlined in Chapter 3. The criteria are discussed below, drawing on this information.

1. Soil Factors (p) (d) (z)

The ranking of soil factors against land suitability classes has been made according to profile factors (p) which include field assessments of texture and structure together with information on soil water relations from MMP (1978) and local evidence of crop performance. Other soil factors considered are profile drainage (d) and salinity (z).

The orchard crops in LUT 1 are regarded as the most sensitive to sub-optimal soil conditions, having a general requirement for deep well drained medium textured soils, high water holding capacities and very low salinity hazards.

In this predominantly vertisol area, no class 1 soils are encountered. The moderate drainability as assessed under present conditions in mapping units A1, A2 and B1 have been measured: hydraulic conductivities are in the slow conductivity class within the top 2 m (MMP 1978). Observations within these mapping units, which have in some areas been under the cropping system of LUT 1 for many years, indicate that there have been no significant changes in drainability despite slow hydraulic conductivity values. However, tests would be required to confirm the values of MMP (1978) and further detailed observations would be needed to assess the purity of the mapping units. Evidence for variations in vertical water movement through the profile as evidenced by MMP (1978) and outlined in Chapter 3, in relation to parent maternal age on vertisols could not be confirmed in this study.

This discussion of soil factors will have similar consequences for LUT 2 although in some cases crops will have less stringent soil requirements than those of LUT 1.

The limits outlined in Table 5.1 also take account of these soil factors in the allocation of LUT suitabilities to the soils in other mapping units which are of lesser importance in relation to the proposed development of these irrigated land utilisation types.

2. Topography (t)

The landscape of the project area is predominantly flat with the majority of slopes being below 1%, exceptions being the areas associated with channel remnants and erosion channels. In the majority of elevated areas associated with

TABLE 5.1

Minimum Requirements for Classes for Irrigated Crops

Criteria	Suitability class			
	S1	S2	S3	N2
1. Soil Factors				
(a) Profile factors (p)				
(i) Soil textures and structures in top 100 cm	Loam to permeable clay	Sandy loam to moderate or slowly permeable clay	Loamy sand or very slowly permeable clay	Land which fails to meet the minimum require-ments of the other classes
(ii) Total available water capacity in upper 1 m	High to moderate	Moderate	Low	
(b) Profile drainage(d)	Moderate to well	Moderate	Imperfect or somewhat excessive	
(c) Salinity (z)	2.5	5.0	10.0	
2. Topography (t) microrelief	None	Very weakly undulating, gilgai	Weakly undulating or slightly dissected	
3. Flooding (f)	None	None or slight brief superficial flooding	Extended periods of flooding necessitating surface drainage methods	

Note: Criteria are discussed in Section 5.2.

the channel remnants both in old and semi-recent alluvium, medium textured soils are predominant. These soils have been shown by MMP (1978) to range from high to marginal with regard to suitability for irrigated agriculture based on purely soil characteristics and present studies would tend to confirm this for LUT 1 and 2, but preliminary studies suggest that the majority of these areas are not commandable or are of too sinuous a nature to be considered for irrigation.

3. Flooding (f)

This includes superficial inundation by water both from river overflow or from rainfall and in this context is mainly confined to the latter, since flood protection measures along the Shabeelle river have been implemented in recent years. The limitation classes are shown in Table 5.1. The Jilaal Moogi area is susceptible to inundation by overflow of the river and account of these factors has been taken with respect to the most susceptible mapping units C1 and C2.

5.3 Land Utilisation Types 3 and 4

Guidelines in assessing suitability for these units under rainfed conditions have been adopted from the Farjano Settlement Project MMP (1985) which was based on earlier studies by HTS in Somalia (1977, 1982) and are shown in Table 5.2.

1. Soil Factors (p) (d) (z)

Soil texture is of primary importance since this will influence the capacity of the soil to store water (AWC) over the growing season. Medium textured soils will receive water readily into the profile, but have relatively low capacities to retain the water for crop growth, unlike the clay textured vertisols, which have high capacities to store water but that available to plants is limited due to the predominance of fine pores.

Since the only water accepted into the profile is via rainfall the water available to the crop is critical in maintaining crop growth until maturity, so that the amount of rainfall and water holding capacity of the profile within the rooting zone is important.

Table 5.2 is used only as a guide for land suitability for LUT 4 and in general land has been upgraded by one class for this land use type compared to those assessed for annual cultivated cropping. This has been done since it is realised that pasture land has less exacting soil requirements than LUT 3 and in addition will contain trees and shrubs which are deeper rooting and are browsed. Evidence from the Jilaal-Moogi area indicates that grasses are more tolerant of less well-drained soils, which can often be inundated from the Shabeelle river for long periods. This area is better suited to grazing than other areas which rely on water purely from rainfall. In areas not cultivated the heavy overgrazing provides little opportunity of regenerative growth of pasture.

Salinity levels in the soils is a critical factor in the evaluation: if there is a significant amount of salt within the rooting zone, rainfall is unlikely to reduce it to satisfactory levels by leaching. Therefore it cannot be considered a rectifiable limitation. Salinity levels as noted in Table 5.1 represent average values above which it is considered that the selected crops for this study will suffer large yield reductions, in view of their low salt tolerances. Sodicity is again not considered since soils are virtually free from exchangeable sodium.

TABLE 5.2

Minimum Requirements for Classes for Rainfed Agriculture

Criteria	Suitability class			
	S1	S2	S3	N1
1. Soil Factors				
(a) Profile factors (p)				
(i) Soil texture and structure in top metre	Loam to permeable clay	Moderate or slowly permeable clay to clay loam	Very slowly permeable clay to sandy day loam	Sand to sandy loam
(ii) Available water capacity	High	Moderate	Low	Poor
(b) Profile drainage (d)	Moderate to well	Moderate to imperfect	Moderately poor or somewhat excessive	
(c) Salinity (z)	2.5	5.0	10.0	10.0
2. Erosion hazard (e)	None	Slight	Moderate	Severe
3. Flooding hazard (f)	None	Slight	Strong seasonal	Permanently flooded
4. Surface conditions (g)	Deep soft mulch	Slightly firm surface; shallow mulch	Firm surface	Very hard crust
5. Rainfall (mm)(r)	550	500-550	400-500	400

Note: Criteria are discussed in Section 5.3.

Drainage is less of a problem under rainfed conditions and will vary with rainfall intensity and duration. On the main floodplains this may cause temporary waterlogging in the saturated profile and affect timeliness of field operations. The problem is potentially more serious in the channel remnants where water may accumulate due to additional surface runoff.

2. Erosion Hazard (e)

Wind erosion was evident during the course of the soil survey. The problem is potentially more serious on the medium textured soils which are not cultivated to any significant extent, and overgrazing has resulted in the exposure of bare soil surfaces. Due to their lower self-mulching characteristic and more sandy or silty surface texture, considerable erosion was observed, leaving small hummocks of vegetation in more exposed elevated areas.

3. Flood Hazard (f)

The flooding of main floodplain areas is not seen as a serious problem as the area is protected from river flooding by a flood bund along the Shabeelle. It is more likely that if strong seasonal flooding occurs it will be most pronounced in localised depressions and channel remnants.

4. Surface Conditions (g)

Surface conditions have most significance with regard to long-term cultivability of the medium-textured soils on slightly elevated areas. Unlike the vertisols these soils have no natural surface mulch and consequently their firm surfaces are less effective in intercepting rainfall. These more freely draining profiles appear to need more frequent rainfall to maintain favourable moisture reserves than are available to the crop over the grazing season; however, further studies are required to confirm this. Local experience suggests that these soils are not cultivated due to the factors discussed above.

5. Rainfall (r)

This has been discussed in Chapter 2, Section 2.2.

5.4 Results of the Land Suitability Evaluation

5.4.1 Introduction

The limiting factors set out in Tables 5.1 and 5.2 have been used as a guide in assigning land suitability classes to each of the soil mapping units in relation to each land utilisation type. The current potential of the land already under the cropping systems at the four land utilisation types is also taken into account in these assessments. The land suitability classes are shown in Table 5.3 and are regarded as provisional, due to the limited field observations and considerable reliance on reference to other studies.

The delineation of land suitability classes are shown on the land suitability map, using the soil map as a basis. To enable the information to be readily presented, mapping units 1 to 5 have been drawn up, representing groupings of suitability classes of the four land utilisation types in relation to soil mapping units under present project conditions. These are shown in Table 5.4.

TABLE 5.3

Land Suitability Classes

Mapping unit	LUT 1	LUT 2	LUT 3[1]	LUT 4[1]
A1	S2[2]	S2[2]	S3	S2
A2	S2	S2	S3	S2
A3	N2	N2	N1	S3
B1	S2	S2	S3	S2
B2	N2	N2	N1	S3
C1	S3	S3	S3	S1
C2	N2	N2	N2	N2

Notes: (1) Rainfall limitations are included in rainfed suitability class assessments.

(2) Some currently not suitable (N1) land included in this unit as indicated on land suitability map 1C due to location within topographically unsuitable areas.

TABLE 5.4

General Mapping Unit Definitions and Areas

Mapping unit	Land utilisation type suitability classes	Area (ha)	Proportion of project area (%)
1	Land moderately suitable (S2) for LUT 1, LUT 2 and LUT 4 and marginal (S3) for LUT 3	9 380	43
2	Land marginally suitable (S3) for LUT 1, LUT 2 and LUT 3 but highly suitable (S1) for LUT 4.	3 175	14
3	Land currently not suitable (N1) for LUT 1 and LUT 2, marginal (S3)for LUT 3 and moderately suitable (S2) for LUT 4.	5 755	26
4	Land permanently not suitable (N2) for LUT 1 and LUT 2, currently not suitable (N1) for LUT 3 and marginally suitable (S3) for LUT 4.	2 250	10
5	Land unsuitable for any agricultural development of land utilisation types (N2).	1 310	6

Note: Excludes 265 ha for villages and main road which occupy approximately 1% of the project area.

Land classified as Class 1 is more suited to a wider range of land uses, whereas Class 5 is unsuitable for any proposed land utilisation type. Classes 2 to 4 reflect the decreasing suitability for all land utilisation types, with the exception of the fourth land utilisation type of which class 2 contains the most suited land.

Areas are given in Tables 5.4 and 5.5 both for the general mapping units and for individual land suitability classes.

5.4.2 Land Suitability of the Soil Mapping Units

(a) Mapping Units A1, A2 and B1

The soils in these mapping units are considered currently moderately suitable for irrigated agriculture for the wide range of crops presently grown. However, the suitability of mapping unit A1 has been downgraded to N1 in certain areas where the topography of mapping unit A3 precludes any canal developments across these often hightly dissected or elevated areas to serve the A1 mapping unit soils. No attempt has been made to modify further the suitability classes of these mapping units in terms of water availability for irrigation due to limited available data. Assessments have been largely made on the physical characteristics of topography, soils and drainage with regard to irrigated agiculture.

In considering areas for rainfed cropping as outlined for LUT 3, these mapping units are described as marginal (S3) due primarily to rainfall limitations. With regard to use of these lands for livestock grazing, including browsing, these soils are considered as moderately suitable for dry season grazing, although it is realised that the land available is limited primarily to fallows and uncultivable areas close to roads, canals and old river channels under present conditions.

(b) Mapping Units B2 and A3

The areas covered by these mapping units are considered as permanently unsuitable (N2) primarily due to topographic limitations, since they are mainly located on elevated areas often bordering old river channels. Within the constraints of this survey they have been assessed as being mainly out of command. Local experience indicates that some limited areas of mapping unit B2 have been irrigated in the past and have, for the purposes of this study, been included as moderately suitable for irrigation.

The medium textured soils are considered as marginal (S3) for rainfed agriculture, including grazing, based on criteria discussed in Section 5.3 and are also considered as marginal for LUT 4, these soils having less favourable characteristics for sustained production than those in mapping units A1, A2 and B1.

The majority of settlement sites are located in these more elevated mapping units.

(c) Mapping Unit C1

This unit was not investigated in detail, therefore only tentative conclusions can be drawn since the soils examined may not be wholly representative of the mapping unit.

TABLE 5.5

Areas of Land Suitability for Land Utilisation Types

Land suitability class		LUT 1	LUT 2	LUT 3	LUT 4
Highly suitable					
S1	(ha)	0	0	0	3 175
	(%)	0	0	0	14
Moderately suitable					
S2	(ha)	9 380	9 380	0	15 135
	(%)	43	43	0	69
Marginally suitable					
S3	(ha)	3 175	3 175	18 310	2 250
	(%)	14	14	83	10
Currently not suitable					
N1	(ha)	5 755	5 755	2 250	0
	(%)	26	26	10	0
Permanently not suitable					
N2	(ha)	3 560	3 560	1 310	1 310
	(%)	16	16	6	6

The area is considered as marginal (S3) for irrigated agriculture since auger observations indicate the presence of very slowly permeable vertic clays characterised by mottling and colour as imperfectly drained. However, pit observations would be needed to confirm this and to assess salinity levels. In addition to profile factors, flooding is presently a major feature of the Jilaal-Moogi area so that soils cannot be considered to fit a higher suitability class due to the flooding constraints.

Rainfed cropping potential of this land is considered as marginal mainly due to extended periods of flooding, whereas current evidence indicates the high suitability for pasture production. Consequently this land has been classed as highly suited to pastoral agriculture, since it is not reliant on rainfed sources alone for pasture production.

(d) Mapping Unit C2

This has been tentatively considered as permanently unsuitable under present project conditions for all land utilisation types due to soil and flooding hazards in the lower basin areas, which result in more or less permanently water-logged conditions.

The land suitability classes and provisional subclasses are shown in Table 5.6 for the various mapping units in relation to land utilisation types, summarising the discussions of this section. Only the most limiting subclasses are shown which are based primarily on field observations since no soil physical tests were carried out. Land suitability for LUT 3 relates to traditional rainfed agriculture and that for LUT 4 is concerned with dry season grazing only.

TABLE 5.6

Land Suitability Classes

Mapping Unit	LUT 1	LUT 2	LUT 3	LUT 4
A1	S2pd/N1t	S2pd/N1t	S3r	S2r
A2	S2pd	S2pd	S3r	S2r
A3	N2t	N2t	N1pqr	S3pqr
B1	S2pd	S2pd	S3r	S2r
B2	N2t	N2t	N1pqr	S3pqr
C1	S3df	S3df	S3f	S1
C2	N2df	N2df	N2df	N2df

Note: Symbols are explained in Sections 5.2 and 5.3.

5.5 Comparison with Previous Surveys

Land classification studies have been carried out which cover the project area or adjacent areas and have been listed in Table 3.1 and considerable discussion has already been made in Chapter 3, Section 3.2. Therefore only a very brief comparison will be made with the most relevant studies.

The study of MMP (1978) places particular emphasis on soil drainability and places irrigable land in USBR Classes 2 and 3 being classed as suitable and moderately suitable respectively. While direct comparison is difficult since the present study uses the FAO system, it can be concluded that there is reasonable similarity between the two surveys.

Assessment of land suitability has been made more recently by MMP (1985) using information from the Inter-Riverine Study (HTS 1977). The study by MMP (1985) assigns the vertisols, which form a greater proportion of the study area, into S2 and S3 FAO suitability classes. When the rainfall limitations are taken into account it can be concluded that these classifications are similar to the findings of the Dara Salaam-Busley study.

APPENDIX I

TERMS OF REFERENCE

APPENDIX I

TERMS OF REFERENCE

1. Background to the Soil Studies

The objective of the soil and land suitability studies is to provide basic data for assisting with project planning activities, notably optimising the proposed land use pattern of irrigated and rainfed agriculture; providing soil information for irrigation and drainage calculations and recommendations on soil management techniques needed for sustained agricultural development.

The soils of the project area along the floodplain of the Shabeelle river consist principally of vertic clays interspersed with minor or relic river channels and their associated coarser levee deposits. The majority of the basic soil differences are reflected in the natural vegetation pattern and can be clearly identified by aerial photographic interpretation (API). Although the pattern is complicated by human influences - in particular by the existing, and abandoned, irrigation activities and fuelwood collection - API will permit delineation of the principal soil/landform/vegetation units required for broad project planning.

In view of the overall time limits of the study and the data already available for the area, the Consultant's approach will be based on a review of the literature on API appraisal of the natural resource units followed by a short field survey and sampling programme to characterise the major soil types and potential constraints to development. Because of the preponderance of vertic clays on the land adjoining the Shabeelle, the Consultants have not included measurement of soil physical parameters, such as infiltration rate or hydraulic conductivities, in the work programme; water movement in such profiles is highly dependent on soil moisture content and under irrigation, when the soil structural units have swelled, will be extremely slow. Should the study subsequently reveal a more variable soil pattern, for which more detailed survey, including these physical tests would be useful, then full specifications would be included in the recommendations for further investigations prior to full project implementation.

2. Soil and Land Suitability Investigations

The Consultants will collect and review all the relevant data on soils, land suitability, natural vegetation, geology and land use, including maps, reports, journal articles, remote sensing imagery and aerial photographs.

Specific recent references that will be used include the 1985 report by the United Kingdom Government Land Resources Development Centre on Land Resources Development in the Shabeelle Valley, and the 1984 FAO/Ministry of Agriculture field document entitled 'A compendium of land resource studies in Somalia. Preparatory assistance in land use planning and management'. Useful data are also given in the 1984 report on Resource Assessment in Somalia using Landsat Data by the Remote Sensing Institute, South Dakota.

From API the major soil/landform/vegetation units will be delineated in order to identify the main areas for irrigated and rainfed development and areas suffering from major deficiencies which render them unsuitable.

The principal API units will be characterised by a field survey consisting of some 40 fee survey auger borings to a depth of 1.2 m, soil conditions permitting, supplemented by 10 soil pits dug at carefully selected sites to characterise the main soil units and potential soil constraints. These soil observations will be concentrated on the 5 000 ha of land that could be served by the existing canals.

The pits will be fully described in accordance with the FAO Guidelines for Soil Profile Description (1977), the following morphological properties being included for each pedologically significant horizon:

- soil colour and mottling (using Munsell notation)
- texture and consistency
- structure and pore size distribution
- soluble salts and carbonates
- gravel, stone and nodule contents
- rooting patterns
- boundary conditions

3. Routine Soil Sampling and Analysis

The major pedological horizons at each pit site will be sampled at an average of four samples per pit. Each sample will be analysed for the following physical and chemical parameters using the services of the Central Agricultural Research Station's Laboratory at Afgoi:

- electrical conductivity (EC)
- exchangeable bases: Ca, Mg, Na and K
- cation exchange capacity
- available phosphorus and potassium
- total carbonate
- organic carbon and nitrogen (topsoil samples only)
- particle size
- soluble anions and cations on samples if the EC of the saturation extracts exceeds 2 m^{S}/cm

Soil samples will be taken as early as possible during the field survey in order to maximise the time available for analyses.

4. Soil and Land Suitability Classification

The soils of the project area will be classified on the basis of their morphological properties, and in particular on those directly relevant to agricultural development of the specific crops. Full correlation will be made with the legend of the FAO Soil Map of the World (FAO-Unesco, 1974 Soil Map of the World. Volume I, Legend. Unesco, Paris) and the USDA Soil Taxonomy (USDA 1975 Soil Taxonomy. USDA, Washington).

For the preparation of the cropping pattern derivative information on land suitability will be included in the study. In addition to soils data, information would therefore be gathered on land characteristics such as micro relief, liability to flooding or erosion and requirements for land clearance, grading and drainage.

A land suitability classification would subsequently be devised, based on the principles of the FAO Framework (FAO, 1976, Framework for Land Evaluation, FAO, Rome).

5. Soil and Land Suitability Mapping and Report

Using the proposed project base map at 1 : 50 000 (Section B1.3.7(a)) two thematic maps would be produced from a final reinterpretation of the aerial photographs showing, respectively, soils and land suitability. The latter will include a legend showing suitability classes and subclasses for each of the recommended crops. The accompanying soil report will follow the broad format indicated in the 1970 FAO Soils Bulletin Nr 9, The Preparation of Soil Survey Reports.

APPENDIX II

METHODS OF LABORATORY ANALYSIS

APPENDIX II

METHODS OF LABORATORY ANALYSIS

1. Introduction

Analysis of soil samples was carried out at Central Agricultural Research Station, Afgoi, Mogadishu, Somalia. The methods of analysis are described briefly in this appendix, and are based primarily on those described in Handbook 60 (USDA, 1954).

2. Sample Preparation

Air dried samples were crushed, ground in a mechanical grinder and screened through a 2 mm sieve. Virtually no particles of more than 2 mm diameter were observed in the soils analysed.

3. Particle Size Analysis

A sample of 10 g of soil was dispersed by leaving it overnight with sodium hexametaphosphate and water. The suspension was then dispersed in a mechanical stirrer for 15 minutes and then screened through a 50 micron sieve to separate the total sand fraction.

The remaining clay and silt suspension was transferred to a 1 l cylinder, made to volume and then shaken. The clay fraction was then sampled with a Lowry pipette at a predetermined time and depth with temperature corrections. The weight of the evaporated aliquot of clay was corrected for the dispersing agent added. Finally, the weight of the silt fraction was calculated by difference.

4. Electrical Conductivity of Saturation Extract

Distilled water was added to the soil until the saturation point was reached. The saturated soil paste was then extracted using suction, to obtain a saturation extract. The electrical conductivity of this extract was measured and the results expressed in mS cm^{-1} as the electricity conductivity of the saturation extract (EC_e).

5. pH Determination

A glass electrode was used for the determination of the pH of the soil paste.

6. Cation Exchange Capacity

A sample of 4 g of ovendried soil was saturated with sodium ions by leaching with 1 normal sodium acetate solution at pH 8.2. After saturation was complete 1 normal ammonium acetate solution was used to leach out the absorbed sodium ions and the sodium determination carried out by flame photometry.

7. Exchangeable Cations

Extractable Ca^{++} and Mg^{++} were determined from sodium acetate extract by titration with EDTA-Na.

Extractable Na^{+} and K^{+} were determined from ammonium acetate extract by flame photometry according to USDA Handbook Nr 60. The exchangeable cation values were corrected to allow for soluble salts.

8. Soluble Cations in Saturation Extract

Soluble cations Na^{+} and K^{+} were determined by flame photometry and the divalent cations Ca^{++} and Mg^{++} were determined by EDTA-Na titration.

9. Soluble Anions in Saturation Extract

(a) Carbonate, Bicarbonate and Chloride

Carbonate anions were absent from all extracts, as indicated by the absence of pink colour upon addition of phenolphthalein indicator.

Bicarbonate was titrated against sulphuric acid with methyl orange indicator followed by chloride titration with silver nitrate after prior destruction of the methyl orange indicator upon addition of chromate indicator.

(b) Sulphate

Determination was carried out by a gravimetric procedure in which sulphate was precipitated as barium sulphate, the precipitate subsequently being ignited and weighed.

10. Total Carbonate

A weighed subsample of soil was mixed with dilute hydrochloric acid and the volume of gas evolved in the reaction was measured by calcimeter. The percentage total carbonate was obtained by calculation.

11. Gypsum

This was determined by one of the methods outlined in USDA Handbook 60, by difference between Ca^{++} and Mg^{++} content of 1 : 10 soil : water suspension and the Ca^{++} and Mg^{++} content of the saturation extract as determined by EDTA-Na titration.

12. Organic Matter Content

This was determined by the Walkley-Black method.

13. Total Nitrogen Content

This was determined by the micro-Kjeldahl method.

14. Available Phosphorus

Available phosphorus was determined by Olsen's method using sodium bicarbonate solution (0.5 M) with pH adjustment to 8.5 using sodium hydroxide. The results are expressed in terms of elemental phosphorus in parts per million.

15. Available Potassium

Available potassium was measured by extracting the soil with ammonium acetate and determining the total potassium (exchangeable and water soluble) extracted, using flame photometry.

APPENDIX III

SOIL PROFILE DESCRIPTIONS AND ANALYSES

APPENDIX III

SOIL PROFILE DESCRIPTIONS AND ANALYSES

1. Abbreviations

The following abbreviations have been used in the tables showing analytical results and not explained in Appendix II:

S	-	sand
Z	-	silt
C	-	clay
ECe	-	The electrical conductivity of the saturation extract expressed in mS cm^{-1} (originally mmhos cm^{-1})
Sat'n	-	Moisture saturation percentage
SAR	-	Sodium adsorption ratio
Cl/SO_4	-	Chloride to sulphate ratio
CEC/100g soil	-	The cation exchange capacity, expressed in milli-equivalents. Values for exchangeable cations are given in the same units
BSP	-	Base saturation percentage - the sum of exchangeable Ca, Mg, Na and K as a percentage of CEC
ESP	-	Exchangeable sodium percentage is given as the calculated value of Na/CEC x 100
me/l	-	Values for soluble salts are expressed in milli-equivalents per litre
OM	-	Organic matter percentage in the air dry soil
Total N	-	Nitrogen given as a percentage of the total N in air dry soil
$CaCO_3$	-	Percentage total carbonate in air dry soil

2. Symbols Used in Tables

(i)	-	no test performed
(ii)	ND	not detected
(iii)	*	exchangeable calcium excessively high due to interference from calcium ions (gypsum and calcium carbonate) dissolved by sodium acetate solution.

PIT NUMBER PG01

Soil classification: FAO Chromic Vertisol USDA Paleustollic Chromusterts

Land suitability: LUT 1 or 2 - S2/N1; LUT 3 - S3, LUT 4 - S2

Mapping unit: A1

(1) SITE CHARACTERISTICS

Date of examination:	26th March 1987
Author:	W.P. Gibson
Location:	Approximately 1°55'N - 44°49'E
Landform:	Main floodplain
Vegetation/land use:	Previously irrigated, now fallow; scattered Salvadora persica bushes and few Dobera glabra trees
Slope:	Level
Micro relief:	Weakly developed gilgai, wide cracks and common sinkholes; few termitaria

(2) SOIL INFORMATION

Parent material:	Shebelle alluvium - old
Profile drainage:	Moderate
Flood hazard:	None
Surface features:	Wide cracks, 3 cm deep surface mulch
Evidence of erosion:	None
Depth to groundwater:	Not encountered

(3) PROFILE DESCRIPTION

Depth (cm)	Field description
0-26	Dry clay; dark yellowish brown (10 YR 3/4) when moist, and dark yellowish brown (10 YR 4/4) when dry; moderate medium angular blocky; very hard when dry, friable when moist, very sticky when wet; few fine pores; few 10 mm wide vertical cracks; few medium $CaCO_3$ nodules; strongly calcareous; common fine roots; gradual smooth boundary.
26-66	Dry clay; dark yellowish brown (10 YR 3/4) when moist and dark brown (7.5 YR 3/2) when dry; weak medium prismatic; very hard when dry, friable when moist, very sticky when wet; few fine and few medium tubular pores; few 10 mm wide vertical cracks; few medium soft rounded $CaCO_3$ nodules; strongly calcareous; few fine roots; gradual smooth boundary.
66-105	Very slightly moist clay; dark brown (10 YR 3/3) when moist and dark yellowish brown (10 YR 3/4) when dry; few fine distinct red brown mottles; massive; very hard when dry, friable when moist, very sticky when wet; few fine tubular pores; few 5 mm vertical cracks; few medium soft $CaCO_3$ nodules; strongly calcareous; common medium soft manganese nodules; no roots; gradual smooth boundary.
105-137	Very slightly moist clay; dark brown (10 YR 3/3) when moist and dark yellowish brown (10 YR 3/4) when dry; few fine faint brown mottles; weak medium angular blocky; very hard when dry, firm when moist and very sticky when wet; very few fine tubular pores; common medium soft $CaCO_3$ nodules; strongly calcareous; no roots; gradual smooth boundary.
137-190	Slightly moist clay; dark brown (10 YR 3/3) when moist and dark yellowish brown (10 YR 3/4) when slightly moist; few fine faint red brown mottles; massive breaking to fine angular blocky; very hard when dry, firm when moist and very sticky when wet; no pores visible; common fine soft $CaCO_3$ nodules; strongly calcareous; no roots.
REMARKS	Vertical cracks 5 mm to 10 mm wide down to 105 cm. Common fine shells between 66 cm and 105 cm. Very compact below 110 cm and virtually all roots confined to upper 20 cm of profile.

PIT NUMBER PG02

Soil classification: FAO Chromic Vertisol USDA Paleustollic Chromusterts

Land suitability: LUT 1 or 2 - S2/N1; LUT 3 - S3; LUT 4 - S2

Mapping unit: A1

(1) SITE CHARACTERISTICS

Date of examination:	27th March 1987
Author:	W.P. Gibson
Location:	Approximately 1°51'N - 44°44'E
Landform:	Main floodplain
Vegetation/land use:	Irrigated perennial cropping - bananas, grapefruit
Slope:	Level
Micro relief:	Levelled and ploughed field

(2) SOIL INFORMATION

Parent material:	Shebelle alluvium - old
Profile drainage:	Moderate
Flood hazard:	None
Surface features:	Large hard clods
Evidence of erosion:	None
Depth to groundwater:	Not encountered

(3) PROFILE DESCRIPTION

Depth (cm)	Field description
0-40	Dry clay; dark yellowish brown (10 YR 3/4) when moist, and dark brown to brown (10 YR 4/3) when dry; moderate medium angular blocky; extremely hard when dry, extremely firm when moist, very sticky when wet; common fine tubular pores; common fine soft round $CaCO_3$ nodules; strongly calcareous; common shell fragments; common fine, few medium roots; abrupt smooth boundary.
40-63	Dry clay; dark yellowish brown (10 YR 3/4) when moist and dark brown to brown (10 YR 4/3) when dry; weak medium prismatic breaking to medium angular blocky; extremely hard when dry, extremely firm when moist, very sticky when wet; few fine tubular pores; few fine soft pseudomycelia $CaCO_3$; strongly calcareous; common shell fragments; common fine, few medium roots; clear wavy boundary.
63-93	Very slightly moist clay; dark yellowish brown (10 YR 3/4) when moist and dark brown to brown (10 YR 4/3) when dry; moderate coarse angular blocky; extremely hard when dry, extremely firm when moist; sticky when wet; few fine tubular pores; abundant medium soft $CaCO_3$ nodules; strongly calcareous; common shell fragments; common fine gypsum crystals; few fine roots; clear wavy boundary.
93-140	Very slightly moist clay; dark brown (10 YR 3/3) when moist and dark yellowish brown (10 YR 3/4) when dry; common fine distinct red brown mottles; weak coarse angular blocky; extremely hard when dry, extremely firm when moist, sticky when wet; few fine tubular pores; common fine soft $CaCO_3$ nodules; strongly calcareous; common fine gypsum crystals; common fine soft manganese concretions; termite channel common; rare fine roots; gradual smooth boundary.
140-200	Very slightly moist clay; dark brown (10 YR 3/3) when moist, and dark yellowish brown (10 YR 3/4) when dry; few fine faint yellow brown mottles; massive breaking to fine angular blocky; extremely hard when dry, extremely firm when moist, sticky when wet; no pores visible; common fine soft $CaCO_3$ nodules; strongly calcareous; common fine gypsum crystals; no roots.

REMARKS Subsoil accumulations of calcium carbonate and gypsum. Very compact profile below 93 cm with 1 to 3 mm few vertical cracks down to 70 cm. Common iron/manganese nodules at 140 to 200 cm.

PIT NUMBER PG 03

Soil classification:	FAO Chromic Vertisol USDA Paleustollic Chromusterts
Land suitability:	LUT 1 or 2 - S2; LUT 3 - S3; LUT 4 - S2
Mapping unit	A2

(1) SITE CHARACTERISTICS

Date of examination:	27th March 1987
Author:	W.P. Gibson
Location:	Approximately 1°51'N - 44°45°E
Landform:	Main floodplain
Vegetation/land use:	Fallow irrigated area, previously maize and sesame
Slope:	1% up to north
Micro relief:	Weak gilgai relief

(2) SOIL INFORMATION

Parent material:	Shebelle alluvium - old
Profile drainage:	Moderate
Flood hazard:	None
Surface features:	Wide cracks (up to 10 cm), 2 to 3 cm deep surface mulch
Evidence of erosion:	None
Depth to groundwater:	Not encountered

(3) PROFILE DESCRIPTION

Depth (cm)	Field description
0-20	Dry clay; very dark greyish brown (10 YR 3/2) when moist, and dark brown (10 YR 3/3) when dry; moderate fine to medium subangular blocky; very hard when dry, firm when moist and sticky when wet; common fine and medium tubular pores; few fine soft $CaCO_3$ nodules, strongly calcareous; few shell fragments; common fine and few medium roots; clear wavy boundary.
20-71	Dry clay; very dark greyish brown (10 YR 3/2) when moist and dark brown (10 YR 3/3) when dry; few fine faint red brown mottles; moderate medium prismatic; very hard when dry, firm when moist, and sticky when wet; common fine and medium tubular pores; few fine soft $CaCO_3$ nodules; strongly calcareous; few gypsum crystals; common shell fragments; few soft manganese concretions; few fine roots; gradual smooth boundary.
71-100	Dry clay; dark brown to brown (10 YR 4/3) when moist, and dark yellowish brown (10 YR 4/4) when dry; common fine faint yellow brown mottles; moderate medium angular blocky; slightly hard when dry, friable when moist, and sticky when wet; common fine and few medium tubular pores; abundant coarse soft white $CaCO_3$ nodules; strongly calcareous; few gypsum crystals; few fine roots; clear smooth boundary.
100-140	Dry clay; dark brown to brown (10 YR 4/3) when moist, and dark yellowish brown (10 YR 4/4) when dry; weak medium angular blocky; slightly hard when dry; friable when moist, and sticky when wet; few fine tubular pores; common fine and medium soft $CaCO_3$ nodules; strongly calcareous; common gypsum crystals; few shell fragments; few fine roots; gradual smooth boundary.
140-180	Very slightly moist clay; dark brown (7.5 YR 3/2) when moist, and brown (7.5 YR 4/2) when dry; common distinct iron staining on root channels and ped faces, moderate medium angular blocky; hard when dry; firm when moist, and very sticky when wet; few fine tubular pores; common large and medium soft $CaCO_3$ nodules and pseudomycelia; strongly calcareous; common gypsum crystals; few fine roots; clear smooth boundary.
180-210	Very slightly moist clay; dark brown (10 YR 3/3) when moist, and dark yellowish brown (10 YR 3/4) when dry; common fine distinct red brown mottles; weak medium angular blocky; very hard when dry, firm when moist and very sticky when wet; no pores visible; few medium soft $CaCO_3$ nodules; strongly calcareous; common fine gypsum crystals; no roots.
REMARKS	Mixed parent material inclusions between 100 to 140 cm with mixed colours. 1 to 3 mm vertical cracks from surface down to 120 cm and below 70 cm structures break to fine angular blocky.

PIT NUMBER PG04

Soil classification: FAO Chromic Vertisol USDA Paleustollic Chromusterts

Land suitability: LUT 1 or 2 - S2; LUT 3 - S3; LUT 4 - S2

Mapping unit B1

(1) SITE CHARACTERISTICS

Date of examination: 27th March 1987
Author: W.P. Gibson
Location: Approximately 1°52'N - 44°49'E
Landform: Main floodplain
Vegetation/land use: Fallow, scattered Dobera glabra trees. Rainfed area
Slope: 0.5% up to north
Micro relief: Weak gilgai

(2) SOIL INFORMATION

Parent material: Shebelle alluvium - semi-recent
Profile drainage: Moderate
Flood hazard: None
Surface features: Common 2 cm to 3 cm wide cracks, 2 cm to 3 cm surface mulch
Evidence of erosion: None
Depth to groundwater: Not encountered

(3) PROFILE DESCRIPTION

Depth (cm)	Field description
0-15	Dry clay; dark yellowish brown (7.5 YR 3/4) when moist and dark brown (7.5 YR 3/2) when dry; moderate medium subangular blocky; extremely hard when dry, very firm when moist and very sticky when wet; few fine and medium tubular pores; few fine soft $CaCO_3$ nodules; common fine and few medium roots; gradual smooth boundary.
15-50	Dry clay; dark yellowish brown (7.5 YR 3/4) when moist and dark brown to brown (7.5 YR 4/4) when dry; weak medium angular blocky; extremely hard when dry, very firm when moist and very sticky when wet; few fine and few medium tubular pores; few fine soft $CaCO_3$ nodules; strongly calcareous; few fine soft manganese nodules; common fine and few medium roots; gradual smooth boundary.
50-60	Dry clay; dark reddish brown (5YR 3/3) when moist and dark brown (7.5 YR 3/2) when dry; weak medium angular blocky; extremely hard when dry; very firm when moist and very sticky when wet; few fine tubular pores; few fine soft $CaCO_3$ nodules; strongly calareous; common soft fine manganese concretions; common fine roots; abrupt smooth boundary.
60-76	Dry sandy loam; dark brown to brown (10 YR 4/3) when moist and yellowish brown (10 YR 5/4) when dry; common fine prominent yellow brown mottles; massive and compact; slightly hard when dry, friable when moist and non-sticky when wet; common fine and few medium tubular pores; few fine soft $CaCO_3$ nodules; strongly calcareous; common shell fragments; few fine roots; abrupt wavy boundary.
76-145	Dry loamy sand; yellowish brown (10 YR 5/4) when moist and light yellowish brown (10 YR 6/4) when dry; thin bands of iron staining; single grained with horizontal striations; soft when dry, very friable when moist and non-sticky when wet; common fine and medium vesicular; termite and rodent activity; few fine roots; abrupt wavy boundary (thin clay band running horizontally through middle of horizon and few fine sandy loam lenses.)
145-197	Dry loamy sand; yellowish brown (10 YR 5/4) when moist and pale brown (10 YR 6/3) when dry; laminated, weak platy; loose when dry, very friable when moist and non-sticky when wet; common fine pores; rodent activity; few fine roots; abrupt wavy boundary.
197-210	Dry fine sand; yellowish brown (10 YR 5/4) when moist and pale brown (10 YR 6/3) when dry; single grained with horizontal striations; loose when dry, very friable when moist and non-sticky when wet; no pores visible; few fine soft manganese concretions; no roots.
REMARKS	Top 60 cm is a chromic vertisol with vertical cracks up to 2 cm wide down to buried soil boundary at 76 cm. The coarser textured horizons are not diagnostic for classification purposes since they are covered by more recent material 60 cm thick. The extent of this coarser textured material was not determined but could be expected to be localised since nearby observations did not reveal coarser subsoil textures.

PIT NUMBER PG 03

Soil classification: FAO Chromic Vertisol USDA Paleustollic Chromusterts

Land suitability: LUT 1 or 2 - S2; LUT 3 - S3; LUT 4 - S2

Mapping unit A2

(1) SITE CHARACTERISTICS

Date of examination: 27th March 1987
Author: W.P. Gibson
Location: Approximately 1°51'N - 44°45'E
Landform: Main floodplain
Vegetation/land use: Fallow irrigated area, previously maize and sesame
Slope: 1% up to north
Micro relief: Weak gilgai relief

(2) SOIL INFORMATION

Parent material: Shebelle alluvium - old
Profile drainage: Moderate
Flood hazard: None
Surface features: Wide cracks (up to 10 cm), 2 to 3 cm deep surface mulch
Evidence of erosion: None
Depth to groundwater: Not encountered

(3) PROFILE DESCRIPTION

Depth (cm)	Field description
0-20	Dry clay; very dark greyish brown (10 YR 3/2) when moist, and dark brown (10 YR 3/3) when dry; moderate fine to medium subangular blocky; very hard when dry, firm when moist and sticky when wet; common fine and medium tubular pores; few fine soft $CaCO_3$ nodules, strongly calcareous; few shell fragments; common fine and few medium roots; clear wavy boundary.
20-71	Dry clay; very dark greyish brown (10 YR 3/2) when moist and dark brown (10 YR 3/3) when dry; few fine faint red brown mottles; moderate medium prismatic; very hard when dry, firm when moist, and sticky when wet; common fine and medium tubular pores; few fine soft $CaCO_3$ nodules; strongly calcareous; few gypsum crystals; common shell fragments; few soft manganese concretions; few fine roots; gradual smooth boundary.
71-100	Dry clay; dark brown to brown (10 YR 4/3) when moist, and dark yellowish brown (10 YR 4/4) when dry; common fine faint yellow brown mottles; moderate medium angular blocky; slightly hard when dry, friable when moist, and sticky when wet; common fine and few medium tubular pores; abundant coarse soft white $CaCO_3$ nodules; strongly calcareous; few gypsum crystals; few fine roots; clear smooth boundary.
100-140	Dry clay; dark brown to brown (10 YR 4/3) when moist, and dark yellowish brown (10 YR 4/4) when dry; weak medium angular blocky; slightly hard when dry; friable when moist, and sticky when wet; few fine tubular pores; common fine and medium soft $CaCO_3$ nodules; strongly calcareous; common gypsum crystals; few shell fragments; few fine roots; gradual smooth boundary.
140-180	Very slightly moist clay; dark brown (7.5 YR 3/2) when moist, and brown (7.5 YR 4/2) when dry; common distinct iron staining on root channels and ped faces, moderate medium angular blocky; hard when dry; firm when moist, and very sticky when wet; few fine tubular pores; common large and medium soft $CaCO_3$ nodules and pseudomycelia; strongly calcareous; common gypsum crystals; few fine roots; clear smooth boundary.
180-210	Very slightly moist clay; dark brown (10 YR 3/3) when moist, and dark yellowish brown (10 YR 3/4) when dry; common fine distinct red brown mottles; weak medium angular blocky; very hard when dry, firm when moist and very sticky when wet; no pores visible; few medium soft $CaCO_3$ nodules; strongly calcareous; common fine gypsum crystals; no roots.
REMARKS	Mixed parent material inclusions between 100 to 140 cm with mixed colours. 1 to 3 mm vertical cracks from surface down to 120 cm and below 70 cm structures break to fine angular blocky.

PIT NUMBER PG 05

Soil classification: FAO Calcaric Fluvisol USDA Typic Ustifluvert

Land suitability: LUT 1 or 2 - N2; LUT 3 - N1; LUT 4 - S3

Mapping Unit: 32

(1) SITE CHARACTERISTICS

Date of examination:	29th March 1987
Author:	W.P. Gibson
Location:	Approximately 1°51' N - 44° 47'E
Landform:	Broad low convex ridge-levee
Vegetation/land use:	Livestock browsing
Slope:	Almost level
Micro relief:	Even, between hummocks

(2) SOIL INFORMATION

Parent material:	Shebelle alluvium - semi-recent
Profile drainage:	Good
Flood hazard:	None
Surface features:	Capped surface with 30% grass cover
Evidence of erosion:	Wind erosion - leaving small hummocks where there are bushes
Depth to groundwater:	Not encountered

(3) PROFILE DESCRIPTION

Depth (cm)	Field description
0-30	Dry sandy loam; dark yellowish brown (10 YR 4/4) when moist and yellowish brown (10 YR 5/4) when dry; weak medium subangular blocky; loose when dry, very friable when moist and non-sticky when wet; common fine and medium tubular pores; few fine soft $CaCO_3$ nodules; termite channels; abundant fine and few medium roots; gradual smooth boundary.
30-87	Dry sandy clay loam; dark brown to brown (10 YR 4/3) when moist, yellowish brown (10 YR 5/4) when dry; massive breaking to medium angular blocky; slightly hard when dry, friable when moist, and non-sticky when wet; few fine and few medium tubular pores; few fine soft $CaCO_3$ nodules; few fine shell fragments; strongly calcareous; termite channels; abundant fine and few medium roots; gradual smooth boundary.
87-140	Dry sandy loam; dark brown to brown (10 YR 4/3) when moist, yellowish brown (10 YR 5/4) when dry; massive breaking to fine subangular blocky and loose; loose when dry, very friable when moist and non-sticky when wet; few fine and few medium tubular pores; few fine soft $CaCO_3$ nodules; strongly calcareous; few shell fragments; common fine and few medium roots; abrupt irregular boundary.
140-161	Dry sandy clay loam; dark yellowish brown (10 YR 4/4) when moist, yellowish brown (10 YR 5/4) when dry; common fine distinct red brown mottles; massive breaking to medium subangular blocky and loose; loose and slightly hard when dry, friable when moist and non-sticky when wet; few fine tubular pores; common fine and medium shell fragments; strongly calcareous; common medium hard manganese nodules; few fine roots; gradual broken boundary. (Discontinuous horizon).
161-196	Dry sandy loam; dark yellowish brown (10 YR 4/4) when moist, light yellowish brown (10 YR 6/4) when dry; massive; loose when dry, friable when moist and non-sticky when wet; few fine and few medium tubular pores; common shell fragments; strongly calcareous; common large, medium and fine angular iron/manganese nodules, strongly calcareous; few fine roots; abrupt smooth boundary.
196-210	Dry clay; dark brown (10 YR 3/3) when moist, dark brown (7.5 YR 3/2) when dry; few fine faint red brown mottles; moderate medium prismatic; hard when dry, friable when moist and very sticky when wet; few fine and few medium vesicular pores; common fine soft $CaCO_3$ nodules and pseudomycelia; strongly calcareous; few fine gypsum crystals; no roots.
REMARKS	Compact sandy loam surface with alternate horizons of sandy loam and sandy clay loam. A compact horizon at 30 cm to 87 cm. The soil is too droughty for rainfed agriculture but well suited for settlements as present land use indicates.

PIT NUMBER PG 06

Soil classification: *FAO Chromic Vertisol USDA Paleustollic Chromusterts*

Land suitability: LUT 1 or 2 - S2; LUT 3 - S3; LUT 4 - S2

Mapping unit: A2

(1) SITE CHARACTERISTICS

Date of examination:	29th March 1987
Author:	W.P. Gibson
Location:	Approximately 1°50'N - 44°49'E
Landform:	Main floodplain
Vegetation/land use:	*Livestock browsing*
Slope:	1½% up to north-west
Micro relief:	Moderate gilgai

(2) SOIL INFORMATION

Parent material:	Shebelle alluvium - old
Profile drainage:	Moderate
Flood hazard:	Slight runoff from higher slope during rainy season
Surface features:	Few large cracks, common sinkholes, 1 cm to 2 cm surface mulch, shell fragments
Evidence of erosion:	None
Depth to groundwater:	*Not encountered*

(3) PROFILE DESCRIPTION

Depth (cm)	Field description
0-15	Dry clay; very dark greyish brown (10 YR 3/2) when moist and dark greyish brown (10 YR 4/2) when dry; moderate fine subangular blocky and fine granular crumb; hard when dry, firm when moist and very sticky when wet; few fine and few medium tubular pores; few fine hard $CaCO_3$ nodules; strongly calcareous; common shell fragments; common fine, few medium and coarse roots; gradual smooth boundary.
15-43	Dry clay; very dark greyish brown (10 YR 3/2) when moist and dark greyish brown (10 YR 4/2) when dry; moderate medium angular blocky; hard when dry, slightly firm when moist and very sticky when wet; few fine tubular pores; few fine soft $CaCO_3$ nodules; strongly calcareous; few shell fragments; common fine, few medium, few coarse roots; gradual smooth boundary.
43-80	Dry clay; very dark greyish brown (10 YR 3/2) when moist and dark greyish brown (10 YR 4/2) when dry; few fine faint red brown mottles; moderate coarse angular blocky; extremely hard when dry, very firm when moist and very sticky when wet; few fine and few medium tubular pores; few fine soft $CaCO_3$ nodules and medium soft white deposits secondary carbonate; strongly calcareous; common shell fragments; few fine roots; gradual smooth boundary.
80-105	*Dry clay; very dark greyish brown (10 YR 3/2) when moist and dark greyish brown (10 YR 4/2) when dry;* few fine distinct orange brown mottles; weak medium angular blocky; extremely hard when dry, very firm when moist and very sticky when wet; no pores visible; common fine soft rounded $CaCO_3$ nodules; strongly calcareous, common shell fragments; common soft fine manganese concretions; few fine roots; gradual smooth boundary.
105-150	Dry clay; very dark greyish brown (10 YR 3/2) when moist and dark greyish brown (10 YR 4/2) when dry; common fine distinct red brown mottles, weak coarse prismatic; extremely hard when dry, firm when moist and very sticky when wet; no pores visible; common fine and medium soft $CaCO_3$ nodules; strongly calcareous; common gypsum crystals; common shell fragments; few medium soft manganese concretions; no roots; gradual smooth boundary.
150-200	Dry clay; very dark greyish brown (10 YR 3/2) when moist and dark brown (10 YR 3/3) when dry; common fine distinct red brown mottles; weak medium angular blocky; extremely hard when dry, firm when moist and very sticky when wet; no visible pores; common fine soft $CaCO_3$ nodules; strongly calcareous; common gypsum crystals; common shell fragments; few fine soft manganese concretions; no roots.

REMARKS *Vertical cracks 1 cm to 2 cm down to 80 cm and less than 1 cm down to base of profile. Well developed* s. ckensides from 80 cm to 150 cm.

The surrounding area is covered by dense bush which is included in the nearby fuelwood project area.

PIT NUMBER PG 07

Soil classification: FAO Chromic Vertisol USDA Paleustollic Chromusterts

Land suitability: LUT 1 or 2 - S2; LUT 3 - S3; LUT 4 - S2.

Mapping unit: B1

(1) SITE CHARACTERISTICS

Date of examination: 29th March 1987
Author: W.P. Gibson
Location: Military farm Nr 73/SH-21, approximately 1°54'N - 44°46'E
Landform: Main floodplain
Vegetation/land use: Irrigated, previous crop
Slope: 0.5% up to south-east
Micro relief: Moderate gilgai, no sinkholes

(2) SOIL INFORMATION

Parent material: Shebelle alluvium - semi-recent
Profile drainage: Moderate
Flood hazard: None due to flood protection measures
Surface features: Few 5 cm cracks, 2 cm to 3 cm surface mulch
Evidence of erosion: None
Depth to groundwater: Not encountered

(3) PROFILE DESCRIPTION

Depth (cm)	Field description
0-38	Dry clay; dark reddish brown (5 YR 3/4) when moist, and brown (10 YR 4/3) when dry; moderate coarse prismatic with granular crumb surface; extremely hard when dry, friable when moist and very sticky when wet; few fine and medium tubular pores; few fine hard rounded $CaCO_3$ nodules; strongly calcareous; common fine and few medium roots; gradual smooth boundary.
38-115	Slightly moist clay; dark reddish brown (5 YR 3/4) when moist; few fine faint red brown mottles; moderate medium prismatic; hard when dry, friable when moist and very sticky when wet; few fine tubular pores; few fine white soft $CaCO_3$ nodules; strongly calcareous, common fine roots along ped faces; gradual smooth boundary.
115-140	Moist clay; dark brown (10 YR 3/3) when moist; common fine distinct red brown mottles; massive breaking to fine angular blocky; firm when moist and sticky when wet; few fine and few medium pores; common medium soft $CaCO_3$ deposits; strongly calcareous; common fine gypsum crystals; few fine roots; clear smooth boundary.
140-155	Moist sandy clay loam; dark yellowish brown (10 YR 4/4) when moist; few medium distinct red brown mottles; weak fine platy, laminated; friable when moist and sticky when wet; few fine vesicular pores; few fine soft $CaCO_3$ nodules; few fine roots; clear smooth boundary.
155-200	Moist clay; dark brown (7.5 YR 3/2) when moist; common fine distinct red brown mottles; medium angular blocky; very firm when moist, very sticky when wet; no visible pores; common fine and medium soft $CaCO_3$ nodules; strongly calcareous; common gypsum crystals; no roots.
REMARKS	The profile has vertical cracks 2 cm to 3 cm wide down to 150 cm. Slickensides are well developed between 77 cm and 140 cm. Iron staining and grey ped faces are present between 155 and 200 cm.

PIT NUMBER PG 08

Soil classification: FAO Chromic Vertisol USDA Paleustollic Chromusterts

Land suitability: LUT 1 or 2 - S2; LUT 3 - S3; LUT 4 - S2.

Mapping unit: A2

(1) SITE CHARACTERISTICS

Date of examination:	29th March 1987
Author:	W.P. Gibson
Location:	Approximately 1°48'N - 44°46'E
Landform:	Main floodplain
Vegetation/land use:	Traditional flood irrigation of maize and sesame
Slope:	< 0.5%
Micro relief:	Weakly developed gilgai, common sinkholes

(2) SOIL INFORMATION

Parent material:	Shebelle alluvium - old
Profile drainage:	Moderate
Flood hazard:	None,
Surface features:	Deep surface mulch 5 cm to 10 cm, large cracks and shell fragments
Evidence of erosion:	None
Depth to groundwater:	Not encountered

(3) PROFILE DESCRIPTION

Depth (cm)	Field description
0-32	Dry clay; dark brown (10 YR 3/3) when moist and dark brown (7.5 YR 3/2) when dry; moderate medium and coarse angular blocky; extremely hard when dry, firm when moist and very sticky when wet; common fine and medium, few large tubular pores; common fine and medium hard rounded $CaCO_3$ nodules; strongly calcareous; common shell fragments; common fine and few medium roots; clear smooth boundary.
32-63	Dry clay; very dark greyish brown (10 YR 3/2) when moist and dark brown (7.5 YR 3/2) when dry; moderate coarse prismatic; extremely hard when dry, firm when moist and very sticky when wet; common fine, few medium and few large tubular pores; common fine and medium hard round $CaCO_3$ nodules; strongly calcareous; common shell fragments; common fine roots; gradual smooth boundary.
63-100	Dry clay; dark brown (10 YR 3/3) when moist and dark brown (7.5 YR 3/2) when dry; few fine faint yellow brown mottles; weak medium prismatic; extremely hard when dry, extremely firm when moist and very sticky when wet; few fine pores; common fine soft and hard $CaCO_3$ nodules; strongly calcareous; common soft iron/manganese concretions; few fine roots; gradual smooth boundary.
100-160	Dry clay; dark yellowish brown (10 YR 3/4) when moist and dark brown (7.5 YR 3/2) when dry; common fine distinct red brown mottles; massive breaking to medium angular blocky; extremely hard when dry, extremely firm when moist and very sticky when wet; no visible pores; common soft and hard medium $CaCO_3$ nodules; strongly calcareous; common shell fragments; few soft manganese concretions; no roots.
REMARKS	Extremely compact profile and too difficult to dig below 160 cm. Vertical cracks, 1 cm wide, to 100 cm. Common gypsum crystals below 100 cm.

PIT NUMBER PG 09

Soil classification: FAO Chromic Vertisol, USDA Paleustollic Chromusterts

Land suitability: LUT 1 or 2 - S2; LUT 3 - S3; LUT 4 - S2

Mapping unit B1

(1) SITE CHARACTERISTICS

Date of examination: 30th March 1987
Author: W.P. Gibson
Location: Approximately 1°51'N - 44°48'E
Landform: Main floodplain
Vegetation/land use: Rainfed subsistence agriculture - maize
Slope: 1% up to north-west
Micro relief: Moderate gilgai

(2) SOIL INFORMATION

Parent material: Shebelle alluvium - semi-recent
Profile drainage: Moderate to good
Flood hazard: Runoff from higher slopes may collect in this slight depressional area
Surface features: 10 cm wide cracks common, 5 cm deep surface mulch
Evidence of erosion: Shallow gulley nearby running down towards old alluvial soils
Depth to groundwater: Not encountered

(3) PROFILE DESCRIPTION

Depth (cm)	Field description
0-20	Dry clay: dark reddish brown (5 YR 3/4) when moist, and dark brown (7.5 YR 3/2) when dry; moderate medium angular blocky and granular crumb; extremely hard when dry, very firm when moist, and sticky when wet; common fine and medium tubular pores; few fine hard round $CaCO_3$ nodules; strongly calcareous; few fine and few medium roots; gradual smooth boundary.
20-70	Dry clay: dark reddish brown (5 YR 3/4) when moist, and dark brown (7.5 YR 3/2) when dry; coarse strong prismatic; extremely hard when dry, very firm when moist, and sticky when wet; few fine and few medium tubular pores; common fine soft $CaCO_3$ nodules; strongly calcareous; few fine and few medium along cracks; gradual smooth boundary.
70-145	Dry clay: dark reddish brown (5 YR 3/3) when moist, and dark brown (7.5 YR 3/2) when dry; moderate coarse prismatic; extremely hard when dry, very firm when moist, and plastic when wet; few fine vesicular pores; few fine soft $CaCO_3$ nodules; strongly calcareous; common medium soft manganese concretions; few fine roots along cracks; gradual smooth boundary.
145-168	Dry silty clay; dark reddish brown (5 YR 3/4) when moist, and dark brown (7.5 YR 3/2) when dry; few fine faint red brown mottles; weak medium angular blocky; extremely hard when dry, very firm when moist, and sticky when wet; few fine pores; few fine soft $CaCO_3$ nodules; strongly calcareous; large inclusions of organic or manganese staining; few fine roots; gradual smooth boundary.
168-190	Slightly moist clay; dark yellowish brown (10 YR 3/4) when moist, and dark reddish brown (5 YR 3/4) when dry; many medium distinct red brown mottles; massive; extremely firm when slightly moist, and plastic when wet; no pores visible; common fine and medium soft $CaCO_3$ nodules; strongly calcareous; common gypsum crystals; common black staining vertically down profile; no roots visible.

REMARKS Large, 5 to 8 cm wide, vertical cracks down to 140 cm running through a very compact horizon between 20 to 70 cm. Slickensides are in evidence between 145 to 180 cm. A transitional horizon to old alluvium occurs between 168 to 180 cm.

PIT NUMBER PG10

Soil classification:	FAO Chromic Vertisol, USDA Paleustollic Chromusterts
Land suitability:	LUT 1 or 2 - S2; LUT 3 - S3; LUT 4 - S2
Mapping unit	A1

(1) SITE CHARACTERISTICS

Date of examination:	30th March 1987
Author:	W.P. Gibson
Location:	Approximately 1°53'N - 44°54'E
Landform:	Main floodplain near coastal dunes
Vegetation/land use:	Livestock browsing
Slope:	1% up to north
Micro relief:	Weakly developed gilgai, few sinkholes

(2) SOIL INFORMATION

Parent material:	Shebelle alluvium - old
Profile drainage:	Moderate
Flood hazard:	Possible in exceptional years
Surface features:	Common large surface cracks, 5 cm deep surface mulch
Evidence of erosion:	None
Depth to groundwater:	Not encountered

(3) PROFILE DESCRIPTION

Depth (cm)	Field description
0-10	Dry clay: dark yellowish brown (10 YR 3/4) when moist, and dark brown (10 YR 3/3) when dry: moderate medium to coarse subangular blocky; extremely hard when dry, friable when moist, and plastic when wet: few fine and few medium tubular pores: few fine hard rounded $CaCO_3$ nodules; strongly calcareous; common fine and few medium roots; abrupt wavy boundary.
10-80	Dry clay: dark yellowish brown (10 YR 3/4) when moist, and dark brown to brown (10 YR 4/3) when dry; massive, compact; extremely hard when dry, friable when moist, and plastic when wet: no visible pores: few fine hard $CaCO_3$ nodules: strongly calcareous; few shell fragments; common fine roots; gradual irregular boundary.
80-103	Dry clay: dark brown (10 YR 3/3) when moist and dark brown (7.5 YR 3/2) when dry; weak medium prismatic: extremely hard when dry, friable when moist, and plastic when wet; few fine pores; common fine and medium soft $CaCO_3$ nodules; strongly calcareous; common gypsum crystals; few shell fragments; common very fine roots; abrupt smooth boundary.
103-125	Dry clay: very dark grey (10 YR 3/1) when moist, and very dark greyish brown (10 YR 3/2) when dry: massive breaking to coarse angular blocky; extremely hard when dry, friable when moist, and plastic when wet: no visible pores: common fine and medium soft $CaCO_3$ concretions: strongly calcareous: rare fine roots: abrupt wavy boundary.
125-149	Dry clay; dark yellowish brown (10 YR 3/4) when moist, and dark brown to brown (10 YR 4/3) when dry: weak medium angular blocky; extremely hard when dry, friable when moist and sticky when wet; no pores visible: common soft fine and medium $CaCO_3$ nodules: strongly calcareous; no roots; abrupt irregular boundary.
149-157	Dry silty clay: dark brown (10 YR 3/3) when moist, and dark brown (7.5 YR 3/2) when dry; few fine distinct yellow brown mottles: massive breaking to fine angular blocky; extremely hard when dry, friable when moist, and very sticky when wet; no pores visible; common fine soft $CaCO_3$ nodules; strongly calcareous; few gypsum crystals; few soft manganese concretions; no roots; abrupt smooth boundary.
157-184	Very slightly moist silty clay; very dark grey (10 YR 3/1) when moist and very dark greyish brown (10 YR 3/2) when dry; few fine distinct yellow brown mottles; massive breaking to medium angular blocky; extremely hard when dry, very friable when moist, very sticky when wet; no pores visible: few fine soft $CaCO_3$ nodules; strongly calcareous: few shell fragments; no roots: abrupt irregular boundary.
184-200	Slightly moist clay; dark brown (10 YR 3/3) when moist; weak medium angular blocky; extremely hard when dry, friable when moist, sticky when wet; no pores visible; few fine soft $CaCO_3$ nodules, strongly calcareous, no roots.

REMARKS Very compact profile with large vertical cracks (up to 50 cm wide) down to 80 cm and approximately 1 cm wide at 160 cm.

PIT Nr PG 01

Soil Analytical Data

Depth (cm)	Texture (lab)	Soil particles (%) s	z	c	pH (paste)	EC_e ($mS\ cm^{-1}$)	Saturation (%)
0 - 26	C	7	28	65	7.8	1.26	52.4
26 - 66	C	15	34	51	7.7	1.05	47.9
66 - 105	C	4	33	63	7.7	2.40	57.2
105 - 137	C	1	30	69	7.6	3.70	73.2

Depth (cm)	Soluble cations (meq/l)				Soluble anions (meq/l)				Cl/SO_4	SAR
	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4		
0 - 26	6.30	2.63	7.15	0.10	0.00	-	-	-	-	3.4
26 - 66	6.83	3.15	5.15	0.26	0.00	-	-	-	-	2.4
66 - 105	13.65	4.75	10.30	0.16	0.00	3.00	6.00	19.7	0.30	3.4
105 - 137	29.40	10.50	16.00	0.21	0.00	4.80	8.40	44.8	0.19	3.6

Depth (cm)	Exchangeable cations (meq/100 g)				CEC (meq/100 g soil)	BSP	ESP
	Ca	Mg	Na	K			
0 - 26	31.17	11.67	2.38	0.71	49.63	92.5	4.8
26 - 66	28.55	12.97	2.00	0.94	48.80	91.1	4.1
66 - 105	32.05	14.18	3.16	0.81	55.66	90.2	5.7
105 - 137	34.60	14.98	3.33	0.90	55.08	97.7	6.0

Depth (cm)	$CaCO_3$ (%)	$CaSO_4$ (meq/100 g)	OM (%)	Total N (%)	Available P (ppm)	Available K (ppm)
0 - 26	28.6	ND	0.67	0.045	5.60	11.08
26 - 66	23.3	ND	-	-	-	-
66 - 105	24.4	ND	-	-	-	-
105 - 137	26.5	ND	-	-	-	-

PIT Nr PG 02

Soil Analytical Data

Depth (cm)	Texture (lab)	Soil particles (%) s	z	c	pH (paste)	EC_e (mS cm^{-1})	Saturation (%)
0 - 40	C	3	37	60	7.6	1.80	65.6
40 - 63	C	2	35	63	7.6	2.70	69.7
93 - 140	Zc	2	54	44	7.7	4.50	60.9
140 - 180	Zb	11	71	18	7.9	5.70	56.2

Depth (cm)	Soluble cations (meq/l) Ca	Mg	Na	K	Soluble anions (meq/l) CO_3	HCO_3	Cl	SO_4	Cl/SO_4	SAR
0 - 40	14.18	6.80	3.65	1.00	0.00	-	-	-	-	1.1
40 - 63	31.50	7.35	4.10	0.79	0.00	6.60	4.80	33.90	0.14	0.9
93 - 140	27.80	18.90	21.50	0.35	0.00	2.40	8.40	-	-	4.5
140 - 180	27.30	24.70	35.00	0.38	0.00	3.00	10.20	76.2	0.13	6.9

Depth (cm)	Exchangeable cations (meq/100 g) Ca	Mg	Na	K	CEC (meq/100 g soil)	BSP	ESP
0 - 40	35.82	11.38	2.89	3.25	55.25	96.5	5.2
40 - 63	38.51	11.32	2.64	2.63	58.75	93.8	4.5
93 - 140	69.18*	17.23	3.69	0.88	39.99	*	9.2
140 - 180	51.60*	18.31	4.50	0.71	44.30	*	10.2

Depth (cm)	$CaCO_3$ (%)	$CaSO_4$ (meq/100 g)	OM (%)	Total N (%)	Available P (ppm)	Available K (ppm)
0 - 40	23.3	+	2.00	0.093	11.50	50.82
40 - 63	23.3	+	-	-	-	-
93 - 140	25.4	+	-	-	-	-
140 - 180	25.4	+	-	-	-	-

PIT Nr PG 03

Soil Analytical Data

Depth (cm)	Texture (lab)	Soil particles (%) s	z	c	pH (paste)	EC_e ($mS\ cm^{-1}$)	Saturation (%)
0 - 20	C	13	33	54	7.6	1.81	54.5
20 - 71	Z	4	89	7	7.8	3.05	55.7
71 - 100	Z	4	88	8	7.8	3.30	48.0
100 - 140	C	18	36	46	7.8	3.78	49.9

Depth (cm)	Soluble cations (meq/l) Ca	Mg	Na	K	Soluble anions (meq/l) CO_3	HCO_3	Cl	SO_4	Cl/SO_4	SAR
0 - 20	17.33	5.78	4.10	0.79	0.00	-	-	-	-	1.2
20 - 71	32.00	6.80	5.00	0.15	0.00	4.80	5.40	36.1	0.15	1.1
71 - 100	31.50	6.80	7.30	0.20	0.00	6.60	6.00	32.6	0.18	1.7
100 - 140	29.40	24.20	7.70	0.21	0.00	2.40	6.00	51.8	0.12	1.5

Depth (cm)	Exchangeable cations (meq/100 g) Ca	Mg	Na	K	CEC (meq/100 g soil)	BSP	ESP
0 - 20	31.89	8.88	2.13	2.08	50.00	90.0	4.3
20 - 71	95.34*	12.75	1.90	0.71	50.00	*	3.8
71 - 100	128.50*	14.12	1.63	0.76	37.50	*	4.3
100 - 140	100.90*	17.17	1.67	0.63	37.50	*	4.5

Depth (cm)	$CaCO_3$ (%)	$CaSO_4$ (meq/100 g)	OM (%)	Total N (%)	Available P (ppm)	Available K (ppm)
0 - 20	18.1	+	2.18	0.092	8.10	32.50
20 - 71	23.3	+	-	-	-	-
71 - 100	20.1	+	-	-	-	-
100 - 140	23.3	+	-	-	-	-

PIT Nr PG 04

Soil Analytical Data

Depth (cm)	Texture (lab)	Soil particles (%) s	z	c	pH (paste)	EC_e ($mS\ cm^{-1}$)	Saturation (%)
0 - 15	Zc	3	44	53	7.6	1.26	55.0
15 - 50	C	4	24	72	7.8	1.58	48.8
60 - 76	C	18	36	46	7.8	2.88	35.6
76 - 120	LS	89	0	11	7.9	2.90	31.2

Depth (cm)	Soluble cations (meq/l) Ca	Mg	Na	K	Soluble anions (meq/l) CO_3	HCO_3	Cl	SO_4	Cl/SO_4	SAR
0 - 15	7.88	4.73	3.27	0.46	0.00	-	-	-	-	1.3
15 - 50	5.78	2.10	11.25	0.16	0.00	-	-	-	-	5.7
60 - 76	7.40	3.20	22.50	0.13	0.00	4.80	21.60	4.8	4.50	9.8
76 - 120	11.00	4.20	19.40	0.23	0.00	4.80	12.60	14.0	0.90	7.0

Depth (cm)	Exchangeable cations (meq/100 g) Ca	Mg	Na	K	CEC (meq/100 g soil)	BSP	ESP
0 - 15	37.65	11.56	2.30	2.08	56.30	95.1	4.1
15 - 50	54.85*	9.10	3.80	0.95	56.30	*	6.8
60 - 76	16.82	5.14	2.40	0.25	27.50	89.4	8.7
76 - 120	10.16	5.12	1.15	0.13	16.80	98.6	7.1

Depth (cm)	$CaCO_3$ (%)	$CaSO_4$ (meq/100 g)	OM (%)	Total N (%)	Available P (ppm)	Available K (ppm)
0 - 15	24.3	+	1.20	0.060	9.80	32.50
15 - 50	15.0	+	-	-	-	-
60 - 76	16.9	+	-	-	-	-
76 - 120	12.8	+	-	-	-	-

PIT Nr PG 05

Soil Analytical Data

Depth (cm)	Texture (lab)	Soil particles (%) s	z	c	pH (paste)	EC_e ($mS\ cm^{-1}$)	Saturation (%)
0 - 30	Scl	59	13	28	7.7	1.89	36.9
30 - 87	Zl	22	57	21	7.7	1.45	37.2
87 - 140	Scl	69	7	24	7.9	1.78	33.6
140 - 161	Scl	69	10	21	7.6	5.78	34.5

Depth (cm)	Soluble cations (meq/l) Ca	Mg	Na	K	Soluble anions (meq/l) CO_3	HCO_3	Cl	SO_4	Cl/SO_4	SAR
0 - 30	8.40	3.15	8.20	0.50	0.00	-	-	-	-	3.4
30 - 87	7.30	2.63	6.10	1.50	0.00	-	-	-	-	2.7
87 - 140	5.25	2.10	15.00	0.25	0.00	-	-	-	-	7.9
140 - 161	24.20	5.25	28.30	0.38	0.00	5.40	51.60	6.0	8.60	7.4

Depth (cm)	Exchangeable cations (meq/100 g) Ca	Mg	Na	K	CEC (meq/100 g soil)	BSP	ESP
0 - 30	19.4*	6.46	1.45	0.63	25.00	*	5.8
30 - 87	27.31*	7.78	2.00	1.70	27.50	*	7.3
87 - 140	10.32	5.18	2.00	0.38	23.50	76.0	8.5
140 - 161	14.92	5.07	1.37	0.31	23.02	94.1	6.0

Depth (cm)	$CaCO_3$ (%)	$CaSO_4$ (meq/100 g)	OM (%)	Total N (%)	Available P (ppm)	Available K (ppm)
0 - 30	15.0	+	0.40	0.030	2.30	9.80
30 - 87	15.0	+	-	-	-	-
87 - 140	20.1	+	-	-	-	-
140 - 161	13.8	+	-	-	-	-

PIT Nr PG 06

Soil Analytical Data

Depth (cm)	Texture (lab)	Soil particles (%) s	z	c	pH (paste)	EC_e (mS cm^{-1})	Saturation (%)
0 - 15	C	19	18	63	7.7	0.63	52.9
15 - 43	C	15	33	52	7.8	0.35	55.9
43 - 80	C	16	30	54	7.6	1.31	60.2
110 - 150	C	17	34	49	7.6	2.84	58.9

Depth (cm)	Soluble cations (meq/l) Ca	Mg	Na	K	Soluble anions (meq/l) CO_3	HCO_3	Cl	SO_4	Cl/SO_4	SAR
0 - 15	5.25	2.10	1.26	0.20	0.00	-	-	-	-	0.7
15 - 43	3.15	1.58	1.64	0.10	0.00	-	-	-	-	1.1
43 - 80	10.50	4.20	3.77	0.20	0.00	-	-	-	-	1.4
110 - 150	29.40	11.00	10.75	0.25	0.00	4.20	3.00	43.4	0.07	2.4

Depth (cm)	Exchangeable cations (meq/100 g) Ca	Mg	Na	K	CEC (meq/100 g soil)	BSP	ESP
0 - 15	40.40	9.08	1.66	1.15	61.25	84.0	2.7
15 - 43	37.88	7.80	1.71	1.00	61.25	79.0	2.8
43 - 80	38.75	8.94	1.82	0.95	56.25	89.7	3.2
110 - 150	49.41*	12.48	2.26	0.86	49.31	*	4.6

Depth (cm)	$CaCO_3$ (%)	$CaSO_4$ (meq/100 g)	OM (%)	Total N (%)	Available P (ppm)	Available K (ppm)
0 - 15	16.9	+	1.33	0.082	4.30	18.00
15 - 43	19.1	+	-	-	-	-
43 - 80	18.1	+	-	-	-	-
110 - 150	19.1	+	-	-	-	-

PIT Nr PG 07

Soil Analytical Data

Depth (cm)	Texture (lab)	Soil particles (%) s	z	c	pH (paste)	EC_e (mS cm^{-1})	Saturation (%)
0 - 38	C	5	28	67	7.7	0.63	55.2
38 - 77	C	1	29	70	7.7	1.10	67.4
77 - 115	C	1	20	79	7.6	3.80	67.0
115 - 140	C	2	38	60	7.7	3.68	66.1

Depth (cm)	Soluble cations (meq/l) Ca	Mg	Na	K	Soluble anions (meq/l) CO_3	HCO_3	Cl	SO_4	Cl/SO_4	SAR
0 - 38	4.20	2.63	1.64	0.40	0.00	-	-	-	-	0.9
38 - 77	4.72	3.68	4.20	0.66	0.00	-	-	-	-	2.0
77 - 115	27.83	12.08	14.80	0.32	0.00	4.20	2.40	44.1	0.05	3.3
115 - 140	26.25	11.03	20.60	0.25	0.00	4.80	2.40	51.2	0.05	4.8

Depth (cm)	Exchangeable cations (meq/100 g) Ca	Mg	Na	K	CEC (meq/100 g soil)	BSP	ESP
0 - 38	31.90	10.35	2.09	2.25	59.40	78.4	2.7
38 - 77	35.74	11.56	2.47	1.25	63.47	80.3	2.8
77 - 115	47.40*	14.94	3.50	1.08	62.75	*	3.2
115 - 140	32.40	11.10	4.89	0.83	56.77	86.7	8.6

Depth (cm)	$CaCO_3$ (%)	$CaSO_4$ (meq/100 g)	OM (%)	Total N (%)	Available P (ppm)	Available K (ppm)
0 - 38	25.4	+	0.94	0.060	7.50	35.20
38 - 77	24.3	+	-	-	-	-
77 - 115	25.4	+	-	-	-	-
115 - 140	25.4	+	-	-	-	-

PIT Nr PG 08

Soil Analytical Data

Depth (cm)	Texture (lab)	Soil particles (%) s	z	c	pH (paste)	EC_e (mS cm^{-1})	Saturation (%)
0 - 32	Zc	8	41	51	7.6	0.74	55.0
32 - 63	C	7	38	55	7.6	2.84	56.6
63 - 100	C	9	38	53	7.6	4.10	63.4
100 - 169	C	9	39	52	7.7	4.73	66.8

Depth (cm)	Soluble cations (meq/l) Ca	Mg	Na	K	Soluble anions (meq/l) CO_3	HCO_3	Cl	SO_4	Cl/SO_4	SAR
0 - 32	5.25	2.10	2.63	0.20	0.00	-	-	-	-	1.4
32 - 63	30.45	7.88	8.20	0.23	0.00	4.20	7.80	36.3	0.21	1.9
63 - 100	28.88	13.12	15.50	0.35	0.00	3.60	4.20	46.2	0.09	3.4
100 - 160	28.88	15.75	24.60	0.35	0.00	4.20	52.20	-	-	5.2

Depth (cm)	Exchangeable cations (meq/100 g) Ca	Mg	Na	K	CEC (meq/100 g soil)	BSP	ESP
0 - 32	37.76	9.06	1.91	1.20	56.25	88.8	3.4
32 - 63	48.15*	10.05	2.29	0.95	55.79	*	4.1
63 - 100	50.67*	16.23	3.00	1.00	55.27	*	5.4
110 - 160	45.32*	17.33	4.11	1.00	48.36	*	8.5

Depth (cm)	$CaCO_3$ (%)	$CaSO_4$ (meq/100 g)	OM (%)	Total N (%)	Available P (ppm)	Available K (ppm)
0 - 32	21.2	+	1.07	0.064	5.40	18.80
32 - 62	20.1	+	-	-	-	-
63 - 100	20.1	+	-	-	-	-
100 - 160	24.3	+	-	-	-	-

PIT Nr PG 09

Soil Analytical Data

Depth (cm)	Texture (lab)	Soil particles (%) s	z	c	pH (paste)	EC_e (mS cm^{-1})	Saturation (%)
0 - 20	C	1	38	61	7.8	0.63	60.3
20 - 70	C	1	37	62	7.8	0.42	65.2
70 - 145	C	1	41	58	7.6	3.40	72.2
145 - 168	C	1	33	66	7.7	4.00	76.6

Depth (cm)	Soluble cations (meq/l) Ca	Mg	Na	K	Soluble anions (meq/l) CO_3	HCO_3	Cl	SO_4	Cl/SO_4	SAR
0 - 20	5.20	2.10	1.13	0.23	0.00	-	-	-	-	0.6
20 - 70	3.68	3.15	2.06	0.13	0.00	-	-	-	-	1.1
70 - 145	31.00	10.00	8.80	0.30	0.00	3.60	4.20	40.60	0.10	1.9
145 - 168	32.55	11.03	15.20	0.26	0.00	3.60	10.80	43.10	0.25	3.3

Depth (cm)	Exchangeable cations (meq/100 g) Ca	Mg	Na	K	CEC (meq/100 g soil)	BSP	ESP
0 - 20	42.98	9.06	1.73	1.63	62.25	90.0	2.8
20 - 70	40.45	10.29	2.07	1.35	62.25	87.0	3.3
70 - 145	31.81	12.33	2.37	1.10	68.12	70.0	3.5
145 - 168	58.81	4.45	3.09	1.00	67.59	99.6	4.6

Depth (cm)	$CaCO_3$ (%)	$CaSO_4$ (meq/100 g)	OM (%)	Total N (%)	Available P (ppm)	Available K (ppm)
0 - 20	23.3	+	1.94	0.058	4.00	25.50
20 - 70	23.3	+	-	-	-	-
70 - 145	23.3	+	-	-	-	-
145 - 168	25.4	+	-	-	-	-

PIT Nr PG 10

Soil Analytical Data

Depth (cm)	Texture (lab)	Soil particles (%) s	z	c	pH (paste)	EC_e ($mS\ cm^{-1}$)	Saturation (%)
0 - 10	C	4	40	56	7.6	1.34	60.3
10 - 40	C	4	38	58	7.8	0.42	63.2
80 - 103	C	2	37	61	7.6	4.80	72.5
125 - 149	C	1	39	60	7.6	4.80	67.5

Depth (cm)	Soluble cations (meq/l) Ca	Mg	Na	K	Soluble anions (meq/l) CO_3	HCO_3	Cl	SO_4	Cl/SO_4	SAR
0 - 10	8.40	3.15	3.48	0.26	0.00	-	-	-	-	1.5
10 - 40	2.63	1.60	2.55	0.08	0.00	-	-	-	-	1.8
80 - 103	29.40	12.08	25.10	0.25	0.00	3.60	13.20	48.8	0.27	5.5
125 - 149	32.55	14.70	28.80	0.26	0.00	4.20	3.90	67.2	0.06	5.9

Depth (cm)	Exchangeable cations (meq/100 g) Ca	Mg	Na	K	CEC (meq/100 g soil)	BSP	ESP
0 - 10	42.81	9.00	1.97	1.19	62.50	88.8	3.4
10 - 40	42.00	10.40	2.17	0.95	64.80	85.7	3.4
80 - 103	66.12*	14.89	3.95	1.13	63.00	*	6.3
125 - 149	47.68*	13.45	1.40	0.83	59.35	*	2.4

Depth (cm)	$CaCO_3$ (%)	$CaSO_4$ (meq/100 g)	OM (%)	Total N (%)	Available P (ppm)	Available K (ppm)
0 - 10	18.1	+	1.20	0.060	4.90	15.60
10 - 40	18.1	+	-	-	-	-
80 - 103	20.1	+	-	-	-	-
125 - 149	24.3	+	-	-	-	-

APPENDIX IV

LAND USE AND PROJECT AREAS IN MARCH 1983

TABLE IV.1

Land Use Areas for March 1983

Land use	Irrigation development area (ha)	Rainfed development area (ha)	Swamp development zone (ha)	Total (ha)
1. Cultivated				
Banana	100	-	-	100
Grapefruit	15	-	-	15
Seasonal crops	4 335	1 150	-	5 485
Total	4 450	1 150	-	5 600
2. Fallow	3 755	3 220	-	6 975
3. Grassland	(see 2, 4 and 6)		2 730	2 730
4. Uncultivated	845	1 260	-	2 105
5. Dense bush	60	235	605	900
6. Currently not suitable for cultivation	295	1 955	-	2 250
7. Permanent swamp	-	-	1 310	1 310
8. Villages	55	55	-	110
9. Main road	-	155	-	155
Total project area	9 460	8 030	4 645	22 135

Notes: Minor adjustments have been made to original unrounded figures in calculation of the above summary totals.

Explanatory Notes for Table IV.1

1. The land area figures have been derived from a brief interpretation of photographs taken in March 1983. March is towards the end of the dry season and thus makes the definition of land cultivated difficult and the distinction between cropped land and seasonal fallow even more difficult without ground surveys and control. Also since 1983 a number of important factors have changed. First the relaxation of GOS price and marketing controls has stimulated increased cultivation and land development has proceeded as was visible in the Consultant's field surveys.

2. The area defined as fallow is land on which no evidence of recent cultivation or cropping could be seen. This category includes land either fallowed in the short term, i.e. within the first 2 years and land lying in a longer fallow. The reasons for this fallow include: land disputes, abandoned land, irrigation difficulties, socio-economic problems, land speculation and out of command land.

3. The availability of grazing in the irrigated and rainfed areas is included under the separate categories of fallow, uncultivated or uncultivable land. In addition certain areas of the gross cultivated areas should be included here such as canal banks, hand-picked fodder, etc.

4. Uncultivated land is where no evidence of old field boundaries or cultivation is directly visible from the aerial photography.

5. Land currently not suitable for cultivation is excluded due to either a soil or topographic limitation for irrigated and rainfed cropping.

6. The area of villages defines only those village sites falling directly within the project boundary and excludes those on the fringes of the dunes.

APPENDIX V

TEXTURAL PROFILES OF AUGER OBSERVATIONS

APPENDIX V

TEXTURAL PROFILES OF AUGER OBSERVATIONS

Explanatory Notes

1. Site Nr: Location shown on Map 1B

2. Photo Nr: Aerial photograph overlay for site

3. Landform: MFp - main floodplain
   CRl - channel remnant levee

4. Textural profile: Gives field texture and horizon thickness, e.g. CL_{20} C_{120} indicates clay loam from 0-20 cm and clay from 20-120 cm

   Textural groups quoted:

   C - clay
   Cl - clay loam
   Zc - silty clay
   ZL - silty loam
   Zcl - silty clay loam
   Sl - sandy loam

5. Soil unit: Soil mapping unit. Descriptions are given in Chapter 4. Some observations may lie slightly outside unit or not be totally representative of unit but have been included on a preliminary basis using API, pending further investigations.

TABLE V.1

Textural Profile of Auger Observations

Site Nr	Photo Nr	Landform	Textural profile	Soil unit
G01	072	MFp	C_{120}	B1
G02	071	MFp	C_{20} Zc_{40} C_{120}	A1
G03	162	MFp	C_{100}	A1
G04	162	MFp	C_{120}	A1
G05	162	MFp	C_{120}	B1
G06	162	MFp	C_{120}	A1
G07	162	MFp	C_{120}	A2
G08	162	MFp	C_{120}	A2
G09	162	CRL	Zl_{40} Zcl_{100} Zc_{120}	B2
G10	206	MFp	C_{120}	A1
G11	164	MFp	Cl_{40} ZiC_{80} C_{120}	B2
G12	206	MFp	C_{120}	A1
G13	206	MFp	Zl_{20} Zcl_{60} Zc_{120}	B1
G14	206	MFp	Cl_{20} C_{50} Sl_{120}	B1
G15	206	MFp	C_{120}	A1
G16	206	MFp	C_{120}	A1
G17	164	MFp	C_{120}	B1
G18	204	MFp	C_{120}	A1
G19	204	MFp	C_{120}	A1
G20	204	CRL	C_{50} Zc_{80} C_{120}	B1
G21	204	MFp	C_{100} Zc_{120}	B1
G22	164	MFp	C_{120}	B1
G23	164	CRL	Zcl_{20} Cl_{120}	B2
G24	164	MFp	C_{120}	A2
G25	069	MFp	C_{120}	A2
G26	163	MFp	C_{60} Cl_{120}	B1
G27	070	MFp	C_{120}	A2
G28	069	MFp	C_{20} Cl_{60} C_{120}	A2
G29	069	MFp	C_{120}	A2
G30	069	MFp	Cl_{20} C_{120}	A2
G31	069	CRL	Cl_{60} C_{120}	A3
G32	070	MFp	C_{120}	A2
G33	164	CRL	Cl_{120}	B2
G34	067	MFp	Cl_{20} C_{120}	A1
G35	027	MFp	C_{120}	C1
G36	201	CRL	Zcl_{40} Cl_{100} C_{120}	A3
G37	201	MFp	Zcl_{20} C_{140} C_{120}	A1
G38	202	MFp	Zc_{20} C_{120}	C1
G39	202	MFp	Zc_{80} C_{120}	C1
G40	167	CRL	Cl_{60} C_{120}	A3

APPENDIX VI

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APPENDIX VI

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ANNEX 2

WATER RESOURCES

ANNEX 2 - WATER RESOURCES

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CHAPTER 1

CLIMATE

1.1 General Description

The study area lies just 2° north of the equator and consequently the prevailing climatic conditions at any time are determined by the strength and position of the inter-tropical convergence zone (ITCZ). This is the region in which the surface winds of the northern and southern hemispheres meet and rise in a zone of low pressure and considerable atmospheric instability. The instability is the cause of most of the rainfall in the Study Area. If the zone is to the north of the study area, the south to south-west monsoon winds will be blowing but if it is to the south the north-east monsoon winds will blow. The movement of the ITCZ is primarily controlled by movement of the sun's declination with the time of year but many terrestrial and atmospheric influences impose their effect upon the movement. Although the seasonal movement of the ITCZ produces a well defined climatic cycle, the terrestrial and atmospheric influences impose short term variations and longer term conditions which affect rainfall.

Taking January 1 as an arbitrary starting point, up to the end of March the ITCZ is south of the equator and strong, dry north-easterly monsoon winds blow down the coast. This season, which has almost no rainfall, is called the jilaal. As the zone moves northwards the winds die away until finally, as it passes the Study Area, the gu rains start. The build-up to the rains lasts approximately three weeks and is characterised by calm, humid conditions.

The gu rains almost always commence during April, usually within the first 15 days. Initially the rainfall is mainly the result of the uplift produced by the ITCZ but during May the zone moves to the north and the south to south-westerly monsoon winds commence, intermittently bringing moist air masses from the Indian Ocean over the Study Area. Consequently the rains are augmented by many coastal showers and as the ITCZ moves steadily further north these take over as the source of rainfall. The true gu rains are therefore limited to April and May, the later coastal showers which last right through until August being known as the hagai rains. From May to October the south to south-west monsoon winds blow almost continuously and only with the approach of the ITCZ, this time from the north, do they subside. This usually occurs in late October or early November, building up to the der rains of November and early December. These rains are lighter than the gu rains and less reliable. In addition they are not followed by a period of coastal showers; the north-easterly monsoon winds that follow the rains are dry because the air mass has traversed the Arabian desert.

1.2 Available Data

There is unfortunately no raingauge or climate station within the project area. The nearest are at Janaale, a few kilometres downstream of the area, and Afgoi which is upstream of the project area and somewhat further away. Previously published data indicate that there is little difference in the main climatic parameters between these locations, with the exception of rainfall which is considered in the next section. Janaale has therefore been selected as the most suitable source of climatic data. The meteorological station at Janaale is well located, with no interference from nearby trees or buildings.

Table 1.1 shows the monthly averages of the main climatic parameters for Janaale. The main features of the climate are as follows:

(i) Very little variation in temperature through the year. The temperatures are generally at their highest in March/April before the gu rains and lowest during the haagai period, but the difference between these periods is only 3°C or 4°C. There is so little variation from year to year.

(ii) Relative humidity is uniformly high at about 80% except for the jilaal period when it drops slightly.

(iii) It is moderately windy through the year with two calmer periods around April and November. The values recorded in the jilaal are somewhat higher for the recent period than for 1953-58, possibly because of a shelter effect from the north-east winds at the original meteorological station. The mean values may therefore be a slight underestimate.

(iv) Half the annual rainfall occurs in three months (April to June); thereafter the rainfall drops off except for the peak of the der rains in November. January to March are almost always dry.

The climate can be classified as tropical, semi-arid.

Previously published data (originally from Fantoli, 1965) has been supplemented by more recent data from the current meteorological station (installed in 1978). In general there is little variation in the pattern from year to year, and it may be concluded that the intermittent nature of the climatic data sets does not significantly affect the mean values obtained.

1.3 Rainfall

There is one important exception to the general climatic uniformity referred to above - that of rainfall which shows both temporal and spatial variability. The annual rainfall at Janaale averages 480 mm but during the period of record it has ranged between 149 mm (1955) and 1 045 mm (1951). At Afgoi the mean rainfall is a little higher (525 mm) and the annual variation is similarly dramatic (91 to 915 mm). There are no other stations to provide further data of spatial variability so the values of the station nearest to the project area (Janaale) have been assumed to be representative. Some form of weighted average could be used, but this might provide some "smoothing" which would not fairly represent the circumstances experienced by an average farmer. However, it is clear (from observation and farmers' reports), that there is considerable variation within the area, with rainfall tending to decrease on moving inland. Appendix I contains the detailed monthly data for both Janaale and Afgoi, together with recent daily data for Janaale. Table 1.2 provides a summary of the data.

There are distinct differences in the rainfall pattern between these two stations. Figure 1.1a shows the monthly mean rainfall. Afgoi receives less rainfall during the period of haagai showers, but substantially more during the der period. Figure 1.1b indicates that the monthly 75% reliable rainfalls are in most cases lower at Afgoi than Janaale, showing that the former has a higher frequency of dry months. However, when the data are considered seasonally, the pattern of reliable rainfall is broadly similar to that of the average rainfall (Table 1.3).

Monthly Mean Rainfall at Afgoi and Janaale

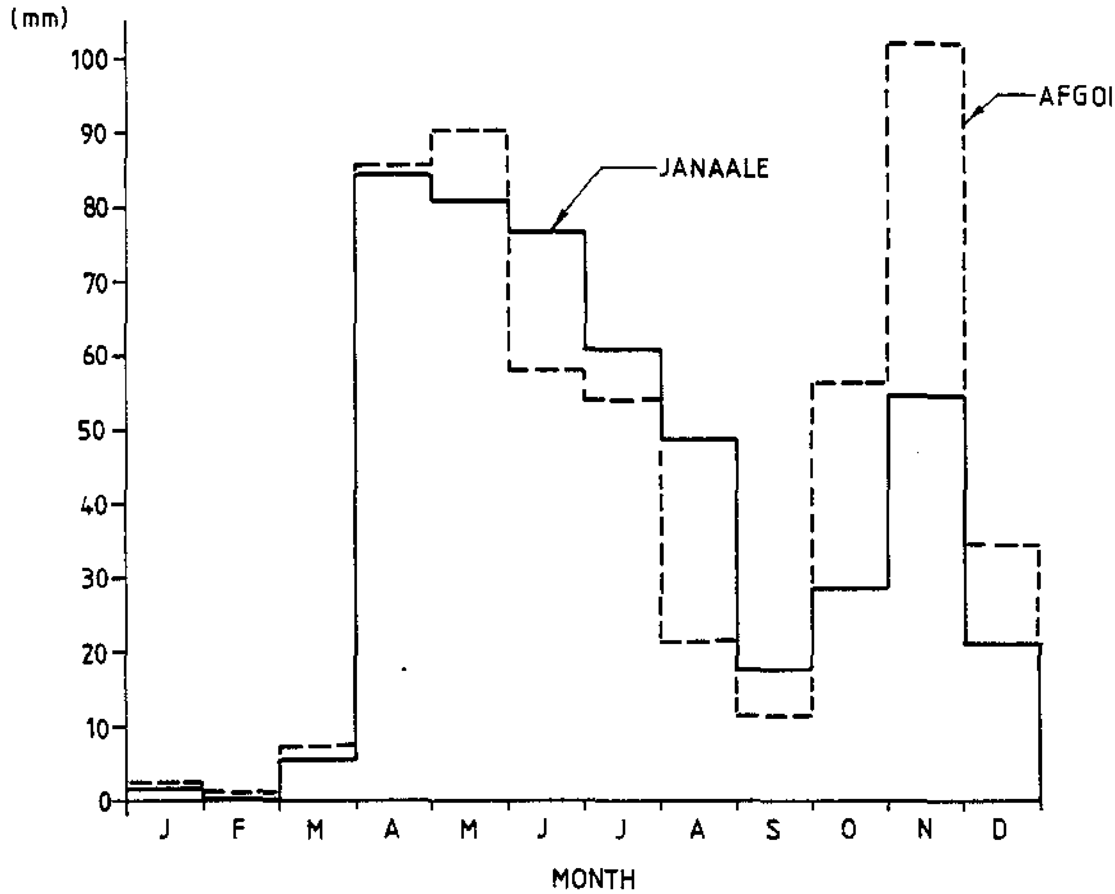


Figure 1.1 b

Monthly 75% Reliable Rainfall at Afgoi and Janaale

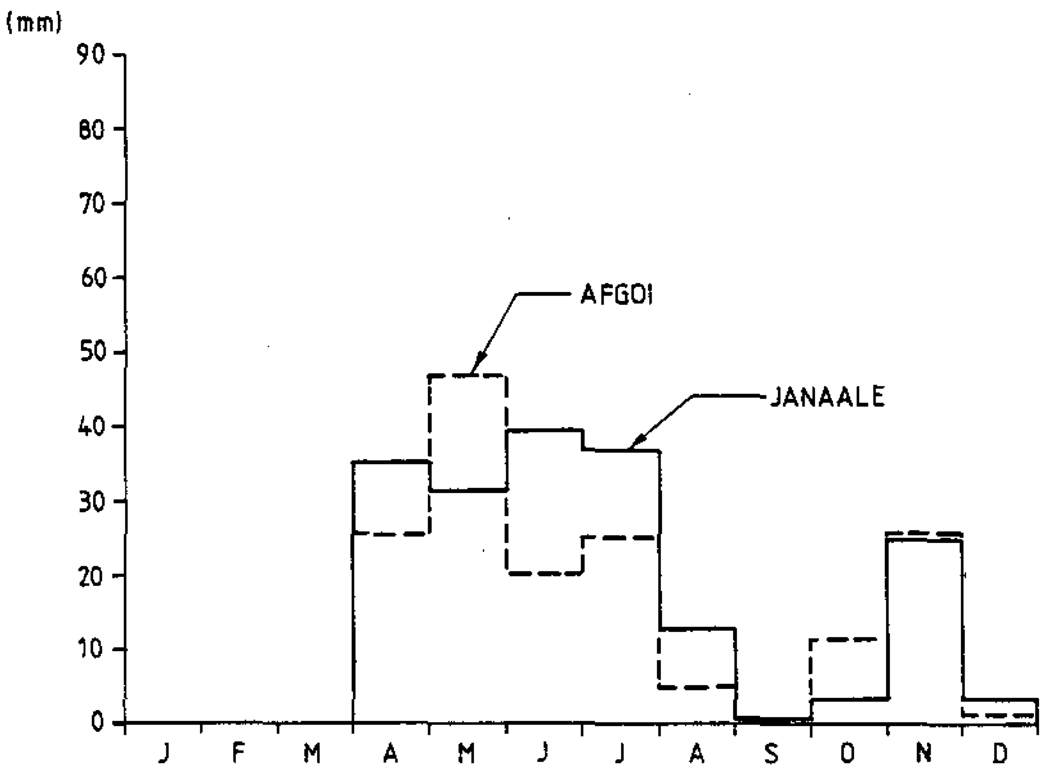


TABLE 1.1

Climatic Data for Janale

	Approximate length of record (years)	Unit	J	F	M	A	M	J	J	A	S	O	N	D	Year
Mean daily maximum temperature	22	°C	32.1	32.6	33.3	32.9	31.2	29.5	28.6	29.0	29.7	30.[illegible]	31.1	31.5	31.0
Mean daily minimum temperature	21	°C	21.3	21.9	23.2	23.9	23.3	21.7	21.6	21.5	22.2	22.[illegible]	22.3	21.8	22.3
Mean monthly temperature	21	°C	26.7	27.2	28.2	28.0	27.3	25.6	25.1	25.3	25.9	26.[illegible]	26.6	26.7	26.6
Absolute maximum temperature by months	15	°C	38.0	38.0	39.0	39.0	38.0	35.0	34.0	35.0	36.0	35.[illegible]	35.0	36.0	39.0
Absolute minimum temperature by months	15	°C	13.0	17.0	18.0	20.0	19.0	18.0	17.2	17.0	18.0	19.[illegible]	19.0	15.0	13.0
Relative humidity	22	%	75	74	76	77	81	82	82	81	80	80	81	79	79
Wind speed at 2 m (mean monthly)	12	m/s	2.1	2.2	1.8	1.8	1.7	2.1	2.5	2.5	2.6	1.[illegible]	1.4	1.5	2.0
Mean monthly cloud cover	14	tenths of sky	2.2	2.2	2.6	3.0	4.4	5.0	5.3	4.3	3.7	4.[illegible]	3.9	3.0	3.7
Mean monthly total sunshine	16	hours	288	265	297	251	236	209	212	240	261	28[illegible]	231	254	2 986
Monthly mean rainfall	36	mm	1.5	0.1	5.3	84.1	80.6	76.0	60.7	48.6	17.7	28.[illegible]	54.3	21.1	479.2
Mean number of rainy days	26	days	0	0	0	6	9	10	11	9	3	[illegible]	5	2	59
Dominant wind direction	12	-	NE	NE&E	E	SE&S	S&S	SW	SW	SW	SW&	[illegible]	E&SE	NE&E	-

Sources: Fantoli (1965) and Food Early Warning Department, Ministry of Agriculture, Mogadishu.

TABLE 1.1

Climatic Data for Janaale

	Approximate length of record (years)	Unit	J	F	M	A	M	J	J	A	S	O	N	D	Year
Mean daily maximum temperature	22	°C	32.1	32.6	33.3	32.9	31.2	29.5	28.6	29.0	29.7	30.5	31.1	31.5	31.0
Mean daily minimum temperature	21	°C	21.3	21.9	23.2	23.9	23.3	21.7	21.6	21.5	22.2	22.8	22.3	21.8	22.3
Mean monthly temperature	21	°C	26.7	27.2	28.2	28.4	27.3	25.6	25.1	25.3	25.9	26.7	26.6	26.7	26.6
Absolute maximum temperature by months	15	°C	38.0	38.0	39.0	39.0	38.0	35.0	34.0	35.0	36.0	35.0	35.0	36.0	39.0
Absolute minimum temperature by months	15	°C	13.0	17.0	18.0	20.0	19.0	18.0	17.2	17.0	18.0	19.5	19.0	15.0	13.0
Relative humidity	22	%	75	74	76	77	81	82	82	81	80	80	81	79	79
Wind speed at 2 m (mean monthly)	12	m/s	2.1	2.2	1.8	1.4	1.7	2.1	2.5	2.5	2.6	1.9	1.4	1.5	2.0
Mean monthly cloud cover	14	tenths of sky	2.2	2.2	2.6	3.8	4.4	5.0	5.3	4.3	3.7	4.3	3.9	3.0	3.7
Mean monthly total sunshine	16	hours	288	265	297	251	236	209	212	240	261	242	231	254	2 986
Monthly mean rainfall	36	mm	1.5	0.1	5.3	84.1	80.8	76.8	60.7	48.6	17.7	28.3	54.3	21.1	479.2
Mean number of rainy days	26	days	0	0	0	6	9	10	11	9	3	3	5	2	59
Dominant wind direction	12	-	NE	NE&E	E	SE&S	S&SW	SW	SW	SW	SW&S	S	E&SE	NE&E	-

Sources: Fantoli (1965) and Food Early Warning Department, Ministry of Agriculture, Mogadishu.

TABLE 1.2

MONTHLY RAINFALL CHARACTERISTICS (mm)

NTHLY RAINFALL AT JANAALE (MM)

AR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
AN	1.5	0.1	5.3	84.1	80.8	76.8	60.7	48.6	17.7	28.3	54.3	21.1	470.3

SUM OF MONTHLY MEANS = 479.2

LUES EQUALLED OR EXCEEDED 75 PERCENT OF THE TIME (NOT AN HOMOGENEOUS SEQUENCE)

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
tal	0.0	0.0	0.0	35.1	31.2	39.4	36.9	12.8	0.8	3.1	24.9	3.1	356.7
fective	0.0	0.0	0.0	31.3	27.9	35.1	32.9	11.5	0.7	2.8	22.4	2.8	

INFALL AT AFGOI (MM)

AR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
AN	2.7	1.1	7.3	85.8	90.6	58.0	54.0	21.4	11.6	56.3	102.0	34.8	527.3

SUM OF MONTHLY MEANS = 525.7

LUES EQUALLED OR EXCEEDED 75 PERCENT OF THE TIME (NOT AN HOMOGENEOUS SEQUENCE)

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
tal	0.0	0.0	0.0	25.9	47.0	20.4	25.2	5.0	0.0	11.7	25.9	1.4	424.1
fective	0.0	0.0	0.0	23.3	41.8	18.4	22.7	4.5	0.0	10.5	23.3	1.3	

The figure of 75% reliability for rainfall (and also for river flow) has been selected in accordance with previous studies of the Shabeelle area. (e.g. HTS 1969, MMP 1978). The data represent the rainfall level which will on average be exceeded in three years out of four, and are alternatively referred to as '1-in-4 dry year' values. It is important to note that the values in Table 1.2 have been calculated for each month independently and should not be considered as a series. The occurrence of these values for two or more consecutive months would be more severe than 1-in-4 years, because dry months do not necessarily occur consecutively. The seasonal values in Table 1.3 indicate that the 75% rainfall for April-June is nearly 50% higher than the sum of the individual monthly figures.

TABLE 1.3

Seasonal Rainfall Characteristics (mm)

Janaale:	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
Mean	6.9	241.7	127.0	103.7
1-in-4 dry year	0.0	149.6	70.9	51.3
Afgoi:				
Mean	1.1	234.4	87.0	193.1
1-in-4 dry year	0.0	161.7	46.2	102.2

As these two raingauges (from outside the project area) exhibit different rainfall patterns, and because all the available information indicates that there may be considerable spatial as well as temporal variation in rainfall, it would clearly be helpful for possible future developments to have raingauges within the area. However, in order to obtain detailed information on the rainfall pattern, a substantial network of raingauges would be required and it is considered that this would be both impractical and too expensive.

CHAPTER 2

THE RIVER SHABEELLE

2.1 Introduction

The Shabeelle river rises on the high plateau of eastern Ethiopia and has a total drainage basin of about 300 000 km^2. Approximately one-third of the catchment lies within Somalia, but over 90% of the river's flow comes from Ethiopia. The river, and the population which relies upon it, is therefore strongly dependent upon runoff from the Ethiopian plateau. Because of seepage losses, over-bank spillage and irrigation abstractions, the river's discharge steadily decreases as it flows through Somalia. The mean annual runoff for various locations is given in Table 2.1.

TABLE 2.1

Mean Annual Runoff - Shabeelle River

	MAR (hm^3)	Distance from Aw Dheegle (km)
Beled Wein	2 230	634
Buulo Burti	2 180	452
Mahaddey Wein	1 880	265
Afgoi	1 490	66
Aw Dheegle	1 330	-

Note: hm^3 represents million cubic metres.

This reduction continues downstream of Aw Dheegle until the river disappears in the swamps close to the Juba river. Although the Shabeelle is theoretically a tributary of the Juba, very little (if any) flow actually passes through the swamps to reach the Juba.

The flow in the Shabeelle shows substantial variation from year to year (e.g. at Aw Dheegle 830 hm^3 in 1980 and 2 080 hm^3 in 1983) and through the year, though there is a clear pattern to the seasonal variations. In the first three months of the year the flows are low, with the river sometimes drying up completely in February or March, particularly in the lower reaches below Afgoi. The gu flood season usually begins in the second half of April and lasts until June. This is followed by a short period of relatively low flows before the der flood which usually begins in late July or August. This is longer than the gu flood, though in the project area the peak flows are not significantly higher and the length of time for which the river flows at a sufficiently high level for gravity irrigation is generally only slightly greater than in the gu. Occasionally the der flood continues into the beginning of the following year.

Figures 2.1 and 2.2 show the hydrographs at Aw Dheegle for a selection of recent years which cover a range of wet and dry years. All broadly exhibit the pattern described above, but there are considerable differences in the magnitude of low flows and in the lengths of the flood seasons.

2.2 River Discharges

2.2.1 Available Data

Staff-gauge levels are available for a number of locations. The longest record is for Beled Wein, near the Ethiopian border, where records date from 1951. However, there are no records of discharge measurements before 1963, so the flow data for the early years may be subject to considerable errors. Other gauging stations were established in 1963, including one at Aw Dheegle which is just upstream of the project area. The stations are operated by the Ministry of Agriculture; all available original data were reprocessed during the Somalia Hydrometry Project and presented by MMP (1985 and 1986). At all stations there have been various periods of missing data and other periods have been identified as suspect by comparison with adjacent stations. Lahmeyer (1986) used cross-correlation techniques to infill missing data by reference to data at other stations. The monthly discharges for Aw Dheegle are presented in Appendix 1.

Although the historic data for Aw Dheegle are considered satisfactory, there has been some deterioration in recent years because of the collapse of the old bridge. The wreckage from the bridge must have some effect on the water level at the gauge, and check measurements using the water level dipper from the bridge are no longer possible. Dips are being made at times from the new bridge some distance downstream, but the separation is too great for accurate adjustments to be made and the use of two sites can only lead to confusion. It is strongly recommended that the staff gauge is moved to a site adjacent to the new bridge and a programme of discharge measurements made, in order to establish a new rating curve.

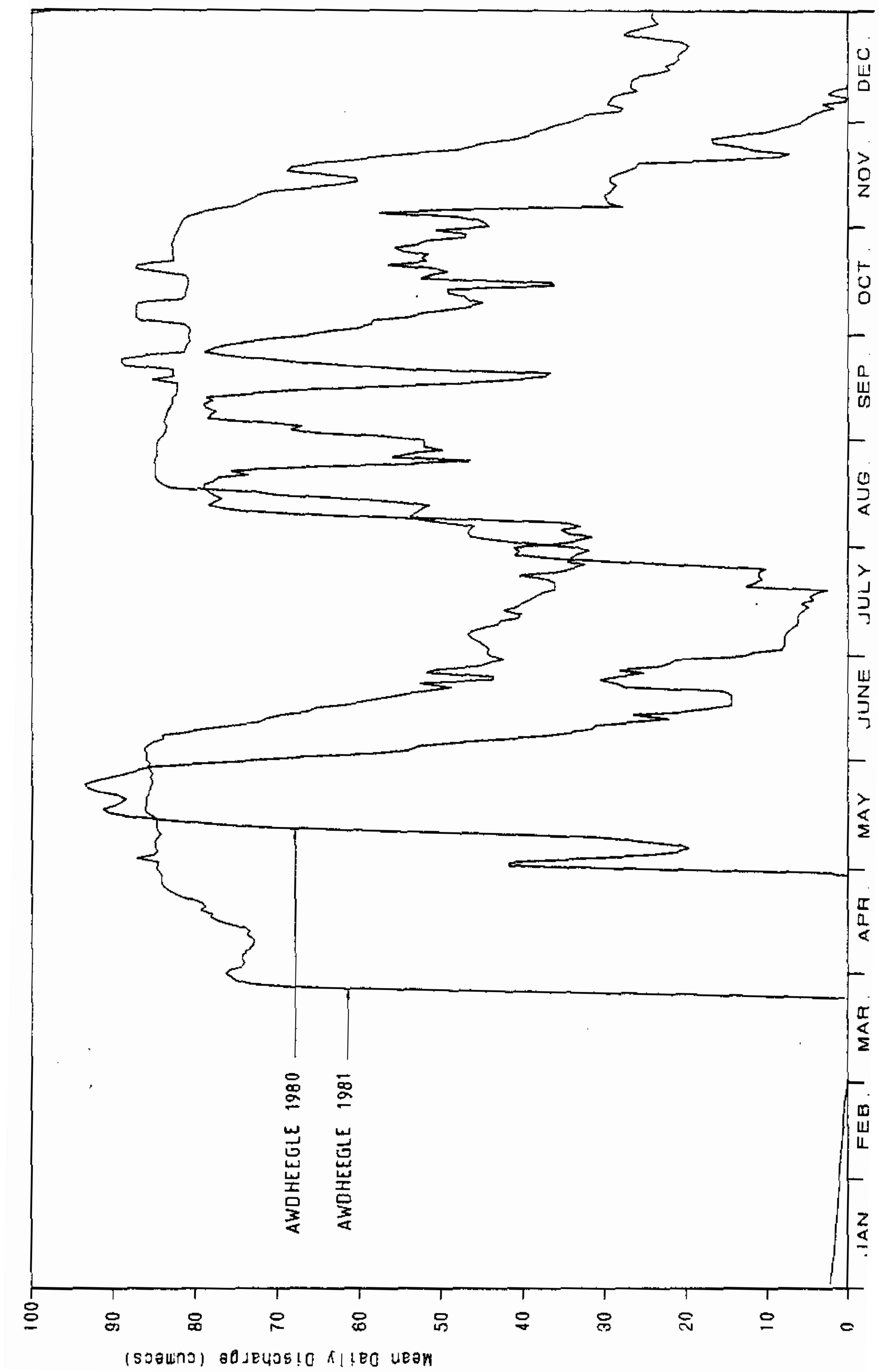
Two aspects of the discharge data for the Shabeelle are of particular importance for this study: the likelihood of the river flowing at a level sufficient to supply the irrigation canals directly; and the interaction of the availability of river water with that of rainfall. Over much of the project area the success of crops (and hence the prosperity of the people) depends on a combination of river irrigation and rainfall. The concurrence of poor rainfall and low river flow would, therefore, be particularly hazardous.

2.2.2 Correlation between Rainfall and Discharge

In most circumstances, strong correlation would be expected between rainfall and river flow; however, this is not necessarily so for the project area because local rainfall makes very little contribution to runoff. The flow in the Shabeelle is largely dependent upon rainfall many hundreds of kilometres away in Ethiopia. Table 2.2 shows the results of cross correlation analysis between monthly rainfall at Janaale and monthly river flow (infilled) at Aw Dheegle.

The cross correlation coefficients do not show any obvious pattern or indicate that there is strong correlation between rainfall and river flow. A few months possibly show some correlation, but the overall results are not strong enough to require special consideration to be given to the coincidence of bad years for rainfall and river flow. If a similar analysis is undertaken between rainfall at Afgoi (where there are fewer months of mising data) and flow at Aw Dheegle, the correlation coefficient for all months falls from 0.27 to 0.18.

Hydrographs at Aw Dheegle, 1980 and 1981



Hydrographs at Aw Dheegle, 1982 and 1984

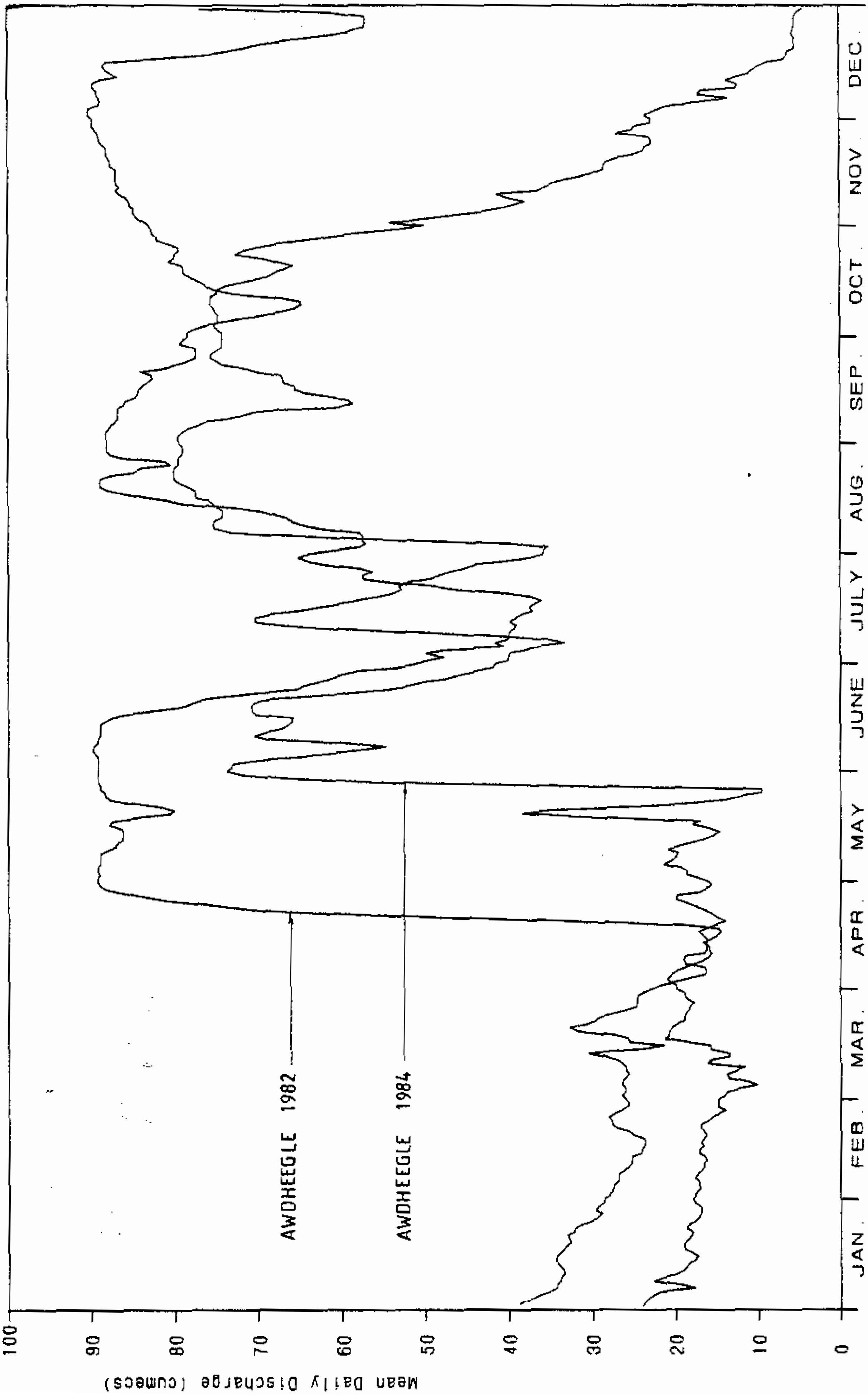


TABLE 2.2

Cross Correlation:
Janaale Rainfall versus Aw Dheegle Discharge

(monthly data)

Month	Cross correlation coefficient
January	0.07
February	-0.11
March	-0.01
April	0.31
May	0.54
June	0.45
July	0.07
August	0.14
September	0.15
October	-0.04
November	-0.08
December	0.54
All months	0.27

2.2.3 Flood Irrigation Canals

Although some water can be abstracted by pumping when the river is low, the main interest for this study is the availability of gravity flow into the irrigation canals. These canals are generally relatively high up the canal bank so they only receive supply when the river is fairly full. Figure 2.3 shows the bed invert levels of the flood irrigation canals within the project area. These are approximate because of the varying amounts of siltation which is usually removed before the irrigation season. The graph shows that the canals nearest to Janaale barrage are exceptions to the general situation and receive water even at relatively low discharges. For the remaining canals there are, in some cases, considerable variations in invert levels between nearby canals so that some will receive supplies for a longer period than others. However, the hydrographs (Figures 2.1 and 2.2) show that flow often rises very rapidly, so a higher level canal may only have to wait an extra one or two days for water to flow from the river. Furthermore, the invert elevation generally increases on moving upstream so that, with the exception of the area nearest Janaale, all parts of the project area have a reasonably equal likelihood of receiving water.

The individual canal invert levels shown in Figure 2.3 are subject to a significant degree of uncertainty because of the siltation referred to above and the difficulty of precisely defining the invert point. Flow thresholds have been calculated for each canal and tabulated in Table 2.3. The table indicates that some 80% of the project canals are receiving Shebeelle water at river discharges in the order of 60 to 65 m^3/s. To put an actual discharge value on each canal for a specific river flow would be misleading but it will be seen that assuming a design flow of 1.2 l/s per hectare would give a total design discharge of over 11 m^3/s for all the canals excluding the Jilaal Moogi. This total discharge is based on the premise that the present invert levels of the canals are maintained so that the total discharge into the Dara Salaam project area does not exceed that which occurs at the present time prior to any improvement or rehabilitation to the existing canals.

TABLE 2.3

Discharges in Canals at Various River Flows

Canal reference Number	Name	Command area (ha)	Design discharge (m^3/s)	Discharge in canals at various river Shabeelle flows 60 (m^3/s)	65 (m^3/s)	70 (m^3/s)	80 (m^3/s)	85 (m^3/s)
1	Gure	970	1.17	F	F	F	F	F
2	Minnow	735	0.78	F	F	F	F	F
3	Itole	100	0.12	F	F	F	F	F
4	Gududu	835	1.00	F	F	F	F	F
5	Matawani	20	0.024	F	F	F	F	F
6	Barbieri/B. Cadde	490	0.59	F	F	F	F	F
7	Xassan Youssef	135	0.16	F	F	F	F	F
8	Abliko Khaliff	45	0.06	F	F	F	F	F
9	Eboleh	200	0.24	F	F	F	F	F
10	Deeq	60	0.072	F	F	F	F	F
11	Dhere	565	0.68	F	F	F	F	F
12	Suuu	165	0.2	F	F	F	F	F
13	Guhaad	250	0.3	F	F	F	F	F
14	Oomaay	75	0.09	F	F	F	F	F
15	Suliman	110	0.13	NF	NF	NF	F	F
16	Saddick	50	0.06	F	F	F	F	F
17	Unknown	70	0.084	F	F	F	F	F
18	Garilan	80	0.1	F	F	F	F	F
19	Dheqere	40	0.05	F	F	F	F	F
20	Sheik Dhere	10	0.012	F	F	F	F	F
21	Aw Gaboow	10	0.012	F	F	F	F	F
22	Dhurey	500	0.6	NF	F	F	F	F
23	Ungunji		0.6	F	F	F	F	F
24	Barwaaqo	135	0.162	F	F	F	F	F
25	Balambaley	60	0.072	NF	F	F	F	F
26	Abdulle Bube	10	0.012	NF	F	F	F	F
27	Mohammed Ekow	10	0.012	F	F	F	F	F
28	Canal no longer exists							
29	Caay Siney	10	0.012	F	F	F	F	F
30	Aw Madae	35	0.042	F	F	F	F	F
31	Aw Barre	435	0.52	NF	NF	F	F	F
32	Xanole		0.52	NF	NF	NF	F	F
33	Muuno	15	0.018	F	F	F	F	F
34	Dhuufe	400	0.48	F	F	F	F	F
35	Dhere	335	0.40	F	F	F	F	F
36	Hahre	80	0.096	F	F	F	F	F
37	Canal no longer exists							
38	Canal no longer exists							
39	Baar	20	0.024	NF	NF	NF	F	F
40	Gaabo Yerro	50	0.06	F	F	F	F	F
41	Unknown	10	0.012	NF	NF	NF	NF	F
42	Unknown	10	0.012	F	F	F	F	F
43	Salhan	95	0.114	NF	NF	NF	F	F
44	Gaabo	150	Survey data not available					
45	Bolay (New)	230	0.28	F	F	F	F	F
46	Bolay (Old)		0.28	NF	NF	NF	NF	NF
47	Canal does not serve project area							
48	Abdi Nasin	30	0.036	NF	F	F	F	F
49	Camoon	35	0.042	NF	NF	NF	F	F
50	Raxoole	40	0.048	NF	NF	F	F	F
51	Duuf	67	0.08	NF	NF	F	F	F
52	Modkadeyo	85	0.10	NF	NF	F	F	F
53	Jilaal Moogi	150	5.0	F	F	F	F	F
54	Xassan Nuur	10	0.12	F	F	F	F	F
55	Siad Berry	275	0.33	F	F	F	F	F
56	Tugaarrey	10	0.012	F	F	F	F	F

Note: F = Canal flowing
NF = No flow in canal
Design Capacity shown is based on using existing invert level and supplying 1.2 l/s per hectare.

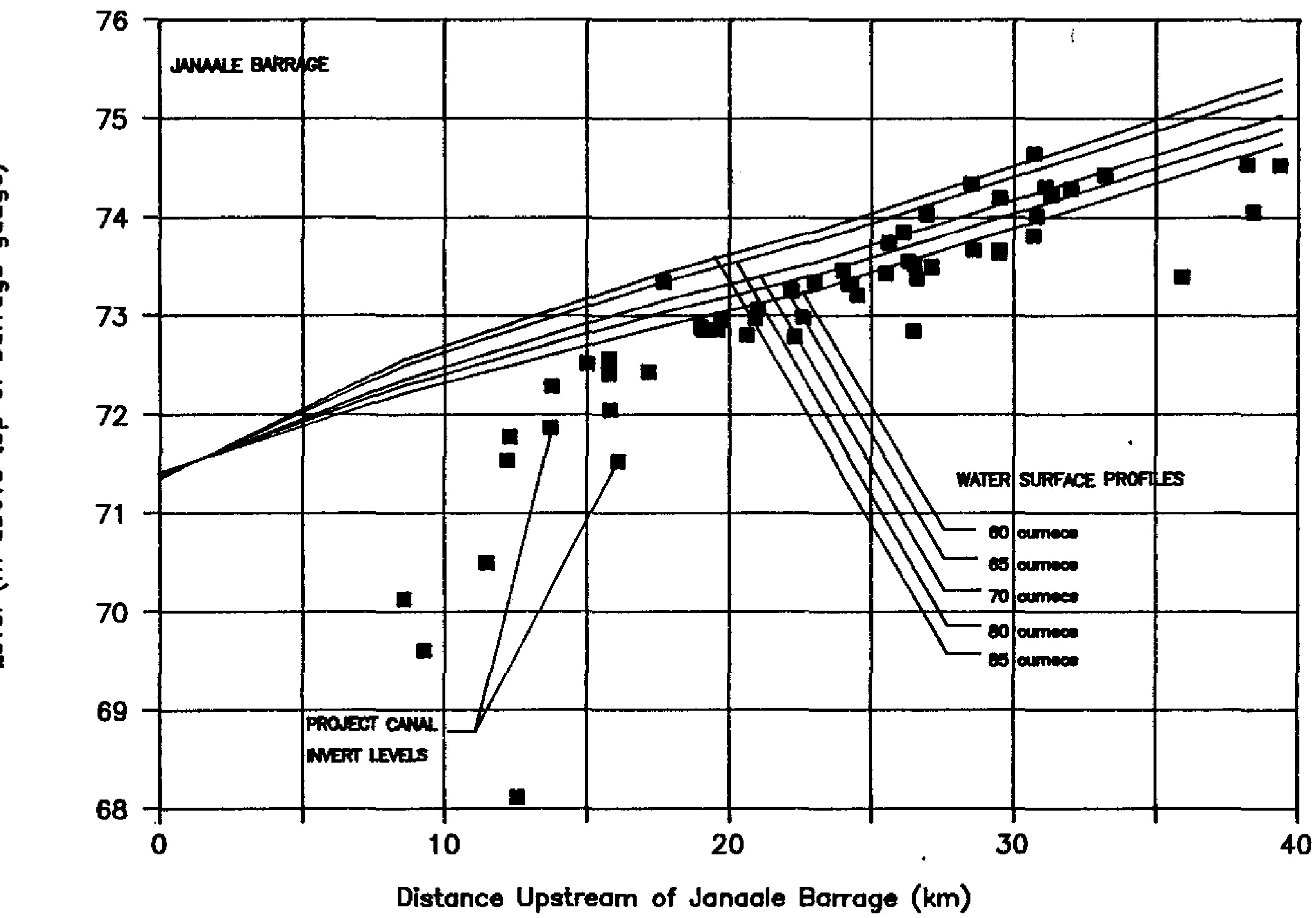


Figure 2.3

Invert Levels of Flood Irrigation Canals

A discharge of 65 m^3/s will provide gravity flow into the majority of canals but, in order to provide significant discharge, a higher river level is required so that there is an adequate head over the invert. A discharge of 75 m^3/s would represent a head in the range 0.5 to 0.75 m, though the effective head will be reduced for the downstream end of the project area by abstractions further upstream.

2.2.4 Flow Duration Analysis

In order to estimate the availability of water to the canals, flow duration analysis was undertaken for the discharge data for Aw Dheegle. Certain allowances must, of course, be made for withdrawals, but the Aw Dheegle record provides a good representation of water availability at the head of the project area. The flow duration analysis was undertaken for the period 1976 to 1986, for which there is a reasonably complete record. For the four preceding years there are no data and for the years 1967 to 1971 the record is extremely sparse. The data for the selected period does show some gaps (especially 1979); for these periods estimates of flow durations have been made from the records for Afgoi, the next station upstream, with due allowance being made for the difference between the two stations. The results are shown in Table 2.4 and the 75% reliable durations are summarised in Table 2.5.

TABLE 2.5

Duration of Flow over Thresholds at 75% Reliability

Flow Threshold (m^3/s)	Number of days gu	Number of days der
60	62	84
65	61	76
70	47	64
80	28	33
85	12	3*
90	0	0

Note: * The low value here is a statistical quirk; for a threshold of 84.5 m^3/s the 75% reliable period would be about 18 days compared with 15 for the gu.

It can be seen that for the high flows (in excess of 75 m^3/s) the durations are similar for the two seasons, but for medium discharges the der flood is somewhat longer. The disparity would increase if the threshold was reduced from 60 m^3/s, but this is of limited significance for this study, because very few of the canals will receive water when the flow at Aw Dheegle drops to 50 m^3/s or less.

In addition to the duration, the dates on which canals are supplied are important for the supply of stock watering points. The critical parameter for this is the length of the longer dry season, for which sufficient water must be stored from the der flood. A discharge at Aw Dheegle of around 70 m^3/s should be sufficient to ensure supply to the watering points; Table 2.6 gives the approximate 'dry periods' for thresholds of 70 and 75 m^3/s.

From these results, a design dry period of 200 days has been selected for determining the required storage at stock watering points.

TABLE 2.4

Periods of Flow over Selected Thresholds

Discharge at Audegle - Number of days over thresholds

				Gu						Der		
(m^3/s)	60	65	70	75	80	85	60	65	70	75	80	85
1976	69	63	56	48	40	9	90	88	87	82	62	1
1977	66	63	51	45	41	35	162	161	159	155	138	99
1978	70	61	46	39	33	24	129	125	124	123	118	111
1979	76	73	61	46	40	36	38	35	34	31	30	28
1980	21	21	20	18	16	15	40	36	28	22	0	0
1981	82	81	77	60	49	23	98	91	88	82	79	13
1982	67	63	61	58	54	47	149	138	125	118	95	65
1983	74	72	69	65	54	47	134	130	127	124	120	38
1984	22	19	10	0	0	0	83	78	63	33	4	0
1985	61	61	57	42	27	11	86	76	69	57	46	28
1986	70	70	63	60	57	53	115	94	75	72	46	35
Mean	62	59	52	44	37	27	102	96	89	82	67	38

Values equalled or exceeded 75% of the time

61.9	61.0	46.9	39.6	28.1	11.7	83.6	76.4	64.1	37.5	33.0	3.2
		Gu							Der		

Note: See note to Table 2.5.

TABLE 2.6

Length of Dry Season (for Stock Watering)

Year	Threshold 70 m^3/s Dry period	Nr of days	Threshold 75 m^3/s Dry period	Nr of days
1976/77	19/10 - 21/4	184	15/10 - 25/4	192
1977/78	28/12 - 29/4	122	27/12 - 10/5	134
1978/79	25/11 - 12/4	138	25/11 - 13/4	139
1979/80	10/9 - 12/5	245	10/9 - 13/5	246
1980/81	29/9 - 28/3	179	28/9 - 29/3	181
1981/82	11/11 - 23/4	137	7/11 - 24/4	142
1982/83	21/12 - 3/5	133	19/12 - 4/5	136
1983/84	10/12 - 30/5	172	7/12 - 7/8	244
1984/85	17/10 - 25/4	159	12/10 - 1/5	170
1985/86	13/10 - 26/4	195	17/9 - 27/4	222
1986/87	13/10 - 1/5 (est)	200	10/10 - 1/5 (est)	203
1 in 4 dry year		193		218

2.2.5 Water Availability for Flood Irrigation

For the reasons already outlined, it is not possible to determine precisely the amount of water which will be available to the farmers via the flood irrigation canals. Various uncertainties affect both the rate of discharge in the canals and the number of days on which flow occurs. It has been shown in the previous section that a discharge of 75 m^3/s can be relied upon for approximately 40 days in each flood season. In theory, this would allow abstraction at 10 m^3/s for this period, or a yearly total of 69 hm^3. For a small number of days, abstraction at more than 10 m^3/s would be possible and for some additional days a smaller discharge is available. Taking account of these factors, the theoretical maximum abstraction for the year would be 120 hm^3.

In practice, the quantity which could usefully be abstracted in the project area would be significantly lower than the theoretical total. There are two principal reasons for this: firstly, not all the water can be used when it is available (particularly the period when availability substantially exceeds 10 m^3/s) and, secondly, some water will be taken on the opposite (right) bank of the river. Since at present there is no project-wise water allocation, abstractions on the right bank cannot now be quantified. However, it is believed that abstractions on the right bank are substantially less than on the left bank. It is concluded that the volume of water available for abstraction for use in the project area is in the range 60 to 80 hm^3 per year.

2.3 Flooding

Flooding has been a problem in the Shabeelle valley for many years. Major floods have occurred in 1968, 1981 and 1987. However, serious flooding does not generally occur in the lower reaches of the river, including the project area. The hydrographs in Figures 2.1 and 2.2 show that the maximum flood levels do not vary greatly from year to year; the river tends to run at a plateau level for most of the two flood periods. This is below the bank full level at Aw Dheegle and also represents a level below bank full on the reach through the project area to Janaale.

Figure 2.4 shows the hydrographs for various locations on the Shabeelle for the flood year of 1981. The major attenuation results from spillage into the flood-plain above Mahaddey Wein. The additional reduction to Aw Dheegle was partly due to further flooding, but the net abstraction to the Jowhar offstream reservoir made a significant contribution. The middle reaches of the Shabeelle would have experienced more severe flooding in 1981 if the Jowhar scheme had not been operational; if a flood of similar size were to occur in the future, there should be relatively little risk of flooding downstream of Jowhar because of the additional attenuation provided by the Duduble flood relief channel just up-stream of Mahaddey Wein, which was brought into operation in 1986.

The evidence from observation and farmers' reports is that the flooding which has occurred in the project area in recent years (including 1987) has resulted from isolated breaches of the river or canal banks and not general overtopping. Therefore, a regular programme of bank maintenance is required, but there is no justification for additional flood relief measures to protect the project area. It is assumed that both Jowhar and Duduble will continue to be operated in such a way as to minimise extreme flood peaks in the middle and lower reaches of the river.

2.4 Regulation of the Shabeelle River

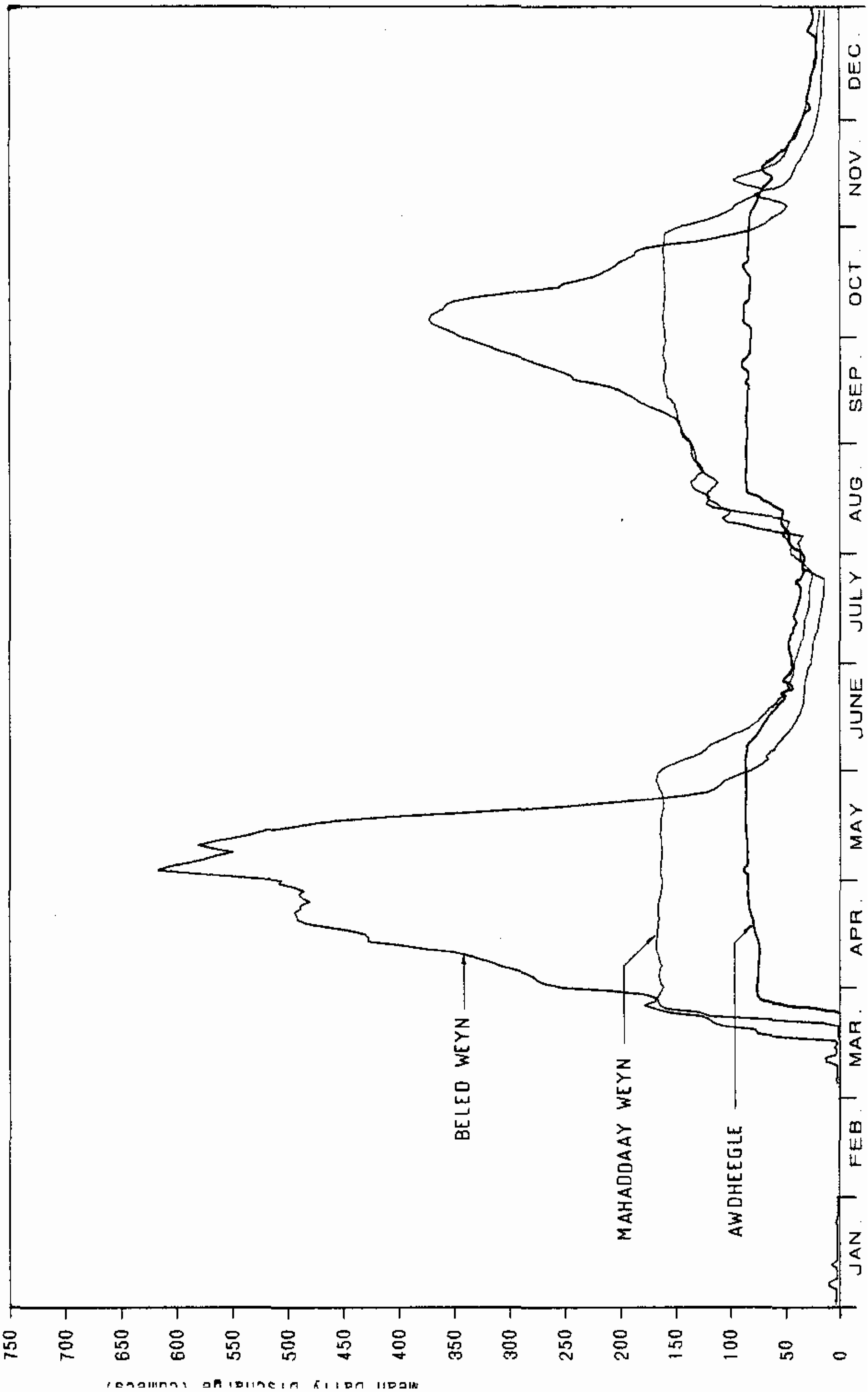
In recent years, two schemes have been introduced in the Shabeelle valley which allow some degree of control to be exercised over the flow in the river. The Jowhar offstream reservoir was commissioned in 1980 and the Duduble flood relief channel in 1986. The possible conversion of the latter scheme to one involving storage is at present under consideration.

Both Jowhar and Duduble are able to remove a proportion of flood flows which would reduce or avoid overbank spillage further downstream; water stored in the Jowhar reservoir may be released later to supplement lower river flows. It is clear that the operation of storage and/or flood relief schemes could significantly affect downstream users, particularly where abstractions are made via high level flood irrigation canals. However, provided that operation is limited to the alleviation of high flood peaks and is not used for regulating medium river flows, water availability in the project area should not be adversely affected, because the effect will be to reduce flooding between Jowhar and Afgoi while 'bank full' discharge beyond Afgoi is maintained. There is no evidence from recent data that the project area has suffered from the operation of Jowhar. On the contrary, the enhancement of low flows has to some extent benefited the middle reaches of the river between Jowhar and Afgoi - additional abstractions in that stretch have removed most of the additional water and reduced the risk of flooding in the Aw Dheegle - Janaale area which by now occurs only when high river flows coincide with heavy rainstorms between Jowhar and Aw Dheegle.

Assessment of the effects of Duduble must await further data; however, there is no reason to suppose that its operation will affect the project area. If the proposed conversion to a storage scheme goes ahead, it is important that the formulation of control rules take account of the needs and wishes of downstream users. The particular requirements for the Dara Salaam Busley area are that the frequency of occurrence of flows in the range 75 to 85 m^3/s at Aw Dheegle should not be reduced and that discharges in excess of 90 m^3/s there should be eliminated or at least minimised. The former requirement can be stated in the following form: the discharge at Aw Dheegle should exceed 75 m^3/s for 40 days or more in each of the gu and der seasons, in each case on average three years out of every four.

Figure 2.4

Shabeelle River Hydrographs, 1981



CHAPTER 3

SEDIMENT AND WATER QUALITY

3.1 Sediment

The Shabeelle river carries a high concentration of suspended sediment which forms a major problem for the maintenance of the canal system. In 1977/78 MMP established a regular sampling programme at the Majabto river bridge, 9.4 km downstream of Janaale barrage. Readings were taken weekly using a point sampler in mid-stream at 0.6 of the depth from the surface. During the main body of the 1977 der flood the average recorded concentration was 2 700 ppm. This compares with 250 to 500 ppm reported for the 1968 der flood of similar flow. Future suspended loads can be expected to increase due to overgrazing in the upper catchment.

3.2 Water Quality for Irrigation

The suitability of the Shabeelle river for irrigation is diagnosed in terms of four parameters:

(a) Salinity.

(b) Sodicity.

(c) Residual bicarbonate.

(d) Boron toxicity.

3.3 Salinity

The build-up of salinity in the soil profile directly affects crop yield. Saline soil water raises the osmotic pressure of the soil solution restricting the uptake of water by the plant and leading to the early onset of water stress. It is also directly toxic to some plants. A high percentage of absorbed sodium ions on the soil exchange can result in poor soil structure and deflocculation. The salinity hazard is diagnosed in terms of the electrical conductivity or EC value of the irrigation water.

EC is measured daily at Afgoi and Jowhar. In 1977 MMP correlated readings at Afgoi with measurements taken at Janaale. The agreement between the two readings was close with the Janaale values being consistently marginally higher. The readings upstream may therefore be taken as representative for the project. There is considerable variation in river salinity from year to year and during the year. Average monthly EC values for the years 1965 to 1983 are shown in Table 3.1. Values range between 440 to 1 800 µmho/cm. The highest values of EC occur during drought periods and at the beginning of the gu rains. At the start of the flood flows water leaches the salts from the soil surface that have accumulated during the previous dry season through evaporation. Figure 3.1 shows the variation of salinity with discharge at Afgoi for the years 1967 and 1968.

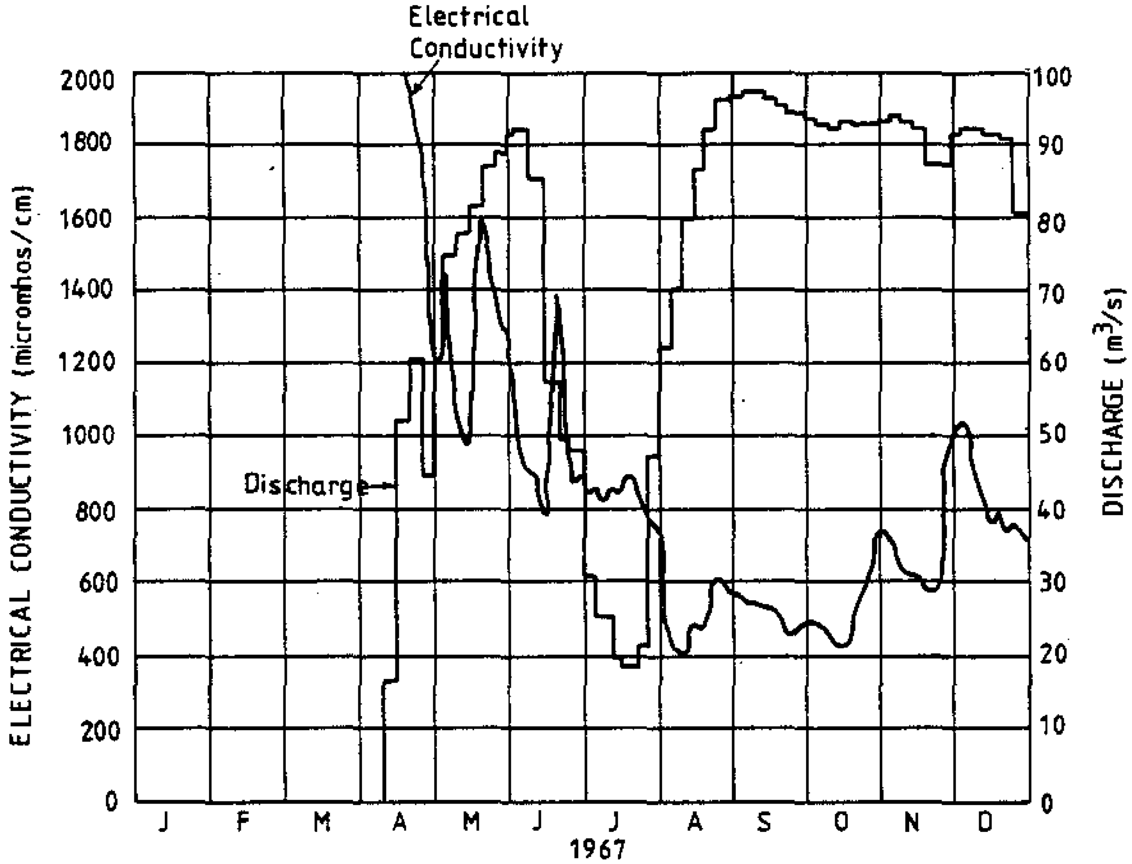
TABLE 3.1

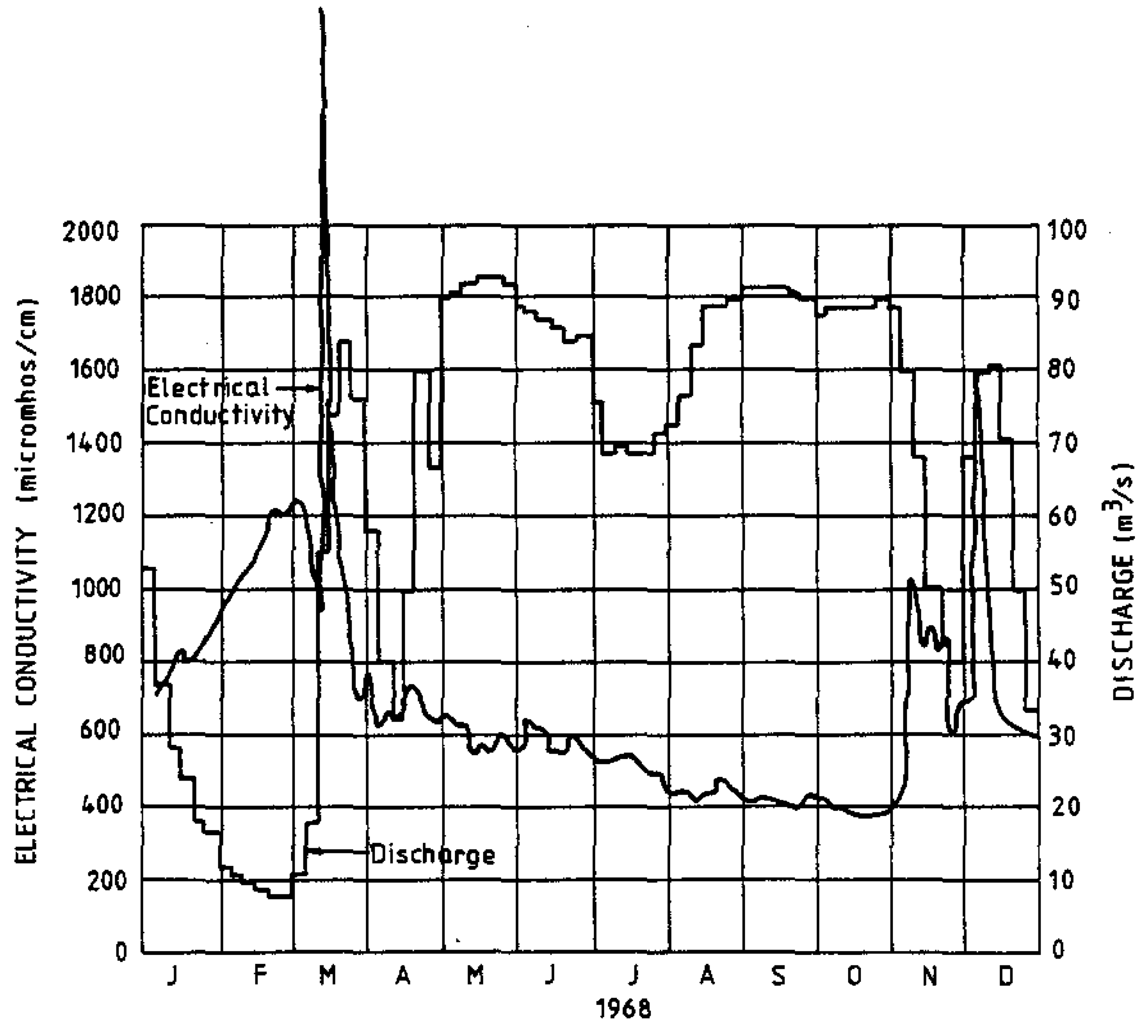
Salinity of the Shabeelle River

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Mean monthly EC (μmho/cm)											
1965	581	(705)	1 313	1 880	1 348	1 064	1 514	1 781	447	607	1 036	1 075
1966	1 100	*	1 094*	610	1 075	848	466	396	476	483	960	883
1967	(1 142)	*	*	(2 250)*	1 272	967	838	522	519	524	664	846
1968	827	1 066	1 076	641	680	593	525	454	427	405	742	845
1969	858	957	607	405	452	640	(556)	398	366	436	1 078	1 121
1970	1 377	1 230	1 066	694	1 206	898	977	513	438	382	714	687
1971	1 038	1 495*	*	1 503*	792	504	381	318	377	391	723	457
1972	755	1 166*	558	651	1 148	1 226	(650)	374	428	(494)	-	(851)
1973	1 182	*	*	*	2 031	1 009	926	424	368	452	777	(664)
1974	*	*	*	988*	1 052	1 025	429	335	365	386	586	(730)*
1975	*	*	*	(2 680)	1 682	1 786	734	408	418	355	894	(950)*
1976	*	*	*	(2 381)*	1 488	(1 588)	1 257	596	(431)	741	(980)	-
1977	1 170	900	690	1 400	1 480	960	720	620	400	450	570	639
1978	1 230	1 794	1 115	861	880	937	1 013	510	563	477	672	915
1979	1 280	888	633	881	887	1 010	1 038	853	585	603	457	1 106
1980	1 858	2 468	3 163	4 427	1 969	1 593	1 314	615	409	428	362	826
1981	1 656	2 273	-	997	807	837	1 353	663	497	463	569	1 431
1982	2 784	3 599	3 288	1 798	599	507	433	390	374	325	550	611
1983	613	990	960	806	417	-	-	-	-	-	-	-
Average	1 216	1 502	1 297	1 428	1 119	996	840	565	438	467	726	861

Note: Salinity records for Jowhar except 1965 to 1976 (Afgoi).
*Excluding no flow period.

Salinity & Discharge of the R.Shabeelle, Afgoi Research Station





Using the USDA classification (Figure 3.2) the river water is of medium to high salinity hazard. If a build-up of salts in the root zone is to be avoided sufficient water must pass through the soil profile to leach out the excess salts. A steady state situation is achieved when the salts entering the root zone in the irrigation water are balanced by salts leached from the soil profile by percolation down to groundwater. The EC value of the soil solution at saturation point (EC_e) is used to assess the effect of salinity on crop yield. The montmorillonitic clay soils of the project have low hydraulic conductivity. A feasible limit of water going to deep percolation is thought to be about 10% of the gross irrigation application or about 16.7% of the net application (assuming an application efficiency of 60%). Not all the irrigation water will mix completely with the soil solution. The leaching fraction represents that portion of deep percolation that is effective in leaching salts from the soil profile the rest will move through large pores without any mixing. Based on a leaching fraction of 0.3, the upper limit recommended for clay soils, Table 3.2 has been calculated to give the resulting EC_e values to achieve a soil balance. Table 3.3 gives the corresponding crop yield reduction. Comparison of the two tables shows that for seasonal irrigation yield reductions of between 10 and 25% can be expected increasing to 25 to 50% for the conjunctive use of groundwater for perennial crops.

TABLE 3.2

Required EC_e Values to provide Salt Equilibrium

Irrigation water supply	Average EC_{iw} (mmho/cm)	EC_e soil (mmho/cm)
100% river water	0.75	3.2
100% groundwater	2.5	10.7
Mixed water (20% groundwater)	1.1	4.7

TABLE 3.3

Crop Yield Reductions for Various Plants at Various Values of Soil Saturated Paste Extract (EC_e mmho/cm)

Crop	Yield reduction 10%	25%	50%	100%
Cotton	9.6	13.0	17.0	27.0
Groundnut	3.5	4.1	4.9	6.5
Rice	3.8	5.1	7.2	11.5
Maize	2.5	3.8	5.9	10.0
Grapefruit	2.4	3.4	4.9	8.0

Source: After FAO (1976).

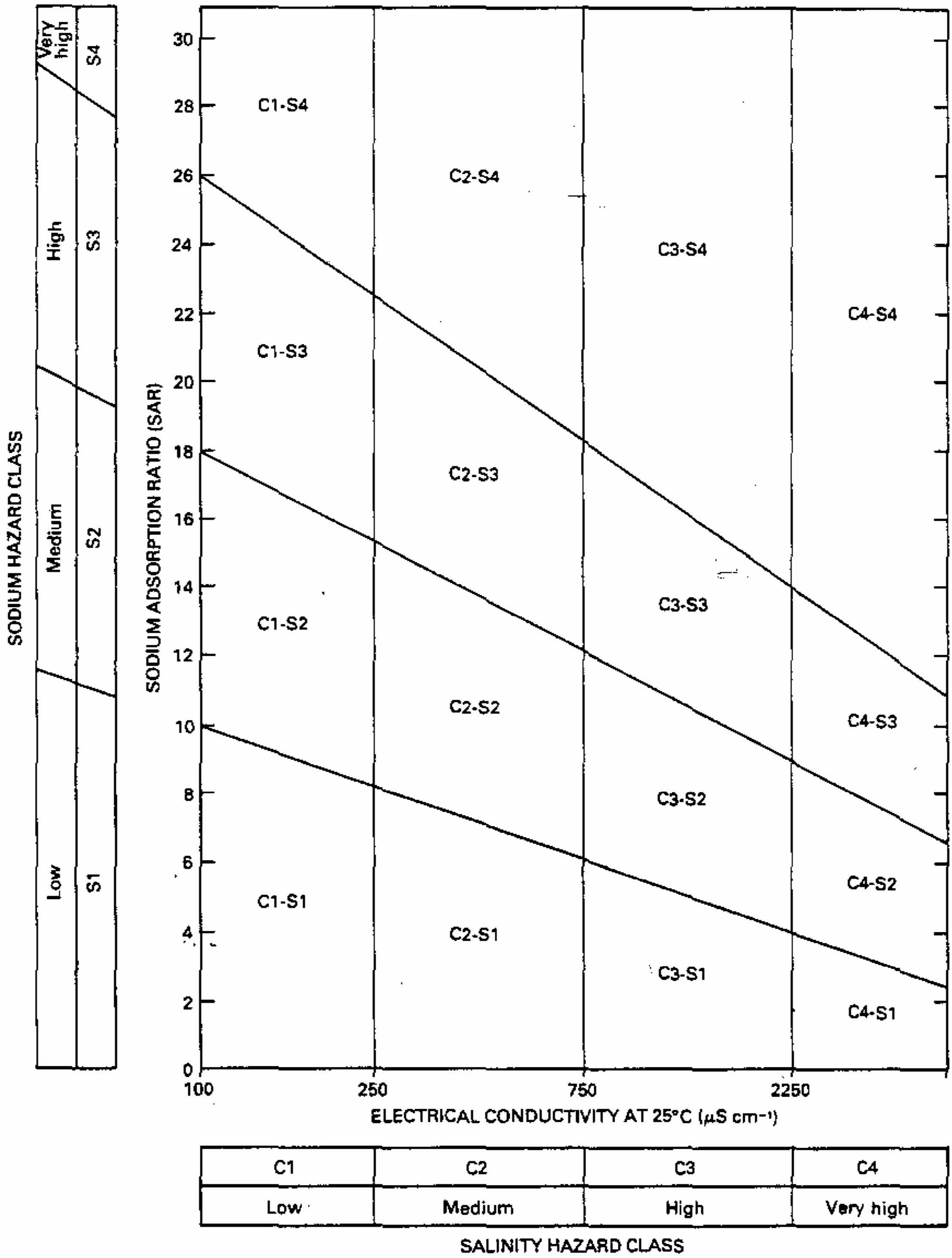
3.4 Sodicity

Cations are adsorbed onto the surface of the clay colloid-forming a diffuse double layer. When the percentage of monovalent ions, especially sodium, becomes too great the layer expands and the soil is likely to disperse or deflocculate. This results in an impaired hydraulic conductivity with risks of waterlogging and high soil salinity. The soil becomes difficult to manage: hard when dry and plastic when moist. The sodicity hazard is appraised on the basis of two main parameters, electrical conductivity (EC) and the sodium adsorption ratio (SAR). The SAR is a measure of the proportion of sodium ions to other divalent cations in the irrigation water. It is correlated closely with the percentage of sodium ions adsorbed onto the clay colloid. Chemical analysis for samples taken at Jowhar between 1966 and 1977 showed that using the USDA classification the sodium hazard is low.

3.5 Residual Sodium Carbonate and Boron Toxicity

When the concentration of carbonate and bicarbonate ions in the irrigation water is high there is a risk that calcium and magnesium ions may precipitate as salts increasing the relative proportion of sodium ions in solution. Boron in excess concentrations is toxic to many crops. Both the bicarbonate hazard and boron toxicity for the Shabeelle are low.

U.S.D.A Classification of Irrigation Water



CHAPTER 4

GROUNDWATER RESOURCES

4.1 Introduction

In 1978, MMP carried out an extensive investigation into the groundwater resources for the Genale-Bulo Marerta irrigation scheme. Since the present project area is underlain by the same aquifer and there are no major hydraulic boundaries between the two adjacent areas, similar groundwater conditions are likely to be found in both areas and the results of that study form the basis of the following comments.

4.2 Geology

The project forms part of the alluvial floodplain of the Shabeelle river. The whole area is underlain by fluvial and marine alluvium to a depth of at least 250 m. Towards the south-west, the alluvium is intercalated with arid lakes replaced by coastal sand dunes. The dunes form the southern boundary of the project. Sediment deposits consist of irregular patches of sand, silt and clay. Some coral also exists. Rapid variation in sediment type is due to the mode of deposition of the materials. From data taken from drilling of tubewells, it is possible to construct a generalised geological section and this is shown in Table 4.1.

TABLE 4.1

Generalised Geological Section

Thickness (m)	Strata
0 - 2	Soil horizons
6 - 30	Dark grey silty clay with occasional sandy lenses; often gypsiferous with shell fragments and interbedded with gravels near the base.
20 - 40	Mainly limestone gravel, with siliceous sand and clay partings, sometimes cemented; 25% clear quartz, 50% calcareous limestone grains, 25% abraded fossils; sand and silty clay bands are common and lenticular in form.
0 - 30	Many logs report an increased clay content giving rise to locally developed thick clay lenses.
0 - 40	Limestone gravel as above with sand and clay lenses more developed.

Below 100 m from the surface, the few available logs indicate alternating sands, clays and gravels to at least 220 m.

4.3 Aquifer Characteristics

The sands and gravels form the main aquifer material. From piezometric readings (MMP, 1978), it appears that the irregular strings of gravel and sands are interconnected and form a major aquifer to a depth of over 100 m below a variable thickness of clay. Local sand lenses within the grey clay contain perched watertables and have in some areas been tapped by shallow hand-dug wells. However, due to the limited storage, these wells are likely to dry up in times of drought. Pumping tests on deep wells and boreholes indicate a leaky aquifer with the presence of aquitards within the aquifer. These probably correspond to overlying grey clay layers and silt lenses within the main aquifer. Values of transmissivity range between 100 and 700 m^2/d probably with a typical value of 350 m^2/d. Values of the storage coefficient indicate a semi-confined condition but with prolonged water abstraction the aquifer would begin to dewater. It is estimated that the specific yield is 0.05.

4.4 Water Levels

The main sources of recharge of the aquifer are irrigation water, river water and rainfall. The latter is probably the least important. Adjacent to the river, water levels are high with correspondingly low values of electrical conductivity. Groundwater levels fall away to the north-east and south-west. Water levels for the project area have been tentatively drawn, based on studies at Genale-Bulo Marerta and Afgoi Mordile and are shown in Figure 4.1. In the area between Janaale and Ugunji records show that water level changes over a 14-year period (1964-1977) were generally less that 2 m. Recorded drops in water level are situated on places where irrigation of perennial crops has ceased, indicating the importance of recharge from irrigation.

4.5 Water Quality

Based on observations of wells in the Genale-Bulo Marerta and Afgoi Mordile projects, a salinity map (Figure 4.2) has been constructed for the project area showing the variation of groundwater conductivity (EC). EC values of groundwater vary from 1.5 mmho/cm to over 10 mmho/cm with most of the aquifer probably containing water of over 2.5 mmho/cm. The best quality of water is found adjacent to the river in the area of high recharge. Around Malable the river is considered to be influent giving rise to lower EC values and high groundwater levels. As river water is the major source of recharge, groundwater quality varies with riverflows. High EC values are recorded after drought periods and at the start of the gu rains with better quality water occurring after longer flow periods and the higher discharges of the der season.

4.6 Groundwater Suitability for Irrigation

The factors determining the suitability of water for irrigation are discussed in Section 3.2. The salinity hazard of the groundwater is high to very high (USDA classification). The salinity levels of even the best quality water are too high to permit the growth of any crop other than cotton. Extensive development of the groundwater resource, therefore, is not possible and groundwater must remain a supplementary supply to surface water. The sodium hazard is low to medium and should not adversely affect the soil structure or permeability. Levels of bicarbonate and boron are low.

Figure 4.1

Groundwater Piezometry

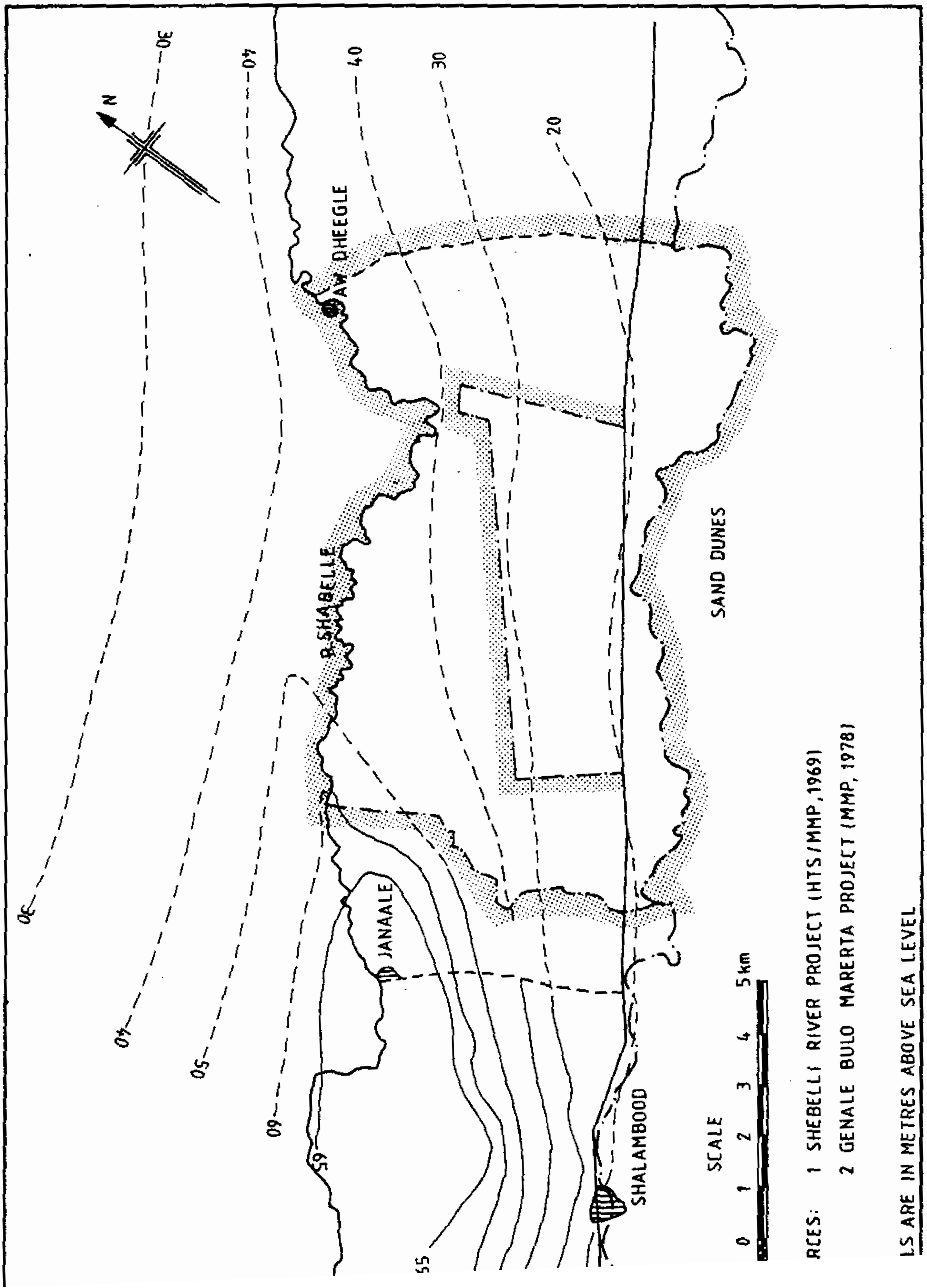
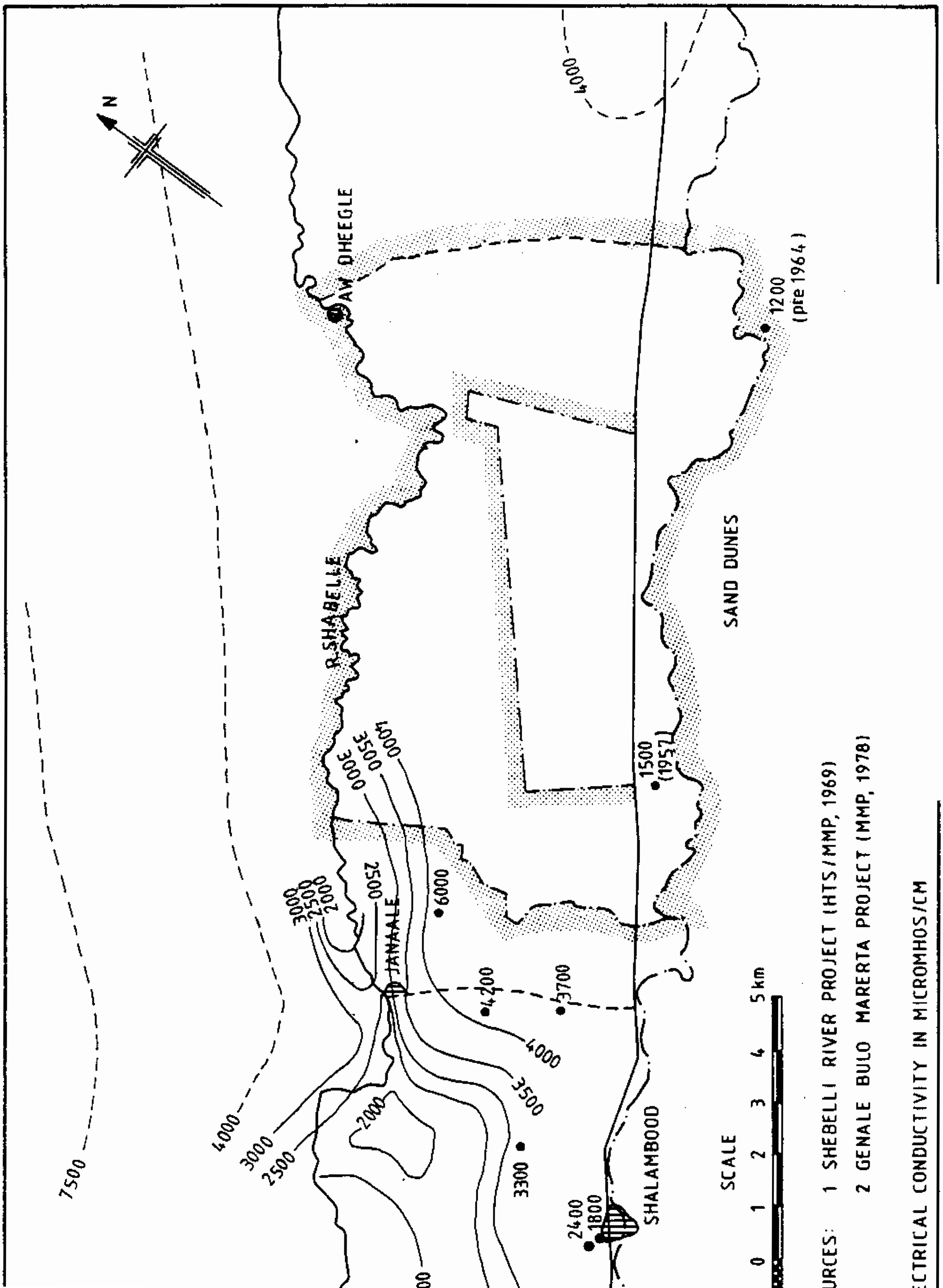


Figure 4.2
Groundwater Electrical Conductivity



The cultivation of perennial crops in this area depends upon the use of groundwater during the jilaal. However, due to the risk of a build-up of salinity and the difficulties of leaching in vertisols, it is recommended that the use of groundwater, even for supplementary irrigation, be restricted.

CHAPTER 5

WATER REQUIREMENTS

5.1 Effective Rainfall

Effective rainfall is the portion of rainfall which is useful for crop growth. Rainfall is not necessarily required at the time, rate or amount in which it occurs; unavoidably, some of the rain is not utilised by crops. In the absence of field data for Somalia, predictions have been made using the United States Bureau of Reclamation (USBR) method. This method which is recommended for arid and semi-arid regions, applies particular values of percentage effectiveness to specified increments of monthly rainfall (Table 5.1). The resulting effective portions of 75% reliable monthly rainfalls are shown in Table 1.2.

TABLE 5.1

Effective Rainfall: USBR Method

Precipitation increment of monthly rainfall (mm)	Percentage effective
0 - 25	90.0
25 - 50	87.5
50 - 75	83.3
75 - 100	75.0
100 - 125	66.0
125 - 150	56.7
Greater than 150	0.0

5.2 Evapotranspiration

Evapotranspiration rates have been calculated using the Penman method which uses a conceptional model of the evaporation/transpiration process when water availability is not a limiting factor. Crop evapotranspiration in these potential conditions is determined primarily by the net energy from the sun and to a lesser extent by the prevailing aerodynamic conditions. The climatic data for Janaale, summarised in Table 1.1, includes the information on temperature, wind, humidity and sunshine needed to use the modified Penman mentod (Doorenbos and Pruitt, 1977) to predict the average reference crop evapotranspiration rate (ET_0). In the absence of extensive records of mean minimum and maximum relative humidity, the average range observed in recent years was applied to the long-term average of monthly mean relative humidity.

The Penman method assesses the potential evapotranspiration of a close cut grass "reference crop" by calculating the net solar energy supply (from latitude, month of year, sunshine, temperature and humidity data) and the prevailing aerodynamic energy (from temperature, humidity and wind speed data) in order to obtain the energy available for evapotranspiration. This is expressed in millimetres of water equivalent. Table 5.2 gives the monthly average values of ET_0 based on the data for Janaale.

TABLE 5.2

ET_0 for Janaale (by Penman)

Month	(mm)
January	174
February	170
March	193
April	169
May	153
June	133
July	138
August	157
September	169
October	163
November	148
December	155
Year	1925

5.3 Crop Water Requirements

The actual crop evapotranspiration is derived by applying a crop coefficient to the reference values given in Table 5.2. This coefficient (f) is dependent upon the individual crop characteristics as well as planting date, rate of crop development and climatic conditions. The coefficients have been derived from FAO Paper 24 (Doorenbos and Pruitt, 1977) and are shown in Table 5.3 for maize and sesame which account for around 95% of the proposed cropping pattern.

The gross irrigation requirement, Ig, for each month is found as follows:

$$Ig = ET_0.f$$

This theoretical requirement will be reduced by rainfall. The standard procedure is to substract the effective portion of the 75% reliable rainfall for each month. However, the values already calculated and presented in Table 1.2 are not suitable for this because they are independent values (see Section 1.3 above). There are various methods for calculating homogeneous sequences which have an overall reliability of 75%, but there is no clear 'best' method. For this study, the independent values have been increased by a constant factor so that the total for each crop season is approximately equal to the 75% value for the season as a whole. From the results in Tables 1.2 and 1.3, a factor of 1.5 has been selected for each crop season. This leads to a conservative estimate of rainfall.

The resulting values are shown in Table 5.4 (reduced for part months where appropriate), together with the gross and net irrigation requirements. The total net requirements are 267 and 422 mm for the two maize crops and 317 mm for sesame.

TABLE 5.3

Crop Coefficients

Crop	Plant	Harvest	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maize 1	mid-Apr	early Aug	-	-	-	0.13	0.55	1.02	0.97	0.26	-	-	-	-
Maize 2	mid-Sep	early Jan	0.29	-	-	-	-	-	-	-	0.12	0.46	1.04	1.06
Sesame	mid-Sep	mid-Dec	-	-	-	-	-	-	-	-	0.15	0.73	0.99	0.43

TABLE 5.4

Crop Water Requirements (mm)

Crop		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Maize 1	Gross requirement	-	-	-	22	84	156	134	41	-	-	-	-	
	Effective rainfall	-	-	-	(24)	42	53	49	(4)	-	-	-	-	
	Net requirement	-	-	-	0	42	103	85	37	-	-	-	-	267
Maize 2	Gross requirement	51	-	-	-	-	-	-	-	20	75	154	164	
	Effective rainfall	(0)	-	-	-	-	-	-	-	(1)	4	34	4	
	Net requirement	51	-	-	-	-	-	-	-	19	71	120	160	421
Sesame	Gross requirement	-	-	-	-	-	-	-	-	25	119	147	67	
	Effective rainfall	-	-	-	-	-	-	-	-	(1)	4	34	(2)	
	Net requirement	-	-	-	-	-	-	-	-	24	115	113	65	317

Note: Brackets indicate part-month values.

5.4 Irrigation Efficiencies

The calculations presented above show the crop irrigation requirements at the root zone. The actual amounts which must be supplied from the river will be substantially greater because of losses in conveyance and in field application. It is estimated that the present situation represents a conveyance efficiency of about 50% and a field efficiency of 40%. Combining these gives an overall efficiency of 20%. This is similar to values reported by MMP (1978) and TAMS (1987) for areas slightly further downstream.

As a result of improvements to the irrigation system (see Annex 6), it is anticipated that the efficiences will increase to 75% (conveyance) and 60% (field), resulting in an overall efficiency of 45%.

APPENDIX I

CLIMATE AND DISCHARGE DATA

Maximum Temperatures at Janaale

Minimum Temperatures at Janaale

Average Temperatures at Janaale

Relative Humidity at Janaale

Wind Speeds at Janaale

Sunshine Hours at Janaale

Monthly Rainfall at Afgoi

Monthly Rainfall at Janaale

Rainy Days at Janaale

Daily Rainfall at Janaale 1978 - 1986

Monthly Discharge (infilled) at Aw Dheegle

Sources:

Climate Data:	Fantoli (1965) Food Early Warning Department, Ministry of Agriculture, Mogadishu
Discharge Data:	Raw data - MMP (1985 and 1986) Infilled data - Lahmeyer (1987)

DAILY MAXIMUM TEMPERATURE AT JANAALE

JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
m	m	35.1	35.0	32.8	32.8	31.7	33.7	34.5	33.9	32.9	33.4	m
34.2	35.4	35.9	37.3	31.8	28.9	29.1	29.0	29.1	29.9	30.2	30.2	31.7
30.6	30.2	31.0	31.3	31.0	29.6	28.0	28.0	28.5	29.5	30.0	30.7	29.9
29.8	30.2	30.6	31.3	30.4	29.0	27.7	m	28.6	29.4	30.5	33.0	m
34.5	34.9	35.2	31.8	31.5	29.0	28.8	28.7	29.2	30.0	30.8	31.2	31.3
31.5	31.8	m	32.9	33.6	30.4	27.8	28.1	29.1	29.9	30.0	30.8	m
30.9	30.8	31.3	31.6	31.8	29.5	28.5	29.0	30.0	31.0	31.9	31.9	30.7
33.3	33.2	34.6	m	m	m	29.2	28.6	28.6	m	30.1	30.1	m
30.3	31.5	31.3	31.2	29.9	28.1	26.6	26.8	28.0	28.6	29.3	30.1	29.3
31.2	31.4	31.5	31.2	30.4	28.6	28.2	28.9	29.1	m	m	m	m
32.7	33.8	35.1	35.5	32.3	29.6	28.6	27.9	29.2	30.0	30.8	32.0	31.5
32.9	33.3	34.0	33.2	31.4	29.0	28.2	28.6	29.7	30.6	31.5	31.8	31.2
32.5	33.3	33.8	33.5	31.7	29.7	28.6	29.1	29.7	31.3	32.5	33.4	31.6
33.9	34.3	35.1	34.0	31.1	29.3	27.9	29.1	29.8	30.6	31.6	32.7	31.6
33.5	34.1	35.0	33.8	31.4	30.3	28.4	29.2	29.2	30.5	31.2	31.5	31.5
32.0	32.5	32.5	33.0	30.5	29.4	28.9	29.2	30.1	31.0	32.1	32.1	31.1
32.7	31.6	32.4	m	m	m	26.7	28.2	29.5	29.9	30.3	30.4	m
31.5	31.7	32.3	30.5	29.6	29.5	29.5	29.1	30.2	30.9	30.6	30.4	30.5
31.5	32.8	33.4	31.7	30.5	29.7	28.6	28.7	30.6	31.2	31.6	32.2	31.0
33.0	34.0	34.0	33.5	31.2	30.2	29.3	29.1	30.2	30.7	31.5	31.4	31.5
31.2	31.3	32.4	33.1	31.6	28.6	28.0	28.9	30.2	31.0	30.2	31.0	30.6
31.1	31.8	32.9	33.1	30.5	29.2	29.6	29.0	30.0	30.8	30.9	31.8	30.9
31.6	32.3	32.5	32.6	30.6	29.2	30.0	30.3	30.1	30.8	32.9	m	m
32.1	32.6	33.3	32.9	31.2	29.5	28.6	29.0	29.7	30.5	31.1	31.5	31.0
0.04	0.05	0.05	0.05	0.03	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.02
0.2	0.2	0.0	0.9	0.7	2.1	0.7	2.5	2.7	1.4	0.4	0.3	-1.3

OF MONTHLY MEANS = 31.0

: m INDICATES A MISSING VALUE

AILY MINIMUM TEMPERATURE AT JANAALE

JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
m	m	24.2	25.0	24.0	21.9	21.4	22.4	22.6	24.3	22.9	22.2	m
22.4	22.9	24.1	24.6	24.4	23.1	23.1	22.2	23.2	24.0	24.1	21.3	23.3
22.7	20.8	23.3	23.3	23.2	21.5	21.3	20.9	22.2	22.9	22.5	22.3	22.2
21.6	22.5	22.4	23.6	23.1	21.1	21.8	m	21.8	22.7	22.1	22.0	m
17.6	20.9	22.3	23.8	23.3	21.2	21.3	21.4	21.5	22.5	21.5	21.7	21.6
20.3	22.1	m	m	21.3	20.2	21.8	21.6	22.2	22.9	22.5	22.6	m
22.9	22.3	23.4	24.1	24.6	23.1	21.9	21.3	22.2	22.6	22.1	21.8	22.7
21.8	22.5	22.7	m	m	m	22.1	20.5	21.7	m	21.8	20.2	m
20.7	21.0	22.6	23.6	23.0	21.7	20.7	20.1	21.7	21.5	21.4	21.3	21.6
19.7	21.1	22.1	22.5	22.4	21.0	20.6	21.8	25.6	m	m	m	m
20.0	21.9	22.8	23.1	23.3	21.7	21.0	21.2	21.6	21.9	22.3	22.0	21.9
19.9	21.5	22.6	23.4	23.5	22.0	21.3	21.1	21.5	22.2	21.7	20.5	21.8
21.8	21.1	22.9	23.3	22.9	21.3	21.5	20.8	21.1	22.5	22.1	22.3	22.0
21.5	21.6	23.5	23.7	23.4	21.7	21.3	21.2	21.8	22.2	21.5	21.3	22.1
21.1	20.5	22.6	23.6	22.8	21.6	20.4	20.5	21.2	22.7	21.8	20.9	21.6
21.4	21.5	22.5	23.0	23.9	23.4	21.0	21.6	21.9	23.0	21.9	22.1	22.3
19.9	20.7	21.5	m	m	m	17.3	16.6	17.0	21.1	20.9	20.5	m
20.4	20.1	21.2	21.3	20.1	17.2	20.2	20.4	20.2	21.5	21.4	20.9	20.4
21.5	23.6	23.8	26.6	26.1	25.8	24.9	24.9	25.5	m	m	m	m
m	m	m	m	m	m	23.0	24.2	23.1	24.1	m	24.2	m
24.2	23.3	24.5	26.0	25.3	22.6	23.1	22.3	24.3	23.5	23.1	21.6	23.6
22.4	23.0	25.3	24.4	22.0	20.1	21.8	22.3	23.2	23.7	23.9	24.7	23.1
23.8	24.2	26.3	25.8	23.8	21.9	23.0	23.8	22.9	24.4	23.8	m	m
21.3	21.9	23.2	23.9	23.3	21.7	21.6	21.5	22.2	22.8	22.3	21.8	22.2
0.07	0.05	0.05	0.05	0.06	0.08	0.07	0.08	0.08	0.04	0.04	0.05	0.04
-0.3	0.4	0.9	0.4	-0.3	-0.3	-0.6	-0.6	-0.6	0.1	0.8	1.1	0.0

OF MONTHLY MEANS = 22.3

: m INDICATES A MISSING VALUE

ILY AVERAGE TEMPERATURE AT JANAALE

JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
m	m	29.7	30.0	28.4	27.4	26.6	28.2	28.6	29.1	27.9	27.8	m
28.3	29.1	30.0	30.9	28.1	26.0	26.1	25.6	26.1	26.9	27.1	25.7	27.5
26.7	25.5	27.2	27.3	27.1	25.6	24.7	24.5	25.4	26.2	26.3	26.5	26.1
25.7	26.3	26.5	27.4	26.7	25.0	24.7	m	25.2	26.1	26.3	27.5	m
26.1	27.9	28.8	27.8	27.4	25.1	25.1	25.1	25.4	26.3	26.2	26.5	26.5
25.9	26.9	m	m	27.4	25.3	24.8	24.8	25.6	26.4	26.2	26.7	m
26.9	26.6	27.4	27.9	28.2	26.3	25.2	25.2	26.1	26.8	27.0	26.9	26.7
27.5	27.8	28.6	m	m	m	25.6	24.5	25.1	m	25.9	25.1	m
25.5	26.3	26.9	27.4	26.5	24.9	23.7	23.5	24.9	25.1	25.4	25.7	25.5
25.4	26.2	26.8	26.8	26.4	24.8	24.4	25.3	27.3	m	m	m	m
26.4	27.9	28.9	29.3	27.8	25.7	24.8	24.6	25.4	25.9	26.6	27.0	26.7
26.4	27.4	28.3	28.3	27.5	25.5	24.8	24.9	25.6	26.4	26.6	26.2	26.5
27.1	27.2	28.3	28.4	27.3	25.5	25.0	24.9	25.4	26.9	27.3	27.8	26.8
27.7	27.9	29.3	28.9	27.2	25.5	24.6	25.2	25.8	26.4	26.5	27.0	26.8
27.3	27.3	28.8	28.7	27.1	25.9	24.4	24.9	25.2	26.6	26.5	26.2	26.6
26.7	27.0	27.5	28.0	27.2	26.4	24.9	25.4	26.0	27.0	27.0	27.1	26.7
26.3	26.2	27.0	m	m	m	22.0	22.4	23.3	25.5	25.6	25.5	m
26.0	25.9	26.8	25.9	24.9	23.4	24.9	24.8	25.2	26.2	26.0	25.7	25.5
26.5	28.2	28.6	29.7	28.3	27.8	26.8	26.8	28.1	m	m	m	m
m	m	m	m	m	m	26.2	26.7	26.7	27.4	m	27.8	m
27.7	27.3	28.5	29.6	28.5	25.6	25.6	25.6	27.3	27.3	26.7	26.3	27.2
26.8	27.4	29.1	28.8	26.3	24.7	25.7	25.7	26.6	27.3	27.4	28.3	27.0
27.7	28.3	29.4	29.2	27.2	25.6	26.5	27.1	26.5	27.6	28.4	m	m
26.7	27.2	28.2	28.4	27.3	25.6	25.1	25.3	25.9	26.7	26.6	26.7	26.6
0.03	0.03	0.04	0.04	0.03	0.04	0.04	0.05	0.04	0.03	0.03	0.03	0.02
0.2	0.1	-0.1	0.0	-0.9	0.3	-0.9	0.2	0.4	0.9	0.6	0.1	-0.8

OF MONTHLY MEANS = 26.6

VE HUMIDITY AT JANAALE

JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
m	m	81	87	91	92	93	94	94	95	95	87	m
82	79	77	78	89	87	94	92	90	85	86	85	85
83	81	86	89	92	80	81	78	77	76	76	77	81
74	75	73	75	81	84	m	m	92	83	m	81	m
80	80	71	77	81	84	77	81	82	80	77	74	79
74	74	m	76	78	81	84	82	82	84	83	80	m
80	73	86	89	92	92	90	91	89	88	88	88	87
86	87	87	m	m	m	93	93	83	m	89	93	m
70	63	69	69	69	73	71	70	70	75	76	75	71
71	76	74	78	81	80	79	79	76	m	m	m	m
65	66	66	69	74	76	77	78	80	82	84	80	75
75	74	74	78	82	86	82	79	78	79	76	78	78
74	70	69	70	76	75	75	74	76	76	75	73	74
69	69	73	75	79	80	79	77	78	77	79	74	76
74	73	72	75	79	81	83	82	82	82	82	80	79
78	79	79	79	82	84	82	80	79	76	78	79	80
77	79	78	m	m	m	77	83	82	82	79	78	m
79	78	78	81	82	80	86	83	86	90	90	84	83
79	84	86	88	86	89	84	79	76	77	80	73	82
70	68	65	70	80	80	78	77	73	75	m	72	m
74	70	71	72	78	80	78	75	74	74	77	70	74
70	67	71	74	74	74	77	74	76	75	78	78	74
75	70	78	76	78	75	73	73	73	74	73	m	m
75	74	76	77	81	82	82	81	80	80	81	79	78
0.07	0.08	0.09	0.08	0.07	0.07	0.08	0.08	0.08	0.07	0.07	0.07	0.06
0.1	0.2	0.4	0.7	0.3	0.4	0.6	0.8	0.6	1.0	0.9	0.7	0.3

OF MONTHLY MEANS = 79.0

: m INDICATES A MISSING VALUE

ND SPEEDS AT JANAALE (m/s)

JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
m	m	m	1.6	1.6	2.6	2.7	2.6	2.4	1.8	0.7	1.2	m
1.5	1.5	1.3	0.9	1.8	2.3	2.5	2.7	2.5	1.3	0.6	0.9	1.6
1.2	1.4	1.0	1.0	1.5	2.0	2.3	2.0	2.1	1.7	0.9	1.1	1.5
1.4	1.6	1.3	1.2	2.0	2.3	2.4	2.4	1.9	1.2	0.4	0.7	1.6
0.9	1.0	0.7	0.6	1.0	1.7	1.6	1.6	2.6	2.5	1.2	1.3	1.4
1.9	2.4	2.4	1.7	2.8	2.6	3.1	3.4	3.5	2.5	1.9	2.0	2.5
2.2	1.9	1.8	m	m	m	2.9	3.1	2.7	2.3	1.0	2.1	m
3.8	6.1	2.3	1.2	1.6	2.0	3.0	2.4	2.6	1.7	1.1	2.0	2.5
2.2	2.2	2.4	1.3	1.4	1.7	2.0	1.9	2.4	1.8	0.9	1.8	1.8
2.8	2.4	2.3	1.8	1.4	2.0	2.5	3.3	2.2	1.6	1.7	1.4	2.1
2.5	1.5	2.2	2.0	2.6	2.3	2.5	2.7	2.6	2.9	2.3	m	m
2.2	2.3	2.2	1.8	1.7	1.9	2.2	2.0	2.3	2.1	3.5	1.7	2.2
2.2	2.0	1.6	1.3	1.4	2.0	2.5	2.3	3.5	1.7	1.4	m	m
2.1	2.2	1.8	1.4	1.7	2.1	2.5	2.5	2.6	1.9	1.4	1.5	1.9
0.38	0.60	0.33	0.31	0.30	0.14	0.16	0.22	0.18	0.26	0.62	0.32	0.22
0.7	2.8	-0.6	-0.2	1.1	0.3	-0.5	0.2	1.1	0.5	1.5	-0.2	0.3

OF MONTHLY MEANS = 2.0

m INDICATES A MISSING VALUE

NE HOURS AT JANAALE

JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
m	m	m	m	257.7	191.6	m	m	270.1	266.0	246.4	258.2	m
309.3	303.7	336.7	274.2	219.2	186.2	180.7	184.6	252.7	227.9	258.3	283.2	3016.7
304.4	237.1	263.1	263.3	247.0	178.0	150.5	214.4	222.7	195.8	267.8	289.8	2833.9
308.3	263.7	307.4	257.8	295.6	208.5	187.6	250.2	270.5	212.3	271.8	272.6	3106.3
308.4	224.8	m	m	m	m	149.0	231.6	218.4	m	m	m	m
m	m	m	m	m	m	m	m	m	m	m	m	m
m	m	m	m	m	213.3	257.0	286.9	m	m	m	m	m
310.5	278.9	266.9	264.3	283.9	206.3	216.2	231.1	273.5	233.4	163.7	284.6	3013.3
292.5	279.6	299.6	205.1	249.0	205.7	240.9	253.5	264.9	258.3	238.7	286.5	3074.3
281.0	256.2	304.3	346.3	233.6	242.0	229.6	192.4	239.1	281.5	270.4	296.8	3173.2
296.5	285.5	304.3	241.4	258.3	184.3	206.1	281.5	272.2	256.1	199.2	279.4	3064.8
282.0	272.4	282.4	223.3	181.3	202.4	194.5	262.3	260.4	240.0	107.1	179.0	2687.1
214.2	244.4	268.4	242.2	173.2	161.2	131.3	198.4	267.1	199.5	176.1	127.5	2403.5
319.3	280.0	316.2	m	m	m	269.7	279.0	297.0	282.1	303.0	275.9	m
m	m	m	m	m	261.0	269.7	257.3	279.0	m	276.0	148.8	m
257.3	268.8	294.5	210.0	186.0	228.0	207.7	254.2	273.0	220.1	234.0	241.8	2875.4
263.5	249.2	300.7	285.0	229.4	237.0	226.3	238.7	270.0	248.0	m	272.8	m
285.2	281.3	300.7	285.0	272.8	189.0	238.7	235.6	m	269.7	225.0	291.4	m
297.6	240.8	306.9	210.0	223.2	246.0	244.9	235.6	246.0	244.9	231.0	269.7	2996.6
272.8	266.6	306.9	204.0	m	m	m	m	m	m	m	m	m
287.7	264.6	297.3	250.8	236.4	208.8	211.8	240.4	261.0	242.4	231.2	253.6	2931.4
0.09	0.08	0.07	0.16	0.16	0.13	0.20	0.13	0.08	0.11	0.22	0.21	0.08
-1.5	-0.2	-0.3	0.8	-0.3	0.3	-0.5	-0.3	-0.8	-0.2	-1.1	-1.7	-1.5

OF MONTHLY MEANS = 2986.1

: m INDICATES A MISSING VALUE

LL AT AFGOI (MM)

JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
0.0	0.0	0.0	90.0	136.0	55.0	26.0	0.0	2.0	166.0	24.0	8.0	507.0
0.0	0.0	0.0	140.0	97.0	28.0	m	0.0	11.0	115.0	m	4.0	m
0.0	0.0	m	m	m	136.0	33.0	m	m	22.0	48.0	m	m
0.0	0.0	0.0	25.0	79.0	27.0	47.0	68.0	1.0	20.0	77.0	15.0	359.0
0.0	0.0	0.0	92.0	m	m	m	m	m	m	m	m	m
m	m	m	m	m	m	m	m	m	m	m	m	m
m	m	m	m	m	m	m	m	m	0.0	245.0	35.0	m
0.0	0.0	0.0	94.0	0.0	m	m	m	m	38.0	203.0	110.0	m
0.0	0.0	0.0	169.0	0.0	0.0	0.0	0.0	0.0	105.0	119.0	58.0	451.0
0.0	0.0	0.0	0.0	58.0	103.0	20.0	25.0	m	m	128.0	0.0	m
0.0	0.0	30.0	8.0	112.0	120.0	50.0	12.0	0.0	28.0	63.0	10.0	433.0
m	m	m	m	m	m	53.0	43.0	0.0	45.0	120.0	90.0	m
0.0	0.0	0.0	47.0	159.0	30.0	m	m	m	116.0	0.0	m	m
0.0	0.0	0.0	22.0	63.0	83.0	42.0	26.0	20.0	72.0	14.0	46.0	388.0
0.0	0.0	0.0	139.0	50.0	75.0	57.0	41.0	16.0	51.0	25.0	42.0	496.0
29.0	0.0	10.0	230.0	84.0	102.0	40.0	m	m	m	m	m	m
m	m	m	m	m	m	m	m	m	m	m	m	m
m	m	m	m	m	m	m	m	m	m	m	m	m
m	m	m	m	m	m	m	m	m	m	m	m	m
m	m	m	m	m	m	m	m	m	m	m	m	m
m	m	m	m	m	m	m	m	m	m	m	m	m
m	m	m	m	m	m	m	m	m	m	m	m	m
m	m	m	m	m	m	m	m	m	m	m	m	m
m	m	m	m	m	m	m	m	m	m	m	m	m
m	m	m	m	m	m	m	m	m	m	m	m	m
m	m	m	m	m	m	m	m	m	m	m	m	m
m	m	m	m	m	m	m	m	m	m	m	m	m
m	m	m	m	m	m	m	m	m	m	m	m	m
m	m	m	m	m	m	m	m	m	m	m	m	m

m	m	m	m	m	m	m	m	m	m	m	m	m
m	m	m	m	m	m	m	m	m	m	m	m	m
0.0	0.0	0.0	91.0	0.0	47.0	89.0	19.0	9.0	32.0	117.0	38.0	442.0
0.0	0.0	0.0	156.0	89.0	16.0	10.0	12.0	0.0	23.0	35.0	13.0	354.0
11.0	0.0	2.0	26.0	47.0	19.0	33.0	5.0	6.0	17.0	26.0	0.0	192.0
0.0	0.0	5.0	70.0	19.0	25.0	52.0	1.0	21.0	62.0	36.0	10.0	301.0
14.0	0.0	0.0	13.0	237.0	56.0	91.0	16.0	9.0	23.0	148.0	46.0	655.0
7.0	0.0	0.0	66.0	183.0	127.0	18.0	19.0	0.0	5.0	1.0	62.0	488.0
0.0	0.0	0.0	92.0	17.0	11.0	80.0	13.0	18.0	0.0	57.0	9.0	297.0
0.0	0.0	66.0	118.0	112.0	49.0	50.0	6.0	7.0	68.0	82.0	8.0	566.0
0.0	0.0	6.0	12.0	72.0	13.0	213.0	124.0	0.0	0.0	0.0	0.0	440.0
0.0	0.0	9.0	181.0	149.0	46.0	103.0	6.0	12.0	90.0	16.0	16.0	628.0
9.0	5.0	0.0	146.0	75.0	24.0	25.0	17.0	153.0	25.0	126.0	53.0	658.0
0.0	0.0	1.0	73.0	283.0	39.0	49.0	30.0	0.0	4.0	0.0	49.0	528.0
0.0	0.0	0.0	99.0	59.0	42.0	46.0	42.0	25.0	163.0	170.0	36.0	682.0
0.0	0.0	1.0	179.0	0.0	88.0	60.0	31.0	6.0	169.0	121.0	0.0	655.0
0.0	0.0	0.0	71.0	175.0	240.0	39.0	36.0	0.0	140.0	214.0	0.0	915.0
0.0	0.0	0.0	167.0	86.0	16.0	107.0	0.0	0.0	68.0	370.0	84.0	898.0
10.0	29.0	7.0	12.0	181.0	35.0	118.0	22.0	1.0	41.0	226.0	5.0	687.0
0.0	0.0	0.0	0.0	m	m	m	m	0.0	0.0	18.0	0.0	m
0.0	0.0	0.0	77.0	87.0	86.0	33.0	5.0	38.0	4.0	74.0	0.0	404.0
0.0	0.0	0.0	0.0	164.0	54.0	64.0	14.0	2.0	211.0	215.0	0.0	724.0
0.0	0.0	0.0	22.0	51.0	48.0	65.0	6.0	0.0	17.0	152.0	68.0	429.0
0.0	0.0	36.0	141.0	136.0	83.0	13.0	7.0	0.0	11.0	103.0	46.0	576.0
6.0	0.0	0.0	43.0	34.0	41.0	128.0	68.0	0.0	13.0	90.0	0.0	423.0
0.0	21.0	0.0	82.0	222.0	15.0	11.0	7.0	0.0	0.0	6.0	124.0	488.0
31.0	0.0	70.0	180.0	55.0	26.0	69.0	26.0	4.0	133.0	104.0	121.0	819.0
0.0	0.0	43.0	69.0	28.0	20.0	22.0	0.0	0.0	118.0	144.0	18.0	462.0
9.0	0.0	0.0	35.0	80.0	180.0	108.0	17.0	0.0	18.0	50.0	34.0	531.0
0.0	0.0	0.0	1.0	144.0	166.0	61.0	43.0	90.0	48.0	196.0	0.0	749.0

0.0	0.0	51.0	109.0	145.0	21.0	47.0	41.0	0.0	28.0	129.0	123.0	694.0
4.0	0.0	0.0	156.0	62.0	48.0	48.0	1.0	0.0	166.0	198.0	107.0	790.0
0.0	0.0	0.0	33.0	16.0	9.0	6.0	7.0	0.0	9.0	9.0	2.0	91.0
0.0	0.0	0.0	63.0	47.0	90.0	21.0	0.0	0.0	92.0	197.0	0.0	510.0
0.0	0.0	0.0	124.8	40.2	0.0	21.7	38.1	35.5	11.8	130.0	16.0	418.1
0.0	0.0	0.0	183.9	54.2	14.6	54.8	3.7	1.5	0.7	64.9	57.6	435.9
0.0	0.0	m	m	m	m	m	m	m	m	m	m	m
2.7	1.1	7.3	85.8	90.6	58.0	54.0	21.4	11.6	56.3	102.0	34.8	527.3
2.49	4.49	2.38	0.72	0.75	0.89	0.74	1.13	2.37	1.02	0.81	1.10	0.34
3.1	4.8	2.6	0.3	0.9	1.6	1.7	2.2	4.0	1.0	0.9	1.1	0.1

OF MONTHLY MEANS = 525.7

: m INDICATES A MISSING VALUE

EQUALLED OR EXCEEDED 75 PERCENT OF THE TIME (NOT AN HOMOGENEOUS SEQUENCE)

JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
0.0	0.0	0.0	25.9	47.0	20.4	25.2	5.0	0.0	11.7	25.9	1.4	424.1

RAINFALL AT JANAALE (MM)

JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
m	m	m	m	m	122.0	64.0	52.9	196.9	26.2	117.8	19.1	m
0.0	0.0	1.0	234.8	70.7	22.7	22.0	13.0	0.0	76.2	25.0	80.5	545.9
0.0	2.0	0.0	33.5	276.6	42.6	45.2	30.7	0.0	3.6	61.1	2.5	497.8
0.0	0.0	0.0	2.8	47.6	49.6	50.2	37.7	15.9	3.2	18.0	20.7	245.7
21.1	0.0	0.0	99.2	13.8	39.4	39.3	34.0	14.7	42.8	41.5	40.2	386.0
0.0	0.0	0.0	64.4	90.0	39.4	57.3	85.3	50.8	15.5	22.7	3.8	429.2
0.0	0.0	0.0	24.1	114.0	77.2	58.2	58.0	10.4	14.0	30.2	34.6	420.7
0.0	0.0	0.0	59.8	0.0	69.6	99.5	57.0	13.3	27.4	2.6	112.4	441.6
0.4	0.0	11.1	204.0	66.0	111.1	110.0	21.7	61.0	70.5	54.8	14.0	724.6
0.0	0.0	0.0	19.0	77.8	137.5	48.0	76.0	10.2	117.5	10.7	14.0	510.7
0.0	0.0	0.0	35.5	28.0	79.9	0.0	24.7	3.0	94.7	29.3	8.0	303.1
0.0	0.0	18.0	m	m	m	m	m	m	m	m	m	m
0.0	0.0	5.0	78.5	29.5	41.0	35.5	88.0	3.5	31.7	2.0	7.5	322.2
0.0	0.0	0.0	101.2	43.8	67.2	60.3	51.5	11.8	3.2	46.0	19.4	404.4
0.0	0.0	0.0	9.0	51.0	164.6	49.5	34.5	9.0	45.0	m	0.0	m
0.0	0.0	0.0	96.0	155.5	38.5	37.0	164.0	0.0	0.0	m	m	m
m	m	m	m	7.0	112.2	m	m	m	m	m	m	m
0.0	0.0	30.2	73.1	226.0	238.4	107.5	73.8	19.7	61.1	88.3	127.3	1045.4
0.0	0.0	0.0	53.2	31.0	105.8	5.4	0.0	0.0	35.8	69.1	0.0	300.3
5.4	0.0	24.2	73.5	10.0	40.2	62.1	60.0	38.4	47.5	172.1	9.9	543.3
0.0	0.0	0.0	76.7	60.2	76.3	20.2	37.9	11.6	10.0	61.2	33.0	387.1
5.3	0.0	0.0	17.0	47.5	30.9	31.5	6.1	1.7	0.5	2.3	6.1	148.9
0.0	0.0	0.0	111.7	31.5	65.5	72.3	7.6	1.2	5.9	108.4	0.2	404.3
1.4	0.0	0.0	61.6	102.8	75.1	145.7	12.5	20.4	19.7	101.9	10.8	551.9
0.5	0.0	0.2	141.9	118.7	84.0	39.5	63.5	0.6	0.6	38.8	12.2	500.5
0.0	0.0	0.0	74.0	17.0	15.0	101.0	22.0	12.0	3.0	94.0	12.0	350.0
0.0	0.0	69.0	210.0	126.0	133.0	5.0	4.0	10.0	4.0	65.0	0.0	626.0

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0.0	0.0	0.0	35.0	0.0	39.0	257.0	191.0	m	m	m	m	m
2.0	0.0	13.0	89.0	56.0	62.0	63.0	22.0	14.0	13.0	86.0	10.0	430.0
m	m	m	m	m	m	m	m	m	m	m	m	m
m	m	m	m	m	56.0	62.0	47.0	28.0	2.0	1.0	20.0	m
0.0	0.0	0.0	19.0	35.0	92.0	m	m	m	m	m	m	m
0.0	0.0	6.5	82.0	110.0	23.3	55.5	1.5	0.0	72.5	74.5	51.0	476.8
20.0	0.0	11.0	75.0	159.5	257.0	79.5	18.0	2.5	0.0	34.0	8.0	664.5
0.0	0.0	0.0	m	m	m	m	68.5	0.0	58.5	66.5	0.0	m
0.0	0.0	8.4	221.2	183.5	3.8	44.3	234.4	4.4	2.0	34.0	11.0	747.0
0.0	0.0	0.0	127.0	71.0	114.0	102.0	10.0	1.0	77.2	56.2	26.6	585.0
0.0	0.0	0.0	48.0	120.2	30.1	46.2	35.3	0.0	13.6	38.4	0.0	331.8
0.0	0.0	0.0	32.0	54.0	94.7	36.8	0.0	0.0	0.0	112.6	0.0	330.1
0.0	0.0	0.0	113.4	170.4	20.0	40.0	45.6	51.7	20.6	59.8	3.0	524.5
0.0	0.0	0.0	149.1	107.1	46.6	31.8	6.9	18.4	0.0	21.6	19.6	401.1
0.0	0.0	m	m	m	m	m	m	m	m	m	m	m
1.5	0.1	5.3	84.1	80.8	76.8	60.7	48.6	17.7	28.3	54.3	21.1	470.3
3.20	6.16	2.43	0.73	0.81	0.73	0.76	1.07	1.95	1.11	0.72	1.42	0.37
3.8	6.2	3.7	1.1	1.1	1.6	2.4	2.1	4.3	1.2	0.9	2.5	1.2

F MONTHLY MEANS = 479.2

m INDICATES A MISSING VALUE

EQUALLED OR EXCEEDED 75 PERCENT OF THE TIME (NOT AN HOMOGENEOUS SEQUENCE)

JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
0.0	0.0	0.0	35.1	31.2	39.4	36.9	12.8	0.8	3.1	24.9	3.1	356.7

AINY DAYS AT JANAALE

EAR	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
930	0	0	1	14	12	9	6	7	0	5	6	2	62
931	0	1	0	1	17	9	8	6	0	3	4	1	50
932	0	0	0	3	14	10	11	6	5	3	4	5	61
933	4	0	0	2	2	6	10	6	7	1	5	4	47
934	0	0	0	9	7	6	14	20	6	5	6	3	76
935	0	0	0	5	2	10	23	15	4	4	7	3	73
936	0	0	0	6	0	16	15	12	6	4	5	8	72
937	1	0	3	m	m	m	15	10	6	m	9	2	m
938	0	0	0	4	7	14	12	11	6	5	2	2	63
939	0	0	0	m	m	m	0	5	2	4	6	1	m
940	0	0	1	m	m	m	m	m	m	m	m	m	m
944	0	0	1	4	5	3	6	3	1	2	1	3	29
945	0	0	0	5	3	9	11	6	m	m	3	m	m
946	0	0	0	4	4	11	15	10	3	4	m	0	m
947	0	0	0	7	19	11	9	13	0	0	m	m	m
948	m	m	m	m	3	11	m	m	m	m	m	m	m
953	3	0	1	4	2	6	17	11	5	7	14	3	73
954	0	0	0	6	7	10	11	13	7	3	7	4	68
955	3	0	0	6	11	12	10	6	1	2	2	2	55
956	0	0	0	10	9	17	10	6	3	5	9	1	70
957	2	0	0	9	19	14	17	13	4	3	12	3	96
958	1	0	1	9	19	14	12	14	1	1	1	5	78
980	0	0	0	m	m	m	9	10	0	2	6	0	m
981	0	0	2	7	12	4	4	8	2	1	3	2	45
982	0	0	0	10	11	13	10	4	1	6	7	2	64
983	0	0	0	2	10	5	5	7	0	3	3	0	35
984	0	0	0	2	7	16	14	0	0	0	9	0	48
985	0	0	0	9	13	3	9	9	6	4	2	1	56
986	0	0	0	10	8	12	9	3	1	0	4	1	48
987	0	0	m	m	m	m	m	m	m	m	m	m	m
EAN	0	0	0	6	9	10	11	9	3	3	5	2	60
CV	2.26	5.39	2.05	0.53	0.64	0.41	0.43	0.51	0.86	0.62	0.60	0.81	0.26
KEW	2.3	5.4	2.4	0.4	0.4	-0.2	0.2	0.4	0.2	0.0	0.8	1.2	0.0

SUM OF MONTHLY MEANS = 59

DAILY RAINFALL AT JANAALE (MM) 1978

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	-	-	-	-	-	-	-	-	-	-	19.5	-
2	-	-	-	-	-	-	-	-	-	-	2.5	-
3	-	-	-	-	-	1.0	-	-	-	-	11.5	25.0
4	-	-	-	5.0	-	-	8.5	-	-	-	-	-
5	-	-	-	1.0	-	-	11.5	-	-	-	-	-
6	-	-	-	6.0	71.5	-	-	-	-	-	5.5	5.5
7	-	-	-	30.0	-	-	4.5	-	-	-	-	-
8	-	-	-	3.5	-	-	-	-	-	-	-	-
9	-	-	-	3.5	-	-	-	1.5	-	-	-	-
10	-	-	-	-	-	-	4.0	-	-	2.0	-	-
11	-	-	6.5	-	-	-	9.5	-	-	-	-	-
12	-	-	-	-	23.0	-	7.5	-	-	-	-	14.5
13	-	-	-	11.5	5.0	-	-	-	-	-	5.5	-
14	-	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-	-	6.0
16	-	-	-	-	-	-	-	-	-	7.0	-	-
17	-	-	-	-	-	2.5	-	-	-	10.0	-	-
18	-	-	-	-	-	3.5	-	-	-	-	-	-
19	-	-	-	-	-	-	1.5	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-	15.5	-
21	-	-	-	-	-	-	2.0	-	-	-	-	-
22	-	-	-	-	-	-	5.5	-	-	1.0	1.5	-
23	-	-	-	-	-	4.5	-	-	-	-	-	-
24	-	-	-	13.5	-	-	-	-	-	2.0	-	-
25	-	-	-	-	-	-	-	-	-	-	13.0	-
26	-	-	-	-	10.0	4.6	-	-	-	-	-	-
27	-	-	-	-	-	1.7	-	-	-	19.5	-	-
28	-	-	-	1.5	-	3.0	-	-	-	10.5	-	-
29	-	-----	-	-	-	-	-	-	-	9.0	-	-
30	-	-----	-	6.5	0.5	2.5	1.0	-	-	3.5	-	-
31	-	-----	-	-----	-	-----	-	-	-----	8.0	-----	-
TOTAL	0.0	0.0	6.5	82.0	110.0	23.3	55.5	1.5	0.0	72.5	74.5	51.0
MAX.	0.0	0.0	6.5	30.0	71.5	4.6	11.5	1.5	0.0	19.5	19.5	25.0
DAYS > 0.0	0	0	1	10	5	8	10	1	0	10	8	4

1978 SUMMARY (365 DAYS) : TOTAL 476.8 MEAN 1.3

DAILY RAINFALL AT JANAALE (MM) 1979

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	-	-	-	-	-	-	-	-	-	-	5.0	-
2	-	-	-	-	-	-	1.0	-	-	-	-	-
3	-	-	-	-	24.0	-	-	-	-	-	-	-
4	-	-	-	-	-	2.5	50.0	-	-	-	-	-
5	-	-	-	-	-	15.5	3.5	-	-	-	4.5	-
6	-	-	-	-	-	-	3.5	-	-	-	18.5	-
7	17.0	-	-	4.5	17.5	-	0.5	-	-	-	-	-
8	-	-	-	-	-	-	2.5	6.0	-	-	-	-
9	-	-	-	-	-	3.0	2.5	-	-	-	-	-
10	-	-	-	16.0	85.0	2.0	3.0	4.0	-	-	-	-
11	-	-	-	19.0	30.5	-	1.0	-	-	-	-	-
12	-	-	-	16.5	-	-	8.0	-	-	-	5.0	-
13	-	-	-	-	-	-	3.0	2.0	-	-	-	-
14	-	-	-	-	-	3.0	-	-	-	-	1.0	-
15	-	-	-	-	-	-	-	-	-	-	-	-
16	-	-	-	3.0	-	9.0	-	6.0	-	-	-	-
17	-	-	-	7.5	2.5	11.0	-	-	-	-	-	-
18	-	-	11.0	-	-	45.5	-	-	-	-	-	-
19	-	-	-	-	-	15.0	-	-	-	-	-	-
20	3.0	-	-	-	-	74.0	-	-	-	-	-	-
21	-	-	-	-	-	15.5	-	-	-	-	-	-
22	-	-	-	-	-	3.0	-	-	-	-	-	3.0
23	-	-	-	-	-	6.0	1.0	-	-	-	-	-
24	-	-	-	-	-	30.5	-	-	-	-	-	2.0
25	-	-	-	7.5	-	7.5	-	-	-	-	-	-
26	-	-	-	-	-	5.0	-	-	-	-	-	3.0
27	-	-	-	-	-	5.0	-	-	-	-	-	-
28	-	-	-	1.0	-	-	-	-	-	-	-	-
29	-	-----	-	-	-	4.0	-	-	-	-	-	-
30	-	-----	-	-	-	-	-	-	2.5	-	-	-
31	-	-----	-	-----	-	-----	-	-	-----	-	-----	-
TOTAL	20.0	0.0	11.0	75.0	159.5	257.0	79.5	18.0	2.5	0.0	34.0	8.0
MAX.	17.0	0.0	11.0	19.0	85.0	74.0	50.0	6.0	2.5	0.0	18.5	3.0
DAYS > 0.0	2	0	1	8	5	18	12	4	1	0	5	3

DAILY RAINFALL AT JANAALE (MM) 1980

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	-	-	-	m	m	m	m	-	-	-	-	-
2	-	-	-	m	m	m	m	-	-	-	1.0	-
3	-	-	-	m	m	m	m	-	-	-	39.5	-
4	-	-	-	m	m	m	m	-	-	-	-	-
5	-	-	-	m	m	m	m	-	-	-	-	-
6	-	-	-	m	m	m	m	-	-	-	-	-
7	-	-	-	m	m	m	m	12.0	-	-	-	-
8	-	-	-	m	m	m	m	11.0	-	-	-	-
9	-	-	-	m	m	m	m	12.0	-	-	10.5	-
10	-	-	-	m	m	m	m	-	-	-	9.0	-
11	-	-	-	m	m	m	-	7.0	-	-	1.0	-
12	-	-	-	m	m	m	6.5	10.0	-	-	-	-
13	-	-	-	m	m	m	4.5	-	-	-	5.5	-
14	-	-	-	m	m	m	0.5	-	-	-	-	-
15	-	-	-	m	m	m	10.0	-	-	-	-	-
16	-	-	-	m	m	m	6.5	3.0	-	-	-	-
17	-	-	-	m	m	m	1.0	-	-	-	-	-
18	-	-	-	m	m	m	-	-	-	-	-	-
19	-	-	-	m	m	m	-	-	-	-	-	-
20	-	-	-	m	m	m	11.0	-	-	-	-	-
21	-	-	-	m	m	m	-	-	-	-	-	-
22	-	-	-	m	m	m	7.0	1.0	-	-	-	-
23	-	-	-	m	m	m	-	5.0	-	-	-	-
24	-	-	-	m	m	m	-	-	-	-	-	-
25	-	-	-	m	m	m	3.5	5.5	-	-	-	-
26	-	-	-	m	m	m	-	-	-	-	-	-
27	-	-	-	m	m	m	-	-	-	-	-	-
28	-	-	-	m	m	m	-	-	-	-	-	-
29	-	-	-	m	m	m	-	2.0	-	-	-	-
30	-	-----	-	m	m	m	-	-	-	17.0	-	-
31	-	-----	-	-----	m	-----	-	-	-----	41.5	-----	-
TOTAL	0.0	0.0	0.0	m	m	m	50.5	68.5	0.0	58.5	66.5	0.0
MAX.	0.0	0.0	0.0	m	m	m	11.0	12.0	0.0	41.5	39.5	0.0
DAYS > 0.0	0	0	0	m	m	m	9	10	0	2	6	0

1980 SUMMARY (265 DAYS) : TOTAL 244.0 MEAN 0.9

DAILY RAINFALL AT JANAALE (MM) 1981

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	-	-	-	13.2	-	-	-	-	-	-	-	-
2	-	-	-	-	31.9	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	25.5	-	-	-	-	-	-	-	5.0
5	-	-	-	-	25.4	-	-	-	-	-	-	-
6	-	-	-	-	3.8	-	-	-	3.0	-	-	6.0
7	-	-	-	-	-	-	-	22.0	-	-	-	-
8	-	-	-	-	84.7	-	22.0	20.2	-	-	18.8	-
9	-	-	-	-	4.8	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	5.2	-	-	-	-
12	-	-	-	-	-	1.5	-	-	-	-	-	-
13	-	-	-	-	1.0	0.3	-	-	-	-	-	-
14	-	-	-	55.7	-	-	19.3	30.0	-	-	-	-
15	-	-	-	28.7	-	1.0	-	30.0	-	-	-	-
16	-	-	-	-	-	-	-	52.0	-	-	-	-
17	-	-	-	-	5.4	-	-	72.0	1.4	-	-	-
18	-	-	-	67.9	15.5	-	2.0	-	-	-	2.0	-
19	-	-	-	-	-	1.0	-	-	-	-	-	-
20	-	-	-	5.4	2.0	-	-	-	-	-	-	-
21	-	-	-	-	2.0	-	-	-	-	-	-	-
22	-	-	-	-	1.0	-	-	-	-	-	-	-
23	-	-	3.4	-	-	-	-	-	-	-	13.2	-
24	-	-	-	-	-	-	-	3.0	-	-	-	-
25	-	-	-	-	6.0	-	-	-	-	-	-	-
26	-	-	-	24.8	-	-	-	-	-	2.0	-	-
27	-	-	-	-	-	-	1.0	-	-	-	-	-
28	-	-	5.0	-	-	-	-	-	-	-	-	-
29	-	-----	-	-	-	-	-	-	-	-	-	-
30	-	-----	-	-	-	-	-	-	-	-	-	-
31	-	-----	-	-----	-	-----	-	-	-----	-	-----	-
TOTAL	0.0	0.0	8.4	221.2	183.5	3.8	44.3	234.4	4.4	2.0	34.0	11.0
MAX.	0.0	0.0	5.0	67.9	84.7	1.5	22.0	72.0	3.0	2.0	18.8	6.0
DAYS > 0.0	0	0	2	7	12	4	4	8	2	1	3	2

1981 SUMMARY (365 DAYS) : TOTAL 747.0 MEAN 2.0

DAILY RAINFALL AT JANAALE (MM)   1982

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	-	-	-	-	-	-	-	-	-	-	-	-
2	-	-	-	-	-	31.0	8.0	-	-	-	-	-
3	-	-	-	4.4	-	-	-	-	-	-	-	-
4	-	-	-	-	1.0	-	-	-	-	-	-	-
5	-	-	-	-	-	1.0	3.0	2.0	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	4.0	-	-	-	-
9	-	-	-	8.0	-	-	3.0	-	-	-	19.0	-
10	-	-	-	-	12.0	-	8.0	-	-	-	-	22.6
11	-	-	-	-	3.0	-	49.0	-	-	-	-	4.0
12	-	-	-	-	25.0	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	3.0	-	-	-	-
14	-	-	-	2.0	-	2.0	-	-	-	-	-	-
15	-	-	-	1.0	-	2.0	-	-	-	11.1	-	-
16	-	-	-	15.4	4.0	1.0	-	-	-	13.7	-	-
17	-	-	-	-	12.0	-	-	-	-	-	1.4	-
18	-	-	-	-	3.0	-	-	-	-	-	-	-
19	-	-	-	26.2	-	2.0	4.0	-	-	-	12.3	-
20	-	-	-	-	-	-	8.0	-	-	-	12.1	-
21	-	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	4.0	-	-	-	-	-
23	-	-	-	-	3.0	1.0	-	-	-	-	-	-
24	-	-	-	-	2.0	5.0	-	-	-	-	-	-
25	-	-	-	21.0	-	48.0	-	-	-	-	3.7	-
26	-	-	-	42.0	1.0	8.0	7.0	-	1.0	4.4	0.7	-
27	-	-	-	-	5.0	2.0	-	-	-	2.7	-	-
28	-	-	-	-	-	-	8.0	1.0	-	12.7	6.0	-
29	-	-----	-	3.0	-	7.0	-	-	-	-	-	-
30	-	-----	-	4.0	-	4.0	-	-	-	-	-	-
31	-	-----	-	-----	-	-----	-	-	-----	32.6	-----	-
TOTAL	0.0	0.0	0.0	127.0	71.0	114.0	102.0	10.0	1.0	77.2	55.2	26.6
MAX.	0.0	0.0	0.0	42.0	25.0	48.0	49.0	4.0	1.0	32.6	19.0	22.6
DAYS > 0.0	0	0	0	10	11	13	10	4	1	6	7	2

1982 SUMMARY (365 DAYS) : TOTAL 584.0 MEAN 1.6

DAILY RAINFALL AT JANAALE (MM) 1983

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	-	-	-	-	30.0	2.5	-	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	19.6	-
5	-	-	-	-	-	4.5	-	-	-	-	12.8	-
6	-	-	-	-	11.0	-	4.2	1.8	-	-	-	-
7	-	-	-	-	-	6.8	-	-	-	-	-	-
8	-	-	-	-	36.0	-	9.4	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	11.8	-	3.6	-	-	-	-
12	-	-	-	-	-	-	9.4	-	-	-	-	-
13	-	-	-	-	-	-	18.4	-	-	-	-	-
14	-	-	-	-	-	-	-	3.6	-	-	-	-
15	-	-	-	-	10.0	-	-	3.6	-	-	-	-
16	-	-	-	-	-	-	-	8.5	-	-	-	-
17	-	-	-	-	-	-	-	1.6	-	-	-	-
18	-	-	-	-	4.0	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-	-
20	-	-	-	-	1.5	-	-	-	-	-	-	-
21	-	-	-	-	12.4	-	-	-	-	4.8	-	-
22	-	-	-	-	5.0	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	4.8	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	12.6	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	4.0	-	-	-	-	-	-	6.0	-
28	-	-	-	-	-	-	-	-	-	-	-	-
29	-	-----	-	-	-	-	-	-	-	-	-	-
30	-	-----	-	44.0	-	4.5	4.8	-	-	5.8	-	-
31	-	-----	-	-----	5.5	-----	-	-	-----	3.0	-----	-
TOTAL	0.0	0.0	0.0	48.0	120.2	30.1	46.2	35.3	0.0	13.6	38.4	0.0
MAX.	0.0	0.0	0.0	44.0	36.0	11.8	18.4	12.6	0.0	5.8	19.6	0.0
DAYS > 0.0	0	0	0	2	10	5	5	7	0	3	3	0

1983 SUMMARY (365 DAYS) : TOTAL 331.8 MEAN 0.9

DAILY RAINFALL AT JANARLE (MM) 1984

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	-	-	-	-	15.0	-	3.0	-	-	-	-	-
2	-	-	-	-	-	-	-	-	-	-	28.8	-
3	-	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	6.0	6.4	-	-	-	5.6	-
5	-	-	-	-	-	5.0	-	-	-	-	-	-
6	-	-	-	-	-	5.0	6.5	-	-	-	8.5	-
7	-	-	-	-	-	-	-	-	-	-	8.6	-
8	-	-	-	-	-	-	1.5	-	-	-	14.6	-
9	-	-	-	-	-	-	-	-	-	-	15.5	-
10	-	-	-	-	-	-	1.6	-	-	-	-	-
11	-	-	-	-	-	-	1.5	-	-	-	2.2	-
12	-	-	-	-	-	-	2.6	-	-	-	27.6	-
13	-	-	-	-	-	-	1.5	-	-	-	-	-
14	-	-	-	-	8.0	-	-	-	-	-	-	-
15	-	-	-	-	-	21.0	-	-	-	-	-	-
16	-	-	-	-	-	15.0	-	-	-	-	1.2	-
17	-	-	-	-	-	3.0	-	-	-	-	-	-
18	-	-	-	7.0	-	4.0	2.6	-	-	-	-	-
19	-	-	-	-	-	-	1.8	-	-	-	-	-
20	-	-	-	-	4.0	1.5	0.8	-	-	-	-	-
21	-	-	-	25.0	-	-	-	-	-	-	-	-
22	-	-	-	-	-	4.0	-	-	-	-	-	-
23	-	-	-	-	18.0	4.0	-	-	-	-	-	-
24	-	-	-	-	4.0	3.0	-	-	-	-	-	-
25	-	-	-	-	-	-	1.5	-	-	-	-	-
26	-	-	-	-	-	4.8	-	-	-	-	-	-
27	-	-	-	-	3.0	3.0	5.5	-	-	-	-	-
28	-	-	-	-	-	5.6	-	-	-	-	-	-
29	-	-	-	-	-	6.8	-	-	-	-	-	-
30	-	-----	-	-	-	3.0	-	-	-	-	-	-
31	-	-----	-	-----	5.0	-----	-	-	-----	-	-----	-
TOTAL	0.0	0.0	0.0	32.0	57.0	94.7	36.8	0.0	0.0	0.0	112.6	0.0
MAX.	0.0	0.0	0.0	25.0	18.0	21.0	6.5	0.0	0.0	0.0	28.8	0.0
DAYS > 0.0	0	0	0	2	7	16	13	0	0	0	9	0

1984 SUMMARY (366 DAYS) : TOTAL 333.1 MEAN 0.9

DAILY RAINFALL AT JANAALE (MM) 1985

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	-	-	-	-	-	-	-	-	-	-	-	3.0
2	-	-	-	1.0	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	2.6	-	-	-	-
4	-	-	-	-	11.5	-	1.6	1.8	-	6.8	-	-
5	-	-	-	-	3.6	-	-	-	-	-	-	-
6	-	-	-	-	2.9	-	-	-	-	-	-	-
7	-	-	-	-	-	-	-	27.8	-	-	-	-
8	-	-	-	7.4	3.2	-	7.6	1.0	-	-	-	-
9	-	-	-	-	4.0	-	4.8	-	32.8	-	-	-
10	-	-	-	-	121.7	-	1.0	1.8	1.8	-	-	-
11	-	-	-	-	3.7	-	14.8	-	3.8	-	-	-
12	-	-	-	12.6	-	-	-	-	1.8	-	-	-
13	-	-	-	14.0	-	-	-	1.6	-	-	-	-
14	-	-	-	-	6.0	-	-	-	-	-	-	-
15	-	-	-	5.7	-	-	-	-	-	-	-	-
16	-	-	-	1.0	-	-	-	-	-	-	18.0	-
17	-	-	-	-	-	-	-	4.8	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-	41.8	-
19	-	-	-	28.8	-	-	2.8	-	10.6	-	-	-
20	-	-	-	-	3.8	-	-	2.6	-	-	-	-
21	-	-	-	-	2.8	-	-	-	-	-	-	-
22	-	-	-	-	-	4.8	-	-	-	-	-	-
23	-	-	-	-	-	-	-	1.6	-	3.4	-	-
24	-	-	-	1.0	3.8	-	-	-	-	-	-	-
25	-	-	-	-	1.8	-	-	-	0.9	-	-	-
26	-	-	-	-	1.6	-	-	-	-	-	-	-
27	-	-	-	-	-	-	1.8	-	-	-	-	-
28	-	-	-	41.9	-	8.6	-	-	-	4.8	-	-
29	-	-----	-	-	-	6.6	2.8	-	-	5.6	-	-
30	-	-----	-	-	-	-	2.8	-	-	-	-	-
31	-	-----	-	-----	-	-----	-	-	-----	-	-----	-
TOTAL	0.0	0.0	0.0	113.4	170.4	20.0	40.0	45.6	51.7	20.6	59.8	3.0
MAX.	0.0	0.0	0.0	41.9	121.7	8.6	14.8	27.8	32.8	6.8	41.8	3.0
DAYS > 0.0	0	0	0	9	13	3	9	9	6	4	2	1

1985 SUMMARY (365 DAYS) : TOTAL 524.5 MEAN 1.4

DAILY RAINFALL AT JANAALE (MM) 1986

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	-	-	-	-	26.6	-	2.8	4.8	-	-	-	-
2	-	-	-	-	-	3.2	-	1.6	-	-	-	-
3	-	-	-	-	13.8	-	-	-	-	-	-	19.6
4	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-	-	-
7	-	-	-	2.6	-	-	-	-	-	-	-	-
8	-	-	-	-	-	4.7	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-	4.8	-
10	-	-	-	-	-	3.8	1.8	-	-	-	-	-
11	-	-	-	-	7.2	9.6	3.0	-	-	-	-	-
12	-	-	-	-	-	3.2	-	-	-	-	8.4	-
13	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	5.8	-	-	-	-	-	-	-	-
15	-	-	-	15.4	-	-	-	-	-	-	-	-
16	-	-	-	2.6	-	-	-	-	-	-	-	-
17	-	-	-	-	-	0.8	-	-	-	-	-	-
18	-	-	-	-	-	3.5	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	6.8	-
20	-	-	-	-	-	1.8	0.7	-	-	-	-	-
21	-	-	-	53.4	-	-	6.5	-	18.4	-	-	-
22	-	-	-	14.0	-	4.0	1.4	-	-	-	-	-
23	-	-	-	-	-	-	2.6	-	-	-	-	-
24	-	-	-	-	-	7.0	1.2	-	-	-	-	-
25	-	-	-	15.8	3.7	2.0	-	0.5	-	-	-	-
26	-	-	-	-	4.6	-	-	-	-	-	1.6	-
27	-	-	-	30.6	-	3.0	-	-	-	-	-	-
28	-	-	-	5.0	9.5	-	-	-	-	-	-	-
29	-	-----	-	-	34.5	-	-	-	-	-	-	-
30	-	-----	-	3.9	-	-	11.8	-	-	-	-	-
31	-	-----	-	-----	7.2	-----	-	-	-----	-	-----	-
TOTAL	0.0	0.0	0.0	149.1	107.1	46.6	31.8	6.9	18.4	0.0	21.6	19.6
MAX.	0.0	0.0	0.0	53.4	34.5	9.6	11.8	4.8	18.4	0.0	8.4	19.6
DAYS > 0.0	0	0	0	10	8	12	9	3	1	0	4	1

1986 SUMMARY (365 DAYS) : TOTAL 401.1 MEAN 1.1

DISCHARGE (INFILLED) AT AW DHEEGLE (million cubic metres)

JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	TOTAL
25.6	7.7	19.5	242.6	225.8	242.6	142.4	208.6	204.4	179.2	193.2	134.3	1825.8
23.6	10.4	26.4	57.4	159.7	87.0	60.6	72.0	166.2	174.8	108.7	42.4	989.2
16.6	3.7	9.6	33.2	159.8	102.5	75.1	164.1	196.6	193.9	152.2	79.0	1186.1
25.3	7.6	19.1	47.7	136.9	76.0	53.2	113.6	184.9	215.9	171.5	102.9	1154.6
13.1	3.4	12.0	37.3	105.4	40.2	24.6	29.2	140.5	183.2	118.0	14.2	721.2
10.4	2.2	4.1	21.9	217.3	110.6	70.0	160.6	198.0	206.4	218.2	103.8	1323.6
30.8	11.5	30.1	75.7	217.7	187.7	131.8	237.5	220.0	165.0	111.1	98.2	1517.1
19.8	21.2	68.2	19.8	130.7	38.8	20.8	143.0	194.6	213.9	170.8	69.6	1111.4
20.4	5.4	13.9	40.7	146.0	75.6	41.2	95.5	177.5	194.5	180.3	81.9	1072.9
25.6	8.5	21.0	14.2	130.5	88.4	51.9	69.8	159.0	162.7	108.7	39.1	879.3
28.2	6.5	15.6	43.6	116.3	61.2	40.8	156.9	203.8	228.7	225.2	158.2	1285.1
31.6	13.1	56.5	9.7	123.1	47.7	29.8	76.2	159.4	160.8	112.4	44.7	865.0
7.6	1.8	53.1	74.2	198.0	161.1	103.4	176.1	191.3	186.7	97.2	180.3	1431.0
89.3	33.3	12.3	29.2	75.2	38.5	52.2	158.2	193.7	197.4	171.9	62.5	1113.7
106.1	27.5	8.4	4.5	94.0	23.6	6.6	18.0	120.4	152.7	192.6	116.8	871.1
22.1	3.6	52.0	51.5	157.4	77.4	65.8	99.1	173.6	182.7	166.2	42.5	1093.9
4.0	0.0	0.0	57.1	184.9	133.3	91.6	194.1	208.1	207.7	202.7	154.0	1437.5
80.8	27.2	124.2	135.7	199.0	186.5	162.9	187.5	192.4	197.2	146.5	151.6	1791.5
58.5	41.2	147.9	226.9	203.8	121.9	95.6	216.7	212.8	188.3	114.7	32.7	1661.0
19.2	14.5	84.9	206.6	222.7	76.1	52.8	190.8	208.9	216.2	132.5	58.4	1483.5
27.2	6.5	1.8	48.7	179.1	106.6	203.5	230.3	228.6	222.2	157.0	94.5	1505.8
32.8	24.7	47.9	33.0	216.4	147.1	141.7	249.4	232.8	212.1	148.2	62.6	1548.7
21.3	3.2	14.8	0.4	89.1	61.7	45.2	132.8	186.5	188.8	89.9	9.1	842.9
5.6	0.3	0.1	99.3	105.3	107.5	145.7	202.0	209.2	174.3	71.4	21.4	1142.0
6.1	0.6	0.1	13.0	115.9	93.6	100.3	249.6	228.0	199.9	104.1	25.6	1136.8
6.5	0.5	1.2	18.7	200.9	210.1	158.6	221.9	214.6	178.3	143.5	107.9	1462.9
28.3	24.5	36.6	103.1	237.9	172.6	135.6	238.9	219.1	217.0	224.7	234.2	1872.5
100.7	31.1	130.7	155.9	217.2	187.6	126.2	250.7	233.2	229.7	222.0	108.9	1993.9
58.0	139.9	120.2	146.7	167.9	242.6	135.7	248.8	153.0	174.0	160.6	68.6	1815.9
4.6	1.5	0.0	2.1	180.9	76.5	34.2	158.0	173.7	135.7	64.9	2.0	833.9

4.8	0.0	114.8	242.6	250.7	156.0	91.8	192.4	210.6	224.6	153.8	59.1	1701.1
32.8	10.3	18.9	90.0	209.1	179.0	118.9	209.0	207.7	201.2	238.6	140.7	1656.1
87.7	92.4	43.6	30.2	183.5	208.3	154.7	250.7	241.1	235.2	226.5	129.9	1883.8
58.2	30.5	29.8	8.4	84.8	88.6	102.0	194.0	201.7	183.2	72.3	19.0	1072.6
33.3	18.1	39.4	71.2	166.0	118.1	90.2	170.5	195.5	193.6	152.1	83.8	1331.9
0.87	1.54	1.09	1.00	0.30	0.52	0.55	0.39	0.14	0.12	0.33	0.65	0.27
1.3	3.2	1.3	1.3	-0.2	0.5	0.3	-0.7	-0.7	-0.3	0.0	0.7	0.1

EQUALLED OR EXCEEDED 75.PERCENT OF THE TIME (NOT AN HOMOGENEOUS SEQUENCE)

JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	YEAR
13.0	3.3	9.6	19.8	122.7	76.0	51.5	131.6	177.3	178.1	111.0	42.2	1072.9

APPENDIX II

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